गोंय विद्यापीठ
ताळगांव पठार,
गोंय - ४०३ २०६
फोन : + ९१ - ८६६९६०९०४८

Goa University
Taleigao Plateau,Goa - 403 206
Tel : +91-8669609048
Email : registrar@unigoa.ac.in
Website : www.unigoa.ac.in

(Accredited by NAAC with Grade A+)

GU/Acad –PG/BoS -NEP/2025-26/602 Date: 01.12.2025

CIRCULAR

In supersession to the Circular No. GU/Acad –PG/BoS -NEP/2025-26/557 dated 18.11.2025, the syllabus of Semester II of the **Master of Science Physical Chemistry** Programme approved by the Academic Council in its meeting held on 13th September 2025 is attached. The syllabus of Semester I approved earlier by the Academic Council in its meeting held on 13th & 14th June 2025 is also attached.

The Dean & Vice-Dean (Academic) of the School of Chemical Sciences and the Principals of affiliated Colleges offering the **Master of Science in Physical Chemistry** Programme are requested to take note of the above and bring the contents of the Circular to the notice of all concerned**.**

ASHWIN VYAS LAWANDE
Digitally signed by ASHWIN VYAS LAWANDE
Date: 2025.12.01 17:52:20 +05'30'

(Ashwin V. Lawande)
Deputy Registrar – Academic

To,
1. The Dean, School of Chemical Sciences, Goa University.
2. The Vice-Dean (Academic), School of Chemical Sciences, Goa University.
3. The Principals of affiliated Colleges offering the Master of Science in Physical Chemistry Programme.

Copy to:
1. Chairperson, BoS in Chemistry, Goa University.
2. Programme Director, M.Sc. Physical Chemistry, Goa University.
3. Controller of Examinations, Goa University.
4. Assistant Registrar Examinations (PG), Goa University.
5. Director, Directorate of Internal Quality Assurance, Goa University for uploading the Syllabus on the University website.

GOA UNIVERSITY

MASTER OF SCIENCE IN PHYSICAL CHEMISTRY

(Effective from the Academic Year 2025-26)

ABOUT THE PROGRAMME
This program is designed by integrating academics with research and industrial needs. Students with this degree will be ready for careers in the pharmaceutical, chemical, healthcare, environmental, material science and related industries. Students are equipped with hands-on research experience and skills through projects and dissertations to pursue advanced degrees like Ph.D. programs and contribute to research in the field. Students with this knowledge would excel in competitive exams like NET, GATE, and others.

OBJECTIVES OF THE PROGRAMME
1. To impart a thorough understanding of fundamental principles like thermodynamics, electrochemistry, and chemical kinetics, including concepts like chemical potential, phase equilibria, electrolytic conductance, electrode equilibrium, reaction rates, and reaction mechanisms. 2. To assimilate understanding of underlying theories and principles of physical chemistry, such as the kinetic theory of gases, the liquid state, and crystalline structures, as well as their applications. 3. To expose students to emerging areas of science and technology where physical chemistry principles are crucial, such as materials science, nanotechnology, catalysis and energy. 4. To familiarise students with use of mathematical models and computational tools to analyse data, predict reaction rates, and understand chemical processes.

PHYSICAL CHEMISTRY (CHP) PROGRAMME SPECIFIC OUTCOMES (PSO)	
PSO1	Understand the fundamental principles and core concepts of Quantum chemistry, Electrochemistry, Spectroscopy, Thermodynamics & Reaction Kinetics, and the scientific theories cum models that govern them.
PSO 2	Demonstrate a proficient understanding of the principles of Group Theory and their applications in chemistry, i.e. molecular symmetry, hybridization, and electronic structure, facilitating the interpretation of spectroscopic data and chemical phenomena.
PSO 3	Understand and interpret spectroscopic data of industrially important compounds using microwave, IR, Raman, NMR, and ESR spectroscopy and elucidate their chemical structure and properties.
PSO 4	Demonstrate hands-on expertise in handling instruments like conductometer, potentiometer, pH meter, colorimeter, linear sweep and cyclic voltammeter, and bomb calorimeter, and use them to monitor the kinetic rates and thermodynamic properties of chemical reactions.
PSO 5	Design, synthesize, and characterize nano-catalysts and use them to address societal problems of wastewater pollution, using adsorption and photocatalytic technology.
PSO 6	Acquire the ability to fabricate efficient electrodes and test their efficiency in electrocatalytic and spectro-electrochemical reactions such as HER and CO_2 reduction, electrochemical energy generation and storage systems such as batteries, fuel cells, photovoltaics, and supercapacitors.
PSO 7	Determine the fundamental physical properties such as density, viscosity, specific gravity, etc., and use them to construct phase diagrams.
PSO 8	Acquire the ability to write computer programs. Ab-initio programs like Gaussian are used to calculate the molecular and spectroscopic properties of chemical compounds.

ANALYTICAL CHEMISTRY (CHA) PROGRAMME SPECIFIC OUTCOMES (PSO)	
PSO 1.	Understand different chemical and instrumental methods of analysis and apply appropriate methods for qualitative and quantitative analysis.
PSO 2.	Select technique for synthesis, separation, structural characterization and microscopic analysis.
PSO 3.	Interpret data pertaining to optical techniques, diffraction techniques and spectral techniques such as IR, UV, NMR, Mass, X-Ray, and others.
PSO 4.	Develop expertise through hands on training for qualitative and quantitative estimation using chemical and instrumental methods.

INORGANIC CHEMISTRY (CHI) PROGRAMME SPECIFIC OUTCOMES (PSO)	
PSO 1.	Understand the properties of elements and compounds and use concepts like molecular symmetry and tools such as spectroscopy, diffraction, thermal techniques and others, to study chemical structures and solve both theoretical and practical problems in inorganic chemistry.
PSO 2.	Apply inorganic chemistry principles to explain and model biological, environmental, and industrial processes.
PSO 3.	Analyse environmental and industrial samples, including pollutants, ores, and alloys that will prepare students for careers in science and industry.
PSO 4.	Design experiments, interpret results, and propose effective solutions to chemical challenges that will help create and develop materials for use in areas like catalysis, energy, environment, electronics, and healthcare using eco-friendly and sustainable methods.

ORGANIC CHEMISTRY (CHO) PROGRAMME SPECIFIC OUTCOMES (PSO)	
PSO 1.	Demonstrate understanding of Organic Chemistry principles, apply them to scientific theories, communicate effectively with critical reasoning, and follow safe practices in handling chemical reagents, laboratory equipment, and glassware
PSO 2.	Utilize knowledge of synthetic organic chemistry, stereochemistry, pericyclic reactions, and photochemistry to synthesize organic molecules and elucidate their structures using various spectroscopic techniques
PSO 3.	Undertake synthetic methodologies towards organic compounds of commercial and scientific interest and also apply the concepts in chemistry of pharmaceuticals, natural products, polymers, synthetic intermediates, petroleum products, etc.
PSO 4.	Develop interdisciplinary approach of the subject of organic chemistry and related fields and augment the new progresses in the arena of Bioorganic Chemistry, Green Chemistry, Pharmaceutical Chemistry, Agrochemicals and relevant fields.

PROGRAMME STRUCTURE

Master of Science in Physical Chemistry

Effective from the Academic Year 2025-2026

Bridge Course			
Sr. No.	**Course Code**	**Title of the Course**	**Credits**
1	CHC-1000	Bridge Course in mathematical concepts for chemistry	1
2	CHC-1001	Bridge Course in organic chemistry	1

SEMESTER I				
Discipline Specific Core (DSC) Courses (16 credits)				
Sr. No.	**Course Code**	**Title of the Course**	**Credits**	**Level**
1	CHO-5000	Fundamental Concepts in Organic Chemistry	4	400
2	CHI-5000	Concise Inorganic Chemistry	4	400
3	CHP-5000	Fundamentals of Physical Chemistry	4	400
4	CHA-5000	Analytical Chemistry Techniques	4	400
		Total Credits for DSC Courses in Semester I	**16**	
Discipline Specific Elective (DSE) Course (4 credits)				
Sr. No.	**Course Code**	**Title of the Course**	**Credits**	**Level**
1	CHO-5201	Organic Chemistry Practical - I	2	400
2	CHO-5202	Organic Chemistry Practical - II	2	400
3	CHI-5201	Inorganic Chemistry Practical - I	2	400
4	CHI-5202	Inorganic Chemistry Practical - II	2	400
5	CHP-5201	Physical Chemistry Practical - I	2	400
6	CHP-5202	Physical Chemistry Practical - II	2	400
7	CHA-5201	Analytical Chemistry Practical - I	2	400
8	CHA-5202	Analytical Chemistry Practical - II	2	400
		Total Credits for DSE Courses in Semester I	**4**	
		Total Credits in Semester I	**20**	

SEMESTER II				
Discipline Specific Core (DSC) Courses				
Sr. No.	**Course Code**	**Title of the Course**	**Credits**	**Level**
1	CHP-5001	Concepts in Quantum Chemistry and Statistical Thermodynamics	4	500
2	CHP-5002	Group Theory and Spectroscopy	4	500
3	CHP-5003	Thermodynamics and Reaction Kinetics	4	500
4	CHP-5004	Principles of Electrochemistry and its Applications	4	500
Total Credits for DSC Courses in Semester II			**16**	
Discipline Specific Elective (DSE) Courses (4 credits)				
Sr. No.	**Course Code**	**Title of the Course**	**Credits**	**Level**
1	CHO-5201	Organic Chemistry Practical - I	2	400
2	CHO-5202	Organic Chemistry Practical - II	2	400
3	CHI-5201	Inorganic Chemistry Practical - I	2	400
4	CHI-5202	Inorganic Chemistry Practical - II	2	400
5	CHP-5201	Physical Chemistry Practical - I	2	400
6	CHP-5202	Physical Chemistry Practical - II	2	400
7	CHA-5201	Analytical Chemistry Practical - I	2	400
8	CHA-5202	Analytical Chemistry Practical - II	2	400
Total Credits for DSE Courses in Semester II			**4**	
Total Credits in Semester II			**20**	

Blooms Taxonomy Cognitive Levels	
Cognitive Level	**Notations**
K1	Remembering
K2	Understanding
K3	Applying
K4	Analyzing
K5	Evaluating
K6	Create

BRIDGE COURSES

Title of the Course	Bridge Course in Mathematical Concepts for Chemistry
Course Code	CHC-1000
Number of Credits	1
Theory/Practical	Theory
Level	400
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	Yes
Course for advanced learners	No

Pre-requisites for the Course:	NIL			
Course Objectives:	To introduce mathematical concepts to the students of MSc Part-I (Chemistry).			
Course Outcomes:	Students will be able to solve problems based on:		**Mapped to PSO**	
	CO 1. Matrices in M.Sc. Chemistry		PSO1	
	CO 2. Determinants in M.Sc. Chemistry		PSO1	
	CO 3. Differential calculus in M.Sc. Chemistry		PSO1	
	CO 4. Integral calculus in M.Sc. Chemistry		PSO1	
Content:		**No of**	**Mapped**	**Cognitive**

		hours	to CO	Level
Module 1:	1. Calculus for thermodynamics and kinetics a. Introduction to Differentiation: Notation, Differentiating various f functions, Differentiating a Sum, Product Rule, Quotient Rule, Chain Rule, Partial Differentiation: exact and inexact differentials. b. Introduction to Integration: Notation, Rules for Integrals, Integrating various functions, Definite and indefinite Integrals.	**8**	CO3, CO4	K5
Module 2:	2. Matrices, Determinants and vector algebra: a. Types of Matrices: Identity, reflection, rotation, inversion, distance matrix, Matrix Algebra, Matrix similarity transformation. b. The Determinant, Minors and Cofactors, Inverse of a Matrix, Character of a matrix, Linear algebra. c. Vectors and molecular structure.	**7**	CO1, CO2	K5
Pedagogy:	Mainly lectures and tutorials. Seminars/assignments/presentations/self-study or a combination of some of these can be used. ICT mode should be preferred. Sessions can preferably be interactive to enable peer group learning.			
Texts:	Robert G. Mortimer, Mathematics for Physical Chemistry, Elsevier,New York. 4th ed., 2013			
References/ Readings:	James R. Barrante, Applied Mathematics for Physical Chemistry, 3rd ed., Prentice-Hall, New Jersey, 1998			

Title of the Course	Bridge Course in Organic Chemistry
Course Code	CHC-1001
Number of Credits	1
Theory/Practical	Theory
Level	400
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	Yes
Course for advanced learners	No

Pre-requisites for the Course:	NIL			
Course Objectives:	• To understand various principles of organic chemistry. • To apply the importance of chirality in organic syntheses. • To analyse stereoselective reactions. • To interpret oxidation and reduction reactions.			
Course Outcomes:	Students will be able to:		**Mapped to PSO**	
	CO 1. understand knowledge of basic reaction mechanisms in organic transformation.		PSO2	
	CO 2. apply chirality in organic synthesis.		PSO2	
	CO 3. compare configurations/ conformations of organic molecules.		PSO2	
	CO 4. assess oxidizing and reducing reagents in organic synthesis.		PSO2	
Content:		**No of**	**Mapped**	**Cognitive**

		hours	to CO	Level
Module 1:	1. Fundamentals of organic chemistry: Electron movement with arrows, half and double headed arrows (Cleavage of bonds: homolysis and heterolysis) in organic reaction mechanisms; inductive effect, electromeric effect, resonance and hyperconjugation, steric hindrance, hydrogen bonding; reactivity of organic molecules: nucleophiles and electrophiles; reactive intermediates: carbocations, carbanions and free radicals; strength of organic acids and bases, aromaticity, benzenoids and Huckel's rule.	**8**	CO1	K1, K2
Module 2:	2. Stereochemistry: Conformations with respect to butane and cyclohexane; interconversion of wedge formula, Newmann, Sawhorse and Fischer representations; CIP Rules: R/S configurations.	**3**	CO2, CO3	K2, K3, K4
Module 3:	3. Substitution, elimination and addition reactions: Substitution and elimination reactions (SN1, SN2, E1 and E2), addition of different groups on olefins.	**2**	CO1	K2, K3
Module 4:	4. Oxidation and reduction reactions: Basic concepts, oxidizing and reducing reagents and some examples.	**2**	CO4	K3, K4
Pedagogy:	Mainly lectures and tutorials. Seminars/assignments/presentations/self-study or a combination of some of these can be used. ICT mode should be preferred. Sessions can preferably be interactive to enable peer group learning.			
Texts:	1. D. Nassipuri, Stereochemistry of Organic compounds - Principles and Application, 4th ed., Wiley Eastern Limited, New Academic Science Limited, Lucknow, India, 2013 2. E. L. Eliel, Stereochemistry of carbon compounds, Tata MacGraw Hill Publishing Company Ltd., New Delhi, 1990. 3. J. March, Advanced Organic Chemistry: Reaction, Mechanism and Structure, 4th ed., Wiley, USA, 2010. 4. J. Clayden, N. Greeves, S. Warren &Wothers, Organic Chemistry, 2nd ed., Oxford University Press, Oxford, 2012 5. I. L. Finar Stereochemistry and Chemistry of Natural products, Vol. 2, 3rd ed., , Longmans, ELBS London, 1963 6. F. A. Carey and R.J. Sundberg, Advanced Organic Chemistry, Vol. I & II. Plenum Press, New York, 1977 7. E. S. Gould et al., Mechanism and structure in Organic Chemistry, Holt, Rinehart And Winston, New York, 1965 8. F. A. Carey, Organic Chemistry, 4th ed., McGraw-Hill Higher Education, USA, 2000			

	9. S. H. Pine, Organic Chemistry, 5th ed., McGraw-Hill International Education, New York, 2010
References/ Readings:	1. V. M. Potapov, Stereochemistry, MIR Publishers, Moscow, 1979 2. J. M. Harris & C.C. Wamser, Fundamentals of Organic Reaction Mechanisms, John Wiley & Sons. Inc. New Jersey, 1976. 3. F. M. Menger, D.J. Goldsmith & L. Mendell, Organic Chemistry, A concise approach, 2nd ed., Addison Wesley Longman, Boston 1975.

SEMESTER I

Discipline Specific Core Courses

Title of the Course	Fundamental Concepts in Organic Chemistry
Course Code	CHO-5000
Number of Credits	4
Theory/Practical	Theory
Level	400
Effective from AY	2025-26
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	NIL	
Course Objectives:	• To study the various concepts based on molecular orbital theory, Aromaticity, Acids and bases. • To understand the concepts of stereochemistry and their significance in determining the structure, reactivity, and properties of organic molecules • To understand the mechanistic aspects of various type of reactions in organic synthesis and the use of selective reagents in organic transformations.	
Course Outcomes:	Students will be able to:	**Mapped to PSO**

	CO 1. Understand the effect of delocalization of electrons & presence or absence of aromaticity in organic compounds.		PSO1, PSO 2	
	CO 2. Apply various concepts in stereochemistry to understand stereochemical outcome in a reaction.		PSO1, PSO 2	
	CO 3. Evaluate plausible mechanisms of organic reactions.		PSO1, PSO2, PSO3	
	CO 4. Apply various reagents for desired organic transformations.		PSO1, PSO2, PSO3, PSO4	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**1.1 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, 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. **1.2 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,examplesofambident nucleophiles & electrophiles. (Including revision of aromatic electrophilic and nucleophilic substitution)	**15**	CO1	K1, K2, K3, K4,K5
Module 2:	**2. 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 centers. b. Conformational analysis of open chain compounds (Butane, 2, 3-butane	**15**	CO2, CO3	K1, K2, K3, K4, K5

	diol, 2,3-dibromobutane etc.). *Erythro*and *threo*nomenclature. c. Topicity and Prostereoisomerism: Topicity of ligands and faces-homotopic, enantiotopic and diastereotopic, ligands and faces. d. Chemoselective, regioselective and stereoselective reactions with examples. e. Conformation and reactivity of cyclohexane and substituted cyclohexanes, cyclohexene / cyclohexanone. Conformational isomerism and analysis in acyclic and simple cyclic systems substituted ethane, cyclopentane, cyclohexane. 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.			
Module 3:	**3.1 Reaction Mechanism** a. Structure, stability and reactivity of reactive intermediates (carbocations, carbanions, free radicals, carbenes, arynes and nitrenes) b. Types of mechanisms, types of reactions, thermodynamic and kinetic control. c. Methods of determining reaction mechanisms: i. Identification of products. ii. Determination of the presence of intermediates (isolation, detection, trapping and addition of suspected intermediate. iii. Isotopic labelling. iv. Stereochemical evidence. v. Kinetic evidence and Isotope effect. (at least two examples to be covered for above methods) **3.2 Selective reagents for Organic transformation** a. Oxidation of organic compounds: PCC, PDC and MnO_2, ozonolysis,	**15**	CO2, CO3	K1, K2, K3, K4, K5

	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			
Module 4:	**4.1 Aliphatic Nucleophilic substitution** a. Nucleophilic substitutions with respect to mechanism and 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) **4.2 Elimination reactions** a. The E2, E1 and E1cB mechanisms. Orientation of the double bond, Saytzeff and Hofmann rule. b. Effects of substrate, base, leaving group and medium on: i. Overall reactivity ii. E1 vs. E2 vs. E1cB iii. Elimination vs substitution, mechanism and orientation in pyrolytic *syn*elimination (various examples involving cyclic and acyclic substrates to be studied).	**15**	CO3. CO4	K1, K2, K3, K4, K5
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.			
Texts:	1. R. T. Morrison, R. N. Boyd, S. K. Bhattacharjee, Organic Chemistry, 7th ed. Pearson Education, New Delhi, 2010 2. D. Nassipuri, Stereochemistry of Organic Compounds: Principles and Applications, 4th ed. New Age International, New Delhi, 2020 3. J. Clayden, N. Greeves, S. Warren, P. Wothers, Organic Chemistry, 2nd ed. Oxford University Press, Oxford, 2012			

	4. J. March, Advanced Organic Chemistry: Reactions, Mechanisms and Structure, 4th ed. Wiley Student Edition, New York, 2003. 5. P. S. Kalsi, Stereochemistry: Conformation and Mechanism, 11th ed. New Age International, New Delhi, 2022 6. E. L. Eliel, S. H. Wilen, Stereochemistry of Organic Compounds, 1st ed. John Wiley and Sons, New York, 1994 7. H. O. House, Modern Synthetic Reactions, 2nd ed. W. A. Benjamin, New York, 1965 8. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry, 5th ed. Springer India Private Limited, New Delhi, 2007
References/ Readings:	1. R. Bruckner, Advanced Organic Chemistry: Reaction Mechanisms, 1st ed. Harcourt/Academic Press, San Diego, 2002. 2. P. Y. Bruice, Organic Chemistry, 8th ed, Pearson, New Delhi, 2020

Title of the Course	ConciseInorganic Chemistry
Course Code	CHI-5000
Number of Credits	4
Theory/Practical	Theory
Level	400
EffectivefromAY	2025-26
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites fortheCourse:	NIL	
Course Objectives:	• To explain fundamentals of solid state, coordination, organometallic, bioinorganic, and environmental chemistry. • To describe atomicstructure,molecularstructure,bonding,andsymmetry in molecules. • To know fundamental aspects of elements & their compounds. • To comprehend the effects of pollution, and its treatments.	
CourseOutcomes:	Students will be able to:	**Mapped to PSO**
	CO 1. explain basic concepts in solid state, coordination, organometallic, bioinorganic, and environmental chemistry.	PSO1, PSO2
	CO 2. illustrate characteristic of inorganic compounds related to biology and environment.	PSO2, PSO3
	CO 3. analyze molecular structure and their properties.	PSO1, PSO3

	CO 4. design compounds for various applications.		PSO4	
Content:		**Noofhours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**1. Atomicstructure,molecularstructureandbonding** a. Atomic Structure: Structures of hydrogenic atoms: some principles of quantum mechanics, atomic orbitals. Manyelectron 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.	**10**	CO1, CO2, CO3, CO4	K2, K3, K4, K5
Module 2:	**2. Solidstatechemistry** a. Structures of solids: crystal structures, lattices and unit cells, 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 Born Haber cycle, calculation of lattice enthalpies (numerical expected).	**10**	CO1, CO2, CO3, CO4	K2, K3, K4, K5
Module 3:	**3. Molecular Symmetry and chemistry of *d*- and *f*- block elements** a. Symmetry elements and symmetry operations, equivalent symmetry elements and equivalent atoms, symmetry point groups and molecular symmetry. Systematic	**15**	CO1, CO2, CO3,	K2, K3, K4, K5

	procedure for symmetry classification of molecules. Dipole moment, optical activity and point groups. b. *d*-block elements**:** Zinc, cadmium and mercury: occurrence and properties. Transition element: IUPAC definition, occurrence and physical properties, chemical properties, metal halides, metal oxides &oxido compounds, metal sulfides and sulfide compounds, metal-metal bonded compound and clusters, magnetic properties. c. *f*-block elements: Lanthanides; occurrence and physical properties, lanthanide contraction, oxidation states, compounds of lanthanides, electronic, optical and magnetic properties. Actinoid; occurrence and properties, oxidation states, general trends, electronic spectra, thorium and uranium.		CO4	
Module 4:	**4. Coordination,Organometallicand Bioinorganic Chemistry** a. Coordination chemistry: Introduction, representative ligands, nomenclature. Constitution and geometry, isomerism & chirality in square planar and octahedral complexes, ligand chirality. Electronic properties of metal complexes: CFT applied to octahedral and tetrahedral complexes, magnetic moments, CFSE. Electronic spectroscopy: basic concepts, Orgel diagram for octahedral and tetrahedral complexes of d^1& d^9 ions. b. Organometallic Chemistry: Introduction to organometallic chemistry, nomenclature, stability and inert gas rules (neutral atom, and donor pair electron count methods). Homoleptic metal carbonyls - synthesis, properties, and spectroscopic studies. c. Bioinorganic Chemistry: Macronutrients/micronutrients. Role of elements in biology. Metallobiomolecules, metalloporphyrins, structure of porphin and heme group, iron porphyrins (Haemoglobin and myoglobin), examples of metalloenzymes of Cu and Zn.	**15**	CO1, CO2, CO3, CO4	K2, K3, K4, K5
Module 5:	**5. EnvironmentalChemistry** Directive of the Supreme Court in 1993 to introduce environmental education at all	**10**	CO1, CO2,	K2, K3, K4, K5

	levels. a. Air Pollution: Classification of air pollutants and photochemical reactions in the atmosphere. Common air pollutants(e.g.CO,NOx,SO_2,hydrocarbonsandparticulates) i. sources ii. physiological and environmental effect iii. monitoring, iv. various remedial & technological measures to curb pollution. Air quality standards. b. Waterpollution:Importanceofbuffer&buffer indexinwaste water treatments. Chemical, physical & biologicalcharacteristics 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.		CO3, CO4	
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 toenable peer group learning.			
Texts:	1. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins Inorganic Chemistry, 5th Ed., Oxford University Press, Oxford, 2009. 2. F. A. Cotton, G. Wilkinson, P. L. Gauss, Basic Inorganic Chemistry, 3rd Ed., Wiley India, New delhi, 2008 (reprint). 3. F. A. Cotton, Chemical applications of group theory, 3rd Ed., Wiley India, New Delhi, 2012 (reprint). 4. A. K. De, Environmental Chemistry, 3rd Ed., New Age Intl. Publishers, New Delhi, 2005. 5. J. E. Huheey, E. A. Kieter, R. L. Kieter, O. K. Medhi, Inorganic Chemistry: Principles of Structure & Reactivity, 4th Ed., Pearson, New Delhi, 2011. 6. J. D. Lee, Concise Inorganic Chemistry, 5th Ed., Wiley India, New Delhi, 2008. 7. H. V. Keer, Principles of Solid State Chemistry, 1st Ed., New Age Intl. Ltd, New Delhi, 1993, (reprint 2008). 8. A. R. West, Solid State Chemistry and Its Applications, 1st Ed., Wiley India, New Delhi, 1984 (reprint 2007). 9. D. K. Chakrabarty, Solid State Chemistry, 2ed Ed., New Age Intl. Publishers, New Delhi, 2010. 10. R. S. Drago, Physical Methods in Inorganic Chemistry, Affiliated East West Press Pvt. Ltd., New Delhi, 2017. 11. A. V. Salker, Environmental Chemistry: Pollution and Remedial Perspective, 1st Ed., Narosa Publication, New			

	Delhi, 2017.
References/ Readings:	1. F. A. Cotton, G. Wilkinson, Advanced Inorganic Chemistry, 6rd Ed., Wiley India, New Delhi, 2003 (reprint 2012). 2. G. C. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Ed., Pearson, New Delhi, 2004.

Title of the Course	Fundamentals of Physical Chemistry
Course Code	CHP-5000
Number of Credits	04
Theory/Practical	Theory
Level	400
Effective from AY	2025-26
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	NIL	
Course Objectives:	• To introduce various mathematical and computational concepts of chemistry • To gain knowledge of core concepts of physical chemistry i.e. thermodynamics, kinetics, quantum chemistry and electrochemistry • To inculcate critical thinking and apply the knowledge of physical chemistry concepts in problem solving • To understand and apply physical chemistry principles to other areas of chemistry	
Course Outcomes:	Students will be able to:	**Mapped to PSO**
	CO 1. Explain various concepts in physical chemistry.	PSO1, PSO2
	CO 2. Utilise concepts of electrochemistry and their applications in renewable energy generation and storage.	PSO1, PSO6

	CO 3. Demonstrate the concepts during the lab course in physical chemistry.		PSO3, PSO4, PSO5	
	CO 4. Apply fundamentals of chemical kinetics and thermodynamics for understanding reaction processes and mechanisms		PSO3, PSO7	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**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).	**10**	CO1, CO3	K1, K2,K3
Module 2:	**2. Quantum Chemistry** a. Operators, Functions, Eigen value equations, Postulates. b. Schrödinger 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, Schrödinger 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**	CO1, CO3	K1, K2, K5
Module 3:	**3. Thermodynamics** a. Thermodynamic properties: Gas laws, real gases, Boyle temperature, critical temperature, state and path properties. Intensive and extensive properties. Exact and inexact differentials. Internal energy, enthalpy, entropy, free energy	**12**	CO1, CO3, CO4	K1, K2, K3, K5

	and their relations and significances. Maxwell relations. Thermodynamic equations of state. b. Joule-Thomson effect. Joule-Thomson coefficient for van der Waals' gas. Joule-Thomson effect and production of low temperature, adiabatic demagnetization, Joule-Thomson 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.			
Module 4:	**4. Electrochemistry** a. EMF series, cell potential: 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.	**9**	CO1, CO2, CO3	K1, K2, K3, K5, K6
Module 5:	**5. Chemical Kinetics** a. General introduction to various types of order of reaction including fractional order, molecularity of the reaction. b. Introduction to reversible and irreversible reactions and reactions leading to equilibrium. van'tHoffs equation and analysis of Gibbs free energy of	**9**	CO1, CO3, CO4	K1, K2, K3, K4, K5

	equilibrium reactions. c. Collision theory and Maxwell Boltzmann distribution of energies of colliding molecules. The concept of collisional cross section and reactive cross section and its significance. d. Comparative study of transition state and collision state theory. 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. 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.			
Texts:	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. 5. S. Glasstone, Text Book of Physical Chemistry, D. Van Nostrand Company, New York, Reprint 1942.			
References/ Readings:	1. B. R. Puri, L. R. Sharma and M. S. Pathania, Principles of Physical Chemistry, 49th ed., Vishal Publishing Co., New Delhi, 2020 2. A. Saggion, R. Faraldo, M. Pierno, Thermodynamics - Fundamental Principles and Applications, Springer, Switzerland, 2019 3. J. Bockris, A. K.N. Reddy, M. E. Gamboa-Aldeco, Modern Electrochemistry: Fundamentals of Electrodics, Vol. 2A, 2nd ed., Kluwer Academic Publishers, New York, 2002 4. J. Bockris, A. Reddy, Modern Electrochemistry: Ionics, Vol. 1, 2nd ed., , 2nd Ed., Kluwer Academic Publishers, New York, 2002 5. J. E. House, Principles of Chemical Kinetics, 2nd ed., Academic Press, Burlington MA, 2007 6. J. P. Lowe, K. Peterson, Quantum Chemistry, 3rd ed., Elsevier, Burlington MA, 2006			

	7. R. G. Mortimer, Physical Chemistry, 3rd ed., Elsevier, Burlington MA, 2008

Title of the Course	Analytical Chemistry Techniques
Course Code	CHA-5000
Number of Credits	4
Theory/Practical	Theory
Level	400
Effective from AY	2025-26
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	NIL	
Course Objectives:	• To learn various methods of data handling in analysis. • To explain the significance of sampling and calibration techniques. • To understand principles and applications of various types of techniques • To train the students to deduce structures based on IR, NMR, MS combined data.	
Course Outcomes:	Students will be able to	**Mapped to PSO**
	CO 1. explain the role of statistical tools for determination of error and organize data management for systematic interpretation.	PSO1
	CO 2. analyse the appropriate technique for thermoanalytical studies.	PSO1
	CO 3. explain basic principles and scope of different methods of separation and techniques of analysis	PSO1. PSO2

	CO 4. solve problems based on IR, NMR, MS combined spectral data.			PSO1, PSO2, PSO3
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**1.1. 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.	**5**	CO1	K1, K2, K3, K4
	1.2. Sampling and Calibration Techniques: Sampling and sample preparation, general steps in chemical analysis, calibration of glassware. Finding the best straight line - least square regression, correlation coefficient; Calibration curves, standard addition, external standards and internal standards. Chemical concentrations. Classical methods of Analysis: Gravimetry and Titrimetric methods: Principle, methodology, advantages & disadvantages over instrumental methods.	**5**	CO1	K1, K2, K3, K4
	1.3. Thermoanalytical techniques: Principle, instrumentation and applications of Thermogravimetric Analysis (TGA), Differential Thermal Analysis (DTA), and Differential Scanning Calorimetry (DSC). Numericals based on TGA.	**5**	CO1, CO2	K1, K2, K3, K4, K5
Module 2:	**2.1. Concepts in Chromatography** Principles of chromatography, classification of 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).	**4**	CO3	K1, K2, K3, K4, K5
	2.2. Chromatographic techniques Principles and applications of Paper chromatography, thin layer chromatography, HPTLC, Size exclusion and Ion exchange chromatography. Counter-current chromatography for isolation of natural products.	**4**	CO3	K1, K2, K3, K4, K5

	2.3. Gas and Liquid Chromatography Introduction; Instrumental Modules; Separation System; Choice of Conditions of Analysis; Sample Inlet Systems; Detectors; Practical Considerations in Qualitative and Quantitative Analysis; Coupled Systems-introduction to GCMS, GCIR, LCMS: Applicability, interpretation and numericals.	**7**	CO3	K1, K2, K3, K4, K5
Module 3:	**3.1.Spectroscopic Techniques** Interaction of Electromagnetic Radiation with Matter, Electromagnetic spectra, regions of spectrum, numericals. 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. 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. Infrared Spectroscopy: Infrared absorption and molecular structures, molecular vibrations, types of vibrations, IR spectra, overtones and bands-basis of NIR absorption. Spectrometric instrumentation of UV-Vis and IR: Sources, monochromators, sample cells, detectors, instrumental wavelength and absorption calibration.	**10**	CO4	K1, K2, K3, K4, K5, K6
	3.2. Applications of UV-Vis spectroscopy for qualitative analysis Calculating λmax for Conjugated Dienes, Trienes, polyenes, α,β-unsaturated carbonyl compounds, Numericals. Applications of IR spectroscopy for qualitative analysis: Spectra interpretation, Frequencies of functional group, Spectral Databases, Identification of unknown compounds.	**5**	CO4	K3, K4, K5

Module 4:	**4.1. Raman Spectroscopy** Theory, Basic instrumentation and Structural analysis using Raman Spectra. Mass Spectrometry: Principle, Instrumentation and various fragmentation patterns.	**5**	CO4	K2, K3, K4
	4.2. 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.	**5**	CO4	K1, K2, K3, K4, K5, K6
	4.3. Conjoint spectrometry problems Structural elucidation of organic molecules using IR, UV, NMR and MS.	**5**	CO4	K3, K4, K5, K6
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.			
Texts:	1. G. D. Christian, Analytical Chemistry, 6th Ed., Wiley, Singapore, 2004. 2. G. W. Ewing, Instrumental Methods of Chemical Analysis, 5th Ed., McGraw- Hill Int., New York, 1985. 3. W. Kemp, Organic Spectroscopy, 3rd Ed., Palgrave, New York, 1991. 4. D. A. Skoog, D. M. West, F. J. Hollar, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed., Cengage learning, USA, 2014. 5. R. M. Silverstein, F. X. Webster, Spectrometric identification of Organic Compounds, 6th Ed., Wiley, USA, 1998. 6. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, B. Sivasankar, Vogel's Text Book of Quantitative Chemical Analysis, 6th Ed., Pearson, New Delhi, 2009 7. F. J. Holler, D. A. Skoog, S. R. Crouch, Principles of Instrumental Analysis, 6th Ed., Thomson Books, London, 2007. 8. H. Willard, L. L. Merritt, J. A. Dean, F. A. Settle, Instrumental methods of Analysis, 7th Ed., HCBS Publishing, India, 2004. 9. C. N. Banwell, E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th Ed., Tata McGraw- Hill, India, 2006. 10. P. S. Kalsi, Spectroscopy of Organic Compounds, 2nd Ed., New Age International, New Delhi, 2000.			
References/ Readings:	1. J. H. Kennedy, Analytical Chemistry: Principles, 2nd Ed., Saunders College Publishing, Philadelphia, 1990. 2. H. Gunzler, A. Williams, Handbook of Analytical Techniques, 1st Ed., Wiley, Germany, 2001. 3. E. Pretsch, P. Buhlmann, C. Affolter, Structural Determination of Organic Compounds, 2nd Ed., Springer,			

	Germany, 2005. 4. L. D. Field, S. Sternhell, J. R. Kalman; Organic Structures from Spectra, 4th Ed., Wiley, Singapore, 2007. 5. R. A. Day, A. L. Underwood, Quantitative Analysis, 6th Ed., Prentice Hall, USA, 2001. 6. B. K Sharma, Instrumental methods of chemical analysis, Goel Publishing House, Meerut, 2004. 7. K. Nakamoto, Infrared and Raman Spectra of Inorganic and Coordination Compounds, 6th Ed., Wiley, USA, 2009. 8. P. J. Larkin, Infrared and Raman Spectroscopy: principles and spectral interpretation, 2^{nd} Ed., Elsevier, Netherland, 2018.

SEMESTER II

Discipline Specific Core (DSC) Courses

Title of the Course	Concepts in Quantum Chemistry and Statistical Thermodynamics
Course Code	CHP-5001
Number of Credits	04
Theory/Practical	Theory
Level	500
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil
Course Objectives:	• To introduce various concepts of quantum chemistry. • To learn quantum mechanical models and approximation methods for problem solving. • To familarize various concepts of statistical thermodynamics. • To understand molecular behavior using quantum statistics and partition functions.

Course Outcomes:	Students will be able to:		**Mapped to PSO**	
	CO 1. explain the concepts of quantum chemistry including the wave function.		PSO1	
	CO 2. use concepts of statistical thermodynamics with emphasis on the partition function.		PSO1, PSO4	
	CO 3. apply the postulates of quantum mechanics to solve simple problems.		PSO1, PSO8	
	CO 4. evaluate the law of equipartition of energy for thermodynamic systems.		PSO1, PSO8	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Quantum Chemistry** The origin of quantum mechanics: Planck's quantum theory, wave particle duality, uncertainty principle concept of wave function, the Born interpretation of wave function. Normalization and orthogonalizations, quantization, Eigen values and Eigen functions. Postulates of quantum mechanics; Schrödinger equation for free particle, particle in a box, degeneracy. Quantum mechanical operators and their properties, commutation relations, Hamiltonian and Laplacian operators, Harmonic oscillators, Angular momentum, Ladder Operators. Approximate methods, Schrödinger equation, its importance and limitations, Born-Oppenheimer approximation, Anti-symmetric wave functions and Slater determinants (many electron system e.g. He atom), Exclusion and Aufbau principle, Variation method, Linear Variation Principle, Perturbation theory (first order non-degenerate) and their applications to simple systems. MO theory, Hückel MO theory, Bond-order, Charge density matrix, Unification of HMO and VB theory, their applications in spectroscopy and chemical reactivity, electron density forces and their role in chemical bonding. Hybridization and valence MOs of H_2O, NH_3 and CH_4. Application of Hückel Theory to ethylene, butadiene and benzene molecules.	**30**	CO1, CO3	K1, K2,K3, K4, K5
Module 2:	**Statistical Thermodynamics** The language of statistical thermodynamics: Probability, ensemble, microstate,	**30**	CO2, CO4	K1, K2, K3, K4,

	degeneracy, permutations and combinations. Configuration and weights, the dominant configuration. The Boltzmann distribution. The molecular partition function: its interpretation and its relation to uniform energy levels. Translational, Rotational, Vibrational and Electronic Partition functions for diatomic molecules. Relation between thermodynamic functions and partition functions and their statistical interpretations. Equilibrium constants from partition function. Law of Equipartition energy. Theories of specific heat of solids. Comparison between Einstein and Debye theories. Concept of symmetric and antisymmetric wave functions. Ortho and para hydrogens. Quantum Statistics: Fermi-Dirac (FD)and Bose-Einstein (BE) statistics. Comparison between MB, FD and BE Statistics.			K5
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.			
Texts:	1. G. M. Barrow, Physical Chemistry, 5th Ed., Tata McGraw Hill, New Delhi. 2016. 2. P. W. Atkins and J. D. Paula, Physical Chemistry, 8th Ed., Oxford University Press, New Delhi. 2007			
References/ Readings:	1. H. Metiu, Physical Chemistry: Statistical Mechanics, 1st Ed.; Taylor & Francis, New York, 2006. 2. I. N. Levine, Quantum Chemistry, 7th Ed., Prentice-Hall, New Delhi. 1999 3. M. C. Gupta, Statistical Thermodynamics, 1st Ed.; Wiley Eastern, New Delhi, 1990.			

Title of the Course	Group Theory and Spectroscopy
Course Code	CHP-5002
Number of Credits	04
Theory/Practical	Theory
Level	500
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	• To introduce concepts in Group Theory and its applications to chemistry. • To learn advanced topics in spectroscopy. • To impart a comprehensive understanding of molecular symmetry. • To aquaint with vibrational and Raman spectroscopy for molecular structure elucidation and chemical analysis.	
Course Outcomes:	Students will be able to:	**Mapped to PSO**
	CO 1. explain the concepts of Group Theory and spectroscopy	PSO1, PSO2, PSO3
	CO 2. apply character tables to analyze molecular symmetry and solve related problems.	PSO1, PSO2, PSO3
	CO 3. differentiate among various spectroscopic techniques	PSO1, PSO3

	CO 4. solve various problems based on Group theory and spectroscopy		PSO1, PSO3	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**1.1. Molecular Symmetry and the Symmetry Groups** Symmetry elements and symmetry operations, Concept of group and group multiplication tables, order of the group, classes and subgroups in a group, Different types of groups (cyclic, abelian and non-abelian groups). **1.2. Representations of Groups** Point groups, Matrix representations of a group, Reducible and Irreducible representations groups, Great Orthogonality Theorem, Properties of Irreducible representations, Mulliken symbols for Irreducible representations, Character tables. Standard reduction formula, Direct products of representations and its applications	**15**	CO1, CO2, CO4	K1, K2,K3, K4, K5
Module 2:	**2.1. Role of Quantum Mechanics in Group theory and hybridisation** Quantum Chemistry and spectroscopy: Vanishing of integrals, Selection rules. Applications of group theory for hybridization of atomic orbitals. Projection operator and Symmetry adapted linear combinations (SALCs), MO treatment (within Huckel Molecular Orbital Theory) of large molecules with symmetry. Applications of group theory to Infra-red and Raman spectroscopy. **2.2. Vector spaces and representations** Space Groups: Symmetry elements, Schoenflies, and Hermann Mauguin notation, Representation of point groups and space groups, point symmetry, space symmetry, glide plane, helical screw axis	**15**	CO1, CO2, CO4	K1, K2,K3, K4, K5
Module 3:	**Microwave, IR and Raman Spectroscopy** Theoretical treatment of Rotational and Vibrational spectroscopy. Principle of Fourier Transform (FT) spectroscopy, FTIR spectroscopy: Theory,	**15**	CO1, CO3, CO4	K1, K2, K3, K4, K5

	instrumentation and applications. Quantum theory of Raman effect, Raman shift, Instrumentation, Resonance Raman spectroscopy, Complimentary nature of IR and Raman spectroscopy in structure determination, Applications.			
Module 4:	**Spin Resonance Spectroscopy** NMR Spectroscopy: Basic principles of NMR; theory of pulse NMR and fourier analysis, FT-NMR.; solid state NMR, magic angle spinning (MAS), dipolar decoupling and cross polarization, applications of solid-state NMR; double resonance, NOE, spin tickling, solvent and shift reagents, structure determination by NMR. ESR Spectroscopy: Theory and experimental techniques, Identification of odd-electron species (methyl and ethyl free radicals) and radicals containing hetero atoms. Spin trapping and isotopic substitution, spin densities and McConell relationship, Double resonance techniques.	**15**	CO1, CO3, CO4	K1, K2, K3, K4, K5
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.			
Texts:	1. C. N. Banwell and E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th Ed.; Tata McGraw-Hill, New Delhi, 1994. 2. F. A. Cotton, Chemical applications of group theory, 3rd Ed.; Wiley Eastern, New York, 2012 (reprint). 3. G. Aruldhas, Molecular structure and spectroscopy, 2nd Ed.; Prentice Hall of India, New Delhi, 2001. 4. G. R. Desiraju, J. J. Vittal, A. Ramanan, Crystal Engineering, 1st Ed.; IISC Press, world Scientific, New York, 2011. 5. P. W. Atkins and J. D. Paula, Physical Chemistry, 8th Ed.; Oxford University Press, New Delhi, 2007. 6. R. S. Drago, Physical Methods in Chemistry, 1st Ed.; W. B. Saunders Company, Philadelphia, 1977.			
References/ Readings:	1. K. Nakamoto, Infrared and Raman Spectra of Inorganic and Coordination Compounds, Part B: Applications in Coordination, Organometallic and Bioinorganic Chemistry, 6th ed.; Wiley, New Jersey, 2009. 2. K. V. Raman, Group Theory and Its Applications to Chemistry, 1st Ed.; Tata McGraw-Hill, New Delhi, 1999. 3. P. Atkins, J. De Paula, J. Keeler, Atkins' Physical Chemistry, 1st Ed.; Oxford University Press, New York, 2018.			

	4. W. Kemp, NMR in Chemistry: A Multinuclear Introduction, 2nd Ed.; Macmillan, London, 1986.
Web Resources:	https://symotter.org/

Title of the Course	Thermodynamics and Reaction Kinetics
Course Code	CHP-5003
Number of Credits	04
Theory/Practical	Theory
Level	500
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	• To introduce concepts of reaction kinetics and thermodynamics • To acquire fundamental knowledge of theories that govern chemical reactions • To learn newer classes of reaction types and their kinetics • To introduce latest developments in the advance instrumental techniques and methods for monitoring reaction kinetics and dynamics.	
Course Outcomes:	Students will be able to:	**Mapped to PSO**
	CO 1. explain various concepts in chemical kinetics and thermodynamics.	PSO1, PSO4, PSO7
	CO 2. apply principles of chemical kinetics and thermodynamics to analyze different chemical systems.	PSO1, PSO4, PSO7

Approved by: Academic Council on 13th September 2025

	CO 3. differentiate between equilibrium and non-equilibrium thermodynamics.		PSO1, PSO4, PSO7	
	CO 4. evaluate experimental data using kinetic and thermodynamic models.		PSO1, PSO4, PSO7	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Theories of reaction rates** Generalized kinetic theory and extended collision theory. Concept of collisional number, collisional frequency factor, collisional and reactive cross section, steric factor, microscopic rate constant. Assumptions and limitations of collision theory. Conventional transition state theory, equilibrium hypothesis and derivation of reaction rates. Thermodynamic formulation of transition state theory. Arrhenius temperature dependent and independent activation energy and its significance. Assumptions and limitations of transition state theory. Lindemann-Hinshelwood theory of thermal unimolecular reactions.	**10**	CO1, CO2, CO4	K1, K2,K3, K4, K5
Module 2:	**Time-Resolved Studies in Reaction Kinetics** Collisional kinetics in solution, effect of solvent polarity, solvent cohesion energy, and ion-dipole and dipole-dipole reactions on reaction rates. Homogeneous kinetics, enzymatic reactions and Michaelis-Menten, Lineweaver-Burk and Eadie Analysis, Autocatalytic reactions. Types of composite mechanisms, kinetics of parallel and consecutive reactions. Introduction to shock tube method and its use in combustion analysis. Photochemical fast reactions, Pulsed laser photolysis, and its use in monitoring fast reactions. Kinetics of reversible reactions and graphical analysis. Oscillatory reactions, Voltera-Lotka hypothesis of oscillatory reactions. The significance of bi-stability in the Briggs-Rauscher, Reaction and Belousov-Zhabotinskii reaction. Introduction to potential energy surfaces, description of H_2O and HF potential energy surface diagrams.	**20**	CO1, CO2, CO4	K1, K2, K3, K4, K5
Module 3:	**Equilibrium Thermodynamics** Important terminologies in Thermodynamics; Thermodynamics state functions; work	**18**	CO1, CO2,	K1, K2, K3, K4,

	& heat; work expansion; Mathematical interlude Exact and inexact differentials. Cyclic rule; partial derivatives. Heat change at constant pressure, volume; relationship between Qp& Qv; Heat capacities Cp, Cv; Concept of Entropy, entropy change for an ideal gas at different conditions; Entropy of mixing of ideal gas and the Gibbs paradox; Physical significance of entropy. Work function and free energy function; Variation of free energy with temperature and pressure; Maxwell relations; Thermodynamic equations of state; Gibbs-Helmholtz equation. Thermodynamics of open systems, partial molar properties; chemical potential, variation of chemical potential with temperature and pressure; Gibbs-Duhem equation; Duhem-Margules equation; applications of chemical potential; thermodynamic derivation of phase rule.		CO3, CO4	K5
Module 4:	**Non-Equilibrium thermodynamics** Concept of internal entropy and spontaneity of a process in relation to free energy. Chemical affinity and extent of a reaction. Phenomenological Laws and Onsager's Reciprocal Relations; Conservation of Mass and energy in closed and open system. Postulates of non-equilibrium thermodynamics. Entropy production in heat flow. Entropy production of chemical reactions and Entropy production/entropy flow in open system. Principle of microscopic reversibility and the Onsager reciprocal relations; Validity of Onsager's equation and its verification; Application of Irreversible Thermodynamics to Biological Systems; Application to thermo-electric and electrokinetic phenomena.	**12**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5
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.			
Texts:	1. Kleidon and R. D. Lorenz (Eds.), Non-equilibrium Thermodynamics and the Production of Entropy: Life, Earth, and Beyond, 1st Ed.; Springer, Berlin–Heidelberg–New York, 2005. 2. Michel Soustelle, An Introduction to Chemical Kinetics, 1st Ed.; Wiley, Hoboken, New Jersey, 2011. 3. P. W. Atkins and J. de Paula, Atkins' Physical Chemistry, 8th Ed.; Oxford University Press, Oxford, 2007.			

	4. Paul L. Houston, Chemical Kinetics and Reaction Dynamics, 1st Ed.; Dover Publications, Mineola, New York, 2006.
References/ Readings:	1. D. A. McQuarrie and John D. Simon, Physical Chemistry: A Molecular Approach, 1st Ed.; Viva Books Pvt. Ltd., New Delhi, 2019. 2. D. K. Chakrabarty and B. Viswanathan, Heterogeneous Catalysis, 2nd Ed.; New Age International Publishers, New Delhi, 2008. 3. E. N. Yeremin, Fundamentals of Chemical Thermodynamics, 1st Ed.; Firebird Publications, Moscow, 1978. 4. G. W. Castellan, Physical Chemistry, 3rd Ed., Addison-Wesley Publishing Company, Reading, Massachusetts, 1983. 5. J. I. Steinfeld, J. S. Francisco and W. L. Hase, Chemical Kinetics and Dynamics, 2nd Ed., Prentice Hall, Upper Saddle River, New Jersey, 1999. 6. J. Rajaram and J. C. Kuriacose, Thermodynamics for Students of Chemistry: Classical, Statistical and Irreversible, 1st Ed.; S. N. & Co., Jalandhar, 1996. 7. K. J. Laidler, Chemical Kinetics, 3rd Ed.; Pearson Education, India 2004. 8. P. W. Atkins and J. de Paula, Atkins' Physical Chemistry, 8th Ed.; Oxford University Press, Oxford, 2007. 9. S. K. Scott, Oscillations, Waves and Chaos in Chemical Kinetics, 1st Ed.; Oxford Science Publications, Oxford, 1994. 10. S. R. De Groot, Non-equilibrium Thermodynamics, 1st Ed.; Dover Publications, Mineola, New York, 2011. 11. T. S. Briggs and W. C. Rauscher, An Oscillating Iodine Clock, Journal of Chemical Education, 50, 496–498; American Chemical Society, Washington, D.C., 1973.

Title of the Course	Principles of Electrochemistry and its Applications
Course Code	CHP-5004
Number of Credits	04
Theory/Practical	Theory
Level	500
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	• To learn electrochemical processes, ionic interaction theories, electrified interfaces and kinetics of electron transfer. • To study electrochemical data and acquire skills in problem solving. • To understand electrochemistry principles in day-to-day life. • To learn the working of electrochemical cells andtechniques such as EIS.	
Course Outcomes:	Students will be able to:	**Mapped to PSO**
	CO 1. explain various concepts of electrochemistry	PSO1, PSO2
	CO 2. predict electrochemical behavior of electrochemical systems.	PSO2, PSO4, PSO5, PSO6
	CO 3. evaluate electrochemical systems for batteries, sensors and solar cells	PSO3, PSO4, PSO5, PSO6

	applications.			
	CO 4. apply theelectrochemical principles in renewable energy, materials science and biological systems.		PSO6, PSO7	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Ionic Interactions and Conductance in Electrolytes** Ion-solvent interactions. Born Theory, validity and limitations. Solvation number and coordination number. Ion-ion interactions and Debye-Huckel theory of ion cloud. Applications of Debye- Huckel equation. Concept of ionic strength and activity coefficient. Debye-Huckel limiting law and its modifications. Debye-Huckel-Onsager equation, validity and limitations. Einstein-Smoluchowski equation. Influence of ionic atmospheres on ionic migration: Relaxation and Electrophoretic effects. Conductance in strong and weak electrolytes. Pure liquid electrolytes: ionic liquids, limiting case of zero solvent, thermal loosening of ionic lattice	**15**	CO1, CO2	K1, K2,K4
Module 2:	**2.1. Electrified Interfaces** Formation of an electrode/electrolyte interface and its structure. Polarizable and non-polarizable interfaces. Potential difference across electrical double layer: outer potential, surface potential, inner potential and relationship between them, chemical and electrochemical potentials. Thermodynamics of electrified interface: Surface tension, surface excess, Electro-capillary curves. Determination of surface excess. Condition for	**15**	CO1, CO2, CO3	K1, K2, K4, K5

	thermodynamic equilibrium at electrified interface. Generalized Gibbs equation, Lippmann equation and electrical capacitance at the double layer. Models of the electrified interface. Ion adsorption at the electrode: hydrated electrodes, contact adsorption. Semiconductor-electrolyte interface: diffuse-charge region, surface states. **2.2. Colloidal interfaces** Interaction of double layers and stability of Sols. DLVO theory. Electrokinetic phenomena: Electroosmosis, streaming potential and current, electrophoresis. Zeta potential. Critical micelle concentration, Krafft temperature Donnan membrane equilibria. Micelles and reverse micelles, Emulsions and Microemulsions.			
Module 3:	**Electrode Kinetics and Corrosion** Disturbance of electrode equilibrium, cause of electron transfer, fast and slow systems and their current-potential relationship. Butler-Volmer equationanditslowandhigh field approximations. Nernst equation as a special case of B-V equation. Tafel plots for anodic and cathodic processes. Fundamentals of Impedance spectroscopy; determining exchange current densities and rate constants from impedance plots. Principles of corrosion, electrochemical methods of avoiding corrosion. pH-potential diagrams: Pourbaix diagram for corrosion of iron and stability of water	**15**	CO1, CO3, CO4	K1, K2, K3, K4, K5
Module 4:	**4.1. Electrochemical Energies: Conversion and Storage** Thermodynamics of electrochemical energy conversion.	**15**	CO1, CO2, CO3, CO4	K1, K2, K3, K5,

	Batteries: Basic principles; rating and shelf life. Zinc-Manganese dioxide: Leclanche and alkaline batteries. Lithium ion batteries and recharge ability. Fuel cells: Principle of a hydrogen-oxygen fuel cell. Classification of fuel cell systems based on types of electrolytes/temperature. Direct methanol-polymer electrolyte fuel cell and electro-catalysts - a case study. Reactions occurring in various fuel cells and calculation of their electrode and cell potentials. Super-capacitors and its applications. **4.2. Photoelectrochemistry** Semiconductor/Electrolyte Interface: Band edge and Band bending. Light absorption and carrier generation at the electrode: photoinduced charge transfer, hot carriers. Photoelectrodes: p-type photocathode, n-type photoanode. d. Determination of surface states. Photoelectrocatalysis: photoelectrochemical water splitting and CO_2 reduction. Types of photoelectrochemical devices.			K6
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.			
Texts:	1. J. M. Stratmann, and D. Licht, Encyclopedia of Electrochemistry: Semiconductor Electrodes and Photoelectrochemistry, Vol. 6; Wiley-VCH, Weinheim, 2002. 2. J. Bard and L. R. Faulkner, Electrochemical Methods: Fundamentals and Applications, 2nd Ed.; John Wiley & Sons, New York, 2001. 3. J. O'M. Bockris and A. K. N. Reddy, Modern Electrochemistry, Vol. 1, 2A and 2B, 2nd Ed.; Kluwer Academic Publishers, New York, 2002. 4. K. S. Birdi, Surface and Colloid Chemistry: Principles and Applications, 4th Ed.; CRC Press, Taylor and Francis, Boca Raton, Florida, 2010.			
References/	1. A. J. Torriero, Electrochemistry in Ionic Liquids, Vol. 1: Fundamentals, 1st Ed.; Springer International			

Readings:	Publishing, Cham, 2015. 2. A. Vincent and B. Scrosati, Modern Batteries, 2nd Ed.; John Wiley & Sons, New York, 1997. 3. C. M. A. Brett and A. M. O. Brett, Electrochemistry: Principles, Methods and Applications, 1st Ed.; Oxford University Press, New York, 1993. 4. D. Crow, Principles and Applications of Electrochemistry, 4th Ed.; Blackie Academic & Professional, London, 1994. 5. J. O'M. Bockris and S. Srinivasan, Fuel Cells: Their Electrochemistry, 1st Ed.; McGraw-Hill Book Co., New York, 1969. 6. R. D. Vold and M. J. Vold, Colloid and Interface Chemistry, 1st Ed.; Addison-Wesley, Reading, Massachusetts, 1983.

SEMESTER I & II

Discipline Specific Elective Courses

Title of the Course	Organic Chemistry Practical - I
Course Code	CHO-5201
Number of Credits	2
Theory/Practical	Practical
Level	400
Effective from AY	2025-26
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	NIL	
Course Objectives:	• To understand essential laboratory equipment, safety protocols, and fundamental experimental purification techniques • To create practical skills in basic organic synthesis through key reactions, including electrophilic substitution and other important transformations. • To understand the methods of isolation and purification of naturally occurring organic compounds.	
Course Outcomes:	Students will be able to:	**Mapped to PSO**

Approved by: Academic Council on 13th& 14th June 2025

	CO 1. Understand stoichiometric requirements during organic syntheses.		PSO1, PSO3, PSO4	
	CO 2. Apply safe and good laboratory practices and develop skills in handling laboratory glassware, equipment and chemical reagents.		PSO1, PSO3, PSO4	
	CO 3. Create the practical knowledge to perform experiments involving common laboratory techniques like reflux, distillation, steam distillation, vacuum distillation, aqueous extraction, thin layer chromatography (TLC).		PSO1, PSO3, PSO4	
	CO 4. Assess their expertise in isolation of some important natural products.		PSO1, PSO2, PSO3, PSO4	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**1.1 Introduction to laboratory equipment, apparatus and safety** a. Use of common laboratory equipment like fume hood, vacuum pump, weighing balance. b. Introduction to various types of quick fit joints and apparatus. c. Safety Techniques: i. Disposal of chemicals ii. Personal Protective Equipment (PPE) iii. First aid iv. Fire extinguishers, types of fire v. Chemical hazards and risk assessment **1.2 Laboratory Techniques-I** a. Simple distillation (any one): i. Toluene-dichloromethane mixture using water condenser. ii. Nitrobenzene and aniline using air condenser. b. Steam distillation (any one): 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)	**16**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5

	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.			
Module 2:	**2 Laboratory Techniques-II** a. Sublimation: Simple or vacuum sublimation of camphor, naphthalene, anthracene or succinic acid (any one).Vacuum distillation (any one): o-dichlorobenzene, diphenyl ether. Explanation of use of nomograph. b. Thin layer Chromatography (any one): i. Separation of o and p-nitroanilines. ii. Separation of analgesic drugs (ibuprofen/paracetamol) iii. Separation of o and p-nitrophenols	**12**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5
Module 3:	**3. Organic synthesis (Any Four experiments)** a. Aliphatic electrophilic substitution: Preparation of iodoform from ethanol & acetone. b. Aromatic electrophilic substitution (any one): 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.	**16**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5

	f. Grignard reaction: Triphenylmethanol from benzoic acid ester or benzophenone. g. Aldol condensation: Dibenzalacetone from benzaldehyde h. Acetoacetic ester condensation: Preparation of ethyl n-butylacetoacetate or ethyl acetoacetate.			
Module 4:	**Organic synthesis and synthetic reagents (Any two)** a. Cannizzaro reaction using 4-chlorobenzaldehyde as substrate. b. Friedel Craft's reaction i. using toluene and succinic anhydride ii. Resorcinol to resacetophenone, benzene and maleic anhydride to benzoylacrylic acid. c. Solvent free preparation of coumarin by the Knoevenagel condensation under MW irradiation. d. Preparation of oxidizing agent (any one): Pyridinium chlorochromate-silica, pyridinium chlorochromate-alumina, MnO_2. e. Preparation of cuprous chloride. **Isolation from natural sources (Any two)** i. Caffeine from tea powder. ii. Piperine from pepper. iii. Cinnamaldehyde from cinnamon iv. Lemongrass oil from lemongrass	**16**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
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.			
Texts:	1. A. I. Vogel, A. R. Tatchell, B. S. Furniss, A. J. Hannaford, Vogel's Textbook of Practical Organic Chemistry, 5th ed. Prentice Hall, New Delhi, 2011 2. K. Tanaka, Solvent-Free Organic Synthesis, 2nd ed, Wiley-VCH, Weinheim, 2009. 3. L. F. Fieser, K. L. Williamson, Organic Experiments, 7th ed. D. C. Heath, Lexington, 1992. 4. K. L. Williamson, K. M. Masters, Macroscale and Microscale Organic Experiments, 6th ed. Cengage Learning, Boston, 2010			

	5. R. K. Bansal, Laboratory Manual in Organic Chemistry, 5th ed. New Age International, New Delhi, 2016 6. O. R. Rodig, C. E. Bell Jr., A. K. Clark, Organic Chemistry Laboratory: Standard and Microscale Experiments, 3rd ed. Saunders College Publishing, Philadelphia, 2009
References/ Readings:	1. S. Delvin, Green Chemistry, 1st ed. Sarup& Sons, New Delhi, 2005 2. J. Mohan, Organic Analytical Chemistry, 1st ed. Narosa Publishing House, New Delhi, 2014 3. T. Laue, A. Plagens, Named Organic Reactions, 1st ed. John Wiley and Sons, Inc., Hoboken, 2005

Title of the Course	Organic Chemistry Practical - II
Course Code	CHO-5202
Number of Credits	2
Theory/Practical	Practical
Level	400
Effective from AY	2025-26
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	NIL	
Course Objectives:	• To familiarize students with essential laboratory equipment, safety protocols, and fundamental experimental purification techniques • To develop practical skills in basic organic synthesis through key reactions, including electrophilic substitution and other important transformations. • To introduce the methods of isolation and purification of naturally occurring organic compounds.	
Course Outcomes:	Students will be able to:	**Mapped to PSO**
	CO 1. Understand stoichiometric requirements during organic syntheses.	PSO1, PSO3, PSO4
	CO 2. Apply safe and good laboratory practices and develop skills in handling laboratory glassware, equipment and chemical reagents.	PSO1, PSO3, PSO4
	CO 3. Create the practical knowledge to perform experiments involving common	PSO1, PSO3, PSO4

	laboratory techniques like reflux, distillation, steam distillation, vacuum distillation, aqueous extraction, thin layer chromatography (TLC).			
	CO 4. Assess their expertise in isolation of some important natural products.		PSO1, PSO2, PSO3, PSO4	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**1.1 Introduction to laboratory equipment, apparatus and safety** a. Common Hazards in Chemical Laboratory, Risk assessment b. Accidents and Emergency procedures **1.2 Laboratory Techniques (Any Three)** a. Simple distillation: i. Simple distillation of thionyl chloride under anhydrous condition ii. Simple distillation under Nitrogen atmosphere of THF b. Fractional distillation: i. Chloroform-dichloromethane mixture using water condenser. ii. Toluene and cyclohexane using fractionating column. c. Vacuum distillation under inert atmosphere: Distillation of DMF, o-dichlorobenzene, $POCl_3$ d. Thin layer Chromatography: i. Purification and isolation of mixture of acids (o-nitrobenzoic acid and p-nitrobenzoic acid) by using Preparative TLC. ii. Purification and isolation of mixture of phenols (o and p-nitrophenols) by using Preparative TLC. iii. Purification and isolation of pharmaceutical drugs (ibuprofen tablet) using Preparative TLC.	**16**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5
Module 2:	**Organic Synthesis (Any Four)** a. p-Iodonitrobenzene by Sandmeyer reaction b. Pinacol- Pinacolone rearrangement	**16**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5

	c. Hydrogenation of Maleic acid (Hydrogen balloon) d. Preparation of nitrostyrene from aldehyde e. Preparation of dibromocinnamic acid f. Reduction of nitro compounds g. Synthesis of Urea from ammonium cyanate			
Module 3:	**3. 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-2,4dinitrophenol e. Acetanilide-p-Bromoacetanilide-p-Bromoaniline f. Acetophenone-Oxime-Acetanilide	**16**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5
Module 4:	**4.1 Solvent Free Organic synthesis (Any One)** a. Reduction using ball milling technique b. Oxidation of 2° alcohol using $KMnO_4$/Alumina by grinding technique. c. Synthesis of 1,1'-Bi-2-naphthol (BINOL) d. Hunsdiecker reaction of cinnamic acid derivatives e. Beckmann rearrangement of oxime derivatives **4.2 Separation, Isolation and Identification of Organic compounds (Any One)** 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.	**12**	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
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.			
Texts:	1. A. I. Vogel, A. R. Tatchell, B. S. Furniss, A. J. Hannaford, Vogel's Textbook of Practical Organic Chemistry, 5th ed. Prentice Hall, New Delhi, 2011 2. K. Tanaka, Solvent-Free Organic Synthesis, 2nd ed, Wiley-VCH, Weinheim, 2009			

	3. L. F. Fieser, K. L. Williamson, Organic Experiments, 7th ed. D. C. Heath, Lexington, 1992 4. K. L. Williamson, K. M. Masters, Macroscale and Microscale Organic Experiments, 6th ed. Cengage Learning, Boston, 2010 5. R. K. Bansal, Laboratory Manual in Organic Chemistry, 5th ed. New Age International, New Delhi 2016 6. O. R. Rodig, C. E. Bell Jr., A. K. Clark, Organic Chemistry Laboratory: Standard and Microscale Experiments, 3rd ed. Saunders College Publishing, Philadelphia, 2009
References/ Readings:	1. S. Delvin, Green Chemistry, 1st ed. Sarup& Sons, New Delhi, 2005. 2. J. Mohan, Organic Analytical Chemistry, 1st ed. Narosa Publishing House, New Delhi, 2014. 3. T. Laue, A. Plagens, Named Organic Reactions, 1st ed. John Wiley and Sons, Inc., Hoboken, 2005

Title of the Course	Inorganic Chemistry Practical-I
Course Code	CHI-5201
Number of Credits	2
Theory/Practical	Practical
Level	400
EffectivefromAY	2025-26
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites fortheCourse:	NIL	
Course Objectives:	• To acquire skills in synthetic inorganic chemistry. • To gain knowledge about various laboratory chemicals. • To determine metal and ligand content in a material. • To evaluate compounds molecular formula to find lattice water molecules.	
CourseOutcomes:	Students will be able	**Mapped to PSO**
	CO 1. explain the synthesis of coordination compounds.	PSO1, PSO4
	CO 2. estimate metals in the coordination compounds by classical methods of analysis.	PSO1, PSO3
	CO 3. characterise commercially available ores and alloys.	PSO2, PSO3
	CO 4. choose the appropriate instrumental methods of analysis for characterization ofcompounds	PSO1, PSO4

Content:		Noofhours	Mapped to CO	Cognitive Level
Module 1:	**1. Preparations of Inorganic Compounds (ANY 07)** a. Preparation of hexaamminenickel(II) chloride or hexaamminenickel(II) sulfate. b. Preparation of tris(ethylenediamine)cobalt(III) chloride. c. Preparation of potash alum from scrap aluminum. d. Preparation of potassium trioxalatoaluminate(III) trihydrate. e. Preparation of potassium hexathiocyanato-κN-chromate(III) tetrahydrate. f. Preparation of potassium trioxalatochromate(III) trihydrate. g. Preparation of α- and γ-Fe_2O_3. h. Preparation of Zinc acetate or $[Zn_4O(CH_3CO_2)_6]$. (Powder X-Ray Diffraction (PXRD), Infrared (IR), UV-vis spectroscopy and magnetic studies is expected)	**28**	CO1, CO2	K2, K3, K4, K5
Module 2:	**2. Estimations / Determinations (ANY 08)** a. Estimation of nickel by complexometry or Gravimetry. b. Estimation of cobalt in $[Co(en)_3]Cl_3$ by complexometry. c. Estimation of oxalate in $K_3[Al(C_2O_4)_3]\cdot xH_2O$ or $K_3[Cr(C_2O_4)_3]\cdot xH_2O$ d. Estimation of nitrite by redox titration. e. Estimation of calcium from calcite ore. f. Iodometric determination of copper in commercial copper compounds / alloys. g. Estimation of sulfate by gravimetry. h. Estimation of zinc by complexometric titration. i. Determination of chromium in chrome alum and $K_3[Cr(C_2O_4)_3]\cdot xH_2O$ and to determine degree of hydration. j. Estimation of potassium from synthesized compounds. k. Colorimetric/Spectrophotometric determination of nickel or chromium or	**32**	CO3, CO4	K2, K3, K4, K5

	manganese.			
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.			
Texts:	1. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, Vogel's Text Book of Quantitative Chemical Analysis,6th Ed., Pearson, New Delhi, 2002. 2. G. Svehla, Vogel's Text Book of Qualitative Inorganic Analysis, 7th Ed., Pearson, New Delhi, 2011. 3. G. Brauer, Handbook of Preparative Inorganic Chemistry, Vol. 1 & 2, Academic Press, New York, 1963. 4. G. Pass & H. Sutcliffe, Practical Inorganic Chemistry, Preparations, Reactions and Instrumental Methods, 2nd Ed., Chapman & Hall, New York, 1974. 5. W. L. Jolly, The Synthesis & Characterization of Inorganic Compounds, Prentice-Hall, INC, New Jersey, 1970. 6. G. Marr, B. W. Rockett, Practical Inorganic Chemistry, Van Nostrand Reinhold, London, 1972.			
References/ Readings:	1. S. De Meo, J. Chem. Ed., 80 (2003) 796-798. 2. A. J. Elias, General Chemistry Experiments, Revised Ed., University Press, Hyderabad, 2008.			

Title of the Course	Inorganic Chemistry Practical-II
Course Code	CHI-5202
Number of Credits	2
Theory/Practical	Practical
Level	400
EffectivefromAY	2025-26
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites fortheCourse:	Nil	
Course Objectives:	• To acquire skills in synthetic inorganic chemistry. • To gain knowledge about various laboratory chemicals. • To determine metal and ligand content in a material. • To evaluate compounds molecular formula to find lattice water molecules.	
CourseOutcomes:	Students will be able to	**Mapped to PSO**
	CO 1. understand methodologies related to compound synthesis.	PSO1, PSO4
	CO 2. experiment with various reagents and metal salts to synthesize useful compounds.	PSO1, PSO4

Approved by: Academic Council on 13th September 2025

	CO 3. analyse synthesized and commercially available compounds.		PSO1, PSO3	
	CO 4. interpret the chemical composition of materials using chemical methods and instrumental techniques.		PSO1, PSO3, PSO4	
Content:		**Noofhours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**1. Preparations / Estimation of Inorganic Compounds: (Any Nine)** a. Preparation of hexaamminecobalt(III) nitrate. b. Estimation of cobalt in hexaamminecobalt(III) nitrate by volumetric titration. c. Preparation of Potassium Trioxalatoferrate(III) Trihydrate d. Estimation of iron and oxalate by redox titration e. Synthesis of metal nanoparticles (Cu, Ag, Au, Ni) and determining the absorption maxima by UV-visible spectrophotometer. f. Estimation of amount of calcium in given sample by gravimetric method. g. Estimation of amount of nickel in given sample by gravimetric method. h. Estimation amount of zinc present in given sample by gravimetric method. i. Estimation of iron by colorimetric / spectrophotometry method. j. Estimation of barium by complexometric titration method. k. Estimation of manganese in presence of iron by complexometric titration method. (Powder X-Ray Diffraction (PXRD), Infrared (IR), UV-vis spectroscopy and magnetic studies is expected)	**40**	CO1, CO2, CO3	K2, K3, K4, K5
Module 2:	**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.	**20**	CO3, CO4	K2, K3, K4, K5

	Cations : Pb^{2+}, Cu^{2+}, Cd^{2+}, Sn^{2+}, Fe^{2+}, Fe^{3+}, Al^{3+}, Cr^{3+}, Zn^{2+}, 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.
Texts:	1. J. Mendham, R.C. Denney, J.D. Barnes, M.J. K. Thomas, Vogel's Text Book of Quantitative Chemical Analysis, 6th Ed., Pearson, New Delhi, 2002. 2. G. Svehla, Vogel's Text Book of Qualitative Inorganic Analysis, 7th Ed., Pearson, New Delhi, 2011. 3. G. Brauer, Handbook of Preparative Inorganic Chemistry, Vol. 1 & 2, Academic Press, New York, 1963. 4. G. Pass & H. Sutcliffe, Practical Inorganic Chemistry, Preparations, Reactions and Instrumental Methods, 2nd Ed., Chapman & Hall, New York, 1974. 5. G. Marr, B. W. Rockett, Practical Inorganic Chemistry, Van Nostrand Reinhold, London, 1972. 6. A. J. Elias, General Chemistry Experiments, Revised Ed., University Press, Hyderabad, 2008. 7. W. L. Jolly, The Synthesis & Characterization of Inorganic Compounds, Prentice-Hall, INC, New Jersey, 1970.
References/ Readings:	1. S. De Meo, J. Chem. Ed., 80 (2003) 796-798.

Title of the Course	Physical Chemistry Practical-I
Course Code	CHP-5201
Number of Credits	02
Theory/Practical	Practical
Level	400
Effective from AY	2025-26
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	NIL	
Course Objectives:	• To develop experimental skills on basic lab techniques in physical chemistry • To understand fundamental laboratory concepts and acquire skills for data acquisition, analysis and interpretation • To understand and follow safety protocols for handling chemicals, equipment and instruments. • To apply the practical laboratory concepts for synthesis, problem solving and critical thinking • To develop research skills through the principles of laboratory chemical research.	
Course Outcomes:	Students will be able to:	**Mapped to PSO**
	CO 1. Explain and perform various fundamental lab techniques and experiments.	PSO1
	CO 2. Handle and operate basic laboratory equipment and use it for research work.	PSO1, PSO4
	CO 3. Apply the laboratory knowledge and skills for their dissertation and research work.	PSO4, PSO5, PSO6, PSO7

	CO 4. Design synthesis and/or experimental methods.		PSO5, PSO6, PSO7	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**1. Non- instrumental Experiments (Any 08)** 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 11. To construct a phase diagram for a two-component system by plotting cooling curves for mixtures of different compositions. 12. To find the surface tension of methyl alcohol, ethyl alcohol and n-hexane at room temperature and then calculate the atomic parachors of carbon, hydrogen and oxygen.	**32**	CO1, CO3, CO4	K2, K3, K4, K5
Module 2:	**2. Instrumental Experiments (Any 07)** 1. To determine the degree of hydrolysis of salt of weak base and strong acid using conductometer.	**28**	CO2, CO3, CO4	K3, K4, K5

	2. To determine the dissociation constants of a tribasic acid (Phosphoric acid obtain derivative plot to get equivalence point. 3. To determine formal redox potential of Fe^{2+}/Fe^{3+} and Ce^{3+}/Ce^{4+} system obtain derivative plot to get equivalence point. 4. To study spectrophotometric titration of ferrous ammonium sulphate with potassium permanganate (or dichromate vs permanganate) 5. To determine Avogadro's number by improved electroplating. 6. To determine the zeta potential of colloidal system and investigate the effect of different surfactants on stability of the colloids. 7. To verify the Kohlrausch's law for weak electrolyte by conductometry. 8. To determine the transport numbers of Cu^{2+} and SO_4^{2-} ions in $CuSO_4$ solution by Hittorf's 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 can preferably be interactive in nature to enable peer group learning.			
Texts:	1. V. D. Athawale, P. Mathur, Experimental Physical Chemistry, New Age International Publishers, 1st ed., New Delhi, 2001. 2. J.N. Gurtu, A. Gurtu, Advanced Physical Chemistry Experiments, Pragati Publications, 1st ed., Meerut, 2008. 3. A. Findlay & J. A. Kitchener, Practical Physical Chemistry, Longmans, Green and Co., 1st ed., London 1954. 4. F. Daniels & J. H. Mathews, Experimental Physical Chemistry, McGraw-Hill, 1st ed., New York, 1941.			
References/ Readings:	1. A. M. James, Practical Physical Chemistry, Prentice Hall Press, 3rd ed., 1974. 2. D.P. Shoemaker & C. W. Garland, Experiments in Physical Chemistry, McGraw-Hill, 1st ed., New York, 1962. 3. T. Kandow& F. Mafune, Progress in experimental and theoretical studies of clusters, World Scientific publishers, 1st ed., New Jersey, 2002. 4. C. Arora & S. Bhattacharya, Advanced Physical Chemistry Practical Guide, Bentham Science Publishers, 1st ed., UAE, 2022. 5. A. K. Hagi, L. Pogliani, A. C. F. Ribeiro, Practical applications of Physical Chemistry in food science and technology, 1st ed., Apple Academic Press, USA, 2021.			

Title of the Course	Physical Chemistry Practical-II
Course Code	CHP-5202
Number of Credits	02
Theory/Practical	Practical
Level	400
Effective from AY	2025-26
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	NIL	
Course Objectives:	• To develop experimental skills on basic lab techniques in physical chemistry • To understand fundamental laboratory concepts and acquire skills for data acquisition, analysis and interpretation • To understand and follow safety protocols for handling chemicals, equipment and instruments. • To apply the practical laboratory concepts for synthesis, problem solving and critical thinking • To develop research skills through the principles of laboratory chemical research.	
Course Outcomes:	Students will be able to:	**Mapped to PSO**
	CO 1. Explain and perform various fundamental lab techniques and experiments.	PSO1
	CO 2. Handle and operate basic laboratory equipment and use it for research work.	PSO1, PSO4
	CO 3. Apply the laboratory knowledge and skills for their dissertation and research work.	PSO4, PSO5, PSO6, PSO7

	CO 4. Design synthesis and/or experimental methods.		PSO5, PSO6, PSO7	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**1. Non- instrumental Experiments (Any 09)** 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 persulphate ($K_2S_2O_8$), 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 viscosity measurement.	**36**	CO1, CO3, CO4	K1, K2, K3, K4, K5
Module 2:	**2. Instrumental Experiments** 1. To determine the relative strength of chloroacetic acid and acetic acid by conductometry. 2. To determine the degree of hydrolysis of salt of weak base and strong acid using conductometry. 3. To determine the composition of a mixture of acetic acid, dichloroacetic acid and hydrochloric acid by conductometric titration. 4. To determine the dissociation constants of monobasic acid and dibasic acid and obtain derivative plot to get equivalence point.	**24**	CO2, CO3, CO4	K2, K3, K4, K5

	5. To determine the redox potential of Fe^{2+}/Fe^{3+} system by titrating it with standard $K_2Cr_2O_7$ solution. 6. To study the electrodeposition of metal.			
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 can preferably be interactive in nature to enable peer group learning.			
Texts:	1. V. D. Athawale, P. Mathur, Experimental Physical Chemistry, New Age International Publishers, 1st ed., New Delhi, 2001. 2. J.N. Gurtu, A. Gurtu, Advanced Physical Chemistry Experiments, Pragati Publications, 1st ed., Meerut, 2008. 3. A. Findlay & J. A. Kitchener, Practical Physical Chemistry, Longmans, Green and Co., 1st ed., London 1954. 4. F. Daniels & J. H. Mathews, Experimental Physical Chemistry, McGraw-Hill, 1st ed., New York, 1941.			
References/ Readings:	1. A. M. James, Practical Physical Chemistry, Prentice Hall Press, USA 3rd ed., 1974. 2. D.P. Shoemaker & C. W. Garland, Experiments in Physical Chemistry, McGraw-Hill, 1st ed., New York, 1962. 3. T. Kandow& F. Mafune, Progress in experimental and theoretical studies of clusters, World Scientific publishers, 1st ed., New Jersey, 2002. 4. C. Arora & S. Bhattacharya, Advanced Physical Chemistry Practical Guide, Bentham Science Publishers, 1st ed., UAE, 2022. 5. A. K. Hagi, L. Pogliani, A. C. F. Ribeiro, Practical applications of Physical Chemistry in food science and technology, 1st ed., Apple Academic Press, USA, 2021.			

Title of the Course	Analytical Chemistry Practical - I
Course Code	CHA-5201
Number of Credits	2
Theory/Practical	Practical
Level	400
Effective from AY	2025-26
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	• To perform various experimental techniques for analysis. • To learn data analysis, handling and interpretation of spectra. • To determine concentration of solutions. • To use techniques for qualitative and quantitative estimation.	
Course Outcomes:	Students will be able to	**Mapped to PSO**
	CO 1. explain data analysis, handling and interpretation of spectra.	PSO1, PSO3, PSO4
	CO 2. apply different techniques for qualitative and quantitative estimation.	PSO1, PSO4
	CO 3. determine concentration of solutions.	PSO1, PSO4
	CO 4. perform various experimental techniques for analysis.	PSO1, PSO2,

			PSO3, PSO4	
Content:	This course consists of 8 units of experiments in various areas of Analytical chemistry. Minimum 15 experiments which include at least 01 experiment from each unit to be performed.	**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**1. Statistics** a. Calibration of selected Volumetric apparatus b. Calibration of selected Laboratory instruments c. Preparation of standard solutions and standardisation.	4	CO1, CO3	K3, K4
Module 2:	**2. Colorimetry/ UV-Visible Spectrophotometry** a. Estimation of Iron from Pharmaceutical sample (Tablet/capsule) by thiocyanate method b. Estimation of phosphoric acid in cola drinks by molybdenum blue method. c. Estimation of KNO_3 by UV spectroscopy and $K_2Cr_2O_7$ by Visible spectroscopy d. Simultaneous determination and Verification of law of additivity of absorbances ($K_2Cr_2O_7$ and $KMnO_4$).	8	CO2, CO3	K3, K4, K5
Module 3:	**3. Flame Spectrophotometry and AES/AAS/ICP Spectroscopy** a. Estimation of Na and K in food supplements or cosmetic products. b. Estimation of Pb in water sample by AES/AAS/ICP. c. Estimation of Fe and Al in Iron ore sample by AES/AAS/ICP.	8	CO1, CO2	K4, K5
Module 4:	**4. Ion Exchange Chromatography and High-Performance Liquid Chromatography (HPLC)** a. Separation and Estimation of chloride and bromide using Ion exchange chromatography. b. Separation of anthracene and naphthalene using reverse phase chromatography c. Separation of benzaldehyde and benzyl alcohol using normalphase chromatography.	8	CO2, CO4	K4, K5
Module 5:	**5. Volumetric Titrations** a. Estimation of Ca in pharmaceutical tablet. b. Estimation of Al and Mg in antacid tablet.	8	CO3, CO4	K4, K5

	c. Estimation of CaO in cement.			
Module 6:	**6. Solvent Extraction and spectrophotometry** a. Extraction of Cu as copper dithiocarbamate (DTC) using solvent extraction and estimation by spectrophotometry. b. Determination of Ni as dimethylglyoxime complex by spectrophotometry. c. Determination of silver as ion association complex with 1,10-phenanthroline and bromopyrogallol red.	8	CO3, CO4	K4, K5
Module 7:	**7. Demonstration and Interpretation Exercises** a. Thermal studies: TG/DTA and Isothermal weight loss studies of various hydrated solids like $CuSO_4 \cdot 5H_2O$, $CaC_2O_4 \cdot H_2O$, $FeC_2O_4 \cdot 2H_2O$. b. X-ray powder diffractometry: Calculation of lattice parameters from X-ray powder pattern of cubic system such as $NiMn_2O_4$, $CoFe_2O_4$. c. IR spectra of urea, benzoic acid, copper sulphate pentahydrate etc.	8	CO1, CO2	K3, K4
Module 8:	**8. Demonstration** a. Turbidimeter. b. KF instrument. c. Polarimeter. d. LCMS. e. NMR.	8	CO1, CO2	K3, K4
Pedagogy:	Prelab exercises / assignments / presentations / lab hand-out or a combinationof some of these. Sessions shall be interactive in nature to enable peer grouplearning.			
Texts:	1. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, B. Sivasankar, Vogel's Text Book of Quantitative Chemical Analysis, 6th Ed., Pearson, New Delhi, 2009. 2. R. A. Day & A.L. Underwood, Quantitative Analysis, 6th Ed., Pearson Education India, 2015. 3. J. Kenkel, Analytical Chemistry for Technicians, 3rd Ed., Lewis publishers, USA, 2002. 4. R. M. Silverstein, F. X. Webster, D. Kiemle, D. Bryce, S. Samant, V. S. Nadkarni, Spectrometric Identification of Organic compounds, An Indian Adaptation, Wiley, India, 8th Ed., 2022 5. A. J. Elias, Collection of interesting chemistry experiments, University press, Hyderabad, 2002.			
References/	1. G. D. Christian, Analytical chemistry, 5th Ed., John Willey and Sons, USA, 1994			

Readings:	2. J. H. Kennedy, Analytical Chemistry: Principles, 2nd Ed., Saunders College Publishing, Philadelphia, 1990. 3. A. Kar, Pharmaceutical Drug Analysis, New Age International, India, 2005. 4. M. Asadi, Beet-Sugar Handbook, John Wiley & Sons, USA, 2006. 5. R. E. Ardrey, Liquid Chromatography - Mass Spectrometry: An Introduction, John Wiley & Sons, England, 2003.

Title of the Course	Analytical Chemistry Practical - II
Course Code	CHA-5202
Number of Credits	2
Theory/Practical	Practical
Level	400
Effective from AY	2025-26
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	• To perform various experimental techniques for analysis. • To learn data analysis, handling and interpretation of spectra. • To determine concentrations of solution. • To use techniques for qualitative and quantitative estimation.	
Course Outcomes:	Students will be able to	**Mapped to PSO**
	CO 1. explain data analysis, handling and interpretation of spectra.	PSO1, PSO3, PSO4
	CO 2. apply different techniques for qualitative and quantitative estimation.	PSO1, PSO4
	CO 3. determine concentration of solutions.	PSO1, PSO4
	CO 4. perform various experimental techniques for analysis.	PSO1, PSO2,

			PSO3, PSO4	
Content:	This course consists of 8 units of experiments in various areas of Analytical chemistry. Minimum 15 experiments which include at least 01 experiment from each unit to be performed.	**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**1. Statistics** a. Calibration of selected Volumetric apparatus b. Calibration of selected Laboratory instruments c. Preparation of standard solutions and standardisation.	4	CO1, CO3	K3, K4
Module 2:	**2. Titrimetric Analysis** a. Standardisation and estimation of Chloride using precipitation titration (Mohr's method) b. Analysis of commercial caustic soda by neutralisation method. c. Determination of sulphates by complexometric titration.	8	CO2, CO3	K3, K4, K5
Module 3:	**3. Flame Spectrophotometry and AES/AAS/ICP Spectroscopy** a. Estimation of sodium and potassium in food supplements or cosmetic products using flame photometer. b. Estimation of chromium in water sample by AES/AAS/ICP. c. Estimation of nickel, molybdenum in Hastelloy C-22 using AES/AAS/ICP.	8	CO1, CO2, CO3	K4, K5
Module 4:	**4. Natural product isolation and Ion Exchange Chromatography** a. Isolation of cinnamaldehyde from cinnamon. b. Isolation of caffeine from tea powder. c. Separation and estimation of cadmium and zinc.	8	CO2, CO4	K4, K5
Module 5:	**5. UV-Visible Spectrophotometry and High-Performance Liquid Chromatography (HPLC)** a. Estimation of KNO_3 and $K_2Cr_2O_7$ using UV- Visible spectroscopy. b. Separation of benzaldehyde and benzoic acid using reverse phase HPLC. c. Quantification of naphthalene in a sample using reverse phase HPLC.	8	CO3, CO4	K4, K5
Module 6:	**6. Solvent Extraction and spectrophotometry**	8	CO3,	K4, K5

	a. Spectrophotometric determination of aspirin/phenacetin/caffeine in APC tablet using solvent extraction. b. Colorimetric determination of iron with salicylic acid. c. Determination of copper in brass sample by colorimetry.		CO4	
Module 7:	**7. Data Interpretation Exercises** a. NMR/Mass spectra. b. HPLC and GC chromatograph. c. XRD powder pattern of cubic systems. d. Thermogram of coordination compounds.	8	CO1, CO2	K3, K4
Module 8:	**8. Demonstration** a. Turbidimeter. b. KF instrument. c. Polarimeter. d. LCMS. e. NMR.	8	CO1, CO2	K3, K4
Pedagogy:	Prelab exercises / assignments / presentations / lab hand-out or a combinationof some of these. Sessions shall be interactive in nature to enable peer grouplearning.			
Texts:	1. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, B. Sivasankar, Vogel's Text Book of Quantitative Chemical Analysis, 6th Ed., Pearson, New Delhi, 2009. 2. R. A. Day & A.L. Underwood, Quantitative Analysis, 6th Ed., Pearson Education India, New-Delhi, 2015. 3. J. Kenkel, Analytical Chemistry for Technicians, 3rd Ed., Lewis publishers, USA, 2002. 4. R. M. Silverstein, F. X. Webster, D. Kiemle, D. Bryce, S. Samant, V. S. Nadkarni, Spectrometric Identification of Organic compounds, An Indian Adaptation, Wiley, India, 8th Ed., 2022 5. A. J. Elias, Collection of interesting chemistry experiments, University press, Hyderabad, 2002. 6. A. Kar, Pharmaceutical Drug Analysis, New Age International, India, 2005.			
References/ Readings:	1. G. D. Christian, Analytical chemistry, 5th Ed., John Willey and Sons, USA, 1994. 2. J. H. Kennedy, Analytical Chemistry: Principles, 2nd Ed., Saunders College Publishing, Philadelphia, 1990. 3. M. Asadi, Beet-Sugar Handbook, John Wiley & Sons, USA, 2006. 4. R. E. Ardrey, Liquid Chromatography - Mass Spectrometry: An Introduction, John Wiley & Sons, England, 2003.			