



GU/Acad –PG/BoS -NEP/2025-26/29

Date: 13.04.2026

CIRCULAR

Ref. No.: GU/Acad –PG/BoS -NEP/2025-26/602 dated 01.12.2025

In supersession to the above referred Circular, the syllabus of Semester III & IV of the **Master of Science in Physical Chemistry** Programme approved by the Standing Committee of the Academic Council in its meeting held on 24th & 25th November 2025 is attached.

The syllabus of Semester II approved earlier by the Academic Council on 13th September 2025 and the syllabus of Semester I approved by the Academic Council 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** are requested to take note of the above and bring the contents of the Circular to the notice of all concerned.

(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.

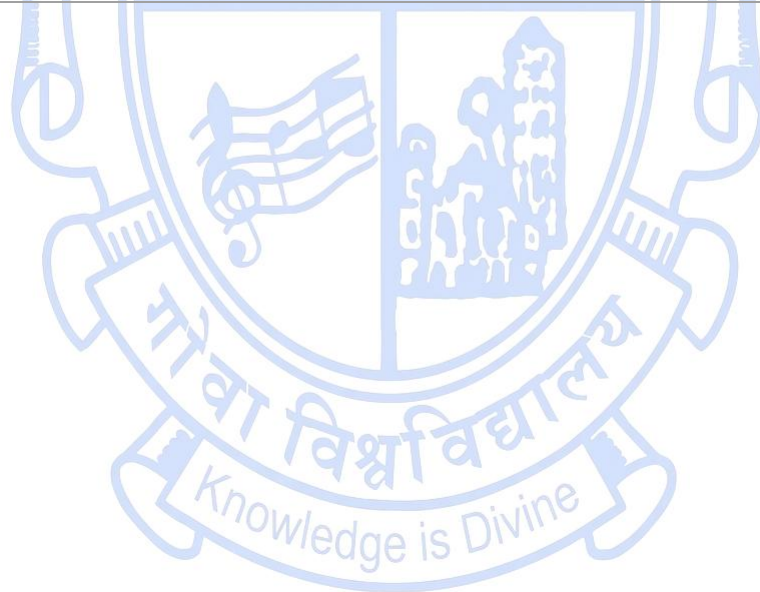
INORGANIC CHEMISTRY (CHI)**PROGRAMME SPECIFIC OUTCOMES (PSO)**

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	<u>CHC-1000</u>	Bridge Course in mathematical concepts for chemistry	1
2	<u>CHC-1001</u>	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	<u>CHO-5000</u>	Fundamental Concepts in Organic Chemistry	4	400
2	<u>CHI-5000</u>	Concise Inorganic Chemistry	4	400
3	<u>CHP-5000</u>	Fundamentals of Physical Chemistry	4	400
4	<u>CHA-5000</u>	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	<u>CHO-5201</u>	Organic Chemistry Practical - I	2	400
2	<u>CHO-5202</u>	Organic Chemistry Practical - II	2	400
3	<u>CHI-5201</u>	Inorganic Chemistry Practical - I	2	400
4	<u>CHI-5202</u>	Inorganic Chemistry Practical - II	2	400
5	<u>CHP-5201</u>	Physical Chemistry Practical - I	2	400
6	<u>CHP-5202</u>	Physical Chemistry Practical - II	2	400
7	<u>CHA-5201</u>	Analytical Chemistry Practical - I	2	400
8	<u>CHA-5202</u>	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	<u>CHP-5001</u>	Concepts in Quantum Chemistry and Statistical Thermodynamics	4	500
2	<u>CHP-5002</u>	Group Theory and Spectroscopy	4	500
3	<u>CHP-5003</u>	Thermodynamics and Reaction Kinetics	4	500
4	<u>CHP-5004</u>	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	<u>CHO-5201</u>	Organic Chemistry Practical - I	2	400
2	<u>CHO-5202</u>	Organic Chemistry Practical - II	2	400
3	<u>CHI-5201</u>	Inorganic Chemistry Practical - I	2	400
4	<u>CHI-5202</u>	Inorganic Chemistry Practical - II	2	400
5	<u>CHP-5201</u>	Physical Chemistry Practical - I	2	400
6	<u>CHP-5202</u>	Physical Chemistry Practical - II	2	400
7	<u>CHA-5201</u>	Analytical Chemistry Practical - I	2	400
8	<u>CHA-5202</u>	Analytical Chemistry Practical - II	2	400
Total Credits for DSE Courses in Semester II			4	
Total Credits in Semester II			20	

SEMESTER III				
Research Specific Elective (RSE) Courses				
Sr. No.	Course Code	Title of the Course	Credits	Level
1	<u>CHP-6000</u>	Physical Chemistry Practical - III	4	500
2	<u>CHP-6001</u>	Physical Chemistry Practical - IV	4	500
3	<u>CHP-6002</u>	Heterogeneous Catalysis: Fundamentals and Applications.	4	500
4	<u>CHP-6003</u>	Solid State Chemistry: Concepts and Applications	4	500
5	<u>CHP-6004</u>	Research Methodology in Physical Chemistry	4	500
Total Credits for RSE Courses in Semester III			12	
Discipline Specific Vocational Elective (DSVE) Courses (4 credits)				
Sr. No.	Course Code	Title of the Course	Credits	Level
1	<u>CHP-6401</u>	Computational Quantum Chemistry	2T+2P	500
2	<u>CHP-6402</u>	Applied electrochemistry for Energy conversion and storage	2T+2P	500
3	<u>CHP-6403</u>	Polymer chemistry for functional materials	2T+2P	500
Total Credits for DSVE Courses in Semester III			8	
Total Credits in Semester III			20	

Discipline Specific Dissertation (DSD) (40 Credit Dissertation)				
Discipline Specific Dissertation (DSD)				
Sr. No.	Course Code	Title of the Course	Credits	Level
1	<u>CHP-6501</u>	Discipline Specific Dissertation (DSD)	40	500

SEMESTER IV				
Generic Elective (GE) Courses (20 Credits)				
Sr. No.	Course Code	Title of the Course	Credits	Level
1	<u>CHP-6201</u>	Colloids and Surface Chemistry	4	500
2	<u>CHP-6202</u>	Nanoscience: Concepts and Applications	4	500
3	<u>CHP-6203</u>	Nuclear and Radiation Chemistry	4	500
4	<u>CHP-6204</u>	Transport processes in Physical Chemistry	4	500
5	<u>CHP-6205</u>	Practicals in computational chemistry	4	500
6	<u>CHP-6206</u>	Instrumental and non-Instrumental techniques in Physical Chemistry	4	500
7	<u>CHP-6207</u>	Practicals in transport processes	4	500
Total Credits for GE courses in Semester IV			20	

Discipline Specific Dissertation (DSD)/ Internship (20 Credit Dissertation)				
Discipline Specific Dissertation (DSD)				
Sr. No.	Course Code	Title of the Course	Credits	Level
1	<u>CHP-6502</u>	Discipline Specific Dissertation (DSD)	20	500

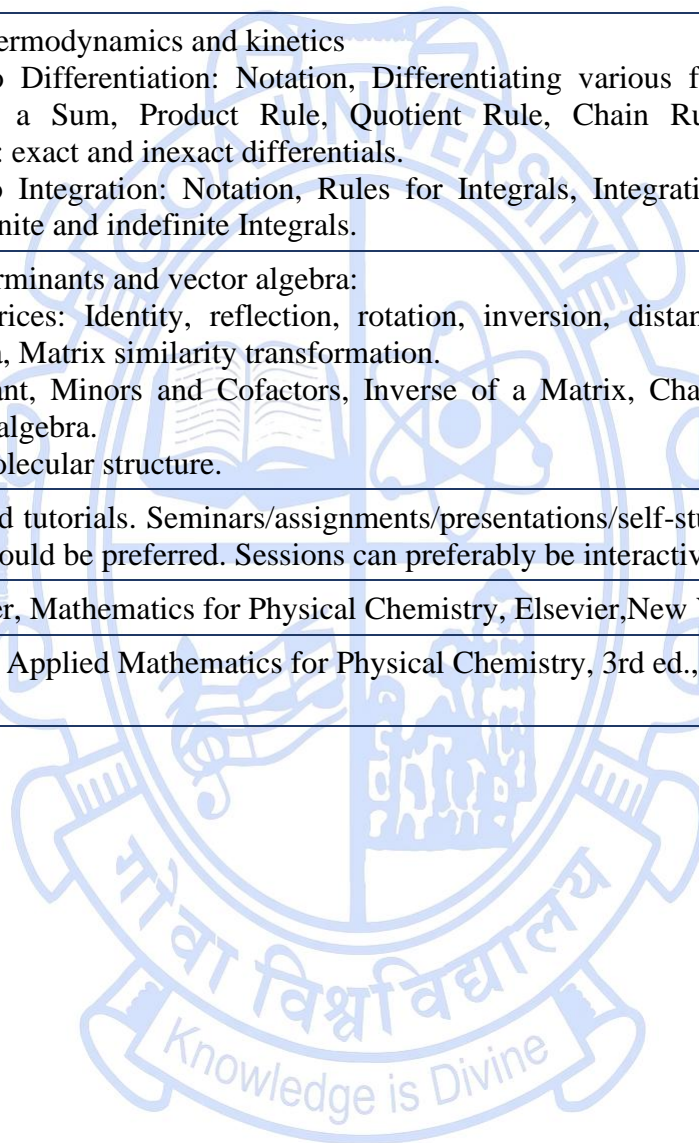
Blooms Taxonomy Cognitive Levels	
Cognitive Level	Notations
K1	Remembering
K2	Understanding
K3	Applying
K4	Analyzing
K5	Evaluating
K6	Create

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			

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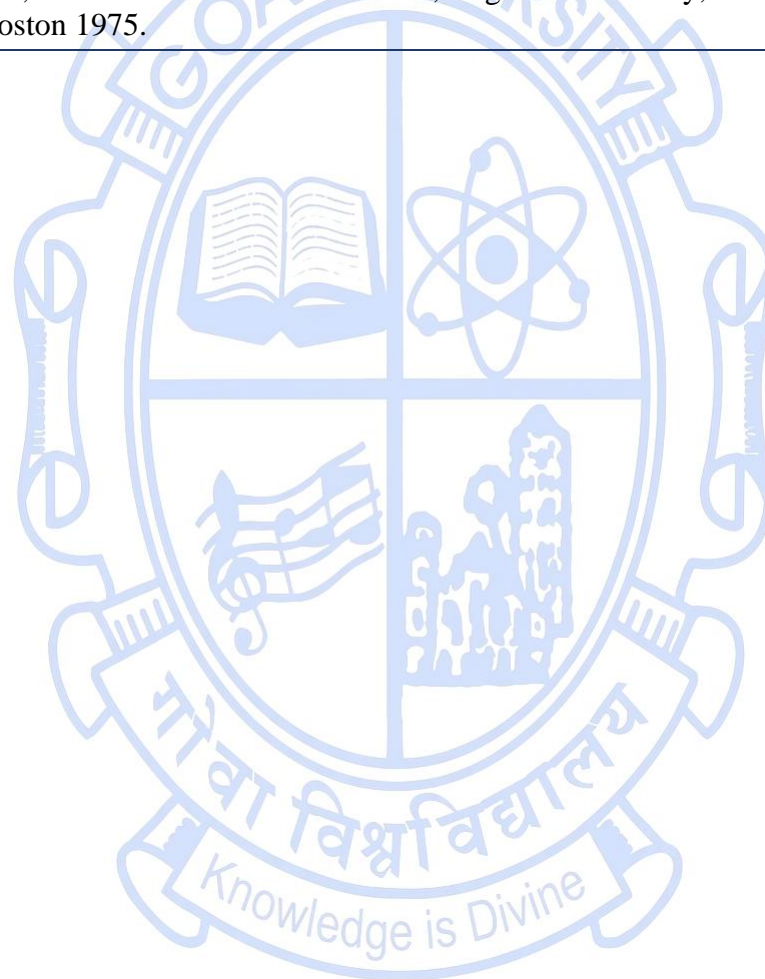


Title of the Course	Bridge Course in Organic Chemistry		
Course Code	CHC-1001		
Number of Credits	1		
Theory/Practical	Theory		
Level	400		
Effective from AY	2025-26		
New Course	No		
Bridge Course/ Value added Course	Yes		
Course for advanced learners	No		
Pre-requisites for the Course:	NIL		
Course Objectives:	<ul style="list-style-type: none"> • 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:	<ol style="list-style-type: none"> 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:	<ol style="list-style-type: none">1. V. M. Potapov, Stereochemistry, MIR Publishers, Moscow, 19792. 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.

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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:	<ul style="list-style-type: none">• 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

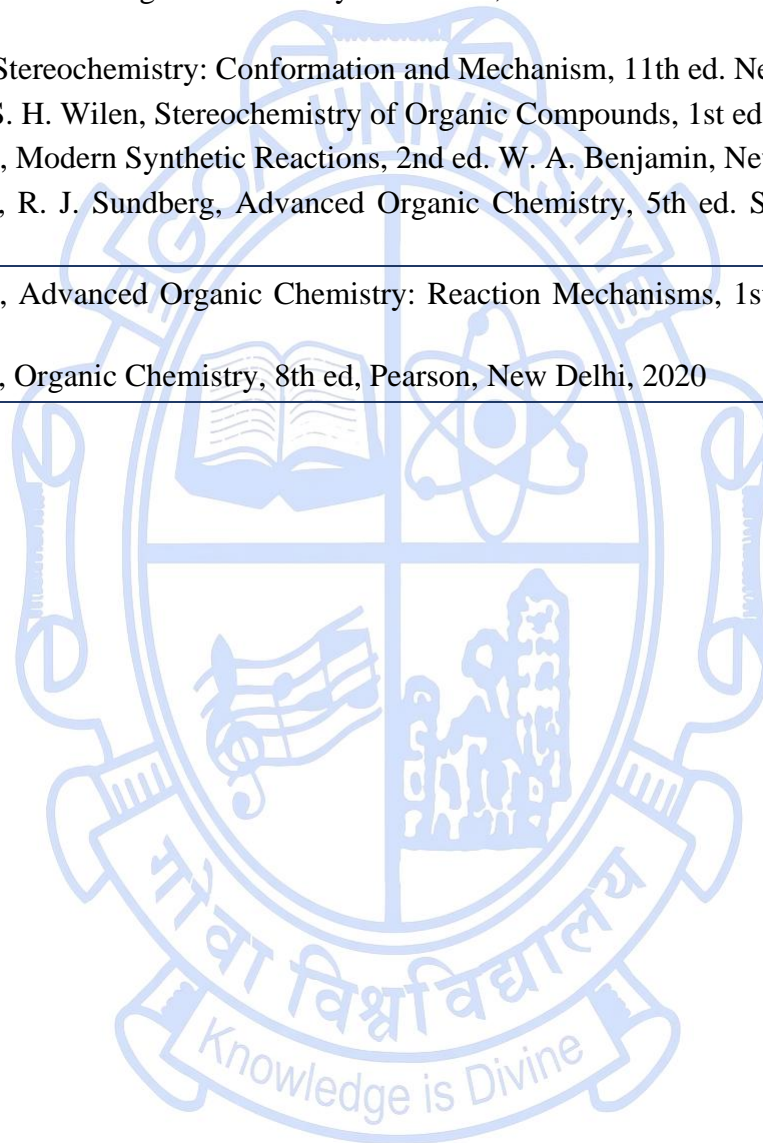
	CO 1. Understand the effect of delocalization of electrons & presence or absence of aromaticity in organic compounds.		PSO1, PSO 2	
	CO 2. Apply various concepts in stereochemistry to understand stereochemical outcome in a reaction.		PSO1, PSO 2	
	CO 3. Evaluate plausible mechanisms of organic reactions.		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:	<p>1.1 Molecular orbitals and delocalized chemical bonding</p> <p>a. Qualitative description of molecular orbitals of simple acyclic and monocyclic systems, frontier molecular orbitals.</p> <p>b. Conjugation, cross conjugation, hyperconjugation and tautomerism (types and examples).</p> <p>c. Aromaticity: Origin of Huckel's rule, examples of aromatic, non-aromatic and antiaromatic compounds; concept of Mobius aromaticity.</p> <p>1.2 Structure & Reactivity</p> <p>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.</p> <p>b. Concept of superacids and superbases.</p> <p>c. Electrophilicity & nucleophilicity, examples of ambident nucleophiles & electrophiles. (Including revision of aromatic electrophilic and nucleophilic substitution)</p>	15	CO1	K1, K2, K3, K4, K5
Module 2:	<p>2. Stereochemistry</p> <p>a. Brief revision of configurational nomenclature: R & S; D & L; E & Z; cis & trans and <i>syn</i> & <i>anti</i> nomenclature. Chirality in molecules with two and more chiral centers.</p> <p>b. Conformational analysis of open chain compounds (Butane, 2, 3-butane</p>	15	CO2, CO3	K1, K2, K3, K4, K5

	<p>diol, 2,3-dibromobutane etc.). <i>Erythro</i> and <i>threo</i> nomenclature.</p> <p>c. Topicity and Prostereoisomerism: Topicity of ligands and faces-homotopic, enantiotopic and diastereotopic, ligands and faces.</p> <p>d. Chemoselective, regioselective and stereoselective reactions with examples.</p> <p>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.</p> <p>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.</p>			
Module 3:	<p>3.1 Reaction Mechanism</p> <p>a. Structure, stability and reactivity of reactive intermediates (carbocations, carbanions, free radicals, carbenes, arynes and nitrenes)</p> <p>b. Types of mechanisms, types of reactions, thermodynamic and kinetic control.</p> <p>c. Methods of determining reaction mechanisms:</p> <p>i. Identification of products.</p> <p>ii. Determination of the presence of intermediates (isolation, detection, trapping and addition of suspected intermediate.</p> <p>iii. Isotopic labelling.</p> <p>iv. Stereochemical evidence.</p> <p>v. Kinetic evidence and Isotope effect. (at least two examples to be covered for above methods)</p> <p>3.2 Selective reagents for Organic transformation</p> <p>a. Oxidation of organic compounds: PCC, PDC and MnO₂, ozonolysis,</p>	15	CO ₂ , CO ₃	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:	<p>4.1 Aliphatic Nucleophilic substitution</p> <p>a. Nucleophilic substitutions with respect to mechanism and various factors affecting such reactions.</p> <p>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)</p> <p>4.2 Elimination reactions</p> <p>a. The E₂, E₁ and E₁cB mechanisms. Orientation of the double bond, Saytzeff and Hofmann rule.</p> <p>b. Effects of substrate, base, leaving group and medium on:</p> <p>i. Overall reactivity</p> <p>ii. E₁ vs. E₂ vs. E₁cB</p> <p>iii. Elimination vs substitution, mechanism and orientation in pyrolytic <i>syn</i>elimination (various examples involving cyclic and acyclic substrates to be studied).</p>	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:	<ol style="list-style-type: none"> 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 			

	<ol style="list-style-type: none">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, 20226. E. L. Eliel, S. H. Wilen, Stereochemistry of Organic Compounds, 1st ed. John Wiley and Sons, New York, 19947. H. O. House, Modern Synthetic Reactions, 2nd ed. W. A. Benjamin, New York, 19658. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry, 5th ed. Springer India Private Limited, New Delhi, 2007
References/ Readings:	<ol style="list-style-type: none">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

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Title of the Course	Concise Inorganic Chemistry
Course Code	CHI-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:	<ul style="list-style-type: none"> • To explain fundamentals of solid state, coordination, organometallic, bioinorganic, and environmental chemistry. • To describe atomic structure, molecular structure, bonding, and symmetry in molecules. • To know fundamental aspects of elements & their compounds. • To comprehend the effects of pollution, and its treatments. 	
Course Outcomes:	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

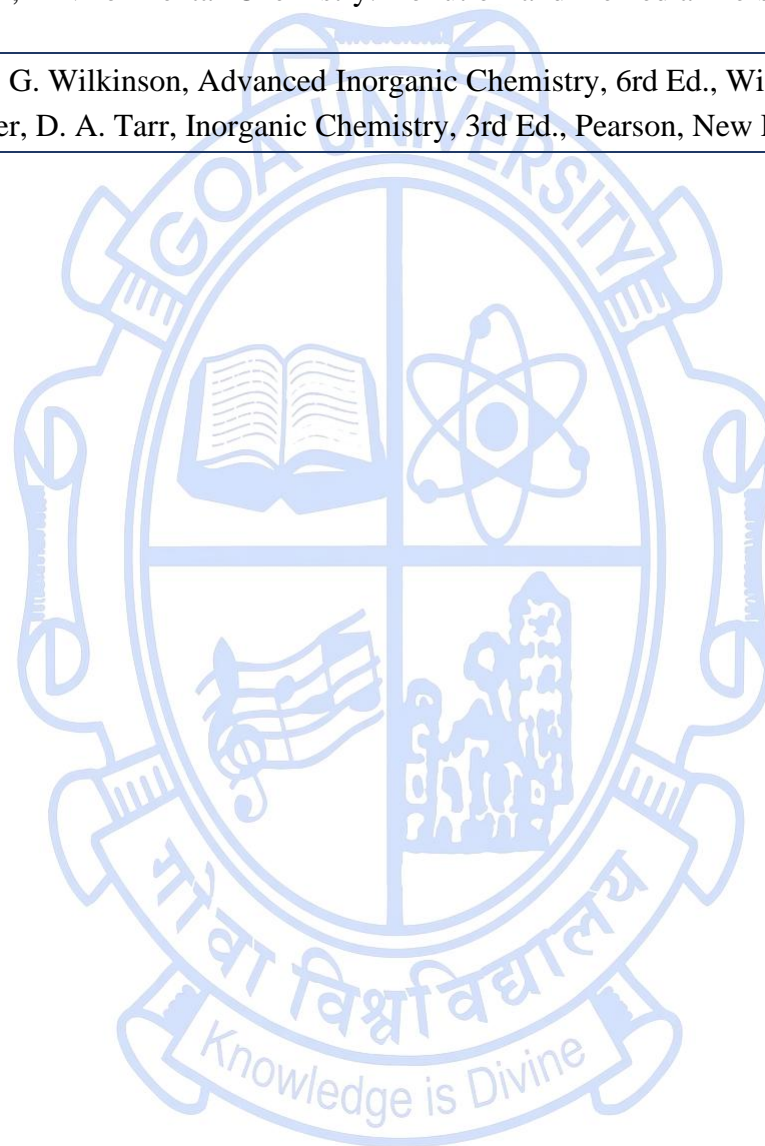
	CO 4. design compounds for various applications.		PSO4	
Content:		Noofhours	Mapped to CO	Cognitive Level
Module 1:	<p>1. Atomic structure, molecular structure and bonding</p> <p>a. Atomic Structure: Structures of hydrogenic atoms: some principles of quantum mechanics, atomic orbitals. Many electron atoms: penetration & shielding, building up principle, classification of elements. Spectroscopic terms. Atomic properties: atomic radii, ionic radii, ionization energy, electron affinity, electronegativity, polarizability.</p> <p>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, bonding & antibonding orbitals. Homonuclear diatomic molecules & heteronuclear diatomic molecules.</p>	10	CO1, CO2, CO3, CO4	K2, K3, K4, K5
Module 2:	<p>2. Solid state chemistry</p> <p>a. Structures of solids: crystal structures, lattices and unit cells, fractional atomic coordinates and projections, close packing of spheres, holes in closed-packed structures.</p> <p>b. Structures of metals & alloys: polytypism, nonclosed-packed structures, polymorphism of metals, atomic radii of metals, alloys, substitutional and interstitial solid solutions, intermetallic compounds.</p> <p>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).</p>	10	CO1, CO2, CO3, CO4	K2, K3, K4, K5
Module 3:	<p>3. Molecular Symmetry and chemistry of d- and f- block elements</p> <p>a. Symmetry elements and symmetry operations, equivalent symmetry elements and equivalent atoms, symmetry point groups and molecular symmetry. Systematic</p>	15	CO1, CO2, CO3,	K2, K3, K4, K5

	<p>procedure for symmetry classification of molecules. Dipole moment, optical activity and point groups.</p> <p>b. <i>d</i>-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.</p> <p>c. <i>f</i>-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.</p>		CO4	
Module 4:	<p>4. Coordination, Organometallic and Bioinorganic Chemistry</p> <p>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.</p> <p>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.</p> <p>c. Bioinorganic Chemistry: Macronutrients/micronutrients. Role of elements in biology. Metallobiomolecules, metalloporphyrins, structure of porphyrin and heme group, iron porphyrins (Haemoglobin and myoglobin), examples of metalloenzymes of Cu and Zn.</p>	15	CO1, CO2, CO3, CO4	K2, K3, K4, K5
Module 5:	<p>5. Environmental Chemistry</p> <p>Directive of the Supreme Court in 1993 to introduce environmental education at all</p>	10	CO1, CO2,	K2, K3, K4, K5

	<p>levels.</p> <p>a. Air Pollution: Classification of air pollutants and photochemical reactions in the atmosphere. Common air pollutants(e.g.CO,NO_x,SO₂,hydrocarbonsandparticulates)</p> <p>i. sources</p> <p>ii. physiological and environmental effect</p> <p>iii. monitoring,</p> <p>iv. various remedial & technological measures to curb pollution. Air quality standards.</p> <p>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.</p>		CO ₃ , CO ₄	
Pedagogy:	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature toenable peer group learning.			
Texts:	<ol style="list-style-type: none"> 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. Kietter, R. L. Kietter, 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.

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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:	<ul style="list-style-type: none"> • 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

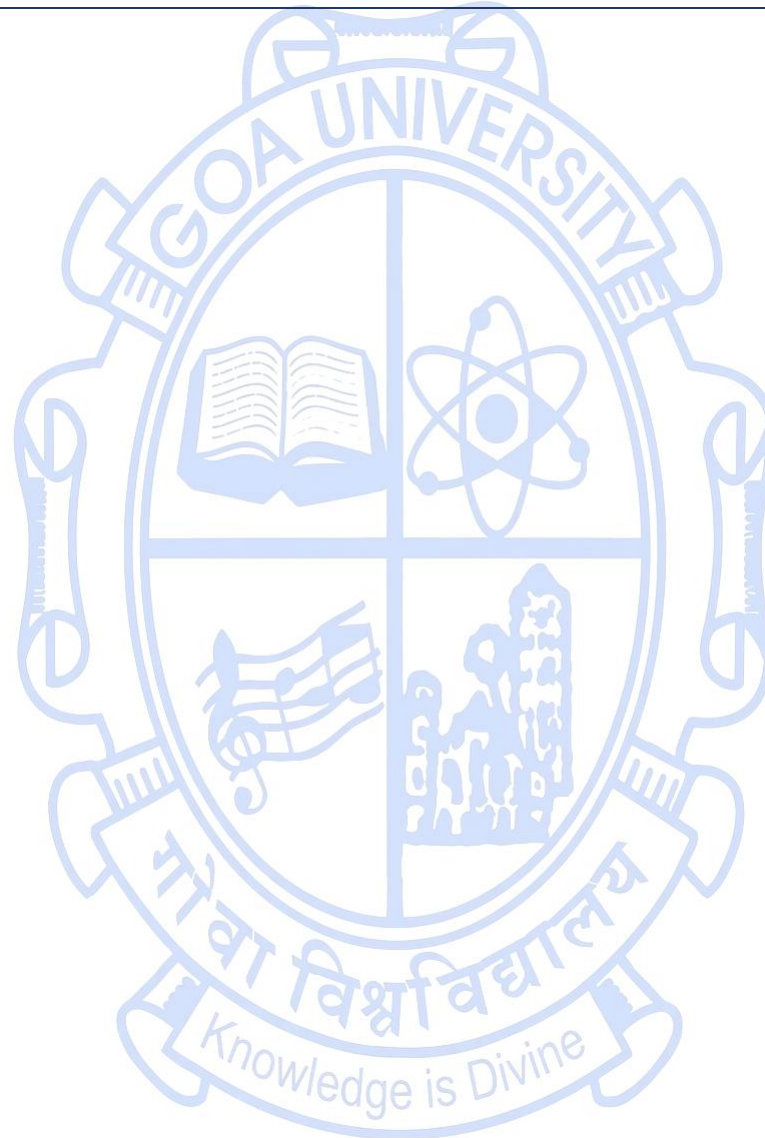
	CO 3. Demonstrate the concepts during the lab course in physical chemistry.		PSO3, PSO4, PSO5
	CO 4. Apply fundamentals of chemical kinetics and thermodynamics for understanding reaction processes and mechanisms		PSO3, PSO7
Content:		No of hours	Mapped to CO
Module 1:	<p>1. Mathematical Preparations</p> <p>a. Introduction to various functions and function plotting (exponential, logarithmic, trigonometric etc.), functions of many variables. complex numbers and complex functions.</p> <p>b. Linear equations, vectors, matrices and determinants.</p> <p>c. Basic rules of differentiation and integration, Partial differentiation, location and characterization of critical points of a function, Regression methods, curve fitting.</p> <p>d. Introduction to series, convergence and divergence, power series, Fourier series</p> <p>e. Probability (permutations and combinations).</p>	10	CO1, CO3 K1, K2, K3
Module 2:	<p>2. Quantum Chemistry</p> <p>a. Operators, Functions, Eigen value equations, Postulates.</p> <p>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).</p> <p>c. Hydrogen like atoms, Schrödinger equation and its solutions, atomic orbital wave functions and interpretation.</p> <p>d. Hückel MO theory, Secular equations, Secular determinant, delocalization energy, charge density, π-bond order, free valence, applications to C₂H₄, C₃H₅ (radical), C₄H₆, C₄H₄, C₆H₆, C₆H₈.</p>	20	CO1, CO3 K1, K2, K5
Module 3:	<p>3. Thermodynamics</p> <p>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</p>	12	CO1, CO3, CO4 K1, K2, K3, K5

	<p>and their relations and significances. Maxwell relations. Thermodynamic equations of state.</p> <p>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.</p> <p>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.</p> <p>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.</p> <p>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.</p>			
Module 4:	<p>4. Electrochemistry</p> <p>a. EMF series, cell potential: Nernst equation, Cells at equilibrium. Determination of thermodynamic functions.</p> <p>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.</p> <p>c. Electroplating and electroless plating, electrosynthesis.</p> <p>d. Concepts of acid-base aqueous and non-aqueous solvents, hard and soft acid-base concept and applications.</p>	9	CO1, CO2, CO3	K1, K2, K3, K5, K6
Module 5:	<p>5. Chemical Kinetics</p> <p>a. General introduction to various types of order of reaction including fractional order, molecularity of the reaction.</p> <p>b. Introduction to reversible and irreversible reactions and reactions leading to equilibrium. van'tHoffs equation and analysis of Gibbs free energy of</p>	9	CO1, CO3, CO4	K1, K2, K3, K4, K5

	<p>equilibrium reactions.</p> <p>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.</p> <p>d. Comparative study of transition state and collision state theory.</p> <p>e. Reaction Mechanisms: elementary reactions, consecutive elementary reactions, steady state approximation, the rate determining step and pre-equilibria.</p> <p>f. Free radical reactions, complex reactions such as acetaldehyde decomposition and reaction between H₂ and Br₂. Homogeneous reactions and acid-base catalysis.</p> <p>g. Elementary enzyme reactions. Lineweaver-Burk plot and its analysis.</p>			
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:	<ol style="list-style-type: none"> 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:	<ol style="list-style-type: none"> 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 Electroics, 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

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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:	<ul style="list-style-type: none"> • 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

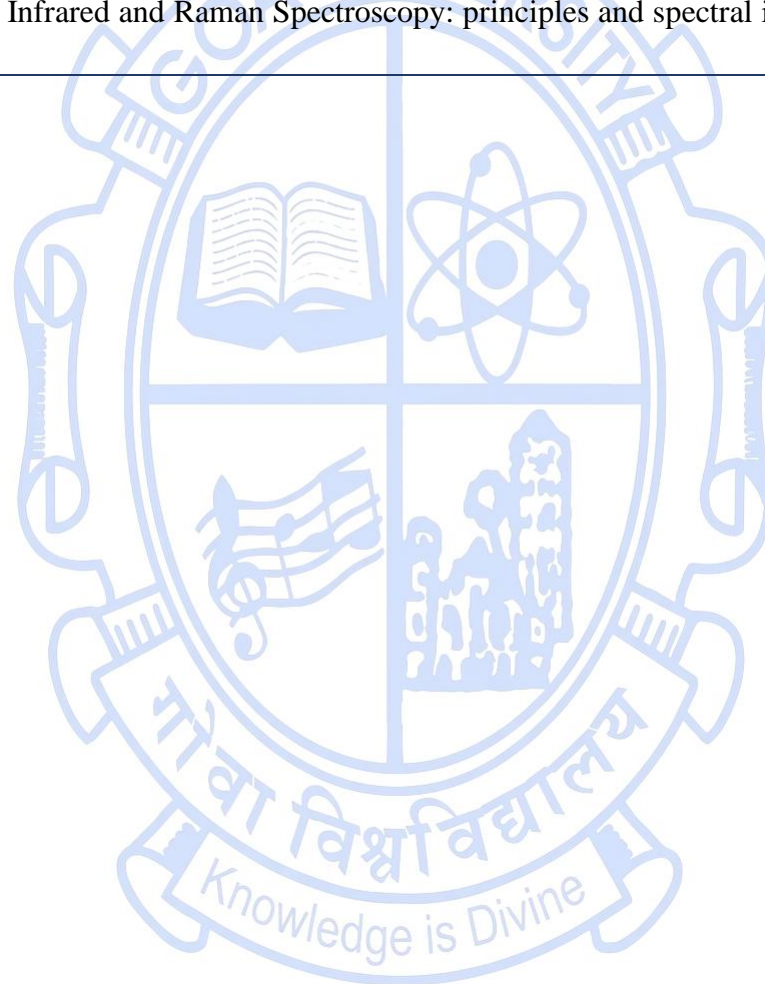
	<p>2.3. Gas and Liquid Chromatography Introduction; Instrumental Modules; Separation System; Choice of Conditions of Analysis; Sample Inlet Systems; Detectors; Practical Considerations in Qualitative and Quantitative Analysis; Coupled Systems-introduction to GCMS, GCIR, LCMS: Applicability, interpretation and numericals.</p>	7	CO3	K1, K2, K3, K4, K5
Module 3:	<p>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.</p>	10	CO4	K1, K2, K3, K4, K5, K6
	<p>3.2. Applications of UV-Vis spectroscopy for qualitative analysis Calculating λ_{max} 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.</p>	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:	<ol style="list-style-type: none"> 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. Holler, 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:	<ol style="list-style-type: none"> 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, 2nd Ed., Elsevier, Netherland, 2018.

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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:	<ul style="list-style-type: none">• To introduce various concepts of quantum chemistry.• To learn quantum mechanical models and approximation methods for problem solving.• To familiarize 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:	<p>Quantum Chemistry</p> <p>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.</p> <p>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.</p> <p>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.</p> <p>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 H₂O, NH₃ and CH₄. Application of Hückel Theory to ethylene, butadiene and benzene molecules.</p>	30	CO1, CO3	K1, K2, K3, K4, K5
Module 2:	<p>Statistical Thermodynamics</p> <p>The language of statistical thermodynamics: Probability, ensemble, microstate,</p>	30	CO2, CO4	K1, K2, K3, K4,

	<p>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.</p> <p>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.</p> <p>Law of Equipartition energy. Theories of specific heat of solids. Comparison between Einstein and Debye theories.</p> <p>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.</p>			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:	<ol style="list-style-type: none"> 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:	<ol style="list-style-type: none"> 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. 			

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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

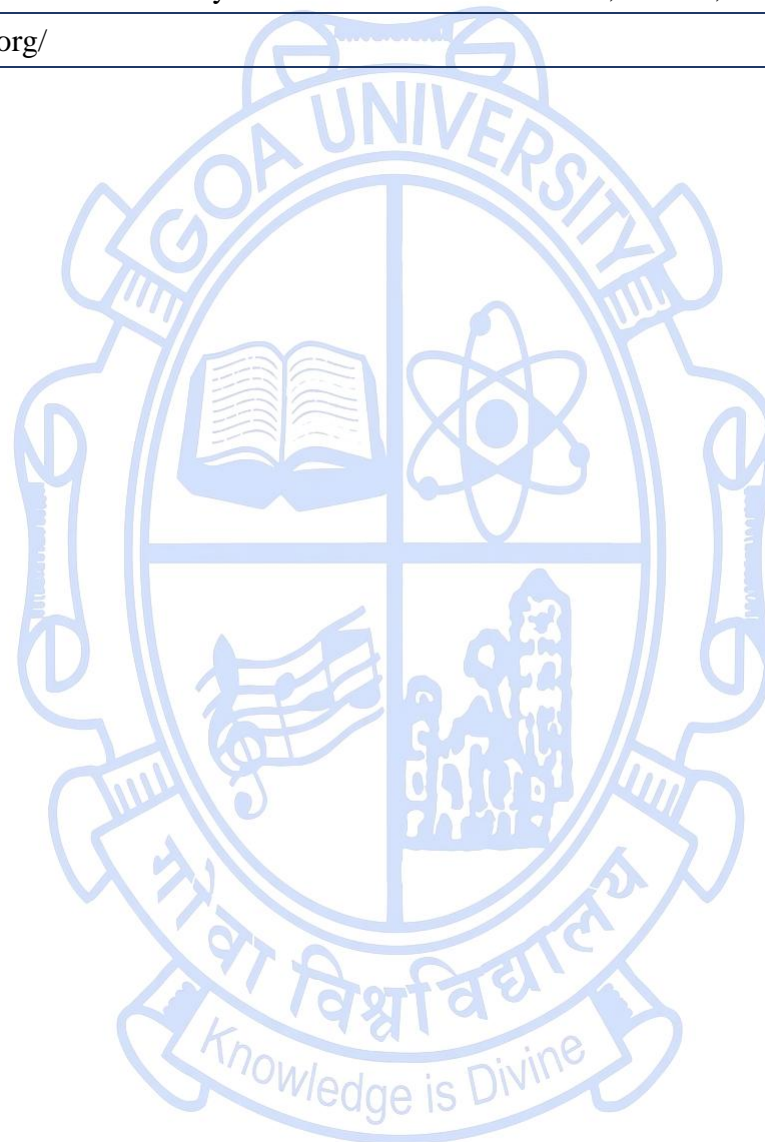
Pre-requisites for the Course:	Nil	
Course Objectives:	<ul style="list-style-type: none"> To introduce concepts in Group Theory and its applications to chemistry. To learn advanced topics in spectroscopy. To impart a comprehensive understanding of molecular symmetry. To acquaint with vibrational and 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:	<p>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).</p> <p>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</p>	15	CO1, CO2, CO4	K1, K2, K3, K4, K5
Module 2:	<p>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.</p> <p>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</p>	15	CO1, CO2, CO4	K1, K2, K3, K4, K5
Module 3:	<p>Microwave, IR and Raman Spectroscopy Theoretical treatment of Rotational and Vibrational spectroscopy. Principle of Fourier Transform (FT) spectroscopy, FTIR spectroscopy: Theory,</p>	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 McConnell 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:	<ol style="list-style-type: none"> 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:	<ol style="list-style-type: none"> 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, 2 nd Ed.; Macmillan, London, 1986.
Web Resources:	https://symotter.org/

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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

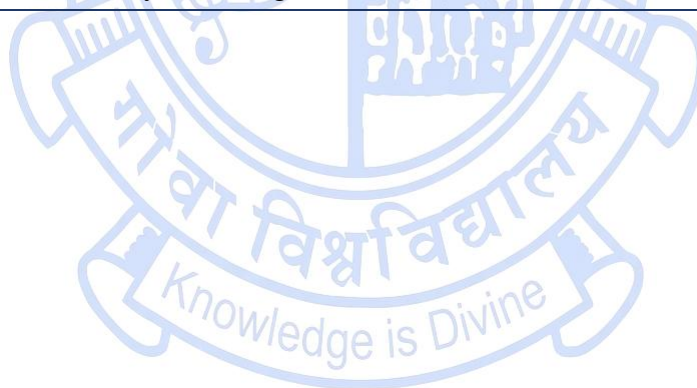
Pre-requisites for the Course:	Nil	
Course Objectives:	<ul style="list-style-type: none"> To introduce concepts of reaction kinetics and thermodynamics To acquire fundamental knowledge of theories that govern chemical reactions To learn newer classes of reaction types and their kinetics To introduce 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

	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:	<p>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.</p>	10	CO1, CO2, CO4	K1, K2, K3, K4, K5
Module 2:	<p>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 H₂O and HF potential energy surface diagrams.</p>	20	CO1, CO2, CO4	K1, K2, K3, K4, K5
Module 3:	<p>Equilibrium Thermodynamics Important terminologies in Thermodynamics; Thermodynamics state functions; work</p>	18	CO1, CO2,	K1, K2, K3, K4,

	<p>& heat; work expansion; Mathematical interlude Exact and inexact differentials. Cyclic rule; partial derivatives.</p> <p>Heat change at constant pressure, volume; relationship between Q_p & Q_v; Heat capacities C_p, C_v; 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.</p> <p>Work function and free energy function; Variation of free energy with temperature and pressure; Maxwell relations; Thermodynamic equations of state; Gibbs-Helmholtz equation.</p> <p>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.</p>		CO3, CO4	K5
Module 4:	<p>Non-Equilibrium thermodynamics</p> <p>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.</p> <p>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.</p>	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:	<ol style="list-style-type: none"> 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, 1 st Ed.; Dover Publications, Mineola, New York, 2006.
References/ Readings:	<ol style="list-style-type: none"> 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. Yerebin, 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.

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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:	<ul style="list-style-type: none"> • 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 and techniques 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 applications.	PSO3, PSO4, PSO5, PSO6

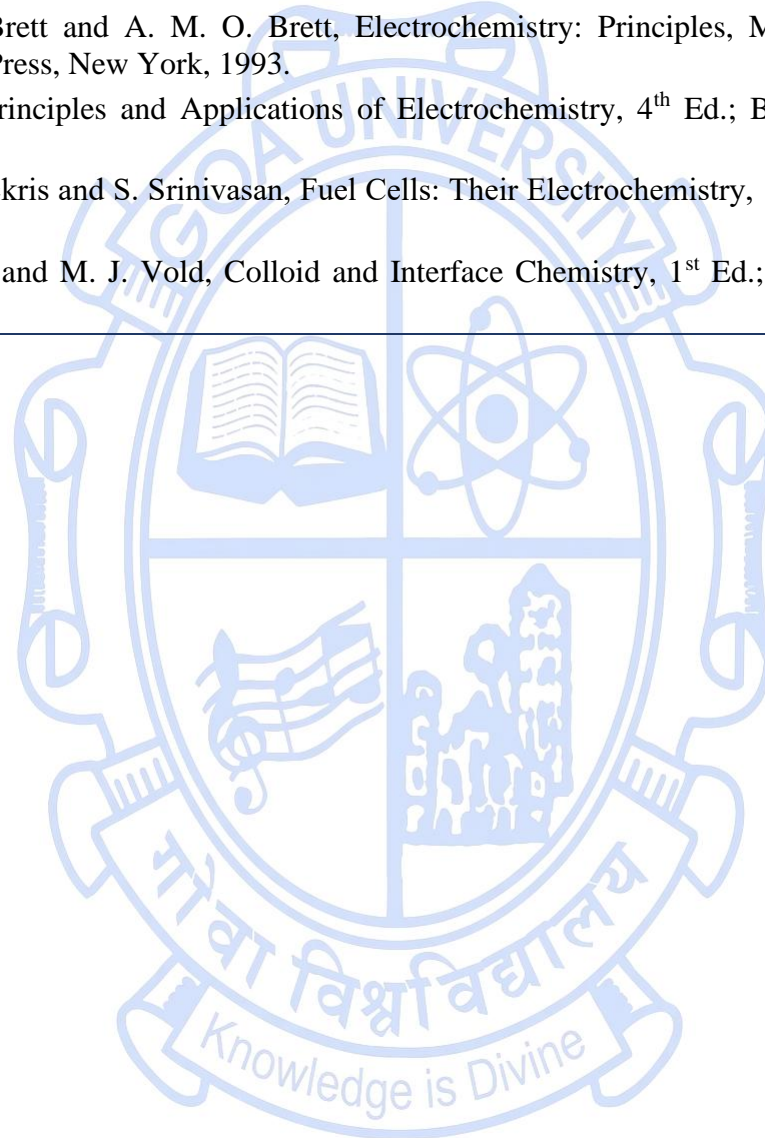
	CO 4. apply the electrochemical principles in renewable energy, materials science and biological systems.		PSO6, PSO7	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Ionic Interactions and Conductance in Electrolytes</p> <p>Ion-solvent interactions. Born Theory, validity and limitations. 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</p>	15	CO1, CO2	K1, K2, K4
Module 2:	<p>2.1. Electrified Interfaces</p> <p>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 thermodynamic equilibrium at electrified interface.</p>	15	CO1, CO2, CO3	K1, K2, K4, K5

	<p>Generalized Gibbs equation, Lippmann equation and electrical capacitance at the double layer.</p> <p>Models of the electrified interface.</p> <p>Ion adsorption at the electrode: hydrated electrodes, contact adsorption.</p> <p>Semiconductor-electrolyte interface: diffuse-charge region, surface states.</p> <p>2.2. Colloidal interfaces</p> <p>Interaction of double layers and stability of Sols. DLVO theory.</p> <p>Electrokinetic phenomena: Electroosmosis, streaming potential and current, electrophoresis. Zeta potential.</p> <p>Critical micelle concentration, Krafft temperature</p> <p>Donnan membrane equilibria.</p> <p>Micelles and reverse micelles, Emulsions and Microemulsions.</p>			
Module 3:	<p>Electrode Kinetics and Corrosion</p> <p>Disturbance of electrode equilibrium, cause of electron transfer, fast and slow systems and their current-potential relationship.</p> <p>Butler-Volmer equation and its low and high field approximations.</p> <p>Nernst equation as a special case of B-V equation.</p> <p>Tafel plots for anodic and cathodic processes.</p> <p>Fundamentals of Impedance spectroscopy; determining exchange current densities and rate constants from impedance plots.</p> <p>Principles of corrosion, electrochemical methods of avoiding corrosion.</p> <p>pH-potential diagrams: Pourbaix diagram for corrosion of iron and stability of water</p>	15	CO1, CO3, CO4	K1, K2, K3, K4, K5
Module 4:	<p>4.1. Electrochemical Energies: Conversion and Storage</p> <p>Thermodynamics of electrochemical energy conversion.</p> <p>Batteries: Basic principles; rating and shelf life. Zinc-Manganese dioxide:</p>	15	CO1, CO2, CO3, CO4	K1, K2, K3, K5, K6

	<p>Leclanche and alkaline batteries. Lithium ion batteries and recharge ability.</p> <p>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.</p> <p>Super-capacitors and its applications.</p> <p>4.2. Photoelectrochemistry</p> <p>Semiconductor/Electrolyte Interface: Band edge and Band bending.</p> <p>Light absorption and carrier generation at the electrode: photoinduced charge transfer, hot carriers.</p> <p>Photoelectrodes: p-type photocathode, n-type photoanode.</p> <p>d. Determination of surface states.</p> <p>Photoelectrocatalysis: photoelectrochemical water splitting and CO₂ reduction.</p> <p>Types of photoelectrochemical devices.</p>			
Pedagogy:	<p>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.</p>			
Texts:	<ol style="list-style-type: none"> 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/ Readings:	<ol style="list-style-type: none"> 1. A. J. Torriero, Electrochemistry in Ionic Liquids, Vol. 1: Fundamentals, 1st Ed.; Springer International 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.

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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:	<ul style="list-style-type: none">• 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
	CO 1. Understand stoichiometric requirements during organic syntheses.	PSO1, PSO3, PSO4

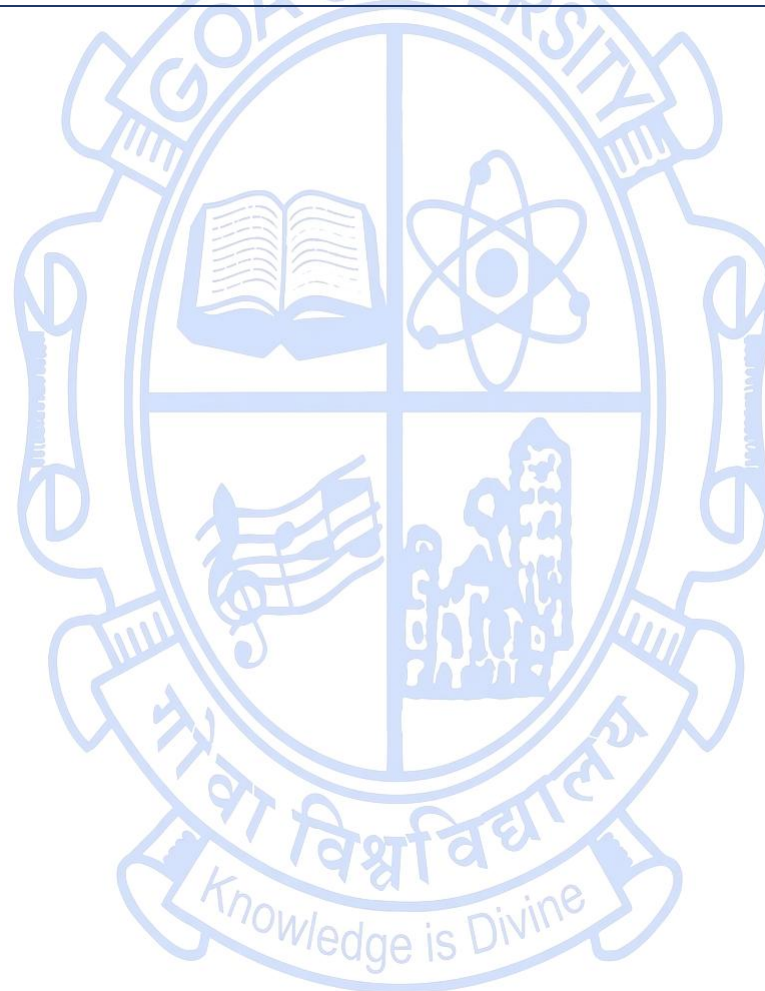
	CO 2. Apply safe and good laboratory practices and develop skills in handling laboratory glassware, equipment and chemical reagents.		PSO1, PSO3, PSO4	
	CO 3. Create the practical knowledge to perform experiments involving common laboratory techniques like reflux, distillation, steam distillation, vacuum 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:	<p>1.1 Introduction to laboratory equipment, apparatus and safety</p> <p>a. Use of common laboratory equipment like fume hood, vacuum pump, weighing balance.</p> <p>b. Introduction to various types of quick fit joints and apparatus.</p> <p>c. Safety Techniques:</p> <ol style="list-style-type: none"> i. Disposal of chemicals ii. Personal Protective Equipment (PPE) iii. First aid iv. Fire extinguishers, types of fire v. Chemical hazards and risk assessment <p>1.2 Laboratory Techniques-I</p> <p>a. Simple distillation (any one):</p> <ol style="list-style-type: none"> i. Toluene-dichloromethane mixture using water condenser. ii. Nitrobenzene and aniline using air condenser. <p>b. Steam distillation (any one):</p> <ol style="list-style-type: none"> i. Separation of o- and p- nitrophenols. ii. Naphthalene from its suspension in water. iii. Clove oil from cloves. <p>c. Crystallisation: Concept of induction of crystallization (any one)</p> <ol style="list-style-type: none"> i. Crystallisation of phthalic acid from hot water using fluted filter paper and stemless funnel. 	16	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5

	<ul style="list-style-type: none"> 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:	<p>2 Laboratory Techniques-II</p> <ul style="list-style-type: none"> 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): <ul style="list-style-type: none"> 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:	<p>3. Organic synthesis (Any Four experiments)</p> <ul style="list-style-type: none"> a. Aliphatic electrophilic substitution: Preparation of iodoform from ethanol & acetone. b. Aromatic electrophilic substitution (any one): <ul style="list-style-type: none"> i. Preparation of p-bromoacetanilide. ii. Bromination of acetophenone to phenacyl bromide iii. Nitration of naphthalene to 1-nitronaphthalene iv. Nitration of benzaldehyde to 3-nitrobenzaldehyde. c. Oxidation (any one) <ul style="list-style-type: none"> i. Benzoic acid from toluene. ii. Cyclohexanone from cyclohexanol. iii. Isoborneol to camphor using Jones reagent. d. Reduction (any one) <ul style="list-style-type: none"> i. Reduction of o-nitroaniline to o-phenylenediamine using Sn/HCl ii. Reduction of p-nitro benzaldehyde to p-nitrobenzyl alcohol using NaBH₄. e. Bromination of an alcohol using CBr₄/ triphenylphosphine. f. Grignard reaction: Triphenylmethanol from benzoic acid ester or benzophenone. 	16	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5

	<p>g. Aldol condensation: Dibenzalacetone from benzaldehyde</p> <p>h. Acetoacetic ester condensation: Preparation of ethyl n-butylacetoacetate or ethyl acetoacetate.</p>			
Module 4:	<p>Organic synthesis and synthetic reagents (Any two)</p> <p>a. Cannizzaro reaction using 4-chlorobenzaldehyde as substrate.</p> <p>b. Friedel Craft's reaction</p> <p>i. using toluene and succinic anhydride</p> <p>ii. Resorcinol to resacetophenone, benzene and maleic anhydride to benzoylacrylic acid.</p> <p>c. Solvent free preparation of coumarin by the Knoevenagel condensation under MW irradiation.</p> <p>d. Preparation of oxidizing agent (any one): Pyridinium chlorochromate-silica, pyridinium chlorochromate-alumina, MnO₂.</p> <p>e. Preparation of cuprous chloride.</p> <p>Isolation from natural sources (Any two)</p> <p>i. Caffeine from tea powder.</p> <p>ii. Piperine from pepper.</p> <p>iii. Cinnamaldehyde from cinnamon</p> <p>iv. Lemongrass oil from lemongrass</p>	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:	<ol style="list-style-type: none"> 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:	<ol style="list-style-type: none">1. S. Delvin, Green Chemistry, 1st ed. Sarup & Sons, New Delhi, 20052. J. Mohan, Organic Analytical Chemistry, 1st ed. Narosa Publishing House, New Delhi, 20143. T. Laue, A. Plagens, Named Organic Reactions, 1st ed. John Wiley and Sons, Inc., Hoboken, 2005

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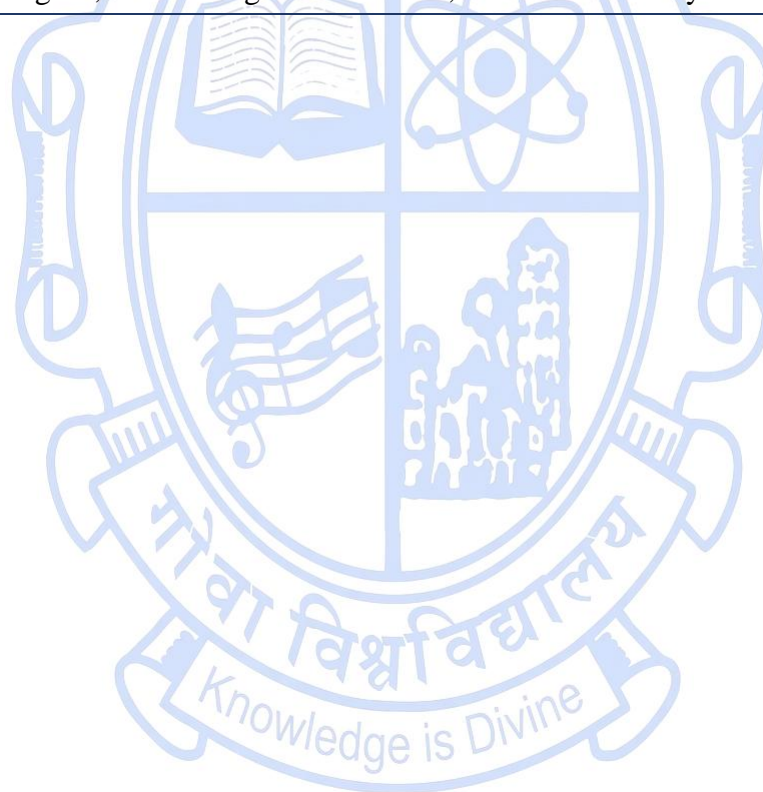
Title of the Course	Organic Chemistry Practical - II	
Course Code	CHO-5202	
Number of Credits	2	
Theory/Practical	Practical	
Level	400	
Effective from AY	2025-26	
New Course	Yes	
Bridge Course/ Value added Course	No	
Course for advanced learners	No	
Pre-requisites for the Course:	NIL	
Course Objectives:	<ul style="list-style-type: none"> 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:	<p>1.1 Introduction to laboratory equipment, apparatus and safety</p> <p>a. Common Hazards in Chemical Laboratory, Risk assessment b. Accidents and Emergency procedures</p> <p>1.2 Laboratory Techniques (Any Three)</p> <p>a. Simple distillation: i. Simple distillation of thionyl chloride under anhydrous condition ii. Simple distillation under Nitrogen atmosphere of THF</p> <p>b. Fractional distillation: i. Chloroform-dichloromethane mixture using water condenser. ii. Toluene and cyclohexane using fractionating column.</p> <p>c. Vacuum distillation under inert atmosphere: Distillation of DMF, o-dichlorobenzene, POCl₃</p> <p>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.</p>	16	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5
Module 2:	<p>Organic Synthesis (Any Four)</p> <p>a. p-Iodonitrobenzene by Sandmeyer reaction b. Pinacol- Pinacolone rearrangement</p>	16	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5

	<ul style="list-style-type: none"> 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:	<p>3. Two-step Organic Synthesis (Any Two)</p> <ul style="list-style-type: none"> 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:	<p>4.1 Solvent Free Organic synthesis (Any One)</p> <ul style="list-style-type: none"> a. Reduction using ball milling technique b. Oxidation of 2° alcohol using KMnO₄/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 <p>4.2 Separation, Isolation and Identification of Organic compounds (Any One)</p> <p>Separation, purification and identification of compounds of binary mixture (Solid-Solid, Solid-liquid and Liquid-liquid) using the TLC and column chromatography, chemical tests.</p> <p>IR spectra to be used for functional group identification.</p>	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:	<ul style="list-style-type: none"> 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 			

	<ol style="list-style-type: none">3. L. F. Fieser, K. L. Williamson, Organic Experiments, 7th ed. D. C. Heath, Lexington, 19924. K. L. Williamson, K. M. Masters, Macroscale and Microscale Organic Experiments, 6th ed. Cengage Learning, Boston, 20105. R. K. Bansal, Laboratory Manual in Organic Chemistry, 5th ed. New Age International, New Delhi 20166. 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:	<ol style="list-style-type: none">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

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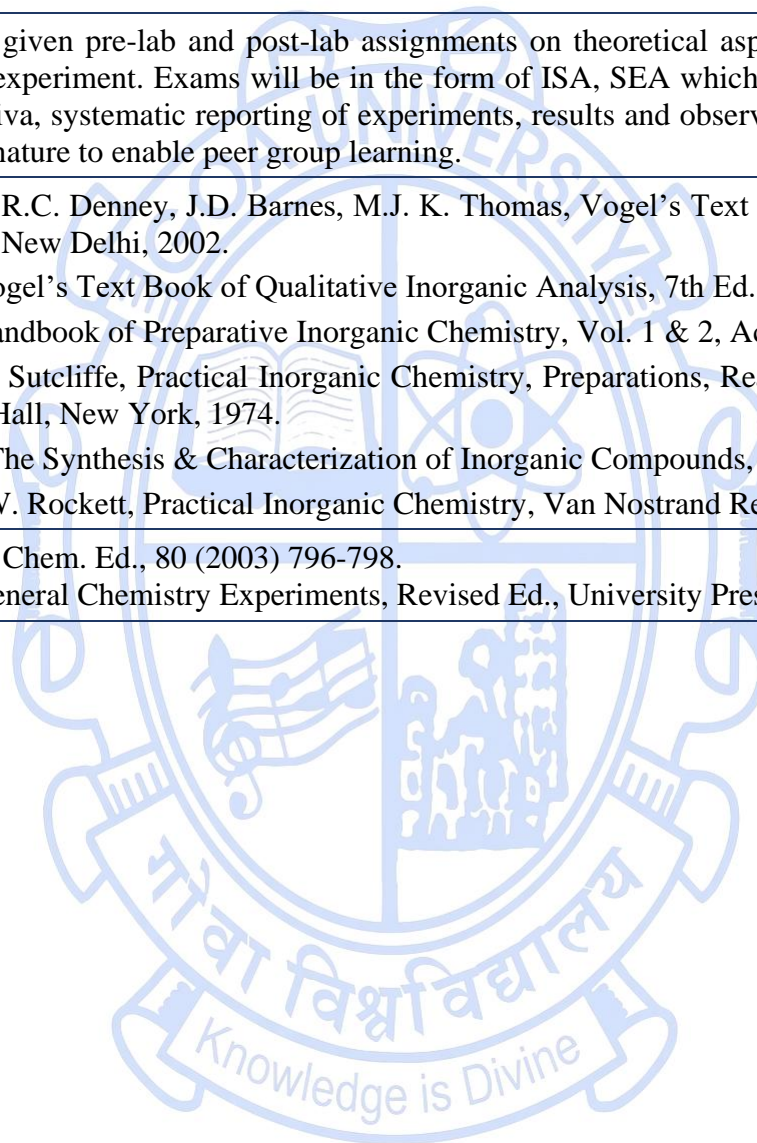
Title of the Course	Inorganic Chemistry Practical-I
Course Code	CHI-5201
Number of Credits	2
Theory/Practical	Practical
Level	400
Effective from AY	2025-26
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	NIL	
Course Objectives:	<ul style="list-style-type: none"> • 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. 	
Course Outcomes:	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 of compounds	PSO1, PSO4

Content:		Noofhours	Mapped to CO	Cognitive Level
Module 1:	<p>1. Preparations of Inorganic Compounds (ANY 07)</p> <p>a. Preparation of hexaamminenickel(II) chloride or hexaamminenickel(II) sulfate.</p> <p>b. Preparation of tris(ethylenediamine)cobalt(III) chloride.</p> <p>c. Preparation of potash alum from scrap aluminum.</p> <p>d. Preparation of potassium trioxalatoaluminate(III) trihydrate.</p> <p>e. Preparation of potassium hexathiocyanato-κN-chromate(III) tetrahydrate.</p> <p>f. Preparation of potassium trioxalatochromate(III) trihydrate.</p> <p>g. Preparation of α- and γ-Fe₂O₃.</p> <p>h. Preparation of Zinc acetate or [Zn₄O(CH₃CO₂)₆].</p> <p>(Powder X-Ray Diffraction (PXRD), Infrared (IR), UV-vis spectroscopy and magnetic studies is expected)</p>	28	CO1, CO2	K2, K3, K4, K5
Module 2:	<p>2. Estimations / Determinations (ANY 08)</p> <p>a. Estimation of nickel by complexometry or Gravimetry.</p> <p>b. Estimation of cobalt in [Co(en)₃]Cl₃ by complexometry.</p> <p>c. Estimation of oxalate in K₃[Al(C₂O₄)₃]\cdotxH₂O or K₃[Cr(C₂O₄)₃]\cdotxH₂O</p> <p>d. Estimation of nitrite by redox titration.</p> <p>e. Estimation of calcium from calcite ore.</p> <p>f. Iodometric determination of copper in commercial copper compounds / alloys.</p> <p>g. Estimation of sulfate by gravimetry.</p> <p>h. Estimation of zinc by complexometric titration.</p> <p>i. Determination of chromium in chrome alum and K₃[Cr(C₂O₄)₃]\cdotxH₂O and to determine degree of hydration.</p> <p>j. Estimation of potassium from synthesized compounds.</p> <p>k. Colorimetric/Spectrophotometric determination of nickel or chromium or</p>	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:	<ol style="list-style-type: none"> 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:	<ol style="list-style-type: none"> 1. S. De Meo, J. Chem. Ed., 80 (2003) 796-798. 2. A. J. Elias, General Chemistry Experiments, Revised Ed., University Press, Hyderabad, 2008. 			

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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:	<ul style="list-style-type: none"> • 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 synthesise useful compounds.	PSO1, PSO4

	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, PSO4	PSO3
Content:		Noofhours	Mapped to CO	Cognitive Level
Module 1:	<p>1. Preparations / Estimation of Inorganic Compounds: (Any Nine)</p> <p>a. Preparation of hexaamminecobalt(III) nitrate.</p> <p>b. Estimation of cobalt in hexaamminecobalt(III) nitrate by volumetric titration.</p> <p>c. Preparation of Potassium Trioxalatoferrate(III) Trihydrate</p> <p>d. Estimation of iron and oxalate by redox titration</p> <p>e. Synthesis of metal nanoparticles (Cu, Ag, Au, Ni) and determining the absorption maxima by UV-visible spectrophotometer.</p> <p>f. Estimation of amount of calcium in given sample by gravimetric method.</p> <p>g. Estimation of amount of nickel in given sample by gravimetric method.</p> <p>h. Estimation amount of zinc present in given sample by gravimetric method.</p> <p>i. Estimation of iron by colorimetric / spectrophotometry method.</p> <p>j. Estimation of barium by complexometric titration method.</p> <p>k. Estimation of manganese in presence of iron by complexometric titration method.</p> <p>(Powder X-Ray Diffraction (PXRD), Infrared (IR), UV-vis spectroscopy and magnetic studies is expected)</p>	40	CO1, CO2, CO3	K2, K3, K4, K5
Module 2:	<p>2. Semi-micro qualitative analysis of cation and anion in a given inorganic mixture: (Any four mixture)</p> <p>Mixture containing total six cations and/or anions.</p>	20	CO3, CO4	K2, K3, K4, K5

	<p>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+}, $(\text{NH}_4)^+$, K^+</p> <p>Anions: Cl^-, Br^-, I^-, NO_2^-, NO_3^-, SO_3^{2-}, CO_3^{2-}, SO_4^{2-}, PO_4^{3-}, S^{2-}</p>			
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:	<ol style="list-style-type: none"> 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:	<ol style="list-style-type: none"> 1. S. De Meo, J. Chem. Ed., 80 (2003) 796-798. 			

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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:	<ul style="list-style-type: none"> 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:	<p>1. Non- instrumental Experiments (Any 08)</p> <ol style="list-style-type: none"> 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. To determine the order of reaction between potassium persulphate and potassium iodide by graphical, fractional change and differential methods. To study the three-component system such as acetic acid, chloroform and water and obtain tie line. To determine the molecular weight of polyvinyl alcohol by viscosity measurement. To study the electro-kinetics of rapid reaction between SO_4^{2-} and I in an aqueous solution. To determine the buffer capacity of acidic buffer solution. To determine the partial molal volume of ethanol-water mixture at a given temperature. To measure energy content of various types of plastics using bomb calorimetry To determine number average molecular weight of a polymer sample with an indirect titration method. To investigate basic hydrolysis of ethyl acetate at four different temperatures and find out energy of activation To construct a phase diagram for a two-component system by plotting cooling curves for mixtures of different compositions. 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:	<p>2. Instrumental Experiments (Any 07)</p> <ol style="list-style-type: none"> To determine the degree of hydrolysis of salt of weak base and strong acid using conductometer. 	28	CO2, CO3, CO4 K3, K4, K5

	<ol style="list-style-type: none"> 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 $\text{Fe}^{2+}/\text{Fe}^{3+}$ and $\text{Ce}^{3+}/\text{Ce}^{4+}$ 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:	<p>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.</p>			
Texts:	<ol style="list-style-type: none"> 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:	<ol style="list-style-type: none"> 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. Kadow & 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:	<ul style="list-style-type: none"> 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:	<p>1. Non- instrumental Experiments (Any 09)</p> <ol style="list-style-type: none"> To determine the radius of a molecule by viscosity measurements. To determine ΔG, ΔH and ΔS of silver benzoate by solubility product method. To investigate the adsorption of oxalic acid by activated charcoal and test the validity of Freundlich and Langmuir's isotherms. To determine the molecular weight of a given polymer by turbidimetry. To study the rate of reaction between ethyl bromoacetate and sodium thiosulphate kinetically. To determine the percentage composition of a given mixture of two liquids by stalagmometer method. 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. 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. To determine the order of reaction for hydrolysis of ethyl acetate by graphical, fractional change and differential methods. To determine the molecular weight of polystyrene by viscosity measurement. 	36	CO1, CO3, CO4 K1, K2, K3, K4, K5
Module 2:	<p>2. Instrumental Experiments</p> <ol style="list-style-type: none"> To determine the relative strength of chloroacetic acid and acetic acid by conductometry. To determine the degree of hydrolysis of salt of weak base and strong acid using conductometry. To determine the composition of a mixture of acetic acid, dichloroacetic acid and hydrochloric acid by conductometric titration. 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

	<ol style="list-style-type: none"> To determine the redox potential of $\text{Fe}^{2+}/\text{Fe}^{3+}$ system by titrating it with standard $\text{K}_2\text{Cr}_2\text{O}_7$ solution. 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:	<ol style="list-style-type: none"> V. D. Athawale, P. Mathur, Experimental Physical Chemistry, New Age International Publishers, 1st ed., New Delhi, 2001. J.N. Gurtu, A. Gurtu, Advanced Physical Chemistry Experiments, Pragati Publications, 1st ed., Meerut, 2008. A. Findlay & J. A. Kitchener, Practical Physical Chemistry, Longmans, Green and Co., 1st ed., London 1954. F. Daniels & J. H. Mathews, Experimental Physical Chemistry, McGraw-Hill, 1st ed., New York, 1941. 			
References/ Readings:	<ol style="list-style-type: none"> A. M. James, Practical Physical Chemistry, Prentice Hall Press, USA 3rd ed., 1974. D.P. Shoemaker & C. W. Garland, Experiments in Physical Chemistry, McGraw-Hill, 1st ed., New York, 1962. T. Kadow & F. Mafune, Progress in experimental and theoretical studies of clusters, World Scientific publishers, 1st ed., New Jersey, 2002. C. Arora & S. Bhattacharya, Advanced Physical Chemistry Practical Guide, Bentham Science Publishers, 1st ed., UAE, 2022. 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. 			

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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

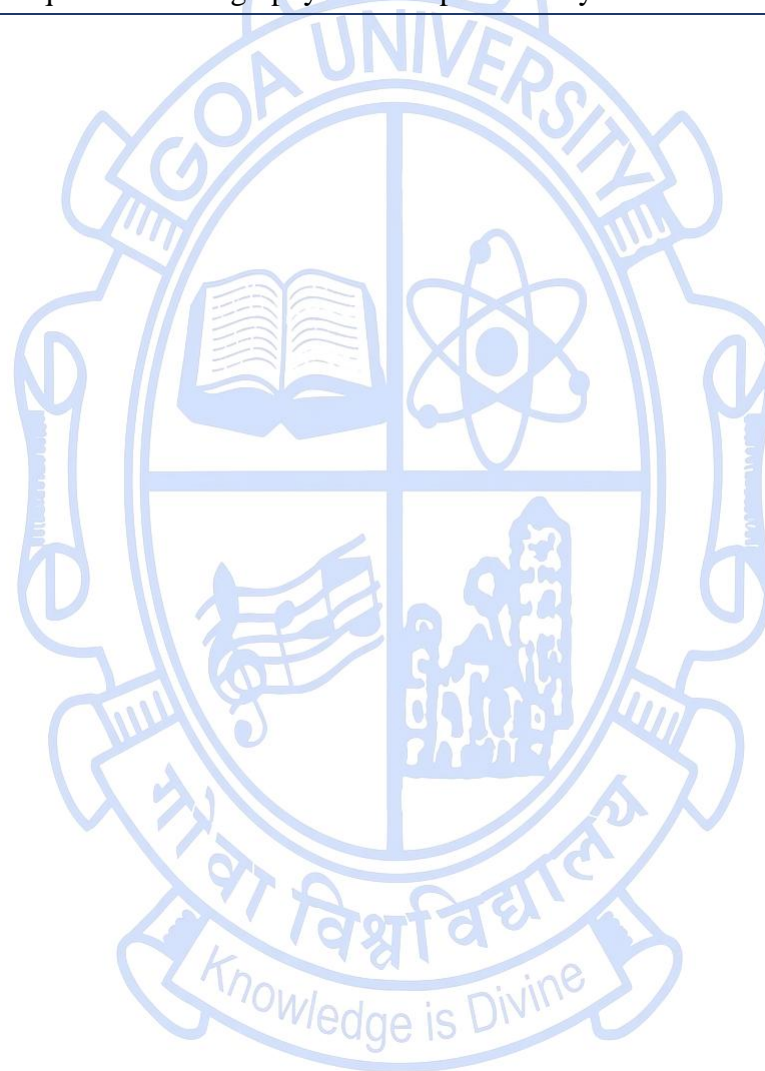
Pre-requisites for the Course:	Nil	
Course Objectives:	<ul style="list-style-type: none"> • To perform various experimental techniques for analysis. • To learn data analysis, handling and interpretation of spectra. • To determine concentration of solutions. • To use techniques for qualitative and quantitative 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 $\text{K}_2\text{Cr}_2\text{O}_7$ by Visible spectroscopy d. Simultaneous determination and Verification of law of additivity of absorbances ($\text{K}_2\text{Cr}_2\text{O}_7$ 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. c. Estimation of CaO in cement.	8	CO3, CO4	K4, K5

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 $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, $\text{CaC}_2\text{O}_4 \cdot \text{H}_2\text{O}$, $\text{FeC}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$. 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 combination of some of these. Sessions shall be interactive in nature to enable peer group learning.			
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/ 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.			

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| | <ol style="list-style-type: none">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. |
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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:	<ul style="list-style-type: none"> • 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 $\text{K}_2\text{Cr}_2\text{O}_7$ 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 a. Spectrophotometric determination of aspirin/phenacetin/caffeine in APC tablet using	8	CO3, CO4	K4, K5

	<p>solvent extraction.</p> <p>b. Colorimetric determination of iron with salicylic acid.</p> <p>c. Determination of copper in brass sample by colorimetry.</p>			
Module 7:	<p>7. Data Interpretation Exercises</p> <p>a. NMR/Mass spectra.</p> <p>b. HPLC and GC chromatograph.</p> <p>c. XRD powder pattern of cubic systems.</p> <p>d. Thermogram of coordination compounds.</p>	8	CO1, CO2	K3, K4
Module 8:	<p>8. Demonstration</p> <p>a. Turbidimeter.</p> <p>b. KF instrument.</p> <p>c. Polarimeter.</p> <p>d. LCMS.</p> <p>e. NMR.</p>	8	CO1, CO2	K3, K4
Pedagogy:	<p>Prelab exercises / assignments / presentations / lab hand-out or a combination of some of these. Sessions shall be interactive in nature to enable peer group learning.</p>			
Texts:	<ol style="list-style-type: none"> 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:	<ol style="list-style-type: none"> 1. G. D. Christian, Analytical chemistry, 5th Ed., John Wiley 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. 			

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SEMESTER III

Research Specific Elective (RSE) Courses

Title of the Course	Physical Chemistry Practical – III	
Course Code	CHP-6000	
Number of Credits	4	
Theory/Practical	Practical	
Level	500	
Effective from AY	2026-27	
New Course	No	
Bridge Course/ Value added Course	No	
Course for advanced learners	No	
Pre-requisites for the Course:	Level 400 course	
Course Objectives:	<ol style="list-style-type: none">1. To introduce concepts of kinetics, thermodynamics, surface science, catalysis, and electrochemistry.2. To understand the concepts of surface science and catalysis, enabling students to analyze surface phenomena, catalytic mechanisms, and their practical applications.3. To provide students with comprehensive knowledge of various principles and phenomena in Electrochemistry.4. To implement use of computers and computational tools in chemistry	
Course Outcomes:	Student will be able to	Mapped to PSO
	CO 1. explain the theoretical basis of kinetics, thermodynamics, electrochemistry, and surface science experiments.	PSO1

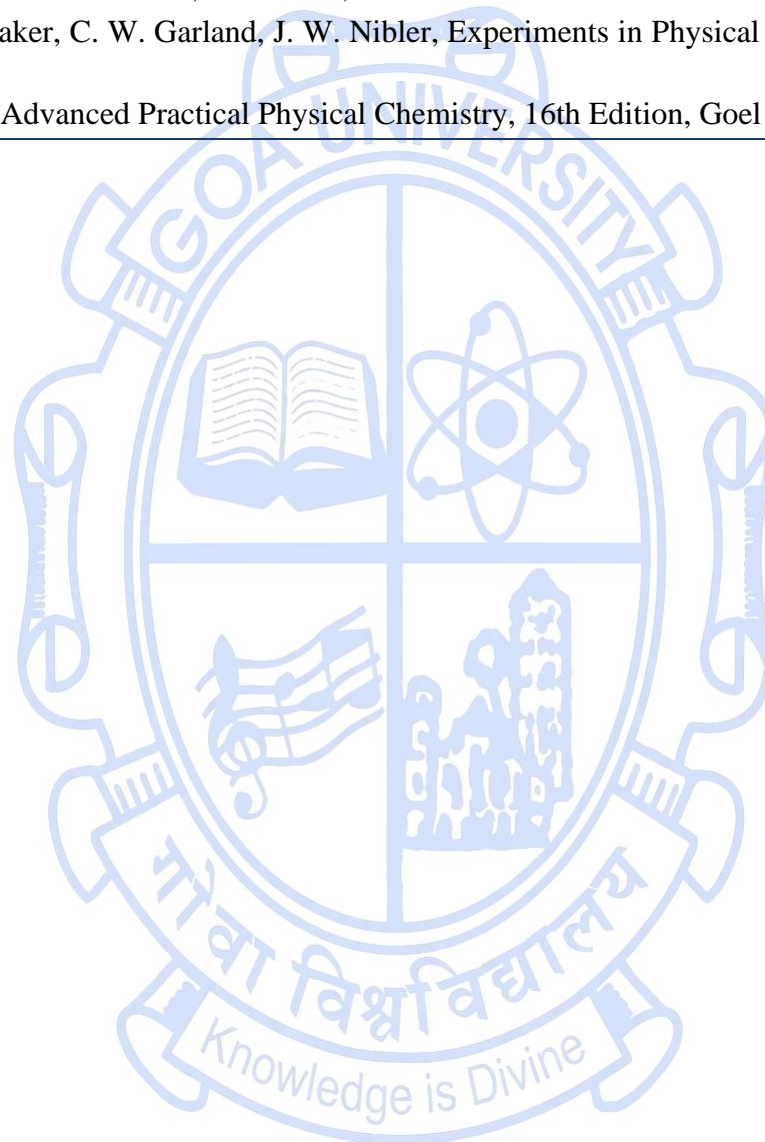
	CO 2. perform and demonstrate experiments using modern instruments and classical techniques.		PSO1, PSO4	
	CO 3. analyze and interpret experimental data to validate theoretical models and determine physical parameters.		PSO1, PSO4	
	CO 4. utilize computational chemistry tools and programming to simulate chemical systems and generate molecular or spectroscopic data.		PSO8	
Content:	<i>Note: A minimum of 8 experiments from each Unit/Module I-III are to be completed.</i>	No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Instrumental</p> <ol style="list-style-type: none"> i. To determine the redox potential of Fe²⁺/Fe³⁺ system using rotating disk voltammetry method. ii. To determine the instability constant of the reaction $[\text{Ag}(\text{NH}_3)_2]^+ \rightarrow \text{Ag}^+ + 2\text{NH}_3$ potentiometrically. iii. To determine the transport number of ions using moving boundary method. iv. To verify Nernst equation and determine the standard oxidation potential of copper and zinc electrodes. v. To study effect of ionic strength on activity coefficient of Ag⁺ ions. vi. To investigate the reaction kinetics between Potassium persulphate and Potassium Iodide colorimetrically. vii. To determine the equivalent conductance of a strong electrolyte (KCl) at several concentration and verify Onsager's equation. viii. To estimate the concentration of sulphuric acid, acetic acid and copper sulphate in a given solution conductometrically. ix. To determine the concentration of Fe²⁺ ions by titrating with potassium dichromate conductometrically. x. To study the kinetics of hydrolysis of tertiary butyl chloride by conductometry. xi. To determine the half wave potential of Cu²⁺/Cd²⁺/Zn²⁺ by using polarography. xii. To study the effect of sol-gel and hydrothermal method of synthesis on crystallite size and surface area of a semiconductor catalyst. 	40	CO1, CO2, CO3	K1, K2, K3, K4, K5

	<ul style="list-style-type: none"> xiii. To investigate the effect of catalyst loading on photocatalytic degradation of azo dye using semiconductor catalyst. xiv. To study the stress-strain response of polymeric materials and compare their strength. xv. To determine the degradation rate of the polymers using thermogravimetric methods. xvi. To determine the curie temperature of conducting polymer samples. xvii. To determine the resistivity of polymeric material using four probe method. 			
Module 2:	<p>Non-Instrumental</p> <ul style="list-style-type: none"> i. To determine the critical micelle concentration of three types of surfactants using a stalagmometer. ii. To determine the partial molal volume of sodium chloride-water, ethanol-water and methanol-water system by apparent molal volume method. iii. To study the effect of surfactants on surface tension of water using stalagmometer. iv. To study the variation of viscosity with composition of mixtures and to verify the formation of compounds by Ostwald's viscometer. v. To study the effect of pH on the kinetics of iodination of Aniline. vi. To study the kinetics of reaction between H₂O₂ and KI (clock reaction). vii. To study the kinetics of rapid reaction between Bromine and Iodine in aqueous media. viii. To investigate the autocatalytic reaction between Potassium Permanganate and Oxalic acid. ix. To study the electroless deposition of Ni on non-conductor substrate and to determine the rate of deposition. x. To study the variation in catalytic activity of three different metal oxides for H₂O₂ decomposition reaction. xi. To investigate the effect of pH on adsorptive separation of azodye from water using MCM-41. 	40	CO1, CO3	K1, K2, K3, K4, K5
Module 3:	<p>Computational Chemistry</p> <ul style="list-style-type: none"> i. To generate a mark sheet and understand various features of spreadsheets. 	40	CO4	K1, K2, K3, K4,

	<ul style="list-style-type: none"> ii. To generate a plot for a given function such as solutions of 1D box, harmonic oscillator, H-like atom wave functions, Gaussians distributions etc. iii. To write a computer program to obtain equivalence point in pH metry and potentiometric experiments (derivative method). iv. To write a computer program to find percent composition for various atoms of a given molecular formula. v. To write a computer program to obtain slope and intercept for linear data using least square fit method. vi. To write a computer program to obtain the center of mass of a given molecule and moment of inertia, hence obtaining classification of the given molecule. vii. To write a computer program to find out various parameters for data analysis viz. minimum, maximum, average, standard deviation, variance, covariance, correlation coefficient, frequency distribution etc. viii. To write a computer program to obtain thermodynamic probability. ix. To write a computer program to obtain degeneracy of a given energy level for a particle in a cube. x. Calculate the ground state energy of hydrogen atom using various basis sets using <i>ab-initio</i> program. xi. Calculate and interpret the IR, RAMAN and NMR spectra of simple organic molecules using ab-initio program. 			K5,
Pedagogy:	Students should be given suitable lab handouts, pre- and post-lab assignments and explanations revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment.			
Texts:	<ol style="list-style-type: none"> 1. A. Finlay, J. A. Kitchener, Findlay's Practical Physical Chemistry, 9th Ed., revised by B. P. Levitt, Longman, London, 1973. 2. A. M. James, F. E. Prichard, Practical Physical Chemistry, 3rd Ed., reprint, Longman, New York, 1974. 3. B. Vishwanathan, P. S. Raghavan, Practical Physical Chemistry, Viva Books Private Limited, New Delhi, 2009. 4. P. S. Sindhu, Practicals in Physical Chemistry, New Age International Publishers, New Delhi, 2007. 5. S. W. Rajbhoj, T. K. Chondhekar, Systematic experimental physical chemistry, 2nd Ed., Anjali publication, Aurangabad, 2000. 			
References/	1. A. Szabo, N. S. Ostlund, Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory, 1st			

Readings:	Edition, Dover Publications, New York, 2012.
	2. D. P. Shoemaker, C. W. Garland, J. W. Nibler, Experiments in Physical Chemistry, 8th Edition, McGraw-Hill, New York, 2003.
	3. J. B. Yadav, Advanced Practical Physical Chemistry, 16th Edition, Goel Publishing House, Meerut, 2006.

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Title of the Course	Physical Chemistry Practical – IV
Course Code	CHP-6001
Number of Credits	4
Theory/Practical	Practical
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

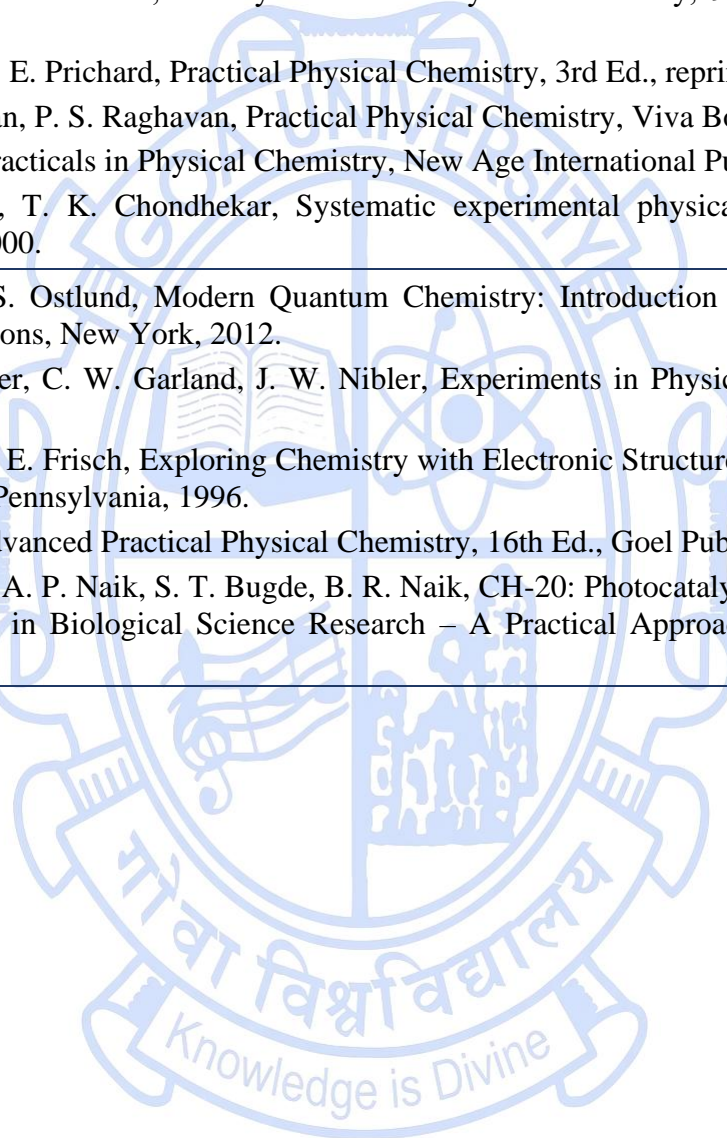
Pre-requisites for the Course:	Level 400 course	
Course Objectives:	<ol style="list-style-type: none"> 1. To introduce concepts of Kinetics and Thermodynamics 2. To understand concepts of Surface science and Catalysis 3. To learn various concepts of Electrochemistry 4. To implement use of computers and computational tools in chemistry 	
Course Outcomes:	Student will be able to	Mapped to PSO
	CO 1. explain the concepts of kinetics, thermodynamics, electrochemistry, and surface science experiments.	PSO1, PSO4
	CO 2. apply modern instruments and classical techniques in Physical chemistry experiments	PSO1, PSO4
	CO 3. analyze experimental data to validate theoretical models and determine physical parameters.	PSO1, PSO4

	CO 4. evaluate results and simulate chemical systems using computational tools and programming in chemistry.		PSO8	
Content:	<i>Note: A minimum of 8 experiments from each Unit/Module I-III are to be completed.</i>	No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Instrumental</p> <ol style="list-style-type: none"> To estimate the concentration of glucose calorimetrically. To determine the redox potential of $\text{Fe}^{3+}/\text{Fe}^{2+}$ system using rotating disk voltammetry method. To determine the transport number of ions using moving boundary method. To verify Nernst equation and determine the standard reduction potential of Ag and Zn electrodes. To determine the equivalent conductance of a strong electrolyte (NaCl) at several concentrations and verify Onsager's equation. To estimate the concentration of Hydrochloric acid, Monochloro acetic acid and Copper sulphate in a given solution conductometrically. To determine the half wave potential of $\text{Ni}^{2+}/\text{Cd}^{2+}/\text{Cu}^{2+}$ by using polarography. To study the effect of precipitation and hydrothermal method of synthesis on acidic sites of a semiconductor catalyst using NH_3 TPD method. To investigate the effect of solution pH on photocatalytic degradation of methylene blue using semiconductor photocatalyst. To determine the curie temperature of polyaniline. 	40	CO1, CO2, CO3	K1, K2,K3, K4, K5
Module 2:	<p>Non-Instrumental</p> <ol style="list-style-type: none"> To determine the critical micelle concentration of Sodium dodecyl sulphate, Cetrimonium bromide using stalagmometer. To study the kinetics of the reaction between acetone and Iodine using titrimetry. To study the effect of pH on the kinetics of iodination of aniline. To study the kinetics of Briggs Rauscher reaction (oscillatory reaction). To study the kinetics of rapid reaction between Bromine and Iodine in aqueous media To investigate the autocatalytic reaction between Potassium Permanganate and 	40	CO1, CO2, CO3	K1, K2,K3, K4, K5

	<p>Citric acid.</p> <p>vii. To study the electroless deposition of Cu on alpha-alumina and to determine the rate of deposition.</p> <p>viii. To compare the catalytic activity of MnO₂, NiO with Degussa-P25 towards H₂O₂ decomposition reaction.</p> <p>ix. To investigate the effect of pH on adsorptive separation of Amaranth dye from water over NiO catalyst.</p> <p>x. To determine the radius of a glycerol molecule by viscosity measurements.</p>			
Module 3:	<p>Computational Chemistry</p> <p>i. To write a computer program to find out various parameters for data analysis viz. minimum, maximum, average, standard deviation, variance, covariance, correlation coefficient, frequency distribution etc.</p> <p>ii. To write a computer program to obtain slope and intercept for linear data using least square fit method</p> <p>iii. To analyze the Gaussian output files and extracts molecular coordinates.</p> <p>iv. To construct and optimize the molecular structure of H₂O, H₂O₂ and HOF using Gaussian/ NWCHEM and calculate bond distances and bond angles.</p> <p>v. To obtain the transition state of the reaction between CH₃Br and OH⁻ ions using Gaussian/ NWCHEM.</p> <p>vi. To study the effect of solvent on the transition state of the reaction between CH₃Br and OH⁻ using Gaussian/ NWCHEM.</p> <p>vii. To study the thermochemistry of the reaction between CH₃Cl and OH⁻ using Gaussian/ NWCHEM.</p> <p>viii. To generate a plot for a given function such as solutions of 1D box, harmonic oscillator, H-like atom wave functions, Gaussians distributions etc.</p> <p>ix. To write a computer program to obtain degeneracy of a given energy level for a particle in a rectangular box.</p> <p>x. Calculate the ground state energy of hydrogen atom using various basis sets using Gaussian 16 program.</p>	40	CO3, CO4	K2, K3, K4, K5
Pedagogy:	Students should be given suitable lab handouts, pre- and post-lab assignments and explanations revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment.			

Texts:	<ol style="list-style-type: none"> 1. A. Finlay, J. A. Kitchener, Findlay's Practical Physical Chemistry, 9th Ed., revised by B. P. Levitt, Longman, London, 1973. 2. A. M. James, F. E. Prichard, Practical Physical Chemistry, 3rd Ed., reprint, Longman, New York, 1974. 3. B. Vishwanathan, P. S. Raghavan, Practical Physical Chemistry, Viva Books Private Limited, New Delhi, 2009. 4. P. S. Sindhu, Practicals in Physical Chemistry, New Age International Publishers, New Delhi, 2007. 5. S. W. Rajbhoj, T. K. Chondhekar, Systematic experimental physical chemistry, 2nd Ed., Anjali publication, Aurangabad, 2000.
References/ Readings:	<ol style="list-style-type: none"> 1. A. Szabo, N. S. Ostlund, Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory, Dover Publications, New York, 2012. 2. D. P. Shoemaker, C. W. Garland, J. W. Nibler, Experiments in Physical Chemistry, 8th Ed., McGraw-Hill, New York, 2003. 3. J. B. Foresman, E. Frisch, Exploring Chemistry with Electronic Structure Methods: A Guide to Using Gaussian, 2nd Ed., Gaussian, Pennsylvania, 1996. 4. J. B. Yadav, Advanced Practical Physical Chemistry, 16th Ed., Goel Publishing House, Meerut, 2006. 5. P. P. Morajkar, A. P. Naik, S. T. Bugde, B. R. Naik, CH-20: Photocatalytic and Microbial Degradation of Amaranth Dye, Advances in Biological Science Research – A Practical Approach, 327–345, Academic Press, New Delhi, 2019.

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Title of the Course	Heterogeneous Catalysis: Fundamentals and Applications
Course Code	CHP-6002
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Level 400 course	
Course Objectives:	<ol style="list-style-type: none"> 1. To Study the foundational principles of surface science, adsorption, and catalytic activity, stability, and selectivity. 2. To learn kinetic models and mechanistic approaches to interpret catalytic reactions. 3. To acquire knowledge of thermal and spectroscopic characterization techniques in catalysis. 4. To introduce various preparation methods and the use of heterogeneous catalyst application in energy and environmental sector. 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. explain the concepts of adsorption, surface area, porosity, and the factors affecting catalytic reactions.	PSO1, PSO5
	CO 2. apply kinetic and mechanistic models to predict catalytic reaction behavior and interpret industrial catalytic processes.	PSO1, PSO5

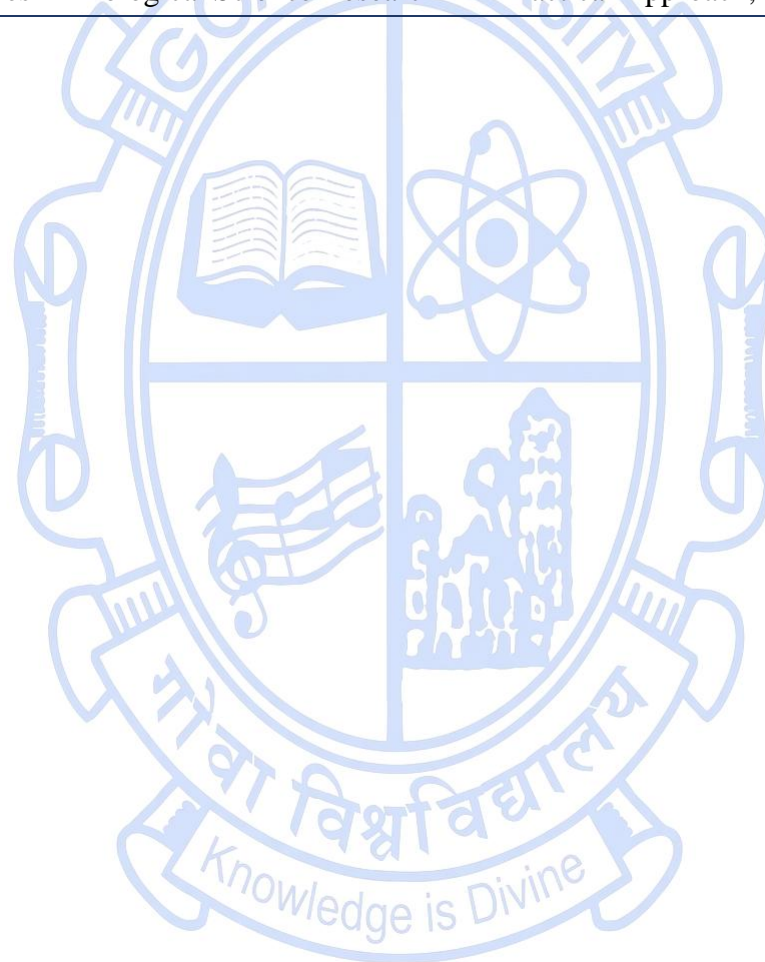
	CO 3. analyze experimental characterization data to identify catalyst properties and their impact on activity and selectivity.		PSO1, PSO5
	CO 4. evaluate catalytic systems for specific applications such as photocatalytic water splitting, CO ₂ reduction, and pollutant degradation.		PSO3, PSO5
Content:		No of hours	Mapped to CO Cognitive Level
Module 1:	<p>Basic Concepts of Heterogeneous Catalysis</p> <p>General Introduction: Catalysis and activation energy. Heterogeneous reactions with suitable illustrations. Catalytic activity, selectivity and stability. Steps in a heterogeneous catalytic reaction. Factors affecting rate of reaction such as temperature, flow rates, molar composition etc.</p> <p>Adsorption and Surface Area: Cause of adsorption. No of molecules striking the surface and sticking probability. Types of adsorption and potential energy profiles for adsorption of H₂. Adsorption isotherms for gases and solutes. Basic types of BET isotherms. Gibbs adsorption equation and changes in surface tension. Free energy, enthalpy and entropy of adsorption. Chemisorption of H₂, O₂ and CO. Surface area and Porosity: Determination of surface area. Porosity and pore size distribution.</p> <p>Classification of catalysts based on electrical conduction: Adsorption on specific crystal planes; geometric factor in catalysis: Balandin's multiplet theory and valence angle conservation. Cumulative & depletive adsorption, electronic effect in catalysis by metals. Role of diffusion in catalysis.</p>	20	CO1 K1, K2, K3, K4
Module 2:	<p>2.1 Kinetics and mechanisms of catalyzed reactions</p> <p>Kinetics of catalyzed reactions and rate expressions. Mechanism of catalyzed reactions obeying Langmuir- Hinshelwood, Eley- Rideal and Mars van Krevelen models with suitable examples.</p> <p>2.2 Preparation of Catalysts</p> <p>Various methods for preparation of bulk catalysts: Precipitation method, Impregnation method catalyst impregnation with or without interaction between support and catalyst. Synthesis of microporous solids. Synthesis of mesoporous solids.</p>	15	CO2, CO4 K2, K3, K4, K5

	2.3 Zeolite based Catalysis and industrial applications Structure building in zeolites such ZSM-5. Nature of active sites and their characterization. Role of Zeolite acidity and Shape Selectivity in catalytic reactions. Zeolite based catalysis in MTG process.			
Module 3:	Thermal and Spectroscopic Methods in Heterogeneous Catalysis Characterization of catalysts by temperature programmed desorption using probes such as ammonia and pyridine molecules. Characterization of surface area using BET method. Characterization of adsorbed molecules/intermediates by IR spectroscopy and XPS. Introduction to EXAFS and Mössbauer spectroscopy in characterizing catalysts.	10	CO3	K1, K2, K3, K4
Module 4:	4.1 Semiconductor catalysis and its application in energy and environmental sector Introduction to semi-conductor surface and catalysis with application in photocatalytic water splitting and CO ₂ reduction to value added chemicals. Case studies on photocatalytic degradation of dyes. Practical demonstration of photocatalytic treatment of laboratory waste water contaminated with dyes, adsorptive separation and kinetic analysis. 4.2 Electrocatalysis and applications Basic electro-catalytic concepts, comparison of electrocatalysts. Electrocatalytic water splitting reaction. Role of catalytic materials in energy storage applications.	15	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:	<ol style="list-style-type: none"> 1. A. V. Salker, Catalysis: Principles and Basic Concepts, 1st Ed., Scientific International, New Delhi, 2019. 2. D. K. Chakrabarty, B. Viswanathan, Heterogeneous Catalysis, 2nd Ed., New Age International Publishers, London, 2008. 3. G. A. Somorjai, Introduction to Surface Chemistry and Catalysis, 2nd Ed., John Wiley, London, 2002. 4. M. Thomas, W. J. Thomas, Principles and Practice of Heterogeneous Catalysis, 1st Ed., VCH Publishers, New York, 1996. 			
References/	1. A. V. Salkar, S. V. Bhosale, P. P. Morajkar, CH-6: Nanostructured WO _{3-x} Based Advanced Supercapacitors for			

Readings:

- Sustainable Energy Applications, Advances in Metal Oxides and Their Composites for Emerging Applications, Elsevier, Amsterdam, 2022, 213–238.
2. B. H. R. Suryanto, Y. Wang, R. K. Hocking, Overall Electrochemical Splitting of Water at the Heterogeneous Interface of Nickel and Iron Oxide, Nature Communications, London, 2019, 10, 5599.
 3. P. P. Morajkar, A. P. Naik, S. T. Bugde, B. R. Naik, CH-20: Photocatalytic and Microbial Degradation of Amaranth Dye, Advances in Biological Science Research – A Practical Approach, Academic Press, Boston, 2019, 327–345.

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Title of the Course	Solid State Chemistry: Concepts and Applications
Course Code	CHP-6003
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Level 400 course	
Course Objectives:	<ol style="list-style-type: none"> 1. To introduce concepts and provide fundamental knowledge of principles of materials chemistry, characterization methods and techniques 2. To provide fundamental knowledge of molecular solids, description of crystal chemistry and classification of phase structure and significance of imperfections in solids. 3. To provide basic understanding of temperature dependence of crystal structure, phase modifications and its influence on magnetic and electronic properties of materials 4. To provide a comparative evaluation of data obtained from various techniques and their use in elucidating the chemical and morphological structure of solid materials. 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. explain solid-state synthesis, crystal defects, and phase transitions in solids.	PSO1
	CO 2. apply the concepts learned to make the best choice of a characterization techniques for	PSO2, PSO3

	elucidation of solids under investigation.			
	CO 3. analyze electronic, magnetic, and thermal properties of solid state materials.		PSO1, PSO3	
	CO 4. evaluate experimental and spectroscopic data to determine material properties.		PSO1, PSO3	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>1.1 Solid state chemistry: Introduction General Principles and experimental procedure; Various methods in solid-state synthesis; Kinetics of solid-state reactions, ion exchange, and intercalation reactions.</p> <p>1.2 Crystal Defects and non-stoichiometry Types of defects. Point defects and thermodynamics; Colour centres, vacancies, and interstitials in nonstoichiometric crystals; Dislocations, mechanical properties, and reactivity of solids</p> <p>1.3 Phase Diagrams and Phase Transitions Basic Concepts and definitions; Three-component condensed systems. Martensitic transformations. Order-disorder transitions.</p>	15	CO1	K1, K2, K3, K4
Module 2:	<p>Crystal Chemistry and X-Ray Diffraction Crystal systems, Bravais lattices and Quasicrystals. Ionic structures and covalent networks. Some important structure types rock salt, zinc blende, wurtzite, nickel arsenide, rutile, and van der Waals heterostructures. Factors that influence crystal structures: valences and coordination numbers. Significance of radius ratio rule and non-bonding electron effects. Powder X-ray diffraction experiment, instrumentation.</p> <p>Introduction to single-crystal X-ray diffraction. Applications of high-temperature powder diffraction. Identification of crystal phases and evaluation of lattice characteristics</p>	15	CO2	K1, K2, K5
Module 3:	<p>3.1 Electronic Properties and Band Theory Electronic structure and band theory of solids. Band structure of metals and semiconductors.</p>	15	CO3	K1, K2, K3, K4

	<p>Magnetic properties of transition metal oxides and applications Electrical conductivity, free electron theory, fermi energy, insulators, semiconductor and conductors, band theory of semiconductor, Brillouin zones, Hall effect, the Seebeck effect, Superconductivity, BCS theory, Meissner effect, high temperature superconductor.</p> <p>3.2 Electron Microscopic Techniques</p> <p>Introduction to Electron Microscopy: Generation of electron beam, elastic and inelastic scattering of electrons by atoms.</p> <p>Scanning Electron Microscopy (SEM): Instrumentation, optics, resolution and compositional imaging, Preparation of specimen, crystallographic information from SEM and Environmental Scanning Electron Microscopy (E-SEM)</p> <p>High Resolution Transmission Electron Microscopy (HRTEM): Instrumentation, contrast mechanism, high voltage and Scanning Transmission Electron microscopy (STEM), preparation of specimen and data interpretation.</p> <p>Cryogenic Electron Microscopy (Cryo-TEM)</p>			
Module 4:	<p>4.1 X-Ray Spectroscopy</p> <p>Intensities: scattering of X-Rays and factors that affect intensities, powder x-ray pattern XRF, X-ray absorption near edge structure (XANES) and extended x-ray absorption fine structure (EXAFS): Absorption coefficient, absorption edges, resonance emission, extended absorption and photoelectron scattering.</p> <p>X-ray photoelectron spectroscopy (XPS): Surface analysis, sensitivity and specificity, photoelectron intensities, binding energies and spectra analysis.</p> <p>Instrumentation and design, characterization of transition metal oxides.</p> <p>4.2 Thermal Analysis</p> <p>Thermogravimetric analysis, Differential Thermal Analysis; Differential scanning calorimetry; Application to the characterization of materials.</p>	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:	<ol style="list-style-type: none"> 1. A. R. West, Solid State Chemistry and Its Applications, 2nd Ed., John Wiley & Sons, Chichester, 2003. 2. C. N. Banwell, E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th Ed., McGraw-Hill Education (India) Private Limited, New Delhi, 1994 3. H. V. Keer, Principles of the Solid State, 1st Ed. (Reprint 2008); New Age International (P) Ltd., (Wiley Eastern Ltd.), New Delhi, 1993.
References/ Readings:	<ol style="list-style-type: none"> 1. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed.; Cengage Learning, Boston, 2014. 2. A. Skoog, F. J. Holler, S. R. Crouch, Principles of Instrumental Analysis, 6th Ed.; Cengage Learning, Boston, 2007. 3. B. D. Fahlman, Materials Chemistry, 2nd Ed.; Springer, New York, 2011. 4. D. K. Chakraborty, Solid State Chemistry, 2nd Ed.; New Age International Publisher, New Delhi, 2010. 5. D. T. Sawyer, A. Sobkowak, J. L. Roberts Jr., Electrochemistry for Chemists, 2nd Ed.; John Wiley, New York, 1995. 6. H. R. Allcock, Introduction to Materials Chemistry, 1st Ed.; John Wiley & Sons, Hoboken, New Jersey, 2011. 7. P. N. Ross, Handbook of Fuel Cells, 7th Ed.; Wiley, New York, 2003. 8. P. van der Heide, X-ray Photoelectron Spectroscopy: An Introduction to Principles and Practices, 2nd Ed., John Wiley & Sons, Chichester, 2012. 9. P. W. Atkins, T. L. Overton, J. P. Rourke, M. T. Weller, & F. A. Armstrong, Shriver & Atkins' Inorganic Chemistry, 5th Ed.; Oxford University Press, Oxford, 2010. 10. R. H. Doremus, Glass Science, 2nd Ed.; Wiley, New York, 1973. 11. W. D. Callister, Materials Science and Engineering: An Introduction, 7th Ed.; John Wiley, New York, 2007.

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Title of the Course	Research Methodology in Physical Chemistry
Course Code	CHP-6004
Number of Credits	04
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

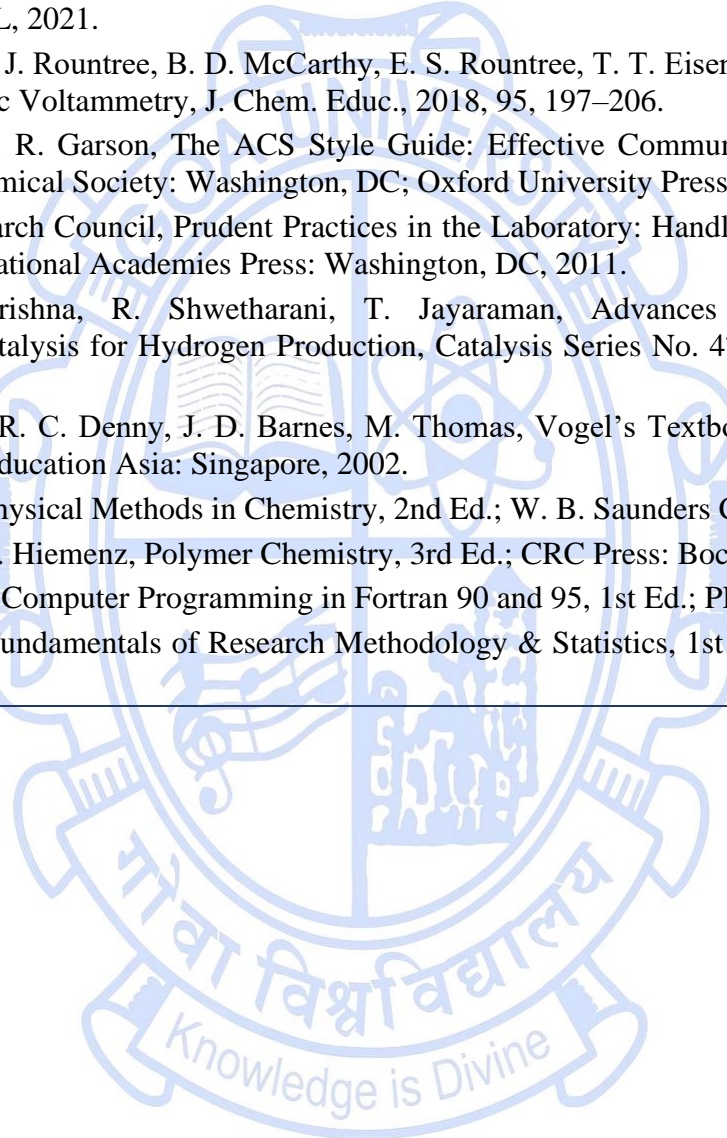
Pre-requisites for the Course:	Level 400 course	
Course Objectives:	<ol style="list-style-type: none"> 1. To understand literature review process, safe laboratory practices and ethics in research. 2. To learn computational techniques applicable to research work. 3. To utilize appropriate methods for data acquisition, analysis, and interpretation in scientific research. 4. To study the synthesis of solid-state materials and learn various instrumental techniques for characterization. 	
Course Outcomes:	Students will be able to:	Mapped to PSO
	CO 1. explain the fundamental concepts and methodologies of scientific research.	PSO1, PSO7
	CO 2. apply principles of laboratory safety and good laboratory practices in experimental work.	PSO1, PSO4
	CO 3. analyze chemical research problems using appropriate computational techniques.	PSO8, PSO6
	CO 4. evaluate the synthesis and characterization of solid-state materials for potential applications.	PSO5, PSO6

Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Literature Review, Academic Writing Brief introduction to research methodology, concept and purpose, logical format of dissertation, types and components. Sources for identifying research problem. Literature Review: types of literature, sources of literature review, primary sources, secondary sources, databases. Research methods: significance, purpose and characteristics of research, research process, necessity and scope. Academic Writing: purpose, types and features, common mistakes, conflicts of Interest, publication misconduct, redundant publications, predatory publishers and journals. Key aspects of ethics in scientific conduct.</p>	15	CO1, CO2	K1, K2, K3, K4, K5
Module 2:	<p>2.1 Safe Laboratory Practices Instructions for safe working and use of personal protective equipment (PPE). <ul style="list-style-type: none"> • The purpose and importance of Safety Data Sheet (SDS), classification and handling of Hazardous substances. • Handling, storage, quenching, and disposal of chemicals, solvents and glassware. • Experimental setup, choice of place and apparatus, precautions. • Fire Hazards (Class A, B, C, D and K), fire extinguishers and emergency procedures. 2.2 Software in Chemistry and Data plotting <ul style="list-style-type: none"> • Introduction to Software Tools for Research and Reference Management with Zotero/Mendeley. • Basics of Data plotting and advanced data plotting techniques. • Structure drawing and reaction schemes with open source / free software. </p>	15	CO2, CO3	K1, K2, K3, K4
Module 3:	<p>Experimental Techniques in Physical Chemistry <ul style="list-style-type: none"> • Synthetic methods for solid state materials: solvothermal, electrochemical, sol-gel, </p>	15	CO3, CO4	K1, K2, K3, K4,

	<p>chemical vapor deposition (CVD), physical vapor deposition (PVD), mechanical ball-milling and microwave techniques.</p> <ul style="list-style-type: none"> • Photocatalysis, electrocatalysis and photoelectrochemistry for hydrogen production, CO₂ reduction, water oxidation; solar energy conversion and wastewater treatment. • Heterogeneous catalysis for pollutant mitigation eg. Catalytic converters in automobiles, industrial waste treatment. Catalysis for organic synthesis. • Polymerization processes viz. free radical and condensation polymerization, kinetics of polymerization, polymerization techniques, determination of molecular weight and glass transition temperature, polymer processing techniques. Polymers and polymer nanocomposites for pollutant degradation. 			K5
Module 4:	<p>Instrumental Techniques Chemical data analysis with following techniques:</p> <ol style="list-style-type: none"> a. Powder XRD and Raman analysis of metal oxides, polymers, sulphides, perovskites. b. SEM & TEM for morphological analysis, EDAX, SAED. c. Cyclic Voltammetry, Linear sweep Voltammetry, Electrochemical impedance spectroscopy for electrocatalytic applications. d. ICP & AES for elemental analysis of doped compounds. 	15	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:	<ol style="list-style-type: none"> 1. C. R. Kothari, Research Methodology: Methods & Techniques, 1st Ed.; New Age International Pvt. Ltd., New-Delhi, 2004. 2. H. V. Keer, Principles of the Solid State, 1st Ed., New Age International (P) Ltd., New-Delhi, 2005. 3. H. Thompson, Polymer Nanocomposites, 1st Ed.; Nova Science Publishers, New York, 2017. 4. V. R. Gowariker, N. V. Viswanathan, J. Sreedhar, Polymer Science, 1st Ed.; Wiley Publishers, 1st edn., 1986. 			
References/ Readings:	<ol style="list-style-type: none"> 1. A. Wold, K. Dwight, Solid State Chemistry: Synthesis, Structure and Properties of Selected Oxides and Sulfides, 1st Ed.; Springer Science: New York, 1993. 			

2. E. A. Moore, L. E. Smart, Solid State Chemistry: An Introduction, 5th Ed.; CRC Press, Taylor & Francis Group: Boca Raton, FL, 2021.
3. K. Elgrishi, K. J. Rountree, B. D. McCarthy, E. S. Rountree, T. T. Eisenhart, J. L. Dempsey, A Practical Beginner's Guide to Cyclic Voltammetry, J. Chem. Educ., 2018, 95, 197–206.
4. M. Coghill, L. R. Garson, The ACS Style Guide: Effective Communication of Scientific Information, 3rd Ed.; American Chemical Society: Washington, DC; Oxford University Press: New York, 2006.
5. National Research Council, Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards, 1st Ed.; The National Academies Press: Washington, DC, 2011.
6. R. G. Balakrishna, R. Shwetharani, T. Jayaraman, Advances in Photocatalysis, Electrocatalysis and Photoelectrocatalysis for Hydrogen Production, Catalysis Series No. 47; Royal Society of Chemistry: Cambridge, 2024.
7. R. Mendham, R. C. Denny, J. D. Barnes, M. Thomas, Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed.; Pearson Education Asia: Singapore, 2002.
8. R. S. Drago, Physical Methods in Chemistry, 2nd Ed.; W. B. Saunders Co. Ltd.: Philadelphia, 2016.
9. T. Lodge, P. C. Hiemenz, Polymer Chemistry, 3rd Ed.; CRC Press: Boca Raton, FL, 2020.
10. V. Rajaraman, Computer Programming in Fortran 90 and 95, 1st Ed.; PHI Learning Pvt. Ltd.: New Delhi, 2013.
11. Y. K. Singh, Fundamentals of Research Methodology & Statistics, 1st Ed.; New Age International Pvt. Ltd.: New Delhi, 2006.

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Discipline Specific Vocational Elective (DSVE) Courses

Title of the Course	Computational Quantum Chemistry	
Course Code	CHP-6401	
Number of Credits	4 (2T +2P)	
Theory/Practical	Theory and Practical	
Level	500	
Effective from AY	2026-27	
New Course	Yes	
Bridge Course/ Value added Course	No	
Course for advanced learners	No	
Pre-requisites for the Course:	Level 400 course	
Course Objectives:	<ol style="list-style-type: none"> 1. Develop a strong theoretical foundation in quantum chemistry methods and electronic structure theories. 2. Cultivate practical computational skills for simulating and analyzing molecular systems. 3. Enable critical analysis and interpretation of computational results for chemical phenomena. 4. Empower students to design, execute, and communicate molecular modeling projects. 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. explain electronic structure theories and their applications.	PSO1, PSO2
	CO 2. discuss topics such as spectroscopy and reaction mechanisms in quantum chemistry.	PSO1, PSO2, PSO3
	CO 3. employ quantum chemistry software to perform molecular simulations and analyze data.	PSO1, PSO8

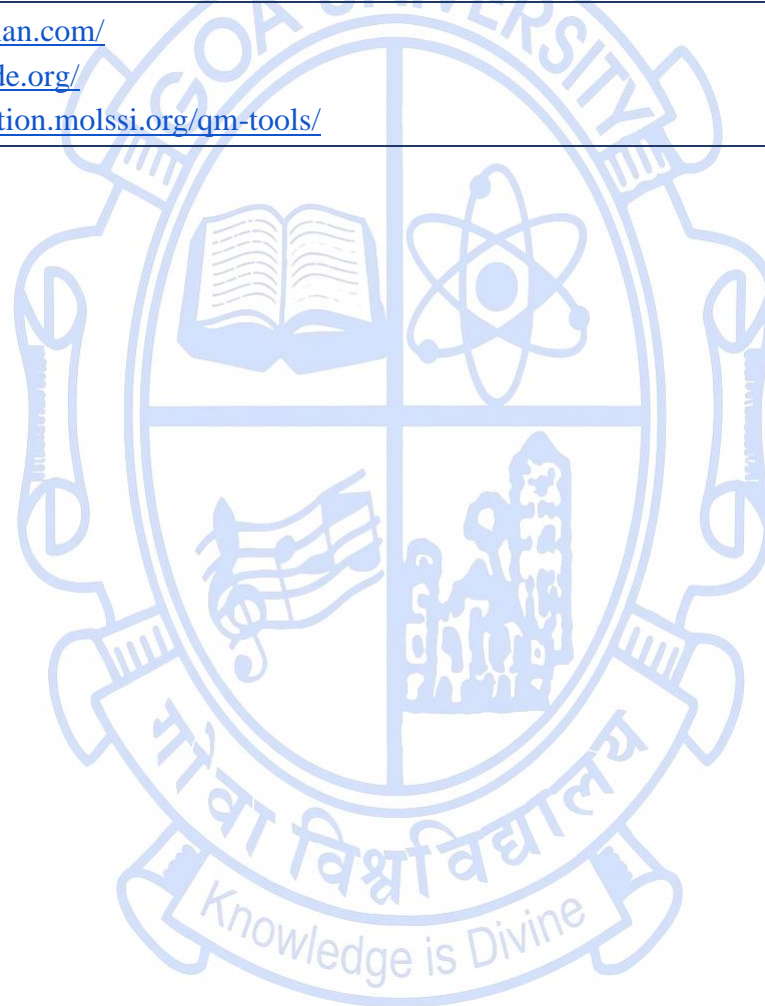
	CO 4. design and conduct molecular simulation projects, presenting findings through reports and presentations.		PSO1, PSO8
Content:		No of hours	Mapped to CO Cognitive Level
Module 1: (Theory)	<p>Quantum Chemistry Overview of the evolution of quantum theory: From classical mechanics to quantum mechanics; Key experiments (blackbody radiation, photoelectric effect, atomic spectra) and their implications; Introduction to the Schrödinger equation and its significance in chemistry; Concepts of wave functions, operators, observables, and the postulates of quantum mechanics.</p> <p>The variation method: Principle of the variational method for approximating ground state energies; Application to simple systems (e.g., hydrogen atom, helium atom, particle in a box); Construction and optimization of trial wavefunctions; Limitations and accuracy of the method.</p> <p>Perturbation Theory: Time-independent perturbation theory, First- and second-order corrections to energy and wavefunctions; Applications to systems with small perturbations; Introduction to time-dependent perturbation theory (qualitative overview).</p> <p>Potential energy surfaces: Definition and significance of PES in molecular systems; Construction and interpretation of PES for diatomic and polyatomic molecules; Role of PES in understanding molecular vibrations, chemical reactions, and transition states; Visualization and analysis of reaction coordinates and energy profiles.</p>	15	CO1 K1, K2, K3, K4, K5
Module 2: (Theory)	<p>Electronic Structure Methods Hartree–Fock theory: Self-consistent field (SCF) approach and the mean-field approximation; Construction of Slater determinants and the Pauli exclusion principle; Limitations of HF: Electron correlation and its consequences.</p> <p>Density Functional Theory (DFT): Fundamentals of DFT: Hohenberg-Kohn theorems and Kohn-Sham equations; Exchange-correlation functionals: LDA, GGA, hybrid functionals; Strengths and weaknesses of DFT for molecular systems.</p> <p>Post-Hartree–Fock methods (CI, CC, MP2)</p>	15	CO2 K1, K2, K3, K4, K5

	<p>Configuration Interaction (CI): Concept and types (CIS, CISD, etc.); Coupled Cluster (CC) methods: CCSD, CCSD(T), and their applications; Møller–Plesset Perturbation Theory (MP2): Second-order corrections and practical use.</p> <p>Comparison of accuracy and computational cost among methods. Basis sets: types and selection; Role of basis sets in quantum chemical calculations; Common types: Minimal, split-valence, polarized, diffuse, correlation-consistent; Criteria for selecting appropriate basis sets for different problems; Basis set superposition error (BSSE) and counterpoise correction.</p>			
PRACTICAL (2 CREDIT)				
Module 3: (Practical)	<p>Quantum Chemistry Software</p> <ol style="list-style-type: none"> i. Installation, interface, and basic workflow of quantum chemistry packages (Gaussian, ORCA, Psi4, etc.). ii. File formats: Input, output, and checkpoint files. iii. Geometry optimization: Preparing input files, specifying molecular geometry (Cartesian, Z-matrix). iv. Single-point energy calculations: Purpose and setup. v. Frequency analysis: Calculating vibrational frequencies, zero-point energy, and thermodynamic properties. vi. Troubleshooting common errors in job submissions. vii. Using visualization software (e.g., GaussView, Avogadro, Jmol) to interpret results. viii. Visualizing molecular structures, normal modes, and vibrational spectra. ix. Plotting and analyzing molecular orbitals and electron density maps. x. Geometry optimization and energy calculation. xi. Frequency analysis and IR spectra prediction. xii. Visualization and interpretation of molecular orbitals. <p>(Step-by-step calculations for H₂, water, and ammonia, hydrogen peroxide, benzene, [Ni(CO)₄])</p>	30	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5

Module 4: (Practical)	Molecular Modeling <ol style="list-style-type: none"> i. Perform HF and DFT calculations for molecules like CO, NH₃, and CH₄. ii. Compare computed properties (bond lengths, angles, dipole moments) with experimental data. iii. Analyze differences between methods and discuss sources of error. iv. Model simple reactions (e.g., S_N2, proton transfer) using quantum chemical calculations. v. Locate transition states and calculate activation energies. vi. Map reaction pathways vii. Interpret potential energy profiles. viii. Select a set of molecules and compute properties using both HF and DFT. ix. Compare results for properties such as ionization energy, electron affinity, and vibrational frequencies. x. Discuss the strengths and limitations of each method for different chemical problems. 	30	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5
Pedagogy:	<p>Theory: Mainly lectures and tutorials. Prelab exercise/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.</p> <p>Practicals: Students should be given suitable lab handouts, pre- and post-lab assignments and explanations revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment.</p>			
Texts:	<ol style="list-style-type: none"> 1. C. J. Cramer, Essentials of Computational Chemistry: Theories and Models, 2nd Ed., John Wiley & Sons, Ltd., USA, 2004. 2. F. Jensen, Introduction to Computational Chemistry, 2nd Ed., John Wiley & Sons, Ltd., UK, 2007. 3. I. N. Levine, Quantum Chemistry, 7th Ed., Pearson India Education Services Pvt. Ltd., India, 2016. 4. J. B. Foresman and Æ. Frisch, Exploring Chemistry with Electronic Structure Methods, 3rd Ed., Gaussian, Inc. Wallingford, CT, USA, 2015. 			
References/	<ol style="list-style-type: none"> 1. D. A. McQuarrie, Quantum Chemistry, 2nd Ed., University Science Books, United States, 2007. 			

Readings:	<ol style="list-style-type: none">2. E. G. Lewars, Computational Chemistry: Introduction to the Theory and Applications of Molecular and Quantum Mechanics, 4th Ed., Springer International Publishing, Switzerland, 2024.3. P. W. Atkins and J. de Paula, Atkins' Physical Chemistry, 8th Ed., Oxford University Press, United Kingdom, 2006.4. Q. Sun, Python for Quantum Chemistry: A Full Stack Programming Guide, 1st Ed., Elsevier, Netherlands, 2025.
Web Resources:	<ol style="list-style-type: none">1. https://gaussian.com/2. https://psicode.org/3. https://education.molssi.org/qm-tools/

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Title of the Course	Applied electrochemistry for Energy conversion and storage
Course Code	CHP-6402
Number of Credits	4 (2T +2P)
Theory/Practical	Theory and Practical
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Level 400 courses	
Course Objectives:	<ol style="list-style-type: none"> 1. To understand fundamentals of electrochemical measurement techniques for application in energy storage and conversion 2. To study the applications of electrochemistry for corrosion, batteries, solar cells and supercapacitors 3. To apply the electrochemical characterization techniques to characterize energy devices and interpret the data 4. To design electrochemical systems for energy storage and conversion technologies 	
Course Outcomes:	Students will be able to:	Mapped to PSO
	CO 1. explain principles governing the functioning of energy storage and conversion devices	PSO1, PSO2
	CO 2. analyze the performance of electrochemical energy devices using key parameters such as efficiency, energy density, cycle life, etc.	PSO2, PSO4, PSO5, PSO6
	CO 3. apply the concepts electrochemistry for targeted energy applications by selecting	PSO2, PSO4, PSO5,

	appropriate electrode material, electrolyte, etc.		PSO6	
	CO 4. design the electrochemical device and evaluate its performance and stability.		PSO6, PSO7	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1: (Theory)	<p>1.1. Electroanalytical Techniques Principles and applications of the following techniques: Linear sweep voltammetry, cyclic voltammetry, Electrochemical Impedance spectroscopy.</p> <p>1.2. Electrochemistry of Corrosion Corrosion and electrochemical kinetics. Mixed electrode and mixed potential. Overpotential and polarization. Current density – potential curves and determination of corrosion current density. Hydrogen and oxygen overpotentials and corrosion. Types of electrolytic corrosion and forms of localized corrosion, practical cases of corrosion. Corrosivity and passivity. Corrosion prevention. corrosion inhibitors. corrosion testing. cathodic and anodic protection.</p>	15	CO1, CO2	K1, K2, K3
Module 2: (Theory)	<p>2.1. Electrochemical Storage and Conversion devices Electrical characteristics of batteries. Batteries with aqueous and non-aqueous electrolytes. Lithium ion batteries, Sodium ion batteries. Working principles of fuel cells. Types of fuel cells. Properties of electrical double layer capacitors. Energy density. Power density. Electrochemical supercapacitors with carbon electrodes. Pseudocapacitor electrodes and supercapacitors. Hybrid supercapacitors: metal oxide (MeOx/C) and electronically conducting polymer/carbon (ECP/C) types.</p> <p>2.2. Electrocatalysis and Photoelectrochemistry Electrocatalytic surfaces. Structure stability and mass transport on electrode surfaces, Basic electrocatalytic mechanisms and kinetics. Electrochemistry of methanol electrooxidation. Types of electrocatalysts, Electrochemistry of ORR and HER.</p>	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5

	Photoelectrochemical cell design, photoconversion efficiency, photoelectrochemical water splitting. Principles and working of first- and second-generation solar cells. Fabrication and operational principles of third generation photovoltaics: perovskite solar cells, dye-sensitized solar cells, quantum dot solar cells. Tandem photovoltaic cells			
PRACTICALS (2 CREDITS)				
Module 3: (Practical)	<p>Any 10 experiments to be performed from the following:</p> <ol style="list-style-type: none"> To study the electrochemical behavior of the redox systems Pb/Pb^{2+} and Pb^{2+}/Pb^{4+} with slow scan rate CV To determine the exchange current density and the symmetry coefficient of a redox system by cyclic voltammetry To study the redox electrochemistry of ferrocene in a non-aqueous electrolyte solution with cyclic voltammetry and determine the formal redox potential To study anodic and cathodic conversions of aromatic hydrocarbon in non-aqueous electrolyte solution To prepare and characterize a supercapacitor electrode To determine the charge transfer resistance (R_{ct}) from the impedance plot of platinum electrode in an electrolyte solution containing a redox system. To determine the corrosion current of metal electrodes immersed in solution of different concentration of respective metal ions To obtain a polarization curve of corroding metal electrode and find corrosion potential and current. To assemble, characterize and test zinc-air battery. To determine Tafel slope for hydrogen evolution reaction (HER) using MoS_2 electrocatalyst To obtain I-V curve of Pt electrode in aqueous perchloric acid containing methanol. To study indirect electrolysis of acetyl acetone in non-aqueous electrolyte solution 	60	CO2, CO3, CO4	K2, K3, K4, K5

	<ul style="list-style-type: none"> xiii. To verify Nernst equation by studying the pH dependence of hydroquinone/quinone redox couple xiv. To prepare modified glassy carbon electrode for electrocatalytic oxidation of methanol xv. To determine overpotential of hydrogen evolution reaction on NiO electrocatalyst xvi. To determine diffusion controlled mechanism of an electrochemical reaction from cyclic voltammetry xvii. To compare the activity of different electrocatalyst for oxygen evolution reaction using linear sweep voltammetry. xviii. To fabricate a simple dye sensitized solar cell (DSSC) xix. To synthesize graphene oxide by hummers method xx. To prepare rGO/metal oxide or polymer composite electrodes xxi. To fabricate electrode for electrocatalytic application using synthesized materials on conductive substrate. xxii. To measure electrical conductivity of electrode films using multimeter. xxiii. To fabricate thin film electrode using drop casting/ spin coating/ blade coating method xxiv. To prepare modified glassy carbon electrode for hydrogen evolution reaction. xxv. To prepare electrode and assemble a coin cell battery using separators and test its efficiency. xxvi. To synthesize anode material for sodium-ion battery and fabricate the anode for coin cell battery xxvii. To calculate specific capacity of supercapacitor electrode using experimental data. xxviii. To study galvanic corrosion between two metal pairs (Copper and Zinc). 			
Pedagogy:	Theory: Mainly lectures and tutorials. Prelab exercise/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			

	<p>nature to enable peer group learning.</p> <p>Practicals: Students should be given suitable lab handouts, pre- and post-lab assignments and explanations revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment.</p>
Texts:	<ol style="list-style-type: none"> 1. A. J. Bard, M. Stratmann, S. Licht, Encyclopedia of Electrochemistry, Semiconductor Electrodes and Photoelectrochemistry, 1st Ed., Wiley-VCH: Weinheim, 2002. 2. A. Vincent, B. Scrosati, Modern Batteries, 1st Ed., John Wiley & Sons: New York, 1997. 3. E. Santos, W. Schmickler, Catalysis in Electrochemistry: From Fundamental to Strategies for Fuel Cell Development, 1st Ed., Wiley: New York, 2011. 4. J. Lipkowski, P. N. Ross, Electrocatalysis, 1st Ed., Wiley-VCH: New York, 1998. 5. J. O'M. Bockris, A. K. N. Reddy, Modern Electrochemistry, Vol. 1, 2A and 2B, 2nd Ed.; Kluwer Academic Publishers: New York, 2002. 6. R. Holze, Experimental Electrochemistry: A Laboratory Textbook, 2nd Ed.; Wiley-VCH: Weinheim, 2019. 7. S. Giménez, J. Bisquert, Photoelectrochemical Solar Fuel Production: From Basic Principles to Advanced Devices, 1st Ed., Springer International Publishing: Cham, 2016.
References/ Readings:	<ol style="list-style-type: none"> 1. C. Jiang, S. J. A. Moniz, A. Wang, T. Zhang, J. Tang, Photoelectrochemical Devices for Solar Water Splitting – Materials and Challenges, Chem. Soc. Rev., 46 (15), 4645–4660, 2017. 2. E. Bakker, Y. Qin, Electrochemical Sensors, Anal. Chem., 78 (12), 3965–3984, 2006. 3. G. N. Kamau, Surface Preparation of Glassy Carbon Electrodes, Analytica Chimica Acta, 207, 1–16, 1988. 4. M. Arunkumar, A. Paul, Importance of Electrode Preparation Methodologies in Supercapacitor Applications, ACS Omega, 2, 8039–8050, 2017. 5. M. Stanley Whittingham, R. F. Savinell, T. Zawodzinski, Introduction: Batteries and Fuel Cells, Chem. Rev., 104 (10), 4243–4244, 2004. 6. N. Perez, Electrochemistry and Corrosion Science, 2nd Ed.; Springer, Cham, Switzerland, 2016. 7. P. P. Morajkar, M. M. Naik, Advances in Nano and Biochemistry: Environmental and Biomedical Applications, 1st Ed.; Elsevier, Amsterdam, 2023 8. V. S. Bagotsky, A. M. Skundin, Y. M. Volfkovich, Electrochemical Power Sources: Batteries, Fuel Cells, and Supercapacitors, 1st Ed.; Wiley, Hoboken, NJ, 2015.

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Title of the Course	Polymer Chemistry for Functional Materials
Course Code	CHP-6403
Number of Credits	4 (2T +2P)
Theory/Practical	Theory and Practical
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Level 400 course	
Course Objectives:	<ol style="list-style-type: none"> 1. To introduce physical and chemical aspects of polymer chemistry. 2. To understand kinetics of polymerization, characteristics and applications of polymers. 3. To provide hands-on experience in polymer synthesis techniques such as solution, precipitation, and suspension polymerizations. 4. To equip students with the knowledge and skills to characterize polymers using modern instrumental techniques (GPC, FT-IR, TGA, DSC, contact angle, conductivity). 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. explain the fundamental concepts, terminology, and classification of polymers, including molecular geometry, tacticity, and types of polymers.	PSO1, PSO7
	CO 2. apply mathematical and instrumental methods for determining molecular weight using end-group analysis, viscometry, Mark–Houwink–Sakurada parameters.	PSO1, PSO7

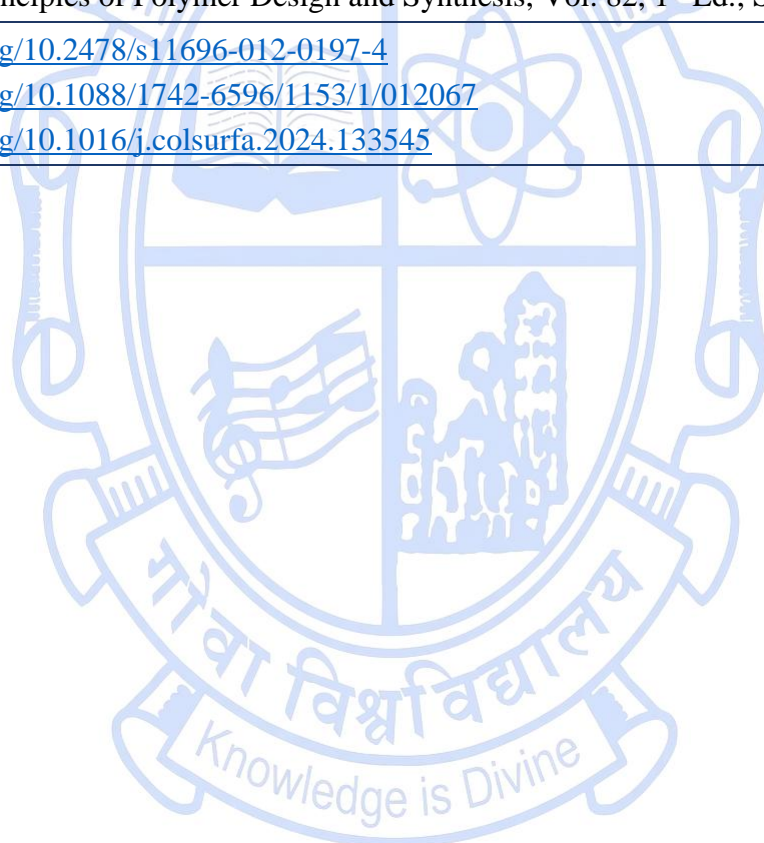
	CO 3. analyze polymer properties such as purity, acid/saponification value, and molecular weight using chemical and instrumental approaches		PSO3, PSO4	
	CO 4. evaluate experimental data from viscometry, GPC, TGA, FTIR, and contact angle measurements to determine polymer quality, stability, and performance		PSO3, PSO4	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1: (Theory)	<p>Polymer chemistry</p> <p>Terminology- Intermolecular forces and polymer types - Chemical and geometrical structure of macromolecules, Classification of polymers. Polymer nomenclature- Polymer tacticity and geometry.</p> <p>Thermoplastics and thermosets- Plastics, elastomers, fibres. Concepts of functionality, terminal groups, homopolymers and copolymers etc.</p> <p>Addition and condensation polymers- linear, branched and cross-linked polymers, graft and block copolymers.</p> <p>Kinetics of polymerization: Free radical chain polymerization; Anionic polymerization, Cationic polymerization, polycondensation; catalyzed polycondensation.</p>	15	CO1	K1, K2, K3, K4
Module 2: (Theory)	<p>Molecular weight of polymers and its determination</p> <p>Concept of average molecular weight - number average, weight average and viscosity average molecular weight - molecular weight distribution theoretical considerations and empirical distribution model - degree of polymerization and molecular weight - influence of molecular weight on physical properties. Polydispersity and Polydispersity index (PDI), Glass transition temperature and other thermal transitions. Importance of T_g plasticizers and their action</p> <p>Molecular weight determination – end-group analysis, colligative property, light scattering, ultracentrifugation and gel permeation chromatography methods. Degree of polymerization and its impact on MW and mechanical properties. Mark-Houwink-Sakurada (MHS) equation, Gel permeation Chromatography.</p>	15	CO2	K1, K2, K3, K4, K5
PRACTICALS (2 CREDITS)				

<p>Module 3: (Practical)</p>	<p>Minimum 10 experiments to be performed from the following:</p> <ol style="list-style-type: none"> i. Synthesis of poly(vinyl acetate) / poly(methyl methacrylate) by solution polymerization. ii. Preparation of polystyrene by bulk polymerization method. iii. Synthesis of polyacrylonitrile by precipitation polymerization. iv. Preparation of poly(methyl methacrylate) by suspension polymerization technique v. Determination of percentage purity of the given epoxy resins. vi. Determination of acid value of a given sample (linseed oil/tung oil). vii. Determination of saponification value and % Purity of Plasticizer. viii. Determination of iodine number of a polymer/plasticizer/Linseed oil. ix. Determination of the conformation and molecular weight of polystyrene in solution by viscometry using a Cannon–Fenske Viscometer. x. Estimation of molecular weight of polyethylene glycol by end group analysis xi. Determination of molecular weight of PS / poly (methyl acrylate) in toluene / polyacrylamide-aq.NaNO₂ solution by viscometry measurements. xii. Determination of iodine absorption value, moisture content, bulk density, bulk volume of carbon black. xiii. Determination of the conformation and molecular weight of polystyrene in solution by viscometry using a Cannon–Fenske Viscometer. xiv. Determination of Molecular Weight and Polydispersity Index using Gel Permeation Chromatography (GPC) – Demonstration. xv. Integrated Thermal and Spectroscopic Analysis of Calcium Acetate Monohydrate using TGA–FTIR–Computational methods. xvi. Thermogravimetric Analysis (TGA) of the thermal stability of poly(methyl methacrylate) films. xvii. Determination of Calorific Value of Plastic Waste Fuels using a Bomb Calorimeter xviii. Synthesis of polyaniline in the presence of anionic surfactant (SDS) / nonionic surfactant (Triton X-100) / cationic surfactant (CTAB) xix. Comparative characterization of polyaniline samples synthesized with different surfactants using UV–Vis, FTIR, and conductivity measurements 	<p>60</p>	<p>CO3, CO4</p>	<p>K1, K2, K3, K4, K5</p>
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	xx. Study of the effect of surfactants on the electrical conductivity of polyaniline xxi. Determination of contact angle and surface wettability of polymer films. xxii. Determination of the surface energy of polymer films using contact angle measurements with multiple liquids.			
Pedagogy:	<p>Theory: Mainly lectures and tutorials. Prelab exercise/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.</p> <p>Practicals: Students should be given suitable lab handouts, pre- and post-lab assignments and explanations revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment.</p>			
Texts:	<ol style="list-style-type: none"> 1. A. M. James, <i>Practical Physical Chemistry</i>, 1st Ed.; Longman: London, 1970. 2. D. P. Shoemaker, C. W. Garland, J. I. Steinfeld, J. W. Nibler, <i>Experiments in Physical Chemistry</i>, 8th Ed., McGraw-Hill Education, New York, 2009. 3. F. Daniels, J. H. Mathews, <i>Experimental Physical Chemistry</i>, 5th Ed., McGraw-Hill, New York, Reprint 2022. 4. F. W. Billmeyer, Jr., <i>Textbook of Polymer Science</i>, 3rd Ed.; Wiley-Interscience: Massachusetts, 2014. 5. J. R. Fried, <i>Polymer Science and Technology</i>, 3rd Ed., Pearson Education, New York, 2014. 6. P. Bahadur, N. V. Sastry, <i>Principles of Polymer Science</i>, 1st Ed.; Narosa Publishing House: New Delhi, 2003. 7. R. Sinha, <i>Outlines of Polymer Technology: Manufacture of Polymers</i>, 1st Ed.; PHI Learning Pvt. Ltd.: New Delhi, 2000. 8. R. Sinha, <i>Outlines of Polymer Technology: Processing of Polymers</i>, 1st Ed.; PHI Learning Pvt. Ltd.: New Delhi, 2003. 9. V. R. Gowariker, N. V. Viswanathan, J. Sreedhar, <i>Polymer Science</i>, 1st Ed.; Wiley Eastern Ltd.: New Delhi, 1986. 			
References/ Readings:	<ol style="list-style-type: none"> 1. E. A. Turi, <i>Thermal Characterization of Polymeric Materials</i>, 1st Ed.; Academic Press Inc.: New York, 1997. 2. J. M. G. Cowie, V. Arrighi, <i>Polymers: Chemistry and Physics of Modern Materials</i>, 3rd Ed., CRC Press, Boca Raton, FL, 2007. 3. J. M. Margolis, <i>Polymer Chemistry: A Practical Approach</i>, 2nd Ed., Wiley-VCH, Weinheim, Germany, 2010. 4. J. R. Fried, <i>Polymer Science and Technology</i>, 2nd Ed., Prentice Hall, Upper Saddle River, NJ, 2014. 5. M. Chanda, <i>Introduction to Polymer Science and Chemistry: A Problem-Solving Approach</i>, 1st Ed.; CRC Press: Boca Raton, FL, 2006. 			

	<ol style="list-style-type: none">6. M. P. Stevens, Polymer Chemistry: An Introduction, 3rd Ed., Oxford University Press, New York, 2005.7. P. Atkins, J. de Paula, Physical Chemistry, 10th Ed., Oxford University Press, Oxford, UK, 2014.8. P. J. Flory, Principles of Polymer Chemistry, 2nd Ed., Cornell University Press, Ithaca, NY, 2012.9. R. A. Alberty, R. J. Silbey, Physical Chemistry, 5th Ed., Wiley, Hoboken, NJ, 2004.10. R. J. Young, P. A. Lovell, Introduction to Polymers, 3rd Ed., CRC Press, Boca Raton, FL, 2011.11. R. M. Silverstein, F. X. Webster, B. J. Kimley, D. L. Bryce, S. D. Samant, V. S. Nadkarni, Spectrometric Identification of Organic Compounds (Indian Adaptation), 8th Ed.; Wiley: New Delhi, 2022.12. W. F. Su, Principles of Polymer Design and Synthesis, Vol. 82, 1st Ed.; Springer: Singapore, 2013.
Web Resources:	<ol style="list-style-type: none">1. https://doi.org/10.2478/s11696-012-0197-42. https://doi.org/10.1088/1742-6596/1153/1/0120673. https://doi.org/10.1016/j.colsurfa.2024.133545

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SEMESTER IV

Generic Elective (GE) Courses

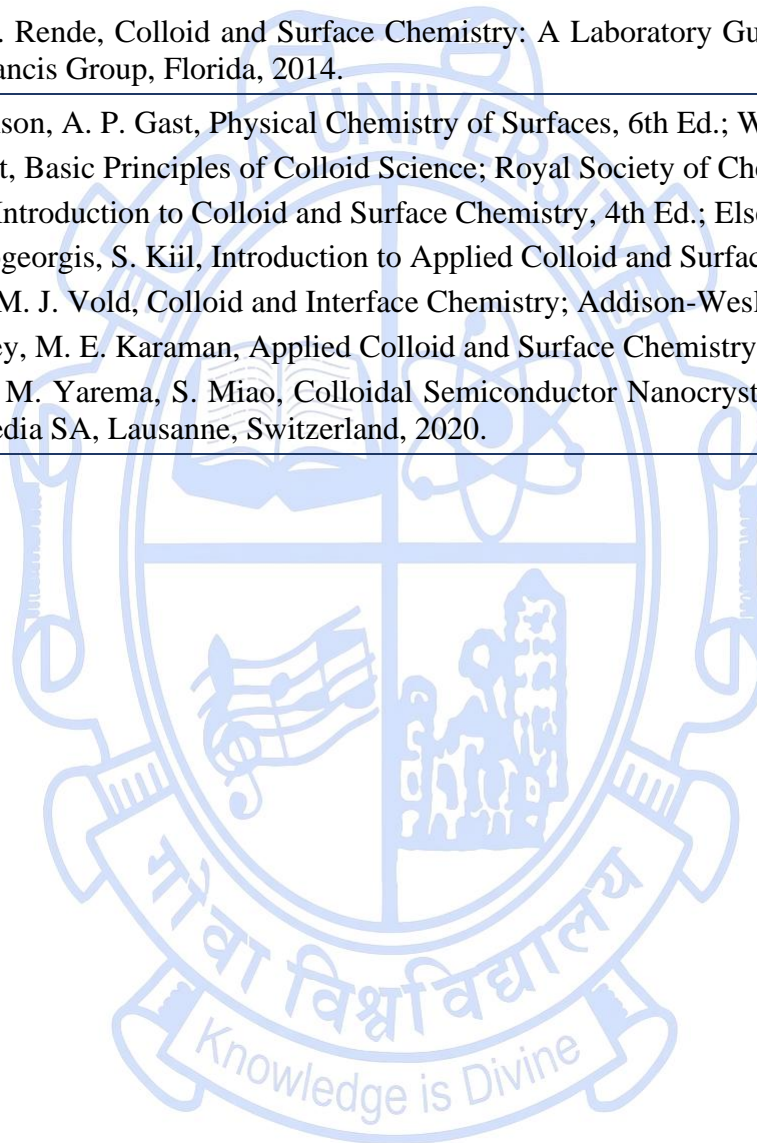
Title of the Course	Colloids and Surface Chemistry	
Course Code	CHP-6201	
Number of Credits	4	
Theory/Practical	Theory	
Level	500	
Effective from AY		
New Course	No	
Bridge Course/ Value added Course	No	
Course for advanced learners	No	
Pre-requisites for the Course:	Level 400 course	
Course Objectives:	<ol style="list-style-type: none">1. To introduce fundamental concepts of colloidal systems and study physicochemical properties of colloids2. To study colloidal stability for coagulation, flocculation, sedimentation, and learn surface and interfacial phenomena3. To learn the synthesis methods of colloidal preparation for lab practicals and research4. To acquaint students with the techniques and knowledge necessary to evaluate and interpret experimental data on colloidal behavior.	
Course Outcomes:	Students will be able to:	Mapped to PSO
	CO 1. explain physicochemical properties of colloids	PSO1, PSO2

	CO 2. apply the DLVO theory and other colloidal properties for stability measurement of colloids		PSO1, PSO2, PSO3, PSO7
	CO 3. analyze the design, synthesize and characterize various colloidal systems to understand their properties		PSO3, PSO4, PSO5, PSO6
	CO 4. evaluate the behavior and properties of colloidal systems.		PSO4, PSO5, PSO6, PSO7
Content:		No of hours	Mapped to CO Cognitive Level
Module 1:	<p>Colloids and Liquid Surfaces Colloids: structural characteristics of colloidal system, preparation and purification. Microscopic picture of liquid surface. Surface energy, surface tension and its measurement. Laplace equation, Surfactant and reduction of surface tension. Curved liquid surfaces. Contact angle and its measurements. Wetting and dewetting. Important wetting geometries.</p> <p>Nucleation in colloidal systems: Classical nucleation theory, heterogenous and homogenous nucleation.</p>	15	CO1, CO2 K1, K2, K3, K4
Module 2:	<p>Electrostatic Forces, Electrokinetic Phenomenon and colloidal stability Charged colloids, Electrical double layer. Surface interactions between surfaces (dipole, induced dipole, H-bonding) Electrokinetic phenomena: concept of zeta potential. Electroosmosis and streaming potential. Electrophoresis and sedimentation potential.</p> <p>Surface forces: Van der Waals forces between molecules. Surface energy and Hamaker constant. Measurement of surface forces. The DLVO theory</p> <p>Charged surfaces such as mercury, silver iodide and oxides. Measurement of surface charge densities</p> <p>Factors affecting colloidal stability. Effect of electrolyte, Flocculation and coagulation, Kinetics of coagulation, Steric stabilization of solid and liquid colloids</p>	15	CO1, CO2, CO4 K1, K2, K4, K5
Module 3:	<p>Preparation and application of colloids Chemical methods for synthesis of colloids: Sol-gel method, polyol synthesis, plasma</p>	15	CO3, CO4 K3, K4, K5, K6

	<p>enhanced chemical vapor deposition, hydrothermal synthesis.</p> <p>Colloidal synthesis of semiconductor nanoparticles: Hot-injection synthesis. Synthesis of colloidal core-shell heterostructures.</p> <p>Surface directed colloidal patterning: Colloidal self-assembly approaches</p> <p>Reducing agents in colloidal nanoparticle synthesis.</p> <p>Colloids as drug delivery agents, Colloidal nanocrystals for optical applications and solar cells, Biomedical applications.</p>			
Module 4:	<p>Surfactants, Micelles, Emulsions and Thin Liquid Films</p> <p>Classification of surfactants. Solubilization and micelle formation</p> <p>Spherical micelles: cmc and influence of temperature. Thermodynamics of micellization. Structure of surfactant aggregates.</p> <p>Emulsions: Macro and microemulsions, properties, formation and factors affecting the stability. Evolution and aging. Coalescence and demulsification. Size of droplets. Elasticity of surfactant films.</p> <p>Thin films on surfaces of liquids: Introduction and phases. Bubbles and foams. Optical and X-Ray methods to study monolayers.</p> <p>Langmuir Blodgett Transfer in colloids to create ultrathin films.</p>	15	CO1, CO2, CO3, CO4	K2, 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:	<ol style="list-style-type: none"> 1. D. Meyers, Surfaces, Interfaces and Colloids, Principles and Applications, 2nd Ed.; John Wiley & Sons, New York, 1999. 2. E. D. Shchukin, A. V. Pertsov, E. A. Amelina, A. S. Zelenev, Studies in Interface Science, Colloid and Surface Chemistry, Elsevier, Netherlands, 2001. 3. F. Caruso, Colloids and Colloid Assemblies, Wiley-VCH, Germany, 2004. 4. H. J. Butt, K. Graf, M. Kappl, Physics and Chemistry of Interfaces, Wiley-VCH, Germany, 2003. 5. K. S. Birdi, Surface and Colloid Chemistry, Principles and Applications, Taylor & Francis Group, New York, 2010. 6. P. C. Heimenz, R. Rajagopalan, Principles of Colloid and Surface Chemistry, 3rd Ed.; Marcel Dekker, Inc., New 			

	<p>York, 1997.</p> <p>7. S. Bucak, D. Rende, Colloid and Surface Chemistry: A Laboratory Guide for the Exploration of the Nano World, Taylor & Francis Group, Florida, 2014.</p>
References/ Readings:	<ol style="list-style-type: none"> 1. A. W. Adamson, A. P. Gast, Physical Chemistry of Surfaces, 6th Ed.; Wiley-VCH, Germany, 1997. 2. D. H. Everett, Basic Principles of Colloid Science; Royal Society of Chemistry, Cambridge, UK, 2007. 3. D. J. Shaw, Introduction to Colloid and Surface Chemistry, 4th Ed.; Elsevier, Oxford, 1992. 4. G. M. Kontogeorgis, S. Kiil, Introduction to Applied Colloid and Surface Chemistry; Wiley, Chichester, UK, 2016. 5. R. D. Vold, M. J. Vold, Colloid and Interface Chemistry; Addison-Wesley, Reading, MA, 1983. 6. R. M. Pashley, M. E. Karaman, Applied Colloid and Surface Chemistry, 2nd Ed.; Wiley, Chichester, UK, 2021. 7. V. Lesnyak, M. Yarema, S. Miao, Colloidal Semiconductor Nanocrystals: Synthesis, Properties and Applications; Frontiers Media SA, Lausanne, Switzerland, 2020.

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Title of the Course	Nanoscience: Concepts and Applications
Course Code	CHP-6202
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Level 400 course	
Course Objectives:	<ol style="list-style-type: none"> To learn various concepts of nanoscience. To describe the various methods employed in the synthesis of nanomaterials. To analyze the diverse characterization techniques employed in the study of nanomaterials. To study the applications of nanomaterials in various scientific and in industry. 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. explain of various synthesis and characterization techniques for nanomaterials	PSO1, PSO2, PSO3
	CO 2. apply theoretical knowledge to dissertation and research activities effectively	PSO1, PSO3
	CO 3. analyze the magnetic, electrical, optical, and catalytic properties of nanomaterials	PSO1, PSO2, PSO3
	CO 4. evaluate the diverse applications of nanomaterials in scientific and technological contexts.	PSO1, PSO3

Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Essential Concepts of nanoscience Nanoscale, quantum effects, thermal properties of nanomaterials, optical properties of nanomaterials, electrical properties of nanomaterials, Metallic nanowires and quantum conductance, Surface to volume ratio of nanoparticles, surface effects and surface energy on Nanoparticle surface. Chemistry of solid surfaces.</p>	10	CO1, CO2, CO4	K1, K2, K3, K4, K5
Module 2:	<p>Methods of nanomaterial synthesis Principles, methods, formation mechanism and structures of nanomaterials for: Gas-phase processes, Liquid-phase processes, Solid-phase processes, Self-assembly processes</p>	15	CO1, CO2, CO4	K1, K2, K3, K4, K5
Module 3:	<p>Characterization techniques Beam Probe methods (SEM, TEM), Scanning probe method (STM, AFM), optical method: principle, sample preparation technique and applications. Case studies: core-shell nanoparticles, metal nanoparticles, composite nanoparticles.</p>	10	CO1, CO3, CO4	K1, K2, K3, K4, K5
Module 4:	<p>Selected nanomaterials of commercial importance Silica: discussion of sol-gel and liquid crystal synthesis method, self-assembly of colloidal silica particles, photoluminescence property of opals, different surface functionalization methods and application study. Gold: Different colloidal synthesis methods, self-assembly methods, surface Plasmon resonance (SPR) of colloidal gold nanoparticles surface functionalization strategies and application study. CdSe: Different synthesis methods, synthesis of core-shell particles, Study of CdSe excitons and CdSe quantum dots, functionalization and application study. Iron oxide (Fe₃O₄): Different synthesis methods, Superparamagnetism property of nanoparticles, Hysteresis and magnetisation of Fe₃O₄ nanomaterial, catalytic and Biomedical applications. Carbon: synthesis methods for carbon nanotubes, Graphene and Buckminster fullerene,</p>	15	CO1, CO3, CO4	K1, K2, K3, K4, K5

	structural study of these materials, electrical property study of these materials, surface functionalization strategies and application study.			
Module 5:	<p>Nanomaterials: applications, risks, and toxicity</p> <p>Heterogeneous catalysts for the synthesis of fine chemicals, Polymer vesicles for drug delivery, Surface-modified metal nanoparticles for recognition of toxic organic molecules, Use of nano TiO₂ and ZnO for water and air pollution control, Carbon Materials for Energy Storage, Thermoelectric Nanomaterials, Toxicity of inorganic-based, carbon-based, composite-based nanomaterials, environmental, health, and safety issues.</p>	10		
Pedagogy:	Mainly lectures and tutorials. Seminars / term papers / assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.			
Texts:	<ol style="list-style-type: none"> 1. C. N. R. Rao, A. Govindaraj, Nanotubes and Nanowires, 1st Ed.; Royal Society of Chemistry: Cambridge, 2005. 2. G. Cao, Nanostructures and Nanomaterials, 1st Ed.; Imperial College Press: London, 2004. 3. L. Cademartiri, G. A. Ozin, Concepts of Nanochemistry, 1st Ed.; Wiley-VCH: Weinheim, 2009. 			
References/ Readings:	<ol style="list-style-type: none"> 1. A. Barhoum, A. S. H. Makhlof, Emerging Applications of Nanoparticles and Architecture Nanostructures: Current Prospects and Future Trends, 1st Ed.; Elsevier: Amsterdam, 2018. 2. B. Zhang, Physical Fundamentals of Nanomaterials, 1st Ed.; Chemical Industry Press: Beijing, 2018. 3. C. M. Hussain, Handbook of Nanomaterials in Analytical Chemistry, 1st Ed.; Elsevier: Amsterdam, 2020. 4. C. P. Poole, F. J. Owens, Introduction to Nanotechnology, 1st Ed.; John Wiley and Sons: Hoboken, NJ, 2003. 5. E. Roduner, Nanoscopic Materials: Size-Dependent Phenomena, 1st Ed.; RSC Publishing: Cambridge, 2006. 6. G. A. Ozin, A. C. Arsenault, Nanochemistry: A Chemical Approach to Nanomaterials, 1st Ed.; RSC Publishing: Cambridge, 2005. 7. H. S. Nalwa (Ed.), Encyclopedia of Nanoscience and Nanotechnology, 1st Ed.; American Scientific Publishers: Stevenson Ranch, CA, 2004. 8. J. M. Tour, Molecular Electronics, 1st Ed.; Imperial College Press: London, 2004. 9. R. G. Chaudhuri, S. Paria, Core/Shell Nanoparticles: Classes, Properties, Synthesis Mechanisms, Characterization, and Applications, Chem. Rev., 2012, 112, 2373–2433. 			

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Title of the Course	Nuclear and Radiation Chemistry
Course Code	CHP-6203
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

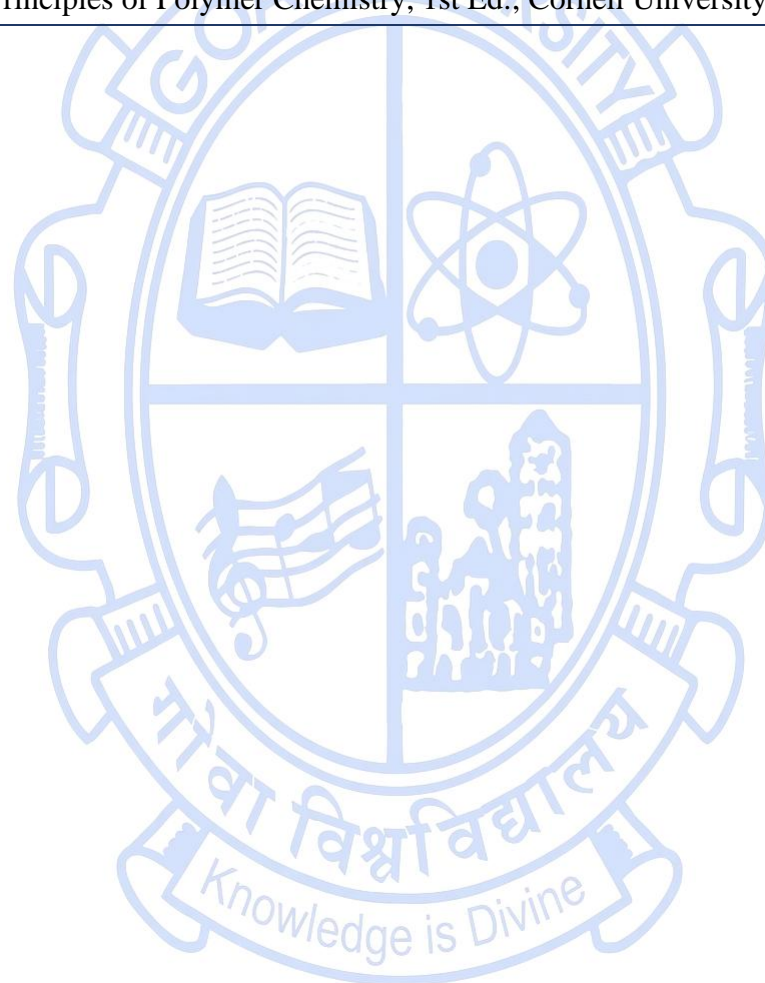
Pre-requisites for the Course:	Level 400 course	
Course Objectives:	<ol style="list-style-type: none"> 1. To introduce the concepts of nuclear chemistry and nuclear forces. 2. To provide an understanding of radiotracer and isotope dilution techniques. 3. To understand radiation effects on polymers and superconducting materials. 4. To learn dosimetry, radiation protection, and environmental monitoring. 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. explain concepts nuclear and radiation chemistry.	PSO1
	CO 2. apply radiometric technique for chemical biological and environmental applications.	PSO1, PSO7
	CO 3. analyze polymers and super conducting materials for radiation chemistry.	PSO1, PSO7
	CO 4. evaluate use and effect of nuclear radiations.	PSO3, PSO5

Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Concepts of Nuclear Chemistry Modern Physical Concepts Needed in Nuclear Chemistry; Types of Forces in Nature; Elementary Mechanics; Relativistic Mechanics; De Broglie Wavelength, Wave-Particle Duality; Heisenberg Uncertainty Principle; Units and Conversion Factors; Particle Physics; Exchange Particles and Force Carriers; Nuclear properties.</p>	10	CO1	K1, K2, K3, K4
Module 2:	<p>Radiotracers and their applications Design of a radiotracer experiment; basic design criteria; practical considerations; preparation of radiotracers and their compounds; chemical synthesis; biosynthesis; tracing of physical process; chemical applications of tracers; isotope effects; biological applications; environmental applications; industrial use of radiotracers; nuclear medicine; Isotope Dilution Analysis; Direct IDA; Inverse IDA; Special IDA techniques; radiometric techniques; problems on radiation chemistry</p>	15	CO2	K1, K2, K3, K4, K5
Module 3:	<p>Polymers and Superconducting Materials for radiation chemistry Effect of radiation on polymer, structure and properties. Application in curing, coating purification, polymer composites etc. radiation induced polymerization, irradiation of blends, post-irradiation effects Superconducting state, high critical temperature superconductors, Low critical temperature superconductors, super conductivity in cuprates, preparation & characterization, Normal state properties, anisotropy, temperature dependents of electrical resistance, optical photon modes, coherent length, elastic constants position life times, heat capacity, micro wave absorption, pairing & multigap structure in hitech materials.</p>	20	CO3	K1, K2, K3, K4, K5
Module 4:	<p>Applications of nuclear reactions Nuclear reactions in nature, analytical applications, nuclear weapons, Cluster radioactivity, proton radioactivity, radioactivity in nature, Nuclear reactions, Bethe's notation, Conservation in nuclear reaction and nuclear reaction cross section, Compound nucleus model Photonuclear reactions, heavy-ion</p>	15	CO4	K1, K2, K3, K4, K5

	<p>reactions, high and low energy nuclear reactions, thermonuclear reactions, direct nuclear reactions.</p> <p>Dosimetry and radiation protection- radiation effects in cell, humans, animals and plants, hazards and safety regulations and environment monitoring.</p>			
Pedagogy:	<p>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.</p>			
Texts:	<ol style="list-style-type: none"> 1. G. Choppin, J.-O. Liljenzin, J. Rydberg, Radiochemistry and Nuclear Chemistry, 3rd Ed.; Butterworth-Heinemann, Oxford, UK, 2002. 2. H. J. Arnikaar, Essentials of Nuclear Chemistry, 4th Ed.; New Age International Pvt. Ltd., New Delhi, 2005. 3. J. V. Kratz, Nuclear and Radiochemistry: Fundamentals and Applications, Vol. 1 & 2, 3rd Ed.; Wiley-VCH, Singapore, 2013. 4. K. H. Lieser, Nuclear and Radiochemistry: Fundamentals and Applications, 2nd Ed.; VCH Publishers, New York, 1997. 5. M. Sharon, M. Sharon, Nuclear Chemistry, 2nd Ed.; Springer, Cham, Switzerland, 2021. 6. R. Kelkar, R. Halz, Textbook of Liquid Crystals, 1st Ed.; Chemie Verlag, Weinheim, 1986. 7. U. N. Dash, Nuclear Chemistry, 1st Ed.; Sultan Chand & Sons, New Delhi, 2007. 8. V. R. Gowarikar, N. V. Viswanathan, J. Sreedhar, Polymer Science, 1st Ed.; Wiley Eastern, New Delhi, 1986. 9. W. D. Loveland, D. J. Morrissey, G. T. Seaborg, Modern Nuclear Chemistry, 1st Ed.; John Wiley & Sons, Hoboken, NJ, 2006. 			
References/ Readings:	<ol style="list-style-type: none"> 1. A. N. Koskinen, Nuclear Chemistry: New Research, 1st Ed.; Nova Science Publishers, New York, 2009. 2. A. Vertes, S. Nagy, Z. Klencsar, R. G. Lovas, F. Rosch, Handbook of Nuclear Chemistry, 2nd Ed.; Springer, New York, 2011. 3. F. Rosch, Nuclear and Radiochemistry, Vol. 2: Modern Applications, 2nd Ed.; Walter de Gruyter, Berlin, 2022. 4. G. Friedlander, J. W. Kennedy, E. S. Macias, J. M. Miller, Nuclear and Radiochemistry, 3rd Ed.; John Wiley & Sons, New York, 1981. 5. H. Morawetz, Macromolecules in Solution, 2nd Ed.; Wiley-Interscience, New York, 1975. 			

6. L. H. Peebles, Molecular Weight Distribution in Polymers, 1st Ed.; Wiley-Interscience, New York, 1971.
7. M. Satake, Y. Mido, An Introduction to Nuclear Chemistry, 1st Ed.; Discovery Publishing House, New Delhi, 2003.
8. P. A. C. McPherson, Principles of Nuclear Chemistry, 1st Ed.; World Scientific Publishing Europe Ltd., New Jersey, 2017.
9. P. J. Flory, Principles of Polymer Chemistry, 1st Ed.; Cornell University Press, Ithaca, NY, 1953.

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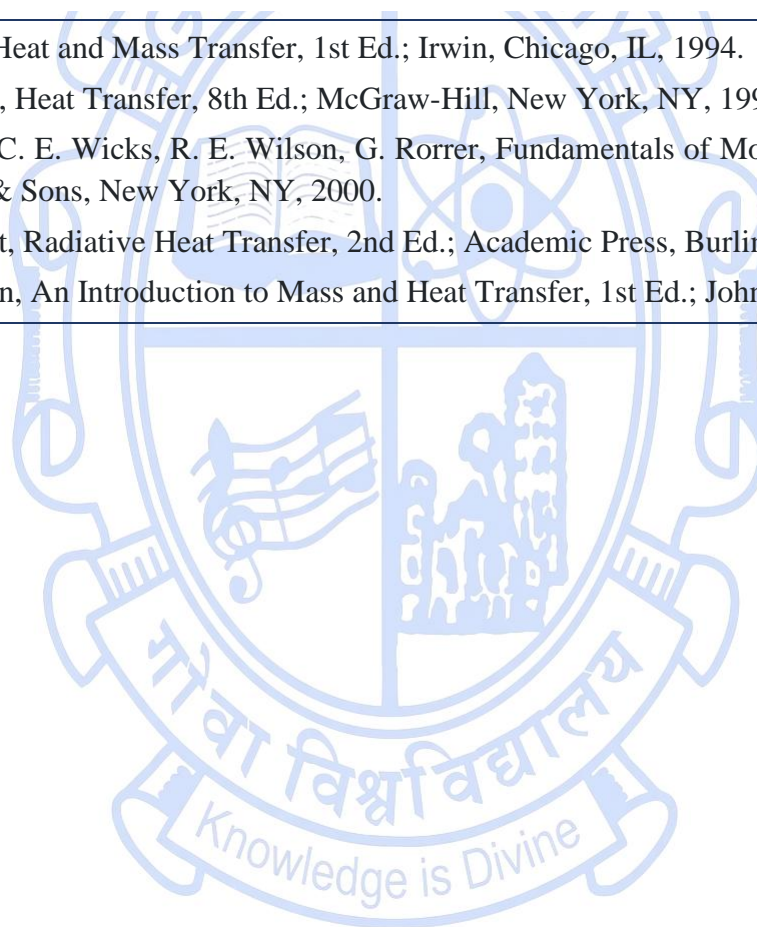
Title of the Course	Transport processes in Physical Chemistry
Course Code	CHP-6204
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Level 400 course	
Course Objectives:	<ol style="list-style-type: none"> 1. To introduce the foundational transport laws governing transport processes. 2. To understand the interplay between convection and diffusion in heat, mass, and momentum transfer at the microscopic scale. 3. To learn the practical applications of transport processes in material processing. 4. To develop the ability to evaluate advanced modeling techniques used to simulate transport phenomena. 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. explain the fundamental laws and principles governing transport processes.	PSO1,
	CO 2. apply theoretical concepts to design and operate processes involving material transformations.	PSO3

	CO 3. analyze experimental data from laboratory studies to interpret transport phenomena effectively.		PSO4	
	CO 4. evaluate and utilize knowledge of transport processes in research and real-world problem solving		PSO7	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	Transport processes: Introduction of transport processes, transport laws, Momentum Transport: Viscosity and the mechanism of momentum transport, shell momentum balances and velocity distributions in laminar flow. The equation of changes for isothermal systems. Velocity distributions with more than one independent variable. Interphase transport in isothermal systems. Case study.	20	CO1, CO2, CO4	K1, K2, K3, K4, K5
Module 2:	Energy Transport: Thermal conductivity and Mechanism of energy transport, shell energy balances and temperature distributions in solids and laminar flow, the equations of change for non-isothermal systems, temperature distribution with more than one independent variable, interphase transport in non-isothermal systems. Case study.	20	CO1, CO2, CO4	K1, K2, K3, K4, K5
Module 3:	Mass Transport: Diffusivity and the mechanism of mass transport, concentration distributions in solids and laminar flow, the equations of change for multi-component systems. Concentration distributions with more than one independent variable, interphase transport in non-isothermal mixtures. Case study.	20	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:	<ol style="list-style-type: none"> 1. E. L. Cussler, Diffusion: Mass Transfer in Fluid Systems, 2nd Ed.; Cambridge University Press, Cambridge, UK, 1997. 2. F. Kreith, M. S. Bohn, Principles of Heat Transfer, 6th Ed.; Brooks/Cole, Pacific Grove, CA, 2000. 3. R. B. Bird, W. E. Stewart, E. N. Lightfoot, Transport Phenomena, 2nd Ed.; John Wiley & Sons, New York, NY, 2001
References/ Readings:	<ol style="list-style-type: none"> 1. A. F. Mills, Heat and Mass Transfer, 1st Ed.; Irwin, Chicago, IL, 1994. 2. J. P. Holman, Heat Transfer, 8th Ed.; McGraw-Hill, New York, NY, 1996. 3. J. R. Welty, C. E. Wicks, R. E. Wilson, G. Rorrer, Fundamentals of Momentum, Heat, and Mass Transfer, 4th Ed.; John Wiley & Sons, New York, NY, 2000. 4. M. F. Modest, Radiative Heat Transfer, 2nd Ed.; Academic Press, Burlington, MA, 2003. 5. S. Middleman, An Introduction to Mass and Heat Transfer, 1st Ed.; John Wiley & Sons, New York, NY, 1998.

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Title of the Course	Practicals in computational chemistry
Course Code	CHP-6205
Number of Credits	4
Theory/Practical	Practical
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Level 400 course	
Course Objectives:	<ol style="list-style-type: none"> 1. To develop proficiency in modern programming and scripting languages for scientific computing. 2. To understand the application of computational tools for simulating and modeling molecular systems. 3. To learn methods for analyzing, interpreting, and visualizing scientific data from computational experiments. 4. To equip students with the ability to design and implement robust, reproducible computational workflows for chemical research. 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. operate in the Linux environment and automate computational tasks with shell scripting.	PSO1, PSO2, PSO3
	CO 2. apply programming fundamentals to scientific problem-solving.	PSO1, PSO2, PSO3
	CO 3. analyze, process, and visualize scientific data.	PSO1, PSO3
	CO 4. design and solve real computational chemistry case studies using integrated tools.	PSO1, PSO3

Content:	<i>Any five experiments from each module to be performed</i>	No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Programming</p> <ul style="list-style-type: none"> i. Hello World and Basic I/O in Python Write a Python script that prints "Hello World" and takes user input for their name. ii. Working with Data Types Practice using integers, floats, strings, and lists; perform simple arithmetic and string manipulations. iii. Branching and Conditionals Write a program that checks if a number is even or odd and prints the result. iv. Loops and Iteration Use for and while loops to print numbers from 1 to 10 and sum a list of numbers. v. Functions and Recursion Define a function to calculate factorial of a number using both iterative and recursive approaches. vi. Exception Handling Write a program that handles invalid user input gracefully (e.g., catching errors when converting strings to numbers). vii. Simple Numerical Optimization Implement a basic gradient descent algorithm to find the minimum of a quadratic function. 	30	CO2	K1, K2, K3
Module 2:	<p>Linux Environment and Shell Scripting</p> <ul style="list-style-type: none"> i. Basic Terminal Navigation Learn to navigate directories, list files, and understand file paths using ls, cd, pwd, and man commands. ii. File Management Operations 	30	CO1	K1, K2, K3

	<p>Practice creating, copying, moving, renaming, and deleting files and folders using touch, cp, mv, rm, and mkdir.</p> <p>iii. Writing and Running Simple Shell Scripts Write a script to automate file organization (e.g., sort files by extension into folders).</p> <p>iv. Using Variables and Standard Input/Output Create a script that takes user input, stores it in a variable, and prints a formatted message.</p> <p>v. Conditional Statements in Shell Scripts Write a script that checks if a file exists and prints a message accordingly.</p> <p>vi. Looping Over Files Automate repetitive tasks (e.g., renaming multiple files or extracting lines from several text files).</p> <p>vii. Regular Expressions and Text Processing Use grep, awk, and sed to search, filter, and modify text data (e.g., extract lines containing a specific keyword from log files).</p>			
Module 3:	<p>Data Processing & Visualization</p> <p>i. Parsing Text Files Write a Python script to read and extract data from a simple text file (e.g., atomic coordinates).</p> <p>ii. Batch Processing Multiple Files Automate the extraction of specific data (e.g., energies) from multiple output files using loops.</p> <p>iii. Working with Tabulated Data Use pandas to load, filter, and summarize tabular data (e.g., CSV files with molecular properties).</p> <p>iv. Data Fitting Fit a linear model to experimental data (e.g., energy vs. bond length)</p>	30	CO3	K2, K3, K4

	<p>using numpy and scipy.</p> <p>v. Basic Data Plotting Visualize data using matplotlib (e.g., plot energy profile of a reaction).</p> <p>vi. Histogram and Scatter Plots Create histograms and scatter plots to analyze distributions and correlations in simulation data.</p> <p>vii. Automated Report Generation Generate a summary report (text and plots) from processed data using Python scripting.</p>			
Module 4:	<p>Computational Chemistry Applications</p> <p>i. Potential energy curve for N₂ Calculate and plot the potential energy curve for N₂ by varying bond length and extracting energies from Gaussian output files.</p> <p>ii. Potential energy surface (PES) for O₃ Extend the PES analysis to O₃, exploring the effect of bond angles and bond lengths.</p> <p>iii. NMR Chemical Shift Calculation from molecular dynamics (MD) output file. Extract structures from MD simulations, run NMR calculations, and analyze chemical shifts.</p> <p>iv. Activation Strain Analysis Perform activation strain analysis for a simple reaction using output from computational chemistry software.</p> <p>v. Parsing and Visualizing Gaussian Output Write scripts to extract key results (energies, frequencies) from Gaussian log files and visualize them.</p> <p>vi. Mini-Project: Integrated Workflow I Design a workflow that combines Linux scripting, Python programming, data analysis, and visualization to solve a real computational chemistry problem (e.g.,</p>	30	CO4	K3, K4, K5

	<p>reaction profile analysis).</p> <p>vii. Mini-Project: Integrated Workflow II Automated Analysis of Geometry Optimization Results for Water Molecules with Different Initial Geometries</p>			
Pedagogy:	Students should be given suitable lab handouts, pre- and post-lab assignments and explanations revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment			
Texts:	<ol style="list-style-type: none"> 1. A. Robbins, N. H. F. Beebe, Classic Shell Scripting, O'Reilly Media, USA, 2005. 2. C. Hill, Python for Chemists, 1st Ed., Cambridge University Press, United Kingdom, 2023. 3. D. Mitsotakis, Computational Mathematics: An Introduction to Numerical Analysis and Scientific Computing with Python, 1st Ed., Chapman and Hall/CRC, New York, 2023. 4. M. Kanagasabapathy, Python for Chemistry, 1st Ed., BPB Publications, London, 2023. 5. S. Lynch, Python for Scientific Computing and Artificial Intelligence, 1st Ed., Chapman and Hall/CRC, New York, 2023. 			
References/ Readings:	<ol style="list-style-type: none"> 1. E. G. Lewars. Computational Chemistry: Introduction to the Theory and Applications of Molecular and Quantum Mechanics, 4th Ed., Springer, Germany, 2024. 2. P. W. Atkins and J. de Paula. Atkins' Physical Chemistry, 8th Ed., Oxford University Press, United Kingdom, 2006. 3. Sun, Q. Python for Quantum Chemistry: A Full Stack Programming Guide, 1st Ed., Elsevier, Netherlands, 2025. 			
Web Resources:	<ol style="list-style-type: none"> 1. https://education.molssi.org/qm-tools/ 2. https://pythoninchemistry.org/ch40208/introduction/about_this_book.html# 3. https://10.1039/b926828f. 4. https://10.1002/jcc.22877. 			

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Title of the Course	Instrumental and non-Instrumental techniques in Physical Chemistry
Course Code	CHP-6206
Number of Credits	4
Theory/Practical	Practical
Level	500
Effective from AY	
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

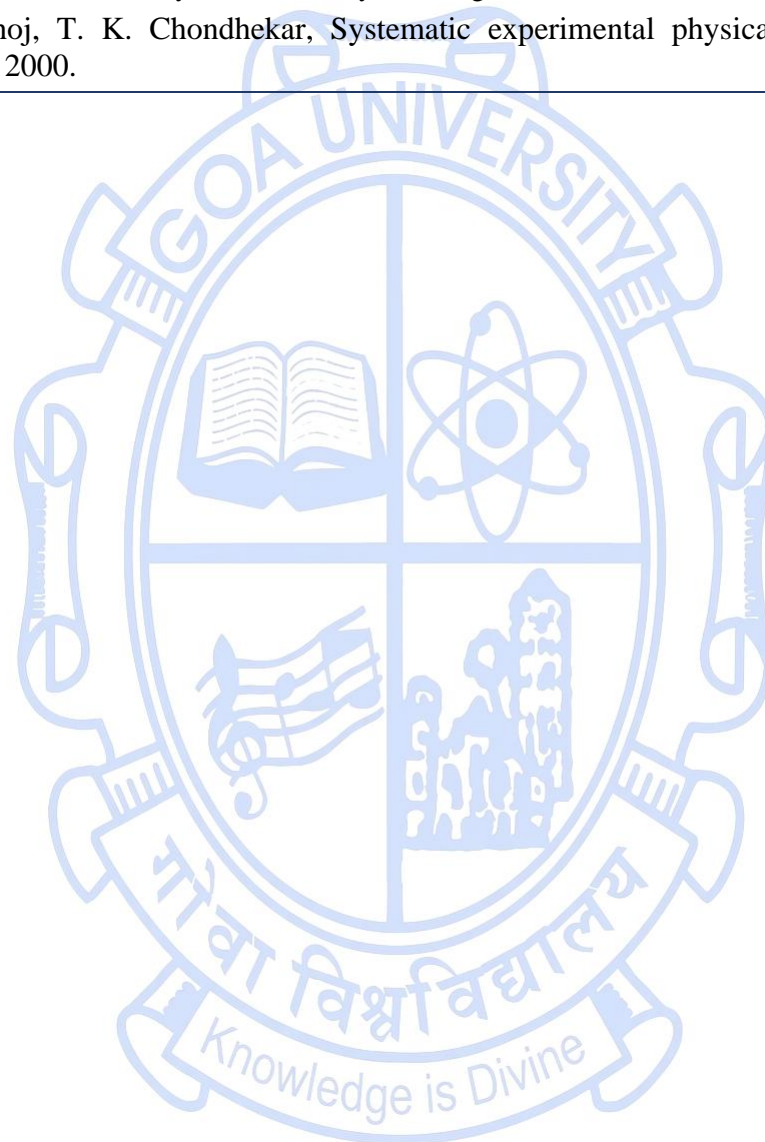
Pre-requisites for the Course:	Level 400 course	
Course Objectives:	<ol style="list-style-type: none"> 1. To understand core physical chemistry concepts through experiments in kinetics, electrochemistry, thermodynamics 2. To develop experimental skills by setting up and conducting experiments and practice data collection 3. To analyse qualitative and quantitative data and correlate experimental results with theoretical models 4. To foster scientific thinking and problem solving useful in research 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. conduct experiments using key physical chemistry techniques and obtain data with accuracy	PSO4
	CO 2. independently handle and operate laboratory instruments	PSO1, PSO4, PSO7
	CO 3. demonstrate scientific writing and reporting skills to correctly and clearly present experimental results	PSO6, PSO7

	CO 4. exhibit lab safety protocols and effectively work in teams		PSO4, PSO6	
Content:	Any 10 experiments to be performed from each module:	No of hours	Mapped to CO	Cognitive level
Module 1:	<ul style="list-style-type: none"> i. To determine the critical micelle concentration of a surfactant using conductometry ii. To determine solubility product of salts like BaSO₄ and AgCl using conductometry iii. To determine the band gap (Eg) of semiconductor material (ZnO and TiO₂) using UV-Vis spectroscopy iv. To measure emf of concentration cells and calculate activity coefficient using potentiometry v. To determine potentiometrically the end point of titration of NaCl with AgNO₃ vi. To prepare a thin film by spin coating/ blade coating/ drop casting method and study its optical/ electrical property vii. To colorimetrically determine equilibrium constant for complex formation reaction between Fe³⁺ and SCN⁻. viii. To determine the rate constant of a first-order reaction using colorimetry ix. To potentiometrically quantify H₂O₂ through redox titration with KMnO₄ x. To determine potentiometrically equilibrium constant for redox reaction between Fe³⁺ and I ions xi. To determine degree of ionization (α) and Ka of a weak acid xii. To study ionic nature and conductivity behavior of different surfactants using conductometry xiii. To differentiate between true double salt (Mohr's salt) and mixture using conductivity. xiv. To study kinetics of urea hydrolysis by urease using pH meter xv. To synthesize metal oxide using hydrothermal method and measure its optical property xvi. To study effect of temperature on decomposition kinetics of CaCO₃ xvii. To colorimetrically determine pKa of a dye. xviii. To test the electrical conductivity of prepared polymer films using multimeter. 	60	CO1, CO3, CO4	K2, K3, K4, K5, K6

Module 2:	<ul style="list-style-type: none"> i. To study the kinetics of iodination of acetone in acidic medium ii. To study the reaction kinetics between BaCl_2 and Na_2SO_4 iii. To study green synthesis of metal oxide nanoparticles using plant extracts iv. To study the adsorption of acetic acid on activated charcoal titrimetry v. To study purification of colloidal sols by dialysis method vi. To determine critical coagulation concentration of different electrolytes vii. To prepare emulsions and study the effect on stability using different emulsifiers viii. To study competitive adsorption of methylene blue and Congo red dye ix. To determine surface tension of liquids using capillary rise method x. To study the effect of impurities such as salts, sugars and acids on the surface tension of water xi. To determine the effect of temperature on the viscosity of liquids xii. To determine the effect of pH on the viscosity of polyelectrolyte solution xiii. To study the effect of temperature on electroless deposition of Copper on glass xiv. To study the effect of pH on the corrosion of Zinc and Iron xv. To analyze gravimetrically the corrosion of iron in acidic and neutral media xvi. To study the transesterification reaction (biodiesel production) using solid base catalyst xvii. To determine catalytic activity of solid acid catalyst for esterification of acetic acid with ethanol by titrimetry. 	60	CO1, CO2, CO3, CO4	K3, K4, K5, K6
Pedagogy:	Students should be given suitable lab handouts, pre- and post-lab assignments and explanations revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment.			
Texts:	<ol style="list-style-type: none"> 1. D. P. Shoemaker, C. W. Garland, J. W. Nibler, Experiments in Physical Chemistry, 5th Ed.; McGraw-Hill, Singapore, Reprint 1989. 2. L. P. Gold, Physical Chemistry Laboratory Manual, 1st Ed.; McGraw-Hill, Ohio, Reprint 1997. 3. R. C. Das, B. Behera, Experimental Physical Chemistry, 1st Ed.; Tata McGraw-Hill, New Delhi, Reprint 1983. 4. V. D. Athwale, P. Mathur, Experimental Physical Chemistry, 1st Ed.; New Age International Ltd., New Delhi, Reprint 2001. 			
References/Readings:	<ol style="list-style-type: none"> 1. B. Vishwanathan, P. S. Raghavan, Practical Physical Chemistry, Viva Books Private Limited, New Delhi, 2009. 2. M. Satish Kumar, Practical Physical Chemistry, 1st Ed.; Sankalp Publications, Chhattisgarh, Reprint 2019. 			

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| | <ol style="list-style-type: none">3. P. S. Sindhu, Practicals in Physical Chemistry, New Age International Publishers, New Delhi, 2007.4. S. W. Rajbhoj, T. K. Chondhekar, Systematic experimental physical chemistry, 2nd Ed., Anjali publication, Aurangabad, 2000. |
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Title of the Course	Practicals in Transport processes
Course Code	CHP-6207
Number of Credits	4
Theory/Practical	Practical
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Level 400 course	
Course Objectives:	<ol style="list-style-type: none"> 1. To introduce the principles and laws that govern transport processes including momentum, heat, and mass transfer. 2. To learn how convection and diffusion interact in various transport phenomena at the microscopic level. 3. To apply the applications of transport processes in material science. 4. To equip skills to use modeling techniques to simulate transport phenomena and interpret experimental data. 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. explain various concepts of transport phenomena momentum, heat, and mass transfer in chemical systems through practical experiments.	PSO1
	CO 2. apply problem-solving skills to optimize process parameters governing transport	PSO3

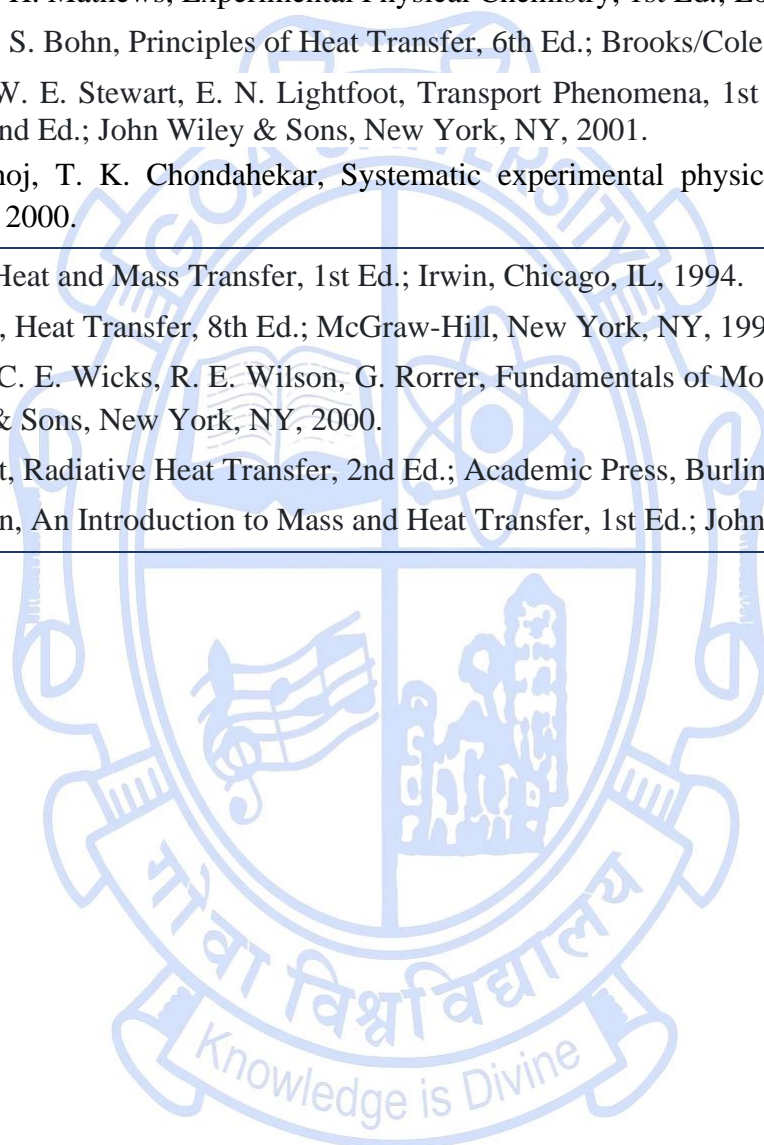
	phenomena			
	CO 3. analyze transport properties such as density and viscosity of chemical substances.		PSO4	
	CO 4. evaluate and utilize knowledge of transport processes to design, operate, and optimize material transformation processes in research and dissertation work		PSO7	
Content:	<i>Any 10 experiments from each module will be performed.</i>	No of hours	Mapped to CO	Cognitive Level
Module 1:	<ul style="list-style-type: none"> i. Determine the viscosity of different Newtonian fluids using an Ostwald viscometer. Investigate the effect of temperature on viscosity. ii. Determine the relative viscosities of mixtures ethanol and water. iii. Determine the surface tension of a pure liquid at 25 °C by the capillary rise method. iv. Determine the variation of the refractive index with composition for mixtures of benzene and carbon tetrachloride. v. To study the apparent Molal property of paracetamol with Ethanol. vi. To study the apparent Molal compressibility of paracetamol with methanol at various temperatures. vii. To study the thermophysical properties of API with different organic solvent. viii. To evaluate thermodynamic parameters of paracetamol with different alcohols. ix. To study thermophysical properties of organic solvents with cooking oils at different temperatures. x. To understand molecular interactions between ethanol and water at different temperatures. xi. Determine the transport number of copper ions in copper sulphate solution by the Hittorf method. xii. Determine the transport number of the hydrogen ion in hydrochloric acid by the 	60	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5

	<p>moving boundary method.</p> <p>xiii. To determine the parachor of a solid by stalagmometer.</p> <p>xiv. To determine the specific and molar refraction of a given liquid by Abbe refractometer.</p> <p>xv. To determine the specific refraction of the given binary mixture of liquids and determine its percentage in unknown composition.</p> <p>xvi. To determine the refractive indices of a series of the solutions of a salt and determine the concentration of the salt in given unknown solution.</p>			
Module 2:	<p>i. To determine the molar volume and partial molar volume of n-propanol at 25°C in dilute aqueous solution.</p> <p>ii. To study the variation of viscosity with composition for binary liquid mixtures (e.g., methanol–water, acetone–water).</p> <p>iii. Determine the viscosity of polymer solutions at different concentrations to study molecular weight dependence.</p> <p>iv. To study the effect of temperature on the density of a pure liquid.</p> <p>v. Study of excess molar volume in binary liquid mixtures (e.g., ethanol–water, acetone–benzene).</p> <p>vi. Determine the excess volume and partial molar volume of solutes like urea or sugars in water.</p> <p>vii. Determine excess volume of binary mixtures of alkanes.</p> <p>viii. Determine the variation of the refractive index with composition for mixtures of toluene and chloroform.</p> <p>ix. To determination of the Transport Number of Ag⁺ Ions in AgNO₃ Solution using Hittorf's Method.</p> <p>x. To determine the radius of a molecule by viscosity measurements.</p>	60	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5

	<ul style="list-style-type: none"> xi. To determine the percentage composition of a given mixture of two liquids by stalagmometer method. xii. To study the effect of surfactants on surface tension of water by using stalagmometer. xiii. To determine the critical micellar concentration of anionic surfactants in water using conductometric method. xiv. To determine the critical micellar concentration of cationic surfactants in water using conductometric method. xv. To determine the critical micellar concentration of neutral surfactants in water using conductometric method. xvi. To determine the critical micellar concentration of anionic surfactants in water using refractive index method. xvii. To determine the critical micellar concentration of cationic surfactants in water using refractive index method. xviii. To verify Rayleigh's equation and material balance equation for simple distillation of a mixture. xix. To determine the critical micellar concentration of neutral surfactants in water using refractive index method. 			
Pedagogy:	Students should be given suitable lab handouts, pre- and post-lab assignments and explanations revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment			
Texts:	<ul style="list-style-type: none"> 1. A. M. James, Practical Physical Chemistry, 1st Ed.; Longman, London, 1970. 2. B. Viswanathan, P. S. Raghavan, Practical physical chemistry, 1st Ed., Viva Books, New Delhi, 2015. 3. D. P. Shoemaker, C. W. Garland, Experimental Physical Chemistry, 1st Ed.; McGraw-Hill, New York, NY, 1962. 4. E. L. Cussler, Diffusion: Mass Transfer in Fluid Systems, 2nd Ed.; Cambridge University Press, Cambridge, UK, 1997. 			

	<ol style="list-style-type: none"> 5. F. Daniels, J. H. Mathews, Experimental Physical Chemistry, 1st Ed.; Longman, London, 1970. 6. F. Kreith, M. S. Bohn, Principles of Heat Transfer, 6th Ed.; Brooks/Cole, Pacific Grove, CA, 2000. 7. R. B. Bird, W. E. Stewart, E. N. Lightfoot, Transport Phenomena, 1st Ed.; John Wiley & Sons, New York, NY, 1960. Also 2nd Ed.; John Wiley & Sons, New York, NY, 2001. 8. S. W. Rajbhoj, T. K. Chondahekar, Systematic experimental physical chemistry, 2nd Ed., Anjali publication, Aurangabad, 2000.
References/ Readings:	<ol style="list-style-type: none"> 1. A. F. Mills, Heat and Mass Transfer, 1st Ed.; Irwin, Chicago, IL, 1994. 2. J. P. Holman, Heat Transfer, 8th Ed.; McGraw-Hill, New York, NY, 1996. 3. J. R. Welty, C. E. Wicks, R. E. Wilson, G. Rorrer, Fundamentals of Momentum, Heat, and Mass Transfer, 4th Ed.; John Wiley & Sons, New York, NY, 2000. 4. M. F. Modest, Radiative Heat Transfer, 2nd Ed.; Academic Press, Burlington, MA, 2003. 5. S. Middleman, An Introduction to Mass and Heat Transfer, 1st Ed.; John Wiley & Sons, New York, NY, 1998.

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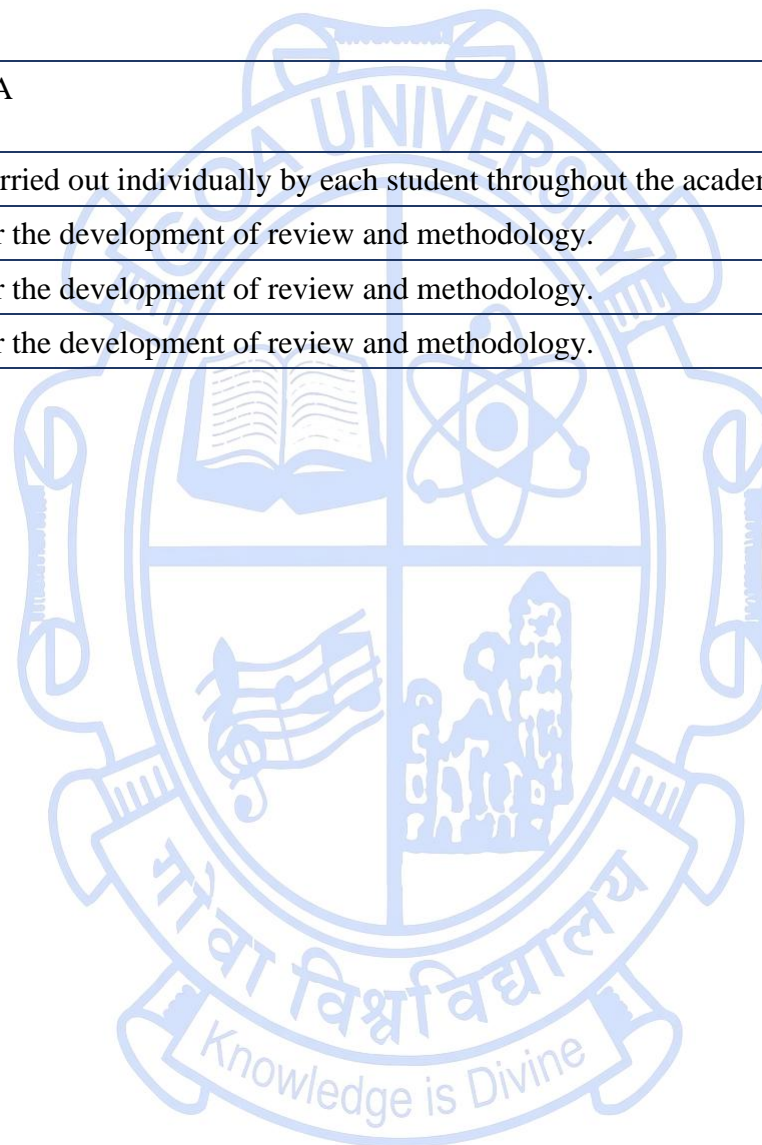


DISSERTATION (40 Credits)

Title of the Course	Discipline Specific Dissertation (DSD)	
Course Code	CHP-6501	
Number of Credits	40	
Theory/Practical	Practical	
Level	500	
Effective from AY	2026-27	
New Course	Yes	
Bridge Course/ Value added Course	No	
Course for advanced learners	No	
Pre-requisites for the Course:	Level 400 courses	
Course Objectives:	To develop the skills of preparing and conducting independent research.	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. explain the principles and techniques used in chemical analysis and experimentation.	PSO3
	CO 2. use appropriate chemical tools and methods to solve experimental problems.	PSO4, PSO5
	CO 3. analyze and interpret experimental data to draw meaningful conclusions.	PSO8
	CO 4. design and conduct independent research projects using appropriate chemical methodologies.	PSO6

Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	As per OA-35A	1200	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Pedagogy:	Dissertation carried out individually by each student throughout the academic year.			
Texts:	As required for the development of review and methodology.			
References/ Readings:	As required for the development of review and methodology.			
Web Resources:	As required for the development of review and methodology.			

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DISSERTATION (20 Credits)

Title of the Course	Discipline Specific Dissertation (DSD)
Course Code	CHP-6502
Number of Credits	20
Theory/Practical	Practical
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Level 400 courses	
Course Objectives:	To develop the skills of preparing and conducting independent research.	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. explain the principles and techniques used in chemical analysis and experimentation.	PSO3
	CO 2. use appropriate chemical tools and methods to solve experimental problems.	PSO4, PSO5
	CO 3. analyze and interpret experimental data to draw meaningful conclusions.	PSO8
	CO 4. design and conduct independent research projects using appropriate chemical	PSO6

methodologies.				
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	As per OA-35A	600	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Pedagogy:	Dissertation carried out individually by each student throughout the academic year.			
Texts:	As required for the development of review and methodology.			
References/ Readings:	As required for the development of review and methodology.			
Web Resources:	As required for the development of review and methodology.			

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