गोंय विद्यापीठ
ताळगांव पठार,
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International Year of Cooperatives 2025

(Accredited by NAAC)

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GU/Acad –PG/BoS -NEP/2025/265 Date: 24.07.2025

ADDENDUM

In continuation to the Circular No. GU/Acad PG/BoS -NEP/2023/78/4 dated:24.05.2023 a Research Methodology Courses (Organic, Inorganic, Analytical and Physical Chemistry) for Semester III is included in the Syllabus of **Master of Science in Chemistry** Programme which was approved by the Academic Council in its meeting held on 13th & 14th June 2025.

The Dean/ Vice-Deans of the School of Chemical Sciences/ Principals of Affiliated Colleges offering the **Master of Science in Chemistry** Programme are requested to take note of the above and bring the contents of the Circular to the notice of all concerned.

ASHWIN VYAS LAWANDE

Digitally signed by ASHWIN VYAS LAWANDE
Date: 2025.07.24 16:23:14 +05'30'

(Ashwin V. Lawande)
Deputy Registrar – Academic

To,

1. The Dean, School of Chemical Sciences, Goa University.
2. The Vice-Deans, School of Chemical Sciences, Goa University.
3. The Principals of Affiliated Colleges offering the Master in Sciences in Chemistry Programme.

Copy to:

1. The Chairperson, Board of Studies in Chemistry PG.
2. The Programme Director, M. Sc. Chemistry, Goa University.
3. The Controller of Examinations, Goa University.
4. The Assistant Registrar, PG Examinations, Goa University.
5. Directorate of Internal Quality Assurance, Goa University for uploading the Syllabus on the University website.

Issued on: 09.07.2025

Semester – III

Name of the Programme: M.Sc. Part-II (Chemistry)
Course Code: CHO-604
Title of the Course: Research Methodology in Organic Chemistry
Number of Credits: 4
Effective from AY: 2025-26

Prerequisites for the course:	Students should have studied chemistry courses at M.Sc. Part I level.	
Course Objective:	1. To understand literature review process, safe laboratory practices and ethics in research. 2. To understand preparation and purification of organic compounds 3. To study the common software and databases in chemistry, and experimental techniques used in organic reaction. 4. To analyse and apply specific modern methodologies in chemical reaction.	
		Hours
Content	**1. Introduction, Literature Review, Academic Writing** A. Research methodology: definition, types and components, significance, purpose and characteristics of research, research process, necessity and scope, B. Literature Review: concept and purpose, logical format of dissertation, sources and search engines, types of literature. C. Academic Writing: purpose, types and features, common mistakes, conflicts of Interest, publication misconduct, redundant publications, predatory publishers and journals, key aspects of ethics in scientific conduct.	15
	2. Safe Laboratory Practices A. Instructions for safe working and use of personal protective equipment (PPE). B. The purpose and importance of Safety Data Sheet (SDS), classification and handling of Hazardous substances. C. Handling, storage, quenching, and disposal of chemicals, solvents and glassware. D. Experimental setup, choice of place and apparatus, precautions. E. Fire Hazards (Class A, B, C, D and K), fire extinguishers and emergency procedures.	5
	3. Software & Databases in Chemistry A. Data plotting, structure drawing, reference management software, literature survey programs, software for docking studies, SAR studies, CAMEO chemicals. B. Introduction to chemistry databases. ACS guide to scholarly communication, arXiv, ASTM compass, Beilstein, bioRxiv, Cambridge Structural Database (CSD), ChemRxiv, ChemSpider, CRC Handbook of Chemistry and Physics,	10

	Drugbank, e-EROS (Encyclopedia of Reagents for Organic Synthesis), Kirk-Othmer Encyclopedia of Chemical Technology, Merck Index, NIST chemistry webbook, Organic Chemistry Portal, PubChem, PubMed, SciFinder-n, Scopus, Web of Science.	
	4. Experimental Techniques in Organic Synthesis A. Planning and execution of organic reaction. B. Drying of solvents. C. Column; preparation, monitoring and product separation. D. Extraction, trituration, purification techniques for organic compounds and sample preparation for spectral characterization E. Inert atmosphere reactions (Schlenk, N_2 atmosphere, Ar atmosphere etc.)	15
	5. Non-Conventional methods in Organic Synthesis A. Microwave-Assisted Organic Synthesis: Principle, Reaction acceleration and energy efficiency, applications in heterocyclic synthesis. B. Photocatalysis in Organic Synthesis: Photoredox mechanism with one example, organic dyes and metal complexes as photocatalysts, visible light-mediated transformations. C. Sonication in Organic Synthesis: Principle, ultrasound-assisted bond formation and cleavage, role in green and solvent-free reactions. D. Electro-organic Synthesis: Anodic and cathodic transformations, electrosynthesis of heterocycles and natural products. E. Flow Chemistry: Microreactor technology and process intensification, applications in multistep synthesis and scalability.	15
Pedagogy	Mainly lectures / recorded video lectures / tutorials / discussions / seminars / internal exams / assignments / classroom demonstration / self-study / Assignment or a combination of some of these. ICT mode should be preferred. Sessions can preferably be interactive in nature to enable peer group learning.	
References / Readings	1. Research Methodology: Methods & Techniques. Kothari, C. R. 2nd ed., New Age International, 2004. 2. Ethical Guidelines to Publication of Chemical Research. ACS Publications, 2015. 3. Fundamentals of Research Methodology & Statistics. Singh, Y. K. New Age International, New Delhi, 2006. 4. Bretherick's Handbook of Reactive Chemical Hazards. 8th ed., Elsevier, 2017. 5. A Comprehensive Guide to the Hazardous Properties of Chemical Substances. Patnaik, P. 3rd ed., John Wiley & Sons, Inc., 2007. 6. Safety Assessment for Chemical Processes. Steinbach, J. Wiley-VCH, 1999.	

	7. Safety in Academic Chemistry Laboratories. Vol. 1 and 2. American Chemical Society, 2003. 8. Vogel's Textbook of Practical Organic Chemistry. Vogel, I., Tatchell, A. R., Furniss, B. S., Hannaford, A. J. 5th ed., Prentice Hall, 2011. 9. Microwave Assisted Organic Synthesis. Tierney, J. P., Lidstrom, P. CRC Press, 2005. 10. Sonochemistry: Fundamentals and Evolution. Mason, T. J., Vinatoru, M. De Gruyter, 2023. 11. Purification of Laboratory Chemicals. Perrin, D. D., Armarego, W. L. F. 4th ed., Butterworth-Heinemann, 1997. 12. Photocatalysis Fundamentals, Materials and Applications. Zhang, J., Tian, B., Wang, L., Xing, M., Lei, J. Springer, 2018. 13. Fundamentals and Applications of Organic Electrochemistry. Fuchigami, T., Inagi, S., Atobe, M. Wiley, 2014. 14. Flow Chemistry – Fundamentals. Darvas, F., Dormán, G., Hessel, V., Ley, S. V. De Gruyter Textbook, 2021.
Course Outcome:	Students will be able to: 1. apply fundamentals of research to perform dissertation work. 2. practice the concepts of laboratory safety along with good laboratory practices. 3. apply their skills in academic writing, scientific conduct and ethics in academic writing and software and database in chemistry. 4. develop competence, expertise in performing routine experimental techniques, reaction monitoring, work-up and handling moisture sensitive reactions and understand the concepts of newer and sustainable techniques in organic synthesis.

Name of the Programme: M.Sc. Part-II (Chemistry)
Course Code: CHI-604
Title of the Course: Research Methodology in Inorganic Chemistry-I
Number of Credits: 4
Effective from AY: 2025-26

Prerequisites for the course:	Students should have studied chemistry courses at M.Sc. Part I level.	
Course Objective:	1. To understand literature review process, safe laboratory practices and ethics in research. 2. To analyse and apply separation techniques. 3. To interpret data from characterization techniques. 4. To develop understanding of a variety of structural data.	
		Hours
Content	**1. Introduction, Literature Review, Academic Writing** A. Research methodology: definition, types and components, significance, purpose and characteristics of research, research process, necessity and scope. B. Literature Review: concept and purpose, logical format of dissertation, sources and search engines, types of literature. C. Academic Writing: purpose, types and features, common mistakes, conflicts of Interest, publication misconduct, redundant publications, predatory publishers and journals, key aspects of ethics in scientific conduct	15
	2. Safe Laboratory Practices A. Instructions for safe working and use of personal protective equipment (PPE). B. The purpose and importance of Safety Data Sheet (SDS), classification and handling of Hazardous substances. C. Handling, storage, quenching, and disposal of chemicals, solvents and glassware. D. Experimental setup, choice of place and apparatus, precautions. E. Fire Hazards (Class A, B, C, D and K), fire extinguishers and emergency procedures.	5

	3. Separation Techniques A. Liquid-liquid extraction and partitioning. B. Ion Exchange Chromatography: role in separation of charged metal-ligand complexes. C. Gas Chromatography (GC): column selection, role of volatility in ligand-based separations, GC detection and quantification methods for separation and identification of ligands. D. High Performance Liquid Chromatography (HPLC): method development and optimization. E. Case studies on application of separation techniques for ligands and metal complexes.	10
	4. Characterization Techniques and Data Interpretation A. Cyclic Voltammetry (CV): Introduction, instrumentation, experimental setup, electrochemical parameters, data analysis, reversibility, electrochemical mechanisms and case studies on applications of CV for metal complexes, introduction to Spectroelectrochemistry. B. Liquid Chromatography-Mass Spectrometry (LC-MS)/ Gas Chromatography-Mass Spectrometry (GC-MS): Principles and instrumentation, ionization techniques and mass analyzers, comparison of LC-MS vs. GC-MS for different analytes and application for separation, identification of products, and isotope labelling studies. C. Electrospray Ionization Mass Spectrometry (ESI-MS)/ Cold Spray Ionization Mass Spectrometry (CSI-MS): Introduction, working principle, instrumentation, time of flight and quadrupole analyzer, mass to charge ratio, isotope distribution pattern, ionization of metal complexes in solution phase (fragments), interpretation of data, identifying metal-ligand stoichiometry, isotope labelling studies, applications in low-temperature analysis of weakly bound metal-ligand interactions, emerging trends in mass spectrometry.	15
	5. Structure Characterization A. Introduction to powder and single-crystal X-ray diffraction. Understanding the difference between amorphous, crystalline, nanomaterials, quasicrystals. B. Crystallisation techniques, Polymorphism, Enantiomorphism, organic, inorganic, organometallic and metal-organic compounds. C. Crystal structure description. Coordination polymers and metal-organic frameworks, Hydrogen bonding and other interaction in solids. Software for structure interpretation and data simulation and data visualization.	15

	D. Case studies on proper characterization of a solid by use of crystallographic aspects and other allied techniques. E. Importance of correct space group assignment and chirality in space groups.	
Pedagogy	Mainly lectures / recorded video lectures / tutorials / discussions / seminars / internal exams / assignments / classroom demonstration / self-study / Assignment or a combination of some of these. ICT mode should be preferred. Sessions can preferably be interactive in nature to enable peer group learning.	
References / Readings	1. C. R. Kothari, Research Methodology: Methods & Techniques, New Age International Pvt. Ltd., New-Delhi, 2004. 2. Y. K. Singh, Fundamentals of Research Methodology & Statistics, New Age International Pvt. Ltd., New Delhi, 2006. 3. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, Vogel's Textbook of Practical Organic Chemistry, 4th ed., Longman, 1986. 4. R. M. Silverstein, F. X. Webster; Spectrometric identification of Organic Compounds; 6th ed., Wiley, 2011. 5. G. Svehla, Vogel's Text Book of Qualitative Inorganic Analysis, 7th ed., Pearson, 2011. 6. J. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, Vogel's Textbook of Quantitative Chemical Analysis, 6th ed., Pearson 2009. 7. G. D. Christian, Analytical Chemistry, 6th ed., Wiley, 2008. 8. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th ed., Cengage learning, 2022. 9. Skoog, F. J. Holler, S. R. Crouch, Principles of Instrumental Analysis, 7th edn., Cengage learning, 2017. 10. E. De Hoffmann, V. Stroobant, Mass Spectrometry: Principles and Applications, 2nd ed., Wiley, 2007. 11. J. T. Watson, O. D. Sparkman, Introduction to Mass Spectrometry: Instrumentation, Applications, and Strategies for Data Interpretation, 4th ed., Wiley, 2007. 12. P. G. Lampman, G. Kriz and J. Vyvyan, Introduction to Organic Spectroscopy, 5th ed., Cengage Learning, 2015. 13. J. E. Huheey, E. A. Keiter, R.L. Keiter, Inorganic Chemistry: Principles of structure and reactivity, 4th ed., Pearson, 2006. 14. G. R. Desiraju, J. J. Vittal, A. Ramanan, Crystal Engineering, IISC Press, World Scientific, 2011.	
Course Outcome:	Students will be able to 1. apply fundamentals of research. 2. practice the concepts of laboratory safety along with good laboratory practices. 3. use separation techniques for experimental research, interpret and evaluate data from characterization techniques. 4. apply crystallography for structure analysis.	

Name of the Programme: M.Sc. Part-II (Chemistry)
Course Code: CHP-604
Title of the course: Research Methodology in Physical Chemistry
Number of Credits: 4
Effective from AY: 2025-26

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I level.	
Course Objective:	1. To understand literature review process, safe laboratory practices and ethics in research. 2. To learn computational techniques applicable to research work. 3. To apply the principles and techniques of data acquisition, analysis and interpretation to research. 4. To study the synthesis of solid state materials and learn various instrumental techniques for characterization.	
		Hours
Content	**1. Introduction, Literature Review, Academic Writing** A. Research methodology: definition, types and components, significance, purpose and characteristics of research, research process, necessity and scope, B. Literature Review: concept and purpose, logical format of dissertation, sources and search engines, types of literature. C. Academic Writing: purpose, types and features, common mistakes, conflicts of Interest, publication misconduct, redundant publications, predatory publishers and journals, key aspects of ethics in scientific conduct.	15
	2. Safe Laboratory Practices A. Instructions for safe working and use of personal protective equipment (PPE). B. The purpose and importance of Safety Data Sheet (SDS), classification and handling of Hazardous substances. C. Handling, storage, quenching, and disposal of chemicals, solvents and glassware. D. Experimental setup, choice of place and apparatus, precautions. E. Fire Hazards (Class A, B, C, D and K), fire extinguishers and emergency procedures.	5
	3. Software in Chemistry and Data Plotting A. Introduction to Software Tools for Research and Reference Management with Zotero/Mendeley. B. Basics of Data plotting and advanced data plotting techniques. C. Structure drawing and reaction schemes with open source / free software.	10
	4. Experimental Techniques in Physical Chemistry A. Synthetic methods for solid state materials: solvothermal, electrochemical, sol-gel, chemical vapor deposition (CVD),	15

	physical vapor deposition (PVD), mechanical ball-milling and microwave techniques. B. Photocatalysis, electrocatalysis and photoelectrochemistry for hydrogen production, CO_2 reduction, water oxidation; solar energy conversion and wastewater treatment. C. Heterogeneous catalysis for pollutant mitigation eg. Catalytic converters in automobiles, industrial waste treatment. Catalysis for organic synthesis. D. Polymerization processes viz. free radical and condensation polymerization, kinetics of polymerization, polymerization techniques, determination of molecular weight and glass transition temperature, polymer processing techniques. Polymers and polymer nanocomposites for pollutant degradation.	
	5. Instrumental Techniques Working principle and data analysis in following techniques: A. Powder XRD and Raman analysis of metal oxides, polymers, sulphides, perovskites. B. SEM & TEM for morphological analysis, EDAX, SAED. C. Cyclic Voltammetry, Linear sweep Voltammetry, Electrochemical impedance spectroscopy for electrocatalytic applications. D. ICP & AES for elemental analysis of doped compounds.	15
Pedagogy	Mainly lectures/recorded video lectures/ tutorials, discussions, seminars, internal exams/ assignments, / classroom demonstration/ self-study or a combination of some of these. ICT mode should be preferred. Sessions can preferably be interactive in nature to enable peer group learning.	
References / Readings	1. C. R. Kothari, Research Methodology: Methods & Techniques, New Age International Pvt. Ltd., New-Delhi, 2004 2. R. S. Drago, Physical Methods in Chemistry, 2nd ed., W. B. Saunders Co. Ltd. 2016 3. M. Coghill & L. R. Garson, The ACS Style Guide: Effective Communication of Scientific Information, American Chemical Society Washington, DC & OXFORD University Press New York, 2006. 4. Y. K. Singh, Fundamentals of Research Methodology & Statistics, New Age International Pvt. Ltd., New-Delhi, 2006. 5. National Research Council, Prudent practices in the laboratory: handling and management of chemical hazards, The National Academies Press, USA, 2011. 6. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, Vogel's Textbook of Quantitative Chemical Analysis, 6th ed., Pearson Education Asia, 2002. 7. H. V. Keer, Principles of the Solid State, 1st ed., New Age International (P) Ltd., New-Delhi, 2005 8. Elgrishi, K. J. Rountree, B. D. McCarthy, E. S. Rountree, T. T. Eisenhart, and J. L. Dempsey, A Practical Beginner's Guide to Cyclic Voltammetry, J. Chem. Educ. ACS, 2018, 95, 197-206.	

	9. V. Rajaraman, Computer Programming in Fortran 90 And 95, PHI Learning Pvt. Ltd., 2013. 10. A. Wold, K. Dwight, Solid State Chemistry: Synthesis, Structure and Properties of selected Oxides and Sulfides, Springer Science, 1993. 11. E. A. Moore, L. E. Smart, Solid State Chemistry: an Introduction, 5th ed., CRC Press, Taylor & Francis Group, 2021. 12. R. G. Balakrishna, R. Shwetharani, T. Jayaraman, Advances in Photocatalysis, Electrocatalysis and Photoelectrocatalysis for Hydrogen Production, Catalysis Series No. 47, Royal Society of Chemistry, 2024. 13. V. R. Gowariker, N. V. Viswanathan, J. Sreedhar, Polymer Science, Wiley Publishers, 1st edn., 1986 14. T. Lodge, P. C. Hiemenz, Polymer Chemistry, 3rd ed., CRC Press, 2020 15. H. Thompson, Polymer Nanocomposites, Nova Science Publishers, 2017.
Course Outcome:	Students will be able to: 1. apply fundamentals of research. 2. practice the concepts of laboratory safety along with good laboratory practices. 3. apply computational techniques to solve the research problems in chemistry. 4. design, synthesize and characterize solid state materials for useful applications.

Name of the Programme: M.Sc. Part-II (Chemistry)
Course Code: CHA-604
Title of the Course: Research Methodology in Analytical Chemistry
Number of Credits: 4
Effective from AY: 2025-26

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied chemistry courses at M.Sc. Part I level.</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. To understand literature review process, safe laboratory practices and ethics in research.
2. To learn isolation procedures for separation of natural product from mixtures
3. To apply different methodologies, basic characterization and data interpretation for material property investigation
4. To evaluate different analytical parameters for method development.</td></tr>
<tr><td></td><td>Content</td><td>Hours</td></tr>
<tr><td></td><td>1. Introduction, Literature Review, Academic Writing
A. Research methodology: definition, types and components, significance, purpose and characteristics of research, research process, necessity and scope,
B. Literature Review: concept and purpose, logical format of dissertation, sources and search engines, types of literature.
C. Academic Writing: purpose, types and features, common mistakes, conflicts of Interest, publication misconduct, redundant publications, predatory publishers and journals, key aspects of ethics in scientific conduct.</td><td>15</td></tr>
<tr><td></td><td>2. Safe Laboratory Practices
A. Instructions for safe working and use of personal protective equipment (PPE).
B. The purpose and importance of Safety Data Sheet (SDS), classification and handling of Hazardous substances.
C. Handling, storage, quenching, and disposal of chemicals, solvents and glassware.
D. Experimental setup, choice of place and apparatus, precautions.
E. Fire Hazards (Class A, B, C, D and K), fire extinguishers and emergency procedures.</td><td>5</td></tr>
<tr><td></td><td>3. Reaction setup and separation methods
A. Setting up of reactions, reaction yields and mass balance.
B. Methods of isolation and purification techniques for organic reaction intermediates and products.
C. Solvent extraction: Batch extractions, continuous extractions, LLE extractions, counter current extraction techniques for isolation of organic compounds.
D. Distillation techniques: Batch distillation, reduced pressure distillation, continuous distillation and wiping film distillation.</td><td>10</td></tr>
</table>

	E. Case studies for isolation of natural products (Quinine oil, cinnamon oil and capsaicin).	
	4. Syntheses, Characterization and Data Processing A. Synthetic methodologies, solution and solid-state synthesis, methods of preparation of crystalline solids, factors affecting product formation. B. Reaction setup, optimisation of reaction conditions. Selection of suitable solvent and analyte concentration. C. Infra-red and UV-Visible Spectroscopy: Standard operating procedures, sample analysis, online reaction study using IR and UV analysis. D. Data conversion of the instrumental file into plottable format in Excel, statistical tools for data processing, data visualization softwares.	15
	5. Analytical method development and structure drawing A. HPLC method development - case studies with pharmaceuticals samples, cosmetic products, natural products, and other chemical compositions. B. GC method development - case studies with pharmaceuticals samples, essential oils, fragrances, and other chemical compositions. C. Structure drawing softwares - Structures, reaction schemes, mechanisms.	15
Pedagogy	Mainly lectures / recorded video lectures / tutorials / discussions / seminars / internal exams / assignments / classroom demonstration / self-study / Assignment or a combination of some of these. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. R. Kothari, Research Methodology: Methods & Techniques, New Age International Pvt. Ltd., New-Delhi, 2004. 2. A. Bird, Philosophy of Science, Routledge, 2006. 3. M. Coghill & L. R. Garson, The ACS Style Guide: Effective Communication of Scientific Information, American Chemical Society Washington, DC & Oxford University Press New York, 2006. 4. Y. K. Singh, Fundamentals of Research Methodology & Statistics, New Age International Pvt. Ltd., New-Delhi, 2006. 5. National Research Council, Prudent practices in the laboratory: handling and management of chemical hazards, The National Academies Press, USA, 2011. 6. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, 7. Vogel's Text book of Practical Organic Chemistry, 5th ed., Longmans, 1989 8. D. Christian, Analytical Chemistry, 6th ed., Wiley, 2004. 9. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th ed., Cengage learning.	

	10. Skoog, F. J. Holler, S. R. Crouch, Principles of Instrumental Analysis, 7th edn., Cengage learning. 11. Rohit Manglik, Research Techniques in Organic Chemistry, EduGorilla Publication, 2024. 12. Rolf Carlson, Johan E. Carlson, Design and Optimization in Organic Synthesis, Elsevier, 2005.
Course Outcome:	Students will be able to: 1. apply fundamentals of research to facilitate dissertation work. 2. practice the concepts of laboratory safety along with good laboratory practices. 3. develop systematic approach to conduct experiments and data evaluation. 4. apply methods for analysis of various chemical compositions.

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GU/Acad –PG/BoS -NEP/2023/78/4 Date:24.05.2023

Ref: GU/Acad –PG/BoS -NEP/2022/339/11 dated 19.08.22

CIRCULAR

In supersession to the above referred Circular, the updated approved Syllabus with revised Course Codes of the **Master of Science in Chemistry Programme** is enclosed.

The approved Syllabus of the **Master of Science in Chemistry** Programme (Organic, Inorganic, Analytical and Physical, Pharmaceutical Chemistry) is attached.

The Dean/ Vice-Deans of the School of Chemical Sciences/ Principals of Affiliated Colleges offering the **Master of Science in Chemistry** Programme are requested to take note of the above and bring the contents of the Circular to the notice of all concerned.

ASHWIN VYAS LAWANDE Digitally signed by ASHWIN VYAS LAWANDE Date: 2023.05.24 17:31:44 +05'30'

(Ashwin Lawande)
Assistant Registrar – Academic-PG

To,

1. The Dean, School of Chemical Sciences, Goa University.
2. The Vice-Deans, School of Chemical Sciences, Goa University.
3. The Principals of Affiliated Colleges offering the Master in Sciences in Chemistry Programme.

Copy to:

1. The Chairperson, Board of Studies in Chemistry PG.
2. The Programme Director, M. Sc. Chemistry, Goa University.
3. The Controller of Examinations, Goa University.
4. The Assistant Registrar, PG Examinations, Goa University.
5. Directorate of Internal Quality Assurance, Goa University for uploading the Syllabus on the University website.

ANNEXURE-I

M.Sc. Chemistry (SEM I & II) Syllabus (80 Credit course) as per NEP 2020 for AY 2022-23

SEM I			
Sr. No.	**Subject code**	**Paper title**	**Credits**
1.	CHO-500	Fundamentals of Organic Chemistry	4
2.	CHI-500	Fundamentals of Inorganic Chemistry	4
3.	CHP-500	General Physical Chemistry	4
4.	CHA-500	Techniques in Analytical Chemistry-I	4
5.	CHO-521	Practical Course in Organic Chemistry-I	2
6.	CHO-522	Practical Course in Organic Chemistry-II	2
7.	CHI-521	Practical Course in Inorganic Chemistry-I	2
8.	CHI-522	Practical Course in Inorganic Chemistry-II	2
9.	CHP-521	Practical Course in Physical Chemistry-I	2
10.	CHP-522	Practical Course in Physical Chemistry-II	2
11.	CHA-521	Practical Course in Analytical Chemistry-I	2
12.	CHA-522	Practical Course in Analytical Chemistry-II	2
SEM II (Inorganic Chemistry)			
1.	CHI-501	Chemistry of Coordination & Organometallic Compounds	4
2.	CHI-502	Chemistry of Materials	4
3.	CHI-503	Concepts in Molecular Symmetry and Spectroscopy	4
4.	CHI-504	Concepts in Inorganic Chemistry	4

SEM II (Analytical Chemistry)			
1.	CHA-501	Chemical Methods of Analysis	4
2.	CHA-502	Techniques in Analytical Chemistry-II	4
3.	CHA-503	Separation Techniques	4
4.	CHA-504	Instrumental Methods of Analysis	4
SEM II (Organic Chemistry)			
1.	CHO-501	Organic Spectroscopy	4
2.	CHO-502	Pericyclic and Organic Photochemical Reactions	4
3.	CHO-503	Synthetic Methodologies in Organic Chemistry	4
4.	CHO-504	Stereochemistry and Organic Transformations	4
SEM II (Physical Chemistry)			
1.	CHP-501	Quantum Chemistry and Statistical Thermodynamics	4
2.	CHP-502	Group Theory and Molecular Spectroscopy	4
3.	CHP-503	Chemical Kinetics and Thermodynamics	4
4.	CHP-504	Electrochemistry and Surface Studies	4

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHA-500 **Title of the course:** Techniques in Analytical Chemistry - I

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objective:	1. Learning various methods of data handling in analysis. 2. Understanding the significance of sampling and calibration techniques. 3. Understanding principles and applications of various types of techniques 4. Training the students to deduce structures based on IR, NMR, MS combined data.	
Content:	**1. Analytical Objectives and Data Handling** Importance of analytical chemistry in research and industry; statistics and data handling in analytical chemistry, standard operating procedures, good laboratory practices: quality assurance, method validation and quality control.	No. of Hours 5
	2. Sampling and Calibration Techniques Sampling and sample preparation, general steps in chemical analysis, calibration of glass wares. Finding the best straight line-least square regression, correlation coefficient; Calibration curves, standard addition technique and internal standards. Chemical concentrations.	5
	3. Classical methods of Analysis Gravimetry and Titrimetric methods, Principle, methodology, Advantages & Disadvantages over instrumental methods. Conditions for identifying a given reaction as method of Analysis, Classification of reactions in titrimetric analysis (Acid-Base, redox, complexometric and precipitation), Standard solutions and their preparation. Selection of Visual Indicators in titrimetric Analysis	6
	4. Introduction to Electroanalytical techniques Introduction to electrochemical cell, electrode potential, Classification of electroanalytical techniques, working principles, and their applications	4
	5. Introduction to Thermoanalytical techniques Principle, Instrumentation and applications of Thermo Gravimetric Analysis, Differential Thermal Analysis, and Differential Scanning Calorimetry. Numericals based on TGA.	5
	6. Introduction to Chromatographic Techniques a. Principles of chromatography, classification of	15

	chromatographic techniques based on mechanism of retention, configuration, mobile and stationary phase. Efficiency of separation- plate theory (theoretical plate concept) and rate theory (van Deemter equation). b. Principles and applications of Paper chromatography, thin layer chromatography, HPTLC, Size exclusion and Ion exchange chromatography. Counter-current chromatography for isolation of natural products. c. Gas and Liquid Chromatography: Introduction; Instrumental Modules; The Separation System; Choice of Conditions of Analysis; Sample Inlet Systems; Detectors; Practical Considerations in Qualitative and Quantitative Analysis; Coupled Systems-introduction to GCMS, LCMS; Applicability-interpretation and numericals.	
	7. Introduction to Spectroscopic Techniques a. Interaction of Electromagnetic Radiation with Matter: Electromagnetic spectra, regions of spectrum, numericals. b. Ultraviolet and visible Spectroscopy: Electronic spectra and Molecular structure: types of electronic transition, Chromophore and auxochrome, absorption by isolated chromophore, conjugated chromophores, aromatic compounds, inorganic chelates. Calculating λmax for Conjugated Dienes, Trienes, polyenes, α,β-unsaturated carbonyl compounds, Numericals. Choices and effect of solvents on UV-Vis. Quantitative Calculations: Beer-Lambert Law; Mixtures of absorbing species-laws of additivity of absorbance; calibration curve for calculation of unknown; Spectrometric errors in measurement; Deviation from Beer-Lambert Law - chemical deviation, instrumental deviation; Numericals for quantitative analysis using UV-VIS spectroscopy. c. Infrared Spectroscopy: Infrared absorption and molecular structures, molecular vibrations, types of vibrations, IR spectra, overtones and bands-basis of NIR absorption. Spectra interpretation, Frequencies of functional group, Spectral Databases, Identification of unknown compounds. d. Spectrometric Instrumentation of UV-Vis and IR: Sources, monochromators, sample cells, detectors, instrumental wavelength and absorption calibration. e. Proton and Carbon NMR Spectroscopy: Theory of NMR, Instrumentation, Chemical shift, factors influencing chemical shift, solvents used in NMR, spin-spin splitting, coupling constant calculation, factors influencing coupling constant. f. Mass Spectrometry: Principle, Instrumentation and various	20

	fragmentation patterns. g. Conjoint spectrometry problems: Structural elucidation of organic molecules using IR, UV, NMR and MS. h. Raman Spectroscopy: Theory, Basic instrumentation and Structural analysis using Raman Spectra. (Note: Assignment based on all above spectrometric methods should be given to student. More weightage of lectures shall be given for solving IR and NMR data problems for structure elucidation)	
Pedagogy:	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings:	1. G. D. Christian, Analytical Chemistry, 6th Ed.; Wiley, 2004. 2. J. H. Kennedy, Analytical Chemistry: Principles, 2nd Ed.; Saunders College Publishing, 1990. 3. G. W. Ewing, Instrumental Methods of Chemical Analysis, 5th Ed.; McGraw- Hill Int., 1985. 4. W. Kemp, Organic Spectroscopy, 3rd Ed.; Palgrave, 1991. 5. D. A. Skoog, D. M. West, F. J. Hollar, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed.; Cengage learning, 2014. 6. F. J. Holler, D. A. Skoog, S. R. Crouch, Principles of Instrumental Analysis, 6th Ed.; Thomson Books, 2007. 7. H. Willard, L. L. Merritt, J. A. Dean, F. A. Settle, Instrumental methods of Analysis, 7th Ed.; HCBS Publishing, 2004. 8. C. N. Banwell, E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th Ed.; Tata McGraw- Hill, 2006. 9. R. M. Silverstein, F. X. Webster, Spectrometric identification of Organic Compounds, 6th Ed.; Wiley, 1998. 10. H. Gunzler, A. Williams, Handbook of Analytical Techniques, 1st Ed.; Wiley, 2001. 11. P. S. Kalsi, Spectroscopy of Organic Compounds, 2nd Ed.; New Age International, 2000. 12. E. Pretsch, P. Buhlmann, C. Affolter, Structural Determination of Organic Compounds, 2nd Ed.; Springer, 2005. 13. L. D. Field, S. Sternhell, J. R. Kalman; Organic Structures from Spectra, 4th Ed.; Wiley, 2007. 14. R. A. Day, A. L. Underwood, Quantitative Analysis, 6th Ed.; Prentice Hall, 2001. 15. B. K Sharma, Instrumental methods of chemical analysis, Goel Publishing House, Meerut, 2004. 16. K. Nakamoto, Infrared and Raman Spectra of Inorganic and Coordination Compounds, 6th Ed.; Wiley, 2009. 17. P. J. Larkin, Infrared and Raman Spectroscopy: principles and	

	spectral interpretation, 2th Ed.; Elsevier, 2018. 18. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, B. Sivasankar, Vogel's Text Book of Quantitative Chemical Analysis, 6th Ed.; Pearson, 2009.
Course outcomes:	1. Students will be able to analyse the role of statistical tools for determination of error and organised data management for systematic interpretation. 2. Student will be able to apply the sampling and calibration methods for obtaining reliable results. 3. Students will be able to understand basic principles and scope of different methods of Analysis 4. Students will be able to solve problems based on IR, NMR, MS combined spectral data.

Name of the Programme: M. Sc -I (Analytical Chemistry)

Course Code: CHA-501 **Title of the course:** Chemical methods of analysis

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied analytical chemistry courses at M.Sc. Chemistry in semester I	
Course Objectives:	1. Introduction to the various chemical method of analysis, details of underlying principle of chemical methods, advantages and limitations 2. Application of chemical methods for qualitative and quantitative analysis	
Content	**1. Acid-Base Titrations** a. Standard acids and Base solutions, b. Theory of acid-base indicators for Acid-Base titrations i. Colour change and range of indicator ii. Selection of proper indicator iii. Indicator errors c. Neutralization curves for strong acid-strong base; weak acid-strong base and weak base-strong acid weak acid-weak base titrations d. Polyfunctional acids and bases; titration curves for poly functional acids and bases; titration curves for amphiprotic species e. Determining the equivalence point; feasibility of acid - base titrations; magnitude of the equilibrium constant; effect of concentration f. Typical applications of acid-base titrations	No of hours 10
	2. Complexometric titrations a. The complex formation reactions; Stability of complexes; stepwise formation constants b. Organic complexing agents; amino carboxylic acid titration c. EDTA; acidic properties of EDTA; EDTA complexes with metal ions; equilibrium calculations involving EDTA in solution; condition of formation constants d. EDTA titration curves; effect of other complexing agents on EDTA; factors affecting the titration curves; completeness of reaction e. Indicators for EDTA titrations; Theory of common indicators f. Titration methods using EDTA- direct titration; back titration and displacement titration; indirect determinations; titration of mixtures; selectivity, masking and damasking agents g. Applications of EDTA titrations- hardness of water; magnesium and Al in antacids; magnesium, manganese and zinc in a	8

	mixture.	
	3. Precipitation titrations a. Introduction to precipitation titrations; feasibility of precipitation titrations b. Titration curves i. Effect of titrant and analyte concentration on titration curves ii. Effect of reaction completeness on titration curves iii. Titration curves for mixture of anions c. Indicators for precipitation titrations d. The Volhard, the Mohr's and the Fajan's methods e. Titration of sulfate with barium	6
	4. Basic concepts in Electrochemical Titrations a. Faradic and non-Faradic currents b. Reversible and irreversible cells c. EMF series; standard electrode potential; Nernst equation; calculation of cell potential; effect of current; ohmic potential; polarization; decomposition potential; over voltage; concentration polarization; mechanism of mass transport. d. Introduction to potentiometric methods	4
	5. Redox and potentiometric titrations a. Redox Titrations: Equilibrium constants for redox reactions-electrode potentials in equilibrium systems; calculation of equilibrium constants b. Redox titration curves- formal redox potentials; derivation of titration curves c. Factors affecting the shape of titration curves concentration; completeness of reaction; titration of mixtures- feasibility of redox titrations d. Detection of end point and redox indicators i. Structural aspect of redox indicators ii. Specific and nonspecific indicators iii. Choice of indicator iv. Potentiometric end point detection e. Sample preparation: pre-reduction and pre-oxidation f. Potentiometric titrations	8
	6. Gravimetric analysis a. Introduction to gravimetric method of analysis b. Properties of precipitates and precipitating reagents i. Completeness of precipitates ii. Super saturation and precipitate formation iii. Particle size and filterability of precipitates c. Colloidal precipitates and crystalline precipitates d. Purity of the precipitate; coprecipitation, post precipitation;	6

	conditions for precipitation. e. Fractional precipitation; precipitation from homogenous solution; f. Organic reagent as precipitants-dimethyl glyoxime, oxine, cupferron, salicylaldoxime g. Washing of precipitates; drying and ignition of precipitates; calculation of results from gravimetric data; h. Applications of gravimetric method	
	7. Clinical methods of analysis a. Composition of Blood; Collection and Preservation of Samples; b. Immunoassay: Radioimmunoassay; its principle and applications; instrumentation for radio bioassay c. Clinical application of the radioimmunoassay of insulin, estrogen and progesterone; receptor techniques of breast cancer d. Enzyme- linked immunosorbent assay; principles; practical aspects; applications e. Blood gas analyzer f. Trace elements in the body	10
	8. Environmental Sampling and Analysis a. Acquiring meaningful Sample b. Air Sample Collection and Analysis c. Water Sample Collection and Analysis d. Soil and Sediment Sampling e. Sample Preparation for Trace Organics f. Methods and Performance-Based Analyses	8
Pedagogy:	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings:	1. G. D. Christian, Analytical Chemistry, 6th Ed., John Wiley, New York, 2004. 2. D. A. Skoog, D. M. West & F. J. Holler, Fundamentals of Analytical Chemistry, 9th Ed., Sounders College publishing, 2014. 3. J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas, Vogel's Textbook of Quantitative Inorganic Analysis, 6th Ed., Pearson Education Asia, 2000. 4. D. Harvey, Modern analytical chemistry, 1st Ed., The McGraw-Hill, 2000. 5. G. H. Jeffery, J. Bassett, J. Mendham, R C. Denney, Vogel's Text Book of Quantitative Chemical Analysis, 5th Ed., John Wiley, New York, 1989.	
Course outcomes:	1. Students will be able to explain the basic principle and chemistry behind different conventional method of analysis. 2. Students will know the limitation of method of analysis and will be in a position to choose an appropriate chemical method for particular analysis.	

	3. Students will understand the various types of titration techniques. 4. Students will understand and will be able to apply various sampling techniques.

Name of the Programme: M. Sc -I (Analytical Chemistry)

Course Code: CHA-502 **Title of the course:** Techniques in Analytical Chemistry - II

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied analytical chemistry courses at M.Sc. Chemistry in semester I	
Course Objective:	1. Provide understanding of the principle of optical analytical techniques like Nephelometry, Turbidimetry, and Polarimetry. 2. Introduce the principles and applications of Absorption and Emission spectroscopic techniques. 3. Develop concepts in various Electroanalytical techniques such as pH-metry, conductometry and Karl Fischer titration. 4. Acquaint the students to the basic principles of Radioanalytical techniques and solvent extraction techniques.	
Content:	**1. Optical analytical techniques** a. Nephelometry and Turbidimetry: Introduction to principle, instrumentation and application of nephelometry, turbidimetry. Factors affecting measurement; comparison between nephelometry, turbidimetry, colorimetry and fluorimetry; applications of nephelometry and turbidimetry. b. Polarimetry: Introduction, principle and Instrumentation of Polarimetry; application of optical rotation method in rate constant determination; acid- catalysed mutarotation of glucose; inversion of cane sugar. Introduction to terms such as optical rotatory dispersion (ORD), cotton effect curves, circular dichroism, octant rule for ketones.	No of hours 15
	2. Introduction to Absorption and Emission Techniques Introduction, principles and applications of atomic absorption Spectroscopy (AAS) Atomic Emission spectroscopy (AES), and Flame Emission spectroscopy (FES). Excitation techniques, electrodes and their shapes, Quantitative and qualitative application, brief introduction to ICP-MS, ICP-OES	5
	3. Electroanalytical techniques a. Brief introduction to electroanalytical techniques. Voltammetry and polarography, cyclic voltammetry, coulometry, controlled potential coulometry and coulometric titrations, Stripping voltammetry, ion-selective electrodes and sensors; Evaluation and Calculation; Application to Inorganic and Organic Trace analysis b. Introduction to Ion selective electrodes; construction, application and selectivity coefficient of Ion selective	15

	electrode; pH measurement; buffer solution; glass electrode; instrument for pH measurement. c. Basic aspects of conductometric titration; types of conductometric titration; advantages and disadvantages of conductometric titration; Introduction; theory; instrumentation; advantages, disadvantages and applications of High frequency titrations.	
	4. Karl Fischer Titration Introduction, theory, instrumentation, advantages and disadvantages Karl Fischer reagent, determination of water content in industrial samples.	5
	5. Radioanalytical techniques Theory and principles of radio analytical technique, detection of nuclear radiation, radiation detectors, pulse height analysis, counting error, analytical application of radioisotopes, neutron activation analysis and isotope dilution analysis.	8
	6. Introduction to Extraction Techniques a. Liquid-liquid extraction/solvent extraction: partition coefficient, distribution ratio and percent extraction, choice of solvents, Solvent extraction of metal ions-ion association complexes and metal chelates, multiple batch extraction, Craig's counter-current distribution. b. Introduction to green analytical extraction methods: Supercritical Fluid Extraction, Pressurized Liquid Extraction, Ultrasound assisted Extraction, Microwave assisted Extraction, Enzyme assisted Extraction, Solid phase microextraction, Solid Phase Extraction.	12
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings:	1. G.D. Christian, Analytical Chemistry, 6th Ed.; Wiley, 2004. 2. D. A. Skoog, D. M. West, F. J. Hollar, S. R. Crouch; Fundamentals of Analytical Chemistry, 9th Ed.; Cengage Learning, 2014. 3. F. J. Holler, D. A. Skoog, S. R. Crouch, Principles of Instrumental Analysis, 6th Ed.; Thomson Books, 2007. 4. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, B. Sivasankar, Vogel's Text Book of Quantitative Chemical Analysis, 6th Ed.; Pearson, 2009. 5. H. H. Willard, L. L. Merritt, J. A. Dean, F.A. Settle, Instrumental Methods of Analysis, 7th Ed.; CBS Publishing, 1988. 6. J. H. Kennedy, Analytical Chemistry: Principles, 2nd Ed.; Saunders College Publishing, 1990.	

	7. G. W. Ewing, Instrumental Methods of Chemical Analysis, 5th Ed.; McGraw-Hill, 1985. 8. R. A. Day, A. L. Underwood, Quantitative Analysis, 6th Ed.; Prentice Hall, 2001. 9. B. K. Sharma, Instrumental methods of chemical analysis, Goel Publishing House, Meerut, 2004. 10. R. D. Braun, Introduction to Instrumental analysis, Pharma Med Press, 2012. 11. G. R. Chatwal, S. K. Anand, Instrumental Methods of Chemical Analysis, 5th Ed.; Himalaya publishing House, 2019. 12. H. Gunzler, A. Williams, Handbook of Analytical Techniques, 1st Ed.; Wiley, 2001 13. M. A. Rostagno, J. M. Prado, Natural Product Extraction: Principles and Applications, RSC, 2013. 14. E. Scholz, Karl Fischer Titration: Determination of Water, Springer, 2011.
Course outcomes:	1. Students will be able to explain the principle of Nephelometry, Turbidimetry, and Polarimetry. 2. Students will be able to describe and differentiate between the absorption and emission techniques such as AAS, AES. 3. Students will be able to illustrate the principle of Electroanalytical techniques such as voltammetry, conductometry and Karl Fischer titration. 4. Students will be able to explain and apply the principles of Radioanalytical techniques and solvent extraction methods.

Name of the Programme: M. Sc -I (Analytical Chemistry)

Course Code: CHA-503 **Title of the course:** Separation Techniques

Number of Credits: 04

Effective from AY: 2022-23

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied analytical chemistry courses at M.Sc. Chemistry in semester I</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. Introduction of various separation techniques.
2. Evaluate the use of chromatographic techniques for chemical analysis.</td></tr>
<tr><td>Content:</td><td>1. Basic Separation Technique:
General aspects of separation techniques-role of separation technique in analysis; separating the analyte from interferents, general theory of separation efficiency: separation factor.
Classifying separation techniques: Separations based on size; separations based on mass or density, separations based on complexation reactions (Masking); separations based on a change of state; separations based on partitioning between phases.
(Note: Following techniques shall be discussed as representative example)
Basic principles of distillation; theory of vacuum, steam, azeotropic and fractional distillation.
Fractionation by solvent extraction: based on chemical nature and based on polarity of analyte.
Membrane techniques: dialysis, reverse osmosis, ultrafiltration.
Centrifugation techniques: Sedimentation velocity, Sedimentation equilibrium, analytical and preparative centrifugation, differential centrifugation, density gradient centrifugation; applications in separation.</td><td>No of hours

10</td></tr>
<tr><td></td><td>2. Chromatographic Methods:
Introduction to chromatography: Principle of chromatographic technique, terms and parameters used in chromatography, classification of chromatographic methods, partition versus adsorption chromatography, qualitative and quantitative analysis by chromatography;
Planar Chromatography (Paper and thin layer):
Paper Chromatography: Principle, types (ascending, descending, circular, two dimensional paper chromatography), choice of solvent, adsorbents, multiple development, qualitative and quantitative measurement</td><td>30</td></tr>
</table>

	applications. Thin Layer Chromatography (TLC): Principle; efficiency of thin layer plates, methodology (technique), criteria for selection of stationary and mobile phases (numerical to calculate elution strength of mixed solvents used as mobile phase), choice of adsorbents, preparation of plates, spotting (spot capacity), development of chromatogram, identification and detection using physical and chemical methods, reproducibility of Rf values and improving resolution, Two-dimensional TLC, comparison of TLC with paper chromatography and column chromatography, thin layer ionophoresis and electrophoresis, qualitative, quantitative evaluation and applications. High-performance TLC (HPTLC): Introduction, theory, classification (classical, high performance, ultra, preparative HPTLC), difference between TLC and HPTLC with respects to the parameters, scanning densitometer, quantitative analysis and applications. Column Chromatography: Introduction, types (conventional, flash, LPLC, Dry column vacuum chromatography), principle, packing, loading, eluting and collecting eluent in the column chromatography and experimental requirements, theory of development, migration rates of solutes, band broadening, resolution and column efficiency, variables that affect column efficiency, van Deemter equation, qualitative and quantitative analysis, numericals and applications. Gas Chromatography (GC): Instrumentation, selection of operating condition, carrier gases, stationary phases, choices of GC column, temperature selection, sampling techniques, methods to prepare derivatives of samples (silylation, acylation, alkylation), factors affecting separation, working principle of GC detectors such as TCD, ECD, FID, quantification methods such as normalizing peak area, internal std., external std, standard addition, advances in GC, hyphenated techniques; GC-FTIR, GC-MS. Analysis of data obtained using GC chromatogram, GC-MS. Liquid-Liquid Partition Chromatography: HPLC Introduction, selection of stationary and mobile phase, types of bonded phase chromatography-NPC and RPC and stationary phases used, reversed phase partition chromatography, steps in HPLC method development in partition chromatography, elution techniques (isocratic and gradient), ion pairing agents, buffer agents, organic modifiers, optimization of capacity factor, gradient	

	selectivity factor and column plate numbers, numericals on method development using Snyder's polarity index, advances in LC, Preparative vs analytical HPLC, Chiral chromatography- Pirkle stationary phases, examples of enantiomer separation such as ibuprofen, calculation of enantiomeric excess. Choosing detectors- working principle of RI, UV-Vis, conductivity and ELSD, hyphenated techniques; LC-MS. Analysis of chemical data obtained using HPLC chromatogram, LC-MS. application of HPLC method development in food analysis/drugs, etc.	
	3. Other Chromatographic Methods: Size Exclusion Chromatography: Principle, types, stationary phases in gel chromatography, physical and chemical characteristics of gel, mechanism of gel permeation chromatography (GPC), instrumentation of GPC, applications of GPC- determination of molecular weight of polymer with numericals. Supercritical-Fluid Chromatography: Introduction, important properties of supercritical-fluids, instrumentation and variables, SFC column vs other column, applications and data analysis. Affinity Chromatography: Principle, affinity matrix, ligands, mobile phase, separation mechanism, application in the separation of proteins, etc. Ion Exchange Chromatography: Introduction, mechanism of separation, types of stationary phases, factor affecting separation; Ion exclusion chromatography; separation mechanism- Donnan theory, application in the separation of alkaloids, carboxylic acids etc.	10
	4. Electrophoresis: Theory of electrophoresis, Types- Free solution and supporting medium electrophoresis, paper electrophoresis, capillary electrophoresis and gel electrophoresis. Capillary electrophoresis- Instrumentation, sample introduction in CE, types of CE methodology, electrophoretic mobility and electroosmotic mobility, total mobility, efficiency and resolution in CE column, numericals. Gel electrophoresis - types of gel, Polyacrylamide gel electrophoresis PAGE, Agarose GE, SDS-PAGE, 2D Gel electrophoresis, factors affecting separation; Capillary Electrochromatography. Separation of neutral molecule by MEKC; Separation and determination of Vitamin B-complex by using CZE and MEKC. Staining and detecting electrophoresis band.	10

Pedagogy:	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
References / Readings:	1. G. D. Christian, Analytical Chemistry, 6^{th} Ed.; John Wiley, 2004. 2. D. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9^{th} Ed.; Cengage Learning, 2014. 3. David. Harvey, Modern Analytical Chemistry, 1^{st} Ed.; The McGraw-Hill, 2000. 4. L. R. Snyder, J. J. Kirkland, J. W. Dolan, Introduction to modern liquid chromatography, 3^{rd} Ed.; John Wiley & Sons, 2009. 5. H. H. Willard, L. L. Merritt, J. A. Dean, F. A. Settle, Instrumental methods of Analysis, 7^{th} Ed.; CBS Publishing, 1986. 6. G. H. Jeffery, J. Bassett, J. Mendham, R. C. Denney, Vogel's Text Book of Quantitative Chemical Analysis, 5^{th} Ed.; John Wiley, 1989. 7. H. Gunzler, A. Williams, Handbook of analytical techniques, 1^{st} Ed.; Wiley, 2002. 8. F. W. Fifield, D. Kealey, Principles and Practice of Analytical Chemistry, 5^{th} Ed.; Blackwell Science Ltd., 2000. 9. A. Braithwaite, F. J. Smith, Chromatographic methods, 5^{th} Ed.; Kluwer academic publishers, 1999. 10. J. Inczedy, Analytical Applications of Ion Exchangers, 1^{st} Ed.; Oxford Pergamon Press, 1966.
Course outcomes:	1. Students will be able to select the separation techniques for purification of analytes from interferents. 2. Students will be able to analyse data and interpret chromatogram. 3. Students will be able to perform qualitative and quantitative estimation using HPLC data. 4. Students will understand and will be able to apply various chromatographic techniques.

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Name of the Programme: M. Sc -I (Analytical Chemistry)

Course Code: CHA-504 **Title of the course:** Instrumental Methods of Analysis

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied analytical chemistry courses at M.Sc. Chemistry in semester I	
Course Objective:	1. Introduction of various instrumental methods for analysis. 2. Understanding the utility of various instrumental methods as a qualitative and quantitative analytical tool.	
Content:	**1. Diffraction Techniques: X-ray and Neutron Diffraction** a. Introduction to X-rays; interaction of X-rays with matter; X-ray diffraction by crystals, Bragg's law. b. Powder X-ray diffraction: instrumentation and applications. Interpretation of powder X-ray diffraction pattern. calculation of lattice parameters. c. Powder diffraction file and other crystallography databases. d. Powder Neutron diffraction: theory, instrumentation and applications.	No of hours 15
	2. X-ray Spectroscopic Techniques: a. X-ray spectroscopy, theory of X-ray absorption and emission. b. X-ray fluorescence (XRF) spectroscopy: introduction, instrumentation, wavelength dispersive and energy dispersive XRF, applications. c. Energy dispersive X-ray (EDX) spectroscopy and Electron probe microanalysis (EPMA): introduction, instrumentation and their applications. d. Introduction to X-ray absorption near edge structure (XANES), Extended X-ray absorption fine structure (EXAFS) and their applications.	15
	3. Electron Spectroscopic Techniques: a. Introduction to Electron spectroscopy techniques. b. X-ray and UV Photoelectron spectroscopy (XPS, UPS): theory, instrumentation and their applications. c. Introduction to Auger electron spectroscopy (AES) and electron energy loss spectroscopy (EELS) and their applications.	5
	4. Microscopic Techniques: a. Optical microscopy: components of microscope, different types of optical microscopy techniques; significance and	10

	applications. b. Electron microscopy: Scanning electron microscopy (SEM), Transmission electron microscopy (TEM) and Scanning transmission electron microscopy (STEM) –Principle, instrumentation and applications. c. Atomic Force Microscopy (AFM): theory, instrumentation, operational modes and applications. d. Sample preparation for microscopy: Sample selection, sectioning, mounting, grinding, different polishing methods; microstructure – etching, heat tinting, different etching methods. e. SEM/TEM sample preparation: TEM grids, ion milling, electropolishing etc.	
	5. Molecular Fluorescence, Phosphorescence and Chemiluminescence Spectrometry: a. Fluorescence and phosphorescence: theory; factors influencing fluorescence and phosphorescence; instrumentation; spectrofluorometer and phosphorimeter; applications of photoluminescence methods b. Chemiluminescence: Introduction; instrumentation; measurement of chemiluminescence, gas phase chemiluminescence analysis, chemiluminescence titrations. Application in Organic and Inorganic Analysis. c. Electrochemiluminescence and Bioluminescence: theory and their applications.	10
	6. Automation of Analytical Methods: a. An overview of automated system, distinction between automatic and automated devices; advantages and disadvantages by automation. b. Process Control with automated instruments, discrete and continuous analysers, automatic instruments. Flow and Sequential Injection Analysis, Laboratory Information Management System.	5
Pedagogy:	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings:	1. A. R. West, Solid State Chemistry and Its Applications, 2nd Ed.; Wiley, 2014. 2. V. K. Pecharsky and P. Y. Zavalij, Fundamentals of Powder Diffraction and Structural Characterization of Materials, 1st Ed.; Springer, 2003. 3. D. A. Skoog, F. J. Holler and S. R. Crouch, Principles of Instrumental Analysis, 7th Ed.; Cengage, 2017.	

	4. T. G. Rochow and E. G. Rochow, An Introduction to Microscopy by Means of Light, Electrons, X-Rays, or Ultrasound, 2^{nd} Ed.; Springer, 2012. 5. Y. Leng, Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, 2^{nd} Ed.; Wiley-VCH, 2013. 6. A. M. Garcia-Campana, Chemiluminescence in Analytical Chemistry, 1^{st} Ed.; CRC Press. 2001. 7. R. F. Egerton, Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM, 2^{nd} Ed.; Springer, 2016. 8. E. H. Kisi and C. J. Howard, Applications of Neutron Powder Diffraction, 1^{st} Ed., Oxford Science Publications, 2008. 9. G. D. Christian, Analytical Chemistry, 6^{th} Ed. Wiley, 2004.
Course outcomes:	1. Students will be able to explain theory and instrumentation of various instrumental methods of analysis. 2. Students will be able to judge suitability of different instrumental methods for qualitative and quantitative analysis. 3. Students will understand and will be able to apply various techniques of X-Ray analysis. 4. Students will understand and will be able to apply various microscopic techniques.

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Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHA-521 **Title of the course:** Practical Course in Analytical Chemistry - I

Number of Credits: 02

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objectives:	1. Introduction of various experimental techniques for analysis. 2. Learning data analysis, handling and interpretation of spectra.	
Content:	*This course consists of 7 units of experiments in various areas of Analytical chemistry. Minimum 13 experiments which include at least 02 experiments from unit 1-6 and 01 experiment from unit 7 shall be conducted.* **Unit 1: Statistics** i. Calibration of selected Volumetric apparatus ii. Calibration of selected Laboratory instruments Preparation of standard solutions and standardisation.	No of hours 9
	Unit 2: Colorimetry/ UV-Visible Spectrophotometry i. Estimation of Iron from Pharmaceutical sample (capsule) by thiocyanate method ii. Estimation of phosphoric acid in cola drinks by molybdenum blue method. iii. Estimation of KNO_3 by UV spectroscopy and $K_2Cr_2O_7$ by Visible spectroscopy iv. Simultaneous determination and Verification of law of additivity of absorbances ($K_2Cr_2O_7$ and $KMnO_4$).	8
	Unit 3: Flame Spectrophotometry and AES/AAS/ICP Spectroscopy i. Estimation of Na and K in food supplements or cosmetic products. ii. Estimation of Pb in water sample by AES/AAS/ICP. iii. Estimation of Fe and Al in Iron ore sample by AES/AAS/ICP.	9
	Unit 4: Ion Exchange Chromatography and High Pressure Liquid Chromatography i. Separation and Estimation of chloride and bromide. ii. Separation of Anthracene and Naphthalene using reverse phase chromatography iii. Separation of Benzaldehyde and Benzyl alcohol using normal phase chromatography	10

	Unit 5: Volumetric Titrations i. Estimation of Ca in pharmaceutical tablet. ii. Estimation of Al and Mg in antacid tablet. iii. Estimation of CaO in cement.	10
	Unit 6: Solvent Extraction and spectrophotometry i. Extraction of Cu as copper dithiocarbamate (DTC) using solvent extraction and estimation by spectrophotometry. ii. Determination of Ni as Dimethylglyoxime complex by spectrophotometry. iii. Determination of Silver as ion association complex with 1,10-Phenanthroline and Bromopyrogallol red.	10
	Unit 7: Interpretation Exercises i. Thermal studies: TG/DTA and Isothermal weight loss studies of various hydrated solids like $CuSO_4 \cdot 5H_2O$, $Ca_2C_2O_4 \cdot H_2O$, $Fe_2C_2O_4 \cdot 2H_2O$. ii. X-ray powder diffractometry: Calculation of lattice parameters from X-ray powder pattern of cubic system such as $NiMn_2O_4$, $CoFe_2O_4$ etc. iii. IR spectra of Urea, benzoic acid, Copper sulphate pentahydrate etc.	4
Pedagogy:	Prelab exercises / assignments / presentations / lab hand-out or a combination of some of these. Sessions shall be interactive in nature to enable peer group learning.	
References / Readings:	1. J. H. Kennedy, Analytical Chemistry Principles, Saunders College Publishing, 2nd Ed., 1990. 2. G. D. Christian, Analytical chemistry, 5thEd., John Willey and Sons, 1994 3. J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas, B. Sivasankar, Vogel's Textbook of Quantitative Chemical Analysis, 6thEd., Pearson Education Asia 2009. 4. A. J. Elias, Collection of interesting chemistry experiments, University press, 2002. 5. R.A. Day & A.L. Underwood, Quantitative Analysis, 6thEd., Prentice Hall, 2001. 6. J. Kenkel, Analytical Chemistry for Technicians, 3rdEd., Lewis publishers, 2002.	
Course outcomes:	1. Students will be able to explain how to determine an unknown concentration of solution. 2. Students will use statistical methods to analyse data in laboratory. 3. Students will be able to use different techniques for qualitative and quantitative estimation. 4. Students will be able to interpret TG/X-Ray/IR spectra.	

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHA-522 **Title of the course:** Practical Course in Analytical Chemistry - II

Number of Credits: 02

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objectives:	1. Introduction of various experimental techniques for analysis. 2. Learning data analysis, handling and interpretation of spectra.	
Content:	*This course consists of 7 units of experiments in various areas of Analytical chemistry. Minimum 13 experiments which include at least 02 experiments from unit 1-6 and 01 experiment from unit 7 shall be conducted.*	No of hours
	Unit 1: Statistics i. Calibration of selected Volumetric apparatus ii. Calibration of selected Laboratory instruments iii. Preparation of standard solutions and standardisation.	9
	Unit 2: Titrimetric Analysis i. Standardisation and estimation of Chloride using precipitation titration (Mohr's method) ii. Analysis of commercial caustic soda by neutralisation titrimetric method iii. Determination of sulphates by complexometric titrations using EDTA.	8
	Unit 3: Flame Spectrophotometry and AES/AAS/ICP Spectroscopy i. Estimation of Na and K in food supplements or cosmetic products using flame photometer. ii. Estimation of chromium in water sample by AES/AAS/ICP. iii. Estimation of nickel, molybdenum in Hastelloy C-22 using AES/AAS/ICP.	10
	Unit 4: Natural product isolation and Ion Exchange Chromatography i. Isolation of cinnamaldehyde from cinnamon ii. Isolation of Caffeine from tea powder iii. Separation and estimation of Cadmium and Zinc	9
	Unit 5: UV-Visible Spectrophotometry and High-Pressure Liquid Chromatography i. Estimation of KNO_3 and $K_2Cr_2O_7$ using UV- Visible	10

<table>
<tr><td></td><td>spectroscopy
ii. Separation of Benzaldehyde and benzoic acid using reverse phase HPLC.
iii. Quantification of naphthalene in a sample using reverse phase HPLC.</td><td></td></tr>
<tr><td></td><td>Unit 6: Solvent Extraction and spectrophotometry
i. Spectrophotometric determination of aspirin/phenacetin/ caffeine in APC tablet using solvent extraction
ii. Colorimetric determination of iron with salicylic acid.
iii. Determination of copper in brass sample by colorimetry.</td><td>10</td></tr>
<tr><td></td><td>Unit 7: Data Interpretation Exercises
i. NMR/Mass spectra
ii. HPLC and GC chromatograph
iii. XRD powder pattern of cubic systems
iv. Thermogram of coordination compounds</td><td>4</td></tr>
<tr><td>Pedagogy:</td><td colspan="2">Prelab exercises / assignments / presentations / lab hand-out or a combination of some of these. Sessions shall be interactive in nature to enable peer group learning.</td></tr>
<tr><td>References / Readings:</td><td colspan="2">1. J. H. Kennedy, Analytical Chemistry Principles, Saunders College Publishing, 2nd Ed., 1990.
2. G. D. Christian, Analytical chemistry, 5th Ed., John Willey and Sons, 1994
3. J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas, B. Sivasankar, Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed., Pearson Education Asia 2009.
4. J. Elias, Collection of interesting chemistry experiments, University press, 2002.
5. R.A. Day & A.L. Underwood, Quantitative Analysis, 6th Ed., Prentice Hall, 2001.
6. J. Kenkel, Analytical Chemistry for Technicians, 3rd Ed., Lewis publishers, 2002.</td></tr>
<tr><td>Course outcomes:</td><td colspan="2">1. Students will be able to standardize a material to determine an unknown concentration.
2. Students will use statistical methods to analyse data in laboratory.
3. Students will be able to use different techniques for qualitative and quantitative estimation.
4. Students will be able to interpret TG/X-Ray/IR spectra.</td></tr>
</table>

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHI-500**Title of the course:** Fundamentals of Inorganic Chemistry

Number of Credits: 04

Effective from AY: 2022-23

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. To introduce atomic structure, molecular structure, bonding, and symmetry.
2. To provide fundamental knowledge of solid state chemistry, coordination chemistry, organometallic chemistry, and bioinorganic chemistry.
3. To provide fundamental aspects of transition & inner transition elements & their compounds.
4. To introduce air and water pollution, and its treatments, to follow directive of the Supreme Court in 1993 to introduce environmental education at all levels.</td></tr>
<tr><td rowspan="3">Content</td><td>1. Atomic structure, molecular structure and bonding
a. Atomic Structure: Structures of hydrogenic atoms: some principles of quantum mechanics, atomic orbitals. Many electron atoms: penetration & shielding, building up principle, classification of elements. Spectroscopic terms. Atomic properties: atomic radii, ionic radii, ionization energy, electron affinity, electronegativity, polarizability.
b. Molecular Structure & bonding: Lewis structures: octet rule, resonance. VSEPR model: basic shapes, modification of the basic shapes. Valence bond theory: hydrogen molecule, homonuclear diatomic molecules, polyatomic molecules, promotion, hypervalence, hybridization. Molecular orbital theory: approximation, boding & antibonding orbitals. Homonuclear diatomic molecules & Heteronuclear diatomic molecules</td><td>No of hours

10</td></tr>
<tr><td>2. Molecular Symmetry
a. Symmetry elements and symmetry operations.
b. Equivalent symmetry elements and equivalent atoms, symmetry point groups with examples, point groups of higher symmetry.
c. Systematic procedure for symmetry classification of molecules and illustrative examples, dipole moment, optical activity and point groups</td><td>4</td></tr>
<tr><td>3. Solid state chemistry
a. Structures of solids: crystal structures, lattices and unit cells,</td><td>10</td></tr>
</table>

	fractional atomic coordinates and projections, close packing of spheres, holes in closed-packed structures. b. Structures of metals & alloys: polytypism, nonclosed-packed structures, polymorphism of metals, atomic radii of metals, alloys, substitutional and interstitial solid solutions, intermetallic compounds. c. Ionic solids: characteristic structures of ionic solids, binary phases, ternary phases, rationalization of structures, ionic radii, radius ratio, structure maps, energetics of ionic bonding, lattice energy and the Born–Haber cycle, The calculation of lattice enthalpies. (numerical expected)	
	4. Chemistry of transition & inner transition elements a. Transition elements**:** IUPAC definition of transition elements, occurrence, physical and chemical properties, noble character, metal halides, oxides & oxido complexes, examples of metal-metal bonded clusters, difference between 1st row and other two rows. b. Inner transition elements: Lanthanides, occurrence, properties, oxidation states, electronic structure, colour and spectra, magnetic properties, lanthanide contraction, compounds of lanthanides. Actinoid chemistry: general trends and properties, electronic spectra, thorium and uranium.	10
	5. Coordination and Organometallic Chemistry a. Coordination chemistry: Introduction, representative ligands, nomenclature. Constitution and geometry: low coordination numbers, intermediate coordination numbers, higher coordination numbers, polymetallic compounds. Isomerism & chirality in square planar and octahedral complexes, ligand chirality. Thermodynamics of complex formation: formation constants, chelate and macrocyclic effects, steric effects and electron delocalization. Electronic properties of metal complexes: CFT applied to octahedral and tetrahedral complexes, magnetic moments, CFSE. Electronic spectroscopy: basic concepts, interpretation of spectra of d^1 & d^9 ions (Orgel diagram for octahedral and tetrahedral complexes). b. Organometallic Chemistry: Introduction to organometallic chemistry, nomenclature, stability and inert gas rules (neutral atom and donor pair electron count methods). Ligands: CO & phosphines, homoleptic carbonyls its synthesis and properties, oxidation-reduction of carbonyls, metal carbonyl basicity, reactions of CO ligand, spectroscopic properties of metal carbonyls. Oxidative addition and reductive elimination.	12
	6. Basic Bioinorganic Chemistry a. Macronutrients/micronutrients. Role of elements in biology.	4

	Metal ion transport role. b. Definition of metallobiomolecules, metalloporphyrins, structure of porphine and heme group, examples of metalloenzymes of Cu and Zn.	
	7. Environmental Chemistry a. Air Pollution: Classification of air pollutants and photochemical reactions in the atmosphere. Common air pollutants (e.g. CO, NOx, SO_2, hydrocarbons and particulates) (a) sources (b) physiological and environmental effect (c) monitoring, (d) various remedial & technological measures to curb pollution. Air quality standards. b. Water pollution: Importance of buffer & buffer index in waste water treatments. Chemical, physical & biological characteristics of water pollution, specific & non-specific characterization of water. DO, BOD, COD, and chlorine demand, typical water treatment & waste water treatment (Municipal). Impact of plastic pollution and its effect.	10
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings:	1. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins Inorganic Chemistry, 5th Ed.; Oxford Publications, 2009. 2. J. E. Huheey, E. A. Kieter, R. L. Kieter, O. K. Medhi, Inorganic Chemistry: Principles of Structure & Reactivity, 4th Ed.; Pearson, 2011. 3. F. A. Cotton, G. Wilkinson, P. L. Gauss, Basic Inorganic Chemistry, 3rd Ed.; Wiley, 2008 (reprint). 4. J. D. Lee, Concise Inorganic Chemistry, 5th Ed.; Wiley, 2008. 5. F. A. Cotton, Chemical applications of group theory, 3rd Ed.; Wiley Eastern, 2012 (reprint). 6. L. Pauling, The Nature of The Chemical Bond, 3rd Ed.; Cornell University Press, 1960. 7. M. C. Day, J. Selbin, Theoretical Inorganic Chemistry, 2ed Ed.; Van Nostrand-Reinhold, 1969. 8. H. V. Keer, Principles of Solid state Chemistry, 1st Ed.; New Age Intl. Ltd, 1993, (reprint 2008). 9. A. R. West, Solid State Chemistry and Its Applications, 1st Ed.; John Wiley & Sons, Singapore, 1984 (reprint 2007). 10. D. K. Chakrabarty, Solid State Chemistry, 2ed Ed.; New Age Intl. Publishers, 2010. 11. F. A. Cotton, G. Wilkinson, Advanced Inorganic Chemistry, 3rd Ed.; Wiley Eastern, 2001. 12. A. V. Salker, Environmental Chemistry: Pollution and Remedial Perspective, 1st Ed.; Narosa Publication, 2017.	

	13. A.K. De, Environmental Chemistry, 3rd Ed.; New Age Intl. Publishers, 2005. 14. A. C. Stern, R. W. Boubel, D. Bruce turner, D. L. Fox, Fundamentals of Air Pollution, 1st Ed.; Academic Press, 1984. 15. R. A. Horne, Chemistry of Our Environment, 1st Ed.; John Wiley, 1978. 16. R. S. Drago, Physical Methods in Inorganic Chemistry, Affiliated East West Press Pvt. Ltd., 2017 17. G. C. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Ed.; Pearson, 2004
Course outcomes:	1. Students will be able to predict geometry and shape of different molecules, and the point group symbols. 2. Students will be able to explain the fundamentals of atomic and molecular structure, solid state chemistry, coordination chemistry, organometallic chemistry, and bioinorganic chemistry. 3. Students should be able to describe and explain the properties and usefulness of transition & inner transition metals. 4. Students will able to explain different air and water pollutants and will be in a position to apply knowledge to treat these pollutants.

Name of the Programme: M.Sc. Part-I (Inorganic Chemistry)

Course Code: CHI-501 **Title of the course:** Chemistry of Coordination & Organometallic Compounds

Number of Credits: 04

Effective from AY: 2022-23

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied Inorganic chemistry courses at M.Sc. Chemistry in semester I</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. To make understand fundamentals of coordination and organometallic chemistry.
2. To gain the knowledge on structural aspects of compounds.
3. To make understand bonding using various models.
4. To correlate spectroscopic and magnetic properties with bonding models.
5. To develop a skill of interpretation of magnetic and spectroscopic properties.
6. To understand fundamental concepts of inorganic chemistry reaction mechanisms.
7. To provide knowledge on applications of organometallic compounds in homogenous catalysis.</td></tr>
<tr><td>Content:</td><td>1. Electronic structure of coordination compounds
Basic introduction to bonding theories:
a. Valence Bond theory & its utility, limitations of VBT.
b. Crystal field theory and its uses in: i) Octahedral compounds; ii) tetrahedral compounds; iii) square-planar compounds and other geometries; iv) tetragonally distorted compounds (Jahn-Teller Effect); v) octahedral vs tetrahedral; vi) Evidences showing covalency to the M-L bonds.
c. Molecular orbital theory (MOT): σ & π-bonding in octahedral, tetrahedral, square planar compounds.</td><td>No of hours
12</td></tr>
<tr><td></td><td>2. Spectra and magnetic studies of coordination compounds
a.(i) Electronic spectra of atoms, (ii) Electronic spectra of complexes; Orgel diagrams, correlation diagrams, T-S diagrams examples and problem solving, (iii) Charge-transfer bands; (iv) Selection rules and intensities, (v) Luminescence.
b. Vibrational spectra of coordination compounds.
c. Magnetic studies: cooperative magnetism, basic concepts of magnetic properties: diamagnetism, paramagnetism,</td><td>12</td></tr>
</table>

	ferromagnetism, antiferromagnetism, temperature dependent magnetism, Curie law, Curie Weiss Law; spin cross over phenomenon.	
	3. Inorganic reaction mechanisms a. The thermodynamics of complex formation: Formation constants; Trends in successive formation constants; The chelate and macrocyclic effects; Steric effects and electron delocalization. b. Ligand substitution reactions and mechanisms: Rates of ligand substitution; The classification of mechanisms; Ligand substitution in square-planar complexes: The nucleophilicity of the entering group; The shape of the transition state. Ligand substitution in octahedral complexes: Rate laws and their interpretation; The activation of octahedral complexes; Base hydrolysis; Stereochemistry; Isomerization reactions. C. Redox reactions: The classification of redox reactions; The inner-sphere mechanism; The outer-sphere mechanism. d. Photochemical reactions: Prompt and delayed reactions; d–d and charge-transfer reactions; Transitions in metal–metal bonded systems.	12
	4. Organometallic chemistry of d-block elements a. Stable electron configurations; Electron count preference; Electron counting and oxidation states. b. Ligands: Carbon monoxide, Phosphines, Hydrides and dihydrogen complexes, η^1-Alkyl, -alkenyl, -alkynyl, and -aryl ligands, η^2-Alkene and -alkyne ligands, Nonconjugated diene and polyene ligands, Butadiene, cyclobutadiene, and cyclooctatetraene, Benzene and other arenes, The allyl ligand, Cyclopentadiene and cycloheptatriene, Carbenes, Alkanes, agostic hydrogens, and noble gases, Dinitrogen and nitrogen monoxide. c. Compounds: *d*-Block carbonyls, Metallocenes, Metal–metal bonding and metal clusters. d. Reactions: Ligand substitution, Oxidative addition and reductive elimination, σ-Bond metathesis, 1,1-Migratory insertion reactions, 1,2-Insertions and β-hydride elimination, α-, β-, and δ-Hydride eliminations and cyclometallations. e. Catalysis: general concepts, catalytic cycle for isomerization of prop-2-en-l-ol to prop-1-en-l-ol, Alkene metathesis, hydrogenation of alkenes, hydroformylation, Wacker oxidation of alkenes, Asymmetric oxidations, Palladium	24

	catalyzed C-C bond forming reactions, methanol carbonylation (Monsanto acetic acid process).	
Pedagogy:	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings:	1. P. W. Atkins, T. L. Overton, J. P. Rourke, M. T. Weller & F. A. Armstrong 2010, Shriver & Atkins' Inorganic Chemistry, 5^{th} Ed., Oxford University Press, 2010. 2. J. E. Huheey, E. A. Keiter& R. L. Keiter, Inorganic Chemistry:Principles of structure and reactivity, 4^{th} Ed.;Pearson, 2014. 3. J. D. Lee, Concise Inorganic Chemistry, 5^{th}Ed, Chapman and Hall, 1996. 4. F. A. Cotton, G. Wilkinson & P. L. Gaus, Basic Inorganic Chemistry, 3^{rd} Ed.; John Wiley, 1995. 5. F. A. Cotton & G. Wilkinson, Advanced Inorganic Chemistry, 3^{rd} Ed. (4^{th} & 5^{th} Eds. preferred);Wiley Eastern, New-Delhi, 1984. 6. D. Banerjee, Coordination Chemistry, 1^{st} Ed.;Tata McGraw–Hill, New Delhi, 1994. 7. N. N. Greenwood & A. Earnshaw, Chemistry of the Elements, Pergamon Press, Exeter, 1984. 8. G. Rodgers, Introduction to coordination, solid state, and descriptiveInorganic chemistry, 1^{st} Ed.; McGraw–Hill,1994. 9. R. S. Drago, Physical Methods in Inorganic Chemistry, Affiliated East West Press Pvt. Ltd., 2017 10. G. C. Miessler, D. A. Tarr, Inorganic Chemistry, 3^{rd} Ed.; Pearson, 2004	
Course outcomes:	1. Students will be able to understand the electronic structure of coordination and organometallic compounds. 2. Students will be well equipped with knowledge of CFT and MOT 3. Students will be in position to understand the magnetic and electronic properties. 4. Students will be able to acquire skill on interpretation of electronic and IR spectra of inorganic compounds 5. Students will be able understand concepts of inorganic reactions & mechanisms. 6. Students will be aware of applications of organometallic compounds in industrial processes.	

Name of the Programme: M. Sc -I (Inorganic Chemistry)

Course Code: CHI-502 **Title of the course:** Chemistry of Materials

Number of Credits: 04

Effective from AY: 2022-23

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied Inorganic chemistry courses at M.Sc. Chemistry in semester I</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1.To provide information about different types of materials.
2.To provide knowledge about different types of synthesis.
3.To be familiar with different solid state properties of materials.</td></tr>
<tr><td rowspan="4">Content:</td><td>1. Introduction to Materials Chemistry
Basic knowledge about properties, structure and applications of materials.</td><td>No of hours
1</td></tr>
<tr><td>2. Structure and bonding in solid materials
Crystal lattice; unit cell; Miller indices and planes; X-Ray diffraction method; Molecular, Metallic, Covalent and Ionic solids, Hydrogen bonding; Structural classification of binary and tertiary compounds; Spinel and Perovskite structures</td><td>6</td></tr>
<tr><td>3. Crystal defects & Non-stoichiometry in Solids
a. Types of defects: Point defects, Dislocations: Line defects and Plane defects.
b. Oxygen deficient oxides; Metal deficient oxides and classification of non-stoichiometry.</td><td>6</td></tr>
<tr><td>4. Materials preparation techniques
a. Broad Classification of methods: Ceramic method, and Different wet chemical methods.
b.Types of Materials: Powdered bulk materials, Single crystal and Thin films, Amorphous materials, and Nanomaterials.
c. Preparation methods for different materials with their advantages and disadvantages:
i. Powder materials: Co-precipitation method, Precursor method, Combustion method: Solid state and solution method, Precursor-combustion method, Sol-gel method, Spray roasting method, Freeze drying method.
ii. Single crystals: (a) Growth from melt (b) from solution (c) using Flux method (d) Epitaxial growth of single crystal thin films: Using Chemical and Physical methods (e) Chemical vapour transport (f) Hydrothermal method (g) Dry high pressure method, electrochemical reduction method.
iii. Amorphous Materials: Synthesis & applications.</td><td>16</td></tr>
</table>

	Nanomaterials: Synthesis, properties: structural, optical and magnetic and applications.	
	5. Reactivity of Solid Materials Tarnish reactions, decomposition reaction, solid-solid reactions, addition reactions, double decomposition reaction, electron transfer reaction, solid-gas reactions, sintering, factors influencing reactivity of solids.	4
	6. Phase Transformations in Solids Thermodynamic consideration, Burgers classification, structural change in phase transformation, Martensite transformation, temperature and pressure induced transformations, order-disorder transitions, electronic transition, transformation with a change in composition, enantiotropy and monotropy, Ehrenfest's classification.	6
	7. Electrical Properties Electrical conductivity, free electron theory, Fermi energy, insulators, semiconductors and conductors, band theory of semiconductor, Brilliouin zones, Hall effect, Peltier effect, Seebeck effect, photo conductivity and ionic conductivity, Superconductivity, BCS theory, Meissner effect, high temperature superconductor.	7
	8. Semiconductor Devices Diodes and transistors, Junction field effect transistor and metal oxide semiconductor field effect transistor, light meter, photodiode, phototransistor, solar cells, light emitting diodes. Laser materials.	5
	9. Optical and dielectric properties Luminescence and phosphorescence, piezoelectric, ferroelectric materials and applications, thermal conductivity, phonon interaction, thermal expansion coefficient.	4
	10. Magnetic properties Introduction to magnetism, behavior of substance in a magnetic field, magnetic moments, diamagnetism, paramagnetism, experimental determinations of susceptibility, ferromagnetism, anti-ferromagnetism and ferrimagnetism, magnetization of ferromagnetic substance.	5
Pedagogy:	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings:	1. A.R. West, Solid State Chemistry and Its Applications, 1st Ed., John Wiley & Sons, Singapore, 1984 (reprint 2007). 2. L.V. Azaroff, Introduction to Solids, 1st Ed., Tata McGraw Hill, 2009,	

		(33rd Reprint).
	3.	N. B. Hannay, Treatise on Solid State Chemistry Vol.4 Reactivity of Solids, 1st Ed.; Plenum Press, 1976.
	4.	D. K. Chakraborty, Solid State Chemistry, 2nd Ed.; New Age International Publisher, 2010.
	5.	H. V. Keer, Principles of the Solid State, 1st Ed., New Age International (P) Ltd., (Wiley Eastern Ltd,), 1993, (Reprint 2008).
	6.	C. N. R. Rao & K. J. Rao, Phase Transitions in Solid, 1st Ed.; McGraw Hill, 1977.
	7.	W. D. Callister, Materials Science and Engineering:An Introduction, 7th Ed.; John Wiley, 2007.
	8.	B. D. Fahlman, Materials Chemistry, 2nd Ed.; Springer, 2011.
	9.	H. R. Allcock, Introduction to materials chemistry, 1st Ed.; John Wiley & Sons, 2011.
	10.	C. N. R Rao & Gopalkrishnan, New directions in solid state chemistry, 2nd Ed.; Cambridge University Press, 1997.
	11.	R. S. Drago, Physical Methods in Inorganic Chemistry, Affiliated East West Press Pvt. Ltd., 2017.
	12.	G. C. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Ed.; Pearson, 2004.
Course outcomes:	1.	Students will be able to explain different methods of material synthesis.
	2.	Students can explaineffect of size variations on solid state properties of materials.
	3.	Students can explain different types of defects and phase transformations in materials.
	4.	Students will be in position to describe magnetic, electrical, dielectric, optical, and semiconductor properties of materials.

Name of the Programme: M. Sc -I (Inorganic Chemistry)

Course Code: CHI-503 **Title of the course:** Concepts in Molecular Symmetry and Spectroscopy

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied Inorganic chemistry courses at M.Sc. Chemistry in semester I	
Course Objective:	1. To train the students to understand the concepts of molecular symmetry and their applications in chemistry 2. To train the students to understand different spectroscopic techniques viz. magnetic resonance, vibrational & Mössbauer spectroscopy with emphasis on spectral interpretation.	
Content	**1. Molecular symmetry** a. Symmetry elements and symmetry operations, symmetry planes and symmetry reflections, inversion center, proper axes and proper rotations, improper axis and improper rotations. b. Products of symmetry operations, equivalent symmetry elements and equivalent atoms, relations among symmetry elements and operations, symmetry elements and optical isomerism, symmetry point groups, symmetries with multiple high order axes, classes of symmetry operations, procedure for symmetry classification of molecules. c. Group and it's defining properties, order of the group, examples of group, group multiplication table, cyclic group, acyclic group, abelian group, non-abelian group. Sub groups, classes, properties of conjugate elements. d. Some properties of matrices and vectors, the great orthogonality theorem, reducible and irreducible representations, irreducible representations and their characters, character tables. Bases for irreducible representations, direct product. Symmetry Adapted Linear Combinations and its applications. Cage and cluster compounds, metal sandwich compounds. e. Crystal symmetry, space groups.	No of hours 30
	2. Spectroscopy a. Magnetic Resonance Spectroscopy; interaction between electron spin and magnetic field, interaction between nuclear spin and magnetic field, Resonance condition, instrumental requirements, b. Presentation of ESR (electron spin resonance) and NMR (nuclear magnetic resonance) spectra, line widths of ESR and	30

	NMR spectra, hyperfine coupling in isotropic systems (e.g. H atom, methyl radical etc.), anisotropic system, number of expected ESR signals for one electron paramagnetic species, zero field splitting and Kramer's degeneracy, Spin energy levels of octahedral Mn(II) complexes, nuclear quadrupole interaction, spin Hamiltonian, ESR spectra of some transition metal compounds, Electron delocalization, NMR spectral interpretation of a few nuclei like ^{19}F, ^{29}Si, ^{31}P. c. Mössbauer spectroscopy; Mössbauer effect, Mössbauer principle, Recoilless emission and absorption spectral line widths, Doppler shift, experimental arrangement of Mössbauer spectroscopy, chemical shift (isomer shift), quadrupole splitting, magnetic hyperfine interaction, discussion of selected Mössbauer nuclei like ^{57}Fe, ^{129}I. d. Vibrational spectroscopy: Infrared spectroscopy and Raman spectroscopy, principle, their use in determination of molecular structure.	
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. F. A. Cotton, Chemical Applications of Group theory, 3rd Ed.; John Wiley,1990 2. J. E. Huheey, E. A. Keiter, R.L. Keiter, Inorganic Chemistry: Principles of structure and reactivity, 4thEd.; Pearson, 1993. 3. G. R. Desiraju, J. J. Vittal, A. Ramanan, Crystal Engineering, IISC Press, world Scientific, 2011. 4. R. L. Dutta, A. Syamal, Elements of Magnetochemistry, 2nd Ed.; Affiliated East-West Press, New Delhi, 1993. 5. C. N. Banwell, E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th Ed.; Tata McGraw Hill, New Delhi, 1994. 6. G. Aruldhas, Molecular structure and spectroscopy, Prentice Hall of India, 2001 7. P. Atkins, J. De Paula, J. Keeler, Atkins' Physical Chemistry, International Ed.; Oxford University Press, 2018. 8. M. Weller, T. Overton, J. Rourke, F. Armstrong, Inorganic Chemistry, International Ed.;Oxford University Press, 2018. 9. E. A. V. Ebsworth, D. W. H. Rankin, S. Cradock, Structural Methods in Inorganic Chemistry, ELBS, 1988. 10. K. Nakamoto, Infrared and Raman Spectra of Inorganic and Coordination Compounds, Part A: Theory and Applications in Inorganic Chemistry, 6thEd.; Wiley, 2009. 11. K. Nakamoto, Infrared and Raman Spectra of Inorganic and Coordination Compounds, Part B: Applications in Coordination,	

	Organometallic and Bioinorganic Chemistry, 6th Ed.; Wiley, 2009. 12. R. S. Drago, Physical Methods in Inorganic Chemistry, Affiliated East West Press Pvt. Ltd., 2017 13. G. C. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Ed.; Pearson, 2004
Course outcomes:	1. Students will be able to explain symmetry aspects of simple molecules and their applications in chemistry. 2. Students will be able to explain IR, Raman, ESR, NMR, Mössbauer spectra of simple molecules to determine molecular geometry. 3. Students will understand fundamental difference between various spectroscopic techniques. 4. Students will be able to explain the space groups.

Name of the Programme: M. Sc -I (Inorganic Chemistry)

Course Code: CHI-504**Title of the course:** Concepts in Inorganic Chemistry

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied Inorganic chemistry courses at M.Sc. Chemistry in semester I	
Course Objective:	1. To gain knowledge in selected topics in inorganic chemistry and study the applications of inorganic compounds in selected areas. 2. To learn in details about the s-block elements and their compounds. 3. To understand the concepts in acid-base reactions in the Inorganic chemistry. 4. To gain knowledge about atomic stability and nuclear reactions. 5. To study the importance of metal ions in the field of medicinal chemistry.	
Content	**1. s-Block elements and their compounds** a. Hydrogen and hydrides; Electronic structure, position in periodic table, abundance, preparation, properties, isotopes, ortho and para hydrogen. Classification of hydrides, preparation & properties of hydrides; hydrogen ion, hydrogen bonding and its influence on properties. b. Group 1 elements; Introduction, abundance, extraction, physical and chemical properties, solubility and hydration, solutions of metal in liquid ammonia, complexes, crowns and cryptands, electrides, alkalides, difference between lithium and the other group 1 elements, diagonal relationship between Li and Mg. c. Group 2 elements; Introduction, abundance, extraction, physical and chemical properties, solutions of metal in liquid ammonia, complexes, anomalous behaviour of beryllium, difference between beryllium and the other group 2 elements, diagonal relationship between Be and Al, preparation and properties of Grignard reagent.	No of hours 17
	2. Inorganic medicinal chemistry a. Anticancer agents; Platinum and Ruthenium complexes as anticancer drugs, Cancerchemotherapy, phototherapy, radiotherapy using borane compounds. b. Chelation therapy. c. Gadolinium and technetium complexes as MRI contrast agents, X-ray contrast agents. d. Anti-arthritis drugs.	16

	e. Anti-bacterial agents (Ag, Hg, Zn and boron compounds). f. Antiseptic and anti-biotic. g. Deodorants and anti-perspirants.	
	3. Chemistry of radioactive elements a. Atomic nucleus; Classification of nuclides and nuclear stability. b. Review of Nuclear models. c. Radioactivity, Decay processes and decay energy, half-life of radioactive elements. d. Nuclear reactions; Nuclear fission and fusion processes. e. Nuclear Reactors; Nuclear reactor components and functions, Q values for nuclear reactions. f. Detection and measurement of activity; Radiation detection principles. g. Physical and Chemical separation techniques of radioactive elements. h. Radio-analytical techniques, Activation analysis. i. Nuclear waste management. j. Applications of radioactivity.	15
	4. Acids and Bases a. Brønsted acidity; Proton transfer equilibria in water, Solvent levelling, The solvent system definition of acids and bases, Characteristics of Brønsted acids, Periodic trends in aqua acid strength, Simple oxoacids, Anhydrous oxides, Polyoxo compound formation, Nonaqueous solvents. b. Lewis acidity; Examples of Lewis acids and bases, Group characteristics of Lewis acids. c. Reactions and properties of Lewis acids and bases; The fundamental types of reaction, Hard and soft acids and bases, Thermodynamic acidity parameters, Solvents as acids and bases. d. Applications of acid–base chemistry, Superacids and superbases, Heterogeneous acid–base reactions.	12
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins Inorganic Chemistry, 5th Ed.;Oxford Publications, 2009. 2. J. E. Huheey, E. A. Kieter, R. L. Kieter, O. K. Medhi, Inorganic Chemistry: Principles of Structure & Reactivity, 4th Ed.;Pearson, 2011.	

	3. F. A. Cotton, G. Wilkinson, P. L. Gauss, Basic Inorganic Chemistry, 3rd Ed.;Wiley, 2008. 4. J. D. Lee, Concise Inorganic Chemistry, 5thEd.;Wiley, 2008. 5. F. A. Cotton, G. Wilkinson, Advanced Inorganic Chemistry, 3rd Ed.; Wiley, 1984. 6. N. N. Greenwood, A. Earnshaw, Chemistry of the Elements, Pergamon Press, 1st Ed.; 1984. 7. A. G. Sykes, Advances in Inorganic Chemistry, UK Ed.;Academic Press Ltd., 1991. 8. H. J. Arnikar, Essentials of Nuclear Chemistry, 4th Revised Ed.; New Age Intl.Publishers, 2011. 9. G. Friedlander, J. W. Kennedy, E. S. Macias, J. M. Miller, Nuclear & Radiochemistry, 3rd Ed.; John Willey & Sons, 1981. 10. K.A. Strohfeldt, Essentials of Inorganic Chemistry, Ist Ed.; John Willey & Sons, 2015. 11. G.R. Choppin, J-O. Linjenzin, Radiochemistry and Nuclear Chemistry, 2nd Ed.; Butterworth-Heinemann Ltd, 1995. 12. R. S. Drago, Physical Methods in Inorganic Chemistry, Affiliated East West Press Pvt. Ltd., 2017 13. G. C. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Ed.; Pearson, 2004
Course outcomes:	1. Students will be able to explain the chemistry of s-block elements. 2. Students will be able to explain fundamentals of inorganic medicinal chemistry. 3. Students will be able to solve numerical problems related to some concepts in acid-base and nuclear chemistry. 4. Students will be able to analyse reactions and processes in field of nuclear chemistry.

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHI-521 **Title of the course:** Practical course in Inorganic Chemistry-I

Number of Credits: 02

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objective:	1. Students shall acquire skills in synthetic inorganic chemistry. 2. Students will learn to prepare coordination compounds. 3. Students will learn to prepare useful potash alum from scrap aluminum. 4. Students will learn how to grow single crystals. 5. Students will acquire skills in determination of chromium, oxalate, and aluminum by redox titrations. 6. Students will be trained to fix the formula of compounds and find lattice water molecules by complexometric, redox & iodometric titrations. 7. Students shall acquire skills in determination of metal content at very low concentrations (ppm) using colorimetry / spectrophotometry.	
Content	*Minimum 13 experiments from the list shall be conducted.* **1. Preparations / Synthesis of Inorganic Compounds: (Any Five)** i. Preparation of hexaamminenickel(II) chloride. ii. Preparation of Trisethylenediaminecobalt(III) chloride. iii. Preparation of potassium trioxalatoaluminate trihydrate. iv. Preparation of potassium hexathiocyanato-*κN*-chromate tetrahydrate. v. Preparation of potassium trioxalatochromate trihydrate. vi. Preparation of potash alum from scrap aluminum.	No of hours 25
	2. Estimations / Determinations: (Any Eight) i. Estimation of nickel in $[Ni(NH_3)_6]Cl_2$by complexometry or Gravimetry. ii. Estimation of cobalt in $[Co(en)_3]Cl_3$ by complexometry. iii. Estimation of oxalate in $K_3[Al(C_2O_4)_3]\cdot xH_2O$ or $K_3[Cr(C_2O_4)_3]\cdot xH_2O$ iv. Estimation of nitrite by redox titration. v. Estimation of calcium from calcite ore. vi. Iodometric determination of Copper in gun metal alloy/Devarda's alloy. vii. Determination of chromium in chrome alum and $K_3[Cr(C_2O_4)_3]\cdot xH_2O$ and to determine degree of hydration. viii. Colorimetric/Spectrophotometric determination of nickel or	35

	chromium. ix. Estimation of manganese by colorimetric / spectrophotometry method.	
Pedagogy	Students will be given pre-lab and post-lab assignments on theoretical aspects of laboratory experiments prior to the conduct of each experiment. Exams will be in the form of ISA, SEA which will involve performing given experiments and conduct of viva, systematic reporting of experiments, results and observations in laboratory report. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. G. Brauer, Handbook of Preparative Inorganic Chemistry, Vol. 1 & 2, 1963. 2. G. Pass & H. Sutcliffe, Practical Inorganic Chemistry, Preparations, Reactions and Instrumental Methods, 2nd Ed.; Chapman & Hall, 1974. 3. S. De Meo, J. Chem. Ed., Vol 80, Pg.No.796-798, 2003. 4. W. L. Jolly, The Synthesis & Characterization of Inorganic Compounds, Prentice-Hall, INC, 1970. 5. A. J. Elias, General Chemistry Experiments, Revised Ed.; University Press, 2008. 6. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, Vogel's Text Book of Quantitative Chemical Analysis,6th Ed.; Pearson, 2002. 7. G. Svehla, Vogel's Text Book of Qualitative Inorganic Analysis, 7th Ed, Pearson, 2011. 8. G. Marr, B. W. Rockett, Practical Inorganic Chemistry, Van Nostrnad Reinhold London, 1972.	
Course outcomes:	1. Students will be in a position to synthesis coordination compounds with different metals and ligands. 2. Students will be able to grow single crystal. 3. Students will be able to prepare potash alum compound from waste scrap Al source. 4. Students will be able to determine metal content in the synthesised inorganic compounds. 5. Students will be able to fix the formula of compounds. 6. Students will be able to use and explain the diverse methods available for estimation of the metals including colorimeters and spectrometers.	

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHI-522 **Title of the course:** Practical course in Inorganic Chemistry-II

Number of Credits: 02

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objective:	1. Students shall acquire skills in synthetic inorganic chemistry. 2. Students will learn to prepare coordination compounds. 3. Students will learn how to grow single crystals. 4. Students will acquire skills in determination of metal present by gravimetric and titrimetric method. 5. Students shall acquire skills in determining the metal content at very low concentrations (ppm) using colorimetry / spectrophotometry.	
Content	*Minimum 13 experiments from the list shall be conducted.*	No of hours
	1. Preparations / Estimation of Inorganic Compounds: (Any Nine) i. Preparation of hexaamminecobalt(III) nitrate. ii. Estimation of cobalt in hexaamminecobalt(III) nitrate by volumetric titration. iii. Preparation of Potassium Trioxalatoferrate(III) Trihydrate iv. Estimation of iron and oxalate by redox titration v. Synthesis of metal nanoparticles (Cu, Ag, Au, Ni) and determining the absorption maxima by UV-visible spectrophotometer. vi. Estimation of amount of calcium in given sample by gravimetric method. vii. Estimation of amount of nickel in given sample by gravimetric method. viii. Estimation amount of zinc present in given sample by gravimetric method. ix. Estimation of iron by colorimetric / spectrophotometry method. x. Estimation of barium by complexometric titration method. xi. Estimation of manganese in presence of iron by complexometric titration method.	40
	2. Semi-micro qualitative analysis of cation and anion in a given inorganic mixture: (Any four mixture) Mixture containing total six cations and/or anions. **Cations :** Pb^{2+}, Cu^{2+}, Cd^{2+}, Sn^{2+}, Fe^{2+}, Fe^{3+}, Al^{3+}, Cr^{3+}, Zn^{2+},	20

	Mn^{2+}, Ni^{2+}, Co^{2+}, Ba^{2+}, Sr^{2+}, Ca^{2+}, Mg^{2+}, $(NH_4)^+$, K^+ **Anions:** Cl^-, Br^-, I^-, NO_2^-, NO_3^-, SO_3^{2-}, CO_3^{2-}, SO_4^{2-}, PO_4^{3-}, S^{2-}	
Pedagogy	Students will be given pre-lab and post-lab assignments on theoretical aspects of laboratory experiments prior to the conduct of each experiment. Exams will be in the form of ISA, SEA which will involve performing given experiments and conduct of viva, systematic reporting of experiments, results and observations in laboratory report. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. G. Brauer, Handbook of Preparative Inorganic Chemistry, Vol. 1 & 2, 1963. 2. G. Pass & H. Sutcliffe, Practical Inorganic Chemistry, Preparations, Reactions and Instrumental Methods, 2nd Ed.; Chapman & Hall, 1974. 3. S. De Meo, J. Chem. Ed., Vol 80, Pg.No.796-798, 2003. 4. W. L. Jolly, The Synthesis & Characterization of Inorganic Compounds, Prentice-Hall, INC, 1970. 5. A. J. Elias, General Chemistry Experiments, Revised Ed.; University Press, 2008. 6. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, Vogel's Text Book of Quantitative Chemical Analysis,6th Ed.; Pearson, 2002. 7. G. Svehla, Vogel's Text Book of Qualitative Inorganic Analysis, 7th Ed, Pearson, 2011. 8. G. Marr & B. W. Rockett, Practical Inorganic Chemistry, Van Nostrand Reinhold Company, London, 1972.	
Course outcomes:	1. Students will be in a position to synthesize coordination compounds with different metals and ligands. 2. Students will be able to grow single crystal. 3. Students will be able to determine metal content in the given sample. 4. Students will be in position to apply diverse methods available for estimation of the metals and can use colorimeters and spectrometers. 5. Students will able to detect cations and anions in the given salt.	

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHO-500 **Title of the course:** Fundamentals of Organic Chemistry

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objective:	1. To study the various concepts based on molecular orbital theory. 2. To understand the concepts of topicity, prostereoisomerism and chemo-, regio- and stereoselectivity in organic reactions. 3. To understand the mechanistic aspects of various type of reactions in organic synthesis.	
Content	**1.Molecular orbitals and delocalized chemical bonding** a. Qualitative description of molecular orbitals of simple acyclic and monocyclic systems, frontier molecular orbitals. b.Conjugation, cross conjugation, resonance, hyperconjugation and tautomerism (types and examples). c. Aromaticity: Origin of Huckel's rule, examples of aromatic, non-aromatic and antiaromatic compounds; concept of Mobius aromaticity.	No of hours 08
	2.Structure & Reactivity a. Acidity, basicity and pKa of organic compounds; Acid and base strengths; HSAB concept & Factors affecting it, effect of structure & medium on acid and base strength. b. Concept of superacids and superbases. c. Electrophilicity&nucleophilicity, examples of ambident nucleophiles & electrophiles. (Including revision of aromatic electrophilic and nucleophilic substitution)	08
	3.Stereochemistry a. Brief revision of configurational nomenclature: R & S; D & L; E & Z; cis & trans and *syn* & *anti* nomenclature. Chirality in molecules with two and more chiral centres. b. Conformational analysis of open chain compounds (Butane, 2, 3-butane diol, 2,3-dibromobutane etc.). *Erythro*and *threo*nomenclature. c. Topicity and Prostereoisomerism: Topicity of ligands and faces-homotopic, enantiotopic and Cram’s rule /diastereotopic ligands and faces. d. Introduction to chemoselective, regioselective and	14

	stereoselective reactions. e. Stereochemistry of *cis*- and *trans*-decalins, conformation and reactivity of cyclohexane and substituted cyclohexanes, cyclohexene / cyclohexanone. conformational isomerism and analysis in acyclic and simple cyclic systems –substituted ethanes, cyclopentane, cyclohexane cycloheptane, cyclooctane and decalins, f. optical isomerism - optical activity - molecular dissymmetry and chirality - elements of symmetry. optical isomerism in biphenyls, allenes and spirans - optical isomerism of nitrogenous compounds racemisation and resolution.	
	4.Reaction Mechanism a. Brief revision of carbocations, carbanions, free radicals, carbenes, Arynes and nitrenes with reference to generation, structure, stability and reactivity; b. Types of mechanisms, types of reactions, thermodynamic and kinetic control. c. The Hammond postulate and principle of microscopic reversibility, d. Methods of determining reaction mechanisms like- i. Identification of products, ii. Determination of the presence of intermediates (isolation, detection, trappingandaddition of suspected intermediate, iii. Isotopic labelling, iv. Stereochemical evidence, v. Kinetic evidence and vi. Isotope effect (at least two reactions to exemplify each method be studied)	08
	5.Aliphatic Nucleophilic substitution a. Brief revision of nucleophilic substitutions with respect to Mechanism, various factors affecting such reactions; b. The Neighbouring Group Participation (NGP)/ Anchimeric assistance: General approach to various NGP processes; NGP by unshared/lone pair of electrons; NGP by π-electrons; NGP by aromatic rings (formation of phenonium ion intermediate); NGP by sigma bonds with special reference to bornyl and nor-bornyl system (formation of nonclassical carbocation)	08
	6.Elimination reactions a. The E2, E1 and E1cB mechanisms. Orientation of the double bond, Saytzeff and Hofmann rule. b. Effects of changes in the substrate, base, leaving group and medium on	08

<table>
<tr><td></td><td>i. Overall reactivity,
ii. E1 vs. E2 vs. E1cB
iii. Elimination vs substitution, Mechanism and orientation in pyrolytic syn elimination (various examples involving cyclic and acyclic substrates to be studied).</td><td></td></tr>
<tr><td></td><td>7. Selective reagents for Organic transformation
a. Oxidation of organic compounds, PCC, PDC and MnO_2, ozonolysis, peracids.
b. Reduction of organic compounds: $NaBH_4$, LAH, DIBAL reduction and reduction with borane and dialkylboranes. Clemmensen reduction, Birch reduction and Wolff-Kishner reduction</td><td>06</td></tr>
<tr><td>Pedagogy</td><td colspan="2">Mainly lectures and tutorials. Seminars/term papers/assignments/presentations/ self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.</td></tr>
<tr><td>References / Readings</td><td colspan="2">1. W. Caruthers, I. Coldham, Modern Methods of Organic Synthesis, Cambridge University Press, 4^{th} Ed., 2016.
2. M. B. Smith, Organic Synthesis, McGraw–HILL, New York, International Edition, 1994.
3. J. Clayden, N. Greeves, S. Warren, P. Wothers, Organic Chemistry, Oxford University Press, 2^{nd} Ed., 2012.
4. R. Bruckner, Advanced Organic Chemistry – Reaction Mechanisms, San Diego, CA: Harcourt /Academic Press, San Diego, 2002.
5. J. Fuhrhop, G. Penxlin, Organic Synthesis – Concepts, Methods, Starting Materials, VCH Publishers Inc., New York, 1994.
6. H. O. House, Modern Synthetic Reactions, W. A. Benjamin, 2^{nd}Ed.,1965
7. M. Nogradi, Stereoselective Synthesis, VCH Publishers, Inc., Revised and Enlarged Edition, 1994.
8. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry, Springer India Private Limited, 5^{th}Ed, 2007.
9. T. Laue, A. Plagens, Named Organic Reactions, John Wiley and Sons, Inc., 2005.</td></tr>
<tr><td>Course outcomes:</td><td colspan="2">1. Students will be in a position to evaluate the effect of delocalization of electrons & presence or absence of aromaticity in organic compounds.
2. Students will be able to apply various concepts in stereochemistry to understand stereochemical outcome in a reaction.
3. Students shall be in a position to understand/propose plausible mechanism of organic reactions.
4. Students will understand and apply various reagents for desired organic transformations.</td></tr>
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Name of the Programme: M. Sc -I (Organic Chemistry)

Course Code: CHO-501 **Title of the course:** Organic Spectroscopy

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied Organic chemistry courses at M.Sc. Chemistry in semester I	
Course Objective:	1. To study various theoretical concepts related to organic spectroscopic techniques. 2. To understand the introductory aspects of commonly used 2D NMR techniques. 3. To learn interpretational aspects of spectral data pertaining to UV, IR, PMR, CMR and MS.	
Content	**1. UV-Visible Spectroscopy** a. Introduction. Electronic transition and energy levels, the absorption laws. b. Measurement of the spectrum, chromophores, Effect of solvent, Conjugation on UV-spectra. c. Study of Tautomerism, Steric effect and geometrical isomerism in UV spectra. d. Woodward-Fieser rule for conjugated dienes and carbonyl compounds.	No of hours 04
	2. **Infrared Spectroscopy** a. IR spectroscopy in structural elucidation of organic compounds (various functional classes to be considered). b. Methods in IR-Spectroscopy, effect of hydrogen bonding and solvent effect on vibrational frequencies, overtones, combination and Fermi resonance bands. c. Factors influencing vibrational frequencies. d. Characteristic frequencies of organic molecules. e. Interpretation of spectra.	08
	3. **NMR Spectroscopy** a. Principles of NMR. b. Instrumentation. c. Chemical shift- (revision of the basic concepts) d. Interpretation of PMR spectra. i.Coupling constants and AB, A_2B_2/A_2X_2, AMX and ABX spin systems. ii. Double resonance and decoupling iii. Nuclear Overhauser Effect and its applications. iv. NMR Shift reagents v. Determination of Absolute and Relative configuration	14

	4. ^{13}C –NMR spectroscopy a. Introductionto ^{13}C –NMR spectroscopy. b. ^{13}C- chemical shifts effects (α-, ß-, γ-, δ-substituent effects, π-conjugation, heavy atom effect and ring size effects) c. Proton coupled and proton decoupled 13Cspectra. d. Off- resonance decoupling, APT & DEPT techniques.	8
	5. ^{19}F- NMR and ^{31}P- NMR spectroscopy Principles and applications; heteronuclear coupling of carbon to ^{19}F and ^{31}P.	6
	6. Two-dimensional NMR spectroscopy Introduction to 2D NMR techniques and interpretation ofspectra of simple organic compounds using following 2d-NMR techniques- COSY, NOESY, HSQC, HMQC, HMBC, TOCSY and INADEQUATE	8
	7. Mass spectrometry a. Ionization Methods, Mass Analysis, Even and odd electron ions and fragmentation modes. b. Molecular Formulae Index (D.B.E), Molecular ion peak, base peak, metastable ions, Nitrogen rule, effect of isotopes. c.Prediction of molecular formulae based on relative abundance. Rules for fragmentation, McLafferty rearrangement, retro-Diels-Alder fragmentation, fragmentation associated with functional groups; rearrangement and mass spectra of some chemical classes. **Note: Problems involving combined use of different type of spectra, in line with course objective/ Course outcomes are to be emphasized.**	12
Pedagogy	Mainly lectures and tutorials. Seminars/term papers/assignments/presentations/self-study or a combination of some of these can be used. ICT mode should be preferred. Sessions should be interactive to enable peer group learning.	
References / Readings	1. P.S. Kalsi, Spectroscopy of Organic compounds, New Age International Pub. Ltd. & Wiley Eastern Ltd., 2^{nd} Ed., 1995. 2. R.M. Silverstein, F. X. Webster, D.Kiemle, D. Bryce, S.Samant, V. S. Nadkarni,Spectrometric Identification of Organic compounds, An Indian Adaptation John Wiley & Sons Inc., 8^{th} Ed., 2022. 3. D. L. Pavia, G. M. Lampman, G. S. Kriz, J. R. Vyvyan, Introduction to Spectroscopy, Brooks Cole, 5^{th} Ed., 2015. 4. R.M. Silverstein, F. X. Webster, Spectrometric Identification of Organic compounds, John Wiley & Sons Inc., 7^{th} Ed. (reprint), 2011. 5. V.M. Parikh, Absorption Spectroscopy of Organic Molecules, Addison Wesley Longman Publishing Co., 1974. 6. D.H Williams & I. Fleming, Spectroscopic Methods in Organic Chemistry, Tata Mcgraw Hill Education, 6^{th} Ed., 2011.	

	7. W. Kemp, Organic Spectroscopy, Palgrave Macmillan, 3rd Ed., 1991. 8. W. Kemp, NMR in Chemistry: A Multinuclear Introduction, Macmillan, 1986. 9. J. R. Dyer, Applications of Absorption Spectroscopy of Organic compounds, Prentice Hall of India, 1987. 10. L. D. Field, H. L. Li., A. M. Magill, Organic Structures from 2D NMR Spectra, Wiley, 2015.
Course outcomes:	1. Students will be in a position to understand how spectral techniques can be used in structure elucidation. 2. Students will be able to deduce structures of simple to moderately complex molecules by combining the spectral data obtained using two or more spectral techniques. 3. Students will be in a position to apply various concepts in organic spectroscopy (PMR, CMR, MS and 2D NMR) and analyse/ predict PMR, CMR, MS and 2D NMR spectral data based on given structures of simple molecules. 4. Students will understand the fundamental difference between various spectroscopic techniques.

Name of the Programme: M. Sc -I (Organic Chemistry)

Course Code: CHO-502 **Title of the course:** Pericyclic and Organic Photochemical Reactions

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied organic chemistry courses at M.Sc. Chemistry in semester I	
Course Objective:	1. To introduce various concepts in pericyclic chemistry based on molecular orbital theory and apply for solving pericyclic reactions 2. To introduce analysis of pericyclic reactions using theoretical concepts. 3. To learn mechanistic aspects of pericyclic & photochemical reactions in organic synthesis.	
Content	**1. Pericyclic Reactions** a. Theory of pericyclic reactions i. Frontier Molecular Orbital (FMO) theory ii. Transition state aromaticity (Mobius-Huckel theory) concept iii. Orbital correlation diagram method. b. Analysis of pericyclic reactions (including stereochemistry) using the above concepts i. Cycloaddition reactions ii. Electrocyclic reactions iii.Sigmatropic rearrangements under thermal and photochemical conditions (Note: Various important features to be discussed taking examples important reactions of each type) c. Some synthetically useful reactions (examples via theory of pericyclic reaction). d. Diels–Alder and retro Diels-Alder reaction: Regiochemistry, stereochemistry and intramolecular reactions. e. 1, 3-dipolar additions f. [3, 3]-Shifts; Claisen and Cope, aza-Cope-, oxy-Cope rearrangements and fluxional molecules, variants of Claisen Rearrangement such as Johnson-Claisen, Eschenmoser-Claisen, Carroll- Claisen and Ireland-Claisen. g. [2,3]-Sigmatropic rearrangements such as Sommelet-Hauser rearrangement, Sulfonium ylide rearrangement, Meisenheimer rearrangement, Wittig rearrangement, Mislow-Evans rearrangement h. Ene reaction, hetero-ene, retro-ene reactions i. [1,5]-Thermal and [1,7]-photochemical sigmatropic hydrogen	No of hours 34

	shifts	
	2. Organic Photochemistry a. Interaction of electromagnetic radiation with matter, laws of photochemistry; fateof excited molecule; principles of energy transfer, types of photochemical reactions. Theoretical concepts in organic photochemistry w. r. t. cycloadditions, Electrocyclicreactions and sigmatropic reactions b. Photochemical reactions of alkenes, dienes, carbonyl compounds and arenes including the following- geometrical isomerisation: *Cis-trans* isomerization andphotostationary equilibrium; Paterno-Buchi reaction; Norrish Type cleavages; Di-pimethane rearrangement; bicycle rearrangement c. Photochemistry of aromatic compounds: valance isomerization; photostationary state of benzene and azabenzenes. [4+4]-photodimerization of derivatives of naphthalenes. cycloaddition reaction of benzene, naphthalene, pyrrole and indoles with alkenes and alkynes d. Reactions involving singlet and triplet oxygen: Photooxygenation reactions, examples of [2+2] and [4+2]-cycloaddition reaction with isocyclic, heterocyclic, dienes and polynuclear aromatic compounds e. Applications of Organic Photochemistry: Photochemical Reactions as Key Steps in Natural Product Synthesis (any four examples); example of photopolymerization; photochemical functionalization at unactivated carbon: Barton reaction, the hypohalite reaction and the Hofmann-Loffler-Freytag reaction	26
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. N. Turro, V. Ramamurthy, J.C. Scaiano, Modern Molecular Photochemistry of Organic molecules , University Science Books, 2010. 2. B. Dinda, Essentials of Pericyclic and Photochemical Reactions, Springer, 1st Ed. 2017. 3. S.Kumar, V. Kumar, S.P. Singh, Pericyclic Reactions: A Mechanistic and Problem-Solving Approach, Elsevier, 2016. 4. R. E. Lehr., A. P. Marchand, Orbital Symmetry: A Problem Solving Approach, Academic Press, 1972. 5. R. B. Woodward, R. Hoffmann, Conservation of Orbital Symmetry, Verlag chemie, Academic Press, NY, 1972. 6. I. Fleming, Frontier Orbitals and Organic Chemical Reactions, John Wiley & Sons, 1st Ed., 1991 7. T. L. Gilchrist, R. C. Storr, Pericyclic Reactions, Cambridge Univ. Press,	

	1972. 8. F. A. Carrey, R. J. Sundberg , Advanced Organic Chemistry Part A and B, Pelnum Pub., 3rd Ed. 1990. 9. T. Lowery, K. Richardson, Mechanisms and Theory in Organic Chemistry, Harper and Row Pub., NY, 3rd Ed., 1987. 10. C. H. DePay, Molecular Reactions and Photochemistry, Prentice Hall (I) Ltd, NewDelhi. 11. J. Kopecky, Organic Photochemistry- A Visual Approach, VCH Pub., 1992.
Course outcomes:	1. Students will be in a position to predict course of a given pericyclic reaction using the theoretical concepts. 2. Students will be able to apply knowledge of stereochemical output in a reaction. 3. Students will be able to understand and propose plausible mechanism of pericyclic/photochemical reactions. 4. Students will understand applications of organic photochemistry.

Name of the Programme: M. Sc -I (Organic Chemistry)

Course Code: CHO-503 **Title of the course:** Synthetic Methodologies in Organic Chemistry

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied organic chemistry courses at M.Sc. Chemistry in semester I	
Course Objective:	1. To study various concepts related to carbon-carbon bond formation. 2. To understand designing of organic synthesis to make molecules of interest. 3. To plan total synthesis based on protection-deprotection strategy.	
Content	**1. Chemistry of enols and enolates** a. Keto-enol tautomerism; Introduction, acidity, basicity concepts & pKa scale, neutral nitrogen and oxygen bases. Formation of enols by proton transfer, mechanism of enolization by acids & bases, types of enols & enolates, kinetically & thermodynamically stable enols, consequences of enolization, stable enolate equivalents, preparation and reactions of enol ethers. b. Formation of Enolates; Introduction, preparation & properties, non-nucleophilic bases, E / Z geometry in enolate formation, kinetic vs. thermodynamic control, other methods for the generation of enolates, issue of enolate ambidoselectivity. c. Alkylation of enolates; diverse reactivity of carbonyl groups, alkylation involving nitriles and nitroalkanes, choice of electrophile for alkylation, lithium enolates of carbonyl compounds and alkylation, specific enol equivalents to alkylate aldehydes and ketones, alkylation of β-dicarbonyl compounds, problem of regioselectivity during ketone alkylation and the remedy provided by enones. d. Reaction of enolates with aldehydes and ketones; Introduction, aldol reaction including cross & intramolecular version, enolisable substrates which are not electrophilic in nature, controlling aldol reactions with specific enol equivalents, specific enol equivalents for carboxylic acids, aldehydes and ketones. e. Acylation at carbon; Introduction, the Claisen ester condensation (intramolecular and inter / crossed), acylation of enolates by esters, preparation of keto-esters by the Claisen reaction, directed C-acylation of enols and enolates & acylation of enamines.	No of hours 22

	f. Conjugate addition of enolates; Introduction, thermodynamic control vs. conjugate addition, utility of various electrophilic alkenes in conjugate addition, formation of six-membered rings via conjugate addition and nitroalkanes as versatile synthons. g. Examples pertaining to the application of following condensation reactions in organic synthesis; Mukaiyama reaction, Perkin reaction, Dieckmann condensation, Michael addition, Robinson annulation, Sakurai reaction, Knoevenagel Reaction, Darzen, Stobbe, Benzoin, Pechmann condensation.	
	2. Synthetic utility of important name reactions / methodology a. Mannich Reaction, Nef Reaction, Mitsunobu and Appel Reaction, Baylis Hillman reaction, Mc. Murry coupling, vicarious nucleophilic substitution, Steglich and Yamaguchi esterification. b. Ring closing and cross metathesis; Grubb's various generation, Grubbs-Hoveyda, Schrock catalysts.	8
	3. The Ylides in Organic Synthesis a. Phosphorus Ylides; Nomenclature and Preparation. Wittig olefination: mechanism, stereoselectivity, cis- and trans selective reactions, Wittig reagents derived from α-halo carbonyl compounds. b. Modified Wittig, Horner – Wadsworth – Emmons, Stille-Gennari modification with achiral and chiral substrates, Peterson reaction, Julia Olefination. c. Sulfur Ylides; Sulfonium & sulfoxonium ylides in synthesis, diphenylcyclopropyl sulfonium ylides & their reactions with carbonyl compounds / Michael acceptors	8
	4. Protecting Groups in Organic Synthesis a. Introduction and effective use of protecting groups, umpolung of reactivity. b. Common protective groups namely acetals & ketals, dithio acetal/ketals, trialkylsilyl, TBDMS, THP, MOM, MEM, SEM & benzyl ether, methyl ether, benzyl amine, Cbz, *t*-Boc, Fmoc, *t*-butyl ester and methods for deprotection. Some examples of multistep synthesis using protection-deprotection procedures.	6
	5. Asymmetric Synthesis a. Chiral pool (chiron approach). b. Chiral auxiliary approach; Oxazolidinone & norephedrine-	12

	derived chiral auxiliary controlled Diels-Alder reaction and alkylation of chiral enolates and aldol reaction, Alkylation using SAMP and RAMP. c. Chiral Reagents - Use of (-)-sparteine. d. Asymmetric catalysis; CBS catalyst, Ruthenium catalyzed chiral reductions of ketones, Catalytic asymmetric hydrogenation of alkenes, Asymmetric epoxidation (Sharpless and Jacobson), Sharpless asymmetric dihydroxylation reaction, Organocatalyzed aldol reaction (Use of proline).	
	6. Halogenation and esterification reactions a. Formation of Carbon Halogen bonds; Substitution in saturated compounds, alcohols, carbonyl compounds, substitution at allylic and benzylic compounds, bromodecarboxylation (Hunsdiecker reaction), Finkelstein reaction, iodolactonisation. b. Acid and base catalyzed esterification and hydrolysis.	4
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. W. Caruthers, I. Coldham, Modern Methods of Organic Synthesis, Cambridge University Press, 4th Ed, 2016. 2. M. B. Smith, Organic Synthesis, McGraw–HILL, New York, International Edition, 1994. 3. J. Clayden, N. Greeves, S. Warren, P. Wothers, Organic Chemistry, Oxford University Press, 2nd edition, 2012. 4. R. Bruckner, Advanced Organic Chemistry – Reaction Mechanisms, San Diego, CA: Harcourt /Academic Press, San Diego, 2002. 5. J. Fuhrhop, G. Penxlin, Organic Synthesis – Concepts, Methods, Starting Materials, VCH Publishers Inc., New York, 1994. 6. H. O. House, Modern Synthetic Reactions, W. A. Benjamin, 1965, 2nd Ed. (revised with corrections). 7. M. Nogradi, Stereoselective Synthesis, VCH Publishers, Inc., Revised and Enlarged Edition, 1994. 8. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry, Springer India Private Limited, 5th Ed, 2007. 9. T. Laue, A. Plagens, Named Organic Reactions, John Wiley and Sons, Inc., 2005.	
Course outcomes:	1. Students will be in a position to explain how a carbon-carbon bond can be constructed along with the selectivity in bond formations. 2. Students will be able to apply knowledge of various reactions in	

	constructions of simple to complex organic molecules. 3. Students will be in a position to design protecting group strategies for synthesis of organic molecules. 4. Students will understand use of protecting groups in organic synthesis.

Name of the Programme: M. Sc -I (Organic Chemistry)

Course Code: CHO-504 **Title of the course:** Stereochemistry and Organic Transformations

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied organic chemistry courses at M.Sc. Chemistry in semester I	
Course Objective:	1. To study various principles of stereochemistry 2. To understand the importance of chirality in organic syntheses 3. To learn stereoselective reactions and toplan oxidation, reduction reactions	
Content	**1. Stereochemistry** a. Stereoselectivity in cyclic compounds: Introduction, stereochemical control in six membered rings, reactions on small rings, regiochemical control in cyclohexene epoxides, Stereoselectivity in bicyclic compounds b. Conformations, stability and reactivity of fused ring compounds: Fused bicyclic systems with small and medium rings: cis- and trans- decalones and decalols, Octahydronaphthalins (octalins), Bicyclo [4.3.0] nonane (cis- and trans-hydrindanes) c. Fused polycyclic systems: Perhydrophenanthrenes, Perhydroanthracenes, Perhydrocyclopentenophenanthrene system (steroids, triterpenoids and hormones). Conformations and reactivity towards esterification, hydrolysis, chromium trioxide oxidation, ionic additions of halogen (X_2) to double bonds, formation and opening of epoxide ring, epoxidation by peroxy acids. d. Spirocyclic compounds e. Reactions with cyclic intermediates or cyclic transition state f. Stereoisomerism due to axial chirality, planar chirality and helicity. g. Stereochemistry and configurational (*R/S*) nomenclature in appropriately substituted allenes, alkylidenecycloalkenes, spiranes, adamantoids, biaryls, trans-cycloalkenes, cyclophanes and ansa compounds. h. Atropisomerism in biphenyls and bridged biphenyls	No of hours 20
	2. Conformation of bridged ring compounds a. Bicyclo [2.2.1] heptane (norbornane): Geometry and topic relationship of hydrogens, solvolysis of bicycle [2.2.1]heptyl	10

	systems, formation, stability and reactivity of norbornylcation, relative stability and the rate of formation of endo and exo isomers in both bornane and norbornane systems. b. Bicyclo [2.2.2] octane system: Geometry and topic relationship of hydrogens, solvolysis of bicycle [2.2.2]octyl system. c. Other bridged ring systems: starting from bicycle [1.1.1]pentane to bicycle [3.3.3] undecane d. Bicyclo system with heteroatom: the relative stabilities of tropine, pseudotropine and benzoyl derivatives of norpseudotropine.	
	3. Dynamic Stereochemistry: Stereoselective Reactions a. Stereoselectivity: classification, terminology and principle. Selectivity in chemistry– substrate and product selectivity. b. Stereoselective reaction of cyclic compounds: Introduction, reactions of four, five and six-membered rings. Conformational control in the formation of six-membered ring. c. Diastereoselectivity: Introduction, making single diastereoisomers using stereospecific reactions of alkenes. d. 1,2-Addition to carbonyl compounds: Predicting various addition outcomes using different predictive models such as, Cram Chelate, Cornforth, Felkin-Anh. Specific reactions: allylation/crotylation by Brown, Roush, BINOL catalyzed. e. Stereoselective reaction of acyclic alkenes: The Houk model	14
	4. Oxidation and reduction reactions a. Oxidation reactions: Oxidation of organic compounds using Oppenauer oxidation, Swern oxidation. Other methods of oxidation such as selenium dioxide, $Pb(OAc)_4$, HIO_4, OsO_4, RuO_4, DMSO (Swern) sodium bromate / CAN &NaOCl, DDQ, Prevost's reagent and Woodward Conditions; Catalytic oxidation over Pt, Photosensitised oxidation of alkenes, oxidation with molecular oxygen, aromatization, silver based reagents. b. Reduction reactions: Reduction of organic compounds using hydride-transfer reagents and related reactions: MPV reduction, Trialkylborohydrides, LAH, mixed LAH-$AlCl_3$ reagents, enzymatic reduction involving liver alcohol dehydrogenase/NADH & Bakers' yeast, catalytic hydrogenation, dissolving metal reductions including acyloin condensation, other methods of reduction: Raney Ni desulphurisation, di-imide.	16
Pedagogy	Lectures & tutorials. Seminars / assignments / presentations / self-study or a combination of some of these could also be used to some extent. ICT	

	mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
References / Readings	1. M. B. Smith, J. March, Advanced Organic Chemistry- 50 Reaction, Mechanism and Structure, Wiley, 2006, 6th Ed. 2. D. Nasipuri, Stereochemistry of Organic compounds, Principles and applications, New Age International Pvt. Ltd., 1994, 2nd Ed. 3. E.L. Eliel, Stereochemistry of Carbon Compound, Tata McGraw Hill, 1975. 4. W. Caruthers, I. Colddham, Modern Methods of Organic Synthesis, Cambridge University Press, 2016, 4th Ed. 5. J. Clayden, N. Greeves, S. Warren, Oxford, 2016. 6. I. L. Finar, Stereochemistry and the Chemistry of Natural Products, ELBS, Vol. 2, Longman Edn, 1975. 5th Ed. 7. E.S. Gould, Mechanism and Structure in Organic Chemistry, Holt, Reinhart and Winston, 1965. 8. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry: Part A and B, Springer India Private Limited, 2007, 5th Ed. 9. R. O. Norman J, M. Coxon, Principles of Organic Syntheses, CRC Press Inc, 1993, 3rd Ed. 10. V.M. Potapov, A. Beknazarov, Stereochemistry, Central Books Ltd., 1980. 11. D. G. Morris, Stereochemistry, Wiley-RSC, 2002, 1st Ed. 12. C., Greeves, W., Wothers, Organic Chemistry, Oxford University Press, 2002, 2nd Ed. 13. M. Nogradi, Stereoselective Synthesis, VCH Publishers, Inc., 1994, Revised and Enlarged Ed.
Course outcomes:	1. Students will be in a position to explain stereochemistry and organic transformations. 2. Students will be in a position to apply knowledge of various reactions in functional group manipulations. 3. Students will be in a position to apply stereoselective reactions for the synthesis of chiral organic molecules. 4. Students will understand conformations of bridged ring compounds.

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHO-521 **Title of the course:** Practical Course in Organic Chemistry-I

Number of Credits: 02

Effective from AY: 2022-23

<table>
<tr><td>Prerequisites for the course</td><td colspan="2">Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.</td></tr>
<tr><td>Course Objective:</td><td colspan="2">To translate certain theoretical concepts learnt earlier into experimental knowledge by providing hands on experience of basic laboratory techniques required for organic syntheses.</td></tr>
<tr><td rowspan="2">Content</td><td>Minimum 13 experiments from the list shall be conducted.

1. Introduction to laboratory equipments, apparatus and safety
a. Use of common laboratory equipments like fume hoods, vacuum pumps, weighing balance etc. to be explained to the students.
b. Introduction to various types of quick fit joints and apparatus to the students.
c. Discussion of Safety Techniques:
i Disposal of chemicals
ii Usage of protective equipment's
iii First aid
iv Fire extinguishers, types of fire
v Hazards of chemicals and risk assessment</td><td>No of hours

04</td></tr>
<tr><td>2. Laboratory Techniques
a. Simple distillation (any one):
i. Toluene-dichloromethane mixture using water condenser.
ii. Nitrobenzene and aniline using air condenser.
b. Steam distillation (anyone):
i. Separation of o- and p- nitrophenols.
ii. Naphthalene from its suspension in water,
iii. Clove oil from cloves.
c. Crystallisation: Concept of induction of crystallization (any one)
i. Crystallisation of phthalic acid from hot water using fluted filter paper and stemless funnel.
ii. Acetanilide from boiling water
iii. Naphthalene from ethanol.
iv. Decolorisation and crystallization of brown sugar (sucrose) with animal charcoal using gravity filtration.
d. Sublimation: Simple or vacuum sublimation of camphor, naphthalene, anthracene or succinic acid (any one).
e. Vacuum distillation (any one): o-dichlorobenzene, diphenyl</td><td>24</td></tr>
</table>

	ether. Also use of nomograph should be explained. f. Thin layer Chromatography (any one): i. Separation of *o* and *p*-nitroanilines. ii. Separation of analgesic drugs iii. Separation of *o* and *p*-nitrophenols,	
	3. Organic synthesis (Any Seven experiments) a. Aliphatic electrophilic substitution: Preparation of iodoform from ethanol & acetone. b. Aromatic electrophilic substitution (anyone): i. Preparation of *p*-bromoacetanilide. ii. Bromination of acetophenone to phenacyl bromide iii. Nitration of napththalene to 1-nitronaphthalene iv. Nitration of benzaldehyde to 3-nitrobenzaldehdye. c. Oxidation (any one) i. Benzoic acid from toluene. ii. Cyclohexanone from cyclohexanol. iii Isoborneol to camphor using Jones reagent. d. Reduction (any one) i. Reduction of *o*-nitroaniline to *o*-phenylenediamine using Sn/HCl ii. Reduction of *p*-nitro benzaldehyde to *p*-nitrobenzyl alcohol using $NaBH_4$. e. Bromination of an alcohol using CBr_4/ triphenylphosphine. f. Grignard reaction: Triphenylmethanol from benzoic acid ester or benzophenone. g. Aldol condensation: Dibenzal acetone from benzaldehyde h. Acetoacetic ester condensation: Preparation of ethyl *n*-butylacetoacetate or ethyl acetoacetate. i. Cannizzaro reaction using 4-chlorobenzaldehyde as substrate. j. Friedel Craft's reaction (any one): i. using toluene and succinic anhydride ii. Resorcinol to resacetophenone, benzene and maleic anhydride to *β*-benzoylacrylic acid k. Solvent free preparation of coumarin by the Knoevenagel condensation under MW irradiation. l. Preparation of oxidizing agent (any one): Pyridinium chlorochromate-silica, pyridinium chlorochromate-alumina, MnO_2. m. Preparation of cuprous chloride.	24
	4. Isolation from natural sources (Any two) i. Caffeine from tea powder. ii. Piperine from pepper. iii. Cinnamaldehyde from cinnamon iv. Lemongrass oil from lemongrass	8
Pedagogy:	Students should be given suitable pre- and post-lab assignments	

	and explanation revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment. Each of the experiments should be done individually by the students.	
References / Readings	1. A.I. Vogel, A., R. Tatchell, B. S. Furniss, A.J. Hannaford, Vogel's Textbook of Practical Organic Chemistry, 5^{th}Ed., Prentice Hall; 2011. 2. D. Pasto, C. Johnson and M. Miller, Experiments and Techniques in Organic Chemistry, 1^{st}Ed., Prentice Hall, 1991. 3. L.F. Fieser, K.L. Williamson,Organic Experiments, 7^{th}edition D. C. Heath, 1992. 4. K.L. Williamson, K.M. Masters, Macroscale and Microscale Organic Experiments, 6^{th}Edition, Cengage Learning, 2010 5. R.K. Bansal, Laboratory Manual in Organic Chemistry, New Age International, 5^{th}Edition, 2016. 6. S. Delvin, Green Chemistry, Sarup& Sons, 2005. 7. O.R. Rodig, C.E. Bell Jr. and A.K. Clark, Organic Chemistry Laboratory Standard and Microscale Experiments, Saunders College Publishing, 3^{rd}edition, 2009. 8. J. Mohan, Organic Analytical Chemistry, Narosa Publishing House, 2014.	
Course outcomes	1. Students will be in a position to understand stoichiometric requirements during organic syntheses. 2. Students will be in a position to understand Safe and good laboratory practices, handling laboratory glassware, equipment and chemical reagents. 3. Students will be in a position to apply the practical knowledge to perform experiments involving common laboratory techniques like reflux, distillation, steam distillation, vacuum distillation, aqueous extraction, thin layer chromatography (TLC) etc. 4. Students will get hands-on experience on isolation of some important natural products.	

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHO-522 **Title of the course:** Practical Course in Organic Chemistry-II

Number of Credits: 02

Effective from AY: 2022-23

<table>
<tr><td>Prerequisites for the course</td><td colspan="2">Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.</td></tr>
<tr><td>Course Objective:</td><td colspan="2">To translate certain theoretical concepts learnt earlier into experimental knowledge by providing hands on experience of basic laboratory techniques required for organic syntheses.</td></tr>
<tr><td rowspan="3">Content</td><td>Minimum 13 experiments from the list shall be conducted.
1. Introduction to laboratory equipments, apparatus and safety
a. Common Hazards in Chemical Laboratory, Risk assessment
b. Accidents and Emergency procedures</td><td>No of hours

04</td></tr>
<tr><td>2. Laboratory Techniques (Any Two)
a. Simple distillation
i. Simple distillation of thionyl chloride under anhydrous condition
ii. Simple distillation under Nitrogen atmosphere
b. Fractional distillation
i. Chloroform-dichloromethane mixture using water condenser.
ii. Toluene and cyclohexane by fractionating column.
c. Vacuum distillation under inert atmosphere
Dry Distillation of DMF, o-dichlorobenzene, $POCl_3$
d. Thin layer Chromatography
i. Purification and isolation of mixture of acids by using Preparative TLC.
ii. Purification and isolation of mixture of phenols by using Preparative TLC.
iii. Purification and isolation of pharmaceutical drugs using Preparative TLC.</td><td>08</td></tr>
<tr><td>3. Organic Synthesis (Any Four)
a. p-Iodonitrobenzene by Sandmeyer reaction
b. Pinacol- Pinacolone rearrangement
c. Hydrogenation of Maleic acid (Hydrogen balloon)
d. Preparation of nitrostyrene from aldehyde
e. Preparation of α,β-dibromocinnamic acid
f. Reduction of nitro compounds
g. Synthesis of Urea from ammonium cyanate</td><td>16</td></tr>
</table>

	4. Solvent Free Organic synthesis (Any Two) a. Reduction using ball milling technique b. Oxidation of 2° alcohol using $KMnO_4$/Alumina by grinding technique. c. Synthesis of (±)-Binol from β-naphthol d. Hunsdiecker reaction of cinnamic acid derivatives e. Beckmann rearrangement of oxime derivatives	08
	5. Two-step Organic Synthesis (Any Two) a. Benzamide-Benzoic acid-Ethyl Benzoate b. Phthalic anhydride – Phthalimide – Anthranilic acid. c. Methyl benzoate- *m*-nitrobenzoate- *m*-nitrobenzoic acid d. Chlorobenzene – 2, 4 – dinitrochlorobenzene – 2,4-dinitrophenol e. Acetanilide – *p*–Bromo acetanilide – *p*–Bromoaniline f. Acetophenone – Oxime – Acetanilide	16
	6. Separation, Isolation and Identification of Organic compounds (Any One) a. Separation, purification and identification of compounds of binary mixture (Solid-Solid, Solid-liquid and Liquid-liquid) using the TLC and column chromatography, chemical tests. IR spectra to be used for functional group identification.	08
Pedagogy	Students should be given suitable pre- and post-lab assignments and explanation revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment.	
References / Readings	1. A. I. Vogel, A. R. Tatchell, B. S. Furniss, A. J. Hannaford, Vogel's Textbook of Practical Organic Chemistry, 5th Ed., Prentice Hall; 2011. 2. K. Tanaka, Solvent-free Organic Synthesis, Wiley-VCH, 2nd Ed., 2009 3. L. F. Fieser, K. L. Williamson "Organic Experiments" 7th edition D. C. Heath, 1992. 4. K. L. Williamson, K. M. Masters, Macroscale and Microscale Organic Experiments, 6th Edition, Cengage Learning, 2010 5. R. K. Bansal, Laboratory Manual in Organic Chemistry, New Age International, 5th Edition, 2016. 6. S. Delvin, Green Chemistry, Sarup& Sons, 2005. 7. O. R. Rodig, C. E. Bell Jr., A. K. Clark, Organic Chemistry Laboratory Standard and Microscale Experiments, Saunders College Publishing, 3rdedition, 2009. 8. J. Mohan, Organic Analytical Chemistry, Narosa Publishing House, 2014.	
Course outcomes	1. Students will be in a position to adopt Safe and good laboratory practices, handling laboratory glassware, equipment and chemical reagents. 2. Students will be in a position to understand and calculate stoichiometric requirements during organic syntheses.	

	3. Students will be in a position to perform common laboratory techniques including reflux, distillation, vacuum distillation, aqueous extraction, thin layer chromatography (TLC). 4. Students will get hands-on experience on isolation of some important natural products.

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHP-500 **Title of the course:** General Physical Chemistry

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objective:	1. Introduction of various concepts on thermodynamics. 2. Introduction of electro chemistry and kinetics. 3. Learning quantum chemistry.	
Content	**1. Mathematical Preparations** a. Introduction to various functions and function plotting (exponential, logarithmic, trigonometric etc.), functions of many variables. Complex numbers and complex functions. b. Linear equations, vectors, matrices and determinants. c. Basic rules of differentiation and integration, Partial differentiation, location and characterization of critical points of a function, Regression methods, curve fitting. d. Introduction to series, convergence and divergence, power series, Fourier series e. Probability (permutations and combinations).	No of hours 12
	2. Quantum Chemistry a. Operators, Functions, Eigen value equations, Postulates. b. Schrodinger equation, application to simple system viz. free particle, particle in one dimensional, two dimensional and three-dimensional box (quantization, separation of variables, degenerate wave functions). c. Hydrogen like atoms, Schrodinger equation and its solutions, atomic orbital wave functions and interpretation. d. Hückel MO theory, Secular equations, Secular determinant, delocalization energy, charge density, π-bond order, free valence, applications to C_2H_4, C_3H_5 (radical), C_4H_6, C_4H_4, C_6H_6, C_6H_8.	20
	3. Thermodynamics a. Thermodynamic properties: Gas laws, Real gasses, Boyle temperature, Critical temperature, State and path properties. Intensive and extensive properties. Exact and inexact differentials. Internal energy, enthalpy, entropy, free energy and their relations and significances. Maxwell relations. Thermodynamic equations of state b. Joule-Thomson effect. Joule-Thomson coefficient for van der	12

	Waals' gas. Joule-Thomson effect and production of low temperature, adiabatic demagnetization, Joule-Thompson coefficient, inversion temperature. c. The third law of thermodynamics. Need for the third law. Apparent exceptions to third law. Application of third law. Use of thermodynamic functions in predicting direction of chemical change. Entropy and third law of thermodynamics. d. Phase equilibria: Phase rule, Discussion of two component systems forming solid solutions with and without maximum or minimum in freezing point curve. Systems with partially miscible solid phases. e. Three component systems: Graphical representation. Three component liquid systems with one pair of partially miscible liquids. Influence of temperature. Systems with two pairs and three pairs of partially miscible liquids. The role of added salts.	
	4. Electrochemistry a. EMF series, The cell potential: The Nernst equation, Cells at equilibrium. Determination of thermodynamic functions. b. Decomposition potential and overvoltage, electronegativity, basic principles, completeness of deposition, Separation with controlled potentials, constant current electrolysis, composition of electrolyte, potential buffers, physical characteristics of metal deposits. c. Electroplating and electroless plating, electrosynthesis. d. Concepts of acid-base aqueous and non-aqueous solvents, hard and soft acid-base concept and applications.	8
	5. Chemical Kinetics a. General introduction to various types of order of reaction including fractional order, Molecularity of the reaction. b. Introduction to reversible and irreversible reactions and reactions leading to equilibrium. Van't Hoffs equation and analysis of Gibbs free energy of equilibrium reactions. c. Collision Theory and Maxwell Boltzmann distribution of energies of colliding molecules (derivation not required). The concept of collisional cross section and reactive cross section and its significance. d. Comparative study of transition state and collision state theory (derivation not required). e. Reaction Mechanisms: elementary reactions, Consecutive elementary reactions, steady state approximation, the rate determining step and pre-equilibria f. Free radical reactions, Complex reactions such as acetaldehyde decomposition and reaction between H_2 and Br_2, Homogeneous reactions and acid-base catalysis.	8

	g. Elementary enzyme reactions. Lineweaver-Burk plot and its analysis	
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. P. W. Atkins and J. D. Paula, Physical Chemistry, 8^{th} Ed., Oxford University Press, New Delhi. 2007 2. G. M. Barrow, Physical Chemistry, 5^{th} Ed., Tata McGraw Hill, New Delhi. 2016 3. J. E. House, Principles of Chemical Kinetics, 2^{nd} Ed., Academic Press, Elsevier Burlington, USA, 2007 4. I. N. Levine, Quantum Chemistry, 7^{th} Ed., Prentice-Hall, New Delhi. 1999	
Course outcomes:	1. Students should be in a position to understand and explain various concepts in physical chemistry. 2. Students should be in a position to apply these concepts during the lab course in physical chemistry. 3. Students will understand concepts of electrochemistry. 4. Students will be able to apply fundamentals of chemical kinetics for understanding reaction mechanisms.	

Name of the Programme: M. Sc -I (Physical Chemistry)

Course Code: CHP-501 **Title of the course:** Quantum Chemistry and Statistical Thermodynamics

Number of Credits: 04

Effective from AY: 2022-23

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied physical chemistry courses at M.Sc. Chemistry in semester I</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. Introduction of various concepts of quantum chemistry.
2. To introduce various concepts of statistical thermodynamics.</td></tr>
<tr><td rowspan="2">Content</td><td>1. Quantum Chemistry
a. The origin of quantum mechanics: Planck's quantum theory, wave particle duality, uncertainty principle concept of wave function, the Born interpretation of wave function. Normalization and orthogonalizations, quantization, Eigen values and Eigen functions.
b. Postulates of quantum mechanics; Schrödinger equation for free particle, particle in a box, degeneracy. Quantum mechanical operators and their properties, commutation relations, Hamiltonian and Laplacian operators, Harmonic oscillators, Angular momentum, Ladder Operators.
c. Approximate methods, Schrödinger equation, its importance and limitations, Born-Oppenheimer approximation, Anti-symmetric wave functions and Slater determinants (many electron system e.g. He atom), Exclusion and Aufbau principle, Variation method, Linear Variation Principle, Perturbation theory (first order non-degenerate) and their applications to simple systems.
d. MO theory, Hückel MO theory, Bond-order, Charge density matrix, Unification of HMO and VB theory, their applications in spectroscopy and chemical reactivity, electron density forces and their role in chemical bonding. Hybridization and valence MOs of H_2O, NH_3 and CH_4. Application of Hückel Theory to ethylene, butadiene and benzene molecules.</td><td>No of hours

34</td></tr>
<tr><td>2. Statistical Thermodynamics
a. The language of statistical thermodynamics: Probability, ensemble, microstate, degeneracy, permutations and combinations. Configuration and weights, the dominant configuration. The Boltzmann distribution. The molecular partition function: its interpretation and its relation to</td><td>26</td></tr>
</table>

	uniform energy levels. b. Translational, Rotational, Vibrational and Electronic Partition functions for diatomic molecules. Relation between thermodynamic functions and partition functions and their statistical interpretations. Equilibrium constants from partition function. c. Law of Equipartition energy. Theories of specific heat of solids. Comparison between Einstein and Debye theories. d. Concept of symmetric and antisymmetric wave functions. Ortho and para hydrogens. Quantum Statistics: Fermi-Dirac (FD)and Bose-Einstein (BE) statistics. Comparison between MB, FD and BE Statistics.	
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. P. W. Atkins and J. D. Paula, Physical Chemistry, 8^{th} Ed., Oxford University Press, New Delhi. 2007 2. G. M. Barrow, Physical Chemistry, 5^{th} Ed., Tata McGraw Hill, New Delhi. 2016. 3. M.C. Gupta, Statistical Thermodynamics, Wiley Eastern, New Delhi. 1990 4. I. N. Levine, Quantum Chemistry, 7^{th} Ed., Prentice-Hall, New Delhi. 1999 5. H. Metiu, Physical Chemistry, Statistical Mechanics, Taylor & Francis, New York , 2006	
Course outcomes:	1. Students should be in a position to understand and explain various concepts of quantum chemistry viz. the wave function and applications. 2. Students should be able to explain various concepts in statistical thermodynamics viz. the partition function and applications. 3. Students will be able to explain postulates of quantum mechanics. 4. Students will be able to explain law of equipartition energy.	

Name of the Programme: M. Sc -I (Physical Chemistry)

Course Code: CHP-502 **Title of the course:** Group Theory and Molecular Spectroscopy

Number of Credits: 04

Effective from AY: 2022-23

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied physical chemistry courses at M.Sc. Chemistry in semester I</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. To introduce concepts in Group Theory and it applications to chemistry.
2. To introduce some advance topics in spectroscopy.</td></tr>
<tr><td rowspan="2">Content</td><td>1. Group Theory for Chemistry
a. Symmetry elements and symmetry operations, Concept of group and group multiplication tables, order of the group, classes and subgroups in a group, Different types of groups (cyclic, abelian and non-abelian groups).
b. Point groups, Matrix representations of a group, Reducible and Irreducible representations groups, Great Orthogonality Theorem, Properties of Irreducible representations, Mulliken symbols for Irreducible representations, Character tables.
c. Standard reduction formula, Direct products of representations and it applications Quantum Chemistry and spectroscopy: Vanishing of integrals, Selection rules. Applications of group theory for hybridization of atomic orbitals. Projection operator and Symmetry adapted linear combinations (SALCs), MO treatment (within Huckel Molecular Orbital Theory) of large molecules with symmetry. Applications of group theory to Infra-red and Raman spectroscopy.
d. Space Groups: Symmetry elements, Schoenflies, and Hermann Mauguin notation, Representation of point groups and space groups, point symmetry, space symmetry, glide plane, helical screw axis</td><td>No of hours

30</td></tr>
<tr><td>2. Microwave, IR and Raman Spectroscopy
a. Theoretical treatment of Rotational and Vibrational spectroscopy.
b. Principle of Fourier Transform (FT) spectroscopy, FTIR spectroscopy: Theory, instrumentation and applications.
c. Quantum theory of Raman effect, Raman shift, Instrumentation, Resonance Raman spectroscopy, Complimentary nature of IR and Raman spectroscopy in</td><td>12</td></tr>
</table>

	structure determination, Applications.	
	3. NMR Spectroscopy a. Basic principles of NMR b. Theory of pulse NMR and Fourier analysis, FT-NMR. c. Solid state NMR, magic angle spinning (MAS), dipolar decoupling and cross polarization, applications of solid-state NMR. d. Double resonance, NOE, Spin tickling, Solvent and shift reagents, Structure determination by NMR.	10
	4. ESR Spectroscopy a. Theory and experimental techniques, Identification of odd-electron species (methyl and ethyl free radicals) and radicals containing hetero atoms. b. Spin trapping and isotopic substitution, Spin densities and McConell relationship, Double resonance techniques.	8
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. P. W. Atkins and J. D. Paula, Physical Chemistry, 8th Ed., Oxford University Press, New Delhi, 2007. 2. F.A. Cotton, Chemical Applications of Group Theory, 3rd Ed., John Wiley & Sons-Asia, New Delhi, 1999 3. K. V. Raman, Group Theory and its applications to chemistry, Tata McGraw-Hill, New Delhi, 1999 4. C. N. Banwell and E.M. McCash, Fundamentals of Molecular Spectroscopy, Tata McGraw-Hill, New Delhi, 1994 5. W. Kemp, NMR in Chemistry a multinuclear introduction, Macmillan, 1986. 6. R.S. Drago, Physical Methods in Chemistry, W.B. Saunders Company, 1977.	
Course outcomes:	1. Students should be in a position to explain various concepts in Group Theory. 2. Should be able to apply character table to solve various problems. 3. Students should be in a position to apply the knowledge of spectroscopy for their dissertation and research work. 4. Students will understand the fundamental difference between various spectroscopic techniques.	

Name of the Programme: M. Sc -I (Physical Chemistry)

Course Code: CHP-503 **Title of the course:** Chemical Kinetics and Thermodynamics

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied physical chemistry courses at M.Sc. Chemistry in semester I	
Course Objective:	1. To introduce concepts of reaction kinetics and thermodynamics 2. To provide fundamental knowledge of theories that govern chemical reactions 3. To introduce newer classes of reaction types and their kinetics 4. To introduce latest developments in the advance instrumental techniques and methods for monitoring reaction kinetics and dynamics.	
Content	**1. Theories of reaction rates** a. Generalized kinetic theory and extended collision theory. Concept of collisional number, collisional frequency factor, collisional and reactive cross section, steric factor, microscopic rate constant. Assumptions and limitations of collision theory. b. Conventional transition state theory, equilibrium hypothesis and derivation of reaction rates. Thermodynamic formulation of transition state theory. Arrhenius temperature dependent and independent activation energy and its significance. Assumptions and limitations of transition state theory. Lindemann-Hinshelwood theory of thermal unimolecular reactions.	No of hours 10
	2. Elementary reactions in solutions Collisional kinetics in solution, effect of solvent polarity, solvent cohesion energy, and ion-dipole and dipole-dipole reactions on reaction rates.	3
	3. Kinetics of Homogeneous reactions Homogeneous kinetics, enzymatic reactions and Michaelis-Menten, Lineweaver-Burk and Eadie Analysis, Autocatalytic reactions.	5
	4. Composite reactions Types of composite mechanisms, kinetics of parallel and consecutive reactions. Introduction to shock tube method and its use in combustion analysis.	3
	5. Fast Reactions Photochemical fast reactions, Pulsed laser photolysis, and its use in monitoring fast reactions.	3
	6. Reversible, Irreversible and Oscillatory reactions.	4

	a. Kinetics of reversible reactions and graphical analysis b. Oscillatory reactions, Voltera-Lotka hypothesis of oscillatory reactions. The significance of bi-stability in the Briggs-Rauscher Reaction and Belousov-Zhabotinskii reaction.	
	7. Reaction Dynamics Introduction to potential energy surfaces, description of H_2O and HF potential energy surface diagrams.	2
	8. Equilibrium Thermodynamics a. Important terminologies in Thermodynamics; Thermodynamics state functions; work & heat; work expansion; Mathematical interlude Exact and inexact differentials. Cyclic rule; partial derivatives. b. Heat change at constant pressure, volume; relationship between Qp & Qv; Heat capacities Cp, Cv; Concept of Entropy, entropy change for an ideal gas at different conditions; Entropy of mixing of ideal gas and the Gibbs paradox; Physical significance of entropy. c. Work function and free energy function; Variation of free energy with temperature and pressure; Maxwell relations; Thermodynamic equations of state; Gibbs-Helmholtz equation. d. Thermodynamics of open systems, partial molar properties; chemical potential, variation of chemical potential with temperature and pressure; Gibbs-Duhem equation; Duhem-Margules equation; applications of chemical potential; thermodynamic derivation of phase rule.	17
	9. Non-Equilibrium thermodynamics a. Concept of internal entropy and spontaneity of a process in relation to free energy. Chemical affinity and extent of a reaction. Phenomenological Laws and Onsager's Reciprocal Relations; Conservation of Mass and energy in closed and open system. b. Postulates of non-equilibrium thermodynamics. Entropy production in heat flow. Entropy production of chemical reactions and Entropy production/entropy flow in open system. c. Principle of microscopic reversibility and the Onsager reciprocal relations; Validity of Onsager's equation and its verification; Application of Irreversible Thermodynamics to Biological Systems; Application to thermo-electric and electrokinetic phenomena.	13
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References /	1. K. J. Laidler, Chemical Kinetics, 3rd Ed.; Pearson Education, 1987;	

Readings	(printed in India by Anand Sons, 2004). 2. P.W. Atkins and J. De. Paulo, Atkins' Physical Chemistry, 8^{th} Ed. Oxford University Press, 2007. 3. J. I. Steinfeld, J. S. Francisco and W. L. Hase, Chemical Kinetics and Dynamics, 2^{nd} Ed.; Prentice Hall, 1999. 4. D. K. Chakrabarty and B. Viswanathan, Heterogeneous Catalysis, New Age International Publishers, 2008. 5. S. K. Scott, Oscillations, waves and Chaos in chemical kinetics, Oxford Science Publications, 1994. 6. T. S. Briggs, and W. C. Rauscher, An oscillating iodine clock, J. Chem. Educ., 1973. 7. G. W. Castellan, Physical Chemistry, 3^{rd} Ed.; University of Maryland, Addison-Wesley Publishing Company, 1983. 8. E. N. Yeremin, Fundamentals of Chemical Thermodynamics Firebird Publications, 1978. 9. D. A. McQuarrie & John D. Simon, Physical Chemistry: A molecular approach, Viva Books Pvt. Ltd., New Delhi, 2019. 10. S. R. De Groot, Non-equilibrium thermodynamics, Dover Publications, 2011. 11. A. Kleidon, R.D. Lorenz (Eds.), Non-equilibrium thermodynamics and the production of entropy: life, earth, and beyond, Springer Berlin Heidelberg New York, 2005. 12. J. Rajaram, J. C. Kuriacose, S. N. & Co., Thermodynamics for students of Chemistry, Classical, Statistical and Irreversible, Jalandhar, 1996. 13. P. W. Atkins & J. De. Paulo, Atkins' Physical Chemistry, 8^{th} Ed.; Oxford Univ. Press, 2007.
Course outcomes:	1. Students should be in a position to understand and explain various concepts in chemical kinetics and thermodynamics. 2. Students should be in a position to apply these concepts during the lab course in experimental physical chemistry. 3. Students will able to explain the concept of equilibrium and non-equilibrium thermodynamics. 4. Students will able to explain the elementary reactions in solutions.

Name of the Programme: M. Sc -I (Physical Chemistry)

Course Code: CHP-504 **Title of the course:** Electrochemistry and Surface Studies

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied physical chemistry courses at M.Sc. Chemistry in semester I	
Course Objective:	1. To introduce some core concepts of electrochemical processes including ionic interaction theories, electrified interfaces, electrochemical kinetics and thermodynamics 2. To develop problem solving skills in electrochemistry 3. To introduce fundamental concepts and applications of electrochemistry in day-today life eg. batteries, solar cells, capacitors	
Content	**1. Ionic Interactions and Conductance in Electrolytes** a. Ion-solvent interactions. Born Theory, validity and limitations. b. Solvation number and coordination number. c. Ion-ion interactions and Debye-Huckel theory of ion cloud. d. Applications of Debye- Huckel equation. Concept of ionic strength and activity coefficient. e. Debye-Huckel limiting law and its modifications. f. Debye-Huckel-Onsager equation, validity and limitations. g. Einstein-Smoluchowski equation. h. Influence of ionic atmospheres on ionic migration: Relaxation and Electrophoretic effects. i. Conductance in strong and weak electrolytes.	No of hours 10
	2. Electrified Interfaces a. Formation of an electrode/electrolyte interface and its structure. b. Polarizable and non-polarizable interfaces. c. Potential difference across electrical double layer: outer potential, surface potential, inner potential and relationship between them, chemical and electrochemical potentials. d. Thermodynamics of electrified interface: Surface tension, surface excess, Electro-capillary curves. Determination of surface excess. Condition for thermodynamic equilibrium at electrified interface. e. Generalized Gibbs equation, Lippmann equation and electrical capacitance at the double layer. f. Models of the electrified interface. g. Ion adsorption at the electrode: hydrated electrodes, contact adsorption,	10

	Gibbs adsorption equation.	
	3. Pure Liquid Electrolytes: Ionic Liquids a. Thermal loosening of ionic lattice. b. Ionic liquids in surface electrochemistry: Electrode/electrolyte interfacial processes in ionic liquids. c. Electrochemistry of Ti (IV) in Ionic liquids.	8
	4. Electrode Kinetics and Corrosion a. Disturbance of electrode equilibrium, cause of electron transfer, fast and slow systems and their current-potential relationship. b. Butler-Volmer equation and its low and high field approximations. c. Nernst equation as a special case of B-V equation. d. Tafel plots for anodic and cathodic processes. e. Fundamentals of Impedance spectroscopy; determining exchange current densities and rate constants from impedance plots. f. Principles of corrosion, electrochemical methods of avoiding corrosion. g. pH-potential diagrams: Pourbaix diagram for corrosion of iron and stability of water.	12
	5. Colloidal Chemistry a. Interaction of double layers and stability of Sols. DLVO theory. b. Colloidal electrolytes, critical micelle concentration, Kraft temperature. c. Electrokinetic phenomena: Electroosmosis, streaming potential and current, electrophoresis. Zeta potential. d. Donnan membrane equilibria. e. Micellesandreversemicelles, Emulsions and Microemulsions.	8
	6. Electrochemical Energies: Conversion and Storage a. Thermodynamics of electrochemical energy conversion. b. Batteries: Basic principles; rating and shelf life. Zinc-Manganese dioxide: Leclanche and alkaline batteries. Lithium ion batteries and recharge ability. c. Fuel cells: Principle of a hydrogen-oxygen fuel cell. Classification of fuel cell systems based on types of electrolytes/temperature. Efficiency w.r.t. thermodynamic efficiency, reliability and economic benefits. Direct methanol-polymer electrolyte fuel cell and electro-catalysts - a case study. Reactions occurring in various fuel cells and calculation of their electrode and cell potentials. d. Super-capacitors: Introduction: Origin of Supercapacitance.	7
	7. Photoelectrochemistry	5

	a. Semiconductor/Electrolyte Interface: Band edge and Band bending. b. Light absorption and carrier generation at the electrode: photoinduced charge transfer, hot carriers. c. Photoelectrodes: p-type photocathode, n-type photoanode. d. Determination of surface states. e. Photoelectrocatalysis: photoelectrochemical water splitting and CO_2 reduction. f. Types of photoelectrochemical devices.	
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. J. O. M. Bockris &A. K. N. Reddy, Modern Electrochemistry, Springer India, Pvt.Ltd, 2000, Vol.1,2and3. 2. D. Crow, Principles and Applications of Electrochemistry, Blackie Academy and Professional, 1994. 3. C. M. A. Brett & A. M. O. Brett, Electrochemistry: Principles, methods and applications, Oxford, NewYork Oxford University Press, 1993. 4. R. D. Vold & M. J. Vold, Colloid and Interface Chemistry, Addison-Wesley, 1983. 5. A. Vincent & B. Sacrosati, Modern Batteries, John Wiley, NewYork,1997. 6. J. O. M. Bockris & S. Srinivasan, Fuelcells: Their Electrochemistry, McGraw-HillBook Co., 1969. 7. A. A. J. Torriero, Electrochemistry in Ionic Liquids, Vol. 1: Fundamentals, Springer International Publishing, 2015 8. B. A.J., Stratmann M., Licht D, Encyclopedia of Electrochemistry, Semiconductor Electrodes and Photoelectrochemistry, Wiley-VCH, 2002.	
Course outcomes:	1. Students will be in a position to explain various fundamental and core concepts of electrochemistry. 2. Students should be in a position to apply the knowledge of electrochemistry for their dissertation and research work 3. Students should be in a position to apply these concepts during the lab course in physical chemistry 4. Students will be able to explain the concepts of Photoelectrochemistry.	

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHP-521 **Title of the course:** Practical course in Physical Chemistry-I

Number of Credits: 02

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objective:	1. To develop experimental skills on basic lab techniques in physical chemistry 2. To acquire skills for data analysis and interpretation 3. To help the students to develop research skills	
Content	Minimum 13 Experiments to be performed per Semester Non-instrumental Experiments (any 7) 1. To study the kinetics of hydrolysis of ethyl acetate and to determine a) Energy of activation b) Entropy of activation and c) Free energy change. 2. To determine the order of reaction between potassium persulphate and potassium iodide by graphical, fractional change and differential methods. 3. To study the three-component system such as acetic acid, chloroform; and water and obtain tie line. 4. To determine the molecular weight of polyvinyl alcohol by viscosity measurement. 5. To study the electro-kinetics of rapid reaction between SO_4^{2-} and I^- in an aqueous solution. 6. To determine the buffer capacity of acidic buffer solution. 7. To determine the partial molal volume of ethanol-water mixture at a given temperature. 8. To measure energy content of various types of plastics using bomb calorimetry 9. To determine number average molecular weight of a polymer sample with an indirect titration method. 10. To investigate basic hydrolysis of ethyl acetate at four different temperatures and find out energy of activation	No of hours 30
	Instrumental Experiments (any 6)	

	11. To determine the degree of hydrolysis of salt of weak base and strong acid using conductometer. 12. To determine the dissociation constants of a tribasic acid (Phosphoric acid obtain derivative plot to get equivalence point. 13. To determine formal redox potential of Fe^{2+}/Fe^{3+} and Ce^{3+}/Ce^{4+} system obtain derivative plot to get equivalence point. 14. To study spectrophotometric titration of ferrous ammonium sulphate with potassium permanganate (or dichromate vs permanganate) 15. To determine Avogadro's number by improved electroplating. 16. To determine the zeta potential of colloidal system and investigate the effect of different surfactants on stability of the colloids 17. To verify the Kohlrausch's law for weak electrolyte by conductometry 18. To determine the transport numbers of Cu^{2+} and SO_4^{2-} ions in $CuSO_4$ solution by Hittorf's method.	30
Pedagogy	Mainly pre-laboratory exercises Seminars / term papers /assignments / presentations / lab hand-out /self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. A. Finlay & J.A. Kitchener, Practical Physical Chemistry, Longman. 2. F. Daniels & J.H. Mathews, Experimental Physical Chemistry, Longman. 3. A. M. James, Practical Physical Chemistry, Longman. 4. D.P. Shoemaker & C.W. Garland, Experimental Physical Chemistry, McGraw-Hill.	
Course outcomes:	1. Students will able to explain various fundamental lab techniques. 2. Students should be in a position to apply the knowledge for their dissertation and research work. 3. Students will be able to use spectrophotometric titrations for appropriate analysis. 4. Students will be able to determine molecular weight of some polymers.	

Name of the Programme: M.Sc. Part-I (Chemistry)

Course Code: CHP-522 **Title of the course:** Practical course in Physical Chemistry-II

Number of Credits: 02

Effective from AY: 2022-23

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test.</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. To develop experimental skills on basic lab techniques in physical chemistry
2. To acquire skills for data analysis and interpretation
3. To help the students to develop research skills</td></tr>
<tr><td>Content</td><td>Minimum 13 experiments to be conducted per Semester
Non-instrumental Experiments (any 8)
1. To determine the radius of a molecule by viscosity measurements.
2. To determine ΔG, ΔH and ΔS of silver benzoate by solubility product method
3. To investigate the adsorption of oxalic acid by activated charcoal and test the validity of Freundlich and Langmuir's isotherms.
4. To determine the molecular weight of a given polymer by turbidimetry
5. To study the rate of reaction between ethyl bromoacetate and sodium thiosulphate kinetically.
6. To determine the percentage composition of a given mixture of two liquids by stalagmometer method.
7. To study the kinetics of hydrolysis of methyl acetate and to determine a) Energy of activation b) Entropy of activation and c) Free energy change.
8. To study the kinetics of the reaction between Potassium per sulphate ($K_2S_2O_8$), and Potassium iodide (KI), and to determine a) Energy of activation b) Entropy of activation and c) Free energy change.
9. To determine the order of reaction for hydrolysis of ethyl acetate by graphical, fractional change and differential methods.
10. To determine the molecular weight of polystyrene by</td><td>No of hours

35</td></tr>
</table>

	viscosity measurement.	
	Instrumental Experiments (any 5) 11. To determine the relative strength of chloroacetic acid and acetic acid by conductometry. 12. To determine the degree of hydrolysis of salt of weak base and strong acid using conductometry. 13. To determine the composition of a mixture of acetic acid, dichloroacetic acid and hydrochloric acid by conductometric titration. 14. To determine the dissociation constants of monobasic acid and dibasic acid and obtain derivative plot to get equivalence point. 15. To determine the redox potential of Fe^{2+}/Fe^{3+} system by titrating it with standard $K_2Cr_2O_7$ solution. 16. To study the electrodeposition of metal.	25
Pedagogy	Mainly pre-laboratory exercises Seminars / term papers /assignments / presentations / lab hand-out /self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. A. Finlay & J.A. Kitchener, Practical Physical Chemistry, Longman. 2. F. Daniels & J.H. Mathews, Experimental Physical Chemistry, Longman. 3. A. M. James, F. E. Prichard, Practical Physical Chemistry, Longman. 4. D.P. Shoemaker & C.W. Garland, Experimental Physical Chemistry, McGraw-Hill.	
Course outcomes:	1. Students will gain knowledge of various fundamental lab techniques. 2. Students should be in a position to apply the knowledge for their dissertation and research work. 3. Students will be able to use spectrophotometric titrations for appropriate analysis. 4. Students will be able to determine molecular weight of some polymers.	

M.Sc. Organic/Inorganic/Analytical/Physical Chemistry Part-II syllabus for AY 2023-24 (SEM III and SEM IV) based on NEP 2020

SEM III & IV			
Research Specific Elective (RSE) Courses			
Sr. No.	**Subject code**	**Paper title**	**Credits**
1.	CHO-600	Practical Course in Organic Chemistry-III	4
2.	CHO-601	Practical Course in Organic Chemistry-IV	4
3.	CHO-602	Retrosynthesis and Heterocyclic Chemistry	4
4.	CHO-603	Chemistry of Natural Products	4
5.	CHI-600	Practical Course in Inorganic Chemistry-III	4
6.	CHI-601	Practical Course in Inorganic Chemistry-IV	4
7.	CHI-602	Principles and applications in catalysis	4
8.	CHI-603	Selected Topics in Inorganic Chemistry	4
9.	CHA-600	Practical Course in Analytical Chemistry-III	4
10.	CHA-601	Practical Course in Analytical Chemistry-IV	4
11.	CHA-602	Advanced Mass Spectrometry	4
12.	CHA-603	Selected Topics in Analytical Chemistry	4
13.	CHP-600	Practical Course in Physical Chemistry-III	4
14.	CHP-601	Practical Course in Physical Chemistry-IV	4
15.	CHP-602	Heterogeneous Catalysis: Fundamentals and Applications	4
16.	CHP-603	Applied Electrochemistry	4
17.	CHC-600	Research Methodology and instrumental techniques-I	4
18.	CHC-601	Research Methodology and instrumental techniques-II	4
19.	CHC-651	Discipline Specific Dissertation	16
Generic Elective (GE) Courses			
Sr. No.	**Subject code**	**Paper title**	**Credits**
1.	CHO-621	Polymer Chemistry: Concepts, Synthesis and Processing of Polymers	4
2.	CHO-622	Concepts in Medicinal Chemistry	4
3.	CHO-623	Concepts in Green Chemistry	4
4.	CHO-624	Chemistry of Life	4
5.	CHO-625	Organometallic Chemistry and Rearrangement Reactions	4
6.	CHI-621	Bioinorganic Chemistry	4
7.	CHI-622	Chemistry of p-block elements & their compounds	4

8.	CHI-623	Environmental Chemistry	4
9.	CHI-624	Inorganic Chemistry: Industrial Perspective	4
10.	CHA-621	Fundamentals of Crystallography	4
11.	CHA-622	Advanced NMR and combined Spectroscopy	4
12.	CHA-623	Bioanalytical Techniques	4
13.	CHA-624	Calibration and Validation in Analytical Chemistry	4
14.	CHP-621	Solid State Chemistry: Concepts and Applications	4
15.	CHP-622	Nanoscience: Concepts and Applications	4
16.	CHP-623	Physical aspects of Polymer Chemistry	4
17.	CHP-624	Colloids and Surface Chemistry	4
		Dissertation	
1.	CHC-651	Discipline Specific Dissertation	16

M.Sc. Organic Chemistry Part-II syllabus for AY 2023-24 (SEM III and SEM IV)

SEM III ORGANIC CHEMISTRY			
Sr. No.	**Subject code**	**Paper title**	**Credits**
1	**CHO-600**	Practical Course in Organic Chemistry-III	4
2	**CHO-601**	Practical Course in Organic Chemistry-IV	4
3	**CHC-600**	Research Methodology and instrumental techniques-I	4
4	**CHC-601**	Research Methodology and instrumental techniques-II	4
5	**CHO-621**	Polymer Chemistry: Concepts, Synthesis and Processing of Polymers	4
6	**CHO-622**	Concepts in Medicinal Chemistry	4
7	**CHO-623**	Concepts in Green Chemistry	4
8	**CHO-624**	Chemistry of Life	4
9	**CHO-625**	Organometallic Chemistry and Rearrangement Reactions	4
SEM-IV ORGANIC CHEMISTRY			
Sr. No.	**Subject code**	**Paper title**	**Credits**
1	**CHO-602**	Retrosynthesis and Heterocyclic Chemistry	4
2	**CHO-603**	Chemistry of Natural Products	4
3	**CHC-651**	Discipline Specific Dissertation	16

Name of the Programme: M.Sc. Part-II (Organic Chemistry)

Course Code: CHO-600 **Title of the course:** Practical Course in Organic Chemistry-III

Number of Credits: 4

Effective from AY: 2023-24

<table>
<tr><td>Prerequisites for the course</td><td colspan="2">Should have studied organic chemistry practical course at M.Sc. Part-I.</td></tr>
<tr><td>Course Objective</td><td colspan="2">1. To translate certain theoretical concepts learnt earlier into experimental knowledge
2. To provide hands-on experience of laboratory techniques required for organic syntheses, organic mixture separations and purification.</td></tr>
<tr><td rowspan="3">Content</td><td>1. Organic ternary mixture separation (Minimum 10 experiments of 6h each)
Three component mixture separation based upon differences in the physical and the chemical properties of the components. Elemental and functional group analysis, determination of physical constant and derivative preparation-its recrystallization and melting point/boiling point of any one compound.</td><td>No of hours

60</td></tr>
<tr><td>2. Organic synthesis (Any Six)
a. Benzophenone oxime to benzanilide (Beckmann rearrangement)
b. Benzil to hydrobenzoin ($NaBH_4$ reduction)
c. Diels - Alder reaction of anthracene and maleic anhydride using microwave irradiation
d. Friedel- Crafts acylation of anisole
e. 2-methyl benzimidazole from o-phenylene diamine
f. Dicoumarol from coumarin derivative
g. Halogenation using NBS: preparation of 9-bromoanthracene (or benzylic bromides)
h. Resolution of racemic phenyl ethylamine using tartaric acid
i. Ferric chloride oxidative coupling of 2-naphthol to [1,1'-binaphthalene]-2,2'-diol]
j. Dimedone from mesityl oxide (Dieckmann condensation)
k. $KMnO_4$ oxidation of toluene assisted by microwave
l. 2-phenylindole from acetophenone (Fisher indole synthesis)</td><td>36</td></tr>
<tr><td>3. Polarimetry and column chromatography
(Any 4 experiments of 6h from ‘sections a and b’)
a. Enantiomeric excess by Polarimetry
Determination of optical rotation and enantiomeric excess of enantiomers and unknown mixtures of:
i. Amino acids</td><td>24</td></tr>
</table>

	ii. Drugs iii. Carbohydrates iv. Other readily available Chiral compounds **b. Purification of organic compounds by column chromatography** i. Mixture of ortho and para nitrophenols ii. Mixture of benzil and benzoin iii. Mixture of acetophenone and benzylideneacetophenone *iv.* Mixture of benzophenone and benzanilide *v.* Other Chiral natural product mixtures
Pedagogy	Students should be given suitable pre- and post-lab assignments and explanations revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment.
References /Readings	1. A. I. Vogel, A. R. Tatchell, B. S. Furniss, A. J. Hannaford, Vogel's Textbook of Practical Organic Chemistry, 5^{th} Ed., Prentice Hall, 2011. 2. N. K. Vishnoi, Advanced Practical Organic Chemistry, South Asia Books, 2010. 3. K. Tanaka, Solvent-free Organic Synthesis, 2^{nd} Ed., Wiley-VCH, 2009. 4. L. F. Fieser, K. L. Williamson, Organic Experiments, 7^{th} Ed., D. C. Heath, 1992. 5. K. L. Williamson, K. M. Masters, Macroscale and Microscale Organic Experiments, 6^{th} Ed., Cengage Learning, 2010. 6. R. K. Bansal, Laboratory Manual in Organic Chemistry, 5^{th} Ed. New Age International, 2016. 7. S. Delvin, Green Chemistry, Sarup & Sons, 2005. 8. O. R. Rodig, C. E. Bell Jr., A. K. Clark, Organic Chemistry Laboratory Standard and Microscale Experiments, 3^{rd} Ed., Saunders College Publishing, 2009. 9. J. Mohan, Organic Analytical Chemistry, Narosa Publishing House, 2014. 10. G. J. Shugar, J. T. Ballinger, Chemical Technicians Ready Reference Handbook, McGraw-Hill, Inc. 1996. 11. D. P. Shoemaker, Experimental Physical Chemistry, McGraw-Hill, 1989.
Course Outcome	1. Students will be in a position to perform separation of organic components based on chemical nature, solubility and boiling points. 2. Students will be in a position to understand stoichiometric requirements in organic syntheses. 3. Students will be able to monitor progress of reaction by chromatographic techniques. 4. Students will be able to carry out purification of reaction products by column chromatography.

Name of the Programme: M.Sc. Part-II (Organic Chemistry)

Course Code: CHO-601 **Title of the course:** Practical Course in Organic Chemistry-IV

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course	Should have studied organic chemistry practical course at M.Sc. Part-I.	
Course Objective	1. To translate certain theoretical concepts learnt earlier into experimental knowledge 2. To provide hands on experience of laboratory techniques required for organic syntheses and organic mixture separations.	
Content	**1. Organic ternary mixture separation and identification** (Minimum 14 experiments of 6h each) Three component mixture separation based upon differences in the physical and the chemical properties of the components. Elemental and functional group analysis and determination of physical constants of the individual compounds. Derivative preparation, its recrystallization and m. p. of each component and characterization of each component and its derivative by m. p. comparison.	No of hours 84
	2. Organic synthesis (Any Six) a. 1,2,3,4 - tetrahydrocarbazole from cyclohexanone (Fischer indole synthesis). b. Resolution of racemic phenylethylamine using tartaric acid. c. Trans - Stilbene by Wittig reaction. d. Enamine alkylation: 2-methyl cyclohexanone pyrrolidine enamine with CH_3I. e. Chlorobenzylidene rhodanine (Perkin reaction). f. Diels-Alder reaction of anthracene and maleic anhydride using microwave irradiation. Oxidation of a primary / secondary alcohol to carbonyl compound by polymer supported chromic acid (Amberlyst A-26, chromate form). g. Phenytoin from benzil and urea. h. Isoborneol from camphor ($NaBH_4$ reduction) i. 3 -Methyl -2-phenyl-2-butanoI from 2-bromopropane and acetophenone j. Triphenyl carbinol from benzophenone or ethyl benzoate (Grignard reaction). k. Benzidine from hydrazobenzene (benzidine rearrangement). l. Methyl orange/red from sulphanilic acid/anthranilic acid	36

	(diazotization). m. Reduction of Nitrobenzene to aniline by Sn/HCl. n. LAH reduction of Anthranilic acid. o. Norborneol to norcarnphor using chromium trioxide/sulfuric acid *p.* Benzhydrol from benzaldehyde (Grignard reaction) *q.* Diethyl 4-butyl malonate by malonic ester condensation
Pedagogy	Students should be given suitable pre- and post-lab assignments and explanations revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment.
References /Readings	1. A. I. Vogel, A. R. Tatchell, B. S. Furniss, A. J. Hannaford, Vogel's Textbook of Practical Organic Chemistry, 5th Ed., Prentice Hall, 2011. 2. N. K. Vishnoi, Advanced Practical Organic Chemistry, South Asia Books, 2010. 3. K. Tanaka, Solvent-free Organic Synthesis, Wiley-VCH, 2nd Ed., 2009. 4. L. F. Fieser, K. L. Williamson, Organic Experiments, 7th Ed. D. C. Heath, 1992. 5. K. L. Williamson, K. M. Masters, Macroscale and Microscale Organic Experiments, 6th Ed., Cengage Learning, 2010. 6. R. K. Bansal, Laboratory Manual in Organic Chemistry, 5th Ed., New Age International, 2016. 7. S. Delvin, Green Chemistry, Sarup & Sons, 2005. 8. O. R. Rodig, C. E. Bell Jr., A. K. Clark, Organic Chemistry Laboratory Standard and Microscale Experiments, Saunders College Publishing, 3rd Ed., 2009. 9. J. Mohan, Organic Analytical Chemistry, Narosa Publishing House, 2014.
Course Outcome	1. Students will be in a position to adopt Safe and good laboratory practices, handling laboratory glassware, equipment and chemical reagents. 2. Students will be in a position to understand and calculate stoichiometric requirements during organic syntheses. 3. Students will be in a position to perform separation of organic components based on chemical nature, solubility and boiling points. 4. Students will be able to identify organic compounds with chemical tests.

Name of the Programme: M.Sc. Part-II (Organic Chemistry)

Course Code: CHO-602 **Title of the course:** Retrosynthesis and Heterocyclic Chemistry

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course	Students should have studied Organic Chemistry courses at M.Sc. Part-I level.	
Course Objective:	1. To apply the knowledge gained in organic synthesis for making new molecules. 2. To understand various strategies involved in retrosynthesis of organic molecules 3. To understand the concepts in heterocyclic chemistry and its applications 4. To be able to propose routes for synthesis of heterocycles	
Content	**1. Disconnection approach – Introduction, types of disconnection** a. One-group disconnection b. Disconnection of simple alcohols and compounds derived from alcohols, disconnections of simple olefins, simple/aryl ketones and carboxylic acids c. Two-group disconnection d. Disconnection of 1,3-dioxygenated skeletons, β-hydroxy carbonyl compounds, α,β-unsaturated carbonyl compounds, 1,5-dicarbonyl compounds, Mannich reaction e. ‘Illogical’ Two-group disconnection f. Disconnection of the 1,2-dioxygenated skeleton, α-hydroxy carbonyl compounds, 1,2-diols, ‘Illogical’ electrophiles, disconnection for the 1,4-dioxygenated pattern in 1,4-dicarbonyl compounds, γ-hydroxy carbonyl compounds, Other ‘Illogical’ synthons, disconnection for the 1,6-dicarbonyl compounds, synthesis of lactones (*General review problems to be discussed for above approaches*)	No of hours 15
	2. Disconnection strategies a. Disconnection of heteroatom and heterocyclic compounds such as ethers, amines, heterocycles, amino acids b. Disconnection strategies of few pericyclic reactions c. Convergent and divergent synthesis d. Strategic devices for carbon-heteroatom bonds, polycyclic compounds: the common atom approach e. Considering all possible disconnections f. Alternative FGI’s before disconnection- the cost of synthesis g. Features which dominate strategy, functional group addition and molecules with unrelated functional groups	15

	3. Heterocyclic compounds a. Introduction, classification and nomenclature of mono- and bicyclic heteroaromatic molecules b. Physical properties, dipole moment, acidity-basicity, aromaticity, electron density distribution and reactivity of furan, thiophene, pyrrole, indole, pyridine, pyridine-N-oxide, quinoline, isoquinoline, diazines and triazines, 1,3- and 1,2-azoles	15
	4. Synthetic strategies for heterocycle synthesis General methods of synthesis of the following: furan, thiophene, pyrrole, indole, pyridine, quinoline, isoquinoline, chromones, imidazoles, oxazoles, thiazoles	15
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. S. Warren, Designing Organic Synthesis, John Wiley & Sons, 2009. 2. G. S. Zweifel, M. H. Nantz, P. Somfai, Modern Organic Synthesis: An Introduction, 3rd Ed. W. H. Freeman and Company, New York, 2022. 3. J. Clayden, N. Greeves & S. Warren, Organic Chemistry, Oxford, 2016. 4. J. A. Joule, K. Mills & G. F. Smith, Heterocyclic Chemistry, 3rd Ed., 1995. 5. J. A. Joule & K. Mills, Heterocyclic Chemistry, Wiley-Blackwell, 5th Ed., 2010. 6. T. L. Gilchrist, Heterocyclic Chemistry, Pitman Publishing, 2005. 7. R. M. Acheson, An Introduction to Chemistry of Heterocyclic Compounds, John Wiley and Sons, 3rd Ed, 1977. 8. D. W. Young, Heterocyclic Chemistry, Longman Group Ltd., London, 1975. 9. R. O. C. Norman and J. M. Coxon. Principles of Organic Synthesis, CRC Press, 3rd Ed., 2009.	
Course Outcome:	1. Students will be in a position to understand how a carbon-carbon bond can be constructed and/or cleaved 2. Students will be in a position to understand how retrosynthesis can be used in finding out easily available chemical precursors for making organic molecules 3. Students will be in a position to apply retrosynthetic strategies and propose routes for synthesis of organic molecules and heterocycles 4. Students will be able to understand and apply the concepts of the reactivity of heterocycles towards electrophilic, nucleophilic, reducing and oxidizing reagents.	

Name of the Programme: M.Sc. Part-II (Organic Chemistry)

Course Code: CHO-603 **Title of the course:** Chemistry of Natural Products

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course	Students should have studied Organic Chemistry courses at M.Sc. Part-I level.	
Course Objectives	1. To study the main classes of natural products. 2. To understand the different methods that are used in natural product chemistry, including extraction, isolation and structural elucidation. 3. To understand the key biosynthetic pathways for the biosynthesis of terpenes, alkaloids and steroids.	
Content	**1. Source and isolation of natural products** General methods of isolation: The modern distillation process, maceration, enfleurage, extraction by cold pressing and extraction with solvents	No of hours 2
	2. General methods of purification and structure elucidation of Natural Products a. Fractionation of the crude extracts and purification of the individual compounds from the respective fractions using chemical and chromatographic techniques such as Column Chromatography, TLC, Preparative TLC, HPLC, etc. b. Chemical methods based on the functional groups present: Bicarbonate extraction, sodium bisulphite adduct formation, derivatization, etc. c. General approach to structure elucidation of the isolated pure compounds using UV, IR, NMR spectroscopy, MS spectrometry, optical polarimetry.	4
	3. Structure elucidation by classical chemical methods a. Terpenoids: α-cedrene b. Alkaloids: Morphine, thebaine and codeine c. Steroids: Cholesterol, bile acids	12
	4. Structure elucidation by combination of chemical and spectral methods a. Terpenoids: α- and β-vetivones, Ishwarone b. Hormones: Cecropia Juvenile hormone, brevicomin and frontalin c. Oxygen heterocycles: Aflatoxin-B1, rotenone	10
	5. Structure elucidation involving stereochemistry, spectral and chemical methods a. Terpenoids: Menthol and hardwickiic acid b. Alkaloids: Reserpene	8
	6. Synthesis of selected natural products, planning and execution a. Terpenoids: Longifolene (E. J. Corey), Caryophyllene (E J	14

	Corey) Nootkatone (A. Yoshikoshi), Menthol (Tagasago) b. Alkaloids: Reserpine (R. B. Woodward), Morphine (Marshall Gates) c. Hormones: Cecropia JH (Edward), Progesterone d. Prostaglandins: Prostaglandin E2 (E. J. Corey) e. Antibiotics: Cephalosporin (R. B. Woodward)	
	7. Biogenesis and biosynthesis of natural products a. Terpenoids and Steroids: General approach towards biosynthesis of mono-, sesqui-, di-, tri-, tetraterpenoids and steroids through mevalonate pathway with special reference to the biosynthesis of terpenoids and steroids included in topics 3 to 6 b. Alkaloids: The shikimate pathway formation of hydroxybenzoic acid derivatives, aromatic amino acids, L-phenylalanine, L-tyrosine, phenolic oxidative coupling, biosynthesis of thebaine, codeine and morphine.	10
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. I. L. Finar, Organic Chemistry: Stereochemistry and the Chemistry of Natural Products, Pearson Education India, 2002. 2. K. Nakanishi, Natural Product Chemistry, Academic Press, 2013. 3. D. R. Dalton, The Alkaloids. New York: M. Dekker, 1979 4. Barton and Olis, Comprehensive Organic Chemistry, Pergamon, 1979. 5. D. Paul, Medicinal Natural Products: A Biosynthetic Approach, John Wiley and Sons, 2002. 6. M. Paolo, Biosynthesis of Natural Products, Wiley, 2010 7. J. ApSimon, The Total Synthesis of Natural Products, John Wiley and Sons, 1992. 8. E. J. Corey & X-M. Cheng, The Logic of Chemical Synthesis, Wiley Interscience, a division of John Wiley and Sons Inc, 1995. 9. K. C. Nicolaou & E. J. Sorensen, Classics in Total Synthesis, Weinhem: VCH, 1996. 10. R. O. C. Norman and J. M. Coxon. Principles of Organic Synthesis, CRC Press, 3rd Ed., 2009.	
Course Outcomes	1. Students will be able to identify different types of natural products 2. Students will be able to describe the properties and structure of natural products, their occurrence, biosynthetic pathways 3. Students will be able to carry out independent investigations of plant materials and natural products 4. Students will be able to understand and explain the synthesis of some classes of natural products.	

Name of the Programme: M.Sc. Part-II (Organic Chemistry)

Course Code: CHO-621 **Title of the course:** Polymer Chemistry: Concepts, Synthesis and Processing

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course	Students should have studied M.Sc. Part-I Chemistry.	
Course Objective	1. To introduce various concepts in organic polymer chemistry. 2. To understand the synthesis, polymer processing and applications.	
Content	**1. Brief history of natural and synthetic polymers** Classification & nomenclature of polymers, functionality concept-linear, -branched and -cross linked polymers. Introduction to biodegradable polymers.	No of hours 5
	2. Methods and chemistry of polymerization Bulk, solution, suspension, emulsion, addition, condensation polymerizations. Free-radical, Ionic and coordination polymerization reactions. Introduction to controlled free radical polymerization. Carothers equation in condensation polymerizations.	12
	3. Properties of polymers a. Number and weight average molecular weights, Molecular weight distribution, polydispersity. b. Glassy state and glass transition temperature, crystallinity in polymers. c. Characterization of polymers.	10
	4. Resources for monomers, manufacture of important monomers and reagents Ethylene, propylene, butadiene, isoprene, styrene, divinyl benzene, acrylonitrile, vinyl chloride, adipic acid, urea, bisphenol-A, melamine, phthalates, glycol, glycerol, ethylene oxide, epichlorohydrin, ϵ-caprolactum, di-isocyanates, pentaerythritol, allylic carbonate monomers.	12
	5. Synthesis, properties and applications of polymers a. Vinyl polymers-LDPE, HDPE, PVC, PVA, polyvinyl acetate, polyacrylates, methacrylates, polystyrene, teflon, ABS, SBR, SAN. b. Condensation polymers- Nylons, polyesters, polyurethanes, polycarbonates. c. Thermoset polycarbonates like CR-39 Cellulose esters-cellulose acetate, nitrates and acetatebutyrates. d. Thermoset resins- phenol-formaldehyde, melamine-	14

<table>
<tr><td></td><td>formaldehyde, epoxy resins - their curing.
e. Natural rubber.</td><td></td></tr>
<tr><td></td><td>6. Additives in polymers and Polymer processing
a. Lubricants, plasticizers, stabilizers, antioxidant, fire retardants, blowing agents, fillers, colorants, crosslinking agents, UV-Vis degradants etc.
b. Introduction to compounding, and processing techniques like calendaring, casting, moulding and spinning in polymer processing.</td><td>7</td></tr>
<tr><td>Pedagogy</td><td colspan="2">Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.</td></tr>
<tr><td>References / Readings</td><td colspan="2">1. V. R. Gowarikar, N.V. Vishwanathan, J. Sreedhar, Polymer Science, New Age International, 2015.
2. J. R. Fried, Polymer Science and Technology, PHI Pvt. Ltd.,2000.
3. R. Sinha, Outlines of Polymer Technology: Manufacture of Polymers, PHI Pvt Ltd., 2000.
4. K. Y. Saunders, Organic Polymer Chemistry, Chapman and Hall, UK, 1976.
5. H. R. Kircheldorf, Handbook of Polymer Synthesis, PART Aand B, Marcel Dekkar Inc., 1992.
6. R. P. Brown, Handbook of Plastic Test Methods, 2nd Ed., George Godwin Ltd., 1981.
7. M. P. Stevens, Polymer Chemistry- An Introduction, 2nd Ed., Oxford Univ. Press, 1990.
8. W. Y. Mijs, New Methods in Polymer Synthesis, PelnumPress Ltd., NY, 1992.
9. M. Arora, Polymer Chemistry, Anmol Publications 2001.
10. C. E. Carraher, Polymer Chemistry, New York M. Dekker 2005.
11. P.C. Hiemenz, Polymer Chemistry, CRC Press, 2007.
12. V. K. Selvaraj, Advanced Polymer Chemistry, New Delhi Campus books, CRC Press, 2008.
13. A. Ravve, Principles of polymer Chemistry, Springer 2012.
14. J. David, Polymers, Oxford University Press 2015.</td></tr>
<tr><td>Course Outcome</td><td colspan="2">1. Students will be in a position to understand and evaluate the differences in structures and properties of small molecules and macromolecules.
2. Students will be in a position to apply concepts involved in polymer synthesis, characterization and processing.
3. Students will be in a position to understand and apply concepts of synthesis and applications of organic polymers.
4. Students will understand properties of polymers</td></tr>
</table>

Name of the Programme: M.Sc. Part-II (Organic Chemistry)

Course Code: CHO-622 **Title of the course:** Concepts in Medicinal Chemistry

Number of Credits: 4

Effective from AY: 2023-24

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied the chemistry courses in M.Sc. Part I level.</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. To understand the concepts of drug discovery and development
2. To learn drug screening, target identification, lead discovery, optimization
3. To understand molecular basis of drug design and drug action</td></tr>
<tr><td>Content</td><td>1. Introduction to Drugs
Requirement of an ideal drug, sources of drugs, important terms used in chemistry of drugs, classification and nomenclature of drugs, drugs and the medicinal chemists.
a. Drug Design: Analogues and pro-drugs, concept of lead compounds, features governing drug design – the method of variation, drug design through disjunction, conjunction, tailoring of drugs, cimetidine – a rational approach to drug design.
b. Drug Development: Screening of natural products, isolation and purification, structure determination, structure-activity relationship, QSAR, synthetic analogues, natural products as leads for new pharmaceuticals, receptor theories, oxamniquine – a case study</td><td>No of hours

15</td></tr>
<tr><td></td><td>2. Mechanism of drug action
Introduction, enzyme stimulation, enzyme inhibition, membrane-active drugs, polymorphism and drug delivery.</td><td>10</td></tr>
<tr><td></td><td>3. Study of Pharmacodynamic Agents (minimum two examples for each)
a. Local anesthetics
b. Analgesics : narcotic and non-steroidal anti-inflammatory, narcotic antagonists
c. Antiepileptic drugs
d. Antiparkinsonism drugs
e. Antihistaminics
f. Seditives and hypnotics
g. Antipsychotics
h. Cardiovascular agents : Cardiovascular diseases, Antianginal agents and vasodilators, Antihypertensive agents, Antiarrhythmic drugs, Adrenergic blocking agents</td><td>15</td></tr>
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<tr><td></td><td>i. Antihyperlipidemic and antiatherosclerotic agents
j. Anticoagulants, blood coagulation and anticoagulant mechanism
k. Diuretics
l. Antidiabetic drugs : Synthetic hypoglycemic agents</td><td></td></tr>
<tr><td></td><td>4. Study of Chemotherapeutic Agents and Antibiotics
a. Chemotherapeutic Agents (with examples)
i. Sulfonamides
ii. Antitubercular and Antilepral agents
iii. Antiamoebics
iv. Anthelmintics
v. Antimalarials
vi. Antiviral agents
vii. Antineoplastic Agents
b. Antibiotics : General information, mode of action and applications
i. β-Lactam antibiotics : Penicillins and Cephalosporins
ii. Aminoglycocides : Streptomycin, Neomycin
iii. Tetracyclines
iv. Macrolides : Erythromycin, Rifamycin, Lincomycin
v. Polypeptides : Bacitracin
vi. Unclassified antibiotics : Chloramphenicol</td><td>15</td></tr>
<tr><td></td><td>5. New Developments in Drug Discovery
Introduction, gene therapy, drug resistance, antisense drugs, cytokines, drugs to combat AIDS.</td><td>5</td></tr>
<tr><td>Pedagogy</td><td colspan="2">Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.</td></tr>
<tr><td>References / Readings</td><td colspan="2">1. R. F. Doerge, J. B. Lippincott, Wilson and Gisvold's Text book of Organic Medicinal and Pharmaceutical Chemistry, 8th Ed, Philadelphia, USA, 2010
2. M. E. Wolff, Burger's Medicinal Chemistry, Part I and II, 4th Ed., John Wiley, 1980
3. W. O. Foye, Principles of Medicinal Chemistry, 7th Ed., K. M. Varghese and Co., Bombay, 2012.
4. Lednicer and Mitscher, Organic Chemistry of Drug Synthesis, Vols I and II, John Wiley, 1980.
5. G. Patrick, An Introduction to Medicinal Chemistry, Oxford University Press, Oxford, 1998.
6. D. J. Abraham, Burgers Medicinal Chemistry and Drug Discovery, Vol. I, 6th Ed., John Wiley and Sons, New Jersey, 2003.
7. J. Janata, Z. Kamenik, R. Gazak, S. Kadlcik and L. Najmanova, Nat. Prod. Rep., 2018, 35, 257–289</td></tr>
</table>

Course Outcome:	1. Students will be able to explain classes of drugs and their structure activity relationship with examples of some important class of drugs. 2. Students will be able to explain mechanism of action of the drugs. 3. Students will be able to describe the therapeutic uses of drugs and specific side effect of ‘Drug Substances’. 4. Students will be able to explain physico-chemical properties related to QSAR. 5. Students will be able to describe various approaches in designing of drug molecules including prodrug and combinatorial chemistry.

Name of the Programme: M.Sc. Part-II (Organic Chemistry)

Course Code: CHO-623 **Title of the course:** Concepts in Green Chemistry

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied M.Sc. Part-I Chemistry/Biochemistry.	
Course Objective:	1. To understand various concepts involved in Green synthesis 2. To understand green technologies used in chemistry 3. To learn application of green chemistry approaches to chemical industry	
Content	**1. Principles and Concepts of Green Chemistry** a. Introduction, twelve green principles, sustainable development and green chemistry. b. Atom Economy: atom economic reactions- rearrangement and addition reactions. c. Atom un-economic reactions- substitution, elimination and Wittig reactions. Reducing toxicity.	No of hours 6
	2. Waste: Production, Problems and Prevention a. Introduction, Some problems caused by waste, sources of waste from the chemical industry and the cost of waste. b. Waste minimization techniques: the team approach and process design for waste minimization, minimizing waste from existing processes. c. On-site waste treatment: Physical, chemical and biotreatment. d. Design for degradation: degradation and surfactants, DDT, polymers and some rules for degradation. e. Polymer recycling: separation and sorting, incineration, mechanical recycling and chemical recycling to monomers.	6
	3. Measuring and Controlling Environmental Performance a. The importance of measurement: Lactic acid production, safer gasoline. b. Introduction to life cycle assessment and green process metrics. c. Environmental management systems: ISO and European Eco-Management and Audit Scheme, eco-labels, green chemical supply, Strategies, Legislation and integrated pollution prevention and control.	6
	4. Catalytic processes and Green Chemistry a. Introduction to catalysis and comparison of catalyst types. b. Heterogeneous catalysts: Basics of heterogeneous catalysis, Zeolites and the bulk chemical industry, heterogeneous	10

	catalysis in the fine chemical and pharmaceutical industries. Catalytic converters. c. Homogeneous catalysis: Transition metal catalysts with phosphine ligands, greener Lewis acids and asymmetric catalysis. d. Phase transfer catalysis: Hazard reduction, C – C bond formation and oxidation using hydrogen peroxide. e. Biocatalysis and photocatalysis.	
	5. Organic Solvents: Environmentally Benign Solutions a. Organic solvents and volatile organic components, solvent free systems. b. Supercritical fluids: supercritical carbon dioxide and supercritical water. c. Water as a reaction solvent and water-based coatings. d. Ionic liquids as catalysts and solvents. e. Fluorous biphase solvents. f. Deep eutectic solvents	10
	6. Renewable Resources a. Biomass as a renewable resource. Energy: Fossil fuels, biomass, solar power, fuel cells and other forms of renewable energy. b. Chemicals and polymers from renewable feedstock. c. Alternative economies: the syngas economy and the biorefinery.	6
	7. Greener Technologies and Alternative Energy Sources a. Design for energy efficiency b. Photochemical reactions: advantages of and challenges faced by photochemical processes, examples of photochemical reactions. c. Chemistry using Microwaves: microwave heating and microwave-assisted reactions. d. Sonochemistry and green chemistry examples. e. Electrochemical synthesis and examples. f. Flow chemistry	10
	8. Industrial case studies a. A brighter shade of green: synthesis of stilbene intermediates for optical brightners. b. Greening of acetic acid manufacture, EPDM rubbers and Vitamin C. c. Leather manufacture: tanning and fatliquoring. d. Dyeing to be green: some manufacturing and products improvement and dye application.	6

	e. Polyethene: Radical process, Ziegler – Natta and metallocene catalysis. f. Eco-friendly pesticides.	
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. M. Lancaster, Green Chemistry, The Royal Society of Chemistry, Cambridge, UK, 2002. 2. V. K. Ahluwalia, Green Chemistry: Environmentally Benign Reactions, Ane Books India, New Delhi, 2006. 3. A. S. Matlack, Introduction to Green Chemistry, Marcel Dekker, Inc., New York, 2001. 4. P. T. Anastas and T. C. Williamson, Green Chemistry: Frontiers in benign chemical synthesis and processes, Oxford University Press, Oxford, Ed. 1998. 5. R. Sanghi and M. M. Srivastava, Green Chemistry: Environment Friendly Alternatives, Narosa Publishing House, Ed. New Delhi, 2007. 6. Samuel Delvin, Green Chemistry, IVY Publishing House, Delhi, 2006. 7. V. K. Ahluwalia and M. Kidwai, New Trends in Green Chemistry, Anamaya Publishers, New Delhi, 2004. 8. P. G. Jessop and W. Leitner, Chemical Synthesis using Supercritical fluids, Wiley – VCH, Verlag, Ed., Weinheim, 1999. 9. K. Tanaka, Solvent Free Organic Synthesis, Wiley – VCH GmbH and Co. KgaA, Weinheim, 2003. 10. P. T. Anastas and J. C. Warner, Green Chemistry, Theory and Practice, Oxford University Press, N. York, 1998. 11. C - Jun Li and T – Hang Chan, Organic Reactions in Aqueous Media, John Wiley and Sons INC., N. York, 2001. 12. F. Z. Dorwald, Organic Synthesis on Solid Phase, Wiley – VCH Verlag, Weinheim, 2002. 13. P. Wasserscheid and T. Welton, Ionic Liquids in Synthesis, Wiley – VCH Verlag, Ed., Weinheim, 2003. 14. A. Loupy, Microwaves in Organic Synthesis, Wiley – VCH Verlag, Weinheim, (Ed.), 2002. 15. R. V. Eldik and F. G. Klarner, High Pressure Chemistry, Wiley – VCH Verlag, (Eds.), Weinheim, 2002. 16. F. Darvas, G. Dorman, V. Hessel, Flow Chemistry - Fundamentals: Vol.1, De Gruyter, 1st Ed. 2014.	
Course Outcome:	1. Students will be in a position to understand how chemistry can be done using greener alternatives 2. Students will be in a position to apply green technologies as a sustainable solution for making molecules	

	3. Students will be able to understand and apply the concepts of green chemistry to develop scalable processes in industry 4. Students will understand various renewable resources

Name of the Programme: M.Sc. Part-II (Organic Chemistry)

Course Code: CHO-624 **Title of the course:** Chemistry of Life

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course	Students should have studied M.Sc. Part-I Chemistry/Biochemistry.	
Course Objective:	1. Introduction to the chemistry of amino acids, proteins, carbohydrates, lipids and their applicability in daily life. 2. Understanding chemicals used in food production through food processing, storage and cooking. 3. Understanding food analysis and the chemistry of the digestion of food and energy provided by food.	
Content	**1. Chemistry of Proteins: Structure, function and food analysis** a. Introduction to amino acids and role of polar, non-polar, acidic and basic side chains, their properties and Isoelectric point b. Introduction to peptides, dipeptides and proteins, types of proteins [primary (1°), secondary (2°), tertiary, (3°) and Quaternary (4°)]: hydrogen bonding, salt bridges, hydrophobic - non-polar interactions and disulfide linkages c. Protein folding, denaturation and functional properties of proteins. d. Food Proteins – Source of Proteins, Analysis of amino acids and proteins in food	No of hours 10
	2. Chemistry of Nucleic Acids Brief history of sugars and bases, conformation of sugar-phosphate backbone, hydrogen bonding by bases, the double helix: A,B, and Z double helices, stability of double helix, DNA intercalators, chemical synthesis of DNA, catalytic RNA, siRNA, micro RNA	15
	3. Chemistry of Carbohydrates and Lipids: Structure, function and food Analysis **a. Carbohydrates** i. Introduction to mono-, di- and oligosaccharides, polysaccharides: starch, dietary, fibre, their physical function. ii. Fischer projections, Haworth Projections, stereoisomerism in carbohydrates. iii. Food Carbohydrates – Source of carbohydrates, Analysis of carbohydrates in food iv. Sugars: Hydrolysis, thermal degradation, Maillard reaction (non-enzymic browning reaction between reducing carbohydrates and proteins), Amadori Rearrangement and Analysis of Sugars, Mutarotation	20

<table>
<tr><td rowspan="2"></td><td>b. Lipids
i. Introduction to lipids, types of lipids and fatty acids
ii. Monoglycerides, diglycerides, triglycerides, polar lipids
iii. Reactions of fatty acids - Oxidative and hydrolytic rancidity
iv. Sources of fats and analysis in food</td><td></td></tr>
<tr><td>4. Chemistry of Enzymes
a. Introduction to Enzyme Catalysis and Kinetics
b. The Catalytic Triad
c. Enzyme Inhibition and Drug design
d. Enzymes in Organic Synthesis
e. Antibody Catalysed Organic Reaction
f. Enzyme Models: Biomimetic Polyene Cyclisation and Squalene Biosynthesis</td><td>15</td></tr>
<tr><td>Pedagogy</td><td colspan="2">Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.</td></tr>
<tr><td>References / Readings</td><td colspan="2">1. J. Clayden, N. Greeves, & S. Warren. Organic Chemistry, 2nd Ed., Oxford University Press, 2012.
2. T. P. Coultate, Food - The Chemistry of its Components, Royal Society of Chemistry, 5th Ed., 2009.
3. H. D. Belitz. & W. Grosch, Food Chemistry, 4th Ed., Springer, 2009.
4. B. Selinger, Chemistry in the Marketplace, 3rd Ed., Harcourt Brace, 1986.
5. O. R. Fennema, Food Chemistry, 4th Ed., Marcel Dekker, 2008.
6. H. Dugas, Bioorganic Chemistry - A Chemical Approach to Enzyme Action, 3rd Ed. Springer, 1999.
7. R. B. Silverman, The Organic Chemistry of Enzyme-catalyzed Reactions, Academic Press, San Diego, 717 pp., 2000.
8. J. S. Davies, Amino acids, Peptides and Proteins, Royal Society of Chemistry, UK, Vol. 35, 4, 2006.
9. L. Stryer, J. M. Berg, and J. L. Tymoczko, Biochemistry, 5th Ed., W. H. Freeman & Co Ltd, 2002.</td></tr>
<tr><td>Course Outcome:</td><td colspan="2">1. Students will be in a position to predict type of proteins, lipids and carbohydrates available in food.
2. Students will be in a position to explore the chemical structure and functionality for the macronutrient categories like carbohydrates, lipids, and proteins in food
3. Student will be able to design experiments through an inquiry-oriented, food chemistry focused laboratory program.
4. The students will be able to identify the essential chemical components of food and have knowledge of their analyses, and gain knowledge of the chemistry of lipids, carbohydrates and proteins</td></tr>
</table>

Name of the Programme: M.Sc. Part-II (Organic Chemistry)

Course Code: CHO-625 **Title of the course:** Organometallic Chemistry and Rearrangement Reactions

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied chemistry courses at M.Sc. Part-I level.	
Course Objective:	1. To understand concepts and various strategies involved in organometallic chemistry. 2. To apply organometallic chemistry in the formation of carbon-carbon, carbon-hetero atom bonds. 3. To understand and apply molecular rearrangements for synthetic applications.	
Content	**1. Introduction to organometallic chemistry** a. Introduction to Organometallic Chemistry, Definitions, Types of Metal-carbon bonds with main-group metals and transition metals b. *Sigma* and *pi* bonds: linear pi system and cyclic pi system c. Organic ligands, Nomenclature, heptacity, Electron counting and 18-electron rule d. Orbital interactions and bonding e. Kinetic stability	No of hours 08
	2. Organometallic compounds of main group elements a. Preparation, properties and applications of Lithium Magnesium, Cadmium, Zinc, Cerium, Mercury and Chromium Compounds. b. Heteroatom directed lithiation reactions	12
	3. Role of transition metals in organic synthesis a. Preparation and properties of Copper, Palladium, Nickel, Rhodium, Ruthenium and Gold reagents/complexes. b. Mechanisms and applications of Mizoroki-Heck, Suzuki, Stille, Hiyama, Negishi, Sonogashira, Wacker, Kumada, Buchwald-Hartwig, carbonylation, homogenous hydrogenation, carbonylation, allylic substitution)	20
	4. Molecular rearrangements and their synthetic applications a. Unifying principles and mechanisms of rearrangements taking place at an electron deficient and electron rich substrates. b. Rearrangements taking place at carbon: Arndt-Eistert, Wagner-Meerwein, benzil-benzilic acid, Pinacol-pinacolone, semipinacol, Tiffeneau Demjanov, dienone-phenol, Wittig, Favorskii, Stevens, Wolff, Baker-Venkatraman, Barton	20

	decarboxylation, Pummerer rearrangement. c. Rearrangements at nitrogen: Hofmann, Curtius, Lossen, Schmidt, Beckmann, Neber, Stieglitz rearrangement. d. Rearrangements at oxygen: Payne (including aza- and thia-Payne) rearrangement, hydroperoxide rearrangement, Criegee rearrangement, Baeyer–Villiger oxidation e. Aromatic rearrangements: Benzidine, Fries, Von Richter, Sommelet-Hauser, Smile's, Jacobsen. Rearrangement on aniline derivatives- Bamberger rearrangement, Fischer-Hepp, Orton, Hofmann-Martius, Reilly-Hickinbottom, rearrangements of *N*-arylazoanilines, Phenylnitramines, Phenylsulfamines. f. Rearrangements involving fragmentations: Eschenmoser fragmentation.	
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. A. Edward, Comprehensive Organometallic Chemistry, 2nd Ed., 14 vols. Pergman, 1995. 2. F. R. Hartley, Chemistry of Metal-Carbon Bond, 6 vols. Wiley, 1982-83. 3. M. Schlosser, Organometallics in Synthesis - A Manual, John & Wiley, 1994. 4. R. H. CraJohn, The Organometallic Chemistry of the Transition Metals, Wiley, 1994. 5. G. R. Stephenson, Transition Metal Organometallics for Organic Synthesis, Cambridge University Press, 1991. 6. L. S. Liebeskind, Advances in Metal Organic Chemistry, Vols. 1 and 2 (Ed.), JAI Press, 1989. 7. J. P. Colliman, L. S. Hegedus, J. R. Norton & R. G. Finke, Principles and Applications of Organotransition Metal Chemistry, University Science Books, 1987. 8. A. Yamamoto, Organotransition Metal Chemistry - Fundamental Concepts and Applications, Wiley, 1986. 9. A. J. Pearson, Metallo-Organic Chemistry, John Wiley, 1985. 10. W. Caruthers & I. Colddham, Modern Methods of Organic Synthesis, 4th Ed., Cambridge University Press, 2016. 11. J. Clayden, N. Greeves and S. Warren, Organic Chemistry, Oxford, 2016. 12. F. A. Carey & R. J. Sundberg, Advanced Organic Chemistry: Part A and B, 5th Ed., Springer India Private Limited, 2007. 13. R. O. C. Norman & J. M. Coxon, Principles of Organic Syntheses, 3rd Ed. CRC Press Inc, 2009. 14. M. B. Smith & Jerry March, Advanced Organic Chemistry- 50 Reaction, Mechanism and Structure, 6th Ed., Wiley, 2006.	

Course Outcome:	1. Students will be in a position to understand how a carbon-carbon and carbon-hetero atom bonds can be constructed using organometallic chemistry. 2. Students will be able to understand and apply the concepts of organometallic chemistry in syntheses of organic molecules. 3. Students will be in a position to write synthetic routes for organic molecules using various molecular rearrangements.

Name of the Programme: M.Sc. Part-II (Chemistry)

Course Code: CHC-600 **Title of the course:** Research Methodology and instrumental techniques-I

Number of Credits: 4

Effective from AY: 2023-24

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied chemistry courses at MSc-I level.</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. To introduce various aspects of research methodology.
2. To provide understanding ethics & scientific conduct.
3. To introduce academic writing.
4. To introduce databases used in chemistry.
5. To provide understanding and importance of lab safety.
6. To understand the usefulness of various instrumental techniques in characterization of chemical compounds.</td></tr>
<tr><td rowspan="3">Content</td><td>1. Introduction to Research Methodology
Research- meaning, objectives, motivation, types and methodology.
Process- formulating the research problem; literature survey; developing the hypothesis and the research design; sample design and collection of the data; execution of the project; analysis of data; testing of hypothesis; generalizations and interpretation, and preparation of the report or presentation of the results & conclusions.</td><td>No of hours

5</td></tr>
<tr><td>2. Scientific conduct and ethics
Ethics: definition, nature of moral judgements and reactions, Ethics with respect to science and research.
Intellectual honesty and research integrity.
Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP).
Redundant publications: duplicate and overlapping publications.
Selective reporting and misrepresentation of data.</td><td>5</td></tr>
<tr><td>3. Academic writing
Publication ethics: definition, introduction and importance
Conflicts of interest
Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa
Violation of publication ethics, authorship and contributorship
Identification of publication misconduct, complaints and appeals
Predatory publishers and journals</td><td>5</td></tr>
</table>

	4. Data bases and research metrics Databases: 1. Indexing databases 2. Citation databases: Web of Science, Scopus, UGC-Care List etc. Research Metrics: 1. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score 2. Metrics: h-index, g index, i10 index etc	3
	5. Safety aspects in Chemistry Good laboratory practices. Handling of various chemicals, solvents & glassware. Fires and fighting with fires. Hazardous substances, classification and handling Safety Data Sheet	5
	6. Softwares in Chemistry Data plotting Structure Drawing Reference management software	7
	7. Instrumental methods of analysis: Demonstration and/ or data analysis in following techniques: Elemental analysis: CHNS analysis and AES Infrared (IR), Raman, Ultraviolet-Visible (UV-Vis) Nuclear magnetic resonance (^{1}H, ^{13}C) Chromatographic techniques: HPLC, GC, Hyphenated Techniques: LC-MS & GC-MS, Diffraction methods: XRD Thermal analysis: DSC Microscopy: SEM, TEM Methods for determination of magnetic & dielectric properties. Cyclic voltammetry	30
Pedagogy	Mainly lectures/recorded video lectures/ tutorials, discussions, seminars, internal exams/ assignments, / demonstration/ self-study or a combination of some of these. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. C. R. Kothari, Research Methodology: Methods & Techniques, New Age International Pvt. Ltd., 2004. 2. Bird, Philosophy of Science, Routledge, 2006. 3. M. Coghill & L. R. Garson, The ACS Style Guide: Effective Communication of Scientific Information, American Chemical Society Washington, DC & OXFORD University Press New York, 2006. 4. Y. K. Singh, Fundamentals of Research Methodology & Statistics, New Age International Pvt. Ltd., 2006. 5. National Research Council, Prudent practices in the laboratory: handling and management of chemical hazards, The National	

	Academies Press, USA, 2011. 6. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, Vogel's Text book of Practical Organic Chemistry, 5th Ed.; Longmann, 1989 7. E. A. V. Ebsworth, D. W. H. Rankin & S. Craddock, Structural Methods in Inorganic Chemistry, Blackwell Scientific Publishers. 1986. 8. R. S. Drago, Physical Methods in Chemistry, 2nd Ed. W. B. Saunders Co. Ltd. 2016 9. R. M. Silverstein, F. X. Webster; Spectrometric identification of Organic Compounds; 6th Ed, Wiley, 2011. 10. J. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed.; Pearson Education Asia, 2002. 11. H. V. Keer, Principles of the Solid State, 1st Ed. New Age International (P) Ltd., 2005. 12. G. D. Christian, Analytical Chemistry, 6th Ed.; Wiley, 2004. 13. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed.; Cengage learning. 14. Skoog, F. J. Holler, S. R. Crouch, Principles of Instrumental Analysis, 7th Ed.; Cengage learning. 15. P. G. Lampman, G. Kriz and J. Vyvyan, Introduction to Organic Spectroscopy, 5th Ed.; Cengage Learning, 2015. 16. N. Elgrishi,´ K. J. Rountree, B. D. McCarthy, E. S. Rountree, T. T. Eisenhart, and J. L. Dempsey, A Practical Beginner’s Guide to Cyclic Voltammetry, J. Chem. Educ. ACS, 2018, 95, 197−206. 17. V. Rajaraman, Computer Programming in Fortran 90 And 95, PHI Learning Pvt. Ltd., 2013. 18. Szabo, N. S. Ostlund, Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory, Dover Publications, Inc. Mineola, 1989.
Course Outcome:	1. Students will be able to apply research methodology concepts. 2. Students will be able to apply computer technology to solve their research problems in chemistry. 3. Students will know in advance the safety precautions to be taken in the chemical lab. 4. Students will gain fundamental knowledge on characterization techniques.

Name of the Programme: M.Sc. Part-II (Chemistry)

Course Code: CHC-601 **Title of the course:** Research Methodology and instrumental techniques-II

Number of Credits: 4

Effective from AY: 2023-24

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied chemistry courses at MSc-I.</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. To introduce various aspects of research methodology.
2. To provide understanding ethics & scientific conduct.
3. To introduce academic writing.
4. To introduce databases used in chemistry.
5. To provide understanding and importance of lab safety.
6. To understand the usefulness of various instrumental techniques in characterization of chemical compounds.</td></tr>
<tr><td>Content</td><td>1. Research Methodology, Scientific conduct, ethics & academic writing
Research- meaning, objectives, motivation, types and methodology.
Process- formulating the research problem; literature survey; developing the hypothesis and the research design; sample design and collection of the data; execution of the project; analysis of data; testing of hypothesis; generalizations and interpretation, and preparation of the report or presentation of the results & conclusions.
Ethics: definition, nature of moral judgements and reactions, Ethics with respect to science and research.
Intellectual honesty and research integrity.
Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP).
Redundant publications: duplicate and overlapping publications.
Selective reporting and misrepresentation of data.
Publication ethics: definition, introduction and importance
Conflicts of interest
Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa
Violation of publication ethics, authorship and contributorship
Identification of publication misconduct, complaints and appeals
Predatory publishers and journals</td><td>No of hours

15</td></tr>
<tr><td></td><td>2. Softwares in chemistry, Data bases and Research metrics</td><td>10</td></tr>
</table>

	Data plotting using GNU plot; Structure Drawing using ChemSktech; Reference management software such as Mendeley and Zotero. Databases: Indexing databases, Citation databases: Web of Science, Scopus, UGC-Care List, Scimago etc. Research Metrics: Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, g-index, i10-index etc Molecular Docking software	
	3. Safety practices in Chemical research Introduction to lab safety. Handling of various chemicals, solvents & glassware. Fires and fighting with fires. Hazardous substances, classification and handling Safety Data Sheet	5
	4. Instrumental methods UV-Visible spectroscopy in elucidation of mechanisms of C-H activation reactions, epoxidation etc by transition metal catalyst. Understanding water oxidation reaction using Cyclic voltammetry (CV) & Linear Sweep voltammetry (LSV) Determining capacity of supercapacitors using Galvanostatic Charge-Discharge (GCD) Electrochemical Impedance Spectroscopy (EIS) Resonance Raman and isotope labelling studies. Infrared (IR) spectroscopy applications ^{1}H, ^{13}C- NMR spectroscopy and applications Selected chromatographic techniques such as HPLC, GC. Hyphenated Techniques/applications: LC-MS, GC-MS, LC-NMR-MS, GC-IR, ICP-MS Diffraction methods: High temperature XRD Thermal analysis: TG/DTA/DSC Microscopy: Fe-SEM, HR-TEM Methods for determination Ms, Mr, Hc, Tc, ε^{1} and Tanδ. Potentiometry	30
Pedagogy	Mainly lectures/recorded video lectures/ tutorials, discussions, seminars, internal exams/ assignments, / demonstration/ self-study or a combination of some of these. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. C. R. Kothari, Research Methodology: Methods & Techniques, New Age International Pvt. Ltd., 2004. 2. Bird, Philosophy of Science, Routledge, 2006. 3. M. Coghill & L. R. Garson, The ACS Style Guide: Effective Communication of Scientific Information, American Chemical Society Washington, DC & OXFORD University Press New	

	York, 2006. 4. Y. K. Singh, Fundamentals of Research Methodology & Statistics, New Age International Pvt. Ltd., 2006. 5. National Research Council, Prudent practices in the laboratory: handling and management of chemical hazards, The National Academies Press, USA, 2011. 6. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, Vogel's Text book of Practical Organic Chemistry, 5th Ed.; Longmann, 1989 7. E. A. V. Ebsworth, D. W. H. Rankin & S. Craddock, Structural Methods in Inorganic Chemistry, Blackwell Scientific Publishers. 1986. 8. R. S. Drago, Physical Methods in Chemistry, 2nd Ed. W. B. Saunders Co. Ltd. 2016 9. R. M. Silverstein, F. X. Webster; Spectrometric identification of Organic Compounds; 6th Ed, Wiley, 2011. 10. J. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed.; Pearson Education Asia, 2002. 11. H. V. Keer, Principles of the Solid State, 1st Ed. New Age International (P) Ltd., 2005. 12. G. D. Christian, Analytical Chemistry, 6th Ed.; Wiley, 2004. 13. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed.; Cengage learning. 14. Skoog, F. J. Holler, S. R. Crouch, Principles of Instrumental Analysis, 7th Ed.; Cengage learning. 15. Pavia, G. Lampman, G. Kriz and J. Vyvyan, Introduction to Organic Spectroscopy, 5th Ed.; Cengage Learning, 2015. 16. N. Elgrishi,´ K. J. Rountree, B. D. McCarthy, E. S. Rountree, T. T. Eisenhart, and J. L. Dempsey, A Practical Beginner's Guide to Cyclic Voltammetry, J. Chem. Educ. ACS, 2018, 95, 197−206. 17. V. Rajaraman, Computer Programming in Fortran 90 And 95, PHI Learning Pvt. Ltd., 2013. 18. Attila Szabo, Neil S. Ostlund, Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory, Dover Publications, Inc. Mineola, 1989. 19. Leach, Molecular Modelling, Principles and applications, Longman, 1998. 20. W. Nam et al, Dioxygen activation by Metalloenzymes & models, Accounts of Chemical Research, 2007, Volume 40 & references cited therein.
Course Outcome:	1. Students will be familiar with research methodology concepts. 2. Students will be able to apply computer technology to solve their research problems in chemistry. 3. Students will know in advance the safety precautions to be taken in the chemical lab. 4. Students will gain fundamental knowledge on characterization techniques.

Name of the Programme: M.Sc. Part-II (Chemistry)

Course Code: CHC-651 **Title of the course:** Discipline Specific Dissertation

Number of Credits: 16

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I level.	
Course Objective:	To develop the skills of preparing and conducting independent research.	
Content	As per OA-35	No of Hours 480
Pedagogy:	Dissertation carried out individually by each student throughout the academic year.	
References / Readings:	As required for the development of review and methodology.	
Course Outcome:	Students will be able to understand and apply the tools and techniques of chemistry in conducting independent research.	

M.Sc. Inorganic Chemistry Part-II syllabus for AY 2023-24 (SEM III and SEM IV)

SEM III INORGANIC CHEMISTRY			
Sr. No.	**Subject code**	**Paper title**	**Credits**
1	**CHI-600**	Practical Course in Inorganic Chemistry-III	4
2	**CHI-601**	Practical Course in Inorganic Chemistry-IV	4
3	**CHC-600**	Research Methodology and instrumental techniques-I	4
4	**CHC-601**	Research Methodology and instrumental techniques-II	4
5	**CHI-621**	Bioinorganic Chemistry	4
6	**CHI-622**	Chemistry of p-block elements & their compounds	4
7	**CHI-623**	Environmental Chemistry	4
8	**CHI-624**	Inorganic Chemistry: Industrial Perspective	4
SEM-IV INORGANIC CHEMISTRY			
Sr. No.	**Subject code**	**Paper title**	**Credits**
1	**CHI-602**	Principles and applications in catalysis	4
2	**CHI-603**	Selected topics in Inorganic Chemistry	4
3	**CHC-651**	Discipline Specific Dissertation	16

Name of the Programme: M.Sc. Part-II (Inorganic Chemistry)

Course Code: CHI-600 **Title of the course:** Practical Course in Inorganic Chemistry-III

Number of Credits: 4

Effective from AY: 2023-24

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Should have studied Inorganic chemistry practical course at M.Sc. Part-I.</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. To introduce practical knowledge in Inorganic Chemistry.
2. To learn techniques of crystallization and synthesis of coordination compounds.
3. To learn characterization of compounds using different instruments.
4. To provide experience of synthesis and characterization of materials.
5. To introduce analysis of ores for metal content.</td></tr>
<tr><td rowspan="2">Content</td><td>Minimum 23 experiments from the entire list shall be conducted

Unit – 1 Experiments in coordination chemistry: complex synthesis, metal analysis (Any Five)
a. Purification (distillation/recrystallisation) of ligands like acacH, en, carboxylic acids etc.
b. Preparation of manganic tris(acetylacetonate) and estimation of manganese.
c. Preparation of tris(thiourea)copper(I) sulfate and estimation of copper.
d. Preparation of isomers; cis and trans-dichloro(ethylenediamine)cobalt(III) chloride and estimation of cobalt.
e. Preparation and resolution of tris(ethylenediamine)cobalt(III) ion and estimation of cobalt.
f. Preparation of cis and trans-potassium dioxalatodiaquochromate(III) and estimation of chromium.
g. Preparation of nitro and nitrito-pentaaminecobalt(III) chlorides and estimation of cobalt.
h. Preparation cobalt(III) porphyrin complex and estimation of cobalt.
i. IR spectral characterization of free ligands and coordinated ligands.
NOTE: In complex synthesis, the student is expected to recrystallise the product, record IR spectra and carry out metal analysis. Spectral analysis can be carried over.</td><td>No of hours

30</td></tr>
<tr><td>Unit –2 Experiments in Solid state chemistry (Any Eight)
a. Preparation of spinel oxides by precursor method.</td><td>36</td></tr>
</table>

	b. Estimation of metals in precursors and oxides. c. Characterization of precursors by thermal analysis. d. Characterization of precursors and oxides by infrared analysis. e. X-ray diffraction studies of metal oxides. f. Direct current electrical resistivity of semiconductor (Ge/Si) by Four Probe method. g. Curie temperature determination of dielectric material (PZT) by measurement of dielectric constant v/s temperature. h. Measurement of saturation magnetization, Ms, Mr and Hc of ferromagnetic materials. i. Determination of Curie temperature of magnetic oxides by A.C. susceptibility studies. j. Preparation of CuO/SiO_2 or NiO/SiO_2 by wet impregnation method.	
	Unit – 3 Instrumental methods / spectral analysis / ion exchange (Any Six) a. Determination of stability constant of Fe(III) – salicylic acid compound (Job's Method). b. Determination of stability constant of Fe(III) – thiocyanate compound. c. Determination of stability constant of Fe(II) – 1,10-phenanthroline compound. d. Determination of instability constant for the reaction between Ag^+ and NH_3. e. Determination of instability constant for the reaction between Ag^+ and en. f. Determination of instability constant for the reaction between Cu^{2+} and NH_3. g. Determination of instability constant for the reaction between Cu^{2+} and en. h. Ion exchange chromatography: Separation of Mg^{2+} and Co^{2+} by anion exchange column. Separation of transition metal cations by anion exchange column.	30
	Unit – 4 Ore / Alloy / commercial sample separation and analysis using Titrimetry / Gravimetry / spectroscopy method (Any Four) a. Analysis of Goan Iron ore: Hematite / magnetite b. Analysis of Devardas alloy c. Analysis of solder (Pb and Sn) d. Analysis of Pyrolusite e. Analysis of Nickel-Aluminium alloy f. Analysis of Brass alloy g. Analysis of Bauxite	24

	h. Analysis of Magnesite	
Pedagogy	Students will be given pre-lab and post-lab assignments on theoretical aspects of laboratory experiments prior to the conduct of each experiment.	
References / Readings	1. G. Brauer, Handbook of Preparative Inorganic Chemistry, Vol. 1 & 2, 1963. 2. G. Pass & H. Sutcliffe, Practical Inorganic Chemistry, Preparations, Reactions and Instrumental Methods, 2^{nd} Ed.; Chapman & Hall, 1974. 3. S. De Meo, J. Chem. Ed., Vol 80, Pg.No.796-798, 2003. 4. W. L. Jolly, The Synthesis & Characterization of Inorganic Compounds, Prentice-Hall, INC, 1970. 5. A. J. Elias, General Chemistry Experiments, Revised Ed.; University Press, 2008. 6. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, Vogel's Text Book of Quantitative Chemical Analysis, 6^{th} Ed.; Pearson, 2002. 7. G. Svehla, Vogel's Text Book of Qualitative Inorganic Analysis, 7^{th} Ed.; Pearson, 2011. 8. G. Marr, B. W. Rockett, Practical Inorganic Chemistry, Van Nostrnad Reinhold London, 1972.	
Course Outcome:	1. Students will be in a position to purify ligands and will apply knowledge to synthesize coordination compounds. 2. Students will be able to study properties of coordination compounds using different instruments. 3. Students will apply knowledge to synthesize solid state material and can study their properties. 4. Students will be in position to separate metal ions by ion exchange chromatography. 5. Students apply knowledge to separate and analyze metals present in ores and alloys.	

Name of the Programme: M.Sc. Part-II (Inorganic Chemistry)

Course Code: CHI-601 **Title of the course:** Practical Course in Inorganic Chemistry-IV

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Should have studied Inorganic chemistry practical course at M.Sc. Part-I.	
Course Objective:	1. To introduce to practical knowledge in Inorganic Chemistry. 2. To learn techniques of crystallization and synthesis of coordination compounds. 3. To learn characterization of compounds using different instruments. 4. To provide experience of synthesis and characterization of materials. 5. To introduce analysis of ores for metal content.	
Content	*Minimum 20 experiments from the entire list shall be conducted* **Unit–1 Preparation of ligands (including distillation / recrystallization) / metal-ligand compounds / inorganic compounds (Any 6)** a. Preparation of Schiff's base and characterization by IR. Ex. Condensation of simple aldehydes with diammines (ethylene diammine, 1,3-propanediammine) b. Preparation of substituted benzoic acids and characterization. c. Preparation of acetylacetonate complexes of Co(II) and Co(III) and estimation of cobalt. d. Preparation of ammonium dichromate and ammonium heptamolybdate. e. Preparation of aluminium(III)tris(acetylacetonate) and estimation of aluminium. f. Preparation of potassium dihydroxodioxalatotitanate(IV) and estimation of titanium. g. Preparation of manganic acetate and estimation of manganese h. Preparation of chromium(II) acetate hydrate and estimation of chromium. i. Preparation of $K_2ON(SO_3)_2$ (Fremy's salt). *Note: Wherever possible IR and other spectral studies should be undertaken for prepared compounds.*	No of hours 36
	Unit –2: Syntheses, characterization and solid state study of ABO_3/AB_2O_4 oxides (Any 6) a. Preparation of Perovskite/Spinel oxide by oxalate precursor method. b. Characterization of precursor using CHN Analyser and estimation of metals in the precursors and oxides by gravimetric and	36

	volumetric analysis. c. Characterization of precursor and Perovskite/Spinel oxide by FTIR. d. Thermal analysis (TG/DTA) of prepared precursors. e. Isothermal Mass Loss Studies. f. X-ray diffraction studies of Perovskite/Spinel oxide prepared. g. Electrical resistivity measurement of the prepared oxide by Two probe / Four Probe method. h. Dielectric studies of prepared oxide: Dielectric constant and dielectric loss V/s I) Frequency and II) Temperature. i. Magnetic Characterization of prepared Spinel oxide by i) Hysteresis loop data (Ms, Mr, Hc) and ii) A.C Susceptibility. *Note: Wherever possible IR and other spectral studies should be undertaken.*	
	Unit – 3: Instrumental experiments/separation of metal ions by ion exchange resins (Any 6) a. Determination of stability constant of Fe(III)-Sulfosalicylic acid compound in the solution. b. UV-visible spectroscopy study of transition metal complexes. c. Potentiometric determination of cobalt/ nickel /zinc by EDTA. d. Conductance measurements: preparation and electrical conductivity measurements of some cobalt complexes. e. Determination of magnetic susceptibility of Mn(II), Cu(II) etc. salts/complexes. f. Colorimetric estimation of Hg/Cd g. Separation of transition metal cations by cation – exchange chromatography h. IR and NMR studies of Inorganic compounds. Ex. $VO(acac)_2$ i. Cyclic voltammetry experiment (ferrocene/hexacyanatoferrate).	36
	Unit – 4: Ore analysis/ Alloy analysis using Titrimetry / Gravimetry / spectroscopy method (Any 2) a. Analysis of Malanchite b. Analysis of Ilmenite c. Analysis of Nickel Steel alloy d. Analysis of Rolled Gold e. Analysis of Gun Metal f. Analysis of magnalium g. Analysis of Bronze	12
Pedagogy	Students will be given pre-lab and post-lab assignments on theoretical aspects of laboratory experiments prior to the conduct of each experiment.	
References / Readings	1. G. Brauer, Handbook of Preparative Inorganic Chemistry, Vol. 1 & 2, 1963. 2. G. Pass & H. Sutcliffe, Practical Inorganic Chemistry, Preparations, Reactions and Instrumental Methods, 2nd Ed.; Chapman & Hall, 1974.	

	3. S. De Meo, J. Chem. Ed., Vol 80, Pg.No.796-798, 2003. 4. W. L. Jolly, The Synthesis & Characterization of Inorganic Compounds, Prentice-Hall, INC, 1970. 5. A. J. Elias, General Chemistry Experiments, Revised Ed.; University Press, 2008. 6. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, Vogel's Text Book of Quantitative Chemical Analysis, 6th Ed.; Pearson, 2002. 7. G. Svehla, Vogel's Text Book of Qualitative Inorganic Analysis, 7th Ed.; Pearson, 2011. 8. G. Marr, B. W. Rockett, Practical Inorganic Chemistry, Van Nostrnad Reinhold London, 1972.
Course Outcome:	1. Students will be in a position to explain general aspects involved in purification of ligands and will apply knowledge to synthesize ligands and coordination compounds. 2. Students will be able to characterize coordination compounds usinf instrumental techniques. 3. Students will be in a position to prepare solid state materials and study their properties. 4. Students will apply knowledge to separate metal ions by ion exchange chromatography. 5. Students will be able to analyze metals in ores and alloys

Name of the Programme: M.Sc. Part-II (Inorganic Chemistry)

Course Code: CHI-602 **Title of the course:** Principles and applications in catalysis

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied chemistry courses at M.Sc. Part-I.	
Course Objective:	1. To understand the fundamentals concepts of chemical reactions over the catalysts. 2. To understand energy saving and making green processes in chemical reactions. 3. To understand fundamentals and basic concepts of chemical reactions for developing higher productivity and viability. 4. To provide knowledge on applications of heterogeneous, homogenous and other catalytic processes. 5. To make aware of catalytic approaches in environmental pollution control processes.	
Content	**1. Origin and development of catalysts** a. Introduction to heterogeneous, homogeneous and bio-catalysis, importance of catalysis in chemical reactions and its industrial applications. b. Concepts of Atom Economy, Turnover number and Turnover frequency.	No of hours 5
	2. Heterogeneous Catalysis a. Introduction to heterogeneous catalysis, energy profile diagram and diffusion of gas, general mechanisms such as Langmuir-Hinshelwood and Rideal-Eiley. b. Adsorptions: Physical and chemical adsorption, chemisorptions of gases on solid surfaces, nature of adsorbed layer, dissociative adsorptions, scattering, trapping and sticking, simple adsorptions isotherm, Langmuir adsorption, the BET adsorption isotherm and Surface area determination. c. Types of Catalysts: Preparations and separations of the catalysts, meso and micro porous materials, nano material catalysts and significance, zeolites and related molecular sieves, supported and bifunctional catalysts and catalyst regeneration, activity and life of the catalysts, active centers, promoters and poisons, catalyst deactivations. d. Characterization of solid catalysts: Structure and surface morphology, porosity, pore volume and diameter, particle size, X-ray diffraction , Thermal analysis (DTA/TG and DSC), SEM, TEM, X-ray absorption spectroscopy, XPS and Auger Electron Spectroscopy to surface studies, TPD for acidity and basicity of	23

	the catalysts. e. Heterogeneous reactions: Thermodynamic consideration in surface reactions, mechanism of catalytic reactions, ammonia synthesis, oxidation reduction reactions, CO oxidation, N_2O decomposition, Fisher tropsch catalysis, selective catalytic reduction, method of finding reaction rate and the rate determining steps. f. Theories of Catalysis: Boundary layer theory, catalysis by semiconductors, Wolkenstein theory, Balanding's approach, electronic factors in catalysis by metals, molecular orbital approach.	
	3. Homogeneous Catalysis a. Homogeneous catalytic reactions, merits and demerits, intermediate stages in homogenous catalysis, energy profile diagram, activation energy, general scheme for calculating kinetics of the reactions. b. Decomposition of hydrogen peroxide, acid-base catalysis. c. Homogeneous catalytic reactions: Hydrogenation, hydroformylation, isomerization, Monsanto acetic acid process, Carboxylation reactions, Wacker reaction, coupling reactions and asymmetric oxidations.	12
	4. Photo-catalysis Homogeneous photo-catalysis, photo-sensitized and photo-oxidations reactions, heterogeneous photo-catalysis, semiconductor photo-catalysts, generation of hydrogen by photo-catalysts and harnessing solar energy, photo-degradation of dyes.	3
	5. Catalytic polymerizations Homogeneous and heterogeneous catalysis in polymerizations reactions (few examples), Ziegler – Natta catalyst in polymerizations reactions.	5
	6. Bio-catalysis Nomenclature and classification of enzymes, metal ions and metalloenzymes, general properties, enzymatic reactions such as redox and decomposition, action of enzymes, mechanistic pathways of few enzymatic reaction, factors affecting enzymes and enzyme applications.	3
	7. Phase transfer catalysis Mechanism of PTC, types of phase transfer catalysis with selected examples, advantages and disadvantage.	3
	8. Catalyst for energy and environment Catalytic gasification, electricity from gas turbine, steam reforming, electro-catalysis, fuel cells for energy production like methanol, molten carbonate and solid oxide fuel cells, catalysts for environmental pollution in emission control and selective catalytic	6

	reduction.	
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. A.V. Salker, Catalysis: Principles and Basic Concepts, Scientific International, 2019. 2. P. H. Emmett, Catalysis, Vol I, Reinhold,1955. 3. D. K. Chakraborty, Adsorption and Catalysis by Solids, New Age International (P) Ltd., 2008. 4. J. M. Thomas, W.J. Thomas, Heterogeneous Catalysis, VCH publication, 1997. 5. A. Clark, The Theory of Adsorption and Catalysis, Academic Press, 1970. 6. E. R. Rideal, Concept in Catalysis, Academic Press, 1968. 7. G. M. Panchenov, V. P. Lebedev, Chemical Kinetics and Catalysis, Mir publication, 1976. 8. S. J. Thomson, G. Webb, Heterogeneous Catalysis, Oliver and Boyd Publications, 1968. 9. R. A. Van Santen, J. W. Niemantsvedict, Chemical Kinetics and Catalysis, Plenum Press, 1995 10. M. Beller, A. Renken, R. van Santen, Catalysis, Wiley VCH, 2012.	
Course Outcome:	1. Students will be able to explain concepts and general properties of different types of catalysts. 2. Students will be able to explain the catalytic reaction mechanisms and green catalytic processes. 3. Students will be in position to prepare and characterized catalysts. 4. Students will apply knowledge to develop reaction specific catalysts using basic concepts. 5. Students will apply knowledge to develop catalysts for useful chemical reactions and environmental pollution control processes.	

Name of the Programme: M.Sc. Part-II (Inorganic Chemistry)

Course Code: CHI-603 **Title of the course:** Selected Topics in Inorganic Chemistry

Number of Credits: 4

Effective from AY: 2023-24

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied Inorganic chemistry courses at M.Sc. Part-I</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. To study the amorphous and glass materials.
2. To learn the properties of refractories and solid lubricants and their applications.
3. To understand the concepts of Inorganic electrochemistry.
4. To study the important instrumental techniques for characterization of Inorganic materials.</td></tr>
<tr><td rowspan="4">Content</td><td>1. Amorphous and Glass Materials
a. Introduction to amorphous materials
b. Glasses
c. Glass transition temperature
d. Composition of glasses
e. Viscosity
f. Glass forming methods
g. Commercial glasses
h. Chalcogenide glasses
i. Ceramic glasses
j. Metallic glasses</td><td>No of hours

7</td></tr>
<tr><td>2. Refractories and Solid lubricants
a. Classification of refractories
b. Properties of refractories: Thermal expansion and contraction, Refractoriness, Spalting resistance, Thermal conductivities
c. Resistance to melts-slags and glasses
d. Refractory materials: Aluminous type, silica type, basic type, insulating type
e. Special refractories: Oxide refractories, other refractories, ideal refractories
f. Solid lubricants: Inorganic, organic, and nanomaterial lubricants</td><td>13</td></tr>
<tr><td>3. Fundamentals of Inorganic Electrochemistry
a. Basic aspects of electrochemistry, electron transfer reactions at electrode surface, potential and electrochemical cells,
b. Voltammetric techniques, linear voltammetry, cyclic voltammetry; reversible, irreversible, and quasi-reversible processes; applications of cyclic voltammetry with reference to ferrocenes, transition metal complexes.</td><td>5</td></tr>
<tr><td>4. Characterisation Techniques
a. Diffraction methods (XRD, Neutron and Electron)</td><td>35</td></tr>
</table>

	b. X-ray spectroscopies (XRF, AEFS, EXAFS) c. Thermal analysis d. SEM, FESEM e. TEM (HR-TEM and Imaging) f. FTIR g. X-ray Absorption spectroscopy h. Electron spectroscopy (XPS, UPS, Auger) i. Atomic emission spectroscopy j. UV-Visible spectroscopy (DRS)	
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. A.R. West, Solid State Chemistry and Its Applications, 1st Ed., John Wiley & Sons, Singapore, 1984 (reprint 2007). 2. L.V. Azaroff, Introduction to Solids, 1st Ed. (33rd Reprint), Tata McGraw Hill, 2009. 3. D. K. Chakraborty, Solid State Chemistry, 2nd Ed.; New Age International Publisher, 2010. 4. H. V. Keer, Principles of the Solid State, 1st Ed. (Reprint 2008); New Age International (P) Ltd., (Wiley Eastern Ltd.), 1993. 5. W. D. Callister, Materials Science and Engineering:An Introduction, 7th Ed.; John Wiley, 2007. 6. B. D. Fahlman, Materials Chemistry, 2nd Ed.; Springer, 2011. 7. H. R. Allcock, Introduction to materials chemistry, 1st Ed.; John Wiley & Sons, 2011. 8. R. H. Doremus, Glass Science, 2nd Ed.; Wiley, 1973. 9. P. N. Ross, Handbook of Fuel Cells, 7th Ed.; Wiley, 2003. 10. D. T. Sawyer, A. Sobkowak, J. L. Roberts Jr., Electrochemistry for chemists, 2nd Ed.; John Wiley, Inc., 1995. 11. P. W. Atkins, T. L. Overton, J. P. Rourke, M. T. Weller & F. A. Armstrong, Shriver & Atkins' Inorganic Chemistry, 5th Ed.; Oxford University Press, 2010. 12. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed.; Cengage learning, 2014. 13. A. Skoog, F. J. Holler, S. R. Crouch, Principles of Instrumental Analysis, 6th Ed.; Cengage learning, 2007. 14. G. Aruldas, Molecular Structure and Spectroscopy, 2ed Ed.; PHI Learning Pvt. Ltd., 2015.	
Course Outcome:	1. Students will be able to explain different amorphous and glass materials and their properties. 2. Students will be able to differentiate between the types of refractories and solid lubricants. 3. Students will be able to analyse a cyclic voltammogrames of inorganic	

	compounds. 4. Students will apply knowledge to characterize inorganic materials by using instrumental techniques.

Name of the Programme: M.Sc. Part-II (Inorganic Chemistry)

Course Code: CHI-621 **Title of the course:** Bioinorganic Chemistry

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students have studied chemistry/biochemistry courses at M.Sc. Part-I.	
Course Objective:	1. To understand the role of inorganic elements especially metal ions in biology. 2. To introduce metallobiolecules, metalloproteins & metalloenymes. 3. To understand the role of small molecule model compounds. 4. To introduce the concept of Biomimetic chemistry.	
Content	**1. Essential elements in biology** Periodicity of elements, distribution of elements in biosphere, bio-availability, bio-stability, building blocks of the biosphere; carbohydrates, nucleic acids and proteins, biological importance of water, and brief review of the chemistry of biopolymers. Metallobiomolecules: classification, metalloproteins (enzymes), metal activated proteins (enzymes), metal functions in metalloproteins, Principles of coordination chemistry related to bioinorganic research, physical methods in bioinorganic chemistry.	No of hours 12
	2. Alkali and alkaline earth metals in biology Introduction, biological importance of the alkali and the alkaline earth cations, Cation transport through membranes (ion pumps). Photosynthesis, Hill reaction, Chlorin macrocycle and chlorophyll, Absorption of light by chlorophyll, role of metals in photosynthesis, in vitro photosynthesis.	12
	3. Non-redox metalloenzymes Zinc metalloenzymes like carboxypeptidase, carbonic anhydrase and alcohol dehydrogenase, Bio-functions of zinc enzymes, active site structure and model complexes.	12
	4. Biochemistry of a few transition metals Role of Fe, Mo, Cu and Ni. Oxygen carriers and oxygen transport proteins, iron porphyrins (Haemoglobin and myoglobin). Haemocyanins and Haemerythrins, Synthetic models for oxygen binding haemproteins. Cytochrome C, catalase, peroxidase, and superoxide dismutase, blue copper proteins, vitamin B_{12} coenzymes, nitrogen fixation and iron-sulfur proteins, biological nitrogen fixation, nitrogenase and dinitrogen complexes, iron-sulfur proteins, synthetic analogues for Fe-S proteins, core extrusion reactions. Metal transport and storage: A brief review of iron transport. transferrin, ferritin, hemosiderin, siderophores, iron biomineralization	12
	5. Biomimetic Inorganic Chemistry Fundamentals of biomimetic chemistry, metal – oxygen intermediates, techniques used to probe the active sites of oxygen carriers, redox chemistry	12

	of free molecular dioxygen, spectroscopy of Fe-O-Fe moiety, geometry and electronic structure of coordinated dioxygen, other ligands for biological oxygen carriers, reactions of metal-oxygen compounds, oxygenases, Cytochrome P-450, synthetic procedures of simple ligands, isolation of S-containing amino acid or extraction of chlorophyll from green leaves, recrystallization of carboxylic acids. Non-Heme and heme ligands.	
Pedagogy	Mainly lectures / tutorials / assignments /group discussion / self-study /presentations or a combination of some of these could also be used to some extent.	
Reference / Readings	1. S. J. Lippard & J. M. Berg, Principles of Bioinorganic chemistry, Panima Publishing Corporation 2. B. I. Britini, H. B. Gray, S. J. Lippard & J. S. Valentine, Bioiorganic chemistry, University Science books, Mill Valey, CA, 1994. 3. D. E. Fenton, Biocoordination Chemistry, Oxford Chemistry Printers, 25 Oxford University Press, 1995 4. E. E. Conn, P.K. Stumpf, G. Bruening & R. H. Doi, Outlines of Bioinorganic Chemistry, 5th Ed.; Wiley Eastern, 1983. 5. F.A. Cotton, G. Wilkinson, P.L. Gaus, Basic Inorganic Chemistry, 3rd Ed. (Chapter 31); Wiley India, 2007. 6. M. Weller, T. Overton, J. Rourke & F. Armstrong Inorganic Chemistry, Int. Ed. (Chapter 25); Oxford University Press, 2018. 7. P Atkins, T Overton, J Rourke, M Weller & F Armstrong, Shriver & Atkins' Inorganic Chemistry, 5th Ed. (Chapter 27); Oxford University Press, 2010. 8. J. E. Huheey, E. A. Keiter, R. L. Keiter, Inorganic Chemistry: Principles of Structure and Reactivity, 5th Ed. (Chapter 19); Addison Wesley Publishing. 9. R. W. Hay, Bioinorganic chemistry, Ellis Horwood Chichester, 1984. 10. M.N. Hughes, The Inorganic Chemistry of Biological processes, 2nd Ed.; Wiley (Interscience), 1984. 11. R. R. Crichton, Biological Inorganic Chemistry, Elsevier, 2012. 12. R. Breslow, Biomimetic Chemistry: Biology as an Inspiration, The Journal of Biological Chemistry, vol. 284, no. 3, pp. 1337–1342, 2009. 13. C. Housecroft, A. G. Sharpe, Inorganic Chemistry, 4th Ed; Pearson Publishing, 2012.	
Course Outcome:	1. Students will be in a position to clarify the significance of essential elements in biology. 2. Students will be able to explain the role played by metal ions in vital processes like i) oxygen storage and transport and ii) electron transfer. 3. Students will be able to explain basic concepts in Biomimetic chemistry. 4. The students will be able use different techniques in Bioinorganic Chemistry.	

Name of the Programme: M.Sc. Part-II (Inorganic Chemistry)

Course Code: CHI-622 **Title of the course:** Chemistry of p-block elements & their compounds

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied chemistry/biochemistry courses at M.Sc. Part-I.	
Course Objective:	1. To study the different trends in physical and chemical properties of p-block elements. 2. To understand the variations in physical and chemical properties of compounds of p-block elements. 3. To study the preparation and structure of some important compounds of p-block elements. 4. To study the applications of some of their compounds.	
Content	**1. General trends of different properties in groups and periods in periodic table**	No of hours 4
	2. Chemistry of Group 13 Elements and their Compounds a. Introduction, physical properties, chemical reactions with oxygen, nitrogen, sulphur, halogens, HCl, NaOH, NH_3, mono-di-tri-chlorides, alums, organo-compounds of B and Al, difference between boron and other Gr. 13 elements, diagonal relationship. b. Preparation, bonding and structure of diborane, higher boranes, borane anions, carboranes and metallocarboranes. c. Borazine: Synthesis, properties, structure, bonding and some of its derivatives. d. Borates: Classification, structure and examples.	13
	3. Chemistry of Group 14 Elements and their Compounds a. Introduction, physical properties, allotropy, compounds of Gr.14: different types of oxides, di, tetra & catenated halides, hydrides, sulphides, cyanides. b. Coordination compounds, organosilicon compounds, silicones, cluster compounds of Ge, Sn and Pb. c. Silicates: classification with examples and applications, zeolite. d. Carbon dating, graphene, metallocarbohedrenes, freons. e. Intercalation compounds of graphite with oxygen and fluorine, heavier Group 1 elements, different halides including $FeCl_3$. f. Carbides: classification, preparation, properties and uses.	13
	4. Chemistry of Group 15 Elements and their Compounds a. Introduction, allotropes, physical properties, Preparation,	9

	properties and structure of: Hydrides, halides, oxides, oxyacids, oxohalides. b. Preparation, properties and structure of Phosphorous: sulphides, oxosulphides, organophosphorous compounds. c. Classification, preparation, properties and structures of phosphazenes.	
	5. Chemistry of Group 16 Elements and their Compounds a. Introduction, allotropes, physical properties, Preparation, properties and structure of: Hydrides, halides, oxohalides, oxides, oxyacids, classification of oxides. b. Compound of sulphur and nitrogen: Preparation, properties and structure of $(SN)_x$, S_2N_2 and S_4N_4. c. Polyatomic sulphur cations, anionic polysulphides, compounds with sulphur as a ligand.	9
	6. Chemistry of Group 17 Elements and their Compounds a. Introduction, physical properties; preparation, properties and structure of: oxides, oxyacids, halides, oxohalides, hydrogenoxide fluorides and related compounds. b. Preparation, properties and structure of: interhalogen compounds, polyhalide anions, polyhalonium cations, halogen cations.	8
	7. Chemistry of Group 18 Elements and their Compounds a. Introduction, physical properties; preparation, properties, structure and bonding of xenon compounds (fluorides and oxides); organoxenon compounds, compound containing Xe-Xe bond. b. Preparation, properties and structure of compounds of other noble gases.	4
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins Inorganic Chemistry, 5th Ed.; Oxford Publications, 2009. 2. J. E. Huheey, E. A. Kieter, R. L. Kieter, O. K. Medhi, Inorganic Chemistry: Principles of Structure & Reactivity, 4th Ed.; Pearson, 2011. 3. N. N. Greenwood, A. Earnshaw, Chemistry of the Elements, 2nd Ed. (reprinted); Elsevier, 2014. 4. J. D. Lee, Concise Inorganic Chemistry, 5th Ed. (reprint); Blackwell Science Wiley, 2015. 5. F. A. Cotton, G. Wilkinson, P. L. Gauss, Basic Inorganic Chemistry, 3rd Ed.; Wiley, 2008. 6. F. A. Cotton, G. Wilkinson, Advanced Inorganic Chemistry, 3rd Ed.; Wiley, 1984.	

	7. G. C. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Ed.; Pearson, 2004.
Course Outcome:	1. Students will be able to explain the trends in physical properties in groups and periods in the periodic table. 2. Students will be able to explain the chemistry of p-block elements as this course will give sufficient information about p-block elements and their compounds in particular. 3. Students will be able to prepare some important compounds of p-block elements. 4. Students will apply the knowledge of chemical properties of compounds to solve day to day problems.

Name of the Programme: M.Sc. Part-II (Inorganic Chemistry)

Course Code: CHI-623 **Title of the course:** Environmental Chemistry

Number of Credits: 4

Effective from AY: 2023-24

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied chemistry/ biochemistry courses at M.Sc.Part-I.</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. To introduce to fundamentals of environmental chemistry.
2. To provide important knowledge of environmental chemistry in day-to-day life.
3. To give the basic knowledge of environmental pollution.
4. To make aware of the harmful effects of environmental pollutants and control measures.</td></tr>
<tr><td rowspan="6">Content</td><td>1. Structure and properties of atmosphere:
Introduction, Temperature profile of the atmosphere, Lapse rate, Temperature inversion.</td><td>No of hours
4</td></tr>
<tr><td>2. Biogeochemical cycles
Introduction, Biogeochemical cycles of Oxygen, Carbon, Sulphur, Nitrogen, Phosphorus, and Hydrogen.</td><td>8</td></tr>
<tr><td>3. Soil Pollution
Introduction, Air and water in the soil, Inorganic and Organic components in the soil, Reactions in the soil, Waste pollutants in the soil and soil contamination, Excess usage of agrochemicals, Adsorption and decomposition of organic matter in the soil.</td><td>6</td></tr>
<tr><td>4. Air pollution
Types of emissions, Air pollution dispersion models, Types of emission sources, Estimation of Dispersion parameters, Types of Plumes, global warming
Particulate matter: Introduction, Particle size range, Health Hazards, Analysis of particulate matter, Control devices, Inorganic Particulates, Radioactive particulates, Organic particulates and other contaminants.</td><td>12</td></tr>
<tr><td>5. Water pollution and Conditioning
a. Introduction.
b. Hard water and water softening by chemical methods.
c. Carbonate hardness removal by lime, Magnesium hardness removal by lime, and non-carbonated hardness removal by soda ash.
d. Calcium carbonate solubility.
e. Re-carbonation and acid process.
f. Barium-lime cold process.
g. Ion exchange process.</td><td>8</td></tr>
<tr><td>6. Plastic pollution
a. Microplastics
b. Global occurrence, distribution, and the fate of plastic in the</td><td>10</td></tr>
</table>

	environment. c. Weathering and degradation of plastics. d. Microplastics, types of microplastics, nanoplastics. e. Analysis and identification of microplastics. f. Impact on the terrestrial and marine environment (estuarine, open ocean, coral reefs). g. Inputs of microplastics into the oceans. h. Transfer of microplastics into the food chain: bioaccumulation and Biomagnification. i. Microplastic ingestion, toxicity, and impact on human health.	
	7. Selected industrial effluent treatment. a. Industrial effluent treatment, b. Effects of Industrial effluents on surface water and land, c. Manufacture process and treatment of fertilizers and pesticides, d. Electroplating process and treatment of the waste, e. Waste from the cement industry, Waste from the sugarcane and paper industry.	8
	8. Waste Management and Case studies a. Waste Management (sources and types of solid wastes, disposal techniques, collection methods, waste management approach). b. Case study (Bhopal gas tragedy, use of DDT).	4
Pedagogy	Mainly lectures and tutorials. Seminars/term papers /assignments/presentations/self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins Inorganic Chemistry, 5th Ed.; Oxford Publications, 2009. 2. J. E. Huheey, E. A. Keiter, R. L. Keiter, O. K. Medhi, Inorganic Chemistry: Principles of Structure & Reactivity, 4th Ed.; Pearson, 2011. 3. N. N. Greenwood, A. Earnshaw, Chemistry of the Elements, 2nd Ed. (reprinted); Elsevier, 2014. 4. J. D. Lee, Concise Inorganic Chemistry, 5th Ed. (reprint); Blackwell Science Wiley, 2015. 5. F. A. Cotton, G. Wilkinson, P. L. Gauss, Basic Inorganic Chemistry, 3rd Ed.; Wiley, 2008. 6. F. A. Cotton, G. Wilkinson, Advanced Inorganic Chemistry, 3rd Ed.; Wiley, 1984. 7. G. C. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Ed.; Pearson, 2004. 8. R. C. Hale, M. E. Seeley, M. J. La Guardia, L. Mai, E. Y. Zeng, A global perspective on microplastics, 2020, Journal of Geophysical Research: Oceans, Wiley, 125 (1), e2018JC014719. 9. S. Sharma, S. Chatterjee, Microplastic pollution, a threat to marine ecosystem and human health: a short review. 2017, Environmental Science and Pollution Research, Springer, 24, 21530–21547.	

	10. L. Andrady, Microplastics in the marine environment, 2011, Marine pollution bulletin, 62(8), 1596-1605. 11. R. C. Thompson, C. J. Moore, F. S. Vom Saal, S. H. Swan, Plastics, the environment and human health: current consensus and future trends. 2009, Philosophical transactions of the royal society B: biological sciences, Royal Society, 364 (1526), 2153-2166.
Course Outcome:	1. Students will be in a position to know the basic environmental chemical processes. 2. Students will be able to explain the origin and harmful effects of toxic chemicals in the environment. 3. Students will be aware of the analysis of some pollutants. 4. Students will be in a position to give examples of case studies.

Name of the Programme: M.Sc. Part-II (Inorganic Chemistry)

Course Code: CHI-624 **Title of the course:** Inorganic Chemistry: Industrial Perspective

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied M.Sc. Part-I chemistry courses.	
Course Objectives:	1. To discuss the economic importance of inorganic materials. 2. To teach the concepts in chemistry useful for inorganic industries. 3. To learn syntheses involved in industrial production. 4. To recognize applications of industrial inorganic materials in several other sectors.	
Content	**1. Economic importance of Inorganic materials in industry** a. Chemical industries & their economic importance b. Commodity, fine and speciality chemicals c. Water: potable water, fresh water from sea water & / or brackish water d. Hydrogen: water electrolysis, petrochemical processes and coal gasification e. Peroxide and inorganic peroxo compounds: hydrogen peroxide, sodium peroxide, sodium perborate, sodium carbonate perhydrate, alkali peroxodisulfate f. Nitrogen / phosphorous / sulphur /halogens and their compounds: ammonia, hydrazine, hydroxylamine, phosphoric acid & its salts, organophosphorus compounds, sulphuric acid, other important sulphur compounds, compounds of fluorine, chloroalkali electrolysis, hydrochloric acid, chlorine-oxygen compounds, compounds of bromine and compounds of iodine	No of hours 15
	2. Minerals in fertilizer industry a. Nitrogen-containing fertilizers: ammonium sulphate, ammonium nitrate and urea b. Phosphorous-containing fertilizers: superphosphates, triple superphosphates, ammonium phosphates and nitrophosphates c. Potassium-containing fertilizers: potassium chloride, potassium sulphate and potassium nitrate	10
	3. Metals / silicon and their compounds in industry a. Alkali metals: lithium, sodium and potassium b. Alkaline-earth metals: beryllium, magnesium, calcium, strontium and barium c. Others metals: aluminium, chromium, manganese and iron d. Silicon: silicon & its inorganic compounds andorgano-silicon	15

<table>
<tr><td></td><td>compounds</td><td></td></tr>
<tr><td></td><td>4. Inorganic solids and their applications
a. Silicates: glass, alkali silicates, zeolites
b. Inorganic fibers: asbestos, textile glass, optical, carbon, metal and ceramic reinforcing fibers
c. Ceramics: clay, electro, magneto and nonoxide ceramics
d. Construction materials: lime, cement, gypsum, coarse ceramic and expanded products
e. Enamels: enamel frit and its raw material as metal oxides / carbonates / nitrates / fluorides
f. Metal carbides: titanium, zirconium, hafnium, vanadium, niobium tantalum, chromium, molybdenum, tungsten, thorium and uranium carbides
g. Inorganic carbon: diamond, natural graphite, synthetic carbon & synthetic graphite, pyrolytic carbon & pyrolytic graphite and activated carbon
h. Fillers: natural and synthetic fillers
i. Inorganic pigments: white, coloured, black and speciality pigments</td><td>20</td></tr>
<tr><td>Pedagogy</td><td colspan="2">Mainly lectures / tutorials / assignments / self-study/ industrial visits/ field trips in and around Goa or combination of some of these could also be used to some extent.</td></tr>
<tr><td>Reference /Readings</td><td colspan="2">1. K.H. Büchel, H.-H. Moretto& P. Woditsch, Industrial Inorganic Chemistry, 2nd completely revised Ed., Wiley VHC, 2000.
2. G. Buxbaum& G. Pfaff, Industrial Inorganic Pigments, 3rd Ed., Wiley VHC, 2005.
3. N.N. Greenwood & A. Earnshaw, Chemistry of the Elements, 3rd Ed., Pergamon Press, Exeter, 1998.
4. F.A. Cotton, G. Wilkinson & P. L. Gaus, Basic Inorganic Chemistry, 3rd Ed., John Wiley, 2007.
5. F.A. Cotton & G. Wilkinson, Advanced Inorganic Chemistry, 6th Ed., Wiley Eastern, 2007.
6. J.E. Huheey, E.A. Keiter, R.L. Keiter, Inorganic Chemistry: Principles of structure and reactivity, 4th Ed., Pearson, 1993.
7. J.D. Lee, Concise Inorganic Chemistry, 5th Ed., Wiley, 2008.
8. M. Weller, T. Overton, J. Rourke & F. Armstrong, Inorganic Chemistry, International Ed., Oxford University Press, 2018.
9. P. Atkins, J. De Paula & J. Keeler, Atkins' Physical Chemistry, International Ed., Oxford University Press, 2018.
10. A.R. West, Solid State Chemistry and Its Applications, 2nd Ed., John Wiley & Sons,2014.</td></tr>
<tr><td>Course Outcomes:</td><td colspan="2">1. Students will be able to discuss the economic importance of inorganic materials.
2. Students will be able to understand concepts in chemistry useful for</td></tr>
</table>

	inorganic industries. 3. Students will be able to describe syntheses involved in industrial production. 4. Students will be able to explain applications of industrial inorganic materials in several other sectors.

Name of the Programme: M.Sc. Part-II (Chemistry)

Course Code: CHC-600 **Title of the course:** Research Methodology and instrumental techniques-I

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I level.	
Course Objective:	1. To introduce various aspects of research methodology. 2. To provide understanding ethics & scientific conduct. 3. To introduce academic writing. 4. To introduce databases used in chemistry. 5. To provide understanding and importance of lab safety. 6. To understand the usefulness of various instrumental techniques in characterization of chemical compounds.	
Content	**1. Introduction to Research Methodology** Research- meaning, objectives, motivation, types and methodology. Process- formulating the research problem; literature survey; developing the hypothesis and the research design; sample design and collection of the data; execution of the project; analysis of data; testing of hypothesis; generalizations and interpretation, and preparation of the report or presentation of the results & conclusions.	No of hours 5
	2. Scientific conduct and ethics Ethics: definition, nature of moral judgements and reactions, Ethics with respect to science and research. Intellectual honesty and research integrity. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP). Redundant publications: duplicate and overlapping publications. Selective reporting and misrepresentation of data.	5
	3. Academic writing Publication ethics: definition, introduction and importance Conflicts of interest Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa Violation of publication ethics, authorship and contributorship Identification of publication misconduct, complaints and appeals Predatory publishers and journals	5

	4. Data bases and research metrics Databases: 1. Indexing databases 2. Citation databases: Web of Science, Scopus, UGC-Care List etc. Research Metrics: 1. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score 2. Metrics: h-index, g index, i10 index etc	3
	5. Safety aspects in Chemistry Good laboratory practices. Handling of various chemicals, solvents & glassware. Fires and fighting with fires. Hazardous substances, classification and handling Safety Data Sheet	5
	6. Softwares in Chemistry Data plotting Structure Drawing Reference management software	7
	7. Instrumental methods of analysis: Demonstration and/ or data analysis in following techniques: Elemental analysis: CHNS analysis and AES Infrared (IR), Raman, Ultraviolet-Visible (UV-Vis) Nuclear magnetic resonance (^{1}H, ^{13}C) Chromatographic techniques: HPLC, GC, Hyphenated Techniques: LC-MS & GC-MS, Diffraction methods: XRD Thermal analysis: DSC Microscopy: SEM, TEM Methods for determination of magnetic & dielectric properties. Cyclic voltammetry	30
Pedagogy	Mainly lectures/recorded video lectures/ tutorials, discussions, seminars, internal exams/ assignments, / demonstration/ self-study or a combination of some of these. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. C. R. Kothari, Research Methodology: Methods & Techniques, New Age International Pvt. Ltd., 2004. 2. Bird, Philosophy of Science, Routledge, 2006. 3. M. Coghill & L. R. Garson, The ACS Style Guide: Effective Communication of Scientific Information, American Chemical Society Washington, DC & OXFORD University Press New York, 2006. 4. Y. K. Singh, Fundamentals of Research Methodology & Statistics, New Age International Pvt. Ltd., 2006. 5. National Research Council, Prudent practices in the laboratory: handling and management of chemical hazards, The National	

	Academies Press, USA, 2011. 6. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, Vogel's Text book of Practical Organic Chemistry, 5th Ed.; Longmann, 1989 7. E. A. V. Ebsworth, D. W. H. Rankin & S. Craddock, Structural Methods in Inorganic Chemistry, Blackwell Scientific Publishers. 1986. 8. R. S. Drago, Physical Methods in Chemistry, 2nd Ed. W. B. Saunders Co. Ltd. 2016 9. R. M. Silverstein, F. X. Webster; Spectrometric identification of Organic Compounds; 6th Ed, Wiley, 2011. 10. J. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed.; Pearson Education Asia, 2002. 11. H. V. Keer, Principles of the Solid State, 1st Ed. New Age International (P) Ltd., 2005. 12. G. D. Christian, Analytical Chemistry, 6th Ed.; Wiley, 2004. 13. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed.; Cengage learning. 14. Skoog, F. J. Holler, S. R. Crouch, Principles of Instrumental Analysis, 7th Ed.; Cengage learning. 15. P. G. Lampman, G. Kriz and J. Vyvyan, Introduction to Organic Spectroscopy, 5th Ed.; Cengage Learning, 2015. 16. N. Elgrishi,′ K. J. Rountree, B. D. McCarthy, E. S. Rountree, T. T. Eisenhart, and J. L. Dempsey, A Practical Beginner’s Guide to Cyclic Voltammetry, J. Chem. Educ. ACS, 2018, 95, 197−206. 17. V. Rajaraman, Computer Programming in Fortran 90 And 95, PHI Learning Pvt. Ltd., 2013. 18. Szabo, N. S. Ostlund, Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory, Dover Publications, Inc. Mineola, 1989.
Course Outcome:	1. Students will be able to apply research methodology concepts. 2. Students will be able to apply computer technology to solve their research problems in chemistry. 3. Students will know in advance the safety precautions to be taken in the chemical lab. 4. Students will gain fundamental knowledge on characterization techniques.

Name of the Programme: M.Sc. Part-II (Chemistry)

Course Code: CHC-601 **Title of the course:** Research Methodology and instrumental techniques-II

Number of Credits: 4

Effective from AY: 2023-24

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied chemistry courses at MSc-I.</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. To introduce various aspects of research methodology.
2. To provide understanding ethics & scientific conduct.
3. To introduce academic writing.
4. To introduce databases used in chemistry.
5. To provide understanding and importance of lab safety.
6. To understand the usefulness of various instrumental techniques in characterization of chemical compounds.</td></tr>
<tr><td rowspan="2">Content</td><td>1. Research Methodology, Scientific conduct, ethics & academic writing
Research- meaning, objectives, motivation, types and methodology.
Process- formulating the research problem; literature survey; developing the hypothesis and the research design; sample design and collection of the data; execution of the project; analysis of data; testing of hypothesis; generalizations and interpretation, and preparation of the report or presentation of the results & conclusions.
Ethics: definition, nature of moral judgements and reactions, Ethics with respect to science and research.
Intellectual honesty and research integrity.
Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP).
Redundant publications: duplicate and overlapping publications.
Selective reporting and misrepresentation of data.
Publication ethics: definition, introduction and importance
Conflicts of interest
Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa
Violation of publication ethics, authorship and contributorship
Identification of publication misconduct, complaints and appeals
Predatory publishers and journals</td><td>No of hours

15</td></tr>
<tr><td>2. Softwares in chemistry, Data bases and Research metrics</td><td>10</td></tr>
</table>

	Data plotting using GNU plot; Structure Drawing using ChemSktech; Reference management software such as Mendeley and Zotero. Databases: Indexing databases, Citation databases: Web of Science, Scopus, UGC-Care List, Scimago etc. Research Metrics: Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, g-index, i10-index etc Molecular Docking software	
	3. Safety practices in Chemical research Introduction to lab safety. Handling of various chemicals, solvents & glassware. Fires and fighting with fires. Hazardous substances, classification and handling Safety Data Sheet	5
	4. Instrumental methods UV-Visible spectroscopy in elucidation of mechanisms of C-H activation reactions, epoxidation etc by transition metal catalyst. Understanding water oxidation reaction using Cyclic voltammetry (CV) & Linear Sweep voltammetry (LSV) Determining capacity of supercapacitors using Galvanostatic Charge-Discharge (GCD) Electrochemical Impedance Spectroscopy (EIS) Resonance Raman and isotope labelling studies. Infrared (IR) spectroscopy applications ^{1}H, ^{13}C- NMR spectroscopy and applications Selected chromatographic techniques such as HPLC, GC. Hyphenated Techniques/applications: LC-MS, GC-MS, LC-NMR-MS, GC-IR, ICP-MS Diffraction methods: High temperature XRD Thermal analysis: TG/DTA/DSC Microscopy: Fe-SEM, HR-TEM Methods for determination Ms, Mr, Hc, Tc, ε^{1} and Tanδ. Potentiometry	30
Pedagogy	Mainly lectures/recorded video lectures/ tutorials, discussions, seminars, internal exams/ assignments, / demonstration/ self-study or a combination of some of these. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. C. R. Kothari, Research Methodology: Methods & Techniques, New Age International Pvt. Ltd., 2004. 2. Bird, Philosophy of Science, Routledge, 2006. 3. M. Coghill & L. R. Garson, The ACS Style Guide: Effective Communication of Scientific Information, American Chemical Society Washington, DC & OXFORD University Press New York,	

	2006. 4. Y. K. Singh, Fundamentals of Research Methodology & Statistics, New Age International Pvt. Ltd., 2006. 5. National Research Council, Prudent practices in the laboratory: handling and management of chemical hazards, The National Academies Press, USA, 2011. 6. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, Vogel's Text book of Practical Organic Chemistry, 5th Ed.; Longmann, 1989 7. E. A. V. Ebsworth, D. W. H. Rankin & S. Craddock, Structural Methods in Inorganic Chemistry, Blackwell Scientific Publishers. 1986. 8. R. S. Drago, Physical Methods in Chemistry, 2nd Ed. W. B. Saunders Co. Ltd. 2016 9. R. M. Silverstein, F. X. Webster; Spectrometric identification of Organic Compounds; 6th Ed, Wiley, 2011. 10. J. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed.; Pearson Education Asia, 2002. 11. H. V. Keer, Principles of the Solid State, 1st Ed. New Age International (P) Ltd., 2005. 12. G. D. Christian, Analytical Chemistry, 6th Ed.; Wiley, 2004. 13. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed.; Cengage learning. 14. Skoog, F. J. Holler, S. R. Crouch, Principles of Instrumental Analysis, 7th Ed.; Cengage learning. 15. Pavia, G. Lampman, G. Kriz and J. Vyvyan, Introduction to Organic Spectroscopy, 5th Ed.; Cengage Learning, 2015. 16. N. Elgrishi,´ K. J. Rountree, B. D. McCarthy, E. S. Rountree, T. T. Eisenhart, and J. L. Dempsey, A Practical Beginner’s Guide to Cyclic Voltammetry, J. Chem. Educ. ACS, 2018, 95, 197−206. 17. V. Rajaraman, Computer Programming in Fortran 90 And 95, PHI Learning Pvt. Ltd., 2013. 18. Attila Szabo, Neil S. Ostlund, Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory, Dover Publications, Inc. Mineola, 1989. 19. Leach, Molecular Modelling, Principles and applications, Longman, 1998. 20. W. Nam et al, Dioxygen activation by Metalloenzymes & models, Accounts of Chemical Research, 2007, Volume 40 & references cited therein.
Course Outcome:	1. Students will be familiar with research methodology concepts. 2. Students will be able to apply computer technology to solve their research problems in chemistry. 3. Students will know in advance the safety precautions to be taken in the chemical lab. 4. Students will gain fundamental knowledge on characterization techniques.

Name of the Programme: M.Sc. Part-II (Chemistry)

Course Code: CHC-651 **Title of the course:** Discipline Specific Dissertation

Number of Credits: 16

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I level.	
Course Objective:	To develop the skills of preparing and conducting independent research.	
Content	As per OA-35	*No of Hours* 480
Pedagogy:	Dissertation carried out individually by each student throughout the academic year.	
References / Readings:	As required for the development of review and methodology.	
Course Outcome:	Students will be able to understand and apply the tools and techniques of chemistry in conducting independent research.	

M.Sc. Analytical Chemistry Part-II syllabus for AY 2023-24 (SEM III and SEM IV)

SEM III ANALYTICAL CHEMISTRY			
Sr. No.	**Subject code**	**Paper title**	**Credits**
1	**CHA-600**	Practical Course in Analytical Chemistry-III	4
2	**CHA-601**	Practical Course in Analytical Chemistry-IV	4
3	**CHC-600**	Research Methodology and instrumental techniques-I	4
4	**CHC-601**	Research Methodology and instrumental techniques-II	4
5	**CHA-621**	Fundamentals of Crystallography	4
6	**CHA-622**	Advanced NMR and combined Spectroscopy	4
7	**CHA-623**	Bioanalytical Techniques	4
8	**CHA-624**	Calibration and Validation in Analytical Chemistry	4
SEM-IV ANALYTICAL CHEMISTRY			
Sr. No.	**Subject code**	**Paper title**	**Credits**
1	**CHA-602**	Advanced Mass Spectrometry	4
2	**CHA-603**	Selected Topics in Analytical Chemistry	4
3	**CHC-651**	Discipline Specific Dissertation	16

Name of the Programme: M.Sc. Part-II (Analytical Chemistry)

Course Code: CHA-600 **Title of the course:** Practical Course in Analytical Chemistry - III

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Should have studied Analytical chemistry practical course at M.Sc. Part-I.	
Course Objectives:	1. To study various experimental techniques for analysis. 2. To learn data analysis, handling and interpretation of spectra.	
Content	*This course consists of 10 units of experiments in various areas of Analytical chemistry. Minimum 20 experiments which include at least 02 experiments from each unit shall be conducted.*	No of hours 120
	Unit 1: Analysis of Pharmaceutical Tablets/Samples (Titrimetry) i. Estimation of Paracetamol by titrimetry. ii. Estimation of streptomycin in tablet sample by Maltol method. iii. Estimation of iron using Zimmermann-Reinhardt reagent by titrating against $KMnO_4$.	12
	Unit 2: Ion exchange Chromatography and Solvent Extraction Method i. Determination of capacity of a cation exchange resin. ii. Concentration and determination of copper (II) ions from a brine solution using a chelating ion exchange resin and AES/AAS iii. Separation of organic mixture (acidic + basic + neutral) by extraction.	12
	Unit 3: Planar and Column Chromatography i. Thin layer chromatography analysis of commercially available analgesic/antipyretic/antihistamine etc and to identify the active ingredients. ii. Purification and determination of amount of paracetamol from commercial tablet by column chromatography. iii. Separation of a mixture of benzoin and benzil on silica gel column.	12
	Unit 4: Spectrophotometric Method i. Determination of pk value of methyl red indicator.	12

	ii. Determination of stoichiometry and stability constant of ferric salicylic acid complex by Job's method and mole ratio method. iii. Determination of the Fe ion as Fe-oxine complex.	
	Unit 5: HPLC Analysis i. Analysis of a mixture (benzene and toluene or nitrobenzene and toluene) by normal/reverse phase-HPLC. ii. HPLC analysis of an analgesic (e.g. Ibuprofen)/or any other drug with method development and validation. iii. Quantitative analysis of Paracetamol tablet by HPLC iv. Determination of plate height/number of theoretical plates by HPLC using Acetophenone as a reference material. v. Study of HPLC method development by using linear/stepwise gradient elution for binary system. vi. Determination of caffeine content in Tea or Coffee	12
	Unit 6: Electrochemical Method i. pH-metric determination of the acid-base dissociation constant and isoelectric point of amino acid. ii. Determination of moisture content in tablet powder by Karl Fischer titration. iii. Analysis of mixture of carbonate/bicarbonate present in water sample using pH metry or Potentiometry.	12
	Unit 7: Gas Chromatographic Analysis i. GC analysis of a given sample mixture (e.g. perfumes, cosmetics). ii. GC analysis of non-volatile analyte by derivatization. iii. Quantitative analysis of a mixture of chloroform and carbon tetrachloride. iv. Gas chromatographic analysis for a mixture of gases like O_2, N_2 and CO_2. v. Determination of alcoholic content in Beer or wine	12
	Unit 8: Analysis of Ores/Minerals/Industrial Material i. Analysis of Iron Ore or Bauxite (from Goa). ii. Analysis of cement or plaster of Paris. iii. Analysis of limestone or dolomite.	12

	Unit 9: Other Instrumental Techniques i. Electrophoretic techniques for the separation of nucleic acids or proteins ii. Study the dissolution rate of commercial tablets. iii. Determination of optical rotation of Chiral compounds using polarimeter (e.g. Amino acids, drugs, natural products, lactic acid, tartaric acid etc) iv. Determination of sulphate ion content by turbidimetry. v. Determination of turbidity in water sample. vi. TG/DTA analysis of sample or mixture (e.g. $MgCO_3$-MgO). vii. Determination of molar composition of Toluene-Anisole mixture by qNMR.	12
	Unit 10: Demonstration/Interpretation Exercises i. Demonstration/Interpretation of LC-MS spectra. ii. Demonstration/Interpretation of NMR spectra of Ethyl cinnamate/Vanilin. iii. Assessment of TG-DTA plot. iv. Statistical Evaluation of Data including Linear Regression Analysis. v. Analysis of materials using Microscopic Techniques. vi. Demonstration of XRD and interpretation of diffraction pattern.	12
Pedagogy:	Prelab exercises / assignments / presentations / lab hand-out or a combination of some of these. Sessions shall be interactive in nature to enable peer group learning.	
References / Readings	1. J. H. Kennedy, Analytical Chemistry Principles, 2nd Ed., Saunders College Publishing, 1990. 2. G. D. Christian, Analytical chemistry, 5thEd., John Willey and Sons, 1994 3. J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas, B. Sivasankar, Vogel's Textbook of Quantitative Chemical Analysis, 6thEd., Pearson Education Asia 2009. 4. A. J. Elias, Collection of interesting chemistry experiments, University press, 2002. 5. R.A. Day & A.L. Underwood, Quantitative Analysis, 6thEd., Prentice Hall, 2001. 6. J. Kenkel, Analytical Chemistry for Technicians, 3rdEd., Lewis publishers, 2002.	

Course Outcomes:	1. Students will be able to use different techniques for qualitative and quantitative estimation. 2. Students will be able to interpret spectra and use statistical methods to analyse data. 3. Students will be able to use different techniques for mixture separation. 4. Students will be able to analyse pharmaceutical samples.

Name of the Programme: M.Sc. Part-II (Analytical Chemistry)

Course Code: CHA-601 **Title of the course:** Practical Course in Analytical Chemistry - IV

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Should have studied Analytical chemistry practical course at M.Sc. Part-I.	
Course Objectives:	1. To understand of various experimental techniques for analysis. 2. To learn data analysis, handling and interpretation of spectra.	
Content	*This course consists of 10 units of experiments in various areas of Analytical chemistry. Minimum 20 experiments which include at least 02 experiments from each unit shall be conducted.*	No of hours 120
	Unit 1: Analysis of Pharmaceutical Tablets/Samples i. Estimation of Ibuprofen by titrimetry. ii. Estimation of iron from given pharmaceutical drug sample using thioglycolic acid. iii. Estimation of sulphadiazine / sulphonamide	12
	Unit 2: Ion exchange Chromatography and Solvent Extraction Method i. Determination of capacity of anion exchange resin ii. Separation and estimation of zinc and nickel ions using an anion exchange resin iii. Separation of organic mixture (acidic + basic + neutral) by extraction	12
	Unit 3: Planar and Column Chromatography i. Separation of alpha amino acids by paper chromatography and to study effect of mobile phase on resolution. ii. Thin layer chromatography analysis of commercially available analgesic/antipyretic/antihistamine etc and to identify the active ingredients. iii. Separation of a mixture of benzaldehyde and benzoic acid on silica gel column	12
	Unit 4: Spectrophotometry Method i. To estimate Cd/Hg by AES/AAS method. ii. To record the UV absorption spectrum of acetone in n-hexane and identify the various transitions. iii. Determination of phosphorous content from fruit juice.	12

	Unit 5: HPLC Analysis i. Analysis of a mixture of hydrocarbons by reverse phase-HPLC ii. Quantitative analysis of Aspirin tablet by HPLC. iii. To determine the number of theoretical plates/plate height by HPLC of aromatic ketone or alcohols. iv. Study of HPLC method development by using linear/stepwise gradient elution for binary system. v. Determination of caffeine content in Soft drinks or Chocolates.	12
	Unit 6: Electrochemical Method i. Determination of moisture content in tablet powder by Karl Fischer titration. ii. pH metric determination of dissociation constant of dibasic, oxalic acid iii. Potentiometric determination of dissociation constant for Cu-ammonia complex.	12
	Unit 7: Gas Chromatographic Analysis i. GC analysis of a given sample mixture (e.g. Flavours and fragrances) ii. Quantitative analysis of a mixture of chlorinated solvents. iii. Optimum flow rate for the determination of chloroform using van Deemter equation. iv. Determination of alcoholic content in Rum or Local drinks.	12
	Unit 8: Analysis of Ores/Minerals/Industrial Material i. Analysis of steel ii. Analysis of solder iii. Analysis of an aluminium alloy iv. Analysis of talcum powder	12
	Unit 9: Other Instrumental Techniques i. Electrophoretic techniques for the separation of DNA ii. Determination of optical rotation of Chiral compounds using polarimeter eg. Amino acids, drugs, natural products etc iii. Determination of chloride ion content by turbidimetry iv. Determination of turbidity in water sample.	12

	v. Study the dissolution rate of pharmaceutical tablets. vi. Determination of molar composition of Toluene-methyl benzoate mixture by qNMR.	
	Unit 10: Demonstration/Interpretation Exercises i. Demonstration/Interpretation of GC-MS spectra. ii. Demonstration/Interpretation of NMR spectra iii. Assessment of TG-DTA plot. iv. Statistical Evaluation of Data including Linear Regression Analysis. v. Analysis of materials using Microscopic Techniques. vi. Demonstration of XRD and interpretation of diffraction pattern.	12
Pedagogy:	Prelab exercises / assignments / presentations / lab hand-out or a combination of some of these. Sessions shall be interactive in nature to enable peer group learning.	
References / Readings	1. J. H. Kennedy, Analytical Chemistry Principles, 2nd Ed. Saunders College Publishing, 1990. 2. G. D. Christian, Analytical chemistry, 5th Ed., Wiley, 1994. 3. J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas, B. Sivasankar, Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed., Pearson Education Asia 2009. 4. A. J. Elias, Collection of interesting chemistry experiments, University press, 2002. 5. R. A. Day & A.L. Underwood, Quantitative Analysis, 6th Ed., Prentice Hall, 2001. 6. J. Kenkel, Analytical Chemistry for Technicians, 3rd Ed., Lewis publishers, 2002.	
Course Outcomes:	1. Students will be able to use different techniques for qualitative and quantitative estimation. 2. Students will be able to interpret spectra and use statistical methods to analyse data. 3. Students will be able to use different techniques for mixture separation. 4. Students will be able to analyse pharmaceutical samples.	

Name of the Programme: M.Sc. Part-II (Analytical Chemistry)

Course Code: CHA-602 **Title of the course:** Advanced Mass Spectrometry

Number of Credits: 4

Effective from AY: 2023-24

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied analytical chemistry course at M.Sc. Part I.</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. To study various ionisation sources and mass analyser.
2. To introduce tandem mass spectrometry techniques.
3. To learn interpretational aspects of spectral data obtained from hyphenated techniques.</td></tr>
<tr><td rowspan="2">Content</td><td>1. Ionization methods:
a. Mass spectrometry: introduction, principle, general instrumentation, general interpretation procedure for mass spectra;
b. Gas Phase ionization: electron ionization (EI), chemical ionization (CI), Field ionization and field desorption (FI, FD)
c. Particle Bombardment: Fast atom bombardment (FAB), Secondary ion mass spectrometry (SIMS).
d. Atmospheric pressure Ionization: electrospray ionization (ESI), atmospheric pressure ionization (APCI).
e. Laser Desorption: MALDI.
f. Inorganic ionization sources: thermal ionization, Spark source, Glow discharge, Inductively coupled plasma (ICP).
g. Problem solving using mass spectrometry.</td><td>No of hours

15</td></tr>
<tr><td>2. Mass analyzers:
a. Characteristics of analysers: nominal mass, mass accuracy, resolving power, resolutions, isotopic composition, numericals to calculate nominal and accurate mass.
b. Magnetic, electromagnetic and double focusing
c. Single Quadrupole and triple quadrupole
d. Time of flight analyzer
e. Ion cyclotron resonance analyzer
f. Hybrid instrumentation
g. Detectors: electron multiplier, photon multiplier, Faraday cup
Note: instrumentation, working principles, characteristic features, advantages, practical consideration shall be discussed.</td><td>15</td></tr>
</table>

	3. Hyphenated Techniques: a. Coupled techniques, Importance of hyphenation of two analytical techniques, Interface and their characteristic features. b. Introduction, principle and instrumentation of following techniques: GC-MS, LC-MS, ICP-MS, CE-MS, TG-MS. c. Tandem mass (MS-MS): Introduction, concepts of tandem mass spectrometry, Ion activation methods. d. Analysis of chromatogram: Total ion chromatogram (TIC), Extracted Ion Chromatogram (XIC). e. Analysis of chemical data of natural product, drugs, etc. Dereplication using hyphenated technique.	15
	4. Tandem Mass spectrometry applications: a. Pharmacokinetic studies: Fate of drug in living organisms, metabolite identification, biotransformation of ziprasidone. b. Tandem MS and fragmentation pattern of following drugs: Paracetamol, 2-mercaptonicotinic acid, Sulfasalazine, amphetamine, Trocade. c. Analysis of biomolecules: Proteins, Peptides, Oligonucleotides, structure and sequence determination using fragmentation, solve problems based on MS/MS data.	15
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. H. Jürgen, Mass Spectrometry: A Textbook Gross, 2nd Ed, Springer publisher, 2011. 2. E. De Hoffmann, V. Stroobant, Mass Spectrometry: Principles and Applications, 2nd Ed, Wiley, 2007. 3. R. B. Cole, Electrospray and MALDI Mass Spectrometry: Fundamentals, Instrumentations, Practicalities and Biological Applications, 2nd Ed, Wiley, 2010. 4. J. T. Watson, O. D. Sparkman, Introduction to Mass Spectrometry: Instrumentation, Applications, and Strategies for Data Interpretation, 4th Ed, Wiley, 2007. 5. K. Wanner, G. Höfner, Mass Spectrometry in Medicinal Chemistry Applications in Drug Discovery, 1st Ed, Wiley-VCH, 2007. 6. M. Kinter, N. E. Sherman, Protein Sequencing and Identification Using Tandem Mass Spectrometry, 1st Ed, Wiley, 2000. 7. P. James, Proteome Research: Mass Spectrometry (Principles and	

	Practice), 1st Ed, Springer publisher, 2000. 8. J. K. Prasain, Tandem Mass Spectrometry-Applications and Principles, InTech publisher, 2012.
Course Outcome:	1. Students will be able to explain principle behind different ionizations sources. 2. Students will be able to select mass analysers and ionization sources for analysis of particular type of analyte. 3. Students will be able to deduce structures of simple to moderately complex molecules/biomolecules by combining the spectral data obtained from hyphenated techniques. 4. Students will be able to apply tandem Mass spectrometry for biomolecule analysis.

Name of the Programme: M.Sc. Part-II (Analytical Chemistry)

Course Code: CHA-603 **Title of the course:** Selected topics in analytical chemistry

Number of Credits: 4

Effective from AY: 2023-24

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied analytical chemistry course at M.Sc. Part I.</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. To understand the basic importance of Quality in industrial products.
2. To provide basic understanding of medical laboratory clinical chemistry.
3. To understand Packaging and regulatory aspects for food, drugs and cosmetics industries.
4. To understand the use of computers in chemistry</td></tr>
<tr><td rowspan="3">Content</td><td>1. Introduction to Quality Control and Quality Assurance:
a. Basic concepts; quality assurance; aspect of specification and tolerance; quality acceptance; sampling reality; cost aspect of quality decisions; quality control in raw materials; production; finished product;
b. Law related to quality control; case studies of quality control in various industries like agrochemicals, petrochemicals, pharmaceuticals, dyes, plastics and polymers.</td><td>No of hours

8</td></tr>
<tr><td>2. Packaging and Regulatory Aspects:
a. Introduction; types of packing material and regulations acts in Food and Pharmaceutical industries; testing of material for packing; legal consideration in packing; regulatory aspects of food, drugs and cosmetics;
b. The Drug and Cosmetic Act, 1940; the Drug and Cosmetic Rules 1945; prevention of food adulteration; the Preventation of Food Adulteration Act, 1954; Fruit Product Order; Meat Product Order; I.S.I., Agmark and other standard for foods and Cosmetic particularly with reference the testing of foods, drug and cosmetic and the raw material concerned;
c. The Government authorities concerned with the testing-their qualification, duties, powers and procedure to be followed; Record to be maintain under the Acts; C.G.M.P. and C.G.L.P.S. requirements of QC; Department of ‘WHO’ certification.</td><td>12</td></tr>
<tr><td>3. Computers in Chemistry:
The students shall learn how to operate a PC and run standard programs and packages like MS-WORD, EXCEL, ORIGIN, SIGMA PLOT, and CHEM SKETCH; to solve Chemistry</td><td>10</td></tr>
</table>

	numerical (numerical taken preferably from Physical Chemistry for plotting first and second derivative curves, linear plots); numerical from Analytical Chemistry, Chemical Kinetics, Electrochemistry, Spectroscopy and other related topics; writing the structures of inorganic and organic molecules, chemical equations, and other applications.	
	4. Clinical Chemistry: a. Composition body fluid; detection of abnormal levels of certain constituents leading to diagnosis of diseases; sample collection and preservation of physiological fluids. b. Analysis of physiological fluids - blood, urine and serum; estimation of blood glucose, cholesterol, urea, haemoglobin; urine-urea, uric acid, albumin, globulins, barbiturates, acid and alkaline phosphates. c. Human-nutrition: d. Estimation of enzymes, carbohydrates, essential amino acids, proteins and lipids.	18
	6. Food Analysis, Processing and Preservation: a. Analysis of food such as milk, milk products, tea, coffee and beverages (soft drinks, alcoholic drinks), Flour, starch, honey, jams and edible oils. Analysis of preservatives, colouring matter, micronutrients. b. Food processing and food preservation: Refining milling, canning, concentration, freezing Drying, pasteurisation sterilization irradiation.	12
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. F. W. Fifield and D. Kealy, Principles and Practice of Analytical Chemistry; 5th Ed. Backwell Science Ltd. London, 2020. 2. G. D. Christian, Analytical chemistry, 5th Ed., Wiley, 1994. 3. J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas, B. Sivasankar, Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed., Pearson Education Asia 2009. 4. H. Kaur, Instrumental Methods of Chemical Analysis; Pragati Prakashan, 2012 5. Indian Pharmacopeia; Volume I and II, 2018 6. W. Funk, V. Dammann, G. Donnevert, Quality Assurance in Analytical Chemistry; VCH Weinheim, 1995 7. E. Prichard, Quality in the Analytical Chemistry Laboratory; John Wiley and Sons, NY, 1997	

	8. R. C. Gribbin, Principals of package Development, 2nd Ed. Springer, 2012 9. Modern Packaging Encyclopedia, Volume 30, McGraw-Hill Publisher, 1957 10. Modern Packaging Encyclopaedia and planning guide, McGraw-Hill Publications, 1972 11. M. L. Mehra, The Handbook of Drug Laws, Univ. Book Agency, 1997. 12. Government of India Publications of Food Drug Cosmetic Acts and Rules. https://cdsco.gov.in/opencms/opencms/en/Acts-Rules/ 13. D. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry; 9th Ed. Brooks Cole Publisher, 2013 14. K. V. Raman, Computers in chemistry, Tata Mc.Graw-Hill, 1993. 15. S. K Pundir, A. bansal, Computers for Chemists, Pragati prakashan, 2018 16. C. S. James, Analytical Chemistry of Foods, Blackie Academic and Professional Publisher, UK, 1995. 17. R. L. Nath, Practical Biochemistry in Clinical Medicine, 2nd Ed. Academic Publishers, 1990, 18. V. Malik, Drug and Cosmetics Act, 25th Ed. Eastern book company, 2016, 19. A. H. Beckett, J.B. Stenlake, Practical Pharmaceutical Chemistry (Part-1), 4th Ed. CBS publisher, 2006, 20. S. R. Mikkelsen, E. Corton, Bioanalytical Chemistry, 2nd Ed. John Wiley and Sons, 2016, 21. M. B. Jacob, Chemical Analysis of Food and Food Products, 3rd Ed. CBS publisher, 2013. 22. Encyclopaedia of Analytical Chemistry, Volume 3, Academic Press, 1995. 23. D. White, N. Lawson, P. Masters, D. McLaughlin, Clinical Chemistry, CRC press, 2016 24. W. J. Marshall, M. Lapsley, A. Day, K. Shipman, Clinical Chemistry, Elsevier, 2020
Course Outcome:	1. Students will understand the basic importance of Quality in industrial products and apply the knowledge in Quality Control and Quality Assurance. 2. Students will understand the medical laboratory clinical chemistry. 3. Students will understand the Packaging and regulatory aspects and apply the knowledge in food, drugs and cosmetics industries. 4. Students will understand the use of computers in chemistry

Name of the Programme: M.Sc. Part-II (Analytical Chemistry)

Course Code: CHA-621 **Title of the course:** Fundamentals of Crystallography

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied M.Sc. Part-I.	
Course Objective:	1. To introduce basic concepts of crystallography. 2. To impart knowledge of single crystal and powder X-ray diffraction methods. 3. To analyse Materials and understand Structure. 4. To familiarize students with various applications of Crystallography	
Content	**1. Basics of Crystallography** a. The Crystalline state, symmetry elements. b. Lattices, unit cell, crystallographic directions, planes, point groups and symmetry classes. c. The Laue classes, the seven crystal systems, Bravais lattices, space groups and International Tables. d. Description of crystal structures, unit cell projections and atomic coordinates, unit cell content. e. Ionic crystals, molecules and molecular crystals, protein crystals, physical properties of crystals.	No of hours 10
	2. Diffraction of X-rays by Crystals: a. Interaction of X-rays with matter. b. Scattering of X-rays by an electron, atom, atomic scattering factor, temperature factor, scattering by molecule or unit cell. c. Diffraction by crystals, structure factor, Bragg's law, the reflection and the limiting spheres, symmetry in reciprocal space, systematic absences, diffraction intensities. d. Experimental methods in X-ray crystallography: X-ray sources, monochromatization, collimation, and focusing of X-rays.	10
	3. Single Crystal X-ray Diffraction: a. Crystals and their properties: crystallization, growing and choosing crystals, microscopic observation b. Data collection techniques for single crystals, diffractometer geometry, measurement of the integrated intensities, data collection with area detectors, c. Data reduction: Lorentz correction, polarization correction, absorption corrections, radiation damage corrections, relative scaling.	10

	d. Solution and refinement of crystal structures: Wilson plot, the heavy atom method, Direct methods, phase determination procedures, figures of merit, e. Completing and refining the structure: difference Fourier method, least-squares method, absolute configuration. f. Introduction to crystallographic softwares (e.g. APEX 4, Olex2 etc) and IUCr validation of the data (CIF)	
	4. Powder X-ray Diffraction: a. Origin of powder diffraction pattern, position, shape, and intensity of powder diffraction peaks. b. Powder diffractometry: beam conditioning, goniometer design, nonambient powder diffractometry. c. Collecting quality powder diffraction data: sample preparation, data acquisition, quality of data, data processing. d. Determination of unit cell: indexing methods. e. Introduction to the Rietveld method. d. Introduction to powder diffraction softwares for indexing, unit cell refinement (e.g. Winplotr, UnitCell).	10
	5. Applications of Crystallography: a. Chemistry and Materials science: understanding crystal structures of compounds, alloys, metals, polymers, phase transitions etc. b. Geology, mineralogy, gemology. c. Pharmaceuticals: polymorphs, excipient analysis, active pharmaceutical ingredients. d. Forensics and environmental analysis. e. Nano materials characterization. f. Biomolecules: determination of structures of proteins, nucleic acids and other biological macromolecules. g. Other diffraction techniques: neutron diffraction, thin film, microstructure properties, pair distribution function analysis, etc.	10
	6. Analysis of Materials and Structural Understanding: a. Characterisation of Solids using diffraction techniques. b. Introduction to databases: powder diffraction files, inorganic and organic crystal structure database, protein data bank etc. c. Inspection of crystals/powders with light microscope. d. Visualization of crystal structures using softwares (e.g. Diamond, VESTA). e. Beyond ideal crystals: crystal twins, modulated structures, quasicrystals.	10

Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.
References / Readings	1. M. Milanesio, G. Zanotti, G. Gilli, M. Catti, H. Monaco, G. Ferraris, G. Artioli, P. Gilli, D. Viterbo, C. Giacovazzo - Fundamentals of Crystallography, 3rd Ed., Oxford University Press, 2015. 2. C. Hammond - The Basics of Crystallography and Diffraction (International Union of Crystallography Texts on Crystallography) 4th Ed., Oxford University Press, 2015. 3. R. West, Solid State Chemistry and Its Applications, 2nd Ed.; Wiley, 2022. 4. F. Hoffmann, Introduction to Crystallography, 1st Ed. Springer, 2020. 5. D. Sherwood, Crystals, X-rays and Proteins: Comprehensive Protein Crystallography, 1st Ed. Oxford University Press, 2015. 6. A. Hofmann, S. Clokie, Wilson and Walkers Principles and Techniques of Biochemistry and Molecular Biology, 8th Ed.; Cambridge University Press, 2018. 7. V. Pecharsky and P. Zavalij, Fundamentals of Powder Diffraction and Structural Characterization of Materials, 2nd Ed.; Springer, 2009. 8. R. Young, The Rietveld Method, 1st Ed., Oxford University Press, 1995 9. W. David, K. Shankland, L. McCusker, C. Bärlocher, Structure Determination from Powder Diffraction Data, 1st Ed., Oxford University Press, 2006. 10. B. He, Two-dimensional X-ray Diffraction, 1st Ed., Wiley, 2009. 11. W. Massa, Crystal Structure Determination, 2nd Ed., Springer, 2010. 12. R. Dinnebier, S. Billinge, Powder Diffraction: Theory and Practice, 1st Ed., Royal Society of Chemistry, 2008.
Course Outcome:	1. Student will acquire fundamental concepts of crystallography. 2. Students will gain insights into single crystal and powder X-ray diffraction methods. 3. Students will be able to use X-ray diffraction methods for materials characterization. 4. Students will be able to correlate crystal structure and materials properties

Name of the Programme: M.Sc. Part-II (Analytical Chemistry)

Course Code: CHA-622 **Title of the course:** Advanced NMR and combined Spectroscopy

Number of Credits: 4

Effective from AY: 2023-24

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied Chemistry courses in MSc Part-I.</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. To understand advance 2D NMR techniques.
2. To develop skills of interpreting spectral data pertaining to two or more 2D NMR techniques.
3. To train students to interpret NMR for quantitative analysis.
4. To understand NMR hyphenated techniques.</td></tr>
<tr><td rowspan="3">Content</td><td>1. Selected concepts in IR and MS
a. IR: Spectral data interpretation for common functional groups like keto, aldehyde, acid, ester, amides, nitro, etc., Correlation of common functional groups with IR spectral differences.
b. MS: Factors governing Mass fragmentation processes, β-cleavage, cleavage α to heteroatoms, cleavage α to carbonyl groups, retro Diels-Alder reaction, McLafferty rearrangement.</td><td>No of hours

5</td></tr>
<tr><td>2. Selected concepts in NMR
a. Chemical Shifts spectral data for proton and carbon nuclei like aliphatic, aromatic, acyl, methoxy, etc., Correlation of common proton and carbon nuclei with NMR signal differences.
b. Nuclear Overhauser Effect
c. Decoupling in ^{13}C NMR Spectroscopy (DEPT-45, DEPT-90, DEPT-135), Proton coupled CMR.
d. ^{15}N-NMR, ^{19}F-NMR, ^{29}Si-NMR, & ^{31}P-NMR spectroscopy: Chemical shift range for ^{15}N, ^{19}F, ^{29}Si & ^{31}P in NMR spectra, coupling with neighbouring nuclei and splitting pattern.</td><td>10</td></tr>
<tr><td>3. 2D-NMR
a. Introduction to 2D-NMR, General Principles, Classification of 2D-NMR experiments.
b. Homonuclear Correlation Spectroscopy
Proton-Proton Interactions - COSY, DQF-COSY, TOCSY, NOESY, REOSY.
Carbon-Carbon Interactions - INADEQUATE.
c. Heteronuclear Correlation Spectroscopy HETCOR
Heteronuclear Single Bond Correlation - HSQC, HMQC and me-HSQC
Heteronuclear Multiple Bond Correlation - HMBC</td><td>10</td></tr>
</table>

	d. Analysing and interpreting spectral data from above 2D spectra for small molecules. e. Assigning NMR signals based on PMR, CMR, ^{1}H-^{1}H &^{1}H-^{13}C Correlation Spectra.	
	4. **Structural analysis of simple compounds using some combined spectral techniques**: PMR, CMR, COSY, HSQC, me-HSQC, HMBC, TOCSY, NOESY, INADEQUATE, along with IR, UV and MS data wherever necessary.	20
	5. **Quantitative NMR analysis** a. Analysis of mixture of compounds using qNMR technique, Relative proportions (mole %) of the 2 or 3 components from NMR integrals. b. Calibration standards, Selection criteria for suitable Reference material. c. Molar concentration Determination, Purity or Yield Determination.	10
	6. **Hyphenated NMR techniques** a. Development of LC-NMR, Technical Considerations regarding LC-NMR: Solvent Compatibility, Solvent Suppression, NMR Flow Cell, LC-NMR Sensitivity. Modes of Operation: On-Flow Mode, Stop-Flow Mode. Applications of LC-NMR. b. Introduction to other hyphenated NMR techniques, Technical Considerations regarding LC-MS-NMR: Modes of Operation, Online coupling in series or in parallel, Challenges in Hyphenated NMR techniques.	5
Pedagogy	Mainly lectures and tutorials, Seminars / assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions shall be interactive in nature to enable peer group learning. *(Note: More emphasis shall be given for structural elucidation using combined spectroscopic data*)	
References /Reading	1. W. Kemp; Organic Spectroscopy; 3rd Ed, Palgrave, 1991. 2. R. M. Silverstein, F. X. Webster; Spectrometric identification of Organic Compounds; 6th Ed, Wiley, 2011. 3. R. M. Silverstein, F. X. Webster, D. J. Kiemle, D. L. Bryce, S. D. Samant, V. S. Nadkarni; Spectrometric identification of Organic Compounds; An Indian Adaptation, 8th Ed, Wiley, 2022. 4. P. S. Kalsi; Spectroscopy of Organic Compounds; 6th Ed, New Age International, 2009. 5. E. Pretsch, P. Buhlmann, C. Affolter; Structural Determination of Organic Compounds, 2nd Ed, Springer, 2005. 6. L. D. Field, S. Sternhell, J. R. Kalman; Organic Structures from Spectra, 4th Ed, Wiley, 2007.	

	7. L. D. Field, H. L. Li, A. M. Magill; Organic Structures from 2DNMR Spectra, Wiley, 2015. 8. W. Kemp; NMR in Chemistry: A Multinuclear Introduction, Macmillan, 1986. 9. D. H Williams, I. Fleming; Spectroscopic methods in organic chemistry, 6^{th} Ed, Tata Mcgraw Hill Education, 2011. 10. J. H. Simpson; Organic Structure Determination using 2-D NMR Spectroscopy, Elsevier, 2008. 11. H. Friebolin; Basic One- and Two-Dimensional NMR Spectroscopy, Wiley, 2011. 12. K. S. Parikh, H. H. Gadape; Quantitative NMR Spectroscopy in Pharmaceuticals, Lambert Academic Publishing, 2012. 13. U. Holzgrabe, I. Wawer, B. Diehl; NMR Spectroscopy in Pharmaceutical Analysis, Elsevier, 2008. 14. M. V. Silva Elipe; LC-NMR and Other Hyphenated NMR Techniques: overview and applications, Wiley, 2012.
Course Outcome:	1. Students will be able to understand various 2D NMR techniques and analyse the 2D NMR spectra of small molecules. 2. Students will be skilled to interpret combined spectral data pertaining to two or more 2D NMR techniques for structural analysis. 3. Students will be skilled to interpret qNMR data for quantitative analysis. 4. Students will be able to understand and apply hyphenated NMR techniques for analysing mixtures.

Name of the Programme: M.Sc. Part-II (Analytical Chemistry)

Course Code: CHA-623 **Title of the course:** Bioanalytical Techniques

Number of Credits: 4

Effective from AY: 2023-24

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied Chemistry courses at M.Sc. Part-I</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. To introduce various bioanalytical techniques used in biochemical analysis and diagnosis.
2. To depict the various concepts used in Biomolecular techniques, Immunochemical Techniques, Radioisotope tracer Techniques, Computed Tomography, and Magnetic Resonance Technology and their significance in clinical analysis.</td></tr>
<tr><td>Content</td><td>1. Biomolecular techniques
a. Introduction, Structure of nucleic acid, Isolation of DNA: Conventional methods of extraction; kit-based extraction; detection of DNA, Extraction of RNA: Conventional methods of extraction; kit-based RNA extraction, DNA sequencing methods: Sequencing by chemical degradation method; Dideoxy chain termination method
b. Polymerase Chain Reaction Thermocycler (PCR thermocycler): Principle; components of PCR, thermal cycler, optimization of PCR, Analysis of PCR product, Reverse Transcriptase PCR(RT-PCR): Steps of RT-PCR; application of RT-PCR, Real-time PCR(q-PCR): Application of PCR
c. Protein DNA Interaction Assays: Specific and non-specific interactions
d. Microarrays: DNA-based microarrays and protein microarrays</td><td>No of hours

12</td></tr>
<tr><td></td><td>2. Immunochemical Techniques
a. Introduction: Development of immune system, Harnessing the immune system for antibody production; antibody structure and function
b. Antibody preparation: Polyclonal antibody production; monoclonal antibody production; Cell banking; Growing hybridomas for antibody production; Antibody recognizing small molecules; Anti-Idiotypic antibodies; Phage display for development of antibody fragments; Antibody Purification; Antibody modification
c. Immunoassay formats: Enzyme immunosorbent Assays;</td><td>12</td></tr>
</table>

	Double antibody Sandwich ELISA (DAS ELISA); Triple antibody Sandwich ELISA (TAS ELISA); Enhanced ELISA system; Competitive ElISA; Modification of traditional sandwiched ELISA d. Immunomicroscopy: Immunoflurosecence Microscopy; Immunosorbent electron microscopy e. Lateral Flow devices; Epitope mapping; Immunoblotting; Fluorescence-Activated Cell Sorting (FACS); Cell and Tissues staining Techniques; Immunoaffinity Chromatography; Antibody-Based biosensors; Luminex Technology; Therapeutics Antibodies	
	3. Radioisotope tracer Techniques Introduction, Autoradiography: Principle of Autoradiography, Selection of emulsion and film. Choice of isotopes; Background; Time of exposure. Practical techniques for use of autoradiography	6
	4. X-Ray Imaging a. Introduction to X-ray imaging, Background: History and basic physics b. Instrumentation, Components; Beam Generation; Reduction of Scattered Radiation; Image Detection, c. Clinical Applications: Diagnostic Devices; Projection Radiography; Mammography; Fluoroscopy; Angiography	8
	5. Computed Tomography a. Introduction to Computed Tomography b. Instrumentation: X-ray Tube and Generator; MDCT Detector Design and Slice Collimation c. Data Rates and Data Transmission; Dual Source CT; Measurement Techniques; MDCT Sequential (Axial) Scanning; 109 MDCT Spiral (Helical) Scanning, Pitch; Collimated and Effective Slice Width d. Multi slice Linear Interpolation and z-Filtering; Three-Dimensional Back projection and Adaptive Multiple Plane Reconstruction (AMPR); Double z-Sampling, ECG-Triggered; and ECG-Gated Cardiovascular CT e. Principles of ECG-Triggering and ECG-Gating; ECG-Gated Single-Segment and Multisegmented Reconstruction f. Principles of prositron emission tomography (PET)	10

<table>
<tr><td rowspan="2"></td><td>g. Clinical Applications of Computed Tomography</td><td></td></tr>
<tr><td>6. Magnetic Resonance Technology
a. Introduction, Magnetic Nuclei Spin in a Magnetic Field: A Pulsed rf Field Resonates with Magnetized Nuclei, the MR Signal, Spin Interactions Have Characteristic Relaxation Times
b. Image Creation: Slice Selection; The Signal Comes Back—The Spin Echo; Gradient Echo, Image Reconstruction: Sequence Parameters, Image Resolution, Noise in the Image—SNR, Image Weighting and Pulse Sequence Parameters TE and TR: T2-Weighted Imaging; $T{*}2$ -Weighted Imaging; Proton-Density-Weighted Imaging; T1-Weighted Imaging
c. Clinical applications: A Menagerie of Pulse Sequences: EPI; FSE; Inversion-Recovery; DWI; MRA; Perfusion, Enhanced Diagnostic Capabilities of MRI—Contrast Agents, Molecular MRI, Functional MRI</td><td>12</td></tr>
<tr><td>Pedagogy</td><td colspan="2">Mainly lectures and tutorials. Seminars/term papers /assignments/ presentations /or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.</td></tr>
<tr><td>References / Readings</td><td colspan="2">1. R. Salzer, Biomedical Imaging: Principles and Applications, 1st Ed. Wiley; 2012.
2. K. Wilson, J. Walker, Principles and Techniques of Practical Biochemistry; 8th Ed. Cambridge University Press; 2010.
3. S. Ghosal, A. S. Avasthi, Fundamentals of Bioanalytical Techniques and Instrumentation, 2nd Ed. PHI learning Pvt. Ltd. Delhi, 2010.
4. D. J. Holme, H. Peck.; Analytical Biochemistry; 3rd Ed. Prentice Hall, Pearson Education Limited; 1998.
5. B. M. Dale, M. A. Brown, R. C. Semelka, MRI: Basic principles and applications, 5th Ed. Wiley, 2015.</td></tr>
<tr><td>Course Outcome:</td><td colspan="2">1. Students will be able to identify, formulate, analyze and solve problems in the analysis of biological compounds.
2. Students will be able to differentiate between various methods, assays, and procedures which will enable them to understand/analyze the substances present in living organisms/ chemical reactions.
3. Students will understand the applications of various diagnostic techniques used in clinical analysis.
4. Students will understand various imaging techniques.</td></tr>
</table>

Name of the Programme: M.Sc. Part-II (Analytical Chemistry)

Course Code: CHA-624 **Title of the course:** Calibration and Validation in Analytical Chemistry

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied M.Sc. Part-I.	
Course Objectives:	1. To understand the terminologies used in measurement science 2. To classify the nature of errors involved in measurements 3. To study the concept of calibration and matrix effect in Analysis 4.To comprehend the role method validation and development in Analytical laboratories of pharmaceutical, clinical, environmental and forensic studies. 5. To gain the knowledge on application of statistical tools in Analysis	
Content	**1. Introduction** a. The vocabulary of analytical chemistry: Analysis, determination and measurement; techniques, methods, procedures, and protocols b. Classifying analytical techniques: Qualitative, quantitative and structural determination, separation and hyphenated techniques, basic principle of analysis and limitations c. Selecting an analytical method: Identification of analytical problem, understanding the selection criteria viz. accuracy, precision, sensitivity, selectivity, robustness, ruggedness, scale of operation, analysis time, availability of equipment, and cost; developing analytical procedure d. Errors in analytical measurements: Classification, methods of minimization of errors, significance of gaussian curve, probability distribution of errors.	No of hours 10
	2. Calibration and Statistical treatment of data a. Calibration in analytical chemistry: Significance and need for calibration, compensating for interferences (method blank), chemical standard, reference material, calibration of glassware and its tolerance limit (standard deviation) b. Matrix effect: Effect of matrix on signal measurement, importance of correlation coefficient, concept of curve fitting, linear regression of good data, linearity and sensitivity of instrumental measurement c. Calibration methods: External standard, standard additions and Internal standard method, case scenario to understand	22

	the suitability of each method for a given analysis. d. Statistical evaluation of analytical results: Confidence limits and interval, testing for significance, detection of bias and presence of outliers, control charts e. Calibration of important analytical instruments: UV-visible spectrophotometer, FTIR spectrophotometer, conductivity meter, GC, HPLC.	
	3. Validation a. Quality in Analytical Laboratories: Good laboratory practices, quality control, quality assurance, accreditation system. b. Validation and qualification: Overview of installation, operation, and performance qualification (IQ, OQ, PQ) of analytical equipment. c. Method validation in pharmaceutical industry: Regulatory requirements for analytical method validation International conference on harmonization (ICH) guideline Q2R1, method validation parameters and timeframe as per ICH guidelines, linearity and range criteria and their role in instrumental method validation, detailed discussion on accuracy and precision role in the method validation, Role of quantification limit and specificity -Limit of Detection (LOD) and Limit of Quantification (LOQ) for a given method.	18
	4. Case study of method development and modifications a. Environment sample monitoring: Estimation of nitrite, lead in wastewater, Measurement of calcium by flame emission spectroscopy b. Food and medicine: Generic drugs, health supplements, nutritional labels and daily nutritional requirement c. Clinical studies: Determination of glucose in human blood and urine, preservation of biological fluid for analysis of different analytes. b. Forensic analysis: Determination of blood alcohol content, Analysis of narcotic drugs, adulterations.	10
Pedagogy:	Mainly lectures and tutorials, Seminars / assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions shall be interactive in nature to enable peer group learning.	

References/ Readings	1. M. E. Swartz, I. S. Krull, Analytical method development & validation, CRC Press book, 1997. 2. G. H. Jeffery, J. Bassett, J. Mendham, R C. Denney, Vogel's Text Book of Quantitative Chemical Analysis, 5^{th} Ed. Wiley, 1989. 3. A. H. Wachter, R. A. Nash, Pharmaceutical Process Validation, Marcel Dekker Inc, 2003. 4. L. Huber, Validation and Qualification in Analytical Laboratories, Informa Healthcare USA Inc; 2007. 5. M. Valcarcel, Principles of analytical chemistry: A text book, Springer Publications, 2000. 6. D. Harvey, Modern Analytical Chemistry, MC Graw Hill, 2000. 7. D. A. Skoog, D. M. West, F. J. Holler, Fundamentals of Analytical Chemistry, 9^{th} Ed. Sounders College publishing, 2014. 8. B. W. Wenclawiak, M. Koch, E. Hadjicostas, Quality Assurance in Analytical Chemistry, Springer, 2004. 9. G. D. Christian, Analytical Chemistry, 6^{th} Ed.; Wiley, 2004. 10. J. H. Kennedy, Analytical Chemistry: Principles, 2^{nd} Ed.; Saunders College Publishing, 1990. 11. B. Magnusson, U. Ornemark, The Fitness for Purpose of Analytical Methods – A Laboratory Guide to Method Validation and Related Topics, 2^{nd} Ed; Eurachem, 2014 12. Willard, Instrumental Methods of Analysis, 7^{th} Ed., CBS Publishers, 1986
Course Outcomes:	1. Students will be able to differentiate between technique, method, protocol and procedure. 2. Students should be able to identify and correct any measurement errors. 3. Students will be able to analyse the reliability of results for a chosen method of analysis 4. Student will be able to evaluate the suitability of method for intended purpose 5. Student will learn to draw conclusions based on statical method.

Name of the Programme: M.Sc. Part-II (Chemistry)

Course Code: CHC-600 **Title of the course:** Research Methodology and instrumental techniques-I

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I level.	
Course Objective:	1. To introduce various aspects of research methodology. 2. To provide understanding ethics & scientific conduct. 3. To introduce academic writing. 4. To introduce databases used in chemistry. 5. To provide understanding and importance of lab safety. 6. To understand the usefulness of various instrumental techniques in characterization of chemical compounds.	
Content	**1. Introduction to Research Methodology** Research- meaning, objectives, motivation, types and methodology. Process- formulating the research problem; literature survey; developing the hypothesis and the research design; sample design and collection of the data; execution of the project; analysis of data; testing of hypothesis; generalizations and interpretation, and preparation of the report or presentation of the results & conclusions.	No of hours 5
	2. Scientific conduct and ethics Ethics: definition, nature of moral judgements and reactions, Ethics with respect to science and research. Intellectual honesty and research integrity. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP). Redundant publications: duplicate and overlapping publications. Selective reporting and misrepresentation of data.	5
	3. Academic writing Publication ethics: definition, introduction and importance Conflicts of interest Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa Violation of publication ethics, authorship and contributorship Identification of publication misconduct, complaints and appeals Predatory publishers and journals	5

	4. Data bases and research metrics Databases: 1. Indexing databases 2. Citation databases: Web of Science, Scopus, UGC-Care List etc. Research Metrics: 1. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score 2. Metrics: h-index, g index, i10 index etc	3
	5. Safety aspects in Chemistry Good laboratory practices. Handling of various chemicals, solvents & glassware. Fires and fighting with fires. Hazardous substances, classification and handling Safety Data Sheet	5
	6. Softwares in Chemistry Data plotting Structure Drawing Reference management software	7
	7. Instrumental methods of analysis: Demonstration and/ or data analysis in following techniques: Elemental analysis: CHNS analysis and AES Infrared (IR), Raman, Ultraviolet-Visible (UV-Vis) Nuclear magnetic resonance (^{1}H, ^{13}C) Chromatographic techniques: HPLC, GC, Hyphenated Techniques: LC-MS & GC-MS, Diffraction methods: XRD Thermal analysis: DSC Microscopy: SEM, TEM Methods for determination of magnetic & dielectric properties. Cyclic voltammetry	30
Pedagogy	Mainly lectures/recorded video lectures/ tutorials, discussions, seminars, internal exams/ assignments, / demonstration/ self-study or a combination of some of these. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. C. R. Kothari, Research Methodology: Methods & Techniques, New Age International Pvt. Ltd., 2004. 2. Bird, Philosophy of Science, Routledge, 2006. 3. M. Coghill & L. R. Garson, The ACS Style Guide: Effective Communication of Scientific Information, American Chemical Society Washington, DC & OXFORD University Press New York, 2006. 4. Y. K. Singh, Fundamentals of Research Methodology & Statistics, New Age International Pvt. Ltd., 2006. 5. National Research Council, Prudent practices in the laboratory: handling and management of chemical hazards, The National	

	Academies Press, USA, 2011. 6. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, Vogel's Text book of Practical Organic Chemistry, 5th Ed.; Longmann, 1989 7. E. A. V. Ebsworth, D. W. H. Rankin & S. Craddock, Structural Methods in Inorganic Chemistry, Blackwell Scientific Publishers. 1986. 8. R. S. Drago, Physical Methods in Chemistry, 2nd Ed. W. B. Saunders Co. Ltd. 2016 9. R. M. Silverstein, F. X. Webster; Spectrometric identification of Organic Compounds; 6th Ed, Wiley, 2011. 10. J. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed.; Pearson Education Asia, 2002. 11. H. V. Keer, Principles of the Solid State, 1st Ed. New Age International (P) Ltd., 2005. 12. G. D. Christian, Analytical Chemistry, 6th Ed.; Wiley, 2004. 13. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed.; Cengage learning. 14. Skoog, F. J. Holler, S. R. Crouch, Principles of Instrumental Analysis, 7th Ed.; Cengage learning. 15. P. G. Lampman, G. Kriz and J. Vyvyan, Introduction to Organic Spectroscopy, 5th Ed.; Cengage Learning, 2015. 16. N. Elgrishi,´ K. J. Rountree, B. D. McCarthy, E. S. Rountree, T. T. Eisenhart, and J. L. Dempsey, A Practical Beginner's Guide to Cyclic Voltammetry, J. Chem. Educ. ACS, 2018, 95, 197−206. 17. V. Rajaraman, Computer Programming in Fortran 90 And 95, PHI Learning Pvt. Ltd., 2013. 18. Szabo, N. S. Ostlund, Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory, Dover Publications, Inc. Mineola, 1989.
Course Outcome:	1. Students will be able to apply research methodology concepts. 2. Students will be able to apply computer technology to solve their research problems in chemistry. 3. Students will know in advance the safety precautions to be taken in the chemical lab. 4. Students will gain fundamental knowledge on characterization techniques.

Name of the Programme: M.Sc. Part-II (Chemistry)

Course Code: CHC-601 **Title of the course:** Research Methodology and instrumental techniques-II

Number of Credits: 4

Effective from AY: 2023-24

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied chemistry courses at MSc-I.</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. To introduce various aspects of research methodology.
2. To provide understanding ethics & scientific conduct.
3. To introduce academic writing.
4. To introduce databases used in chemistry.
5. To provide understanding and importance of lab safety.
6. To understand the usefulness of various instrumental techniques in characterization of chemical compounds.</td></tr>
<tr><td rowspan="2">Content</td><td>1. Research Methodology, Scientific conduct, ethics & academic writing
Research- meaning, objectives, motivation, types and methodology.
Process- formulating the research problem; literature survey; developing the hypothesis and the research design; sample design and collection of the data; execution of the project; analysis of data; testing of hypothesis; generalizations and interpretation, and preparation of the report or presentation of the results & conclusions.
Ethics: definition, nature of moral judgements and reactions, Ethics with respect to science and research.
Intellectual honesty and research integrity.
Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP).
Redundant publications: duplicate and overlapping publications.
Selective reporting and misrepresentation of data.
Publication ethics: definition, introduction and importance
Conflicts of interest
Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa
Violation of publication ethics, authorship and contributorship
Identification of publication misconduct, complaints and appeals
Predatory publishers and journals</td><td>No of hours

15</td></tr>
<tr><td>2. Softwares in chemistry, Data bases and Research metrics</td><td>10</td></tr>
</table>

	Data plotting using GNU plot; Structure Drawing using ChemSktech; Reference management software such as Mendeley and Zotero. Databases: Indexing databases, Citation databases: Web of Science, Scopus, UGC-Care List, Scimago etc. Research Metrics: Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, g-index, i10-index etc Molecular Docking software	
	3. Safety practices in Chemical research Introduction to lab safety. Handling of various chemicals, solvents & glassware. Fires and fighting with fires. Hazardous substances, classification and handling Safety Data Sheet	5
	4. Instrumental methods UV-Visible spectroscopy in elucidation of mechanisms of C-H activation reactions, epoxidation etc by transition metal catalyst. Understanding water oxidation reaction using Cyclic voltammetry (CV) & Linear Sweep voltammetry (LSV) Determining capacity of supercapacitors using Galvanostatic Charge-Discharge (GCD) Electrochemical Impedance Spectroscopy (EIS) Resonance Raman and isotope labelling studies. Infrared (IR) spectroscopy applications ^{1}H, ^{13}C- NMR spectroscopy and applications Selected chromatographic techniques such as HPLC, GC. Hyphenated Techniques/applications: LC-MS, GC-MS, LC-NMR-MS, GC-IR, ICP-MS Diffraction methods: High temperature XRD Thermal analysis: TG/DTA/DSC Microscopy: Fe-SEM, HR-TEM Methods for determination Ms, Mr, Hc, Tc, ε^{l} and Tanδ. Potentiometry	30
Pedagogy	Mainly lectures/recorded video lectures/ tutorials, discussions, seminars, internal exams/ assignments, / demonstration/ self-study or a combination of some of these. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. C. R. Kothari, Research Methodology: Methods & Techniques, New Age International Pvt. Ltd., 2004. 2. Bird, Philosophy of Science, Routledge, 2006. 3. M. Coghill & L. R. Garson, The ACS Style Guide: Effective Communication of Scientific Information, American Chemical Society Washington, DC & OXFORD University Press New York,	

	2006. 4. Y. K. Singh, Fundamentals of Research Methodology & Statistics, New Age International Pvt. Ltd., 2006. 5. National Research Council, Prudent practices in the laboratory: handling and management of chemical hazards, The National Academies Press, USA, 2011. 6. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, Vogel's Text book of Practical Organic Chemistry, 5th Ed.; Longmann, 1989 7. E. A. V. Ebsworth, D. W. H. Rankin & S. Craddock, Structural Methods in Inorganic Chemistry, Blackwell Scientific Publishers. 1986. 8. R. S. Drago, Physical Methods in Chemistry, 2nd Ed. W. B. Saunders Co. Ltd. 2016 9. R. M. Silverstein, F. X. Webster; Spectrometric identification of Organic Compounds; 6th Ed, Wiley, 2011. 10. J. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed.; Pearson Education Asia, 2002. 11. H. V. Keer, Principles of the Solid State, 1st Ed. New Age International (P) Ltd., 2005. 12. G. D. Christian, Analytical Chemistry, 6th Ed.; Wiley, 2004. 13. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed.; Cengage learning. 14. Skoog, F. J. Holler, S. R. Crouch, Principles of Instrumental Analysis, 7th Ed.; Cengage learning. 15. Pavia, G. Lampman, G. Kriz and J. Vyvyan, Introduction to Organic Spectroscopy, 5th Ed.; Cengage Learning, 2015. 16. N. Elgrishi,´ K. J. Rountree, B. D. McCarthy, E. S. Rountree, T. T. Eisenhart, and J. L. Dempsey, A Practical Beginner’s Guide to Cyclic Voltammetry, J. Chem. Educ. ACS, 2018, 95, 197−206. 17. V. Rajaraman, Computer Programming in Fortran 90 And 95, PHI Learning Pvt. Ltd., 2013. 18. Attila Szabo, Neil S. Ostlund, Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory, Dover Publications, Inc. Mineola, 1989. 19. Leach, Molecular Modelling, Principles and applications, Longman, 1998. 20. W. Nam et al, Dioxygen activation by Metalloenzymes & models, Accounts of Chemical Research, 2007, Volume 40 & references cited therein.
Course Outcome:	1. Students will be familiar with research methodology concepts. 2. Students will be able to apply computer technology to solve their research problems in chemistry. 3. Students will know in advance the safety precautions to be taken in the chemical lab. 4. Students will gain fundamental knowledge on characterization techniques.

Name of the Programme: M.Sc. Part-II (Chemistry)

Course Code: CHC-651 **Title of the course:** Discipline Specific Dissertation

Number of Credits: 16

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I level.	
Course Objective:	To develop the skills of preparing and conducting independent research.	
Content	As per OA-35	No of Hours 480
Pedagogy:	Dissertation carried out individually by each student throughout the academic year.	
References / Readings:	As required for the development of review and methodology.	
Course Outcome:	Students will be able to understand and apply the tools and techniques of chemistry in conducting independent research.	

M.Sc. Physical Chemistry Part-II syllabus for AY 2023-24 (SEM III and SEM IV)

SEM III ORGANIC CHEMISTRY			
Sr. No.	**Subject code**	**Paper title**	**Credits**
1	**CHP-600**	Practical Course in Physical Chemistry-III	4
2	**CHP-601**	Practical Course in Physical Chemistry-IV	4
3	**CHC-600**	Research Methodology and instrumental techniques-I	4
4	**CHC-601**	Research Methodology and instrumental techniques-II	4
5	**CHP-621**	Solid State Chemistry: Concepts and Applications	4
6	**CHP-622**	Nanoscience: Concepts and Applications	4
7	**CHP-623**	Physical aspects of Polymer Chemistry	4
8	**CHP-624**	Colloids and Surface Chemistry	4
SEM-IV ORGANIC CHEMISTRY			
1	**CHP-602**	Heterogeneous Catalysis: Fundamentals and Applications	4
2	**CHP-603**	Applied Electrochemistry	4
3	**CHC-651**	Discipline Specific Dissertation	16

Name of the Programme: M.Sc. Part-II (Physical Chemistry)

Course Code: CHP-600 **Title of the course:** Practical Course in Physical Chemistry - III

Number of Credits: 4

Effective from AY: 2023-24

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Should have studied Physical chemistry practical course at M.Sc. Part-I.</td></tr>
<tr><td>Course Objectives:</td><td colspan="2">1. To introduce concepts of Kinetics and Thermodynamics
2. To introduce concepts of Surface science and Catalysis
3. To introduce various concepts of Electrochemistry
4. Introduction to the use of computers and computational tools in chemistry</td></tr>
<tr><td>Contents</td><td>Note: A minimum of 7 experiments from each Unit I-III are to be completed.
Unit - I. Instrumental
a. To determine the redox potential of Fe^{2+}/Fe^{3+} system using rotating disk voltammetry method.
b. To determine the instability constant of the reaction $[Ag(NH_3)_2]$----> $Ag + 2NH_3$ potentiometrically.
c. To determine the transport number of ions using moving boundary method.
d. To verify Nernst equation and determine the standard oxidation potential of copper and zinc electrodes.
e. To study effect of ionic strength on activity coefficient of Ag^+ ions.
f. To investigate the reaction kinetics between Potassium Persulphate and Potassium Iodide colorimetrically.
g. To determine the equivalent conductance of a strong electrolyte (KCl) at several concentrations and verify Onsager's equation.
h. To estimate the concentration of Sulphuric acid, Acetic acid and Copper sulphate in a given solution conductometrically.
i. To determine the concentration of Fe^{2+} ions by titrating with potassium dichromate conductometrically.
j. To study the kinetics of hydrolysis of tertiary butyl chloride by conductometry.
k. To determine the half wave potential of $Cu^{2+}/Cd^{2+}/Zn^{2+}$ by using polarography.
l. To study the effect of sol-gel and hydrothermal method of synthesis on crystallite size and surface area of a semiconductor catalyst.
m. To investigate the effect of catalyst loading on photocatalytic degradation of azo dye using semiconductor catalyst.
n. To study the stress-strain response of polymeric materials and compare their strength.</td><td>No of hours

40</td></tr>
</table>

	o. To determine the degradation rate of the polymers using thermogravimetric methods. p. To determine the curie temperature of conducting polymer samples. q. To determine the resistivity of polymeric material using four probe method.	
	Unit - II. Non-Instrumental a. To determine the critical micelle concentration of three types of surfactants using stalagmometer. b. To determine the partial molal volume of sodium chloride-water, ethanol-water and methanol-water system by apparent molal volume method. c. To study the effect of surfactants on surface tension of water using stalagmometer. d. To study the variation of viscosity with composition of mixtures and to verify the formation of compounds by Oswald's viscometer. e. To study the effect of pH on the kinetics of iodination of Aniline. f. To study the kinetics of reaction between H_2O_2 and KI (clock reaction). g. To study the kinetics of rapid reaction between Bromine and Iodine in aqueous media. h. To investigate the autocatalytic reaction between Potassium Permanganate and Oxalic acid. i. To study the electroless deposition of Ni on non-conductor substrate and to determine the rate of deposition. j. To study the variation in catalytic activity of three different metal oxides for H_2O_2 decomposition reaction. k. To investigate the effect of pH on adsorptive separation of azodye from water using MCM-41.	40
	Unit - 3. Computational Chemistry a. To generate a mark sheet and understand various features of spreadsheets. b. To generate a plot for a given function such as solutions of 1D box, harmonic oscillator, H-like atom wave functions, Gaussians distributions etc. c. To write a computer program to obtain equivalence point in pH metry and potentiometric experiments (derivative method). d. To write a computer program to find percent composition for various atoms of a given molecular formula. e. To write a computer program to obtain slope and intercept for linear data using least square fit method. f. To write a computer program to obtain center of mass of a given molecule and moment of inertia, hence obtain classification of the	40

	given molecule. g. To write a computer program to find out various parameters for data analysis viz. minimum, maximum, average, standard deviation, variance, covariance, correlation coefficient, frequency distribution etc. h. To write a computer program to obtain thermodynamic probability. i. To write a computer program to obtain degeneracy of a given energy level for a particle in a cube. j. Calculate the ground state energy of hydrogen atom using various basis sets using *ab-initio* program. k. Calculate and interpret the IR, RAMAN and NMR spectra of simple organic molecules using *ab-initio* program.	
Pedagogy:	Mainly pre-labs / practicals or a combination of some of these could also be used to some extent.	
References / Readings:	1. A. Finlay and J.A. Kitchener, Practical Physical Chemistry, Longman Publisher, 1963. 2. A. M. James, Practical Physical Chemistry, Longman Publisher, 1974. 3. D.P. Shoemaker and C.W. Garland, Experimental Physical Chemistry, McGraw-Hil, 1981. 4. J. B. Yadav, Advance Practical Physical Chemistry, Krishna Educational Publishers, 2014. 5. S.Attila, and N. S. Ostlund. Modern quantum chemistry: introduction to advanced electronic structure theory. Courier Corporation, 2012. 6. P.P. Morajkar, A. P. Naik, S. T. Bugde, B. R. Naik, CH-20: Photocatalytic and microbial degradation of Amaranth dye, Advances in Biological Science Research-A Practical Approach 2019, 327-345, Academic Press. 7. J.B. Foresman, E. Frisch, Exploring Chemistry with Electronic Structure Methods: A Guide to Using Gaussian, 2nd Ed. Gaussian, 1996	
Course Outcomes:	1. Student should be able to apply the concepts of physical chemistry in M.Sc. Dissertations. 2. Students shall be equipped with practical skills needed for research and development. 3. Students will understand the instrumental and non-instrumental methods of analysis. 4. Students will understand use of computers and computational tools in chemistry.	

Name of the Programme: M.Sc. Part-II (Physical Chemistry)

Course Code: CHP-601 **Title of the course:** Practical Course in Physical Chemistry - IV

Number of Credits: 4

Effective from AY: 2023-24

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Should have studied Physical chemistry practical course at M.Sc. Part-I.</td></tr>
<tr><td>Course Objectives:</td><td colspan="2">1. To introduce concepts of Kinetics and Thermodynamics
2. To introduce concepts of Surface science and Catalysis
3. To introduce various concepts of Electrochemistry
4. Introduction to the use of computers and computational tools in chemistry</td></tr>
<tr><td rowspan="2">Content</td><td>Unit - I. Instrumental
a. To estimate the concentration of glucose calorimetrically.
b. To determine the redox potential of Fe^{3+}/Fe^{2+} system using rotating disk voltammetry method.
c. To determine the transport number of ions using moving boundary method.
d. To verify Nernst equation and determine the standard reduction potential of Ag and Zn electrodes.
e. To determine the equivalent conductance of a strong electrolyte (NaCl) at several concentrations and verify Onsager's equation.
f. To estimate the concentration of Hydrochloric acid, Monochloro acetic acid and Copper sulphate in a given solution conductometrically.
g. To determine the half wave potential of $Ni^{2+}/Cd^{2+}/Cu^{2+}$ by using polarography.
h. To study the effect of precipitation and hydrothermal method of synthesis on acidic sites of a semiconductor catalyst using NH_3 TPD method.
i. To investigate the effect of solution pH on photocatalytic degradation of methylene blue using semiconductor photocatalyst.
j. To determine the curie temperature of polyaniline.</td><td>No of hours

40</td></tr>
<tr><td>Unit II. Non-Instrumental
a. To determine the critical micelle concentration of Sodium dodecyl sulphate, Cetrimonium bromide using stalagmometer.
b. To study the kinetics of the reaction between acetone and Iodine using titrimetry.
c. To study the effect of pH on the kinetics of iodination of aniline.
d. To study the kinetics of Briggs Rauscher reaction (oscillatory</td><td>40</td></tr>
</table>

	reaction). e. To study the kinetics of rapid reaction between Bromine and Iodine in aqueous media f. To investigate the autocatalytic reaction between Potassium Permanganate and Citric acid. g. To study the electroless deposition of Cu on alpha-alumina and to determine the rate of deposition. h. To compare the catalytic activity of MnO_2, NiO with Degussa-P25 towards H_2O_2 decomposition reaction. i. To investigate the effect of pH on adsorptive separation of Amaranth dye from water over NiO catalyst. j. To determine the radius of a glycerol molecule by viscosity measurements.	
	Unit III. Computational Chemistry a. To write a computer program to find out various parameters for data analysis viz. minimum, maximum, average, standard deviation, variance, covariance, correlation coefficient, frequency distribution etc. b. To write a computer program to obtain slope and intercept for linear data using least square fit method c. To analyze the Gaussian output files and extracts molecular coordinates. d. To construct and optimize the molecular structure of H_2O, H_2O_2 and HOF using Gaussian/ NWCHEM and calculate bond distances and bond angles. e. To obtain the transition state of the reaction between CH_3Br and OH^- ions using Gaussian/ NWCHEM. f. To study the effect of solvent on the transition state of the reaction between CH_3Br and OH^- using Gaussian/ NWCHEM. g. To study the thermochemistry of the reaction between CH_3Cl and OH^- using Gaussian/ NWCHEM. h. To generate a plot for a given function such as solutions of 1D box, harmonic oscillator, H-like atom wave functions, Gaussians distributions etc. i. To write a computer program to obtain degeneracy of a given energy level for a particle in a rectangular box. j. Calculate the ground state energy of hydrogen atom using various basis sets using Gaussian 16 program. *Note: A minimum of 7 experiments from each Unit I-III are to be completed.*	40

Pedagogy:	Mainly pre-labs / practicals or a combination of some of these could also be used to some extent.
References / Readings:	1. A. Finlay and J.A. Kitchener, Practical Physical Chemistry, Longman Publisher, 1963. 2. A. M. James, Practical Physical Chemistry, Longman Publisher, 1974. 3. D.P. Shoemaker and C.W. Garland, Experimental Physical Chemistry, McGraw-Hil, 1981. 4. J. B. Yadav, Advance Practical Physical Chemistry, Krishna Educational Publishers, 2014. 5. S. Attila, and N.S. Ostlund. Modern quantum chemistry: introduction to advanced electronic structure theory. Courier Corporation, 2012. 6. P. P. Morajkar, A. P. Naik, S. T. Bugde, B. R. Naik, CH-20: Photocatalytic and microbial degradation of Amaranth dye, Advances in Biological Science Research-A Practical Approach 2019, 327-345, Academic Press. 7. J.B. Foresman, E. Frisch, Exploring Chemistry With Electronic Structure Methods: A Guide to Using Gaussian, 2nd ed. Gaussian, 1996.
Course Outcomes:	1. Student should be able to apply the concepts of physical chemistry in M.Sc. Dissertations. 2. Students shall be equipped with practical skills needed for research and development. 3. Students will understand the instrumental and non-instrumental methods of analysis. 4. Students will understand use of computers and computational tools in chemistry.

Name of the Programme: M.Sc. Part-II (Physical Chemistry)

Course Code: CHP-602 **Title of the course:** Heterogeneous Catalysis: Fundamentals and Applications

Number of Credits: 4

Effective from AY: 2023-24

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied Chemistry courses at MSc Part-I.</td></tr>
<tr><td>Course Objectives:</td><td colspan="2">1. To introduce concepts of surface science and catalysis.
2. To provide fundamental knowledge of theories that govern heterogeneous catalytic reactions.
3. To introduce newer methods of synthesizing nanocatalysts and its characterization.
4. To introduce latest developments about application of catalyst in environment and energy sector.</td></tr>
<tr><td rowspan="2">Concepts</td><td>1. Basic Concepts
a. General Introduction: Catalysis and activation energy. Heterogeneous reactions with suitable illustrations. Catalytic activity, selectivity and stability. Steps in a heterogeneous catalytic reaction. Factors affecting rate of reaction such as temperature, flow rates, molar composition etc.
b. Adsorption and Surface Area: Cause of adsorption. No of molecules striking the surface and sticking probability. Types of adsorption and potential energy profiles for adsorption of H_2. Adsorption isotherms for gases and solutes. Basic types of BET isotherms. Gibbs adsorption equation and changes in surface tension. Free energy, enthalpy and entropy of adsorption. Chemisorption of H_2, O_2 and CO. Surface area and Porosity: Determination of surface area. Porosity and pore size distribution.
c. Classification of catalysts based on electrical conduction. Adsorption on specific crystal planes; geometric factor in catalysis: Balandin’s multiplet theory and Valence angle conservation. Cumulative & depletive adsorption, Electronic effect in catalysis by metals. Role of diffusion in catalysis.</td><td>No of hours

20</td></tr>
<tr><td>2. Kinetics and mechanisms of catalyzed reactions
Kinetics of catalyzed reactions and rate expressions. Mechanism of catalyzed reactions obeying Langmuir-Hinshelwood, Eley- Rideal and Mars van Krevelen models with suitable examples.</td><td>5</td></tr>
</table>

	3. **Preparation of Catalysts** Various methods for preparation of bulk catalysts: Precipitation method, Impregnation method catalyst impregnation with or without interaction between support and catalyst. Synthesis of microporous solids. Synthesis of mesoporous solids.	5
	4. **Thermal and Spectroscopic Methods in Heterogeneous Catalysis** Characterization of the catalysts by temperature programmed desorption using probes such as ammonia and pyridine molecules. Characterization of surface area using BET method. Characterization of adsorbed molecules/intermediates by IR spectroscopy and XPS. Introduction to EXAFS and Mössbauer spectroscopy in characterizing catalysts.	10
	5. **Zeolite based Catalysis and industrial applications** Structure building in zeolites such ZSM-5. Nature of active sites and their characterization. Role of Zeolite acidity and Shape Selectivity in catalytic reactions. Zeolite based catalysis in MTG process.	5
	6. **Semiconductor catalysis and its application in energy and environmental sector** Introduction to semi-conductor surface and catalysis with application in photocatalytic water splitting and CO_2 reduction to value added chemicals. Case studies on photocatalytic degradation of dyes. Practical demonstration of photocatalytic treatment of laboratory waste water contaminated with dyes, adsorptive separation and kinetic analysis.	10
	7. **Electrocatalysis and applications** Basic electro-catalytic concepts, comparison of electro-catalysts. Electrocatalytic water splitting reaction. Role of catalytic materials in energy storage applications.	5
Pedagogy:	Mainly lectures, tutorials, assignments, demonstration, self-study or a combination of some of these could also be used to some extent.	
Reference / Readings:	1. D. K. Chakrabarty and B. Viswanathan, Heterogeneous Catalysis, New Age International Publishers, 2008. 2. G. A. Somorjai, Introduction to Surface Chemistry and Catalysis, John Wiley, 2002. 3. M. Thomas and W. J. Thomas, Principles and Practice of Heterogeneous Catalysis, VCH Publishers, 1996. 4. P.P. Morajkar, A. P. Naik, S. T. Bugde, B. R. Naik, CH-20:	

	Photocatalytic and microbial degradation of Amaranth dye, Advances in Biological Science Research-A Practical Approach 2019, 327-345, Academic Press. 5. B.H.R. Suryanto, Y. Wang, R. K. Hocking, Overall electrochemical splitting of water at the heterogeneous interface of nickel and iron oxide. Nature Commun. 2019, 10, 5599. 6. A. V. Salkar; S. V. Bhosale; P. P. Morajkar, CH-6: Nanostructured WO_{3-x} Based Advanced Supercapacitors for Sustainable Energy Applications, Advances in Metal Oxides and Their Composites for Emerging Applications; Elsevier, 2022, 213–238. ELSEVIER. 7. A.V. Salker, Catalysis: Principles and Basic Concepts, Scientific International, 2019.
Course Outcomes:	1. Students will be able to design a nanocatalysts for adsorption application. 2. Students will be able to interpret characterization data of nano catalysts. 3. Students will be able to design a catalyst for environmental and energy applications. 4. Students will learn about semiconductor catalysis.

Name of the Programme: M.Sc. Part-II (Physical Chemistry)

Course Code: CHP-603 **Title of the course:** Applied Electrochemistry

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied Chemistry courses at M.Sc. Part-I.	
Course Objective:	1.Introduction to core concepts of electrochemical applications 2. To enable design and development of electrochemical systems for specific applications 3. Introduction of applications and working principles of electrochemical devices in day-today life eg. batteries, solar cells, capacitors	
Content	**1. Electroanalytical Techniques** Principles and applications of the following techniques: a. Amperometry b. Cyclic voltammetry c. Voltammetry at rotating disk electrodes d. Electrochemical impedance spectroscopy	No of hours 10
	2. Corrosion a. Corrosion and electrochemical kinetics. Pourbaix diagrams Mechanism of electrochemical corrosion. b. Mixed electrode and mixed potential. Overpotential and polarization. c. Current density – potential curves and determination of corrosion current density. d. Hydrogen and oxygen overpotentials and corrosion e. Types of electrolytic corrosion and forms of localized corrosion, practical cases of corrosion. Corrosivity and passivity f. Corrosion prevention. Corrosion inhibitors. Corrosion Testing. Cathodic and anodic protection g. Polarization tests and impedance spectroscopic measurements.	10
	3. Electrochemical Power Sources: Batteries, Fuel Cells and Supercapacitors a. Electrical characteristics of batteries. Batteries with aqueous and non-aqueous electrolytes. Types of batteries, Ohmic losses and thermal processes in batteries. Next generation batteries: Lithium ion batteries, Sodium ion batteries b. Thermodynamic aspects of fuel cells. Working principles of fuel cells. Types of fuel cells: polymer electrolyte membrane fuel cells (PEMFCs), direct liquid fuel cells (DLFCs), molten carbonate fuel cells (MCFCs), solid oxide fuel cells (SOFCs), alkaline fuel cells (AFCs) c. Properties of electrical double layer capacitors. Energy density.	10

	Power density. Electrochemical supercapacitors with carbon electrodes. Pseudocapacitor electrodes and supercapacitors. Hybrid supercapacitors: metal oxide (MeO_x/C) and electronically conducting polymer/carbon (ECP/C) types .	
	4. Electrocatalysis and Electrochemical Sensors a. Introductory aspects to fuel cell electrocatalysis. Electrochemical energy conversion. b. Electrocatalytic surfaces. Structure stability and mass transport on electrode surfaces, Basic electrocatalytic mechanisms and kinetics c. Electrochemistry of methanol electrooxidation d. Types of electrocatalysts, Electrochemistry of ORR and HER e. Introduction to principles of chemical sensing; Signal transduction; Physico-chemical and biological transducers; Sensor types and technologies, Chemically modified electrodes for sensing f. Types of electrochemical sensors (voltammetric, potentiometric, amperometric, impedimetric), Methods for sensors fabrication: self-assembled monolayers, screen printing, photolithography, microcontact printing, MEMS g. Test-strips for glucose monitoring	15
	5. Photoelectrochemical devices a.Photoelectrochemical cell design, photoconversion efficiency, photoelectrochemical water splitting b. Principles and applications of dual-working-electrode photoelectrochemistry c. Principles and working of first and second generation solar cells d. Fabrication and operational principles of third generation photovoltaics: perovskite solar cells, dye-sensitized solar cells, quantum dot solar cells e. Tandem photovoltaic cells	15
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. J.O.M. Bockris and A.K.N. Reddy, Modern Electrochemistry, Vol. 1, 2 and 3, Kluwer Academic Publishers, New York, 2002 2. A. Vincent & B. Sacrosati, Modern Batteries, John Wiley, NewYork, 1997. 3. J.O.M.Bockris & S.Srinivasan, Fuel cells: Their Electrochemistry, McGraw-HillBookCo., 1969. 4. E. Santos & W. Schmickler, Catalysis in Electrochemistry: From Fundamental to Strategies for Fuel Cell Development, Wiley, 2011	

	5. J. Lipkowski& P. N. Ross, Electrocatalysis, Wiley-VCH, New York, 1998 6. A.J. Bard, M. Stratmann , S. Licht, Encyclopedia of Electrochemistry, Semiconductor Electrodes and Photoelectrochemistry, Wiley-VCH, 2002. 7. S. Gimenez & J. Bisquert, Photoelectrochemical Solar Fuel Production: From Basic Principles to Advanced Devices, Springer International Publishing, 2016 8. V. S. Bagotsky, A. M. Skundin& Y. M. Volfkovich, Electrochemical Power Sources: Batteries, Fuel Cells, and Supercapacitors, John Wiley & Sons, Inc., New Jersey, 2015 9. N. Perez, Electrochemistry and Corrosion Science, Kluwer Academic Publishers, Boston, 2004. 10. C. Jiang, S. J. A. Moniz, A. Wang, T. Zhang, J. Tang, Photoelectrochemical devices for solar water splitting – materials and challenges, Chem. Soc. Rev., 2017, 46, 4645-4660. 11. M. Stanley, W. R. F. Savinell, T. Zawodzinski, Introduction: Batteries and Fuel Cells, Chem. Rev., 2004, 104, 10, 4243 12. E. Bakker, Y. Qin, Electrochemical Sensors, Eric Bakker, Anal. Chem. 2006, 78, 3965-3984
Course Outcome:	1. Students will be in a position to apply these concepts during the lab course in physical chemistry. 2. Students will gain knowledge and apply the same in electrochemistry dissertation and research work. 3. Students will learn about electrochemical sensors. 4. Students will learn about fuel cells.

Name of the Programme: M.Sc. Part-II (Physical Chemistry)

Course Code: CHP-621 **Title of the course:** Solid State Chemistry: Concepts and Applications

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied the chemistry/physics courses at M.Sc. Part-I	
Course Objective:	1.To introduce concepts and provide fundamental knowledge of principles of materials chemistry, characterization methods and techniques 2. To provide fundamental knowledge of molecular solids, description of crystal chemistry and classification of phase structure and significance of imperfections in solids. 3. To provide basic understanding of temperature dependence of crystal structure, phase modifications and its influence on magnetic and electronic properties of materials 4. To provide a comparative evaluation of data obtained from various techniques and their use in elucidating the chemical and morphological structure of solid materials	
Content	**1. Solid State: Introduction** General Principles and experimental procedure. Various methods in solid-state synthesis c. Kinetics of solid-state reactions, ion exchange, and intercalation reactions.	No of hours 6
	2. Crystal Chemistry and X-Ray Diffraction: a. Crystal systems, Bravais lattices and Quasicrystals. b. Ionic structures and covalent networks. c. Some important structure types –rock salt, zinc blende, wurtzite, nickel arsenide, rutile, and van der Waals heterostructures. d. Factors that Influence Crystal Structures: valences and coordination numbers. e. Significance of radius ratio rule and non-bonding electron effects. f. Powder X-ray diffraction experiment, instrumentation g. Introduction to single-crystal X-ray diffraction. Applications of high-temperature powder diffraction. h. Identification of crystal phases and evaluation of lattice characteristics	15
	3. Crystal Defects and non-stoichiometry a. Types of defects. Point defects and thermodynamics.	6

	b. Colour Centres, vacancies, and interstitials in non-stoichiometric crystals. c. Dislocations, mechanical properties, and reactivity of solids	
	4. Phase Diagrams and Phase Transitions a. Basic Concepts and definitions. b. Three-component condensed systems. Martensitic transformations. Order-disorder transitions.	6
	5. Electronic Properties and Band Theory a. Electronic structure and band theory of solids. Band structure of metals and semiconductors. b. Magnetic properties of transition metal oxides and applications Electrical conductivity, free electron theory, fermi energy, insulators, semiconductor and conductors, band theory of semiconductor, Brilliouin zones, Hall effect, the Seebeck effect, Superconductivity, BCS theory, Meissner effect, high temperature superconductor.	6
	6. Electronic Microscopic Techniques a. Introduction to Electron Microscopy: Generation of electron beam, elastic and inelastic scattering of electrons by atoms. b. Scanning Electron Microscopy (SEM): Instrumentation, optics, resolution and compositional imagining, Preparation of specimen, crystallographic information from SEM and Environmental Scanning Electron Microscopy (E-SEM) c. High Resolution Transmission Electron Microscopy (HR-TEM): Instrumentation, contrast mechanism, high voltage and Scanning Transmission Electron microscopy (STEM), preparation of specimen and data interpretation. d. Cryogenic Electron Microscopy (Cryo-TEM)	8
	7. X-Ray Spectroscopy a. Intensities: scattering of X-Rays and factors that affect intensities, powder x-ray pattern b. XRF, X-ray absorption near edge structure (XANES) and extended x-ray absorption fine structure (EXAFS): Absorption coefficient, absorption edges, resonance emission, extended absorption and photoelectron scattering. c. X-ray photoelectron spectroscopy (XPS): Surface analysis, sensitivity and specificity, photoelectron intensities, binding energies and spectra analysis c. Instrumentation and design, characterization of transition metal oxides.	8
	8. Thermal Analysis a. Thermogravimetric analysis, Differential Thermal Analysis b. Differential scanning calorimetry	5

	c. Application to the characterization of materials	
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. A. R. West, Solid State Chemistry and Its Applications, John Wiley & Sons 2003. 2. H. V. Keer, Principles of the Solid State, New Age International Publishers, 1993. 3. C. N. Banwell, E. M. McCash, Fundamentals of Molecular Spectroscopy, McGraw-Hill Education (India) Private Limited, 1994 4. P. van der Heide, X-ray Photoelectron Spectroscopy: An Introduction to Principles and Practices, John Wiley & Sons, Inc. 2012	
Course Outcome:	1. Students will be in a position to explain the concept of solid state synthesis, identify different crystal structure 2. Students will be in a position to explain the design of the instrumental techniques, data acquisition, and analysis to elucidate structural information of solid materials 3. Students will be able to apply the concepts learned to make the best choice of a characterization technique(s) for elucidation of unknown solids under investigation. 4. Students will learn about electronic microscopic techniques.	

Name of the Programme: M.Sc. Part-II (Physical Chemistry)

Course Code: CHP-622 **Title of the course:** Nanoscience: Concepts and Applications

Number of Credits: 4

Effective from AY: 2023-24

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied the M.Sc. I courses of chemistry/ physics/ biological sciences</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. Introduction of various concepts for nanoscience.
2. Introduction of various synthesis methods of nanomaterials.
3. Introduction of various characterisation techniques and application study of nanomaterials</td></tr>
<tr><td rowspan="4">Content</td><td>1. Essential Concepts and definitions
Nanoscale, quantum effects, thermal properties of nanomaterials, optical properties of nanomaterials, electrical properties of nanomaterials, Metallic nanowires and quantum conductance, Surface to volume ratio of nanoparticles, surface effects and surface energy on
Nanoparticle surface. Chemistry of solid surfaces.</td><td>No of hours

15</td></tr>
<tr><td>2. Methods of nanomaterial synthesis
Principles, methods, formation mechanism and structures of nanomaterials for:
Gas-phase processes, Liquid-phase processes, Solid-phase processes, Self-assembly processes</td><td>10</td></tr>
<tr><td>3. Characterization techniques
Beam Probe methods (SEM, TEM), Scanning probe method (STM, AFM), optical method: principle, sample preparation technique and applications. Case studies: core-shell nanoparticles, metal nanoparticles, composite nanoparticles.</td><td>10</td></tr>
<tr><td>4. Important nanomaterials
Silica: discussion of sol-gel and liquid crystal synthesis method, self-assembly of colloidal silica particles, photoluminescence property of opals, different surface functionalization methods and application study.
Gold: Different colloidal synthesis methods, self-assembly methods, surface Plasmon resonance (SPR) of colloidal gold nanoparticles surface functionalization strategies and application study.
CdSe: Different synthesis methods, synthesis of core-shell particles, Study of CdSe excitons and CdSe quantum dots, functionalization and application study.</td><td>15</td></tr>
</table>

	Iron oxide (Fe_3O_4): Different synthesis methods, Superparamagnetism property of nanoparticles, Hysteresis and magnetisation of Fe_3O_4 nanomaterial, catalytic and Biomedical applications. **Carbon:** synthesis methods for carbon nanotubes, Graphene and Buckminster fullerene, structural study of these materials, electrical property study of these materials, surface functionalization statergies and application study.	
	5. Applications of nanomaterials Heterogeneous catalysts for the synthesis of fine chemicals, Polymer vesicles for drug delivery, Surface-modified metal nanoparticles for recognition of toxic organic molecules, Use of nano TiO_2 and ZnO for water and air pollution control, Carbon Materials for Energy Storage, Thermoelectric Nanomaterials	8
	6. Nanomaterials: risk, toxicity Toxicity of inorganic-based, carbon-based, composite-based nanomaterials, environmental, health, and safety issues.	2
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. L. Cademartiri and G.A.Ozin, Concepts of Nanochemistry, Wiley-VCH, 2009. 2. C.N.R. Rao and A. Govindaraj, Nanotubes and nanowires, Royal society of Chemistry, 2005. 3. G. Cao, Nanostructures and Nanomaterials, Imperial College Press, 2004. 4. J. M. Tour, Molecular Electronics, Imperial College Press, 2004 5. H. S. Nalwa (Ed), Encyclopedia of Nanoscience and Nanotechnology, American Scientific Publishers,2004. 6. E. Roduner, Nanoscopic Materials Size-Dependent Phenomena, RSC, Publishing, Cambridge, 2006. 7. G.A. Ozin and A.C. Arsenault, Nanochemistry: A Chemical Approach to Nanomaterials, RSC Publishing, Cambridge, 2005. 8. C.P. Poole and F.J. Owens, Introduction to Nanotechnology, John Wiley and Sons, 2003. 9. B. Zhang, Physical Fundamentals of Nanomaterials, Chemical industry press, 2018. 10. C. M. Hussain, Handbook of Nanomaterials in Analytical Chemistry, Elsevier, 2020. 11. A. Barhoum and A. S. H. Makhlouf, Emerging Applications of Nanoparticles and Architecture Nanostructures: Current Prospects and Future Trends, Elsevier, 2018. 12. R.G. Chaudhuri and S. Paria. Core/shell nanoparticles: classes,	

	properties, synthesis mechanisms, characterization, and applications, Chemical reviews ACS, 2012, 112, 2373-2433.
Course Outcome:	1. Students will learn different techniques of synthesis and characterisation of nanomaterials. 2. Students should be in a position to understand and explain magnetic, electrical, optical and catalytic properties of materials at nanoscale. 3. Students should be in a position to apply the knowledge of subject for their dissertation and research work. 4. Students will learn about applications of nanomaterials.

Name of the Programme: M.Sc. Part-II (Physical Chemistry)

Course Code: CHP-623 **Title of the course:** Physical aspects of Polymer Chemistry

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied chemistry courses at M.Sc. I.	
Course Objective:	1. To introduce physical and chemical aspects of polymer chemistry. 2. To introduce kinetics of polymerization, different characteristics of polymers, applications of biodegradable and thermoset polymers.	
Content	**1. Introduction to polymer chemistry** a. Historical development in polymer chemistry, polymer industry in 21st century. b. Classification of polymers, Polymer nomenclature. Polymer tacticity, geometry and stereoregularity. c. Thermoplastics and thermosets- Plastics, elastomers, fibres. Concepts of Functionality, terminal groups, homopolymers and copolymers etc. d. Addition and condensation polymers- - linear, branched, IPN and cross-linked polymers-graft and block co-polymers.	No of hours 10
	2. Molecular weight and other classification of polymers a. Polymer molecular weight, arithmetic mean – Number average, weight average, polydispersity and Polydispersity index (PDI)) b. Degree of polymerization and its impact on MW and mechanical properties. c. Amorphous and crystalline polymers. Methods of analysis of crystallinity. d. Glass transition temperature and other thermal transitions. Importance of T_g –Plasticizers and their action. Secondary bonding forces in polymers.	10
	3. Polymerization techniques a. Methods of polymerization (homogeneous and heterogenous polymerization) b. Co-ordination polymerization, Zeigler–Natta and other catalytic polymerization techniques. c. Atom transfer radical polymerization (ATRP), Reversible addition-fragmentation chain transfer polymerization (RAFT). d. Advantages and disadvantages of polymerization techniques	10

	4. Polymer molecular weight and its determination a. Molecular weight averages: Arithmetic mean; Number average molecular weight; Weight average molecular weight. b. Molecular weight determination: end group analysis; colligative property measurement; dilute solution viscosity; Mark-Houwink-Sakurada (MHS) equation. c. Gel permeation Chromatography	8
	5. Kinetics of polymerization Introduction; Free radical chain polymerization; Equation for kinetic chain length; degree of polymerization; ceiling temperature, Anionic polymerization, Cationic polymerization, Polycondensation; Non catalyzed polycondensation; catalyzed polycondensation	8
	6. Characterization of polymers by various techniques a. Instruments and testing methods for polymer characterization b. Characterization of chemical structure of polymers: by chemical reaction methods; IR spectroscopy; Raman spectroscopy; UV-Visible spectroscopy; NMR and ESR spectroscopy. c. Characterization of polymer morphology and Physical structure of Polymers: TEM; X-ray scattering; WAXS; SAXS; AFM. d. Characterization of Thermal Properties of Polymers: Differential thermal analysis (DTA), Physical transitions, melting thermograms, Melt crystallization; Differential Scanning coulometry (DSC); Thermogravimetric analysis (TGA).	14
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. V. R. Gowarikar, N. V. Viswanathan, and J. Sreedhar, Polymer Science, Wiley Eastern Ltd., 1986. 2. P. Bahadur and N. V. Sastry, Principles of Polymer science, Narosa Publishing House, 2003. 3. J. R. Fried, Polymer Science and Technology, PHI Pvt Ltd., 2000. 4. R. Sinha, Outlines of Polymer Technology: Manufacture of Polymers, PHI Pvt Ltd., 2000. 5. R. Sinha, Outlines of Polymer Technology: Processing Polymers, PHI Pvt Ltd., 2003.	

	6. J. A. Brydson, Plastic Materials, Newnes-Butterworths, 1979, 3rd edition. 7. J. Urbanski, W. Czerwinski, K. Janicka, F. Majewska, and H. Zowall, Handbook of analysis of synthetic polymers and plastics, John Wiley, 1977. 8. K. Y. Saunders, Organic polymer chemistry, Chapman and Hall, UK, 1976. 9. R. W. Lenz, Organic chemistry of synthetic high polymers, 1967. 10. R. P. Brown, Handbook of plastic test methods, George Godwin Ltd., 1981, 2nd edition. 11. M. P. Stevens, Polymer Chemistry- An Introduction, Oxford Univ. Press, 1990, 2nd edition. 12. W. Y. Mijs, New methods in polymer synthesis, Plenum Press Ltd., NY, 1992. 13. P. C. Hiemenz, Polymer chemistry- the basic concepts, Marcell Dekker Inc., 1984. 14. W. R. Moore, Introduction to polymer chemistry, Univ. of London Press, 1961. 15. N. P. Cheremisinoff (Ed), Handbook of polymer science and technology, Marcel Dekker Inc., 1989. 16. M. Chanda, Introduction to polymer science and chemistry, A problem-solving approach, CRC press, 2006. 17. W. F. Su, Principles of Polymer design and synthesis, Volume 82, Springer, 2013. 18. R. M. Silverstein, F. X. Webster, B. J. Kimley, D. L. Bryce, S. D. Samant, V. S. Nadkarni, Spectrometric Identification of Organic Compounds, An Indian Adaptation, 8th Ed. Wiley, 2022.
Course Outcome:	1. Students will be able to explain various fundamental concepts of polymer chemistry. 2. Students should be in a position to apply the knowledge of polymer chemistry for their dissertation and research work. 3. Students should be in a position to apply these concepts during the lab course. 4. Students will learn about characterisation of polymers.

Name of the Programme: M.Sc. Part-II (Physical Chemistry)

Course Code: CHP-624 **Title of the course:** Colloids and Surface Chemistry

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied chemistry courses at M.Sc. I.	
Course Objective:	1. To introduce some core concepts of colloidal chemistry including DLVO theory, electrokinetic phenomena and diversity in colloids. 2. To introduce fundamental concepts and applications of colloids in day-today life.	
Content	**1. Colloids and Liquid Surfaces** a. Colloids: General introduction, classification and structural characteristics of colloidal system, preparation and purification b. Microscopic picture of liquid surface c. Surface tension and its measurement. Surfactant and reduction of surface tension. Curved liquid surfaces. d. Nucleation theory. e. Surface modification: self-assembly monolayer formation. Physisorption of polymers. Polymerization on surfaces.	No of hours 10
	2. Electrostatic Forces and Electrokinetic Phenomenon a. Electrical double layer. Surface interactions between surfaces (dipole, induced dipole, H-bonding) b. Surface forces: Van der Waals forces between molecules. Surface energy and Hamaker constant. Measurement of surface forces. The DLVO theory c. Charged surfaces such as mercury, silver iodide and oxides. Measurement of surface charge densities d. Electrocapillarity - theory and measurement e. Electrokinetic phenomena: concept of zeta potential. Electroosmosis and streaming potential. Electrophoresis and sedimentation potential. f. Contact angle and its measurements. Wetting and dewetting. Important wetting geometries.	12
	3. Colloidal Stability a. Charged colloids. Electrical charge distribution at interfaces b. Factors affecting colloidal stability. Effect of electrolyte.	8

	c. Flocculation and coagulation. Kinetics of coagulation d. Steric stabilization of solid and liquid colloids	
	4. Preparation of colloids a. Chemical methods for synthesis of colloids: Sol-gel method, polyol synthesis, plasma enhanced chemical vapor deposition, hydrothermal synthesis b. Colloidal synthesis of semiconductor nanoparticles: Hot-injection synthesis. Synthesis of colloidal core-shell heterostructures c. Surface directed colloidal patterning: Colloidal self-assembly approaches d. Reducing agents in colloidal nanoparticle synthesis	12
	5. Surfactants, Micelles, Emulsions and Thin Liquid Films a. Classification of surfactants. Solubilization and micelle formation b. Spherical micelles: cmc and influence of temperature. Thermodynamics of micellization. Structure of surfactant aggregates. c. Emulsions: Macro and microemulsions, properties, formation and factors affecting the stability. Evolution and aging. Coalescence and demulsification. Size of droplets. Elasticity of surfactant films. d. Thin films on surfaces of liquids: Introduction and phases. Bubbles and foams. Optical and X-Ray methods to study monolayers. e. Langmuir Blodgett Transfer	13
	6. Applications of Colloids in Science, Technology and Industry a. Colloids as drug delivery agents b. Colloidal nanocrystals for optical applications and solar cells. c. Biomedical applications	5
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. H. J. Butt, K. Graf and M. Kappl, Physics and Chemistry of Interfaces, Wiley-VCH, 2003. 2. A. W. Adamson and A.P.Gast, Physical Chemistry of Surfaces; Wiley-VCH, 1997, 6th edition 3. R. D. Vold and M. J. Vold, Colloid and Interface Chemistry, Addison-Wesley, 1983.	

	4. K. S. Birdi, Surface and Colloid Chemistry, Principles and Applications; Taylor & Francis Group ,2010. 5. D. Meyers, Surfaces, Interfaces and Colloids, Principles and Applications; John Wiley & Sons, Inc. 1999. 2nd edition. 6. E. D. Shchukin, A. V. Pertsov, E. A. Amelina, A. S. Zelenev, Studies in Interface Science, Colloid and Surface Chemistry; Elsevier, 2001. 7. D. J. Shaw, Introduction to Colloid and Surface Chemistry, 4th Ed. Elsevier, 1992. 8. F. Caruso, Colloids and Colloid Assemblies, Wiley-VCH, 2004. 9. V. Lesnyak, M. Yarema, S. Miao, Colloidal Semiconductor Nanocrystals: Synthesis, Properties and Applications, Frontiers Media SA, 2020.
Course Outcome:	1. Students will be able to explain various fundamental and core concepts of colloid chemistry. 2. Students should be in a position to apply the knowledge of colloidal chemistry for their dissertation and research work 3. Students should be in a position to apply these concepts during the lab course in physical chemistry. 4. Students will understand applications of colloids.

Name of the Programme: M.Sc. Part-II (Chemistry)

Course Code: CHC-600 **Title of the course:** Research Methodology and instrumental techniques-I

Number of Credits: 4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I level.	
Course Objective:	1. To introduce various aspects of research methodology. 2. To provide understanding ethics & scientific conduct. 3. To introduce academic writing. 4. To introduce databases used in chemistry. 5. To provide understanding and importance of lab safety. 6. To understand the usefulness of various instrumental techniques in characterization of chemical compounds.	
Content	**1. Introduction to Research Methodology** Research- meaning, objectives, motivation, types and methodology. Process- formulating the research problem; literature survey; developing the hypothesis and the research design; sample design and collection of the data; execution of the project; analysis of data; testing of hypothesis; generalizations and interpretation, and preparation of the report or presentation of the results & conclusions.	No of hours 5
	2. Scientific conduct and ethics Ethics: definition, nature of moral judgements and reactions, Ethics with respect to science and research. Intellectual honesty and research integrity. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP). Redundant publications: duplicate and overlapping publications. Selective reporting and misrepresentation of data.	5
	3. Academic writing Publication ethics: definition, introduction and importance Conflicts of interest Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa Violation of publication ethics, authorship and contributorship Identification of publication misconduct, complaints and appeals Predatory publishers and journals	5

	4. Data bases and research metrics Databases: 1. Indexing databases 2. Citation databases: Web of Science, Scopus, UGC-Care List etc. Research Metrics: 1. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score 2. Metrics: h-index, g index, i10 index etc	3
	5. Safety aspects in Chemistry Good laboratory practices. Handling of various chemicals, solvents & glassware. Fires and fighting with fires. Hazardous substances, classification and handling Safety Data Sheet	5
	6. Softwares in Chemistry Data plotting Structure Drawing Reference management software	7
	7. Instrumental methods of analysis: Demonstration and/ or data analysis in following techniques: Elemental analysis: CHNS analysis and AES Infrared (IR), Raman, Ultraviolet-Visible (UV-Vis) Nuclear magnetic resonance (^{1}H, ^{13}C) Chromatographic techniques: HPLC, GC, Hyphenated Techniques: LC-MS & GC-MS, Diffraction methods: XRD Thermal analysis: DSC Microscopy: SEM, TEM Methods for determination of magnetic & dielectric properties. Cyclic voltammetry	30
Pedagogy	Mainly lectures/recorded video lectures/ tutorials, discussions, seminars, internal exams/ assignments, / demonstration/ self-study or a combination of some of these. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. C. R. Kothari, Research Methodology: Methods & Techniques, New Age International Pvt. Ltd., 2004. 2. Bird, Philosophy of Science, Routledge, 2006. 3. M. Coghill & L. R. Garson, The ACS Style Guide: Effective Communication of Scientific Information, American Chemical Society Washington, DC & OXFORD University Press New York, 2006. 4. Y. K. Singh, Fundamentals of Research Methodology & Statistics, New Age International Pvt. Ltd., 2006. 5. National Research Council, Prudent practices in the laboratory: handling and management of chemical hazards, The National	

	Academies Press, USA, 2011. 6. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, Vogel's Text book of Practical Organic Chemistry, 5th Ed.; Longmann, 1989 7. E. A. V. Ebsworth, D. W. H. Rankin & S. Craddock, Structural Methods in Inorganic Chemistry, Blackwell Scientific Publishers. 1986. 8. R. S. Drago, Physical Methods in Chemistry, 2nd Ed. W. B. Saunders Co. Ltd. 2016 9. R. M. Silverstein, F. X. Webster; Spectrometric identification of Organic Compounds; 6th Ed, Wiley, 2011. 10. J. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed.; Pearson Education Asia, 2002. 11. H. V. Keer, Principles of the Solid State, 1st Ed. New Age International (P) Ltd., 2005. 12. G. D. Christian, Analytical Chemistry, 6th Ed.; Wiley, 2004. 13. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed.; Cengage learning. 14. Skoog, F. J. Holler, S. R. Crouch, Principles of Instrumental Analysis, 7th Ed.; Cengage learning. 15. P. G. Lampman, G. Kriz and J. Vyvyan, Introduction to Organic Spectroscopy, 5th Ed.; Cengage Learning, 2015. 16. N. Elgrishi,´ K. J. Rountree, B. D. McCarthy, E. S. Rountree, T. T. Eisenhart, and J. L. Dempsey, A Practical Beginner's Guide to Cyclic Voltammetry, J. Chem. Educ. ACS, 2018, 95, 197−206. 17. V. Rajaraman, Computer Programming in Fortran 90 And 95, PHI Learning Pvt. Ltd., 2013. 18. Szabo, N. S. Ostlund, Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory, Dover Publications, Inc. Mineola, 1989.
Course Outcome:	1. Students will be able to apply research methodology concepts. 2. Students will be able to apply computer technology to solve their research problems in chemistry. 3. Students will know in advance the safety precautions to be taken in the chemical lab. 4. Students will gain fundamental knowledge on characterization techniques.

Name of the Programme: M.Sc. Part-II (Chemistry)

Course Code: CHC-601 **Title of the course:** Research Methodology and instrumental techniques-II

Number of Credits: 4

Effective from AY: 2023-24

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied chemistry courses at MSc-I.</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. To introduce various aspects of research methodology.
2. To provide understanding ethics & scientific conduct.
3. To introduce academic writing.
4. To introduce databases used in chemistry.
5. To provide understanding and importance of lab safety.
6. To understand the usefulness of various instrumental techniques in characterization of chemical compounds.</td></tr>
<tr><td>Content</td><td>1. Research Methodology, Scientific conduct, ethics & academic writing
Research- meaning, objectives, motivation, types and methodology.
Process- formulating the research problem; literature survey; developing the hypothesis and the research design; sample design and collection of the data; execution of the project; analysis of data; testing of hypothesis; generalizations and interpretation, and preparation of the report or presentation of the results & conclusions.
Ethics: definition, nature of moral judgements and reactions, Ethics with respect to science and research.
Intellectual honesty and research integrity.
Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP).
Redundant publications: duplicate and overlapping publications.
Selective reporting and misrepresentation of data.
Publication ethics: definition, introduction and importance
Conflicts of interest
Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa
Violation of publication ethics, authorship and contributorship
Identification of publication misconduct, complaints and appeals
Predatory publishers and journals</td><td>No of hours

15</td></tr>
<tr><td></td><td>2. Softwares in chemistry, Data bases and Research metrics</td><td>10</td></tr>
</table>

	Data plotting using GNU plot; Structure Drawing using ChemSktech; Reference management software such as Mendeley and Zotero. Databases: Indexing databases, Citation databases: Web of Science, Scopus, UGC-Care List, Scimago etc. Research Metrics: Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, g-index, i10-index etc Molecular Docking software	
	3. Safety practices in Chemical research Introduction to lab safety. Handling of various chemicals, solvents & glassware. Fires and fighting with fires. Hazardous substances, classification and handling Safety Data Sheet	5
	4. Instrumental methods UV-Visible spectroscopy in elucidation of mechanisms of C-H activation reactions, epoxidation etc by transition metal catalyst. Understanding water oxidation reaction using Cyclic voltammetry (CV) & Linear Sweep voltammetry (LSV) Determining capacity of supercapacitors using Galvanostatic Charge-Discharge (GCD) Electrochemical Impedance Spectroscopy (EIS) Resonance Raman and isotope labelling studies. Infrared (IR) spectroscopy applications ^{1}H, ^{13}C- NMR spectroscopy and applications Selected chromatographic techniques such as HPLC, GC. Hyphenated Techniques/applications: LC-MS, GC-MS, LC-NMR-MS, GC-IR, ICP-MS Diffraction methods: High temperature XRD Thermal analysis: TG/DTA/DSC Microscopy: Fe-SEM, HR-TEM Methods for determination Ms, Mr, Hc, Tc, ε^{1} and Tanδ. Potentiometry	30
Pedagogy	Mainly lectures/recorded video lectures/ tutorials, discussions, seminars, internal exams/ assignments, / demonstration/ self-study or a combination of some of these. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. C. R. Kothari, Research Methodology: Methods & Techniques, New Age International Pvt. Ltd., 2004. 2. Bird, Philosophy of Science, Routledge, 2006. 3. M. Coghill & L. R. Garson, The ACS Style Guide: Effective Communication of Scientific Information, American Chemical Society Washington, DC & OXFORD University Press New York,	

	2006. 4. Y. K. Singh, Fundamentals of Research Methodology & Statistics, New Age International Pvt. Ltd., 2006. 5. National Research Council, Prudent practices in the laboratory: handling and management of chemical hazards, The National Academies Press, USA, 2011. 6. B. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, Vogel's Text book of Practical Organic Chemistry, 5th Ed.; Longmann, 1989 7. E. A. V. Ebsworth, D. W. H. Rankin & S. Craddock, Structural Methods in Inorganic Chemistry, Blackwell Scientific Publishers. 1986. 8. R. S. Drago, Physical Methods in Chemistry, 2nd Ed. W. B. Saunders Co. Ltd. 2016 9. R. M. Silverstein, F. X. Webster; Spectrometric identification of Organic Compounds; 6th Ed, Wiley, 2011. 10. J. Mendham, R. C. Denny, J. D. Barnes & M. Thomas, Vogel's Textbook of Quantitative Chemical Analysis, 6^{th} Ed.; Pearson Education Asia, 2002. 11. H. V. Keer, Principles of the Solid State, 1st Ed. New Age International (P) Ltd., 2005. 12. G. D. Christian, Analytical Chemistry, 6th Ed.; Wiley, 2004. 13. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed.; Cengage learning. 14. Skoog, F. J. Holler, S. R. Crouch, Principles of Instrumental Analysis, 7th Ed.; Cengage learning. 15. Pavia, G. Lampman, G. Kriz and J. Vyvyan, Introduction to Organic Spectroscopy, 5th Ed.; Cengage Learning, 2015. 16. N. Elgrishi,´ K. J. Rountree, B. D. McCarthy, E. S. Rountree, T. T. Eisenhart, and J. L. Dempsey, A Practical Beginner's Guide to Cyclic Voltammetry, J. Chem. Educ. ACS, 2018, 95, 197−206. 17. V. Rajaraman, Computer Programming in Fortran 90 And 95, PHI Learning Pvt. Ltd., 2013. 18. Attila Szabo, Neil S. Ostlund, Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory, Dover Publications, Inc. Mineola, 1989. 19. Leach, Molecular Modelling, Principles and applications, Longman, 1998. 20. W. Nam et al, Dioxygen activation by Metalloenzymes & models, Accounts of Chemical Research, 2007, Volume 40 & references cited therein.
Course Outcome:	1. Students will be familiar with research methodology concepts. 2. Students will be able to apply computer technology to solve their research problems in chemistry. 3. Students will know in advance the safety precautions to be taken in the chemical lab. 4. Students will gain fundamental knowledge on characterization techniques.

Name of the Programme: M.Sc. Part-II (Chemistry)

Course Code: CHC-651 **Title of the course:** Discipline Specific Dissertation

Number of Credits: 16

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I level.	
Course Objective:	To develop the skills of preparing and conducting independent research.	
Content	As per OA-35	No of Hours 480
Pedagogy:	Dissertation carried out individually by each student throughout the academic year.	
References / Readings:	As required for the development of review and methodology.	
Course Outcome:	Students will be able to understand and apply the tools and techniques of chemistry in conducting independent research.	

ANNEXURE-I

M.Sc. Pharmaceutical Chemistry AY 2022-23

SEM I			
Sr. No.	**Subject code**	**Paper title**	**Credits**
1.	CHO-500	Fundamentals of Organic Chemistry	4
2.	CHH - 500	Fundamentals of Pharmaceutical Chemistry-I	4
3.	CHP-500	General Physical Chemistry	4
4.	CHA-500	Techniques in Analytical Chemistry-I	4
5.	CHO-521	Practical Course in Organic Chemistry-I	2
6.	CHO-522	Practical Course in Organic Chemistry-II	2
7.	CHH - 521	Practical Course in Pharmaceutical Chemistry-I	2
8.	CHH - 522	Practical Course in Pharmaceutical Chemistry-II	2
9.	CHP-521	Practical Course in Physical Chemistry-I	2
10.	CHP-522	Practical Course in Physical Chemistry-II	2
11.	CHA-521	Practical Course inAnalytical Chemistry-I	2
12.	CHA-522	Practical Course in Analytical Chemistry-II	2
SEM II (Pharmaceutical Chemistry)			
1.	CHH - 501	Fundamentals of Pharmaceutical Chemistry-II	4
2.	CHH - 502	Drug Product Formulation, Development and Manufacture	4
3.	CHH - 503	Drug Design, Discovery and Development	4
4.	CHH - 504	Biopharmaceutics and Pharmacokinetics	4

SEM III			
1.	CHH-600	Practical Course in Pharmaceutical Chemistry-III	4
2.	CHH-601	Practical Course in Pharmaceutical Chemistry-IV	4
3.	CHH-604	Retrosynthetic Approach and Heterocyclic Drug Synthesis	4
4.	CHH-605	Research Methodology in Pharmaceutical Chemistry and instrumental techniques	4
5.	CHH-621	Polymers in Pharmaceuticals and novel drug delivery systems	4
6.	CHH-622	Pharmacotherapeutics	4
7.	CHH-623	API Process, Manufacture and Green Chemistry	4
8.	CHH-624	Pharmaceutical and Spectral analysis	4
9.	CHH-625	Bioorganic and Medicinal Chemistry	4
SEM IV			
1.	CHH-602	Pilot Plant Scale-Up Techniques for Pharmaceuticals	4
2.	CHH-603	Pharmacological and Toxicological Screening Techniques	4
3.	CHC-651	Discipline Specific Dissertation	16

<u>M.Sc. Part-I (Chemistry)</u>

<u>Title of the course: Fundamentals of Organic Chemistry</u>

Course Code: CHO-500

Number of Credits: **04**

Effective from AY: **2022-23**

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objective:	1. To study the various concepts based on molecular orbital theory. 2. To understand the concepts of topicity, prostereoisomerism and chemo-, regio- and stereoselectivity in organic reactions. 3. To understand the mechanistic aspects of various type of reactions in organic synthesis.	
Content	**1.Molecular orbitals and delocalized chemical bonding** a. Qualitative description of molecular orbitals of simple acyclic and monocyclic systems, frontier molecular orbitals. b.Conjugation, cross conjugation, resonance, hyperconjugation and tautomerism (types and examples). c. Aromaticity: Origin of Huckel's rule, examples of aromatic, non-aromatic and antiaromatic compounds; concept of Mobius aromaticity.	No of hours 08
	2.Structure & Reactivity a. Acidity, basicity and pKa of organic compounds; Acid and base strengths; HSAB concept & Factors affecting it, effect of structure & medium on acid and base strength. b. Concept of superacids and superbases. c. Electrophilicity & nucleophilicity, examples of ambident nucleophiles &electrophiles. (Including revision of aromatic electrophilic and nucleophilic substitution)	08
	3.Stereochemistry a. Brief revision of configurational nomenclature: R & S; D & L; E & Z; cis &trans and *syn* & *anti* nomenclature. Chirality in molecules with two and more chiral centres. b. Conformational analysis of open chain compounds (Butane, 2, 3-butane diol, 2,3-dibromobutane etc.). *Erythro* and *threo* nomenclature. c. Topicity and Prostereoisomerism: Topicity of ligands and faces-homotopic, enantiotopic and Cram's rule /diastereotopic ligands and faces.	14

	d. Introduction to chemoselective, regioselective and stereoselective reactions. e. Stereochemistry of *cis*- and *trans*-decalins, conformation and reactivity of cyclohexane and substituted cyclohexanes, cyclohexene / cyclohexanone. conformational isomerism and analysis in acyclic and simple cyclic systems –substituted ethanes, cyclopentane, cyclohexane cycloheptane, cyclooctane and decalins, f. optical isomerism - optical activity - molecular dissymmetry and chirality - elements of symmetry. optical isomerism in biphenyls, allenes and spirans - optical isomerism of nitrogenous compounds racemisation and resolution.	
	4.Reaction Mechanism a. Brief revision of carbocations, carbanions, free radicals, carbenes, Arynes and nitrenes with reference to generation, structure, stability and reactivity; b. Types of mechanisms, types of reactions, thermodynamic and kinetic control. c. The Hammond postulate and principle of microscopic reversibility, d. Methods of determining reaction mechanisms like- i. Identification of products, ii. Determination of the presence of intermediates (isolation, detection, trapping and addition of suspected intermediate, iii. Isotopic labelling, iv. Stereochemical evidence, v. Kinetic evidence and vi. Isotope effect (at least two reactions to exemplify each method be studied)	08
	5.Aliphatic Nucleophilic substitution a. Brief revision of nucleophilic substitutions with respect to Mechanism, various factors affecting such reactions; b. The Neighbouring Group Participation (NGP)/ Anchimeric assistance: General approach to various NGP processes; NGP by unshared/lone pair of electrons; NGP by π-electrons; NGP by aromatic rings (formation of phenonium ion intermediate); NGP by sigma bonds with special reference to bornyl and nor-bornyl system (formation of nonclassical carbocation)	08
	6.Elimination reactions a. The E2, E1 and E1cB mechanisms. Orientation of the double bond, Saytzeff and Hofmann rule. b. Effects of changes in the substrate, base, leaving group and	08

	medium on i. Overall reactivity, ii. E1 vs. E2 vs. E1cB iii. Elimination vs substitution, Mechanism and orientation in pyrolytic *syn* elimination (various examples involving cyclic and acyclic substrates to be studied).	
	7. Selective reagents for Organic transformation a. Oxidation of organic compounds, PCC, PDC and MnO_2, ozonolysis, peracids. b. Reduction of organic compounds: $NaBH_4$, LAH, DIBAL reduction and reduction with borane and dialkylboranes. Clemmensen reduction, Birch reduction and Wolff-Kishner reduction	06
Pedagogy	Mainly lectures and tutorials. Seminars/term papers/assignments/presentations/ self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. W. Caruthers, I. Coldham, Modern Methods of Organic Synthesis, Cambridge University Press, 4^{th} Ed., 2016. 2. M. B. Smith, Organic Synthesis, McGraw–HILL, New York, International Edition, 1994. 3. J. Clayden, N. Greeves, S. Warren, P. Wothers, Organic Chemistry, Oxford University Press, 2^{nd} Ed., 2012. 4. R. Bruckner, Advanced Organic Chemistry – Reaction Mechanisms, San Diego, CA: Harcourt /Academic Press, San Diego, 2002. 5. J. Fuhrhop, G. Penxlin, Organic Synthesis – Concepts, Methods, Starting Materials, VCH Publishers Inc., New York, 1994. 6. H. O. House, Modern Synthetic Reactions, W. A. Benjamin, 2^{nd}Ed.,1965 7. M. Nogradi, Stereoselective Synthesis, VCH Publishers, Inc., Revised and Enlarged Edition, 1994. 8. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry, Springer India Private Limited, 5^{th}Ed, 2007. 9. T. Laue, A. Plagens, Named Organic Reactions, John Wiley and Sons, Inc., 2005.	
Course outcomes:	1. Students will be in a position to evaluate the effect of delocalization of electrons & presence or absence of aromaticity in organic compounds. 2. Students will be able to apply various concepts in stereochemistry to understand stereochemical outcome in a reaction. 3. Students shall be in a position to understand/propose plausible mechanism of organic reactions. 4. Students will be able to understand and apply various reagents for desired organic transformations.	

Title of the course: Fundamentals of Pharmaceutical Chemistry-I

Course Code: CHH-500

Number of Credits: 04

Effective from AY: 2022-23

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University. Knowledge of Pharmaceutical Chemistry is added advantage but not mandatory. This is to understand the basics in pharmaceutical chemistry and importance of chemistry in pharmacy.</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. To get introduced to pharmaceutical chemistry and terms involved.
2. To understand the various classes of drugs with examples with special reference to Structure, IUPAC name, Mechanism of action, Structure Activity Relationships and Synthesis.</td></tr>
<tr><td rowspan="2">Content</td><td>1. Pharmaceutical chemistry, physicochemical properties of drugs, drug metabolism and assay of drugs: Role of Chemistry in Pharmacy: Introduction to pharmaceutical chemistry. Need to study pharmaceutical chemistry. Important terminologies: Pharmacodynamics, Pharmacokinetics, Pharmacognosy, Materia medica, Toxicology, Pharmacopoeia, Pharmacophore- Effect of functional groups on physiological activity of drugs: hydroxy, acidic, alkyl, aldehyde, ketone, cyano, halogens, ether and ester groups with examples.
Physicochemical properties of Drugs: Effect of Solubility, Partition Coefficient, Ionisation constant, Surface Active agents, Chelation, Hydrogen bonding, stereoisomers on the pharmacological action of drugs (specific example of API to be given). Drug Action, Drug Metabolism-Significance of drug metabolism. Phase I, Phase II pathways with reactions. Factors on which drug metabolism depends. Assay of drugs-Chemical, biological and immunological assay.</td><td>No of hours

12</td></tr>
<tr><td>Classification of Chemotherapeutic Drugs: Development of the following drugs including structure activity relationship (S.A.R.), mechanisms of action (MA), outline of synthesis ($), chemical nomenclature, generic names (GN) and side effects (SE) (outline of synthesis only of those marked$)
2. Anti-Infective agents-I:
Antiseptics and Disinfectants: Alcohols, substituted phenols, methenamine mandalate, Chloramine-T (MA), 8-hydroxy</td><td>12</td></tr>
</table>

	quinoline derivatives, Acridine derivatives, Mercurials like (Mercurochrome, Thiomersal) and Nitrofurantoin derivative,Triclosan $. **Antitubercular agents**- Aminosalicylic acid, PAS (MA), Pyrazinamide$, Ethambutol (SAR and $), Clofazemine, **Antimalarials**: Life cycle of parasite, drug acting on different stages- Quinine, Chloroquine$, Primaquine, Trimethoprim, Proguanil (MA), Cycloguanil, Drug combinations. **Antiamoebics**: General aspect of infection, Life cycle of parasite, Hydroxyl quinolines, Metronidazole (SAR and $), Lucanthone (MA), **Anthelmentics**: Diethylcarbamazine, Niclosamide, Mebendazole$, Oxamniquine.	
	3. Anti-Infective agents-II: **Antivirals** including drugs acting on HIV Idoxuridines, Amantadine Hydrochloride$,Acylclovir. **Antineoplastics**: 6-Mercaptopurine (MA), Thiotepa$, Chlorombucil, Taxol, **Antifungal**: **Antibiotics** like Nystatin, Tolnaflate$, Clotrimazole$. Sulfonamides and other antifolics: Sulfonamides (MA) and other para-aminobenzoic acid antagonist, Sulfacetamide$, Sulfamethoxazole, Newer antibacterial agents: Quinoline carboxylic acids such as Ciprofloxacin, Temafloxacin. Hypoglycemics: Insulin and various sulfonyl ureas like tolbutamide$, Tolazamide, phenformin, Glipizide.	12
	4. Anti-lipidemics, Diuretics, and diagnostic agents: **Anti-lipidemics**: Clofibrate$, nicotinic acid, boxidine**Diuretics**: Acid forming osmotic diuretics, Mercurials-Meralurides,Sulfonamides-Acetazolamide$. Chlorthiazide$, Hydrochlorthiazide, Ethacrynic acid. **Synthetic sweeteners.** Diagnostic agents Inorganic compounds- Iodoxyl, Iodophendylate. **Dyes**- Rose Bengal, Fluorescein, Aminohippuric acid$.	12
	5. Hypotensive agents, General and Local Anaesthetics: **Hypotensive agents** acting on vascular smooth muscles: Nitrites, Amylnitrites, Glyceryl nitrite$, Pentaerythritol	12

	tetranitrate, Isosorbide dinitrate (MA). **General Anaesthetics**: Ether, Nitrous oxide, Halothane$, Ultra short acting Barbiturates-Thiopental sodium $. **Local anaesthetics**: Cocaine, Benzocaine$, Procaine (MA), Lidocaine$, Purgatives and cathartics: Phenolphthalein, Castor oil.	
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. D. A. Williams & T. L. Lemke, Foye's principles of medicinal chemistry, 5th edition, Lippincott Williams and Wilkins, 2006. 2. J. M. Beale & J. M. Block, Wilson &Gisvold's Text book of Organic Medicinal & Pharmaceutical Chemistry, Lippincott Williams and Wilkins, 2004. 3. D. J. Abraham & D.P. Rotella, Burger's Medicinal Chemistry Drug Discovery and Development (John Wiley & Sons N.Y), 7th edition, 2010. 4. D. Shriram, P. Yogeshwari, Medicinal Chemistry, Pearson Education, 2007. 5. G. L. Patrick: Introduction to Medicinal Chemistry, Oxford University Press, UK. 6th edition, 2017. 6. D. Lednicer& L.A. Mitscher, The Organic Chemistry of Drug Synthesis. (6 volume set) III. John Wiley & Sons, 2005. 7. H. Singh & V. K. Kapoor: Medicinal and Pharmaceutical Chemistry, Vallabh Prakashan, Pitampura, New Delhi, 2010. 8.G. R Chatwal, Medicinal Chemistry (Organic Pharmaceutical Chemistry), Himalaya Publishing house, 2002.	
Course Outcome:	1. Students will be able to identify the examples in different classes of drugs. 2. Students will be able to write IUPAC names and Structure of drugs. 3. Students will be in a position to understand the mechanism of action of selected classes of drugs. 4. The students will have a clear understanding of concepts on SAR analysis. 5. The students will be able to apply synthetic organic chemistry knowledge in devising a synthesis for a drug.	

Title of the course: General Physical Chemistry

Course Code: CHP-500

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objective:	1. Introduction of various concepts on thermodynamics. 2. Introduction of electro chemistry and kinetics. 3. Learning quantum chemistry.	
Content	**1. Mathematical Preparations** a. Introduction to various functions and function plotting (exponential, logarithmic, trigonometric etc.), functions of many variables. Complex numbers and complex functions. b. Linear equations, vectors, matrices and determinants. c. Basic rules of differentiation and integration, Partial differentiation, location and characterization of critical points of a function, Regression methods, curve fitting. d. Introduction to series, convergence and divergence, power series, Fourier series e. Probability (permutations and combinations).	No of hours 12
	2. Quantum Chemistry a. Operators, Functions, Eigen value equations, Postulates. b. Schrodinger equation, application to simple system viz. free particle, particle in one dimensional, two dimensional and three-dimensional box (quantization, separation of variables, degenerate wave functions). c. Hydrogen like atoms, Schrodinger equation and its solutions, atomic orbital wave functions and interpretation. d. Hückel MO theory, Secular equations, Secular determinant, delocalization energy, charge density, π-bond order, free valence, applications to C_2H_4, C_3H_5 (radical), C_4H_6, C_4H_4, C_6H_6, C_6H_8.	20
	3. Thermodynamics a. Thermodynamic properties: Gas laws, Real gasses, Boyle temperature, Critical temperature, State and path properties. Intensive and extensive properties. Exact and inexact differentials. Internal energy, enthalpy, entropy, free energy and their relations and significances. Maxwell relations. Thermodynamic equations of state b. Joule-Thomson effect. Joule-Thomson coefficient for van	12

	der Waals' gas. Joule-Thomson effect and production of low temperature, adiabatic demagnetization, Joule-Thompson coefficient, inversion temperature. c. The third law of thermodynamics. Need for the third law. Apparent exceptions to third law. Application of third law. Use of thermodynamic functions in predicting direction of chemical change. Entropy and third law of thermodynamics. d. Phase equilibria: Phase rule, Discussion of two component systems forming solid solutions with and without maximum or minimum in freezing point curve. Systems with partially miscible solid phases. e. Three component systems: Graphical representation. Three component liquid systems with one pair of partially miscible liquids. Influence of temperature. Systems with two pairs and three pairs of partially miscible liquids. The role of added salts.	
	4. Electrochemistry a. EMF series, The cell potential: The Nernst equation, Cells at equilibrium. Determination of thermodynamic functions. b. Decomposition potential and overvoltage, electronegativity, basic principles, completeness of deposition, Separation with controlled potentials, constant current electrolysis, composition of electrolyte, potential buffers, physical characteristics of metal deposits. c. Electroplating and electroless plating, electrosynthesis. d. Concepts of acid-base aqueous and non-aqueous solvents, hard and soft acid-base concept and applications.	8
	5. Chemical Kinetics a. General introduction to various types of order of reaction including fractional order, Molecularity of the reaction. b. Introduction to reversible and irreversible reactions and reactions leading to equilibrium. Van'tHoffs equation and analysis of Gibbs free energy of equilibrium reactions. c. Collision Theory and Maxwell Boltzmann distribution of energies of colliding molecules (derivation not required). The concept of collisional cross section and reactive cross section and its significance. d. Comparative study of transition state and collision state theory (derivation not required). e. Reaction Mechanisms: elementary reactions, Consecutive elementary reactions, steady state approximation, the rate determining step and pre-equilibria f. Free radical reactions, Complex reactions such as acetaldehyde decomposition and reaction between H_2 and	8

	Br_2, Homogeneous reactions and acid-base catalysis. g. Elementary enzyme reactions. Lineweaver-Burk plot and its analysis	
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. P. W. Atkins and J. D. Paula, Physical Chemistry, 8th Ed., Oxford University Press, New Delhi. 2007 2. G. M. Barrow, Physical Chemistry, 5th Ed., Tata McGraw Hill, New Delhi. 2016 3. J. E. House, Principles of Chemical Kinetics, 2nd Ed., Academic Press, Elsevier Burlington, USA 2007 4. I. N. Levine, Quantum Chemistry, 7th Ed., Prentice-Hall, New Delhi. 1999	
Course outcomes:	1. Students should be in a position to understand and explain various concepts in physical chemistry. 2. Students should be in a position to apply these concepts during the lab course in physical chemistry. 3. Students will be able to understand concepts of electrochemistry. 4. Students will be able to apply fundamentals of chemical kinetics for understanding reaction mechanisms.	

Title of the course: Techniques in Analytical Chemistry - I

Course Code: CHA-500

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objective:	1. Learning various methods of data handling in analysis. 2. Understanding the significance of sampling and calibration techniques. 3. Understanding principles and applications of various types of techniques 4. Training the students to deduce structures based on IR, NMR, MS combined data.	
Content:	**1. Analytical Objectives and Data Handling** Importance of analytical chemistry in research and industry; statistics and data handling in analytical chemistry, standard operating procedures, good laboratory practices: quality assurance, method validation and quality control.	No. of Hours 5
	2. Sampling and Calibration Techniques Sampling and sample preparation, general steps in chemical analysis, calibration of glass wares. Finding the best straight line-least square regression, correlation coefficient; Calibration curves, standard addition technique and internal standards. Chemical concentrations.	5
	3. Classical methods of Analysis Gravimetry and Titrimetric methods, Principle, methodology, Advantages & Disadvantages over instrumental methods. Conditions for identifying a givenreaction as method of Analysis, Classification of reactions in titrimetricanalysis (Acid-Base, redox, complexometric and precipitation), Standardsolutions and their preparation. Selection of Visual Indicators in titrimetric Analysis	6
	4. Introduction to Electroanalytical techniques Introduction to electrochemical cell, electrode potential, Classification of electroanalytical techniques, working principles, and their applications	4
	5. Introduction to Thermoanalyticaltechniques Principle, Instrumentation and applications of Thermo Gravimetric Analysis, Differential Thermal Analysis, and Differential Scanning Calorimetry. Numericals based on TGA.	5
	6. Introduction to Chromatographic Techniques a. Principles of chromatography, classification of	15

	chromatographic techniques based on mechanism of retention, configuration, mobile and stationary phase. Efficiency of separation- plate theory (theoretical plate concept) and rate theory (van Deemter equation). b. Principles and applications of Paper chromatography, thin layer chromatography, HPTLC, Size exclusion and Ion exchange chromatography. Counter-current chromatography for isolation of natural products. c. Gas and Liquid Chromatography: Introduction; Instrumental Modules; The Separation System; Choice of Conditions of Analysis; Sample Inlet Systems; Detectors; Practical Considerations in Qualitative and Quantitative Analysis; Coupled Systems-introduction to GCMS, LCMS; Applicability-interpretation and numericals.	
	7. Introduction to Spectroscopic Techniques a. Interaction of Electromagnetic Radiation with Matter: Electromagnetic spectra, regions of spectrum, numericals. b. Ultraviolet and visible Spectroscopy: Electronic spectra and Molecular structure: types of electronic transition, Chromophore and auxochrome, absorption by isolated chromophore, conjugated chromophores, aromatic compounds, inorganic chelates. Calculating λmax for Conjugated Dienes, Trienes, polyenes, α,β-unsaturated carbonyl compounds, Numericals. Choices and effect of solvents on UV-Vis. Quantitative Calculations: Beer-Lambert Law; Mixtures of absorbing species-laws of additivity of absorbance; calibration curve for calculation of unknown; Spectrometric errors in measurement; Deviation from Beer-Lambert Law - chemical deviation, instrumental deviation; Numericals for quantitative analysis using UV-VIS spectroscopy. c. Infrared Spectroscopy: Infrared absorption and molecular structures, molecular vibrations, types of vibrations, IR spectra, overtones and bands-basis of NIR absorption. Spectra interpretation, Frequencies of functional group, Spectral Databases, Identification of unknown compounds. d. Spectrometric Instrumentation of UV-Vis and IR: Sources, monochromators, sample cells, detectors, instrumental wavelength and absorption calibration. e. Proton and Carbon NMR Spectroscopy: Theory of NMR, Instrumentation, Chemical shift, factors influencing chemical shift, solvents used in NMR, spin-spin splitting, coupling constant calculation, factors influencing coupling constant. f. Mass Spectrometry: Principle, Instrumentation and various	20

	fragmentation patterns. g. Conjoint spectrometry problems: Structural elucidation of organic molecules using IR, UV, NMR and MS. h. Raman Spectroscopy: Theory, Basic instrumentation and Structural analysis using Raman Spectra. (Note: Assignment based on all above spectrometric methods should be given to student. More weightage of lectures shall be given for solving IR and NMR data problems for structure elucidation)	
Pedagogy:	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings:	1. G. D. Christian, Analytical Chemistry, 6^{th} Ed.; Wiley, 2004. 2. J. H. Kennedy, Analytical Chemistry: Principles, 2^{nd} Ed.; Saunders College Publishing, 1990. 3. G. W. Ewing, Instrumental Methods of Chemical Analysis, 5^{th} Ed.; McGraw- Hill Int., 1985. 4. W. Kemp, Organic Spectroscopy, 3^{rd} Ed.; Palgrave, 1991. 5. D. A. Skoog, D. M. West, F. J. Hollar, S. R. Crouch, Fundamentals of Analytical Chemistry, 9^{th} Ed.; Cengage learning, 2014. 6. F. J. Holler, D. A. Skoog, S. R. Crouch, Principles of Instrumental Analysis, 6^{th} Ed.; Thomson Books, 2007. 7. H. Willard, L. L. Merritt, J. A. Dean, F. A. Settle, Instrumental methods of Analysis, 7^{th} Ed.; HCBS Publishing, 2004. 8. C. N. Banwell, E. M. McCash, Fundamentals of Molecular Spectroscopy, 4^{th} Ed.; Tata McGraw- Hill, 2006. 9. R. M. Silverstein, F. X. Webster, Spectrometric identification of Organic Compounds, 6^{th} Ed.; Wiley, 1998. 10. H. Gunzler, A. Williams, Handbook of Analytical Techniques, 1^{st} Ed.; Wiley, 2001. 11. P. S. Kalsi, Spectroscopy of Organic Compounds, 2^{nd} Ed.; New Age International, 2000. 12. E. Pretsch, P. Buhlmann, C. Affolter, Structural Determination of Organic Compounds, 2^{nd} Ed.; Springer, 2005. 13. L. D. Field, S. Sternhell, J. R. Kalman; Organic Structures from Spectra, 4^{th} Ed.; Wiley, 2007. 14. R. A. Day, A. L. Underwood, Quantitative Analysis, 6^{th} Ed.; Prentice Hall, 2001. 15. B. K Sharma, Instrumental methods of chemical analysis, Goel Publishing House, Meerut, 2004. 16. K. Nakamoto, Infrared and Raman Spectra of Inorganic and Coordination Compounds, 6^{th} Ed.; Wiley, 2009. 17. P. J. Larkin, Infrared and Raman Spectroscopy: principles and	

	spectral interpretation, 2th Ed.; Elsevier, 2018. 18. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, B. Sivasankar, Vogel's Text Book of Quantitative Chemical Analysis, 6th Ed.; Pearson, 2009.
Course outcomes:	1.Students will be able to analyse the role of statistical tools for determination of error and organised data management for systematic interpretation. 2. Student will be able to apply the sampling and calibration methods for obtaining reliable results. 3. Students will be able to understand basic principles and scope of different methods of Analysis 4. Students will be able to solve problems based on IR, NMR, MS combined spectral data.

Title of the course: Practical Course in Organic Chemistry-I

Course Code: CHO-521

Number of Credits: 02

Effective from AY: 2022-23

Prerequisites for the course	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objective:	To translate certain theoretical concepts learnt earlier into experimental knowledge by providing hands on experience of basic laboratory techniques required for organic syntheses.	
Content	*Minimum 13 experiments from the list shall be conducted.* **1. Introduction to laboratory equipments, apparatus and safety** a. Use of common laboratory equipments like fume hoods, vacuum pumps, weighing balance etc. to be explained to the students. b. Introduction to various types of quick fit joints and apparatus to the students. c. Discussion of Safety Techniques: i Disposal of chemicals ii Usage of protective equipment's iii First aid iv Fire extinguishers, types of fire v Hazards of chemicals and risk assessment	No of hours 04
	2. Laboratory Techniques a. Simple distillation (any one): i. Toluene-dichloromethane mixture using water condenser. ii. Nitrobenzene and aniline using air condenser. b. Steam distillation (anyone): i. Separation of *o*- and *p*- nitrophenols. ii. Naphthalene from its suspension in water, iii. Clove oil from cloves. c. Crystallisation: Concept of induction of crystallization (any one) i. Crystallisation of phthalic acid from hot water using fluted filter paper and stemless funnel. ii. Acetanilide from boiling water iii. Naphthalene from ethanol. iv. Decolorisation and crystallization of brown sugar (sucrose) with animal charcoal using gravity filtration. d. Sublimation: Simple or vacuum sublimation of camphor,	24

	naphthalene, anthracene or succinic acid (any one). e. Vacuum distillation (any one): o-dichlorobenzene, diphenyl ether. Also use of nomograph should be explained. f. Thin layer Chromatography (any one): i. Separation of *o* and *p*-nitroanilines. ii. Separation of analgesic drugs iii. Separation of *o* and *p*-nitrophenols,	
	3. Organic synthesis (Any Seven experiments) a. Aliphatic electrophilic substitution: Preparation of iodoform from ethanol &acetone. b. Aromatic electrophilic substitution (anyone): i. Preparation of *p*-bromoacetanilide. ii. Bromination of acetophenone to phenacyl bromide iii. Nitration of napththalene to 1-nitronaphthalene iv. Nitration of benzaldehyde to 3-nitrobenzaldehdye. c. Oxidation (any one) i. Benzoic acid from toluene. ii. Cyclohexanone from cyclohexanol. iii Isoborneol to camphor using Jones reagent. d. Reduction (any one) i. Reduction of *o*-nitroaniline to *o*-phenylenediamine using Sn/HCl ii. Reduction of *p*-nitro benzaldehyde to *p*-nitrobenzyl alcohol using $NaBH_4$. e. Bromination of an alcohol using CBr_4/ triphenylphosphine. f. Grignard reaction: Triphenylmethanol from benzoic acid ester or benzophenone. g. Aldol condensation: Dibenzal acetone from benzaldehyde h. Acetoacetic ester condensation: Preparation of ethyl *n*-butylacetoacetate or ethyl acetoacetate. i. Cannizzaro reaction using 4-chlorobenzaldehyde as substrate. j. Friedel Craft’s reaction (any one): i. using toluene and succinic anhydride ii. Resorcinol to resacetophenone, benzene and maleic anhydride to *β*-benzoylacrylic acid k. Solvent free preparation of coumarin by the Knoevenagel condensation under MW irradiation. l. Preparation of oxidizing agent (any one): Pyridinium chlorochromate-silica, pyridinium chlorochromate-alumina, MnO_2. m. Preparation of cuprous chloride.	24
	4. Isolation from natural sources (Any two) i. Caffeine from tea powder. ii. Piperine from pepper. iii. Cinnamaldehyde from cinnamon	8

	iv. Lemongrass oil from lemongrass	
Pedagogy:	Students should be given suitable pre- and post-lab assignments and explanation revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment. Each of the experiments should be done individually by the students.	
References / Readings	1. A.I. Vogel, A., R. Tatchell , B. S. Furniss, A.J. Hannaford, Vogel's Textbook of Practical Organic Chemistry, 5^{th}Ed., Prentice Hall; 2011. 2. D. Pasto, C. Johnson and M. Miller, Experiments and Techniques in Organic Chemistry, 1^{st}Ed., Prentice Hall, 1991. 3. L.F. Fieser, K.L. Williamson,Organic Experiments, 7^{th}edition D. C. Heath, 1992. 4. K.L. Williamson, K.M. Masters, Macroscale and Microscale Organic Experiments, 6^{th}Edition, Cengage Learning, 2010 5. R.K. Bansal, Laboratory Manual in Organic Chemistry, New Age International, 5^{th}Edition, 2016. 6. S. Delvin, Green Chemistry, Sarup& Sons, 2005. 7. O.R. Rodig, C.E. Bell Jr. and A.K. Clark, Organic Chemistry Laboratory Standard and Microscale Experiments, Saunders College Publishing, 3^{rd}edition, 2009. 8. J. Mohan, Organic Analytical Chemistry, Narosa Publishing House, 2014.	
Course outcomes	1. Students will be in a position to understand stoichiometric requirements during organic syntheses. 2. Students will be in a position to understand Safe and good laboratory practices, handling laboratory glassware, equipment and chemical reagents. 3. Students will be in a position to apply the practical knowledge to perform experiments involving common laboratory techniques like reflux, distillation, steam distillation, vacuum distillation, aqueous extraction, thin layer chromatography (TLC) etc. 4. Students will be able to acquire hands-on experience on isolation of some important natural products.	

<u>Title of the course: Practical Course in Organic Chemistry-II</u>

Course Code: CHO-522

Number of Credits: 02

Effective from AY: 2022-23

<table>
<tr><td>Prerequisites for the course</td><td colspan="2">Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.</td></tr>
<tr><td>Course Objective:</td><td colspan="2">To translate certain theoretical concepts learnt earlier into experimental knowledge by providing hands on experience of basic laboratory techniques required for organic syntheses.</td></tr>
<tr><td rowspan="3">Content</td><td>Minimum 13 experiments from the list shall be conducted.

1. Introduction to laboratory equipments, apparatus and safety
a. Common Hazards in Chemical Laboratory, Risk assessment
b. Accidents and Emergency procedures</td><td>No of hours

04</td></tr>
<tr><td>2. Laboratory Techniques (Any Two)
a. Simple distillation
i. Simple distillation of thionyl chloride under anhydrous condition
ii. Simple distillation under Nitrogen atmosphere
b. Fractional distillation
i. Chloroform-dichloromethane mixture using water condenser.
ii. Toluene and cyclohexane by fractionating column.
c. Vacuum distillation under inert atmosphere
Dry Distillation of DMF, o-dichlorobenzene, $POCl_3$
d. Thin layer Chromatography
i. Purification and isolation of mixture of acids by using Preparative TLC.
ii. Purification and isolation of mixture of phenols by using Preparative TLC.
iii. Purification and isolation of pharmaceutical drugs using Preparative TLC.</td><td>08</td></tr>
<tr><td>3. Organic Synthesis (Any Four)
a. p-Iodonitrobenzene by Sandmeyer reaction
b. Pinacol- Pinacolone rearrangement
c. Hydrogenation of Maleic acid (Hydrogen balloon)
d. Preparation of nitrostyrene from aldehyde
e. Preparation of α,β-dibromocinnamic acid
f. Reduction of nitro compounds</td><td>16</td></tr>
</table>

	g. Synthesis of Urea from ammonium cyanate	
	4. Solvent Free Organic synthesis (Any Two) a. Reduction using ball milling technique b. Oxidation of 2° alcohol using $KMnO_4$/Alumina by grinding technique. c. Synthesis of (±)-Binol from β-naphthol d. Hunsdiecker reaction of cinnamic acid derivatives e. Beckmann rearrangement of oxime derivatives	08
	5. Two-step Organic Synthesis (Any Two) a. Benzamide-Benzoic acid-Ethyl Benzoate b. Phthalic anhydride – Phthalimide – Anthranilic acid. c. Methyl benzoate- *m*-nitrobenzoate- *m*-nitrobenzoic acid d. Chlorobenzene – 2, 4 – dinitrochlorobenzene – 2,4-dinitrophenol e. Acetanilide – *p*–Bromo acetanilide – *p*–Bromoaniline f. Acetophenone – Oxime – Acetanilide	16
	6. Separation, Isolation and Identification of Organic compounds (Any One) a. Separation, purification and identification of compounds of binary mixture (Solid-Solid, Solid-liquid and Liquid-liquid) using the TLC and column chromatography, chemical tests. IR spectra to be used for functional group identification.	08
Pedagogy	Students should be given suitable pre- and post-lab assignments and explanation revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment.	
References / Readings	1. A. I. Vogel, A. R. Tatchell, B. S. Furniss, A. J. Hannaford, Vogel's Textbook of Practical Organic Chemistry, 5th Ed., Prentice Hall; 2011. 2. K. Tanaka, Solvent-free Organic Synthesis, Wiley-VCH, 2nd Ed., 2009 3. L. F. Fieser, K. L. Williamson "Organic Experiments" 7th edition D. C. Heath, 1992. 4. K. L. Williamson, K. M. Masters, Macroscale and Microscale Organic Experiments, 6th Edition, Cengage Learning, 2010 5. R. K. Bansal, Laboratory Manual in Organic Chemistry, New Age International, 5th Edition, 2016. 6. S. Delvin, Green Chemistry, Sarup& Sons, 2005. 7. O. R. Rodig, C. E. Bell Jr., A. K. Clark, Organic Chemistry Laboratory Standard and Microscale Experiments, Saunders College Publishing, 3rdedition, 2009. 8. J. Mohan, Organic Analytical Chemistry, Narosa Publishing House, 2014.	
Course outcomes	1. Students will be in a position to adopt Safe and good laboratory practices, handling laboratory glassware, equipment and chemical reagents. 2. Students will be in a position to understand and calculate stoichiometric	

	requirements during organic syntheses. 3. Students will be in a position to perform common laboratory techniques including reflux, distillation, vacuum distillation, aqueous extraction, thin layer chromatography (TLC). 4. Students will be able to acquire hands-on experience on isolation of some important natural products.

<u>**Title of the course: Practical Course in Pharmaceutical Chemistry-I**</u>

Course Code: CHH-521

Number of Credits: 02

Effective from AY: 2022-23

<table>
<tr><td>Prerequisites for the course</td><td colspan="2">Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. To acquire hands on training in laboratory techniques.
2. To understand organic synthesis with reference to medicinal compound preparations.</td></tr>
<tr><td rowspan="7">Content</td><td>1) Qualitative and Quantitative tests of (Any 1)
(1) Purified Water as per IP Monograph
(2) Ibuprofen as per IP Monograph</td><td>No of hours

10</td></tr>
<tr><td>2) Titrimetric Assay of the following bulk drugs:
(4 x 2 = 8) (Any 2)

a) Pheniramine Maleate
b) Salbutamol
c) Ofloxacin</td><td>08</td></tr>
<tr><td>3) UV. Spectrophotometric Assay of the following drugs (in different dosage forms):
(4 x 4= 16) (Any 4)
Rifampicin, Meloxicam, Salbutamol, Ofloxacin,Isoniazid, Diazepam, Acyclovir, Bisacodyl, Tinidazole,</td><td>16</td></tr>
<tr><td>4) Synthesis of following bioactive or drug molecules (2x3=6 hours) Any 2
a) 3-Acetylcoumarin
b) 2-Phenylbenzimidazole
c) 2,3-Diphenyl Quinoxaline</td><td>06</td></tr>
<tr><td>5) Multistep synthesis (Any one)
a) Flavone from 2-hydroxyacetophenone
b) Paracetamol from Acetanilide</td><td>08</td></tr>
<tr><td>6)Dissolution experiment:
To study the dissolution rate of sustained release Theophylline tablets IP.</td><td>06</td></tr>
<tr><td>7) High Performance liquid Chromatographic experiment:
To develop and validate the analytical method of any one drug using high performance liquid chromatography.</td><td>06</td></tr>
<tr><td>Pedagogy</td><td colspan="2">Pre-lab and Post-lab exercises. Demonstrations of experiments. Explanation</td></tr>
</table>

	of procedures.
References/ Readings	1. A. I. Vogel, A. R. Tatchell, B. S. Furniss, A. J. Hannaford, Vogel's Textbook of Practical Organic Chemistry, 5th Edition, Prentice Hall; 2011. 2. K. A. Connors, Text book of Pharmaceutical analysis, 3rd Edition, Wiley Interscience Publication, 1990. 3. J. Bassett, J. Mendhan, R. C. Denny, Vogel's Text book of quantitative chemical analysis revised by G.H. Jeffery , 6th Edition, Pearson Education Publication, 2007. 4. Indian Pharmacopoeia., United States Pharmacopoeia, British Pharmacopoeia. European Pharmacopoeia. 5. J. E. F. Reynolds, Martindale-The Extra Pharmacopoeia, 30th Edition, Pharmaceutical Press, London, 1993. 6. J. Moini, Pharmaceutical Laboratory Procedures, 1st Edition, Cengage Learning India Pvt. Ltd., New Delhi, 2010.
Course Outcome	1. Students will be able to understand the theoretical concepts and practical applications. 2. Students will be able to handle analytical instruments like UV-VIS spectrophotometer and carry out drug analysis. 3. Students will be able to perform multistep synthesis. 4. Students will be able to perform HPLC analysis

Title of the course: Practical Course in Pharmaceutical Chemistry-II

Course Code: CHH-522

Number of Credits: 02

Effective from AY: 2022-23

Prerequisites for the course	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objective:	1. To acquire hands on training in laboratory techniques. 2. To understand organic synthesis with reference to medicinal compound preparations.	
Content	**1) Qualitative and Quantitative tests of** (Any 1) (1) Paracetamol as per IP Monograph (2) Aspirin as per IP Monograph	No of hours 10
	2) Titrimetric Assay of the following bulk drugs: (2 x 4 = 8) Any 2 a) Chloramphenicol capsules IP b) Furosemide injection IP c) Ketoprofen d) Phenytoin	08
	3) UV Spectrophotometric Assay of the following drugs (in different dosage forms): (4 x 2= 8) Any 2 Mefenamic acid, Furosemide, Chloramphenicol	08
	4) Synthesis of following bioactive or drug molecules: (2 x 4 = 8 hours) Any 2 a) Warfarin b) 2-(*p*-Chlorophenyl)benzoxazole c) Monastrol d) Nitazoxanide	08
	5)Dissolution experiment: Dissolution rate study of sustained release Diclofenac tablets IP.	06
	6) Thin Layer Chromatographic experiments on Pharmaceuticals (Any 1) a) To identify the given drug amongst the paracetamol, aspirin and caffeine citrate with the help of thin layer chromatography and calculate its *Rf* value. b) To identify the given sulpha drug among the sulphadiazine, sulphamethoxazole and trimethoprim with the help of thin layer chromatography and calculate its *Rf*	04

	value.	
	7) High Performance liquid Chromatographic experiment: To demonstrate high Performance liquid chromatography and analyse Diazepam Tablets by High Pressure Liquid Chromatography.	06
	8)Separation of mixture of o-nitroaniline and p-nitroaniline using column chromatography.	06
	9)Infrared Spectroscopic analysis **Demonstration of Instrumentation and Interpretation of Representative Spectra (Any 1)** a) To differentiate between analgesic-NSAIDs:Aspirin, Ibuprofen, Paracetamol. b) To differentiate between Acetophenone, *p*-Nitroacetophenone, Benzamide	04
Pedagogy	Pre-lab and Post-lab exercises. Demonstrations of experiments. Explanation of procedures.	
References/ Readings	1. A. I. Vogel, A. R. Tatchell, B. S. Furniss, A. J. Hannaford, Vogel's Textbook of Practical Organic Chemistry, 5th Edition, Prentice Hall; 2011. 2. K. A. Connors, Text book of Pharmaceutical analysis, 3rdEdition, Wiley Interscience Publication, 1990. 3. J. Bassett, J. Mendhan, R. C. Denny, Vogel's Text book of quantitative chemical analysis revised by G.H. Jeffery , 6th Edition, Pearson Education Publication, 2007. 4. Indian Pharmacopoeia., United States Pharmacopoeia, British Pharmacopoeia. European Pharmacopoeia. 5. J. E. F. Reynolds, Martindale-The Extra Pharmacopoeia, 30th Edition, Pharmaceutical Press, London, 1993. 6. J. Moini, Pharmaceutical Laboratory Procedures, 1st Edition, Cengage Learning India Pvt. Ltd., New Delhi, 2010	
Course Outcome	1. Students will be able to understand the theoretical concepts and practical applications. 2. Students will be able to handle analytical instruments like UV-VIS spectrophotometer and carry our drug analysis. 3. Students will be able to perform synthesis.. 4. Students will be able to perform HPLC analysis	

Title of the course: Practical course in Physical Chemistry-I

Course Code: CHP-521

Number of Credits: 02

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objective:	1. To develop experimental skills on basic lab techniques in physical chemistry 2. To acquire skills for data analysis and interpretation 3. To help the students to develop research skills	
Content	Minimum 13 Experiments to be performed per Semester Non-instrumental Experiments (any 7) 1. To study the kinetics of hydrolysis of ethyl acetate and to determine a)Energy of activation b) Entropy of activation and c) Free energychange. 2. To determine the order of reaction between potassium persulphateand potassium iodide by graphical, fractional change and differential methods. 3. To study the three-component system such as acetic acid, chloroform;and water and obtain tieline. 4. To determine the molecular weight of polyvinyl alcohol by viscosity measurement. 5. To study the electro-kinetics of rapid reaction between SO_4^{2-} and I^- in an aqueous solution. 6. To determine the buffer capacity of acidic buffer solution. 7. To determine the partial molal volume of ethanol-water mixture at a given temperature. 8. To measure energy content of various types of plastics using bomb calorimetry 9. To determine number average molecular weight of a polymer sample with an indirect titration method. 10. To investigate basic hydrolysis of ethyl acetate at four different temperatures and find out energy of activation	No of hours 30
	Instrumental Experiments (any 6)	30

	11. To determine the degree of hydrolysis of salt of weak base and strong acid usingconductometer. 12. To determine the dissociation constants of a tribasic acid (Phosphoricacid obtain derivative plot to get equivalencepoint. 13. To determine formal redox potential of Fe^{2+}/Fe^{3+} and Ce^{3+}/Ce^{4+} system obtain derivative plot to get equivalencepoint. 14. To study spectrophotometric titration of ferrous ammonium sulphate with potassium permanganate (or dichromate vs permanganate) 15. To determine Avogadro's number by improved electroplating. 16. To determine the zeta potential of colloidal system and investigate the effect of different surfactants on stability of the colloids 17. To verify the Kohlrausch's law for weak electrolyte by conductometry 18. To determine the transport numbers of Cu^{2+} and SO_4^{2-} ions in $CuSO_4$ solution by Hittorf's method.	
Pedagogy	Mainly pre-laboratory exercises Seminars / term papers /assignments / presentations / lab hand-out /self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. A. Finlay & J.A. Kitchener, Practical Physical Chemistry,Longman, 2. F. Daniels & J.H. Mathews, Experimental Physical Chemistry,Longman 3. A.M.James, Practical PhysicalChemistry, Longman 4. D.P. Shoemaker & C.W. Garland, Experimental Physical Chemistry, McGraw-Hill	
Course outcomes:	1. Students will able to explain various fundamental lab techniques. 2. Students should be in a position to apply the knowledge for their dissertation and research work. 3. Students will be able to use spectrophotometric titrations for appropriate analysis. 4. Students will be able to determine molecular weight of some polymers.	

Title of the course: Practical course in Physical Chemistry-II

Course Code: CHP-522

Number of Credits: 02

Effective from AY: 2022-23

Prerequisites for the course:	Students should have studied chemistry courses at graduate level or must have cleared change of discipline entrance test.	
Course Objective:	1. To develop experimental skills on basic lab techniques in physical chemistry 2. To acquire skills for data analysis and interpretation 3. To help the students to develop research skills	
Content	Minimum 13 experiments to be conducted per Semester **Non-instrumental Experiments (any 8)** 1. To determine the radius of a molecule by viscosity measurements. 2. To determine ΔG, ΔH and ΔS of silver benzoate by solubility product method 3. To investigate the adsorption of oxalic acid by activated charcoal and test the validity of Freundlich and Langmuir's isotherms. 4. To determine the molecular weight of a given polymer by turbidimetry 5. To study the rate of reaction between ethyl bromoacetate and sodium thiosulphate kinetically. 6. To determine the percentage composition of a given mixture of two liquids by stalagmometer method. 7. To study the kinetics of hydrolysis of methyl acetate and to determine a) Energy of activation b) Entropy of activation and c) Free energy change. 8. To study the kinetics of the reaction between Potassium per sulphate ($K_2S_2O_8$), and Potassium iodide (KI), and to determine a) Energy of activation b) Entropy of activation and c) Free energy change. 9. To determine the order of reaction for hydrolysis of ethyl acetate by graphical, fractional change and differential methods. 10. To determine the molecular weight of polystyrene by	No of hours 35

	viscosity measurement.	
	Instrumental Experiments (any 5) 11. To determine the relative strength of chloroacetic acid and acetic acid by conductometry. 12. To determine the degree of hydrolysis of salt of weak base and strong acid using conductometry. 13. To determine the composition of a mixture of acetic acid, dichloroacetic acid and hydrochloric acid by conductometric titration. 14. To determine the dissociation constants of monobasic acid and dibasic acid and obtain derivative plot to get equivalence point. 15. To determine the redox potential of Fe^{2+}/Fe^{3+} system by titrating it with standard $K_2Cr_2O_7$ solution. 16. To study the electrodeposition of metal.	25
Pedagogy	Mainly pre-laboratory exercises Seminars / term papers /assignments / presentations / lab hand-out /self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. A. Finlay & J.A. Kitchener, Practical Physical Chemistry,Longman, 2. F. Daniels & J.H. Mathews, Experimental Physical Chemistry,Longman, 3. A. M. James, F. E. Prichard, Practical PhysicalChemistry, Longman, 4. D.P. Shoemaker & C.W. Garland, Experimental Physical Chemistry, McGraw-Hill,	
Course outcomes:	1. Students will gain knowledge of various fundamental lab techniques. 2. Students should be in a position to apply the knowledge for their dissertation and research work. 3. Students will be able to use spectrophotometric titrations for appropriate analysis. 4. Students will be able to determine molecular weight of some polymers.	

<u>**Title of the course: Practical Course in Analytical Chemistry - I**</u>

Course Code: CHA-521

Number of Credits: 02

Effective from AY: 2022-23

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.</td></tr>
<tr><td>Course Objectives:</td><td colspan="2">1. Introduction of various experimental techniques for analysis.
2. Learning data analysis, handling and interpretation of spectra.</td></tr>
<tr><td rowspan="5">Content:</td><td>This course consists of 7 units of experiments in various areas of Analytical chemistry. Minimum 13 experiments which include at least 02 experiments from unit 1-6 and 01 experiment from unit 7 shall be conducted.

Unit 1: Statistics
i. Calibration of selected Volumetric apparatus
ii. Calibration of selected Laboratory instruments
Preparation of standard solutions and standardisation.</td><td>No of hours

9</td></tr>
<tr><td>Unit 2: Colorimetry/ UV-Visible Spectrophotometry
i. Estimation of Iron from Pharmaceutical sample (capsule) by thiocyanate method
ii. Estimation of phosphoric acid in cola drinks by molybdenum blue method.
iii. Estimation of KNO_3 by UV spectroscopy and $K_2Cr_2O_7$ by Visible spectroscopy
iv. Simultaneous determination and Verification of law of additivity of absorbances ($K_2Cr_2O_7$ and $KMnO_4$).</td><td>8</td></tr>
<tr><td>Unit 3: Flame Spectrophotometry and AES/AAS/ICP Spectroscopy
i. Estimation of Na and K in food supplements or cosmetic products.
ii. Estimation of Pb in water sample by AES/AAS/ICP.
iii. Estimation of Fe and Al in Iron ore sample by AES/AAS/ICP.</td><td>9</td></tr>
<tr><td>Unit 4: Ion Exchange Chromatography and High Pressure Liquid Chromatography
i. Separation and Estimation of chloride and bromide.
ii. Separation of Anthracene and Naphthalene using reverse phase chromatography
iii. Separation of Benzaldehyde and Benzyl alcohol using normal phase chromatography</td><td>10</td></tr>
<tr><td>Unit 5: Volumetric Titrations</td><td>10</td></tr>
</table>

	i. Estimation of Ca in pharmaceutical tablet. ii. Estimation of Al and Mg in antacid tablet. iii. Estimation of CaO in cement.	
	Unit 6: Solvent Extraction and spectrophotometry i. Extraction of Cu as copper dithiocarbamate (DTC) using solvent extraction and estimation by spectrophotometry. ii. Determination of Ni as Dimethylglyoxime complex by spectrophotometry. iii. Determination of Silver as ion association complex with 1,10-Phenanthroline and Bromopyrogallol red.	10
	Unit 7: Interpretation Exercises i. Thermal studies: TG/DTA and Isothermal weight loss studies of various hydrated solids like $CuSO_4 \cdot 5H_2O$, $Ca_2C_2O_4 \cdot H_2O$, $Fe_2C_2O_4 \cdot 2H_2O$. ii. X-ray powder diffractometry: Calculation of lattice parameters from X-ray powder pattern of cubic system such as $NiMn_2O_4$, $CoFe_2O_4$ etc. iii. IR spectra of Urea, benzoic acid, Copper sulphate pentahydrate etc.	4
Pedagogy:	Prelab exercises / assignments / presentations / lab hand-out or a combination of some of these. Sessions shall be interactive in nature to enable peer group learning.	
References / Readings:	1. J. H. Kennedy, Analytical Chemistry Principles, Saunders College Publishing, 2^{nd} Ed., 1990. 2. G. D. Christian, Analytical chemistry, 5^{th}Ed., John Willey and Sons, 1994 3. J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas, B. Sivasankar, Vogel's Textbook of Quantitative Chemical Analysis, 6^{th}Ed., Pearson Education Asia 2009. 4. A. J. Elias, Collection of interesting chemistry experiments, University press, 2002. 5. R.A. Day & A.L. Underwood, Quantitative Analysis, 6^{th}Ed., Prentice Hall, 2001. 6. J. Kenkel, Analytical Chemistry for Technicians, 3^{rd}Ed., Lewis publishers, 2002.	
Course outcomes:	1. Students will be able to explain how to determine an unknown concentration of solution. 2. Students will use statistical methods to analyse data in laboratory. 3. Students will be able to use different techniques for qualitative and quantitative estimation. 4. Students will be able to interpret TG/X-Ray/IR spectra.	

Title of the course: Practical Course in Analytical Chemistry - II

Course Code: CHA-522

Number of Credits: 02

Effective from AY: 2022-23

Prerequisitesfor the course:	Students should have studied chemistry practical courses at graduate level or must have cleared change of discipline entrance test conducted by Goa University.	
Course Objectives:	1. Introduction of various experimental techniques for analysis. 2. Learning data analysis, handling and interpretation of spectra.	
Content:	*This course consists of 7 units of experiments in various areas of Analytical chemistry. Minimum 13 experiments which include at least 02 experiments from unit 1-6 and 01 experiment from unit 7 shall be conducted.*	No of hours
	Unit 1: Statistics i. Calibration of selected Volumetric apparatus ii. Calibration of selected Laboratory instruments iii. Preparation of standard solutions and standardisation.	9
	Unit 2: Titrimetric Analysis i. Standardisation and estimation of Chloride using precipitation titration (Mohr's method) ii. Analysis of commercial caustic soda by neutralisation titrimetric method iii. Determination of sulphates by complexometric titrations using EDTA.	8
	Unit 3: Flame Spectrophotometry and AES/AAS/ICP Spectroscopy i. Estimation of Na and K in food supplements or cosmetic products using flame photometer. ii. Estimation of chromium in water sample by AES/AAS/ICP. iii. Estimation of nickel, molybdenum in Hastelloy C-22 using AES/AAS/ICP.	10
	Unit 4: Natural product isolation and Ion Exchange Chromatography i. Isolation of cinnamaldehyde from cinnamon ii. Isolation of Caffeine from tea powder iii. Separation and estimation of Cadmium and Zinc	9
	Unit 5: UV-Visible Spectrophotometry and High-Pressure Liquid Chromatography i. Estimation of KNO_3 and $K_2Cr_2O_7$ using UV- Visible spectroscopy	10

<table>
<tr><td></td><td>ii. Separation of Benzaldehyde and benzoic acid using reverse phase HPLC.
iii. Quantification of naphthalene in a sample using reverse phase HPLC.</td><td></td></tr>
<tr><td></td><td>Unit 6: Solvent Extraction and spectrophotometry
i. Spectrophotometric determination of aspirin/phenacetin/ caffeine in APC tablet using solvent extraction
ii. Colorimetric determination of iron with salicylic acid.
iii. Determination of copper in brass sample by colorimetry.</td><td>10</td></tr>
<tr><td></td><td>Unit 7: Data Interpretation Exercises
i. NMR/Mass spectra
ii. HPLC and GC chromatograph
iii. XRD powder pattern of cubic systems
iv. Thermogram of coordination compounds</td><td>4</td></tr>
<tr><td>Pedagogy:</td><td colspan="2">Prelab exercises / assignments / presentations / lab hand-out or a combination of some of these. Sessions shall be interactive in nature to enable peer group learning.</td></tr>
<tr><td>References / Readings:</td><td colspan="2">1. J. H. Kennedy, Analytical Chemistry Principles, Saunders College Publishing, 2nd Ed., 1990.
2. G. D. Christian, Analytical chemistry, 5th Ed., John Willey and Sons, 1994
3. J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas, B. Sivasankar, Vogel’s Textbook of Quantitative Chemical Analysis, 6th Ed., Pearson Education Asia 2009.
4. J. Elias, Collection of interesting chemistry experiments, University press, 2002.
5. R.A. Day & A.L. Underwood, Quantitative Analysis, 6th Ed., Prentice Hall, 2001.
6. J. Kenkel, Analytical Chemistry for Technicians, 3rd Ed., Lewis publishers, 2002.</td></tr>
<tr><td>Course outcomes:</td><td colspan="2">1. Students will be able to standardize a material to determine an unknown concentration.
2. Students will use statistical methods to analyse data in laboratory.
3. Students will be able to use different techniques for qualitative and quantitative estimation.
4. Students will be able to interpret TG/X-Ray/IR spectra.</td></tr>
</table>

Title of the course: Fundamentals of Pharmaceutical Chemistry-II

Course Code: CHH-501

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Should have studied Pharmaceutical Chemistry at Semester I.	
Course Objective:	1. To learn major classes of drugs w.r.t. IUPAC nomenclature, structure and functional groups. 2. To understand the SAR of selected drugs and their Mechanism of action. 3. To get acquainted with the synthesis of selected drug molecules	
Content	**Classification of Chemotherapeutic Drugs: Development of the following drugs including structure activity relationship (S.A.R.), mechanisms of action (MA), outline of synthesis ($), chemical nomenclature, generic names (GN) and side effects (SE) (outline of synthesis only of those marked$)**	
	1. Cholinergic and Adrenergic Agents, General Anaesthetics and Hypotensive agents Classification of cholinergic agents: Drugs acting on cholinergic nervous system: Bethanechol$, Methacholine$, Neostigmine, Pyridostigmine, Parathion, Malathion, Atropine, Dicyclomine$, Tropicamide$, Papaverine, Classification of adrenergic agents, Drugs acting on adrenergic nervous system: Methyldopa (MA,$), Guanethidine, Ephedrine, Amphetamine, Tranylcypromine, Pragyline, Norepinephrine, Epinephrine, Pronethalol, Propranalol$, Atenolol$, Metoprolol.(SAR)	No of hours 12
	2. **Drugs acting on the central nervous system**: Hypnotics and sedatives: Chloral hydrate, Phenobarbital$, Secobarbital, Thiopental$, Nitrazepam, (SAR) Drugs acting as anticonvulsants: Phenytoin$, phenacemide, Clonazepam, Phensuximide, Phenobarbital, (Classification of Barbiturates), Primidone, Carbamazepine$. Psychotherapeutic agents: Phenothiazines such as Chloropromazine, Chlorodiazepoxide$, Oxazepam, Diazepam$, Imipramine, Nialamide, Tranylcypromine, Pargyline. CNS stimulants: Phenmetrazine, Nikethamide$, Iproniazid, Picrotoxines, Tetrazole, Amphetamine.	12

	3.**Antihistaminics, antiemetic, antiulcer drugs, Drugs used in parkinsonism and Alzhemeier's:** Diphenhydramine, Triprolidine, Cyclizine, Promethazine$(SAR), Cimetidine, Omeprazole (MA), Ranitidine, Sumatriptan, Ondansetron. Drugs used in Parkinsonism: Benzotronine mesylate, Levodopa, Carbidopa, Amantadine hydrochloride. Drugs for Alzheimer's diseases: Serine, Velnacrine (MA), Aniracetam.	10
	4. **Cardiovascular drugs, antihypertensive agents**, **and antibiotics:** Digitoxin, Quinidine, Procainamide, Verapamil. Antihypertensive agents which elicit their action through autonomous nervous system previously described under 1 and 2, Clonidine, Hydralazine, ACE inhibitors- Enalapril and related drugs vasodilators such as Nitroglycerine, Isoxsuprine, Nylidrin, Antibiotics: Penicillin and semisynthetic penicillin's and Cephalosporins, Amoxicillin, Cloxacillin, Streptomycin, Chloramphenicol, Tetracycline and derivatives, Erythromycin.	10
	5. Analgesics, Antipyretics and Inflammatory agents: Analgesics, antipyretics and anti-inflammatory agents: Sodium salicylate, Acetaminophen$, Phenacetin, Phenylbutazone, Oxyphenabutazone$, Naproxen$, Probenecid, Allopurinol, Profen, Diclofenac $. Narcotic analgesic agents: Morphine, Codeine, Meperidine, Methadone, Dextropropoxyphene. Non-narcotic analgesic agents: Dextropropoxyphene Levallorphan.	10
	6. **Neglected Tropical diseases**. Background, overview of Neglected tropical diseases, (Poverty diseases) Human Schistosomiasis, African trypanosomiasis (Chagas), leishmaniasis, sleeping sickness. Nitroheterocycles, Benznidazole, Nifurtimox ($, MA and side-effects)	06
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings:	1. D. A. Williams & T. L. Lemke, Foye's principles of medicinal chemistry, 5th edition, Lippincott Williams and Wilkins, 2006. 2. J. M. Beale & J. M. Block, Wilson &Gisvold's Text book of Organic Medicinal & Pharmaceutical Chemistry, Lippincott Williams and Wilkins;	

	2004. 3. D. J. Abraham & D. P. Rotella, Burger's Medicinal Chemistry Drug Discovery and Development, 7th edition, John Wiley & Sons N.Y, 2010. 4. D. Shriram, P. Yogeshwari, Medicinal Chemistry, Pearson Education, 2007. 5. G. L. Patrick: Introduction to Medicinal Chemistry, Oxford University Press, UK. 6th edition, 2017. 6. D. Lednicer& L. A. Mitscher, The Organic Chemistry of Drug Synthesis. (6 volume set) III. John Wiley & Sons, 2005. 7. H. Singh & V. K. Kapoor, Medicinal and Pharmaceutical Chemistry, Vallabh Prakashan, 2010. 8.G. R Chatwal, Medicinal Chemistry (Organic Pharmaceutical Chemistry), Himalaya Publishing house, 2002.
Course Outcome:	1. Students will be able to identify the examples in different classes of drugs. 2. Students will be able to write IUPAC names and Structure of drugs. 3. Students will be in a position to understand the mechanism of action of selected classes of drugs. 4. The students will have a clear understanding of concepts on SAR analysis. 5. The students will be able to apply synthetic organic chemistry knowledge in devising a synthesis for a drug.

<u>Title of the course: Drug Product Formulation, Development and Manufacture</u>

Course Code: CHH-502

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Should have studied Pharmaceutical Chemistry at Semester I.	
Course Objective:	1. To understand the concept of drug dosage forms, types of formulations and pilot plant processes. 2. To study the drug formulation development with specific examples.	
Content	1. **Introduction and Classification**: Introduction to drugs, Dosage Forms & Drug Delivery system – Definitions of Common terms. Development of dosage forms: Four stage development including preformulation. Preformulation studies, objectives, factors to be considered, study protocol, including prototype development, scale up studies and commercialization. For example analysing polymorphs using ultraviolet, infra-red, solid state NMR, DSA-DTA and X-Ray Crystallography. Drug Regulation and control, pharmacopoeias-formularies, sources of drug, drug nomenclature, routes of administration of drugs products their advantages and disadvantages, need for a dosage form, classification of dosage forms & brief description, study of excipients.	No of hours 15
	2. **Pilot plant** Scale up techniques, Benefits of pilot plant- Broad guidelines of process development. General Consideration. Industrial manufacturing method and flow charts of sulphamethoxazole, Rifampicin, Chloramphenicol maleate, Actinobolin, BTZO43, Piperaquine, Propranolol hydrochloride.	15
	3. **Pharmaceutical manufacturing operations** Brief discussion on unit operations and types of equipments/ machines used. Unit operations like size reduction, mixing/blending, drying, compression , granulation, coating etc. Three most frequently used unit operations within biopharmaceutical manufacturing, that includes chromatography, virus filtration, and tangential flow filtration (TFF), Quality by design (QbD): Fundamentals of pharmaceutical quality by design, identification of critical quality attributes, critical material attributes, critical process parameters and quality risk management.	15

	4. Dosage forms-formulation components, manufacturing and QC Types of dosage forms: Liquids-monophase &biophase including ENT preparation, sprays. Semisolid eg. Ointment, creams, gels, liniment, paste, lotion etc. Solid dosage forms eg. Tablets-Types of tablets, capsules, granules, powders, pastilles, lozenges, Sterile dosage forms eg. Injectables and ophthalmic preparations. Suppositories etc. Routes of drug administration, their advantages and disadvantages. Details pertaining to manufacturing processes for variety of dosage forms as listed above. Quality control evaluation of the dosage forms for assurance.	15
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings:	1. L. V. Allen Jr., N. G. Popovich, H. C. Ansel, *Ansel‟s pharmaceutical dosage forms and drug delivery systems,* Lippincott Williams & Wilkins, 2005. 2. R. K. Khar, *Lachman/Lieberman's The Theory and Practice of Industrial Pharmacy*, 4th Edition, CBS Publishers & Distributors, 2020. 3. G. Banker, *Modern Pharmaceutics*, Marcel Dekker, Inc, 2002. 4. S. J. Carter, *Dispensing for Pharmaceuticals students*, CBS Publishers & Distributors, Delhi, 2007. 5. J. P. Remington, *Remington's Pharmaceuticals Sciences*, Mack Publishers,1990. 6. M. E. Aulton, *Pharmaceutics Science of Dosage forms and design,* Kevin Taylor Elsevier, Health Sciences Division, 2001.	
Course Outcome:	1. Students should will be able to formulate APIs. 2. Students will be able to apply this knowledge for formulation experiments in laboratory. 3. Students will be able to evaluate formulations qualitatively. 4. Students will be able to understand Pharmaceutical manufacturing operations	

<u>Title of the course: Drug Design, Discovery and Development</u>

Course Code: CHH-503

Number of Credits: 04

Effective from AY: 2022-23

<table>
<tr><td>Prerequisites for the course:</td><td colspan="2">Should have studied Pharmaceutical Chemistry at Semester I.</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. To make the students well versed with theories of drug action.
2. To make the students understand the Structure Activity Relationship studies citing various examples.
3. To acquaint the students with the concepts ofdrug designing by molecular modelling.
4. To introduce various terms involved in patenting and IPR.</td></tr>
<tr><td rowspan="3">Content</td><td>1. Introduction to Drug design, Lead compounds and Pro-drug Concept.

Development of new drugs: Introduction, procedure followed in drug design, the search for lead compounds, molecular modification of lead compounds, prodrugs and soft drugs, prodrug; introduction, prodrug formation of compounds containing various chemical groups, multiple prodrug formation, soft drugs; design of soft drugs.</td><td>No of hours

12</td></tr>
<tr><td>2.SAR and QSAR Studies in drug discovery

Structure-Activity Relationship (SAR): Factors effecting bioactivity, resonance, inductive effect, isosterism, bioisosterism, spatial considerations, biological properties of simple functional groups. 4-5 illustrative examples depicting structural activity relationship studies. Theories of drug activity, occupancy theory, rate theory, induced-fit theory. Quantitative structure-activity relationship (QSAR): history and development of QSAR, drug receptor interactions, the additivity of group contributions, physico-chemical parameters, lipophilicity parameters, electronic parameter, ionization constants, steric parameters, chelation parameters, redox potential, indicator-variables, quantitative models.</td><td>12</td></tr>
<tr><td>3. QSAR Approaches in drug designing and modern methods in discovery Hansch analysis- Advantages and drawbacks. Free-Wilson analysis, Advantages and drawbacks. Their application, relationship between Hansch and Free-Wilson analysis (the mixed approach), non-linear relationship, Introduction to other QSAR approaches- Free Topliss Method-Postulates and Illustration.</td><td>12</td></tr>
</table>

	Introduction to molecular modelling using computers and docking, uses of molecular modelling manual use, further computer programming.	
	4.**Designing of Enzyme Inhibitors as drugs** Structure-based drug design: Process of structure based drug design, deactivation of certain drugs necessary for T cell functioning, determination of the active site with special reference to chymotryspin, design of inhibitors**.** Design of Enzyme Inhibitors, 9-alkylpurines, 9-mercaptopurines and allopurines, active site directed irreversible enzyme inhibition, suicide enzyme inactivators.	12
	5. Development of New drugs High throughput screening. Drug Design software's and its applications. Intellectual property rights, patents, industrial designs, geographical indications, trademarks, trade secrets. Patentable inventions. Patentable drugs. Role of patents in Pharmaceutical industry. Trade related aspects (TRIPS), international & regional agreements. Patent writing for drug designed. Examples of new drugs developed.(5 examples with one designing strategy)	12
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings:	1. S. S. Pandeya and J. R. Dimmock, An Introduction to Drug Design New Age International (P) Ltd. Publishers, 2007. 2.M. E. Wolff., Burger's Medicinal Chemistry and Drug Discovery, Vol I (Ch 9 and 14), John Wiley and Sons, New York, 1997. 3. Alen-Gringauz, Introduction to Medicinal Chemistry, 1st edition, Wiley-VCH,1996. 4. D. Lednicer and L. A. Mitscher, The Organic Chemistry of Drug Synthesis, Vol. I to V, John Wiley, 2005. 5. Alen-Gringauz, Introduction to Medicinal Chemistry, Wiley-VCH, 1997. 6. R.B. Silverman, Organic Chemistry of Drug design and Drug action, 3rd edition, Academic Press, 2014. 7. A. Leach, Molecular Modelling: Principles and applications, 2nd edition, Pearson India, 2001. 8. Norman Bailey, Statistical methods in Biology, 3rd edition, Cambridge University Press, 1995. 9. P. Krogsgaard-Larsen, U. Madsen, T. Liljefors A Textbook of Drug Design	

	and Development, 2nd edition, CRC Press, 1996. 10. G. Jolles and R. H. Wooldridge, Drug Design–Fact or Fantasy, Academic Press, 1984. 11. E. B. Roche, Design of Biopharmaceutical properties through prodrug and analogs, Am. Pharm. Assoc. Academy of Pharm. Sci., 1977. 12. G. L. Patrick, An Introduction to Medicinal Chemistry, 2nd edition, (Indian edition), Oxford University Press, 2001 13. N.R. Subbaran, What everyone should know about Patent, Pharma Book Syndicate, 2005. 14. Current Patent Acts of various countries. 15. P. W. Grubb, Patents for Chemicals, Pharmaceuticals & Biotechnology, 4th edition, Oxford University Press, 2005.
Course Outcome:	1. Students will be able to explain the theories of drug action. 2. Students will have a clear understanding of concepts on SAR analysis and will be able to apply Quantitative Structure Activity Relationship knowledge in drug designing. 3. Students will be able to analyze the effect of different functional groups on the biological activity of drugs. 4. The students will be able to illustrate an example of drug designing by molecular modelling. 5. The students will be able to explain the terms in patents.

Title of the course: Biopharmaceutics and Pharmacokinetics

Course Code: CHH-504

Number of Credits: 04

Effective from AY: 2022-23

Prerequisites for the course:	Should have studied Pharmaceutical Chemistry at Semester I.	
Course Objective:	1. To learn ADMET. Drug absorption drug distribution Drug Action Drug metabolism and excretion. 2. To learn how bioavailability is important in understanding the efficacy of a drug product.	
Content	1. **Introduction:** Definitions, ADME, concentration time profile, plotting the data, different fluid compartments and blood flow rate compartment models, biological half life, elimination rate constant. Biopharmaceutics and pharmacokinetics in drug research.	No of hours 08
	2. **Drug Absorption, Dissolution and Distribution** GIT Absorption of drugs: Mechanism, physico-chemical, biological and pharmaceutical factors affecting drug absorption through GIT. Techniques for the GIT absorption assessment. mechanisms of drug absorption, factors affecting drug absorption: Biological, physiological, physico-chemical and pharmaceutical. Noyes-Whitney's dissolution rate law, study of various approaches to improve dissolution of poorly soluble drugs, In-vitro dissolution testing models, In-vitro-in-Vivo correlation. Factors affecting drug distribution, volume of distribution, protein binding – factors affecting, significance and kinetics of protein binding.	12
	3.**Drug Metabolism and Excretion** Metabolism of drugs, Xenobiotics, Drug metabolizing organs and enzymes (microsomal &nonmicrosomal), Chemical pathways - Phase I reactions (Oxidative, reductive and hydrolytic reactions) and Phase II reactions (Conjugation), Significance of cytochrome P_{450} oxidation – reduction cycle, Factors affecting biotransformation of drugs. Renal excretion – Glomerular filtration, Active tubular secretion, Active (or) passive tubular reabsorption. Factors affecting renal excretions of drugs. Non renal excretions – Biliary, pulmonary, salivary, mammary, skin/dermal, gastrointestinal and genital excretions	12

	of drugs (Any two types).	
	4. **Bioavailability and Bioequivalency studies** Objectives and considerations in bioavailability studies, Definitions, federal requirements, methods of determination of bioavailability using blood and urinary excretion data. Protocol design for bioavailability assessment. Concept of equivalence, Methods for bioequivalence determination. Measurements of bioavailability, Determination of the rate of absorption, Bioequivalence studies and its importance. Biopharmaceutical classification of drugs, Importance of biopharmaceuticals.	12
	5. Pharmacokinetics: Protein and tissue binding: Factors affecting protein binding, kinetics of protein binding, determination of rate constant and different plots (direct, scatchard and reciprocal), Implication of protein binding on pharmacokinetic parameters. Pharmacokinetic characterization of drugs: Pharmacokinetics of drugs following one/ two compartment open models with first order elimination kinetics as applied to rapid intravenous injection, Intravenous transfusion and oral administration. Determination of absorption rate constant using Wagner-Nelson, Loo Riegelman methods. Non Linear Pharmacokinetics: Various causes of non-linearity, Michaelis-Menten kinetics, In-vivo estimation of Km and Vm. Case studies. Physiologic pharmacokinetics models: Mean Residence Time; Statistical Moment Theory; Application and limitations of physiologic pharmacokinetic models. Miscellaneous Topics: Chronopharmacokinetics, Drug toxicity and forensic pharmacokinetics, kinetics of maternal-fetal drug transfer, pharmacokinetics v/s pharmacological/ clinical response, metabolic kinetics.	16
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings:	1. M. Gibaldi, *Biopharmaceutics and Clinical Pharmacokinetics*, 4^{th} edition, Philadelphia, Lea &Febiger, 1991. 2. D.M. Brahmankar& Sunil B. Jaiswal, *Biopharmaceutics and Pharmacokinetics: A Treatise,* Vallabh Prakasan, Pitambura, Delhi, 1998. 3. L Sharjel. & A. B. C. Yu, *Applied Biopharmaceutics and Pharmacokinetics,* 2^{nd} edition, Connecticut, Appleton Century Crofts,	

	1985. 4. J. Swarbrick., Lea &Febiger, *Current Concepts in Pharmaceutical Sciences: Biopharmaceutics,* Philadelphia, 1970. 5. H. M. Abdou, *Dissolution, Bioavailability and Bioequivalence*, Mack Publishing Company, Pennsylvania, 1989. 6. R. E. Notari, *Biopharmaceutics and Clinical Pharmacokinetics-An Introduction*, 4^{th} edition, Marcel Dekker Inc, New York and Basel, 1987. 7. J. G. Wagner and M. Pernarowski, *Biopharmaceutics and RelevantPharmacokinetics*, 1^{st} edition, Drug intelligence Publications, Hamilton, Illionois, 1971. 8. J. Swarbrick, J. C. Boylan, *Encyclopedia of Pharmaceutical Technology*, Vol. I, 2^{nd} edition, Marcel Dekker Inc, New York, 2002. 9. S. K. Niazi, *Textbook of Biopharmaceutics and Clinical Pharmacokinetics*, BSP Books Private Limited, 2010. 10. Niazi, S. K., *Handbook of Bioequivalence Testing*, 1^{st} edition, CRS Press, 2007.
Course Outcome:	1. Students will be able to relate drug absorption to bioavailability. 2. Students will be able to get an in depth knowledge of drug metabolism concept. 3. Students will be able to understand Bioavailability 4. Students will be able to understand Pharmacokinetics

Title of the course: Practical Course in Pharmaceutical Chemistry-III

Course Code: CHH-600

Number of Credits:4

Effective from AY: 2023-24

<table>
<tr><td>Prerequisites for the course</td><td colspan="2">Should have studied the courses at M.Sc. Part-I.</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1.To translate certain theoretical concepts learnt earlier into experimental knowledge.
2.To provide hands-on experience of laboratory techniques required for drugsyntheses, analysis and purification.</td></tr>
<tr><td rowspan="2">Content</td><td>1. Syntheses of drugs and drug like entities (Minimum 8 experiments of 6h each)
a) Phenothiazine from diphenylamine
b) Propranolol from α-Naphthol
c) Eosin from Fluorescein
d) Gramine from Indole
e) 3-Methyl-1-phenyl pyrazolone from phenyl hydrazine
f) Schiff base of Antipyrine with p-bromobenzaldehyde
g) Methyl Salicylate from Salicylic acid
h) Sulphanilamide from p-acetamido benzene sulphanilamide
i) Chlorbutanol from acetone
j) 1,2,3,4-Tetrahydrocarbazole from cyclohexanone
k) 1,5-Benzodiazepine from acetophenone
l) Ethyl Nalidixate from 2-amino-6-methylpyridine
m) 2-Phenyl Benzothiazole from 2-Amino thiophenol
n) 2-Methylbenzimidazole from o-phenylene diammine
o) Monastrol from thiourea, ethylacetoacetate and 3-hydroxybenzaldehyde p) Substituted chalcone from 4-chlorobenzaldehyde (Claisen Schmidt condensation)</td><td>No of hours

48</td></tr>
<tr><td>2. Selected experimentsin organic synthesis (Minimum 3 experiments of 4h each)
a) p-Iodotoluene from p-toluidine. (Diazotisation)
b) Cinnamic acid from benzaldehyde (Perkin reaction)
c) Benzanilide from benzophenone (Beckmann Rearrangement)
d) Vanillin to Vanillyl alcohol (using $NaBH_4$)</td><td>12</td></tr>
</table>

	e) Methyl orange from sulphanilic acid (coupling diazotization process) f) Benzhydrol from Benzaldehyde (Grignard reaction)	
	3.Titrimetric assay of the following bulk drug/tablets. (Any 2) Paracetamol, Isoniazid, Dapsone, Metronidazole, Calcium Gluconate	6
	4. Spectrophotometric assay of the following tablets. (Any 2) Allopurinol, Propranolol, p-Aminosalicylic acid	6
	5.Dissolution Experiments (Any 2) Carbamazepine tablets, Diclofenac, Ibuprofen, Isoniazid	8
	6. Quality Control Evaluation of Tablets (1 experiment) Hardness tests, friability testing and disintegration testing to be performed.	4
	7. Chromatographic techniques **a. Thin Layer Chromatography (Any 1)** i. To identify the given drug amongst the Ibuprofen, Aspirin and caffeinecitrate with the help of thin layer chromatography and calculate its Rf value. ii. To identify the given sulpha drug amongst the sulphacetamide, sulphanilamide and trimethoprim with the help of thin layer chromatography and calculate its Rf value. **b. Column Chromatography (Any 1)** i. Salicylic acid and Acetylsalicylic acid ii. p-Aminobenzoic acid and Benzocaine iii. Benzil and Dilantin iv. Salicylaldehyde and 3-Acetyl coumarin c. **HPLC analysis of the following drugs and combination of drugs: (Any 2)** i. Paracetamol ii. Ibuprofen iii. Celecoxib iv. Sulphanilamide v. Diclofenac sodium and Paracetamol in combined	20

	dosage form.	
	8. Identification of following drugs by IR spectroscopy (Any 2) Celecoxib, Antipyrine, Chloramphenicol, Sulphanilamide	4
	9. Drug Design Experiments Use of software packages in chemistry for the following: Towrite a computer program to obtain a slope and intercept forlinear data using least square fit. a. Use of ChemDraw, ISISDraw for drawing structures, chemicalreactions, equations. b. Molecular docking softwares such as Hex software orautodocking. c. Energy minimization of molecules and finding intermolecularinteractions of small molecule with macromolecule such as Coxinhibitor, thymidilate synthase, glycogen synthase, E.Coli protein. **(Any 2)** d. Viewing Tools and Graphics Tools: Rasmol (http://www.umass.edu/microbio/rasmol/) VMD (http://www.ks.uiuc.edu/Research/vmd/) Molscript (http://www.avatar.se/molscript/) e. Determination of log P, MR, hydrogen bond donors and acceptors of selected drugs using softwares. f. 2D based experiments.	12
Pedagogy	Students should be given suitable pre- and post-lab assignments and explanations revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment.	
References /Readings	1. K.A. Connors, Text book of Pharmaceutical analysis, 3rd Ed., Wiley Interscience Publication 1990, 2. J. Bassett, J. Mendhan, R.C. Denny, Vogel‘s Text Book of Quantitative Chemical Analysis, revised by G.H. Jeffery, 6th Ed., Pearson Education Publication, 2007. 3. Indian Pharmacopoeia., United States Pharmacopoeia, British Pharmacopoeia. European Pharmacopoeia. 4. JEF Reynolds, Martindale, The Extra Pharmacopoeia, The Pharmaceutical Press, London, 1989. 5. M. Jahangir, Pharmaceutical Laboratory Procedures, 1st Ed., New Delhi	

	Cengage Learning India Pvt. Ltd. 2010. 6. A. Kar, Advanced Practical Medicinal Chemistry, New Age International Limited Publishers 2004. 7. A. I. Vogel, A. R. Tatchell, B. S. Furniss, A. J. Hannaford, Vogel's Textbook of Practical Organic Chemistry, 5th Ed., Prentice Hall 2011. 8. N.K. Vishnoi, Advanced Practical Organic Chemistry, South Asia Books, 2010. 9. L. F. Fieser, K. L. Williamson, Organic Experiments, 7th Ed., D. C. Heath, 1992. 10. R. K. Bansal, Laboratory Manual in Organic Chemistry, 5th Ed. New Age International, 2016. 11. S. Delvin, Green Chemistry, Sarup& Sons, 2005. 12. J. Mohan, Organic Analytical Chemistry, Narosa Publishing House, 2014. 13. F. D. King, Medicinal Chemistry: Principles and Practice, Royal Society of Chemistry: Cambridge, 1994. 14. K. V. Raman, Computers in Chemistry, Tata Mc.Graw-Hill, 1993. 15. S. K Pundir, A. Bansal, Computers for Chemists, Pragati Prakashan, 2010. 16. A. Leach, Molecular Modelling, Principles and applications, Longman, 1998.
Course Outcome:	1. Students will be in a position to perform synthesis of drugs. 2. Students will be in a position to understand stoichiometric requirements in drug syntheses. 3. Students will be able to analyse drug spectrophotometrically and chromatographically 4. Students will be able to carry out purification of drug by column separation. 5. Students will be able to apply this knowledge for their dissertation work.

Title of the course: Practical Course in Pharmaceutical Chemistry-IV

Course Code: CHH-601

Number of Credits:4

Effective from AY: 2023-24

Prerequisites for the course	Should have studied the courses at M.Sc. Part-I.	
Course Objective:	1. To translate certain theoretical concepts learnt earlier into experimental knowledge. 2. To provide hands-on experience of laboratory techniques required for drug syntheses, analysis and purification.	
Content	**1. Syntheses of drugs and drug like entities (Minimum 8 experiments of 6h each)** a. 2-Phenylbenzimidazole from o-phenylene diammine and benzoic acid b. 6-Bromo-2-chloro-3-formylquinoline from acetanilide c. Schiff base of Antipyrine with p-Chlorobenzaldehyde d. Sodium benzoate from Salicylic acid e. Sorbic acid from crotonaldehyde f. Barbiturate from diethyl-n-butylmalonate g. Tolbutamide from p-toluene sulphonamide h. 1,4-dihyropyridine from ethylacetoacetate i. 2-MethylBenzothiazole from 2-Amino thiophenol j. Substituted of 2'-hydroxychalcone (Claisen Schmidt condensation) k. Synthesis of azo-stilbene compounds	No of hours 48
	2. Selected experimentsin organic synthesis (Minimum 3 experiments of 4h each) a)Benzhydrol from benzophenone (Reduction) b) p-Iodobenzoic acid from p-aminobenzoic acid (Diazotization) c) 3-Acetylindole from Indole (Friedal Crafts reaction) d)Acetophenone oxime to Acetanilide (Beckmann Rearrangement) e) Enzymatic reduction of ethylacetoacetate using Baker's yeast f) Terephthalic acid from p-xylene (Oxidation process).	12
	3.Titrimetric assay of the following bulk drug/tablets. (Any 2)	6

	Ferrous sulphate, Chlorpheniramine Maleate , Benzyl Penicillin, Phenobarbitone	
	4. Spectrophotometric assay of the following tablets. (Any 2) Chloroquine phosphate (CHP) Zolmitriptan. Promethazine HCl, Indomethacin,	6
	5.Dissolution Experiments (Any 2) Saccharin, Celecoxib, Chlorpheniramine maleate, Chloramphenicol	8
	6. Quality Control Evaluation of Capsules (1 experiment) Hardness tests, friability testing and disintegration testing to be performed.	4
	7. Chromatographic techniques **a) Thin Layer Chromatography (Any 1)** i. i) To identify the given drug amongst the paracetamol, acetanilide, and caffeine citrate with the help of thin layer chromatography and calculate its Rf value. ii. To identify the given sulpha drugs amongst the Dapsone, sulphaacetamide and trimethoprim with the help of thin layer chromatography and calculate its Rf value. **b) Column Chromatography (Any 1)** i. Benzil and Benzilic acid ii. Glycine and Hippuric acid iii. o-phenylene diamine and 2,3-diphenylquinoxaline iv. Salicylaldehyde and coumarin **c) HPLC analysis of the following drugs: (Any 1)** i. Methyl Dopa ii. Sulphaacetamide iii. Paclitaxel	20
	8. Identification of following drugs by IR spectroscopy (Any 2) Benzocaine, Caffeine, Phenytoin, Suphaacetamide	4
	9. Drug Design Experiments Use of software packages in chemistry for the following: Towrite a	12

	computer program to obtain a slope and intercept forlinear data using least square fit. a. Use of ChemDraw, ISISDraw for drawing structures, chemicalreactions, equations. b. Molecular docking softwares such as Hex software orautodocking. c. Energy minimization of molecules and finding intermolecularinteractions of small molecule with macromolecule such as Coxinhibitor, thymidilate synthase, glycogen synthase, E.Coli protein. **(Any 2)** d. Viewing Tools and Graphics Tools: Rasmol (http://www.umass.edu/microbio/rasmol/) VMD (http://www.ks.uiuc.edu/Research/vmd/) Molscript (http://www.avatar.se/molscript/) e. Determination of log P, MR, hydrogen bond donors and acceptors of selected drugs using softwares. 2D based experiments.	
Pedagogy	Students should be given suitable pre- and post-lab assignments and explanations revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment.	
References /Readings	1. 1. K.A. Connors, Text book of Pharmaceutical analysis, 3rd Ed., Wiley Interscience Publication 1990. 2. 2. J. Bassett, J. Mendhan, R.C. Denny, Vogel's Text Book of Quantitative Chemical Analysis, revised by G.H. Jeffery, 6th Ed., Pearson Education Publication, 2007. 3. 3.Indian Pharmacopoeia., United States Pharmacopoeia, British Pharmacopoeia. European Pharmacopoeia. 4. 4. J.E.F. Reynolds, Martindale, The Extra Pharmacopoeia, The Pharmaceutical Press, London, 1989. 5. 5. M. Jahangir, Pharmaceutical Laboratory Procedures, 1st Ed., New Delhi Cengage Learning India Pvt. Ltd. 2010. 6. 6.A. Kar, Advanced Practical Medicinal Chemistry, New Age International Limited Publishers 2004. 7. 7. A. I. Vogel, A. R. Tatchell, B. S. Furniss, A. J. Hannaford, Vogel's Textbook of Practical Organic Chemistry, 5th Ed., Prentice Hall 2011. 8. 8. N.K. Vishnoi, Advanced Practical Organic Chemistry, South Asia Books,	

	2010. 9. 9. L. F. Fieser, K. L. Williamson, Organic Experiments, 7^{th} Ed., D. C. Heath, 1992. 10. R. K. Bansal, Laboratory Manual in Organic Chemistry, 5^{th} Ed. New Age International, 2016. 11. S. Delvin, Green Chemistry, Swarup & Sons, 2005. 12. J. Mohan, Organic Analytical Chemistry, Narosa Publishing House, 2014. 13.F. D. King, Medicinal Chemistry: Principles and Practice, Royal Society of Chemistry: Cambridge, 1994. 14.K. V. Raman, Computers in Chemistry, Tata Mc.Graw-Hill, 1993. 15.S. K Pundir, A. Bansal, Computers for Chemists, Pragati Prakashan, 2010. 16.A. Leach, Molecular Modelling, Principles and applications, Longman, 1998.
Course Outcome:	1. Students will be in a position to perform synthesis of drugs. 2. Students will be in a position to understand stoichiometric requirements in drug syntheses. 3. Students will be able to analyse drug spectrophotometrically and chromatographically 4. Students will be able to carry out purification of drug by column separation. 5. Students will be able to apply this knowledge for their dissertation work.

Title of the course: Retrosynthetic Approach and Heterocyclic Drug Synthesis

Course Code: CHH-604

Number of Credits:4

Effective from AY: 2023-24

Prerequisites for the course	Students should have studied Pharmaceutical Chemistry courses at M.Sc. Part-I.	
Course Objective:	1.To apply the knowledge gained in organic synthesis for making new molecules. 2.To understand various strategies involved in retrosynthesis of organic molecules 3.To understand the concepts of heterocyclic chemistry in drug designing 4.To be able to propose routes for synthesis of heterocycles	
Content	**1. Synthon approach and retrosynthetic applications** a. Basic principles, terminologies and advantages of retrosynthesis; guidelines for dissection of molecules. Functional group interconvertion and addition (FGI and FGA) b. C-X disconnections; C-C disconnections – alcohols and carbonyl compounds; 1,2-, 1,3-,1,4-, 1,5-, 1,6-difunctionalized compounds c. Strategies for synthesis of three, four, five and six-membered ring. (*General review problems to be discussed for above approaches*)	No of hours 12
	2. Disconnection strategies a. Disconnection of heteroatom and heterocyclic compounds such as ethers, amines, heterocycles, amino acids b. Convergent and divergent synthesis c. Strategic devices for carbon-heteroatom bonds, polycyclic compounds: the common atom approach d. Considering all possible disconnections e. Alternative FGI's before disconnection- the cost of synthesis f. Features which dominate strategy, functional group addition and molecules with unrelated functional groups	12
	3. Protecting groups a. Role of protection in organic synthesis	12

	b. Protection for the hydroxyl group, including 1,2-and1,3-diols: as ethers, esters, carbonates, cyclic acetals & ketals c. Protection for the carbonyl group: as acetals and ketals d. Protection for the carboxyl group: as amides and hydrazides, esters e. Protection for the amino group: as carbamates and amides.	
	Heterocyclic Chemistry: Introduction, classification and nomenclature of mono- and bicyclic heteroaromatic molecules. Organic Name reactions with their respective mechanism and application involved in synthesis of drugs containing five, six membered and fused heterocyclics such as Debus-Radziszewski imidazole synthesis, Knorr Pyrazole Synthesis Pinner Pyrimidine Synthesis, Combes Quinoline Synthesis, Bernthsen Acridine Synthesis, Smiles rearrangement and Traube purine synthesis.	12
	5. Synthesis of representative drugs with retrosynthetic approach Retrosynthetic approach and synthesis of few representative drugs containing these heterocyclic nucleus such as Metronidazole, Miconazole, Celecoxib, Alprazolam, Triamterene, Sulfamerazine, Trimethoprim, Hydroxychloroquine, Quinacrine, Prochlorpherazine, Chlorpromazine, Theophylline, Mercaptopurine and Thioguanine.	12
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. S. Warren, *Designing Organic Synthesis*, John Wiley & Sons, 2009. 2. G. S. Zweifel, M. H. Nantz, P. Somfai, Modern *Organic Synthesis: An Introduction*, 3rd Ed. W. H. Freeman and Company, New York, 2022. 3. J. Clayden, N. Greeves & S. Warren, *Organic Chemistry*, Oxford, 2016. 4. J. A. Joule, K. Mills & G. F. Smith, *Heterocyclic Chemistry*, 3rd Ed., Wiley-Blackwell, 1995. 5. J. A. Joule & K. Mills, *Heterocyclic Chemistry*, 5th Ed., Wiley-Blackwell, 2010. 6. T. L. Gilchrist, *Heterocyclic Chemistry*, Pitman Publishing, 2005. 7. R. M. Acheson, *An Introduction to Chemistry of Heterocyclic Compounds*, 3rdEd., John Wiley and Sons, 1977. 8. D. W. Young, *Heterocyclic Chemistry*, Longman Group Ltd., London, 1975.	

	9. A. Weissberger & E. Taylor, *Chemistry of Heterocyclic Compounds*,Vol.47,Wiley Publishers, 1987. 10. A. R. Katritzky, *Advances in Heterocyclic Chemistry*, 1st Ed., Academic Press Inc., Vol.47,1990. 11. R. O. C. Norman and J. M. Coxon. *Principles of Organic Synthesis*, 3rd Ed., CRC Press,2009. 12. Stephen R Wilson & Anthony W Czarnik, *Combinational Chemistry – Synthesis and applications*, Wiley – Blackwell, 1997. 13.V.K Ahluwalia and R. Agarwal, *Organic Synthesis - Special Techniques,* Narosa Publishers, 2001. 14. D. Shriram, P. Yogeshwari, Medicinal Chemistry, Pearson Education, 2007. 15. D. Lednicer& L.A. Mitcher*Organic Chemistry of Drug Synthesis* Vol. I to III. John Wiley & Sons, 2005. 16. Drug Preparation Database.http://www.drugfuture.com/synth/synth_query.asp
Course Outcome:	1.Students will be in a position to understand how a carbon-carbon bond can be constructed and/or cleaved 2.Students will be in a position to understand how retrosynthesis can be used in finding out easily available chemical precursors for making molecules 3.Students will be in a position to apply retrosynthetic strategies and propose routes for synthesis of containing heterocycles 4.Students will be able to understand and apply the concepts of the reactivity of heterocycles towards electrophilic, nucleophilic, reducing and oxidizing reagents. 5.Students will be able to apply this knowledge for their dissertation work.

Title of the course: Research Methodology in Pharmaceutical Chemistry and instrumental techniques

Course Code: CHH-605

Number of Credits:4

Effective from AY: 2023-24

Prerequisites	Students should have studied chemistry courses at MSc-I.	
Course Objective:	1.To introduce various aspects of research methodology. 2.To provide understanding ethics & scientific conduct 3. To introduce academic writing 4. To introduce databases used in chemistry 5.To provide understanding and importance of lab safety. 6.To understand the usefulness of various instrumental techniques in characterization of chemical compounds. 7.To provide knowledge about tissue culture for pharmacological screening methods.	
Content	**Unit 01: Introduction to Research Methodology** a. Research- meaning, objectives, motivation, types and methodology. Process- formulating the research problem; literature survey; developing the hypothesis and the research design; sample design and collection of the data; execution of the project; analysis of data; testing of hypothesis; generalizations and interpretation, and preparation of the report or presentation of the results & conclusions.	No of hours **5**
	Unit 02: Scientific conduct and ethics a. Ethics: definition, nature of moral judgements and reactions, Ethics with respect to science and research b. Intellectual honesty and research integrity c. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP) d. Redundant publications: duplicate and overlappingpublications e. Selective reporting and misrepresentation of data	**5**
	Unit 03. Academic writing a. Publication ethics: definition, introduction and importance b. Conflicts of interest	**5**

	c. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa d. Violation of publication ethics, authorship and contributorship e. Identification of publication misconduct, complaints and appeals f. Predatory publishers and journals	
	Unit 04. Data bases and research metrics Databases: 1. Indexing databases 2. Citation databases: Web of Science, Scopus, UGC-Care List etc. Research Metrics: 1. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score 2. Metrics: h-index, g index, i10 index etc	**3**
	Unit 06. Safety in Chemistry a. Good laboratory practices. b. Handling of various chemicals, solvents & glassware. c. Fires and fighting with fires. d. Hazardous substances, classification and handling e. Safety Data Sheet	**5**
	Unit 06. Softwares in Chemistry a. Data plotting b. Structure Drawing c. Molecular docking softwares	**7**
	5. Instrumental methods of analysis: Demonstration and/ or data analysis in following techniques. a. Elemental analysis: CHNS analysis and AES b. Infrared (IR), Raman, Ultraviolet-Visible (UV-Vis) c. Nuclear magnetic resonance (^{1}H, ^{13}C) d. Chromatographic techniques: HPLC, GC, e. Hyphenated Techniques: LC-MS & GC-MS, f. Diffraction methods: XRD g. Thermal analysis: DSC	**20**
	6. Animal Tissue Culture for pharmacological screening a. Basic concepts b. Laboratory safety and Biohazards c. Role of media components d. Handling and storage of cell lines e. Cell culture technique	**10**

	f. Types of cell culture system	
Pedagogy	Mainly lectures/recorded video lectures/ tutorials, discussions, seminars, internal exams/ assignments, / demonstration/ self-study or a combination of some of these. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. C.R. Kothari. Research Methodology: Methods & Techniques New Age International Pvt. Ltd., 2004. 2. Bird, A. Philosophy of Science. London:Routledge. 2006. 3. Anne M. Coghill &Lorrin R. Garson, The ACS Style Guide: Effective Communication of Scientific Information, OXFORD University press 2006. 4. Y K Singh Fundamentals of Research Methodology & Statistics, New Age International Pvt. Ltd., 2006. 5. Prudent practices in the laboratory: handling and management of chemical hazards, The National Academies Press, USA, 2011. 6. B.S. Furniss, A.J. Hannaford, V. Rogers, P.W.G. Smith & A. R. Tatchell. Vogel's Textbook of Practical Organic Chemistry, 5th Ed., ELBS London, 2007. 7. E.A. V. Ebsworth, D. W. H. Rankin & S. Craddock, Structural Methods in Inorganic Chemistry, ELBS, 1987. 8. R.S. Drago. Physical Methods in Chemistry,W. B. Saunders Company, 2016. 9. R. M. Silverstein, G. C. Bassler& T.C. Morrill, Spectrometric Identification of organic Compounds, 5th Ed., John Wiley 1991 10. J. Mendham, R.C. Denny, J. D. Barnes & M. Thomas, Vogel's Textbook of Quantitative Chemical Analysis 6th Ed., Pearson Education Asia, Delhi, 2002. 11. H. V. Keer, Principles of the Solid State new Age International, 1994 12. G.D. Christian, Analytical Chemistry, 6th Ed., Wiley, 2004. 13. D. A. Skoog, D. M. West, F. J. Holler & S. R. Crouch. Fundamentals of Analytical Chemistry Cengage learning 9th Ed., 2013. 14. D. A. Skoog, F. J. Holler & S. R. Crouch. Principles of Instrumental Analysis,7th Ed., Cengage learning 2017 15. D. Pavia, G. Lampman, G. Kriz& J. Vyvyan, Introduction to Organic Spectroscopy 5th Ed, Cengage Learning, 2015. 16. V. Rajaraman, Computer Programming in Fortran 90 And 95, PHI Learning Pvt. Ltd., 2013. 17. A. Szabo & N. S. Ostlund, Modern Quantum Chemistry Introduction to Advanced Electronic Structure Theory, Dover Publications, Inc. Mineola,	

	New York 1989. 18. F.D. King, Medicinal Chemistry: Principles and Practice, Royal Society of Chemistry, 1994. 19. K.V. Raman, Computers in Chemistry, Tata Mc.Graw Hill,1993. 20. S.K Pundir, A. Bansal, Computers for Chemists, Pragati Prakashan, 2010. 21. A. Leach, Molecular Modelling, Principles and applications, Longman Publications, 1998. 22. R. R. Spier, J. B. Griffiths, Animal Cell Biotechnology, Academic Press, London, 1990. 23. E. J. Gareth, Human Cell Culture Protocols, Humana Press.1996. 24. E. Julio, Celis, Cell Biology-A Laboratory Hand Book, Vol. I-IV, 2nd Ed., Academic Press, New York. 1998. 25. M. Butler, Animal Cell Technology, 2nd Ed., BIOS Scientific Publishers, U.K. 2004. 26. R. T. Freshney, Culture of Animal Cells, 5th Ed., John Wiley and Sons, New York. 2006.
Course Outcome:	1. Students will be able to apply the concepts of research methodology during their research work. 2. Students will be able to apply computer technology to solve their research problems in chemistry. 3. Students will know in advance the safety precautions to be taken in the chemical lab. 4. Students will gain fundamental knowledge on characterization techniques. 5. Students will acquire adequate knowledge on animal tissue culture.

<u>Title of the course: Polymers in Pharmaceuticals and novel drug delivery systems</u>

Course Code: CHH-621

Number of Credits:4

Effective from AY: 2023-24

Prerequisites for the course	Students should have studied the courses in M.Sc. Part I.	
Course Objective:	1. To learn classification synthesis and properties of polymers. 2.To learn the role of polymers in drug delivery systems. 3.To learn new innovations in drug delivery systems	
Content	**1. Brief history of natural and synthetic polymers** Classification & nomenclature of polymers, functionality concept- linear, -branched and -cross linked polymers. Introduction to biodegradable polymers:General methods of synthesis, properties, mechanism of biodegradation in the body.Analytical methods for monitoring biodegradation processes of environmentally degradable polymers. Characterization and evaluation of biodegradable polymers.	No of hours 8
	2. Introduction to Novel drug delivery systems Foundations of drug delivery in a conceptual and mathematical context. Drug deliverycarriers, routes of administration.Recent developments in responsive polymers, polymer therapeutics, and advanced systems designed for molecular recognition or engineered for intracellular delivery of novel therapeutics.Polymeric devices for drug delivery systems: Diffusion-controlled (monolithic devices), solvent-activated (swelling- or osmotically-controlled devices), chemically controlled (biodegradable), or externally-triggered systems (e.g., pH, temperature).	10
	3. Types of polymers for novel drug delivery systems Poly lactic-co-glycolic acid (PLGA), PGA(poly glycolic acid), Polyglutamic acid (PGA) , Polylactic acid, PNIPAAm [Poly(N-isopropylacrylamide)], pHEMA[Poly 2-hydroxyethyl methacrylate], PPy [Polypyrrole], PAMAM [Poly (amidoamine)], DEXTRAN.	8
	4. Types of drug delivery systems Theory of controlledrelease drug delivery systems. Microencapsulation – Methods ofencapsulation. Transdermal	8

	drug delivery systems – Theory,formulation, production and evaluation. Targeted drug deliverysystems – concept of drug targeting, importance in therapeutics.	
	5.**Advanced biopolymeric systems for drug delivery** Critical Points in Biopolymeric-Controlled Release Matrix Systems, Biopolymeric Gels in Drug Delivery, In Situ Polymeric Gels for Topical Drug Delivery, Smart Polysaccharide Hydrogels in Drug Delivery and Release, Polysaccharide-Based Nanoparticles: Nanocarriers for Sustained Delivery of Drugs, Polysaccharide-Based Nanocarriers for Oral Delivery of Insulin in DiabetesLiposomes and Dendrimers for Advanced Drug Delivery, Marine Polysaccharides Systems for Drug Delivery applications.	14
	6.**Recent Innovations in polymeric drug delivery systems and its applications** Recent innovations in conventional dosage form like tablets, capsules, sterile dosage forms, pellets, Mucoadhesive system, GRDDS, peptide drug delivery, supercritical fluid technique, PEGylation, Nanoparticulate drug delivery. Sustained In Vitro and In Vivo Delivery of Metformin from Plant Pollen-Derived Composite MicrocapsulesPolymeric Hydrogels for Controlled Drug Delivery to Treat ArthritisAdvancements in Rectal Drug Delivery Systems: Clinical Trials, and Patents Perspective. Future opportunities and challenges.	12
Pedagogy	Lectures/ tutorials/ project work/ industry visits/viva/seminars/ term papers/assignments/ presentations/ self-study/Case Studies etc. or a combination of some of these. Sessionshall be interactive in nature to enable peer group learning.	
References / Readings	1. V. R. Gowarikar, N.V. Vishwanathan, J. Sreedhar, Polymer Science, New Age International, 2015. 2. J. R. Fried, Polymer Science and Technology, PHI Pvt. Ltd.,2000. 3. R. Sinha, Outlines of Polymer Technology: Manufacture of Polymers, PHI Pvt Ltd., 2000. 4. K. Y. Saunders, Organic Polymer Chemistry, Chapman and Hall, UK, 1976. 5. H. R. Kircheldorf, Handbook of Polymer Synthesis, PART A and B, Marcel Dekkar Inc., 1992. 6. R. P. Brown, Handbook of Plastic Test Methods, 2ndEd.,George Godwin Ltd., 1981.	

	7. M. P. Stevens, Polymer Chemistry- An Introduction, 2nd Ed., Oxford Univ. Press, 1990. 8. W. Y. Mijs, New Methods in Polymer Synthesis, PelnumPress Ltd., NY, 1992. 9. M. Arora, Polymer Chemistry, Anmol Publications 2001. 10. C. E. Carraher, Polymer Chemistry, New York M. Dekker 2005. 11. P.C. Hiemenz, Polymer Chemistry, CRC Press, 2007. 12. V. K. Selvaraj, Advanced Polymer Chemistry, New Delhi Campus books, CRC Press, 2008. 13. A. Ravve, Principles of polymer Chemistry, Springer 2012. 14. J. David , Polymers, Oxford University Press 2015. 15. U.S. Beans, A.K. Beckett & J.E. Caralem, Advances in Pharm Sci,Vol 1-4, Elsevier, 2009. 16. G.S. Banker, Modern Pharmaceutics, Dekker Incorporated, Marcel, 2002. 17. L. Lliun& S. S. Davis, Polymer in Controlled Drugs Delivery, Wright, Bristol, 1987. 18. J. R. Crompton, Analysis of Polymer- An Introduction, Pergamon Press, Oxford, 1989. 19. M. P. Steven, Polymer Chemistry An Introduction, New York, Oxford, Oxford University Press, 1990. 20. M. Charin, Biodegradable Polymers as Drug Delivery Systems, Informa HealthCare, 1990. 21. A.H. Beckett & J. B. Stenlake, Practical Pharmaceutical Chemistry Vol I &II, CBS Publishers, 2005. 22. P. J. Sinko, Martin's Physical Pharmacy and Pharmaceutical Sciences, 6th Ed., Lippincott William and Wilkins, 2006. 23. S.J. Carter, Cooper and Gunn's Tutorial Pharmacy, 6th Ed., CBS Publisher Ltd, 2008. 24. Indian Pharmacopoeia, British Pharmacopoeia. 25. J.R. Robinson & Vincent H.L. Lee, Controlled Drug Delivery, Drugs and Pharm. Sci. Series, Vol. 29, Marcel Dekker Inc. N.Y, 987. 26. J.R. Juliano, Drug Delivery Systems, Oxford University Press, Oxford, 1980. 27. M.I. Gutcho, Microcapsules and Microencapsulation Techniques, Noyes Data Corporation, 1976. 28. A. Lendlein&A. Sisson, Handbook of Biodegradable Polymers: Isolation,

	Synthesis, Characterization and Applications, 1st Ed., Wiley Publishers, 2011. 29. V. V. Ranade & J. B. Cannon, Drug Delivery Systems, 3rd Ed., CRC Press, 2011. 30. A.K. Nayak & Md. S. Hasnain, Advanced Biopolymeric Systems for Drug Delivery, 1st Ed., Springers, 2020. 31. V.A. Guerrera, Innovative Polymers for controlled drug delivery, Pharmaceutics, 1st Ed., Vol.14, Multidisciplinary Digital Publishing Institute, 2022.
Course Outcome:	1. Students will be able to identify the type of polymers that can be used for drug delivery systems. 2. Students will be able to get the knowledge of innovative drug delivery systems and apply it for their lab project. 3. Students will be able to understand the Advanced biopolymeric systems for drug delivery 4. Students will be able to understand the new innovations in drug delivery systems

<u>Title of the course: Pharmacotherapeutics</u>

Course Code: CHH-622

Number of Credits:4

Effective from AY: 2023-24

Prerequisites for the course	Students should have studied the courses in M.Sc. Part I.	
Course Objective:	1. To enable the students to understand the different approaches to treat and manage various disease conditions. 2. To impart knowledge and skills in optimizing drug therapy of a patient by personalizing the treatment. 3. To summarize the therapeutic approach for management of various diseases. 4. To explain the rationale for drug therapy andplan through evidence-based medicines.	
Content	**1. Diseases of central nervous system**: Epilepsy, Parkinson's disease, Stroke, Headache, Alzheimer's disease, Neuralgias and Pain pathways and Pain management. Psychiatric disorders: Schizophrenia, Depression, Anxiety disorders, Sleep disorders, drug induced psychiatric disorders.	No of hours 10
	2. Infectious diseases: General guidelines for the rational use of antibiotics and surgical prophylaxis, urinary tract infections, respiratory tract infections, Gastroenteritis, tuberculosis, malaria, bacterial endocarditis, septicemia. meningitis, HIV and opportunistic infections, rheumatic fever, dengue fever, H1N1, helmenthiasis, fungal infections. Neglected tropical diseases: leishmaniasis, schistosomiasis, chagas, sleeping sickness.	10
	3. Diseases of cardiovascular and respiratory system: Hypertension, Congestive cardiac failure, Acute coronary syndrome, Arrhythmias, Hyperlipidemias, Asthma, Chronic obstructive airways disease, Drug induced pulmonary diseases.	10
	4. Diseases of gastrointestinal system: Peptic ulcer diseases, Reflux esophagitis, Inflammatory bowel diseases, Jaundice & hepatitis, Cirrhosis, Diarrhoea and Constipation, Drug-induced liver disease.	10
	5.Oncologicaldisorders: General principles of cancer chemotherapy, pharmacotherapy of breast cancer, lung cancer,	8

	head & neck cancer, hematological malignancies, management of nausea and vomiting, Palliative care.	
	6. Other Diseases Bone and joint disorders: Rheumatoid arthritis, osteoarthritis, gout, osteoporosis. Dermatological Diseases: Psoriasis, eczema and scabies, impetigo, drug induced skin disorders. Ophthalmology: Conjunctivitis, glaucoma. Diseases of renal system: Acute renal failure, chronic renal failure, renal dialysis, drug induced renal disease. Gynaecological disorders: Dysmenorrhea, hormone replacement therapy. Endocrine system: Diabetes Mellitus, thyroid diseases. Hematological diseases: Anaemia, deep vein thrombosis, drug induced hematological disorders.	12
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. R. Walker. Clinical Pharmacy and Therapeutics, 5^{th} Ed., Churchill Livingstone publication, 2012. 2. J. DiPiro, Pharmacotherapy: A Pathophysiologic Approach, 7^{th} Ed., McGraw Hill Publishers 2008. 3. S.L.Robins, Pathologic basis of disease., 9^{th} Ed., W.B. Saunders publication 2014. 4. E. T. Herfindal. Clinical Pharmacy and Therapeutics, 3^{rd} Ed., Lippincott Williams and Wilkins Publication, 1984. 5. L.Young and M.A. Koda-Kimble, Applied Therapeutics: The clinical Use of Drugs, 9^{th} Ed., Lippincott Williams and Wilkins, 2008. 6. C.B. Wells, S. Malone and J. P. Dipiro. Pharmacotherapy Principles and practice, 4^{th} Ed., McGraw Hill Publication. 2016. 7. C. M. Porth. Principles of Pathophysiology, 3^{rd} Ed., Lippincott Williams and Wilkins Publications, 2010. 8. Harrison's Principles of Internal Medicine. (Vol1 and 2), 20^{th} Ed., McGraw Hill Publications, 2018. 9. R. Mannhold& H. Buschmann, Neglected Tropical Diseases Drug Discovery and Development, Vol 37, John Wiley and Sons, 2019. 10. P. Hotez, Neglected Tropical Diseases, Vol 1-5(book series), Springers, 2022.	

Course Outcome:	1. Students will be able to discuss the clinical controversies in drug therapy. 2. Students will be able to identify the patient specific parameters relevant in initiating drug. 3. Students will be able to prepare individualized therapeutic plans based on diagnosis, medicine therapy, and monitoring therapy. 4. Students will be able understand various infectious and non-infectious diseases.

Title of the course: API Process, Manufacture and Green Chemistry

Course Code: CHH-623

Number of Credits:4

Effective from AY: 2023-24

Prerequisites for the course:	Should have studied courses at M.Sc. Part-I.	
Course Objective:	1. To learn about the selected drugs. 2. To learn about the role of process chemistry. 3. To understand the process research and development of PenicillinG CAS and Rabeprazole CAS 4. To understand the drug optimization and drug discovery. 5. To understand various concepts involved in green synthesis. 6. To understand green technologies used in chemistry. 7. To learn application of green chemistry approaches to pharmaceutical industry.	
Content	**1.Process chemistry in pharmaceutical industry –** Background of process chemistry – role of process chemistry. Strategy of process research & development in pharma industry. Case studies: A practical synthesis of Ifetrobansodium. Synthesis of 5-lipoxygenase inhibitors Chemistry of Vitamin D: A challenging field for process researchDilevalol Hydrochloride: Development of a commercial processThe process research and development of DuPont Merck's cyclic urea diols, anew class of HIV protease inhibitors. Process research and development of PenicillinG CAS Reg. No.[61-33-6] (antibacterial); Fosinopril CAS Reg. No.[98048-97-6](antihypertensive) ; Combinatorial chemistry: Introduction – Drug Optimization – Drug discovery – Solid Phase Technique – parallel synthesis – Mixed Combinatorial Synthesis.	No of hours 12
	2.Biocatalysis, phase transfer catalysis, asymmetric synthesis and polymorphism: Biocatalysis and Engineering: An interdisciplinary approach to the manufacture of the Benzodiazepine drug candidate LY 300164. Application of phase transfer catalysis technology in pharmaceutical industry for drug synthesis. Asymmetric Synthesis and Enantioselectivity: Enantioselective synthesis of chiral 2-hydroxycarboxylic acids and esters – asymmetric catalysis –eg.asymmetric	12

	hydrogenation – L-Dopa process ;Sharpless asymmetric epoxidations eg.synthesis of Fluoxetine enantiomers. Chiral (Salen)Mn(III) Complexes in asymmetric epoxidations: Practical Synthesis of cis-Aminoindanol and its application to enantiopure drug synthesis. Practical Enantio- and Diastereo-selective Processes for Azetidinones. Polymorphism – solid state – crystallization – recrystallization of drug molecules eg.isolation techniques and characterization of polymorphs of Venlafaxine hydrochloride[99300-78-4] Clopidogrelbisulphate [135046-48-9] and Lorazepam[846- 49-1] (any two).	
	3. Chemical Process safety norms: Concept of Green Chemistry, its 12 principles and Green Chemistry Metrics. Introduction, industrial disasters of the world, definition of green chemistry, twelve green principles, Need for green chemistry in pharmaceuticals, green chemistry for better sustainability. Green Chemistry metrics for measuring greenness (E-factor, atom economy, mass intensity, process mass intensity, process mass efficiency, chemical yield). Waste prevention, management andhierarchy. Atom Economy: Calculation and predicting greenness of a reaction. Comparison of Diels Alder reaction and Wittig Reaction. Addition v/s Elimination v/s Substitution. Less hazardous chemical synthesis: Avoiding use of hazardous substances for any synthesis (Thiamine hydrochloride to be preferred over KCN for benzoin condensation). Role of chirality in the need for designing safer chemicals with illustration of Thalidomide.	8
	4. Safer solvents in chemistry. Knoevenagel condensation by grinding method. Advantages and disadvantages of solvent-free reaction. Water as green solvent in organic synthesis (Diels Alder Reaction). In water and on water mechanisms. Ionic liquids as designer solvents with one application. Supercritical solvents and their application in extractions. Deep Eutectic solvent (DES) with example and one application. Fluorous solvents and biphasic extraction.	8
	5. Emerging greener technologies for energy efficiency and catalysis	10

	Organic synthesis at ambient temperature and pressure, photochemical reactions as green process (advantages). Microwave assisted organic synthesis: Principle and applications. Sonochemistry as a sustainable alternative for organic synthesis, giving examples. Electrifying organic synthesis in designing new target molecules. Continuous flow synthesis as a sustainable technology for pharmaceutical industry. Impact of continuous flow chemistry in the synthesis of naturalproducts and active pharmaceutical ingredients. Recent examples of green chemistry articles of interest to the pharmaceutical industry: C-H activation, green fluorination, continuous processing and process intensification.	
	6. Green Synthesis of representative drugs Multicomponent synthesis: Ugi, Biginelli, Passerni, Mannich, Strecker. One-Pot Synthesis of (S)-Baclofen.Synthesis of Ibuprofen, Boots (conventional) and green synthesis. Comparison and atom economy. Green synthesis of Paracetamol, Aspirin, Celecoxib, Sildenafil citrate, Sertraline, Artemisinin, Paroxetine, Pregabalin, Imatinib, Simvastatin, Quinapril HCl.	10
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / industry visits/field trips/self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. M. Lancaster, Green Chemistry, The Royal Society of Chemistry, Cambridge,UK, 2002. 2. V. K. Ahluwalia, Green Chemistry: Environmentally Benign Reactions, Ane Books India, New Delhi, 2006. 3. A. S. Matlack, Introduction to Green Chemistry, Marcel Dekker, Inc., New York, 2001. 4. P. T. Anastas and T. C. Williamson, Green Chemistry: Frontiers in benign chemical synthesis and processes, Oxford University Press, Oxford, Eds. 1998. 5. R. Sanghi and M. M. Srivastava, Green Chemistry: Environment Friendly Alternatives, Narosa Publishing House, Eds. New Delhi, 2007. 6. Samuel Delvin, Green Chemistry, IVY Publishing House, Delhi, 2006. 7. V. K. Ahluwalia and M. Kidwai, New Trends in Green Chemistry, 1st Ed., Anamaya Publishers, New Delhi, 2004.	

	8. P. G. Jessop and W. Leitner, Chemical Synthesis using Supercritical fluids, Wiley – VCH, Verlag, (Eds., Weinheim, 1999. 9. K. Tanaka, Solvent Free Organic Synthesis, 2nd Ed., Wiley – VCH GmbH and Co. KgaA, Weinheim, 2003. 10. P. T. Anastas and J. C. Warner, Green Chemistry, Theory and Practice, Oxford University Press, N. York, 1998. 11. C - Jun Li and T – Hang Chan, Organic Reactions in Aqueous Media, John Wiley and Sons INC., N. York, 2001. 12. F. Z. Dorwald, Organic Synthesis on Solid Phase, Wiley – VCH Verlag, Weinheim, 2002. 13. P. Wasserscheid and T. Welton, Ionic Liquids in Synthesis, Wiley – VCH Verlag, Ed., Weinheim, 2003. 14. A. Loupy, Microwaves in Organic Synthesis, Wiley – VCH Verlag, Weinheim, 2002. 15. R. V. Eldik and F. G. Klarner, High Pressure Chemistry, , Wiley – VCH Verlag, Weinheim, 2002. 16. R. Hilfiker, Polymorphism in Pharmaceutical industry, Wiley-VCH, 2006. 17. H. G. Brittain, Polymorphism in Pharmaceutical solids, 2nd Ed., CRC Press, 1998. 18. C. Starks, C. Liotta, M. Halpern, “Phase-Transfer Catalysis: Fundamentals, Applications and Industrial Perspectives,” Chapter 16, Chapman & Hall, New York,1994. 19. A. Kumar&A. Anjali, Adoption of green methodology in industry for the synthesis of sildenafil citrate and Celecoxib: case study.Volume 60, Part 2, 2022, Pages 1021-1025. 20. P. J. Harrington, Pharmaceutical Process Chemistry for Synthesis: Rethinking the Routes to Scale-Up, Wiley Publishers, 2011. 21. J. M. DeSouza, R. Galaverna, A. A. N. De Souza, T. J. Brocksom, J. C. Pastre, R.M.A. De Souza & K. T. De Oliveira. Impact of continuous flow chemistry in the synthesis of natural products and active pharmaceutical ingredients, Anais da Academia Brasileira de Ciências ,2018, 90(1 Suppl. 2): 1131-1174. 22. F. Fanelli, G. Parisi, L. Degennaro& R. Luisi, Contribution of microreactor technology and flow chemistry to the development of green and sustainable synthesis, Beilstein J. Org. Chem. 2017, 13, 520–542. 23. E. Yu, H. P. R. Mangunuru, N.l S. Telang, C. J. Kong, J.Verghese, S. E. Gilliland , S. Ahmad, R. N. Dominey& B. F. Gupton, Beilstein , High-yielding continuous-flow synthesis of antimalarial drug

	hydroxychloroquine, J. Org. Chem. 2018, 14, 583– 592. 24. R. Porta, M. Benaglia, & A. Puglisi. Flow Chemistry: Recent Developments in the Synthesis of Pharmaceutical Products. Org. Process Res. Dev. 2016, 20, 2−25. 25. K. G. Gadamasetti, Process chemistry in the pharmaceutical industry, 1st Ed., Taylor and Francis, 1999. 26. K. G. Gadamasetti, Process chemistry in the pharmaceutical industry: Challenges in an everchanging climate, 2nd Ed., Taylor and Francis, 2019.
Course Outcome:	1. Students will be able toacquire knowledge about the Top drugs. 2. Students will be to learn about the role of process chemistry and understand the Process research and development of PenicillinG CAS and Rabeprazole CAS 3. Students will be able to understand the drug optimization and drug discovery. 4. Students will be in a position to understand how chemistry can be done using greener alternatives. 5. Students will be able to apply green technologies as a sustainable solution for making drug molecules. 6. Students will be able to understand and apply the concepts of green chemistry to develop scalable processes in industry.

Title of the course: Pharmaceutical and Spectral Analysis

Course Code: CHH-624

Number of Credits:4

Effective from AY: 2023-24

Prerequisites for the course	Students should have studied the courses in M.Sc. Part I.	
Course Objective:	1. To study the advanced pharmaceutical analytical techniques. 2. To acquire the knowledge of theory and practical skills of instruments. 3. To understand and interpret the spectral data.	
Content	**1. Introduction to pharmaceutical analysis and techniques**: Scope and range of modern pharmaceutical analysis. Listing of various pharmaceutical analytical techniques, with broad discussion on their instrumentation, working and pharmaceutical applications: HPLC, GC, HPTLC, DSC-DTA, XRD. Material and product specifications: Definition of specifications, study of ICH Q6 guidelines and understanding of specifications through study of pharmacopoeial monographs on drug substances and products. Reference standards used: Types (primary, secondary, working and test standards), preparation, containers, labelling, storage and use. Documentation of analytical data-STPs, certificate of analysis, laboratory books: Typical documents used in a GLP laboratory including standard test protocols, COA and laboratory notebooks. Electronic records & signatures (21CFR Part-11 requirement)	No of hours 10
	2. Calibration and Validation: Method validation: Definition and methodology, discussion on each parameter with examples, special considerations in bioanalytical method validation. Calibration and qualification of equipment: Difference of definitions, calibration standards, calibration frequency, examples of calibration of pH meter, potentiometer, Flame photometer, FTIR, UV spectrophotometer and HPLC. Definition of qualification process involving URS [user requirement specification], DQ, IQ, OQ, CQ and PQ.	10
	3. Quality and risk management in analytical laboratory: Definition of quality risk management in ICH Q9 guideline. Its	8

	importance and application to analytical laboratory with examples. Quality of analysis by design. Impurity profiling: Types of impurities in drug substances and products. Method development for impurity analysis, techniques, identification and quantization. Management of analytical laboratory: Organization of laboratories based on their types, staffing, skill development and training, budgeting and financing, purchase of costly equipment, qualities of laboratory manager and management styles. Laboratory inspections and audit: Internal inspection, external audit, concepts, preparing for inspections and audits.	
	4. Spectral Analysis-I **i) Ultra Violet (UV)-visible spectroscopy and its pharmaceutical applications**: a) Electronic excitations, Beer Lamberts Law, predicting UV absorption using Woodward-Fieser, Fieser-Kuhn and Nelson rules; Calculation of λmax for β-Carotene, Lycopene, Piperine, Curcumin, Factors affecting UV spectra Non-conjugative effect, solvent effect, S-Cis band. Types of UV spectroscopic analytical techniques with illustrative examples: Simultaneous equation method: Paracetamol and Diclofenac sodium, Norfloxacin and Tinidazole,Quercetin, curcumin, and piperine. Difference spectrophotometric method:Leflunomide, Pioglitazone and metformin. Derivative spectrophotometric method: Quantitative assay of Diazepam. Variants of derivative spectroscopy: Ratio derivative: Successive ratio derivative spectra method, absorption ratio method with application. **ii) Infrared (IR)spectroscopy**: Principle of Infra Red spectroscopy, Hooke's Law, types of vibrations, Correlation of structure with IR spectra: Influence of substituents, ring size, hydrogen bonding, vibrational coupling and field effect on frequency. Applications: Identification of functional groups in the following drugs:Acyclovir, Chloroquine, Mebendazole, Ethambutol, Metronidazole,Dapsone, Cis-Platin, Ibuprofen, Chloramphenicol, Lidocaine, Aminohippuric acid, Theophylline, Determination of stereochemistry-Ethambutol and Methyl Dopa. Spectral interpretation with examples. Problem solving of UV and IR for structure elucidation.	12
	5.Spectral Analysis-II **Nuclear Magnetic Resonance (NMR) spectroscopy**: Principle of	14

	proton NMR spectroscopy,chemical shift-shielding and deshielding effect, magnetic anisotropic effect, TMS as reference standard, spin-spin splitting-coupling constant, NMR solvents and their residual peaks. Interpretation of NMR spectra of some compounds and drugs (Ibuprofen, Metronidazole, Morphine, Chloramphenicol, Isoniazid, Mebendazole, Lidocaine, 2-methylbenzothiazole, benzoxazole, pyrimidine,2-phenylbenzminidazole).^{13}C-NMR, correlation of structure with spectra: Chemical environment, shielding and carbon-13 chemical shift, calculation, proton-coupled Carbon Spectra, Protondecoupled Cspectra, Nuclear Overhauser Enhancement (NOE), Distortion less Enhancement by Polarization Transfer (DEPT), Heteronuclear coupling for carbon to deuterium, carbon to ^{19}F, carbon to ^{31}P.Fluorine chemical shift Anisotropy and exchange for Screening (FAXS). Three Fluorine Atoms for Biochemical Screening (3-FABS). NMR for Lead optimization and SAR studies. Explanation of spectra of some compounds and drugs. (Fluconazole, Thiotepa, Chlorphenaramine, Dapsone, Nitrogen mustard) NMR problem solving for structure elucidation.	
	6.Mass spectrometry (MS): Molecular ion and metastable peak, fragmentation patterns, nitrogen and ring rules, McLafferty rearrangement, electron and chemical ionization modes, applications. Mass spectra of any 2 drugs. (Combined UV, IR, NMR, Mass Problems for structure elucidation)	6
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. F. Rouessac& A. Rouessac, Chemical Analysis: Modern Instrumentation Methods and Techniques, 2nd Ed., Wiley Publishers, 2013. 2. M. Valcarcer, Principles of Analytical Chemistry, 2000th Ed., Springers, 2012. 3. M. E. Swartz& I. S. Krull, Analytical Method Development and Validation, 1st ed., 1997, CRC Press. 4. J. P. Seiler, Good Laboratory Practices, Springer, 2001. 5. D. A. Skoog, F. J. Holler & T. A. Nineman, Principles of Instrumental	

	Analysis, 7^{th} Ed., 2018. 6. S. Ahuja & S. Scypinski, Handbook of Modern Pharmaceutical Analysis, 2^{nd} Ed., Elseviers Publishers, 2010. 7. R. F. Venn, Principles and Practice of Bioanalysis, CRC Press, 2008. 8. D. L Pavia, Gary M Lampman, George S Kriz, James A Vyvyan. Spectroscopy, 3^{rd} Ed., Thomson learning, 2001. 9. W. Kemp, Organic Spectroscopy, 3^{rd} Ed., New York Palgrave, 2019. 10. D. H. Williams & I. Fleming, Spectroscopic Methods in Organic Chemistry, 5^{th} Ed., McGraw Hill, 1995. 11. R. M. Silverstein, F. X. Webster & D. J. Kiemie, Spectrometric Identification of Organic Compounds, 7^{th} Ed., Wiley and Sons, 2005. 12. J. R. Dyer, Applications of Absorption Spectroscopy of Organic Compounds, Prentice Hall of India Pvt.Ltd., 1978. 13. D.M. Atole& H. H. Rajput, Ultraviolet spectroscopy and its pharmaceutical applications-A brief review, Asian J Pharm Clin Res, Vol 11, Issue 2, 2018, 59-66. 14. P. Agarwal, NMR Spectroscopy in Drug Discovery and Development, Materials and Methods, 2014, 4, 599. 15. M. Pellecchia, D. Sem & K. Wuthrich, NMR in drug discovery. Nat. Rev. Drug Discov., 2002;1:211-9. 16. Y. Zhong , K. Huang, Q. Luo, S. Yao, X. Liu ,N. Yang, C. Lin ,& X. Luo, The Application of a Desktop NMR Spectrometer in Drug Analysis, Hindawi International Journal of Analytical Chemistry, Volume 2018, Article ID 3104569. 1. H.W. Dibbem, UV and IR Spectra of some important drugs, Annals of Pharmacotherapy, Vol.15 (2), Editio Cantor Aulendorf Publishers, 1978. 2. D. T. Rossi & M. Sinz, Mass Spectrometry in Drug Discovery, 1^{st} Ed., Taylor and Francis, 2001. 3. I. Sunshine &M.Caplis, CRC handbook of mass spectra of drugs, Boca Raton Fla: CRC Press, 1981.
Course Outcome:	1. Students will be able understand various pharmaceutical analytical techniques. 2. Students will be able to apply this knowledge to various pharmaceutical industries. 3. Students will be able to explain all characterization techniques for pharmaceutical products. 4. Students will be able to analyse spectral data.

<u>**Title of the course: Bioorganic and Medicinal Chemistry**</u>

Course Code: CHH-625

Number of Credits:4

Effective from AY: 2023-24

Prerequisites for the course	Students should have studied the courses in M.Sc. Part I.	
Course Objective:	1. To understand the concepts of bioorganic chemistry and medicinal chemistry. 2. To study in brief about carbohydrates, nucleic acids and enzyme chemistry. 3. To introduce the topic of biomimetics. 4. To acquire knowledge on biosynthesis of natural products. 5. To understand the concept of drugs as enzyme inhibitors. 6. To synthesize selected drugs and understand its mechanism.	
Content	**1. Introduction to Bioorganic chemistry**: Basic concepts, definition, Proximity effects in organic chemistry and overlapping subject biochemistry and organic chemistry, Molecular adaptation, Molecular recognition.	No of hours 4
	2. Carbohydrates, Nucleic acids and Protein Chemistry. Chemical structure and properties of nucleosides, nucleotides, nucleic acids. The biological and biochemical mechanisms of DNA replication and transcription.The structure of amino acids and the primary, secondary and tertiary structure of peptides and proteins. Determination of configuration of Glucose (Fischer's proof). Cyclic structure of glucose. Mutarotation Haworth projections. Lobry de Bruyn-van Ekenstein rearrangement; stepping–up (Kiliani- Fischer method) and stepping–down (Ruff's &Wohl's methods) of aldoses; end-group interchange of aldoses. Linkage between monosachharides, structure of disacharrides (sucrose, maltose, lactose.)	6
	3. Enzyme Chemistry: Introduction, Nomenclature, classification and extraction of enzymes, Introduction to catalysis and enzymes; Multifunctional catalysis, Intramolecular catalysis, mechanism of enzyme action, factors responsible for enzyme specificity, enzyme activity and kinetics (Michaelis Menten and Lineweaver–Burk plots), enzyme inhibitions (Reversible and irreversible), structure, mechanism of action and applications of α-Chymotrypsin, Ribonuclease, lysozyme and Carbopeptidase-A. Enzymes in synthetic organic chemistry. [Reactions to be covered-Additions, eliminations, substitutions,	8

	condensations, oxidations, reductions and rearrangement]	
	4. Biomimetics and Biosynthesis of Natural products- **Biomimetics**: Definition**,** biological mechanisms, natural mechanisms, biomimetic structures, biomimicry at the cell-material interface, tissue structure and biomimetic applications. Biomimetic chemistry for NADH model. **Biosyntheses of natural products:** Biosyntheses of Alkaloids: Types of Metabolites of plants (Primary and secondary), Types of metabolic pathways: Shikimic and Mevalonic. Biosyntheses of Morphine from tyrosine and Nicotine from Ornithine. Biosyntheses of Steroids: Testosterone and Cholesterol.Biosyntheses of 6-methylsalicylic acid, tetracyclins. Modular polyketide synthase, Erythromycin biosynthesis, engineering novel polyketide antibiotics.	10
	5. Co-Enzyme Chemistry-Chemical structures of co-enzymes and cofactors, Oxidoreduction (NAD+, NADP+), Pyridoxal phosphate (PLP) in transamination, Thiamine pyrophosphate (TPP), Biotin (CO_2 carrier), Haemoglobin (O_2- carrier), Flavin (FMN, FAD, $FADH_2$), Oxene Reactions, Lipoic acid, Mechanisms of reactions catalyzed by co-factors. Oxidation by cytochrome-450. Hansester as NADH model (give an example)	10
	6. Medicinal Chemistry and Pharmacology Role of medicinal chemistry, properties of drug and receptor, Pharmacophore, toxicophore and metabiophore. Pharmacodynamics and Pharmacokinetics. Drug Design based on Target based and phenotype approach. Enzyme inhibitors as drugs. Antagonist behaviour of Caffeine, Role of Enoyl acp reductase, cyclooxygenase inhibitors, Kinase, α-Glucosidase, Dihydrofolate reductase, ACE-2 in the biological processes. Designing the drug and Mechanism of action of Isoniazid, Ibuprofen, Erlotinib, acarbose, captopril. Concept of molecular docking in computer aided drug designing. Structure –activity relationships of drug molecules, binding role of –OH group,-NH_2 group, double bond and aromatic ring to receptor. SAR of following drugs (Chloramphenicol, Procaine, Isoniazid, Chloroquine, Methyl Dopa).	12
	5. Synthesis of drugs with mechanism: **Anti inflammatory Drugs**: Naproxen, Celecoxib. **Anti-hypertensive**	10

	Drugs: Captopril, Atenolol. **Drugs acting on CNS**: (a) CNS Stimulant : Dextro-amphetamine (b) Respiratory Stimulant : Doxapram (c) CNS anti-depressant : (i) Chlorpromazine (Antipsychotic) (ii) Diazepam(Anxiolytic) (iii) Phenobarbital (Antiepileptic) (d) Anaesthetic Drugs: (a) General : Ketamine (b) Local : (i) Lidocaine. **Antibiotics**: Amoxycillin**.** **Antimycobactrial**: Ethambutol. **Antiviral**: Acyclovir. **Antimicrobial**: Sulfamethoxazole. **Antidiabetics**: Tolbutamide (k). **Antineopastic Drugs**: (a) Antagonist: Fluorouracil (b) Alkylating agents: i) Chlorambucil (ii) Cis-Platin. **Antimalarial**: Hydroxychloroquine	
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. D. A. Williams & T. L. Lemke, *Foye's principles of medicinal chemistry*, 5th edition, Lippincott Williams and Wilkins, 2006. 2. J. M. Beale & J. M. Block, *Wilson &Gisvold's Text book of Organic Medicinal & Pharmaceutical Chemistry*, Lippincott Williams and Wilkins; 2004. 3. D. J. Abraham & D. P. Rotella, *Burger's Medicinal Chemistry Drug Discovery and Development*, 7th edition, John Wiley & Sons N.Y, 2010. 4. D. Shriram, P. Yogeshwari, *Medicinal Chemistry*, Pearson Education, 2007. 5. G. L. Patrick: *Introduction to Medicinal Chemistry*, Oxford University Press, UK. 6th edition, 2017. 6. D. Lednicer& L. A. Mitscher, *The Organic Chemistry of Drug Synthesis*. (6 volume set) III. John Wiley & Sons, 2005. 7. H. Singh & V. K. Kapoor, *Medicinal and Pharmaceutical Chemistry*, Vallabh Prakashan, 2010. 8. G. R Chatwal, *Medicinal Chemistry (Organic Pharmaceutical Chemistry)*, Himalaya Publishing house, 2002. 9. N. K. Tripathi & R. C. Verma, *Bioorganic and Medicinal Chemistry, Theory and Practical*s, Thakur Publications Pvt Limited, 2021. 10.T. M. Kutchan,*Alkaloid biosynthesis – the basis for metabolic engineering of medicinal plants*. Plant Cell, 1995. 7, 1059-1070. 11. Y. Bar-Cohen,*Biomimetics: Nature-Based Innovation*, CRC Press, 2012. 12. I. L. Finar, *Organic Chemistry: Stereochemistry and the Chemistry of Natural Products*, Pearson Education India, 2002. 13. K. Nakanishi, *Natural Product Chemistry*, Academic Press, 2013.	

	14. D. R. Dalton, *The Alkaloids*. New York: M. Dekker, 1979. 15. D. Barton & W. D.Olis, *Comprehensive Organic Chemistry*, Pergamon, 1979. 16. D. Paul, *Medicinal Natural Products:A Biosynthetic Approach*, John Wiley and Sons, 2002. 17. M. Paolo, *Biosynthesis of Natural Products*, Wiley Publishers, 2010. 18. J. ApSimon, *The Total Synthesis of Natural Products*, John Wiley and Sons, 1992. 19. J. M. Beale Jr. & J. Block, *Wilson and Gisvold's Textbook of organic and medicinal chemistry*, 12thEd.,Wolters Kluwer India Pvt. Ltd, 2010.
Course Outcome:	1.Students will be able to apply the knowledge of carbohydrates, proteins, nucleic acids, enzymes, co-enzymes for designing enzyme inhibitors. 2.Students will be able to put into practice the knowledge of biomimetics. 3.Students will be able to biosynthesize natural products. 4.Students will be able to synthesize drugs, present structure activity relationship studies and also write its mechanism.

<u>Title of the course: Pilot Plant Scale-Up Techniques for Pharmaceuticals</u>

Course Code: CHH-602

Number of Credits:4

Effective from AY: 2023-24

<table>
<tr><td>Prerequisites for the course</td><td colspan="2">Students should have studied the courses in M.Sc. Part I.</td></tr>
<tr><td>Course Objective:</td><td colspan="2">1. To understand the various Pilot Plant scale-up techniques as adopted for industrial processes.
2. To examine Pilot Plant formula to determine its ability to with stand Batch-scale and process modification
3. To learn unit processes involving various chemical reactions.
4. To learn industrial synthesis of selected list of drugs.
5. To learn the need for pilot plant in industry and also the flowchart on various manufacturing methods of drugs.</td></tr>
<tr><td rowspan="3">Content</td><td>1. Introduction to Pilot Plant:
Definition, objectives and significance of Pilot Plant. Need to conduct Pilot Plant studies. Uses of Pilot Plant Scale-Up. Several considerations in Pilot Plant scale up activities in R and D development Scale up process. The layout of the relationship between different activities during technology transfers from the pilot plant to the production facility. Future developments. The layout of the relationship between different activities during technology transfers from the pilot plant to the production facility. Limitations of pilot plant.</td><td>No of hours

10</td></tr>
<tr><td>2. Unit processes for various chemical reaction types for pilot plant:
Concept of unit processes in systematization of chemicalreactions, explanation of one example each for unit processes:Alkylation, amination, (by ammonolysis, reduction), carbonylation,carboxylation, condensation, dehydration, diazotization,
disproportionation, esterification, halogenation, hydration,hydroformylation, hydrogenation, hydrolysis, hydroxylation,nitration, oxidation and reduction.</td><td>10</td></tr>
<tr><td>3. Industrial Synthesis:</td><td></td></tr>
</table>

	Introduction to pharmaceutical manufacturing – raw materials, detailed manufacturing procedure, therapeutic function, commonname, chemical name, structural formulae of the following drugs:Acyclovir, alprazolam, propanolol, naproxen, ibuprofen, aspirin,levodopa and cimetidine, lidocaine, ethambutol hydrochloride, 5-fluorouracil, amoxycillin sodium.	12
	4.General Considerationsfor Pilot Plant scale up process: Reporting Responsibility: Space requirements, Personnel requirements, Training, Review of the Formula, Raw Materials, Relevant processing equipment, process rate and evaluation, Preparation of Master Manufacturing Procedure, GMP Consideration-advantages and disadvantages, Transfer of Analytical Methods to Quality Assurance, Pilot plant scale up considerations for solids.	10
	5. Pilot Plant Scale Up considerations for solids, oral liquids and semi-solids. Layout of pilot plant, Stages of Production of Tablets, Material handling, Dry blending, Granulation, Drying, Reduction of particle size, Blending, Direct compression, Slugging (dry granulation techniques). Process evaluation. Master Manufacturing Procedures, Product, stability, and uniformity. Good Manufacturing practices. Flow chart on Pilot plant process scale-up.Steps of liquid manufacturing process, Critical aspects of liquid manufacturing, solution, suspension, emulsions. Pilot plant scale up considerations for semi-solids.Contract manufacturing: Scope and limitations	12
	6. SUPAC (Scale Up and Post-approval changes guidelines) and Platform Technology: The SUPAC Guidelines define, the components or composition changes, The site changes of manufacture, Changes in Batch Size (Scale-Up/Scale-Down), Manufacturing Changes. Introduction to platform technology:Pharmaceutical Platform technologies, Importance platform technology, Types of platform technology.	6
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations /industry visits/ self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	7. Levin M. *Pharmaceutical Process Scale-Up*. New York: Marcel Dekker, Inc..2001.	

	4. Groggins, *Unit processes in Chemical Engineering*, 1st Ed., McGraw-Hill, 1958. 5. Drydens, *Unit processes in chemical engineering*, McGraw-Hill Higher Education, 2004. 6. William Andrew, *Pharmaceutical Manufacturing Encyclopedia Vol.I& II.*, 3rd Ed William Andrew, 2007, 7. W.W.M. Wenland, *Thermal Analysis*, 2nd Ed., John Willey & Sons, New York, 1974, 8. S.B. Chandalia, *Hand Book of Process Development*, Multitech Publishing Company, Mumbai, 1998. 9. K. G. Gadamasetti, *Process Chemistry in PharmaceuticalIndustries*, 1st Ed., Taylor & Francis Group, 1999. 10. Shreve's, *Chemical Process Industries*, 5th Ed., McGraw Hill Book Company, 2000. 11. M.V. Krishnan, *Safety Management in Industries*, Jaico Publishers, Mumbai, 2002. 12. R. K. Khar, S.P. Vyas, F. J. Ahmad, G.K. Jain, *Industrial Pharmacy*. 4th Ed., New Delhi: CBS Publishers & Distributors Pvt Ltd, 2013. pp. 947-1002. 13. V. P. Shah, J.P. Skelly, W.H. Barr, H. Malinowski, G.L. Amidon. *Scale-up of Controlled Release Products - Preliminary Considerations*. Pharm Technol 1992; 16(5):35-40. 14. N.V.N. Mounica, R.V. Sharmila, S. Anusha, L. Evangeline, M. V. Nagabhushanam, D. Nagarjunareddy. *Scale up and Postapproval changes (SUPAC) Guidance for Industry: A Regulatory note*. Int J Drug Regul. Aff., 2017; 5(1): 13-19. 15. L. Lachman, H. A. Lieberman, J. L.Kanig: *The Theory and Practice of Industrial Pharmacy: Section IV: Chapter 23:Pilot Plant Scale-Up Techniques:* 3rd edition,Varghese Publishing house, 2009; 681-710. 16. J. Swarbrick, J. C. Boylan: *Encyclopedia of Pharmaceutical Technology: Pilot Plant Design, Volume 12* New York, 2001; 171-186. 17. Leon Lachman, Herbert A. Lieberman, Joseph B. Schwartz: *Pharmaceutical dosage forms: Tablets. Volume 3*, 2nd edition. 2001, 303-365. 18. J. P. Sitompul, H.W. Lee, Y. C. Kim &W. Mathew, A. Chang: *Scaling-up Synthesis from Laboratory Scale toPilot Scale and to near Commercial Scale for Paste-Glue Production,* J. of Eng. and Tech. Sci. 2013; 45(1): 9-24.

	19. J. W. Zawistowski, A.I.A. and J.D. Rago, *Pilot Plant Scale-Up Facilities: Establishing the Basis for a Design*, J. of Pharm. eng.july/august. 1994, 24-32.
Course Outcome:	1.Students will be able to explain unit processes for various organic chemical reactions. 2.Students will be able to apply industrial synthesis knowledge for the synthesis of drug like molecules in laboratory. 3.Students will be able to apply the knowledge of waste effluent treatment methods. 4.Students will be able to apply the knowledge of pilot plant scale-up techniques in industry.

Title of the course: Pharmacological and Toxicological Screening Techniques

Course Code: CHH-603

Number of Credits:4

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied Pharmaceutical Chemistry courses at M.Sc. Part-I.	
Course Objective:	1. To learn screening methods of biological assay. 2. To learn terms involved in toxicology. 3. To learn methods of analysis for toxicology	
Content	**1. Laboratory Animals, Principles of Biological Standardisation, Screening methods** a. Introduction to pharmacological research. Animal ethics, regulations for conducting animal experimentation. Common laboratory animals: Description, handling and applications of different species and strains of animals. Transgenic animals: Production, maintenance and applications Anaesthesia and euthanasia of experimental animals. Maintenance and breeding of laboratory animals. CPCSEA guidelines to conduct experiments on animals Good laboratory practice. b. Statistical treatment of model problems in evaluation of drugs-methods of biological assay, principles of biological assays-methods used in bioassay of vitamins, hormones, vaccines,cardiac drugs and other pharmacopeial preparations. c. Zebrafish model to screen pharmaceutical molecules Organisation of Screening for the pharmacological activity ofnew substances. Anti-inflammatory agents-carrageenan inducedpaw oedema, cotton pellet method. Anticonvulsants: Convulsions induced by chemicals, induced by electroshock, combined procedures. Sympathomimetic agents: Mydriasis, theuterus and ascending colon of the rat.	No of hours 20
	2. Introduction to Toxicology: Definition and types of toxicology, Basic principles of toxicology,	12

	Carcinogenicity, mutagenicity, teratogenicity, acute, sub acute and chronic toxicity. Detailed toxicity (mild/moderate/severe toxicology wherever applicable) and treatment of drugs such as salicylates/ paracetamol, opium, quinine, ethyl alcohol, etc. Toxic chemicals in the environment, impact of toxic chemicals on enzymes. Biochemical effects of arsenic, lead mercury, cadmium, carbon monoxide, pesticides and carcinogens	
	3. Essentials of Analytical Toxicology Physicochemical, biochemical & genetic basis of toxicity; Principles of toxicokinetics, mutagenesis and carcinogenesis – Behavioural, inhalation toxicity, hypersensitivity and immune response, range finding tests – Acute, subacute and chronic toxicity studies. Classification of Toxins: Acute toxicity tests, Determination of LD50 value, Subacute tests - Histopathological and biochemical estimations on toxicity induced in animal models – Modern methods of analysis for Toxins-Barbiturate poisoning, Amphetamine poisoning.	12
	4. Safety aspects in pharmacological studies Preclinical toxicological requirements for biological and biotechnological products: Safety analysis; problems specific to recombinant products secondary pharmacology. Safety Pharmacology - ICH S7 and S7B guidelines. Safety pharmacological studies for pharmaceuticals. Safety pharmacological studies for biological products.	8
	5. Applications of Toxicology Clinical Toxicology, Environmental Toxicology/ Ecotoxicology Forensic Toxicology/ Post-mortem, Toxicology Industrial/Occupational Toxicology. Food Toxicology Behavioural toxicology Preventive toxicology Descriptive Toxicology Mechanistic Toxicology Regulatory Toxicology Genetic Toxicology Systemic Toxicology.	8
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References /	1. S.K. Gupta, Uma Singh and T. Velpandian, Analytical Toxicology	

Readings	for Poisoning Management and Toxicovigilance, Varosa Publishing House, 2002. 2. E.G.C.Clarke, Isolation and Identification of Drugs, Body Fluids and Post-mortem Material. The Pharmaceutical Press, 1986. 3. A. K. De, Environment Chemistry, Wiley Eastern Ltd., New Delhi, 2003. 4. R.K. Trivedi & P.K. Goel, Chemical and Biological Methods for Water, Pollution Studies, Environment Publications, Karad (India), 1984. 5. B. K. Sharma, Industrial Chemistry, 1st Ed., Narosa Publishing House,1998. 6. W. Andrew, Pharmaceutical Manufacturing Encyclopaedia Vol I and II, 3rd Ed., William Andrew Publishing, 2007. 7. R. A. Turner, P. Hebborn, Screening Methods in Pharmacology, Vol.-1 &2, Elsevier Science & Technology Books, 1971. 8. H. G. Vogel & W. H. Vogel, Drug Discovery and Evaluation, Springer, 2006. 9. S. K. Kulkarni, Handbook of Experimental Pharmacology, Vallabh Prakashan, Delhi, 1993. 10. R.S. Satoskar& S.D. Bhandarkar, Pharmacology and Pharmacotherapeutics, Popular Prakashan Ltd, 2006. 11. Louis S. Goodman & Alfred Gillman, The Pharmacology Basis of Therapeutics, McGraw-Hill Professional Publishing, 2010. 12. H.P. Rang & M.A. Dale, Pharmacology, Elsevier – Health Sciences Division, 2011. 13. CPCSEA guidelines (http://cpcsea.nic.in)
Course Outcome:	1.Students will be able to apply the role of various screening methods in bioassay. 2.Students will be able to create various in vivo and in vitro assay methods for various targets. 3. Students will be able to evaluate various effects of toxins. 4. Students will be able to analyse the safety aspects in pharmaceuticals 5. Students will be able to apply this knowledge for their dissertation work.

<u>Title of the course: Discipline Specific Dissertation</u>

Course Code: CHC-651

Number of Credits: 16

Effective from AY: 2023-24

Prerequisites for the course:	Students should have studied chemistry courses at MSc-I level.	
Course Objective:	To develop the skills of preparing and conducting independent research.	
Content	As per OA-35	No of Hours 480
Pedagogy:	Dissertation carried out individually by each student throughout the academic year.	
References / Readings:	As required for the development of review and methodology.	
Course Outcome:	Students will be able to understand and apply the tools and techniques of chemistry in conducting independent research.	