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ताळगांव पठार
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(Accredited by NAAC)

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. 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, 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. 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 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

	spectroscopy ii. Separation of Benzaldehyde and benzoic acid using reverse phase HPLC. iii. Quantification of naphthalene in a sample using reverse phase HPLC.	
	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.	10
	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	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, 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.	
Course outcomes:	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.	

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

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 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.	
Content	**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	No of hours 10
	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	4
	3. Solid state chemistry a. Structures of solids: crystal structures, lattices and unit cells,	10

	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 1^{st} 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 (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.* **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.	No of hours 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

	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, 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 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, 2nd 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, 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 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.	

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

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, naphthalene, anthracene or succinic acid (any one). e. Vacuum distillation (any one): o-dichlorobenzene, diphenyl	24

	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, 5thEd., Prentice Hall; 2011. 2. D. Pasto, C. Johnson and M. Miller, Experiments and Techniques in Organic Chemistry, 1stEd., Prentice Hall, 1991. 3. L.F. Fieser, K.L. Williamson,Organic Experiments, 7thedition D. C. Heath, 1992. 4. K.L. Williamson, K.M. Masters, Macroscale and Microscale Organic Experiments, 6thEdition, Cengage Learning, 2010 5. R.K. Bansal, Laboratory Manual in Organic Chemistry, New Age International, 5thEdition, 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, 3rdedition, 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

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. Common Hazards in Chemical Laboratory, Risk assessment b. Accidents and Emergency procedures	No of hours 04
	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.	08
	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	16

	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, 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 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. 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

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 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.	

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

Prerequisites for the course:	Students should have studied analytical chemistry courses at M.Sc. Chemistry in semester I	
Course Objective:	1. Introduction of various separation techniques. 2. Evaluate the use of chromatographic techniques for chemical analysis.	
Content:	**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.	No of hours 10
	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	30

	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, 6th Ed.; John Wiley, 2004. 2. D. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed.; Cengage Learning, 2014. 3. David. Harvey, Modern Analytical Chemistry, 1st Ed.; The McGraw-Hill, 2000. 4. L. R. Snyder, J. J. Kirkland, J. W. Dolan, Introduction to modern liquid chromatography, 3rd Ed.; John Wiley & Sons, 2009. 5. H. H. Willard, L. L. Merritt, J. A. Dean, F. A. Settle, Instrumental methods of Analysis, 7th Ed.; CBS Publishing, 1986. 6. G. H. Jeffery, J. Bassett, J. Mendham, R. C. Denney, Vogel's Text Book of Quantitative Chemical Analysis, 5th Ed.; John Wiley, 1989. 7. H. Gunzler, A. Williams, Handbook of analytical techniques, 1st Ed.; Wiley, 2002. 8. F. W. Fifield, D. Kealey, Principles and Practice of Analytical Chemistry, 5th Ed.; Blackwell Science Ltd., 2000. 9. A. Braithwaite, F. J. Smith, Chromatographic methods, 5th Ed.; Kluwer academic publishers, 1999. 10. J. Inczedy, Analytical Applications of Ion Exchangers, 1st 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, 2nd Ed.; Springer, 2012. 5. Y. Leng, Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, 2nd Ed.; Wiley-VCH, 2013. 6. A. M. Garcia-Campana, Chemiluminescence in Analytical Chemistry, 1st Ed.; CRC Press. 2001. 7. R. F. Egerton, Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM, 2nd Ed.; Springer, 2016. 8. E. H. Kisi and C. J. Howard, Applications of Neutron Powder Diffraction, 1st Ed., Oxford Science Publications, 2008. 9. G. D. Christian, Analytical Chemistry, 6th 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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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. 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

Prerequisites for the course:	Students should have studied analytical chemistry course at M.Sc. Part I.	
Course Objective:	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.	
Content	**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.	No of hours 15
	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*.	15

	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

Prerequisites for the course:	Students should have studied analytical chemistry course at M.Sc. Part I.	
Course Objective:	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	
Content	**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.	No of hours 8
	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.	12
	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	10

	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

Prerequisites for the course:	Students should have studied Chemistry courses in MSc Part-I.	
Course Objective:	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.	
Content	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.	No of hours 5
	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.	10
	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	10

	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, 6th 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

Prerequisites for the course:	Students should have studied Chemistry courses at M.Sc. Part-I	
Course Objective:	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.	
Content	**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	No of hours 12
	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;	12

	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

	g. Clinical Applications of Computed Tomography	
	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	12
Pedagogy	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.	
References / Readings	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.	
Course Outcome:	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.	

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, 5th 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, 9th 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, 6th Ed.; Wiley, 2004. 10. J. H. Kennedy, Analytical Chemistry: Principles, 2nd 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, 2nd Ed; Eurachem, 2014 12. Willard, Instrumental Methods of Analysis, 7th 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

Prerequisites for the course:	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.	
Content	**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	No of hours 15
	2. Softwares in chemistry, Data bases and Research metrics	10

	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.	