



GU/Acad –PG/BoS -NEP/2025-26/13

Date: 09.04.2026

CIRCULAR

Ref. No.: GU/Acad –PG/BoS -NEP/2025-26/604 dated 01.12.2025

In supersession to the above referred Circular, the syllabus of Semester III & IV of the **Master of Science in Analytical 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 Analytical 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 Analytical Chemistry Programme.

Copy to:

1. Chairperson, BoS in Chemistry, Goa University.
2. Programme Director, M.Sc. Analytical 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 ANALYTICAL 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 provide a comprehensive understanding of fundamental knowledge and core chemical principles for analytical applications.
2. To impart knowledge of various analytical methods like chromatographic, spectroscopic, electroanalytical and other analytical techniques.
3. To familiarize students with modern analytical instruments and their applications.
4. To develop skills in interpreting analytical data and applying statistical methods.
5. To empower students and encourage the problem-solving approach by coordinating different analytical techniques.

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.

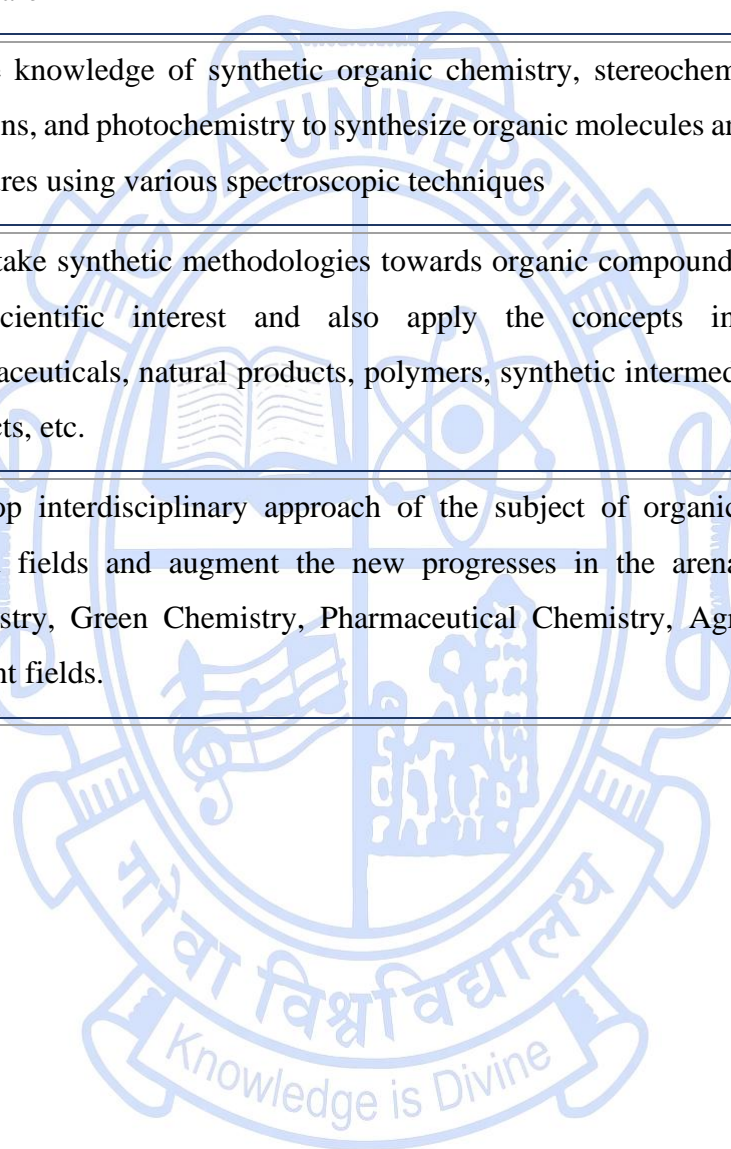
PHYSICAL CHEMISTRY (CHP)**PROGRAMME SPECIFIC OUTCOMES (PSO)**

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.

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 Analytical 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>CHA-5001</u>	Methods of Chemical Analysis	4	500
2	<u>CHA-5002</u>	Selected Techniques in Analytical Chemistry	4	500
3	<u>CHA-5003</u>	Separation Techniques	4	500
4	<u>CHA-5004</u>	Instrumental Methods of Analysis	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 (12 Credits)				
Sr. No.	Course Code	Title of the Course	Credits	Level
1	CHA-6000	Analytical Chemistry Practical- III	4	500
2	CHA-6001	Analytical Chemistry Practical- IV	4	500
3	CHA-6002	Advanced Mass Spectrometry	4	500
4	CHA-6003	Advanced NMR and combined Spectroscopy	4	500
5	CHA-6004	Applied Electro-analytical techniques	4	500
6	CHA-6005	Research Methodology	4	500
Total Credits for RSE Courses in Semester III			12	
Discipline Specific Vocational Elective (DSVE) Courses (8 Credits)				
Sr. No.	Course Code	Title of the Course	Credits	Level
1	CHA-6401	Calibration, Validation and Method Development	2T+2P	500
2	CHA-6402	Chemical Crystallography	2T+2P	500
3	CHA-6403	Forensic Analytical Chemistry	2T+2P	500
Total Credits for DSVE Courses in Semester III			8	
Total Credits in Semester III			20	

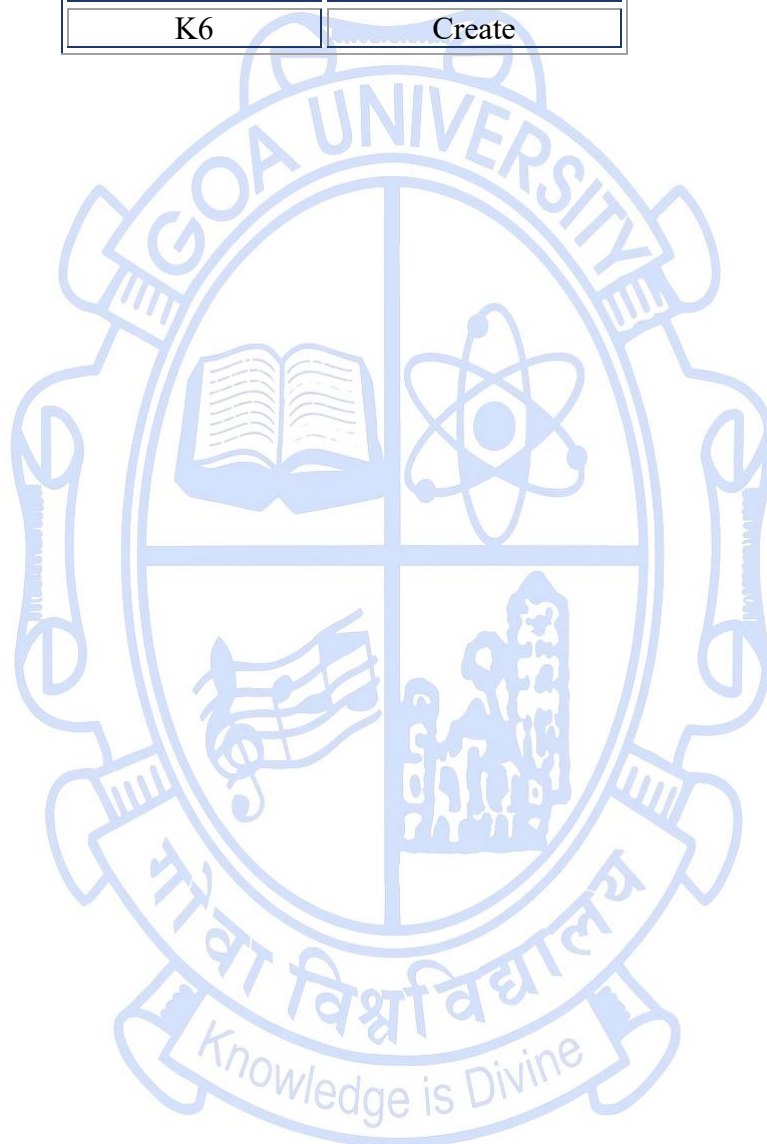
Discipline Specific Dissertation (DSD) (40 Credit Dissertation)				
Discipline Specific Dissertation (DSD)				
Sr. No.	Course Code	Title of the Course	Credits	Level
1	CHA-6501	Discipline Specific Dissertation (DSD)	40	500

SEMESTER IV				
Generic Electives (GE) Courses (20 Credits)				
Sr. No.	Course Code	Title of the Course	Credits	Level
1	<u>CHA-6201</u>	Trends in Analytical Chemistry	4	500
2	<u>CHA-6202</u>	Bioanalytical Chemistry	4	500
3	<u>CHA-6203</u>	Applied analytical Chemistry	4	500
4	<u>CHA-6204</u>	Microscopic and Imaging Techniques	4	500
5	<u>CHA-6205</u>	Practical course in Industrial Analytical Chemistry-I	4	500
6	<u>CHA-6206</u>	Practical course in Industrial Analytical Chemistry-II	4	500
7	<u>CHA-6207</u>	Practical Course in Environmental Analytical Chemistry *	4	500
Total Credits for GE 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>CHA-6502</u>	Discipline Specific Dissertation (DSD)	20	500
Total Credits in Semester IV			20	

*Note: *Students who opt for Discipline Specific Vocational Elective (DSVE) Course **CHI-6401 Environmental chemistry and Sustainability** will not have an option to choose Generic elective course **CHA – 6207 Practical Course in Environmental Analytical Chemistry**.*

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

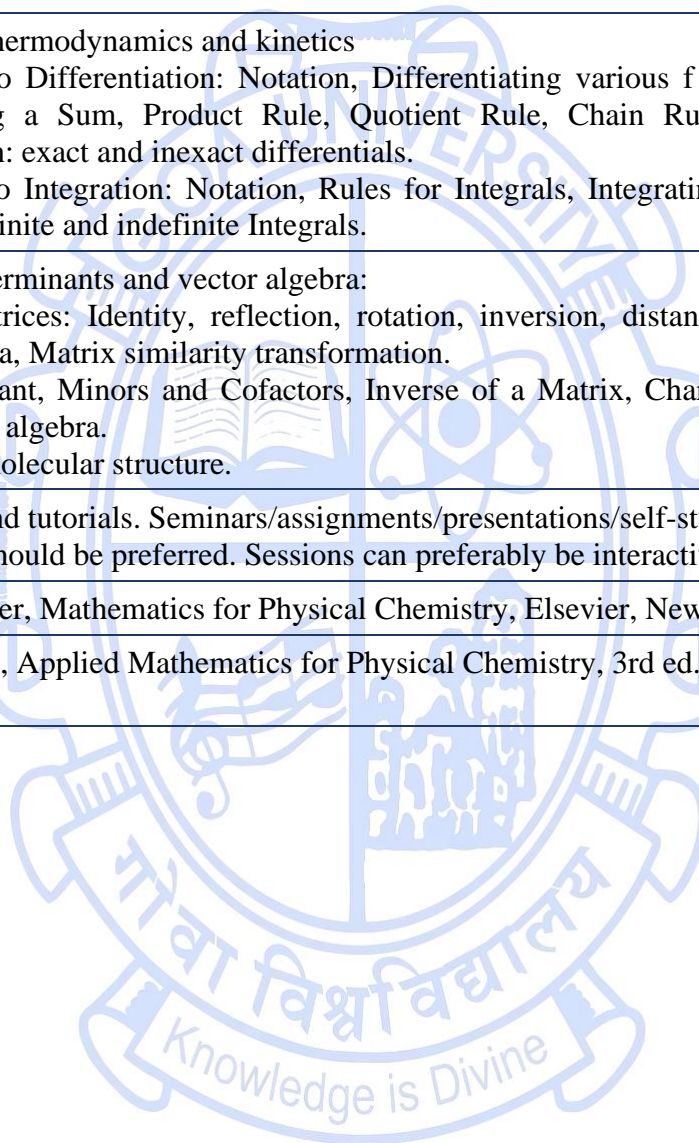


BRIDGE COURSES

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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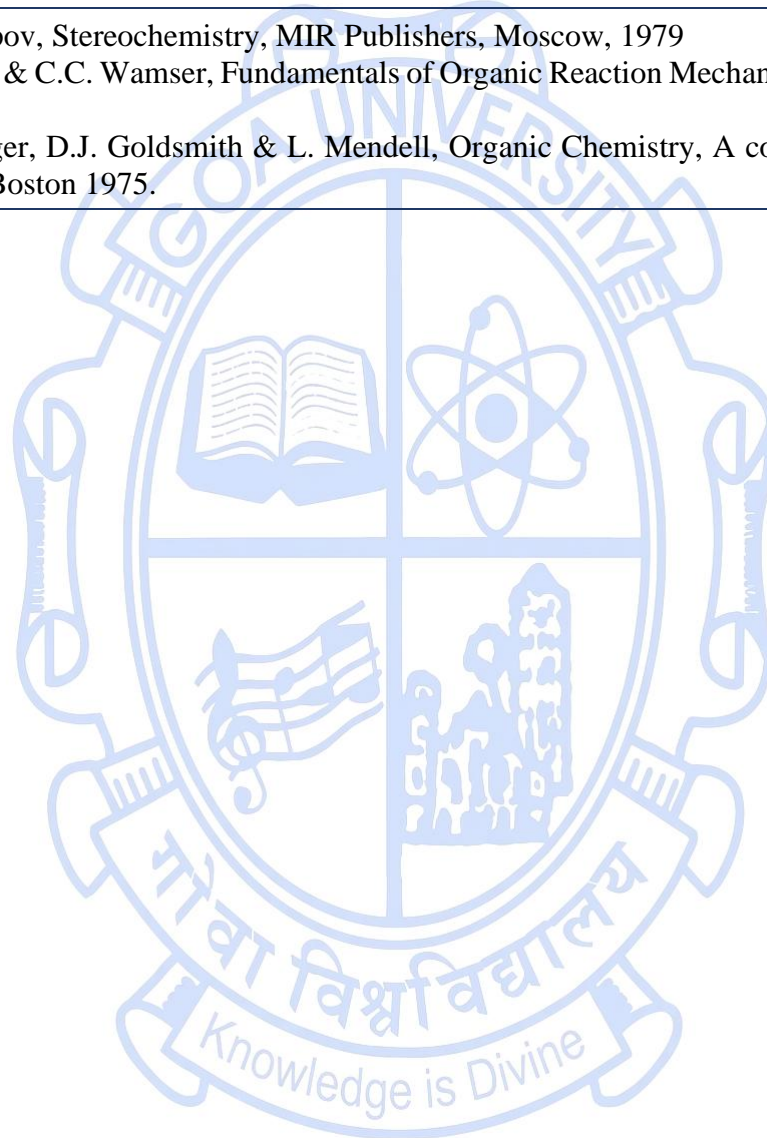


Title of the Course	Bridge Course in Organic Chemistry		
Course Code	CHC-1001		
Number of Credits	1		
Theory/Practical	Theory		
Level	400		
Effective from AY	2025-26		
New Course	No		
Bridge Course/ Value added Course	Yes		
Course for advanced learners	No		
Pre-requisites for the Course:	NIL		
Course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

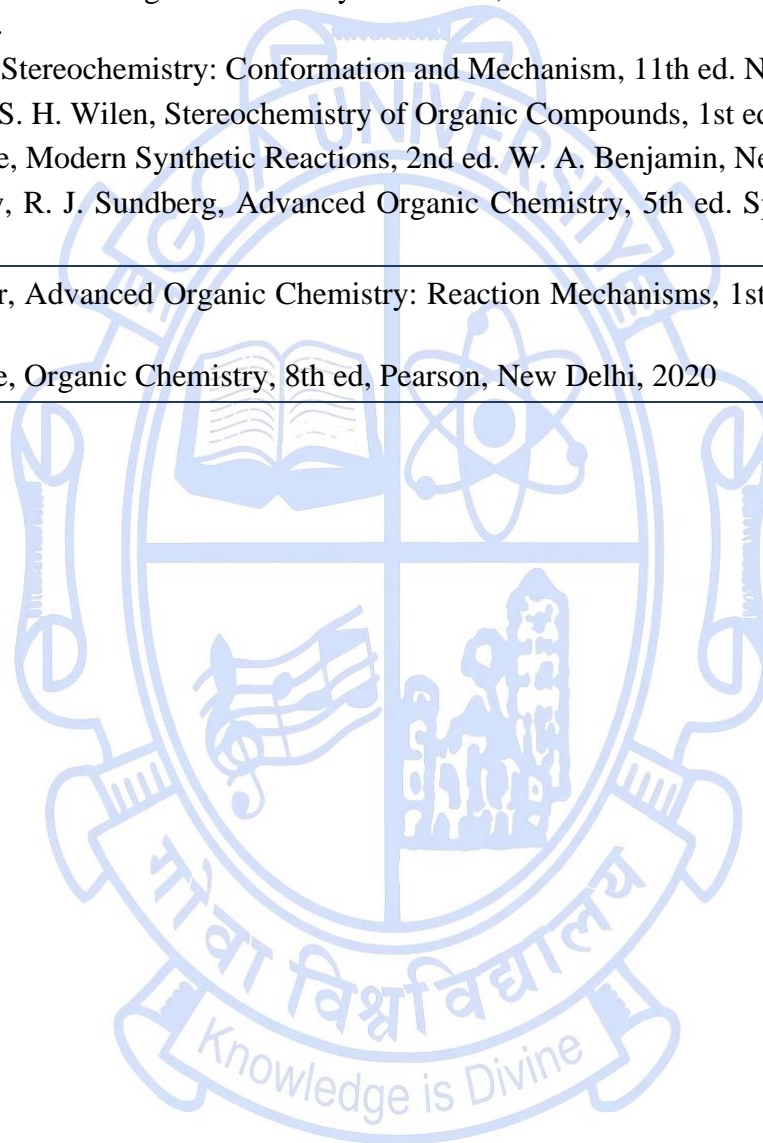
	CO 1. Understand the effect of delocalization of electrons & presence or absence of aromaticity in organic compounds.		PSO1, PSO 2
	CO 2. Apply various concepts in stereochemistry to understand stereochemical outcome in a reaction.		PSO1, PSO 2
	CO 3. Evaluate plausible mechanisms of organic reactions.		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, <i>Advanced Organic Chemistry: Reactions, Mechanisms and Structure</i>, 4th ed. Wiley Student Edition, New York, 2003.5. P. S. Kalsi, <i>Stereochemistry: Conformation and Mechanism</i>, 11th ed. New Age International, New Delhi, 20226. E. L. Eliel, S. H. Wilen, <i>Stereochemistry of Organic Compounds</i>, 1st ed. John Wiley and Sons, New York, 19947. H. O. House, <i>Modern Synthetic Reactions</i>, 2nd ed. W. A. Benjamin, New York, 19658. F. A. Carey, R. J. Sundberg, <i>Advanced Organic Chemistry</i>, 5th ed. Springer India Private Limited, New Delhi, 2007
References/ Readings:	<ol style="list-style-type: none">1. R. Bruckner, <i>Advanced Organic Chemistry: Reaction Mechanisms</i>, 1st ed. Harcourt/Academic Press, San Diego, 2002.2. P. Y. Bruice, <i>Organic Chemistry</i>, 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

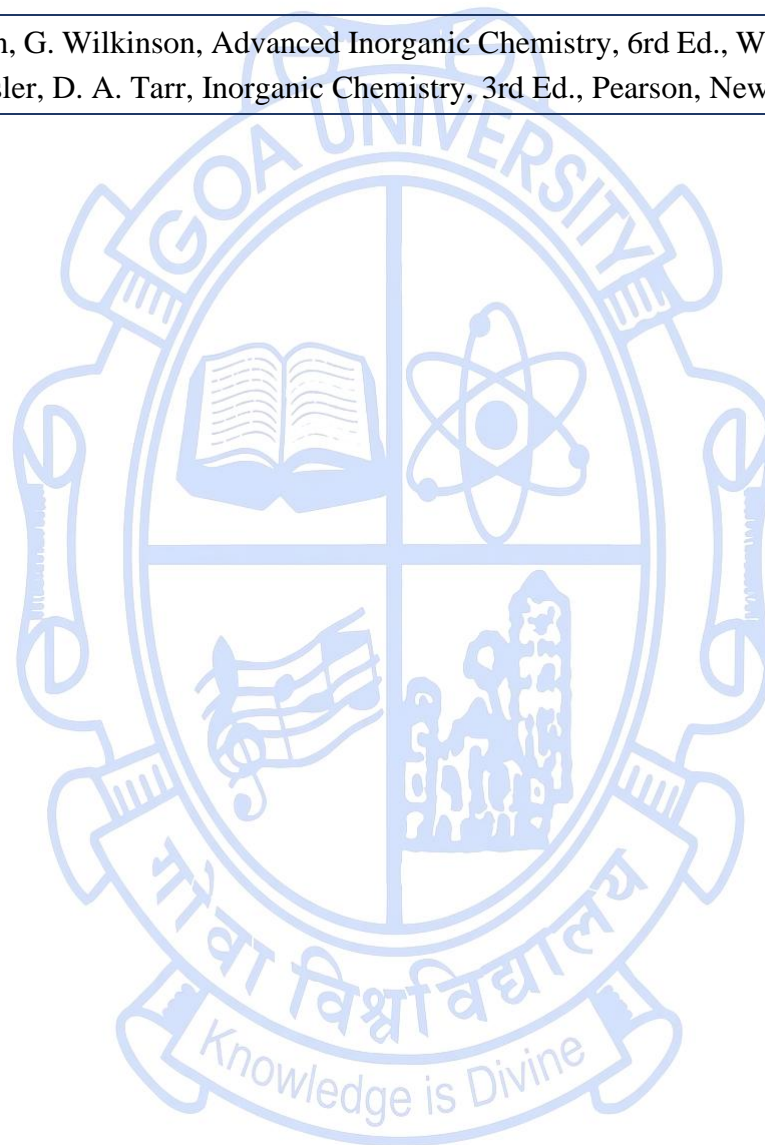
	CO 4. design compounds for various applications.		PSO4	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>1. Atomic structure, molecular structure and bonding</p> <p>a. Atomic Structure: Structures of hydrogenic atoms: some principles of quantum mechanics, atomic orbitals. Many electron 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 <i>d</i>- and <i>f</i>- 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 porphin 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 levels.</p>	10	CO1, CO2, CO3,	K2, K3, K4, K5

	<p>a. Air Pollution: Classification of air pollutants and photochemical reactions in the atmosphere. Common air pollutants (e.g. CO, NO_x, SO₂, hydrocarbons and particulates)</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. Water pollution: Importance of buffer & buffer index in waste water treatments. Chemical, physical & biological characteristics of water pollution, specific & non-specific characterization of water. DO, BOD, COD, and chlorine demand, typical water treatment & waste water treatment (Municipal). Impact of plastic pollution and its effect.</p>		CO4	
Pedagogy:	Mainly lectures and tutorials. Seminars / term papers / assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable 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. Gaus, 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. Keiter, R. L. Keiter, 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:	<ol style="list-style-type: none">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

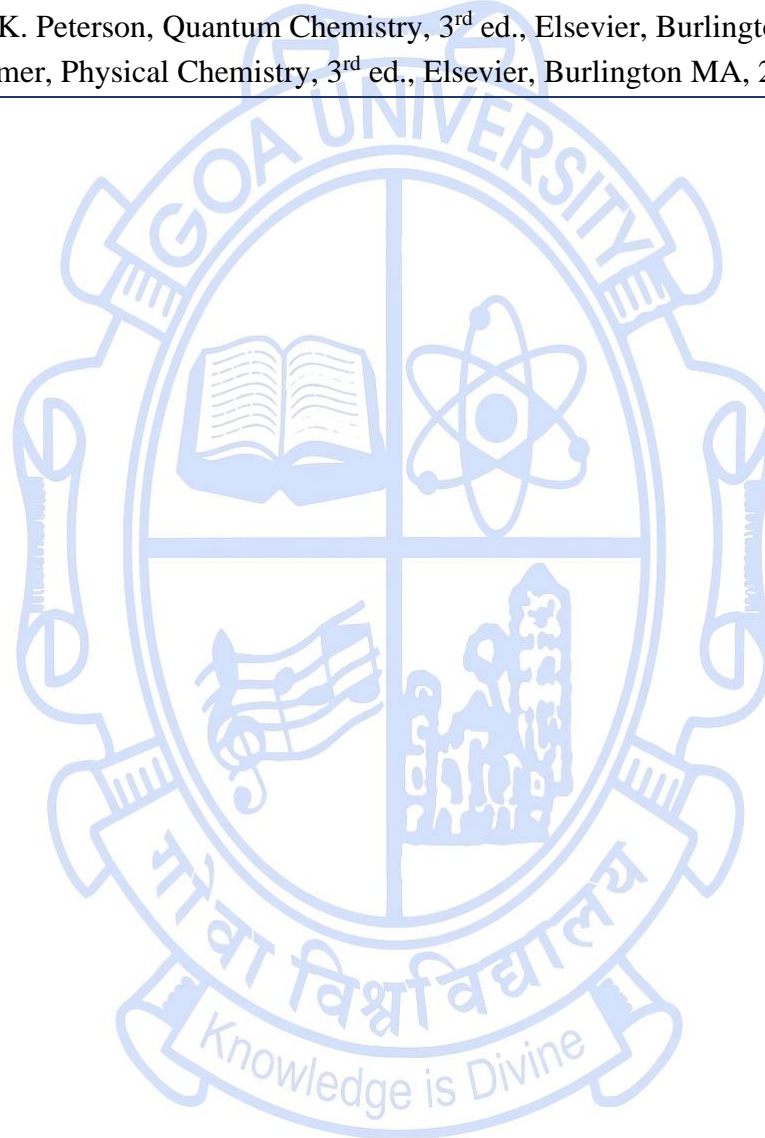
	CO 4. Apply fundamentals of chemical kinetics and thermodynamics for understanding reaction processes and mechanisms		PSO3, PSO7
Content:		No of hours	Mapped to CO Cognitive Level
Module 1:	1. Mathematical Preparations a. Introduction to various functions and function plotting (exponential, logarithmic, trigonometric etc.), functions of many variables. complex numbers and complex functions. b. Linear equations, vectors, matrices and determinants. c. Basic rules of differentiation and integration, Partial differentiation, location and characterization of critical points of a function, Regression methods, curve fitting. d. Introduction to series, convergence and divergence, power series, Fourier series e. Probability (permutations and combinations).	10	CO1, CO3 K1, K2, K3
Module 2:	2. Quantum Chemistry a. Operators, Functions, Eigen value equations, Postulates. b. Schrödinger equation, application to simple system viz. free particle, particle in one dimensional, two dimensional and three-dimensional box (quantization, separation of variables, degenerate wave functions). c. Hydrogen like atoms, Schrödinger equation and its solutions, atomic orbital wave functions and interpretation. d. Hückel MO theory, Secular equations, Secular determinant, delocalization energy, charge density, π -bond order, free valence, applications to C ₂ H ₄ , C ₃ H ₅ (radical), C ₄ H ₆ , C ₄ H ₄ , C ₆ H ₆ , C ₆ H ₈ .	20	CO1, CO3 K1, K2, K5
Module 3:	3. Thermodynamics a. Thermodynamic properties: Gas laws, real gases, Boyle temperature, critical temperature, state and path properties. Intensive and extensive properties. Exact and inexact differentials. Internal energy, enthalpy, entropy, free energy and	12	CO1, CO3, CO4 K1, K2, K3, K5

	<p>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>	9	CO1, CO3, CO4	K1, K2, K3, K4, K5

	<p>b. Introduction to reversible and irreversible reactions and reactions leading to equilibrium. van't Hoffs equation and analysis of Gibbs free energy of equilibrium reactions.</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 Electrodeics, 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 			

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| <ol style="list-style-type: none">5. J. E. House, Principles of Chemical Kinetics, 2nd ed., Academic Press, Burlington MA, 20076. J. P. Lowe, K. Peterson, Quantum Chemistry, 3rd ed., Elsevier, Burlington MA, 20067. 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

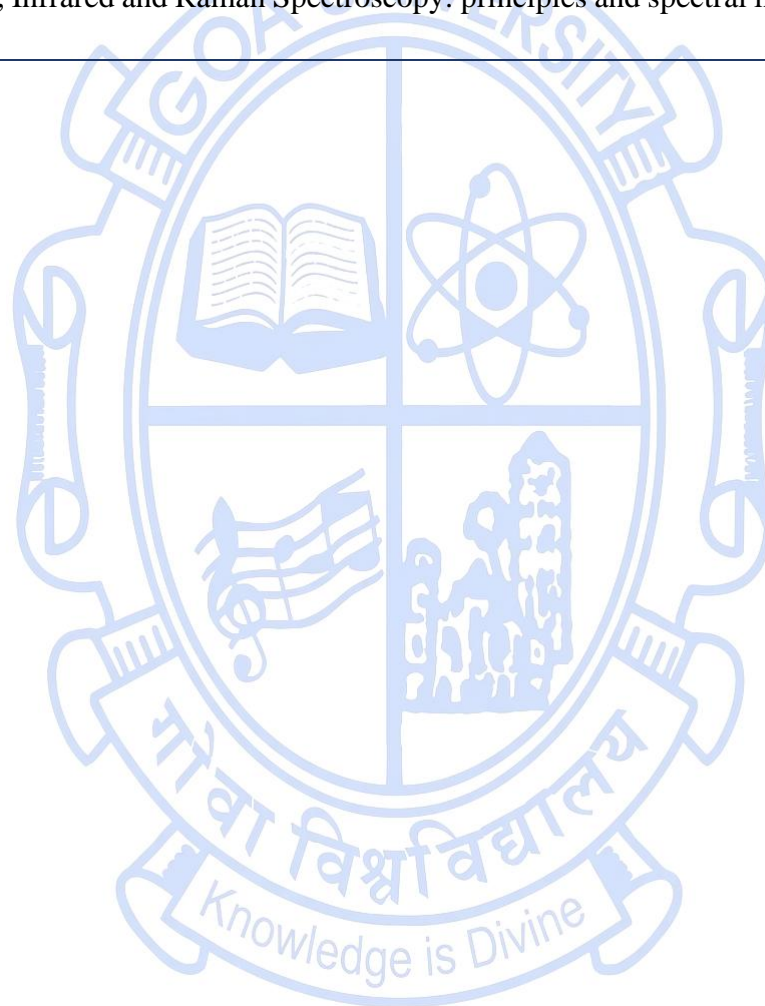
	CO 4. solve problems based on IR, NMR, MS combined spectral data.		PSO1, PSO2, PSO3	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	1.1. Analytical Objectives and Data Handling: Importance of analytical chemistry in research and industry; statistics and data handling in analytical chemistry, 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:	<p>4.1. Raman Spectroscopy</p>	5	CO4	K2, K3, K4

	Theory, Basic instrumentation and Structural analysis using Raman Spectra. Mass Spectrometry: Principle, Instrumentation and various fragmentation patterns.			
	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 Courses

Title of the Course	Methods of Chemical Analysis
Course Code	CHA-5001
Number of Credits	4
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 students to the fundamental principles and chemical theories underlying various classical and instrumental methods of chemical analysis.• To develop an understanding of the strengths, limitations, and appropriate applications of different chemical analytical techniques.• To provide students with comprehensive knowledge of various titration methods, clinical analysis procedures, and

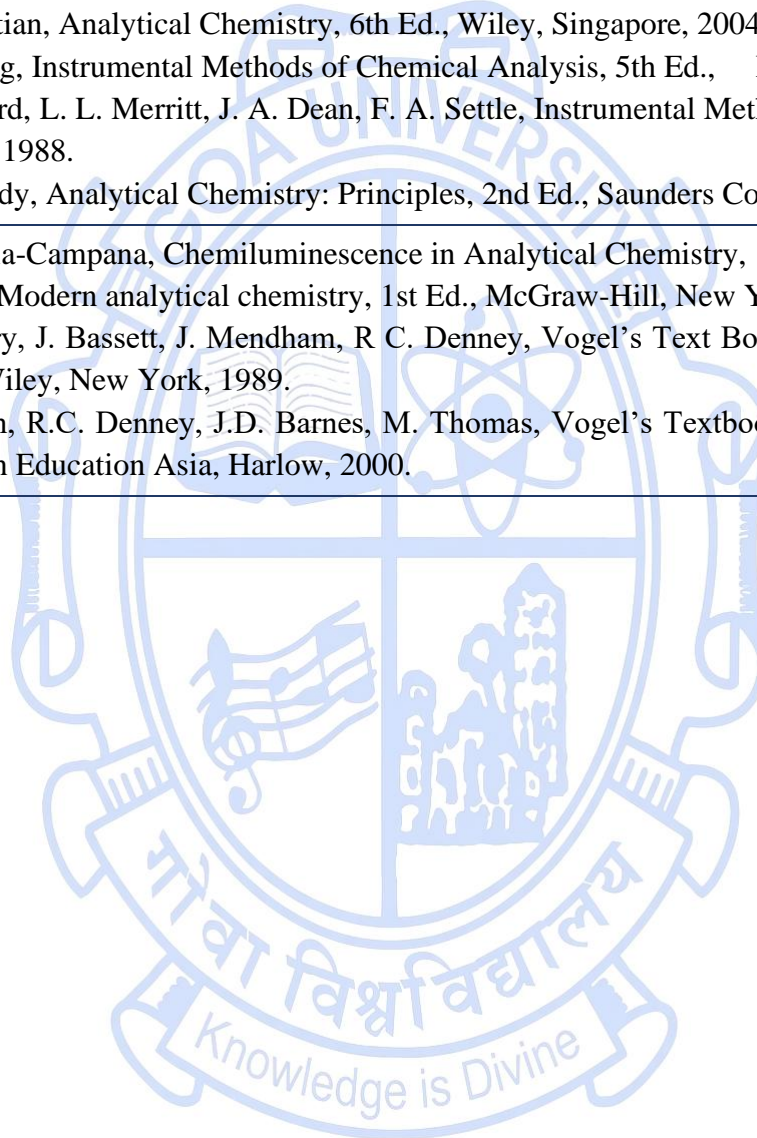
	<p>spectroscopic techniques employed in chemical analysis.</p> <ul style="list-style-type: none"> To equip students with the skills necessary to select and apply proper sampling techniques for qualitative and quantitative chemical analysis. 			
Course Outcomes:	Students will be able to		Mapped to PSO	
	CO 1. explain the fundamental principles and chemistry underlying various chemical methods of analysis.		PSO1, PSO2	
	CO 2. analyze the limitations of different analytical methods and evaluate their suitability for specific chemical analyses		PSO1, PSO2	
	CO 3. apply titration techniques, clinical analytical methods, and emission spectroscopy for sample analysis.		PSO1, PSO2, PSO3	
	CO 4. choose appropriate sampling techniques in chemical analysis and justify their use in different analytical scenarios.		PSO1, PSO2	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Acid-Base Titrations</p> <p>Standard acids and base solutions, Theory of acid-base indicators for acid-base titrations: colour change and range of indicator; selection of proper indicator; indicator errors. Neutralization curves for strong acid-strong base; weak acid-strong base, weak base-strong acid, weak acid-weak base titrations. Polyfunctional acids and bases; titration curves for polyfunctional acids and bases; titration curves for amphoteric species. Determining the equivalence point; feasibility of acid- base titrations; magnitude of the equilibrium constant; effect of concentration. Applications of acid-base titrations.</p>	10	CO1, CO2, CO3	K1, K2, K3, K4, K5, K6
Module 2:	<p>Complexometric and precipitation titrations</p> <p>The complex formation reactions; stability of complexes; stepwise formation constants;</p>	15	CO1, CO2,	K1, K2, K3, K4,

	<p>organic complexing agents; amino carboxylic acid titration. EDTA: acidic properties of EDTA; EDTA complexes with metal ions; equilibrium calculations involving EDTA in solution; condition of formation constants; EDTA titration curves; effect of other complexing agents on EDTA titrations; factors affecting the titration curves; completeness of reaction; indicators for EDTA titrations; Theory of common indicators; Titration methods using EDTA- direct titration; back titration and displacement titration; indirect determinations; titration of mixtures; selectivity, masking and damasking agents; Applications of EDTA titrations- hardness of water; magnesium and Al in antacids; magnesium, manganese and zinc in a mixture.</p> <p>Introduction to precipitation titrations; feasibility of precipitation titrations; titration curves; Effect of titrant and analyte concentration on titration curves; Effect of reaction completeness on titration curves; titration curves for mixture of anions; indicators for precipitation titrations; the Volhard, the Mohr's and the Fajan's methods; titration of sulfate with barium.</p>		CO3	K5, K6
Module 3:	<p>Basic Concepts in Electrochemical Titrations and Redox Titrations</p> <p>Faradic and non-Faradic currents; Reversible and irreversible cells; EMF series; standard electrode potential; Nernst equation; calculation of cell potential; effect of current; ohmic potential; polarization; decomposition potential; over voltage; concentration polarization; mechanism of mass transport; introduction to potentiometric methods</p> <p>Redox and potentiometric titrations: equilibrium constants for redox reactions electrode potentials in equilibrium systems; calculation of equilibrium constants; redox titration curves- formal redox potentials; derivation of titration curves; factors affecting the shape of titration curves concentration; completeness of reaction; titration of mixtures- feasibility of redox titrations</p> <p>Detection of end point and redox indicators: structural aspect of redox indicators; specific and nonspecific indicators; choice of indicator; potentiometric end point detection;</p>	10	CO1, CO2, CO3	K1, K2, K3, K4, K5, K6

	sample preparation: pre-reduction and pre-oxidation; potentiometric titrations.			
Module 4:	<p>Molecular Fluorescence, Phosphorescence and Chemiluminescence Spectrometry</p> <p>Fluorescence and phosphorescence: theory; factors influencing fluorescence and phosphorescence; instrumentation; spectrofluorometer and phosphorimeter; applications of photoluminescence methods.</p> <p>Chemiluminescence: Introduction; instrumentation; measurement of chemiluminescence, gas phase chemiluminescence analysis, chemiluminescence titrations; application in organic and inorganic analysis.</p> <p>Electrochemiluminescence and bioluminescence: theory and their applications.</p>	10	CO1, CO2, CO3	K1, K2, K3, K4, K5
Module 5:	<p>Clinical Chemistry</p> <p>Composition of Blood; Collection and Preservation of Samples; Radioimmunoassay: principle, instrumentation and applications. Fluorescence Immunoassay: principle, instrumentation and applications.</p> <p>Enzyme Immunoassay: principle, instrumentation and applications.</p> <p>Blood gas analyzer: principle, instrumentation and applications.</p> <p>Overview of trace elements in the body.</p>	10	CO1, CO2, CO3	K1, K2, K3, K4
Module 6:	<p>Environmental Sampling and Analysis</p> <p>Air sample collection and analysis; water sample collection and analysis; soil and sediment sampling; Sample preparation for trace organics; methods and performance-based analysis.</p>	5	CO1, CO2, CO4	K1, K2, K3, K4, K5
Pedagogy:	Mainly lectures and tutorials. Seminars / term papers / assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.			
Texts:	1. D. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed., Cengage			

	<p>Learning, Boston, 2014.</p> <ol style="list-style-type: none"> G. D. Christian, Analytical Chemistry, 6th Ed., Wiley, Singapore, 2004. G. W. Ewing, Instrumental Methods of Chemical Analysis, 5th Ed., McGraw-Hill, New York, 1985. H. H. Willard, L. L. Merritt, J. A. Dean, F. A. Settle, Instrumental Methods of Analysis, 7th Ed., CBS Publishers, New Delhi, 1988. J. H. Kennedy, Analytical Chemistry: Principles, 2nd Ed., Saunders College Publishing, Philadelphia, 1990.
References/ Readings:	<ol style="list-style-type: none"> A. M. Garcia-Campana, Chemiluminescence in Analytical Chemistry, 1st Ed., CRC Press., Boca Raton, 2001. D. Harvey, Modern analytical chemistry, 1st Ed., McGraw-Hill, New York, 2000. G. H. Jeffery, J. Bassett, J. Mendham, R C. Denney, Vogel's Text Book of Quantitative Chemical Analysis, 5th Ed., John Wiley, New York, 1989. J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas, Vogel's Textbook of Quantitative Inorganic Analysis, 6th Ed., Pearson Education Asia, Harlow, 2000.

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Title of the Course	Selected Techniques in Analytical Chemistry
Course Code	CHA-5002
Number of Credits	4
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 understand the principle of optical analytical techniques like Nephelometry, Turbidimetry, and Polarimetry. To introduce the principles and applications of Absorption and Emission spectroscopic techniques. To learn the concepts in various Electroanalytical techniques such as pHmetry, conductometry and Karl Fischer titration. To acquaint with the basic principles of Radioanalytical techniques and solvent extraction techniques. 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. explain Nephelometry, Turbidimetry, Polarimetry, AAS, AES, voltammetry, conductometry, Karl Fischer titrimetry, extraction and radioanalytical methods.	PSO1, PSO3

	CO 2. select appropriate techniques for sample analysis.		PSO1, PSO3
	CO 3. apply the techniques such as Nephelometry, Turbidimetry, Polarimetry, AAS, AES, voltammetry, conductometry, Karl Fischer titrimetry, radioanalytical analysis and extraction.		PSO1, PSO3
	CO 4. apply and solve the problems based on the analytical techniques.		PSO1, PSO3
Content:		No of hours	Mapped to CO Cognitive Level
Module 1:	<p>Optical analytical techniques</p> <p>Nephelometry and Turbidimetry: Principle, Mathematical relation and the parameters for analysis, instrumentation of nephelometry and turbidimetry. factors affecting sensitivity and measurement; comparison between nephelometry and fluorimetry, and turbidimetry and colorimetry; applications of nephelometry and turbidimetry.</p> <p>Polarimetry: Introduction, principle and Instrumentation of Polarimetry; application of optical rotation method in rate constant determination; acid-catalysed mutarotation of glucose; inversion of cane sugar. Introduction to terms such as optical rotatory dispersion (ORD), cotton effect curves, circular dichroism, octant rule for ketones.</p>	15	CO1, CO2, CO3, CO4 K1, K2, K3, K4
Module 2:	<p>Atomic Absorption and Emission Techniques</p> <p>Introduction, principles and applications of atomic absorption Spectroscopy (AAS), atomic emission spectroscopy (AES), and flame emission spectroscopy (FES). Excitation techniques, electrodes and their shapes, Quantitative and qualitative application, brief introduction to ICP-MS, ICP-OES.</p>	5	CO1, CO2, CO3, CO4 K1, K2, K3, K4
Module 3:	<p>Electroanalytical techniques</p> <p>Voltammetry and polarography, cyclic voltammetry, coulometry, controlled potential coulometry and coulometric titrations, Stripping voltammetry, ion-selective electrodes</p>	15	CO1, CO2, CO3, K1, K2, K3, K4

	<p>and sensors; Evaluation and Calculation; Application to Inorganic and Organic Trace analysis</p> <p>Ion selective electrodes: construction, application and selectivity coefficient of Ion selective electrode; pH measurement; buffer solution; glass electrode; instrument for pH measurement.</p> <p>Conductometric titration: types of conductometric titration; advantages and disadvantages of conductometric titration.</p> <p>High frequency titrations: Introduction, theory, instrumentation; advantages, disadvantages and applications.</p>		CO4	
Module 4:	<p>Karl Fischer Titration</p> <p>Introduction, theory, instrumentation, advantages and disadvantages, Karl Fischer reagent, determination of water content in industrial samples.</p>	5	CO1, CO2, CO3, CO4	K1, K2, K3, K4
Module 5:	<p>Radioanalytical techniques</p> <p>Theory and principles of radio analytical technique, detection of nuclear radiation, radiation detectors, pulse height analysis, counting error, analytical application of radioisotopes, neutron activation analysis and isotope dilution analysis.</p>	10	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5
Module 6:	<p>Extraction Techniques</p> <p>Liquid-liquid extraction/solvent extraction: partition coefficient, distribution ratio and percent extraction, choice of solvents, Solvent extraction of metal ions-ion association complexes and metal chelates, multiple batch extraction, Craig's counter-current distribution.</p> <p>Green analytical extraction methods: Supercritical Fluid Extraction, Pressurized Liquid Extraction, Ultrasound assisted Extraction, Microwave assisted Extraction, Enzyme assisted Extraction, Solid phase microextraction, Solid Phase Extraction.</p>	10	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. D. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed., Cengage Learning, Boston, 2014. 2. G. D. Christian, Analytical Chemistry, 6th Ed., Wiley, Singapore, 2004. 3. G. W. Ewing, Instrumental Methods of Chemical Analysis, 5th Ed., McGraw-Hill, New York, 1985. 4. H. H. Willard, L. L. Merritt, J. A. Dean, F. A. Settle, Instrumental Methods of Analysis, 7th Ed., CBS Publishing, New Delhi, 1988. 5. J. H. Kennedy, Analytical Chemistry: Principles, 2nd Ed., Saunders College Publishing, Philadelphia, 1990.
References/ Readings:	<ol style="list-style-type: none"> 1. B. K. Sharma, Instrumental Methods of Chemical Analysis, Goel Publishing House, Meerut, 2004. 2. E. Scholz, Karl Fischer Titration: Determination of Water, Springer, Berlin, 2011. 3. F. J. Holler, D. A. Skoog, S. R. Crouch, Principles of Instrumental Analysis, 6th Ed., Thomson Books, Belmont, 2007. 4. G. R. Chatwal, S. K. Anand, Instrumental Methods of Chemical Analysis, 5th Ed., Himalaya Publishing House, Mumbai, 2019. 5. H. Günzler, A. Williams, Handbook of Analytical Techniques, 1st Ed., Wiley-VCH, Weinheim, 2001. 6. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, B. Sivasankar, Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed., Pearson, New Delhi, 2009. 7. M. A. Rostagno, J. M. Prado, Natural Product Extraction: Principles and Applications, RSC Publishing, Cambridge, 2013. 8. R. A. Day, A. L. Underwood, Quantitative Analysis, 6th Ed., Prentice Hall, Upper Saddle River, 2001. 9. R. D. Braun, Introduction to Instrumental Analysis, Pharmamed Press, Hyderabad, 2012.

Title of the Course	Separation Techniques
Course Code	CHA-5003
Number of Credits	4
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 understand the basic principle of various separation techniques. • To learn to select appropriate techniques for purification of analyte and interferent. • To acquaint with qualitative and quantitative methods for the sample analysis. • To acquire the concept of method development using separation techniques. 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. explain the principle of different separation techniques.	PSO1
	CO 2. choose appropriate separation techniques for purification of analyte.	PSO1, PSO2

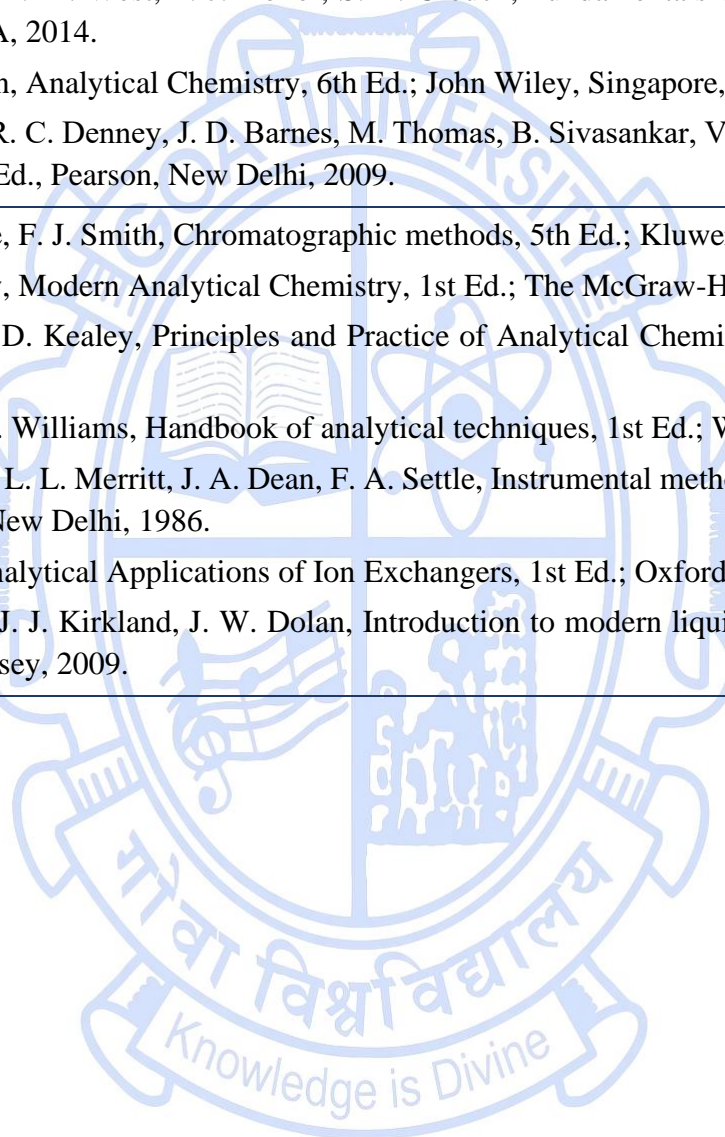
	CO 3. apply the separation techniques for qualitative and quantitative analysis.		PSO1, PSO2, PSO3
	CO 4. develop method for chemical analysis using separation techniques.		PSO1, PSO2, PSO3
Content:		No of hours	Mapped to CO Cognitive Level
Module 1:	<p>Concepts in Separation Techniques</p> <p>General aspects of separation techniques, separation of analyte from interferents, Separation efficiency and separation factor.</p> <p>Classification of separation techniques, distillation: principle and types, complexation reaction (masking), solvent extraction (based on chemical nature and polarity of analyte), membrane techniques: dialysis, reverse osmosis, ultrafiltration. centrifugation techniques: types, analytical and preparative centrifugation, sedimentation velocity, sedimentation equilibrium. Electrophoresis, chromatographic methods: Principles, classification, terms and parameters used in chromatography, applications.</p>	10	CO1, CO2, CO3 K1, K2, K3, K4
Module 2:	<p>2.1. Planar Chromatography (Paper Chromatography, Thin Layer Chromatography and High Performance Thin Layer Chromatography)</p> <p>Principles, types, efficiency, selection of stationary and mobile phases, choice of adsorbents, spotting, development of chromatogram, elution strength (numericals), identification and detection using physical and chemical methods, reproducibility of R_f values and improving resolution, comparison of PC, TLC and HPTLC, qualitative and quantitative applications.</p> <p>2.2. Column Chromatography</p> <p>Introduction, types (conventional, flash, LPLC, Dry column vacuum chromatography), principle, packing, loading, eluting and collection, and experimental requirements, theory of development, migration rates of solutes, band broadening, resolution and</p>	10	CO1, CO2, CO3, CO4 K1, K2, K3, K4, K5, K6

	column efficiency, variables that affect column efficiency, van Deemter equation, numericals, qualitative and quantitative analysis, applications.			
Module 3:	<p>3.1. Gas Chromatography (GC) Instrumentation, selection of operating condition, carrier gases, stationary phases, choices of GC column, temperature selection, sampling techniques, methods to prepare derivatives of samples (silylation, acylation, alkylation), factors affecting separation, working principle of GC detectors such as TCD, ECD, FID, etc, quantification methods such as normalizing peak area, internal standard, external standard, standard addition, advances in GC, application in pharmaceutical, industry, flavors, food and fragrances analysis.</p> <p>3.2. High Performance liquid chromatography (HPLC) Introduction, selection of stationary and mobile phase, types of bonded phase chromatography-NPC and RPC and stationary phases used, reversed phase partition chromatography, steps in HPLC method development in partition chromatography, method validation, elution techniques (isocratic and gradient), ion pairing agents, buffer agents, organic modifiers, optimization of capacity factor, gradient selectivity factor and column plate numbers, numericals on method development using Snyder's polarity index, advances in LC, preparative vs analytical HPLC, chiral chromatography-Pirkle stationary phases, examples of enantiomer separation such as ibuprofen, calculation of enantiomeric excess. Choice of detectors- working principle of RI, UV-Vis, conductivity and ELSD, application of HPLC method development in food analysis/drugs, etc.</p>	20	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
Module 4:	<p>Other Chromatographic Methods Size Exclusion Chromatography: Principle, types, stationary phases in gel chromatography, physical and chemical characteristics of gel, mechanism of gel</p>	10	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5

	<p>permeation chromatography (GPC), instrumentation of GPC, applications of GPC-determination of molecular weight of polymer with numericals.</p> <p>Affinity Chromatography: Principle, affinity matrix, ligands, mobile phase, separation mechanism, application in the separation of proteins, etc.</p> <p>Supercritical Fluid Chromatography: Introduction, important properties of supercritical fluids, instrumentation and variables, SFC column vs other column, applications and data analysis. Chiral & achiral SFC, applications in pharmaceuticals, food analysis and natural products.</p> <p>Ion Exchange Chromatography: Introduction, mechanism of separation, types of stationary phases, factor affecting separation; Ion exclusion chromatography; separation mechanism- Donnan theory, application in the separation of alkaloids, carboxylic acids etc.</p>			
Module 5:	<p>Electrophoresis</p> <p>Theory of electrophoresis, types- free solution and supporting medium electrophoresis, paper electrophoresis, capillary electrophoresis and gel electrophoresis, factors affecting separation, staining and detecting electrophoresis bands, applications.</p> <p>Capillary electrophoresis; instrumentation, sample introduction, types, electrophoretic mobility and electroosmotic mobility, total mobility, efficiency and resolution, numericals. Gel electrophoresis; types of gel, Polyacrylamide gel electrophoresis PAGE, Agarose GE, SDS-PAGE, 2D Gel electrophoresis.</p> <p>Capillary Electrochromatography; column, mobile phase, applications.</p> <p>Separation of neutral molecules by MEKC.</p>	10	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5
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. D. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed.; Cengage Learning, USA, 2014. 2. G. D. Christian, Analytical Chemistry, 6th Ed.; John Wiley, Singapore, 2004. 3. 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.
References/ Readings:	<ol style="list-style-type: none"> 1. A. Braithwaite, F. J. Smith, Chromatographic methods, 5th Ed.; Kluwer academic publishers, Netherland, 1999. 2. David. Harvey, Modern Analytical Chemistry, 1st Ed.; The McGraw-Hill, USA, 2000. 3. F. W. Fifield, D. Kealey, Principles and Practice of Analytical Chemistry, 5th Ed.; Blackwell Science Ltd., UK, 2000. 4. H. Gunzler, A. Williams, Handbook of analytical techniques, 1st Ed.; Wiley, Germany, 2002. 5. H. H. Willard, L. L. Merritt, J. A. Dean, F. A. Settle, Instrumental methods of Analysis, 7th Ed.; CBS Publishers & Distributors, New Delhi, 1986. 6. J. InczEdy, Analytical Applications of Ion Exchangers, 1st Ed.; Oxford Pergamon Press, London, 1966. 7. L. R. Snyder, J. J. Kirkland, J. W. Dolan, Introduction to modern liquid chromatography, 3rd Ed.; John Wiley & Sons, New Jersey, 2009.

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Title of the Course	Instrumental Methods of Analysis
Course Code	CHA-5004
Number of Credits	4
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 understand working principles of various instrumental techniques for analysis. • To learn application of diffraction and spectroscopy techniques for analysis of materials. • To acquaint with different microscopic and other techniques for analysis of materials. • To solve material characterization challenges through selection of suitable techniques 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. explain theory and instrumentation of various instrumental techniques of analysis.	PSO1, PSO2
	CO 2. apply diffraction and spectroscopic techniques for qualitative and quantitative analysis of materials.	PSO3

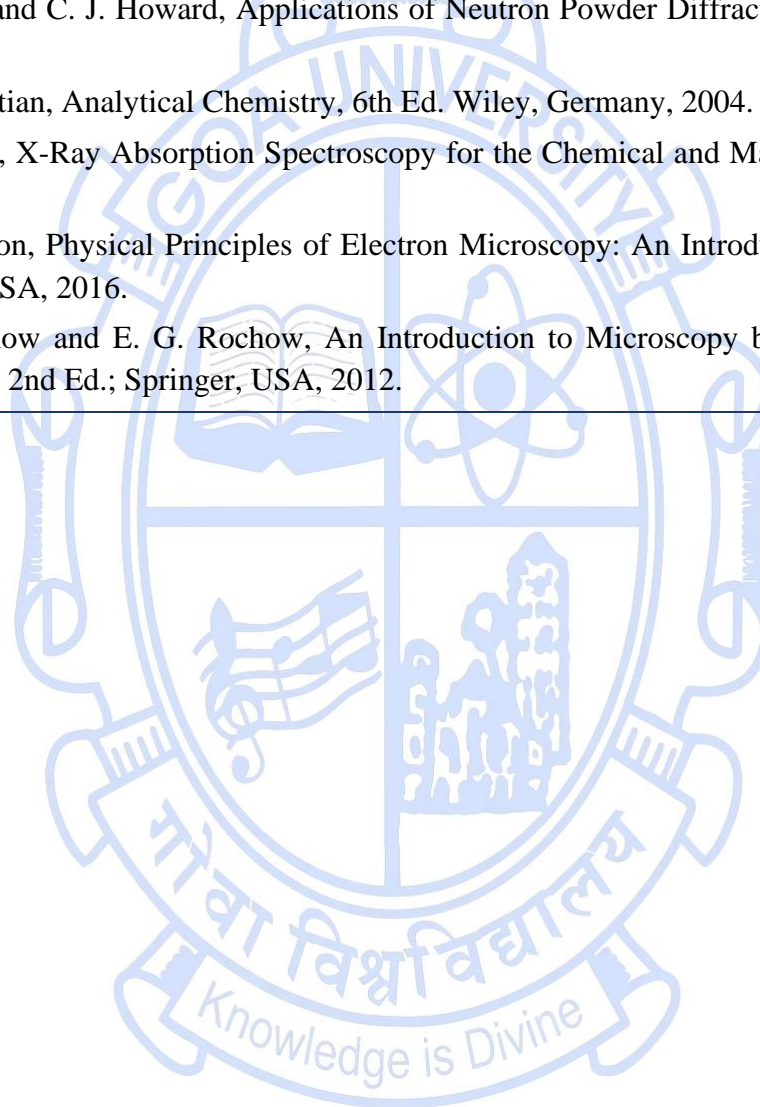
	CO 3. choose suitable microscopic and other techniques for analyzing materials.		PSO1, PSO2	
	CO 4. evaluate suitability of instrumental methods for solving material characterization challenges through the expertise acquired.		PSO3	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Diffraction Techniques: X-ray and Neutron Diffraction</p> <p>Crystalline solids, interaction of X-rays with matter, generation of X-rays, X-ray diffraction by crystals, Bragg's law</p> <p>X-ray diffraction methods: Single crystal and Powder X-ray diffraction: principle, instrumentation and applications, crystallography databases.</p> <p>Interpretation of powder X-ray diffraction pattern, calculation of lattice parameters.</p> <p>Powder Neutron diffraction: theory, instrumentation, and applications</p>	15	CO1, CO2, CO4	K1, K2, K3, K4, K5, K6
Module 2:	<p>X-ray Spectroscopic Techniques</p> <p>X-ray spectroscopy, theory of X-ray absorption and emission.</p> <p>X-ray fluorescence (XRF) spectroscopy: introduction, instrumentation, wavelength dispersive and energy dispersive XRF, applications.</p> <p>Energy dispersive X-ray (EDX) spectroscopy and Electron probe microanalysis (EPMA): introduction, instrumentation and their applications.</p> <p>Introduction to X-ray absorption near edge structure (XANES), Extended X-ray absorption fine structure (EXAFS) and their applications.</p>	15	CO1, CO2, CO4	K1, K2, K3, K4, K5, K6
Module 3:	<p>Electron Spectroscopy and Mössbauer spectroscopy</p> <p>Introduction to Electron spectroscopy techniques.</p> <p>X-ray and UV Photoelectron spectroscopy (XPS, UPS): theory, instrumentation and their applications.</p>	15	CO1, CO3, CO4	K1, K2, K3, K4, K5

	<p>Introduction to Auger electron spectroscopy and electron energy loss spectroscopy (EELS) and their applications.</p> <p>Electron spectroscopy for chemical analysis (ESCA): theory and applications.</p> <p>Mössbauer spectroscopy: theory and applications.</p>			
Module 4:	<p>Microscopic and Dynamic Light Scattering Techniques:</p> <p>Light microscopy: optical principles, instrumentation, sample preparation, imaging modes, applications.</p> <p>Electron microscopy: Scanning electron microscopy (SEM), Transmission electron microscopy (TEM) and Scanning transmission electron microscopy (STEM) – Principle, instrumentation, sample preparation (TEM grids, ion milling, electropolishing etc) and applications. Selected Area Electron Diffraction (SAED)</p> <p>Atomic Force Microscopy (AFM): theory, instrumentation, operational modes and applications.</p> <p>Dynamic Light Scattering (DLS): theory, instrumentation, and applications in particle size distribution.</p>	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. A. R. West, Solid State Chemistry and Its Applications, 2nd Ed.; Wiley, UK, 2014. 2. Bradley D. Fahlman, Materials Chemistry, 4th Ed. Springer International Publishing AG, USA, 2023. 3. V. K. Pecharsky and P. Y. Zavalij, Fundamentals of Powder Diffractions and structural characterisation of materials, 2nd Ed.; Springer, USA, 2008. 4. Y. Leng, Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, 2nd Ed.; Wiley-VCH, Germany, 2013. 			

**References/
Readings:**

1. D. A. Skoog, F. J. Holler and S. R. Crouch, Principles of Instrumental Analysis, 7th Ed.; Cengage, USA, 2017.
2. E. H. Kisi and C. J. Howard, Applications of Neutron Powder Diffraction, 1st Ed., Oxford Science Publications, UK, 2008.
3. G. D. Christian, Analytical Chemistry, 6th Ed. Wiley, Germany, 2004.
4. John Evans, X-Ray Absorption Spectroscopy for the Chemical and Materials Sciences, 1st Ed. Wiley, Germany, 2018
5. R. F. Egerton, Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM, 2nd Ed.; Springer, USA, 2016.
6. T. G. Rochow and E. G. Rochow, An Introduction to Microscopy by Means of Light, Electrons, X-Rays, or Ultrasound, 2nd Ed.; Springer, USA, 2012.

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SEMESTER I & II

Discipline Specific Elective Courses

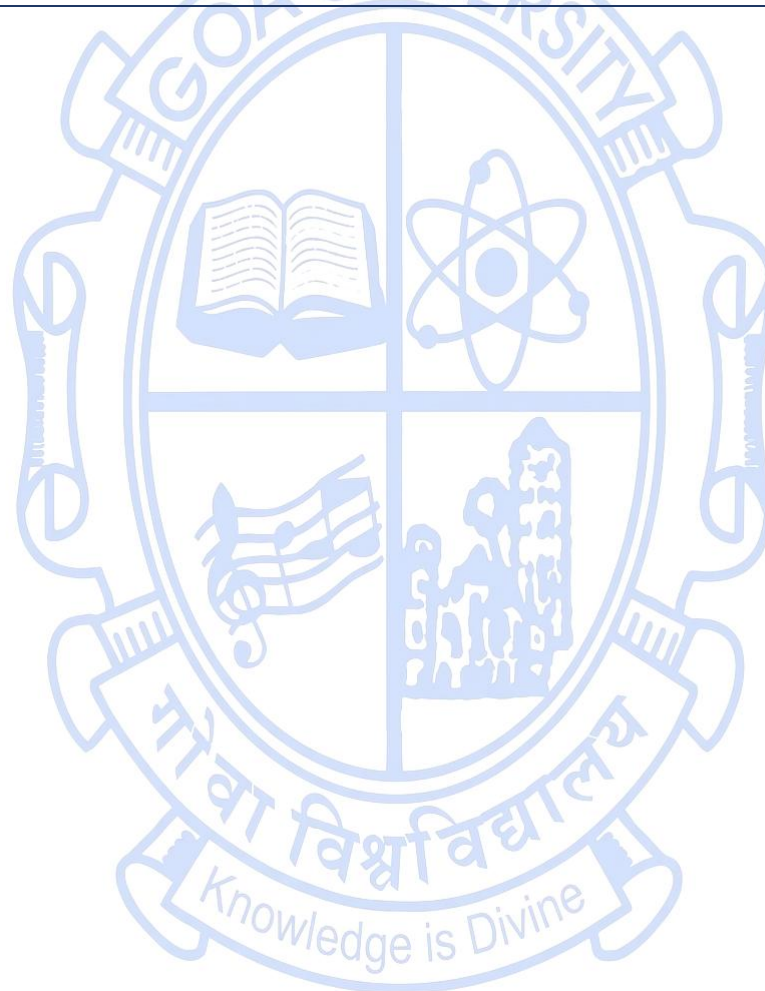
Title of the Course	Organic Chemistry Practical - I	
Course Code	CHO-5201	
Number of Credits	2	
Theory/Practical	Practical	
Level	400	
Effective from AY	2025-26	
New Course	Yes	
Bridge Course/ Value added Course	No	
Course for advanced learners	No	
Pre-requisites for the Course:	NIL	
Course Objectives: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



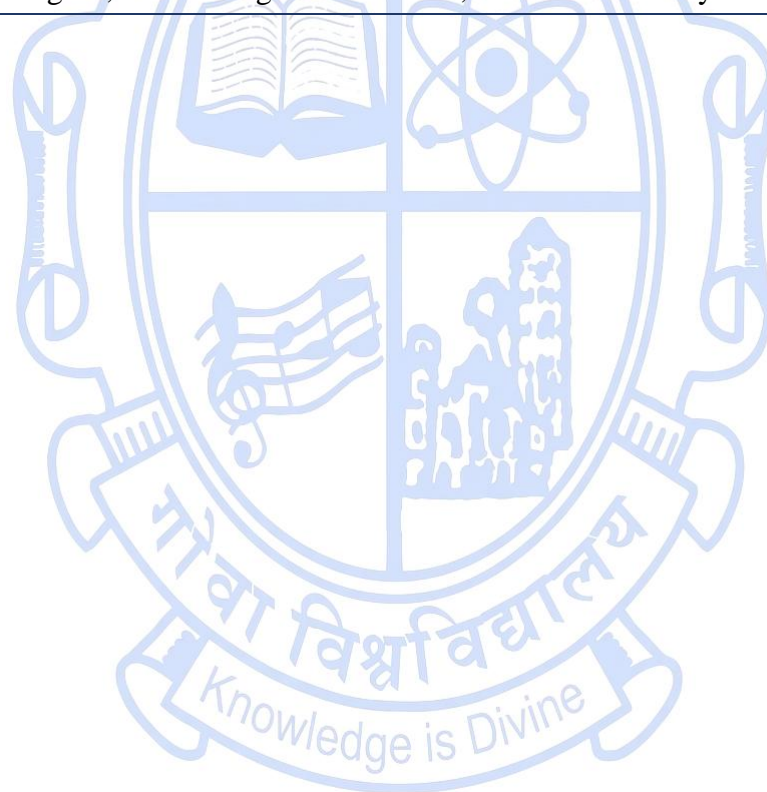
Title of the Course	Organic Chemistry Practical - II	
Course Code	CHO-5202	
Number of Credits	2	
Theory/Practical	Practical	
Level	400	
Effective from AY	2025-26	
New Course	Yes	
Bridge Course/ Value added Course	No	
Course for advanced learners	No	
Pre-requisites for the Course:	NIL	
Course Objectives:	<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-2,4 dinitrophenol 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:	<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 			

	<ol style="list-style-type: none"> 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, 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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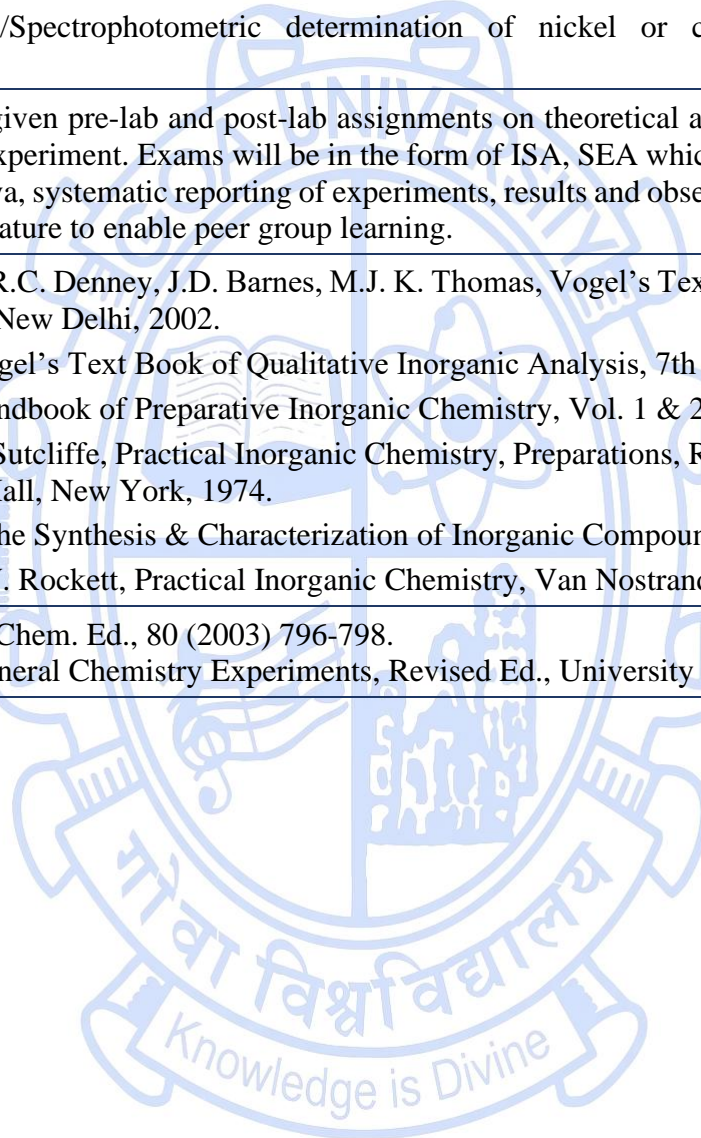
Title of the Course	Inorganic Chemistry Practical-I
Course Code	CHI-5201
Number of Credits	2
Theory/Practical	Practical
Level	400
Effective from AY	2025-26
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

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:		No of hours	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]·xH₂O or K₃[Cr(C₂O₄)₃]·xH₂O</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]·xH₂O and to determine degree of hydration.</p>	32	CO3, CO4 K2, K3, K4, K5

	<p>j. Estimation of potassium from synthesized compounds.</p> <p>k. Colorimetric/Spectrophotometric determination of nickel or chromium or manganese.</p>			
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 should 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.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
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 to	Mapped to PSO
	CO 1. understand methodologies related to compound synthesis.	PSO1, PSO4
	CO 2. experiment with various reagents and metal salts to synthesize useful compounds.	PSO1, PSO4

	CO 3. analyse synthesized and commercially available compounds.		PSO1, PSO3	
	CO 4. interpret the chemical composition of materials using chemical methods and instrumental techniques.		PSO1, PSO3, PSO4	
Content:		No of hours	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:	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"> To determine the dissociation constants of a tribasic acid (Phosphoric acid obtain derivative plot to get equivalence point. 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. To study spectrophotometric titration of ferrous ammonium sulphate with potassium permanganate (or dichromate vs permanganate) To determine Avogadro's number by improved electroplating. To determine the zeta potential of colloidal system and investigate the effect of different surfactants on stability of the colloids. To verify the Kohlrausch's law for weak electrolyte by conductometry. To determine the transport numbers of Cu^{2+} and SO_4^{2-} ions in CuSO_4 solution by Hittorf's method. 			
Pedagogy:	Students will be given pre-lab and post-lab assignments on theoretical aspects of laboratory experiments prior to the conduct of each experiment. Exams will be in the form of ISA, SEA which will involve performing given experiments and conduct of viva, systematic reporting of experiments, results and observations in laboratory report. Sessions can preferably be interactive in nature to enable peer group learning.			
Texts:	<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, 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. 			

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"> 5. 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. 6. To study the electrodeposition of metal. 			
Pedagogy:	Students will be given pre-lab and post-lab assignments on theoretical aspects of laboratory experiments prior to the conduct of each experiment. Exams will be in the form of ISA, SEA which will involve performing given experiments and conduct of viva, systematic reporting of experiments, results and observations in laboratory report. Sessions can preferably be interactive in nature to enable peer group learning.			
Texts:	<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, USA 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. 			

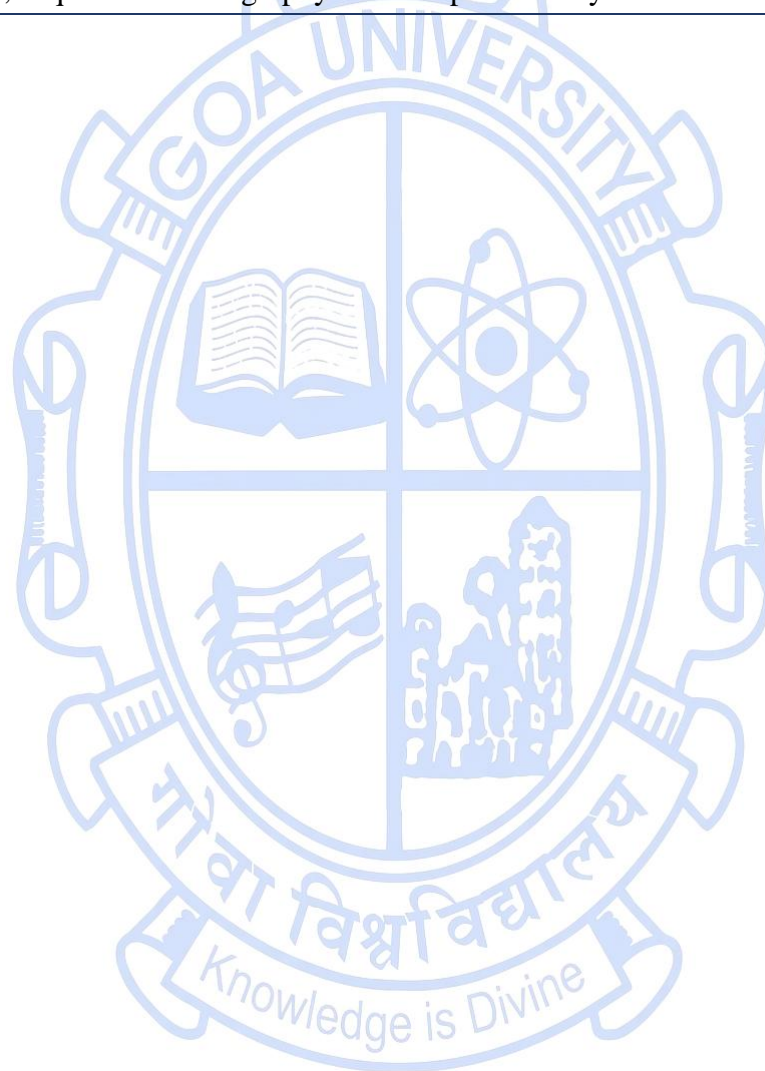
Title of the Course	Analytical Chemistry Practical - I	
Course Code	CHA-5201	
Number of Credits	2	
Theory/Practical	Practical	
Level	400	
Effective from AY	2025-26	
New Course	Yes	
Bridge Course/ Value added Course	No	
Course for advanced learners	No	
Pre-requisites for the Course:	Nil	
Course Objectives:	<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 K ₂ Cr ₂ O ₇ by Visible spectroscopy d. Simultaneous determination and Verification of law of additivity of absorbances (K ₂ Cr ₂ 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 normal phase 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, 6 th Ed., Pearson Education India, 2015. 3. J. Kenkel, Analytical Chemistry for Technicians, 3 rd 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, 5 th 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

	solvent extraction. b. Colorimetric determination of iron with salicylic acid. c. Determination of copper in brass sample by colorimetry.			
Module 7:	7. Data Interpretation Exercises a. NMR/Mass spectra. b. HPLC and GC chromatograph. c. XRD powder pattern of cubic systems. d. Thermogram of coordination compounds.	8	CO1, CO2	K3, K4
Module 8:	8. Demonstration a. Turbidimeter. b. KF instrument. c. Polarimeter. d. LCMS. e. NMR.	8	CO1, CO2	K3, K4
Pedagogy:	Prelab exercises / assignments / presentations / lab hand-out or a 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, New-Delhi, 2015. 3. J. Kenkel, Analytical Chemistry for Technicians, 3rd Ed., Lewis publishers, USA, 2002. 4. R. M. Silverstein, F. X. Webster, D. Kiemle, D. Bryce, S. Samant, V. S. Nadkarni, Spectrometric Identification of Organic compounds, An Indian Adaptation, Wiley, India, 8th Ed., 2022 5. A. J. Elias, Collection of interesting chemistry experiments, University press, Hyderabad, 2002. 6. A. Kar, Pharmaceutical Drug Analysis, New Age International, India, 2005.			
References/ Readings:	1. G. D. Christian, Analytical chemistry, 5th Ed., John Willey and Sons, USA, 1994. 2. J. H. Kennedy, Analytical Chemistry: Principles, 2nd Ed., Saunders College Publishing, Philadelphia, 1990. 3. M. Asadi, Beet-Sugar Handbook, John Wiley & Sons, USA, 2006. 4. R. E. Ardrey, Liquid Chromatography - Mass Spectrometry: An Introduction, John Wiley & Sons, England, 2003.			

SEMESTER III

Research Specific Elective (RSE) Courses

Title of the Course	Analytical Chemistry Practical- III	
Course Code	CHA-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 Courses	
Course Objectives:	<ol style="list-style-type: none">1. To study various experimental techniques for analysis.2. To learn data analysis, handling and interpretation of spectra.3. To understand different techniques for the separations4. To interpret data for the sample analysis	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. choose different techniques for qualitative and quantitative estimation.	PSO1, PSO4
	CO 2. interpret spectra and use statistical methods to analyse data.	PSO3, PSO4

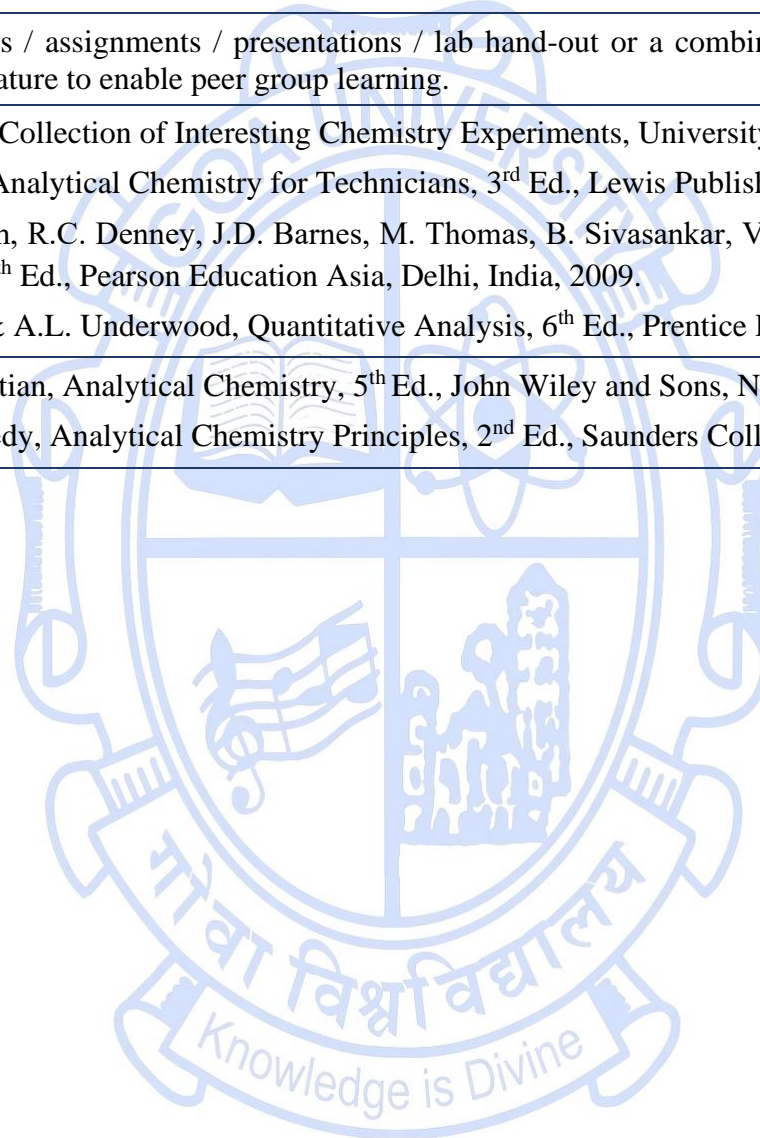
	CO 3. apply different techniques for the separation.		PSO3, PSO4	
	CO 4. analyse pharmaceutical samples using different techniques.		PSO4	
Content:	Minimum 20 experiments from atleast 8 units shall be conducted	No of hours	Mapped to CO	Cognitive Level
Module 1:	Analysis of Pharmaceutical Tablets/samples (Titrimetry) <ol style="list-style-type: none"> Estimation of Paracetamol or any other drug by titrimetry. Determination of the Vitamin C content in tablets Using iodometric titration Estimation of streptomycin in tablet sample by Maltol method. Estimation of iron using Zimmermann-Reinhardt reagent by titrating against $KMnO_4$. 	12	CO1, CO2, CO4	K1, K2, K3, K4, K5
Module 2:	Ion exchange Chromatography and Solvent Extraction Method <ol style="list-style-type: none"> Determination of capacity of a cation exchange resin. Concentration and determination of copper (II) ions from a brine solution using a chelating ion exchange resin and AES/AAS Separation of organic mixture (acidic + basic + neutral) by extraction. Separation and quantification of Cationic Impurities in pharmaceutical tablets by Ion exchange chromatography 	12	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5
Module 3:	Planar and Column Chromatography <ol style="list-style-type: none"> Thin layer chromatography analysis of commercially available analgesic/antipyretic/antihistamine etc and to identify the active ingredients. Purification and determination of amount of paracetamol from commercial tablet by column chromatography. Separation of a mixture of benzoic acid and benzil on silica gel column. 	12	CO1, CO3, CO4	K1, K2, K3, K4, K5
Module 4:	Spectrophotometric Method <ol style="list-style-type: none"> Determination of pK value of methyl red indicator. 		CO1, CO2,	K1, K2, K3, K4,

	<ul style="list-style-type: none"> ii. Determination of stoichiometry and stability constant of ferric salicylic acid complex by Job's method and mole ratio method. iii. Determination of the Fe ion as Fe-oxime complex. iv. Spectrophotometric determination of aspirin/phenacetin/caffeine in APC tablet using solvent extraction. 		CO4	K5
Module 5:	<p>HPLC Analysis</p> <ul style="list-style-type: none"> i. Analysis of a mixture (benzene and toluene or nitrobenzene and toluene) by normal/reverse phase- HPLC. ii. HPLC analysis of an analgesic (e.g. Ibuprofen)/or any other drug with method development and validation. iii. Quantitative analysis of Paracetamol tablet by reverse-phase HPLC iv. Determination of plate height/number of theoretical plates by HPLC using Acetophenone as a reference material. v. Study of HPLC method development by using linear/stepwise gradient elution for binary system. vi. Determination of caffeine content in Tea or Coffee 	12	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5
Module 6:	<p>Electrochemical Method</p> <ul style="list-style-type: none"> i. pH-metric determination of the acid-base dissociation constant and isoelectric point of amino acid. ii. Determination of moisture content in tablet powder by Karl Fischer titration. iii. Analysis of mixture of carbonate/bicarbonate present in water sample using pH metry or Potentiometry. 	12	CO1, CO2, CO4	K1, K2, K3, K4, K5
Module 7:	<p>Gas Chromatographic Analysis</p> <ul style="list-style-type: none"> i. GC analysis of a given sample mixture (e.g. perfumes, cosmetics). 	12	CO1, CO2, CO3,	K1, K2, K3, K4, K5

	<ul style="list-style-type: none"> ii. GC analysis of non-volatile analyte by derivatization. iii. Quantitative analysis of a mixture of chloroform and carbon tetrachloride. iv. Gas chromatographic analysis for a mixture of gases like O₂, N₂ and CO₂. v. Determination of alcoholic content in Beer or wine 		CO4	
Module 8:	<p>Analysis of Ores/Minerals/Industrial Material</p> <ul style="list-style-type: none"> i. Analysis of Iron Ore or Bauxite (from Goa). ii. Analysis of cement or plaster of Paris. iii. Analysis of limestone or dolomite. 	12	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5
Module 9:	<p>Other Instrumental Techniques</p> <ul style="list-style-type: none"> i. Electrophoretic techniques for the separation of nucleic acids or proteins. ii. Study the dissolution rate of commercial tablets. iii. Determination of optical rotation of Chiral compounds using polarimeter (e.g. Amino acids, drugs, natural products, lactic acid, tartaric acid etc) iv. Determination of sulphate ion content by turbidimetry. v. Determination of turbidity in water sample. vi. TG/DTA analysis of sample or mixture (e.g. MgCO₃-MgO). vii. Determination of molar composition of Toluene- Anisole mixture by qNMR. 	12	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5
Module 10:	<p>Demonstration and Interpretation Exercises</p> <ul style="list-style-type: none"> i. Demonstration/Interpretation of LC-MS spectra. ii. Demonstration/Interpretation of NMR spectra of Ethyl cinnamate / Vanilin. iii. Assessment of TG-DTA plot. iv. Statistical Evaluation of Data including Linear Regression Analysis. v. Analysis of materials using Microscopic Techniques. 	12	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5

	vi. Demonstration of XRD and interpretation of diffraction pattern.			
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:	<ol style="list-style-type: none"> 1. A. J. Elias, Collection of Interesting Chemistry Experiments, University Press, Hyderabad, India, 2002. 2. J. Kenkel, Analytical Chemistry for Technicians, 3rd Ed., Lewis Publishers, Boca Raton, Florida, USA, 2002. 3. J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas, B. Sivasankar, Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed., Pearson Education Asia, Delhi, India, 2009. 4. R.A. Day & A.L. Underwood, Quantitative Analysis, 6th Ed., Prentice Hall, New Jersey, USA, 2001. 			
References/ Readings:	<ol style="list-style-type: none"> 1. G. D. Christian, Analytical Chemistry, 5th Ed., John Wiley and Sons, New York, USA, 1994. 2. J. H. Kennedy, Analytical Chemistry Principles, 2nd Ed., Saunders College Publishing, Philadelphia, USA, 1990. 			

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Title of the Course	Analytical Chemistry Practical- IV	
Course Code	CHA-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 Courses	
Course Objectives:	<ol style="list-style-type: none"> 1. To study various experimental techniques for analysis. 2. To learn data analysis, handling and interpretation of spectra. 3. To understand different techniques for the separations 4. To interpret data for the sample analysis 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. choose different techniques for qualitative and quantitative estimation.	PSO1, PSO4
	CO 2. interpret spectra and use statistical methods to analyse data.	PSO3, PSO4
	CO 3. apply different techniques for the separation.	PSO3, PSO4
	CO 4. analyse pharmaceutical samples using different techniques.	PSO4

Content:	Minimum 20 experiments from atleast 8 units shall be conducted	No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Analysis of Pharmaceutical Tablets/Samples</p> <ul style="list-style-type: none"> i. Estimation of Ibuprofen or any other drug by titrimetry. ii. Estimation of iron from given pharmaceutical drug sample using thioglycolic acid. iii. Estimation of sulphadiazine / sulphonamide 	12	CO1, CO2, CO4	K1, K2, K3, K4, K5
Module 2:	<p>Ion exchange Chromatography and Solvent Extraction Method</p> <ul style="list-style-type: none"> i. Determination of capacity of anion exchange resin ii. Separation and estimation of zinc and nickel ions using an anion exchange resin iii. Separation of organic mixture (acidic + basic + neutral) by extraction 	12	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5
Module 3:	<p>Planar and Column Chromatography</p> <ul style="list-style-type: none"> i. Separation of alpha amino acids by paper chromatography and to study effect of mobile phase on resolution. ii. Thin layer chromatography analysis of commercially available analgesic/antipyretic/antihistamine etc and to identify the active ingredients. iii. Separation of a mixture of benzaldehyde and benzoic acid on silica gel column 	12	CO1, CO3, CO4	K1, K2, K3, K4, K5
Module 4:	<p>Spectrophotometry Method</p> <ul style="list-style-type: none"> i. To estimate Cd/Hg by AES/AAS method. ii. To record the UV absorption spectrum of acetone in n- hexane and identify the various transitions. iii. Determination of phosphorous content from fruit juice 	12	CO1, CO2, CO4	K1, K2, K3, K4, K5

Module 5:	HPLC Analysis <ol style="list-style-type: none"> Analysis of a mixture of hydrocarbons by reverse phase-HPLC Quantitative analysis of Aspirin tablet by HPLC. To determine the number of theoretical plates/plate height by HPLC of aromatic ketone or alcohols. Study of HPLC method development by using linear / stepwise gradient elution for binary system. Determination of caffeine content in soft drinks or Chocolates. 	12	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5
Module 6:	Electrochemical Method <ol style="list-style-type: none"> Determination of moisture content in tablet powder by Karl Fischer titration. pH metric determination of dissociation constant of dibasic, oxalic acid Potentiometric determination of dissociation constant for Cu-ammonia complex. 	12	CO1, CO2, CO4	K1, K2, K3, K4, K5
Module 7:	Gas Chromatographic Analysis <ol style="list-style-type: none"> GC analysis of a given sample mixture (e.g. Flavours and fragrances) Quantitative analysis of a mixture of chlorinated solvents. Optimum flow rate for the determination of chloroform using van Deemter equation. Determination of alcoholic content in Rum or Local drinks. 	12	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5
Module 8:	Analysis of Ores/Minerals/Industrial Material <ol style="list-style-type: none"> Analysis of steel Analysis of solder Analysis of an aluminium alloy Analysis of talcum powder 	12	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5
Module 9:	Other Instrumental Techniques	12	CO1,	K1, K2, K3,

	<ul style="list-style-type: none"> i. Electrophoretic techniques for the separation of DNA ii. Determination of optical rotation of Chiral compounds using polarimeter eg. amino acids, drugs, natural products etc iii. Determination of chloride ion content by turbidimetry iv. Determination of turbidity in water sample. v. Study the dissolution rate of pharmaceutical tablets. vi. Determination of molar composition of Toluene-methyl benzoate mixture by qNMR. 		CO2, CO3, CO4	K4, K5
Module 10:	<p>Demonstration/Interpretation Exercises</p> <ul style="list-style-type: none"> i. Demonstration/Interpretation of GC-MS spectra. ii. Demonstration/Interpretation of NMR spectra iii. Assessment of TG-DTA plot. iv. Statistical Evaluation of Data including Linear Regression Analysis. v. Analysis of materials using Microscopic Techniques. vi. Demonstration of XRD and interpretation of diffraction pattern. 	12	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5
Pedagogy:	Pre-lab 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:	<ol style="list-style-type: none"> 1. A. J. Elias, Collection of Interesting Chemistry Experiments, University Press, Hyderabad, India, 2002. 2. J. Kenkel, Analytical Chemistry for Technicians, 3rd Ed., Lewis Publishers, Boca Raton, Florida, USA, 2002. 3. J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas, B. Sivasankar, Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed., Pearson Education Asia, Delhi, India, 2009. 4. R.A. Day & A.L. Underwood, Quantitative Analysis, 6th Ed., Prentice Hall, New Jersey, USA, 2001. 			
References/ Readings:	<ol style="list-style-type: none"> 1. G. D. Christian, Analytical Chemistry, 5th Ed., John Wiley and Sons, New York, USA, 1994. 2. J. H. Kennedy, Analytical Chemistry Principles, 2nd Ed., Saunders College Publishing, Philadelphia, USA, 1990. 			

Title of the Course	Advanced Mass Spectrometry
Course Code	CHA-6002
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 Courses	
Course Objectives:	<ol style="list-style-type: none"> 1. To study various ionisation sources and mass analysers. 2. To understand tandem mass spectrometry concept. 3. To interpret data obtained from hyphenated techniques. 4. To study cleavage of biomolecules and drugs by tandem mass spectrometry. 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. explain principle of different ionizations sources and mass analysers.	PSO1
	CO 2. select mass analysers and ionization sources for analysis of particular type of analyte.	PSO1, PSO2
	CO 3. analyze data of the samples obtained from hyphenated techniques.	PSO1, PSO2, PSO3
	CO 4. deduce structure of molecules/biomolecules using tandem mass spectrometry.	PSO1, PSO2, PSO3

Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Ionization methods: Mass spectrometry: introduction, principle, general instrumentation, general interpretation procedure for mass spectra; Gas Phase ionization: electron ionization (EI), chemical ionization (CI), Field ionization and field desorption (FI, FD) Particle Bombardment: Fast atom bombardment (FAB), Secondary ion mass spectrometry (SIMS). Atmospheric pressure Ionization: electrospray ionization (ESI), atmospheric pressure ionization (APCI). Laser Desorption: MALDI. Inorganic ionization sources: thermal ionization, Spark source, Glow discharge, inductively coupled plasma (ICP). Problem solving using mass spectrometry. (Note: Above techniques to be explained with suitable example.)</p>	15	CO1, CO2	K1, K2, K3, K4, K5
Module 2:	<p>Mass analyzers: Characteristics of analysers: nominal mass, mass accuracy, resolving power, resolutions, isotopic composition, numericals to calculate nominal, accurate mass and isotopic abundance. Magnetic, electromagnetic and double focusing Single Quadrupole and triple quadrupole Time of flight analyzer Ion cyclotron resonance analyzer Hybrid instrumentation</p>	15	CO1, CO2	K1, K2, K3, K4, K5

	Detectors: electron multiplier, photon multiplier, Faraday cup (Note: instrumentation, working principles, characteristic features, advantages, practical consideration shall be discussed.)			
Module 3:	<p>Hyphenated Techniques: Coupled techniques, Importance of hyphenation of two analytical techniques, Interface and their characteristic features.</p> <p>Introduction, principle and instrumentation of following techniques: GC-MS, LC-MS, ICP-MS, CE-MS, TG-MS.</p> <p>Tandem mass (MS-MS): Introduction, concepts of tandem mass spectrometry, Ion activation methods.</p> <p>Analysis of chromatogram: Total ion chromatogram (TIC), Extracted Ion Chromatogram (XIC).</p> <p>Analysis of chemical data of natural products, Drugs (Dipyron metabolite, acebutolol, cocaine, etc).</p> <p>Dereplication using hyphenated technique.</p>	15	CO3, CO4	K1, K2, K3, K4, K5
Module 4:	<p>Tandem Mass spectrometry applications: Pharmacokinetic studies: Fate of drug in living organisms, metabolite identification, biotransformation of ziprasidone.</p> <p>Tandem MS and fragmentation pattern of following drugs: Paracetamol, 2-mercaptanonicotinic acid, Sulfasalazine, amphetamine, Trocade.</p> <p>Analysis of biomolecules: Proteins and Peptides, structure and sequence determination using fragmentation, lipids, solve problems based on MSn data.</p>	15	CO3, CO4	K1, 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. E. De Hoffmann, V. Stroobant, Mass Spectrometry: Principles and Applications, 3rd Ed, Wiley, England, 2007. 2. H. Jürgen, Mass Spectrometry: A Textbook Gross, 2nd Ed, Springer publisher, Switzerland, 2011.
References/ Readings:	<ol style="list-style-type: none"> 1. J. K. Prasain, Tandem Mass Spectrometry-Applications and Principles, InTech publisher, UK, 2012. 2. J. T. Watson, O. D. Sparkman, Introduction to Mass Spectrometry: Instrumentation, Applications, and Strategies for Data Interpretation, 4th Ed, Wiley, England, 2007. 3. K. Wanner, G. Höfner, Mass Spectrometry in Medicinal Chemistry Applications in Drug Discovery, 1st Ed, Wiley-VCH, Weinheim, 2007. 4. M. Kinter, N. E. Sherman, Protein Sequencing and Identification Using Tandem Mass Spectrometry, 1st Ed, Wiley, New York, 2000. 5. P. James, Proteome Research: Mass Spectrometry (Principles and Practice), 1st Ed, Springer publisher, New York, 2001. 6. R. B. Cole, Electrospray and MALDI Mass Spectrometry: Fundamentals, Instrumentations, Practicalities and Biological Applications, 2nd Ed, Wiley, New Jersey, 2010.
Web Resources:	<ol style="list-style-type: none"> 1. https://doi.org/10.1016/j.jpha.2018.03.001 2. https://link.springer.com/article/10.1007/s11101-015-9448-7

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Title of the Course	Advanced NMR and combined Spectroscopy
Course Code	CHA-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 Courses	
Course Objectives:	<ol style="list-style-type: none"> 1. To understand advanced 2D NMR techniques. 2. To develop skills of interpreting spectral data pertaining to two or more 2D NMR techniques. 3. To train students to interpret NMR for quantitative analysis. 4. To understand NMR hyphenated techniques. 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. understand various spectroscopic techniques to analyse small molecules.	PSO2, PSO3, PSO4
	CO 2. interpret combined spectral data pertaining to two or more 2D NMR techniques for structural analysis.	PSO3
	CO 3. analyse qNMR data for quantitative estimation.	PSO3, PSO4
	CO 4. apply hyphenated NMR techniques for analysing mixtures.	PSO1, PSO3, PSO4

Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Selected concepts in IR and MS for structure determination</p> <p>IR: Spectral data interpretation for common functional groups like keto, aldehyde, acid, ester, amides, nitro, etc., Correlation of common functional groups with IR spectral differences.</p> <p>MS: Factors governing Mass fragmentation processes, β- cleavage, cleavage α to heteroatoms, cleavage α to carbonyl.</p> <p>Groups, retro Diels-Alder reaction, McLafferty rearrangement.</p>	5	CO2	K1, K2, K3, K4, K5, K6
Module 2:	<p>Selected concepts in NMR</p> <p>Chemical Shifts spectral data for proton and carbon nuclei like aliphatic, aromatic, acyl, methoxy, etc., Correlation of common proton and carbon nuclei with NMR signal differences.</p> <p>Nuclear Overhauser Effect</p> <p>Decoupling in ^{13}C NMR Spectroscopy (DEPT-135, DEPT-90, DEPT-45), Proton coupled CMR.</p> <p>^{15}N-NMR, ^{19}F-NMR, ^{29}Si-NMR, & ^{31}P-NMR spectroscopy: Chemical shift range for ^{15}N, ^{19}F, ^{29}Si & ^{31}P in NMR spectra,</p> <p>Coupling with neighboring nuclei and splitting pattern.</p>	10	CO2	K1, K2, K3, K4, K5, K6
Module 3:	<p>2D-NMR</p> <p>Introduction to 2D-NMR, General Principles, Classification of 2D-NMR experiments.</p> <p>Homonuclear Correlation Spectroscopy: Proton-Proton Interactions - COSY, DQF-COSY, TOCSY, NOESY, REOSY. Carbon-Carbon Interactions - INADEQUATE.</p>	10	CO1, CO2	K1, K2, K3, K4

	<p>Heteronuclear Correlation Spectroscopy HETCOR: Heteronuclear Single Bond Correlation - HSQC, HMQC and me- HSQC</p> <p>Heteronuclear Multiple Bond Correlation – HMBC</p> <p>Analyzing and interpreting spectral data from above 2D spectra for small molecules.</p> <p>Assigning NMR signals based on PMR, CMR, ^1H-^1H & ^1H-^{13}C Correlation Spectra.</p>			
Module 4:	<p>Structural analysis of simple compounds using some combined spectral techniques:</p> <p>PMR, CMR, COSY, HSQC, me-HSQC, HMBC, TOCSY, NOESY, INADEQUATE, along with IR, UV and MS data wherever necessary.</p>	20	CO1, CO2	K1, K2, K3, K4, K5, K6
Module 5:	<p>Quantitative NMR analysis</p> <p>Analysis of mixture of compounds using qNMR technique, Relative proportions (mole %) of the 2 or 3 components from NMR integrals.</p> <p>Calibration standards, Selection criteria for suitable Reference material.</p> <p>Molar concentration determination, Purity or Yield determination.</p>	10	CO3	K1, K2, K3, K4, K5
Module 6:	<p>Hyphenated NMR techniques</p> <p>Development of LC-NMR, Technical Considerations regarding LC-NMR: Solvent Compatibility, Solvent Suppression, NMR Flow Cell, LC-NMR Sensitivity. Modes of Operation: On-Flow Mode, Stop-Flow Mode. Applications of LC-NMR.</p> <p>Introduction to other hyphenated NMR techniques, Technical Considerations regarding LC-MS-NMR: Modes of Operation, Online coupling in series or in parallel, Challenges in Hyphenated NMR techniques.</p>	5	CO4	K1, K2, K3
Pedagogy	<p>Mainly lectures and tutorials, Seminars / assignments / presentations / self- study or a combination of some of these can also be used. ICT mode should be preferred. Sessions shall be interactive in nature to enable peer group learning. (Note: More emphasis shall be given for structural elucidation using combined spectroscopic data)</p>			

Texts:	<ol style="list-style-type: none"> 1. E. Pretsch, P. Buhlmann, C. Affolter, Structural Determination of Organic Compounds, 2nd Ed., Springer, Berlin, Germany, 2005. 2. L. D. Field, S. Sternhell, J. R. Kalman, Organic Structures from Spectra, 4th Ed., Wiley, Hoboken, New Jersey, USA, 2007. 3. M. V. Silva Elipe, LC-NMR and Other Hyphenated NMR Techniques: Overview and Applications, Wiley, Chichester, UK, 2012. 4. R. M. Silverstein, F. X. Webster, D. J. Kiemle, D. L. Bryce, S. D. Samant, V. S. Nadkarni, Spectrometric Identification of Organic Compounds: An Indian Adaptation, 8th Ed., Wiley, Hoboken, New Jersey, USA, 2022. 5. R. M. Silverstein, F. X. Webster, Spectrometric Identification of Organic Compounds, 6th Ed., Wiley, Hoboken, New Jersey, USA, 2011. 6. W. Kemp, Organic Spectroscopy, 3rd Ed., Palgrave, Basingstoke, UK, 1991.
References/ Readings:	<ol style="list-style-type: none"> 1. D. H. Williams, I. Fleming, Spectroscopic Methods in Organic Chemistry, 6th Ed., Tata McGraw Hill Education, New Delhi, India, 2011. 2. J. H. Simpson, Organic Structure Determination Using 2-D NMR Spectroscopy, Elsevier, Amsterdam, Netherlands, 2008. 3. H. Friebolin, Basic One- and Two-Dimensional NMR Spectroscopy, Wiley, Hoboken, New Jersey, USA, 2011. 4. K. S. Parikh, H. H. Gadape, Quantitative NMR Spectroscopy in Pharmaceuticals, Lambert Academic Publishing, Saarbrücken, Germany, 2012. 5. L. D. Field, H. L. Li, A. M. Magill, Organic Structures from 2D NMR Spectra, Wiley, Hoboken, New Jersey, USA, 2015. 6. U. Holzgrabe, I. Wawer, B. Diehl, NMR Spectroscopy in Pharmaceutical Analysis, Elsevier, Amsterdam, Netherlands, 2008. 7. W. Kemp, NMR in Chemistry: A Multinuclear Introduction, Macmillan, London, UK, 1986.
Web Resources:	<ol style="list-style-type: none"> 1. http://sites.esa.ipb.pt/pdf/saps23.pdf 2. https://nmr-challenge.uochb.cas.cz/

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Title of the Course	Applied Electro-analytical techniques
Course Code	CHA-6004
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 Courses	
Course Objectives:	<ol style="list-style-type: none"> 1. To understand the instrumentation and working principles of polarography, potentiometry, cyclic voltammetry, stripping methods, and hydrodynamic voltammetry. 2. To apply electrochemical techniques to solve numerical problems and analyze experimental data effectively. 3. To differentiate among various electrochemical methods based on their principles, advantages, and applications. 4. To develop the ability to critically evaluate electrochemical results and select appropriate techniques for specific analytical problems. 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. explain instrumentations and functioning of polarography, potentiometry, cyclic voltammetry, stripping methods, and hydrodynamic voltammetry.	PSO1

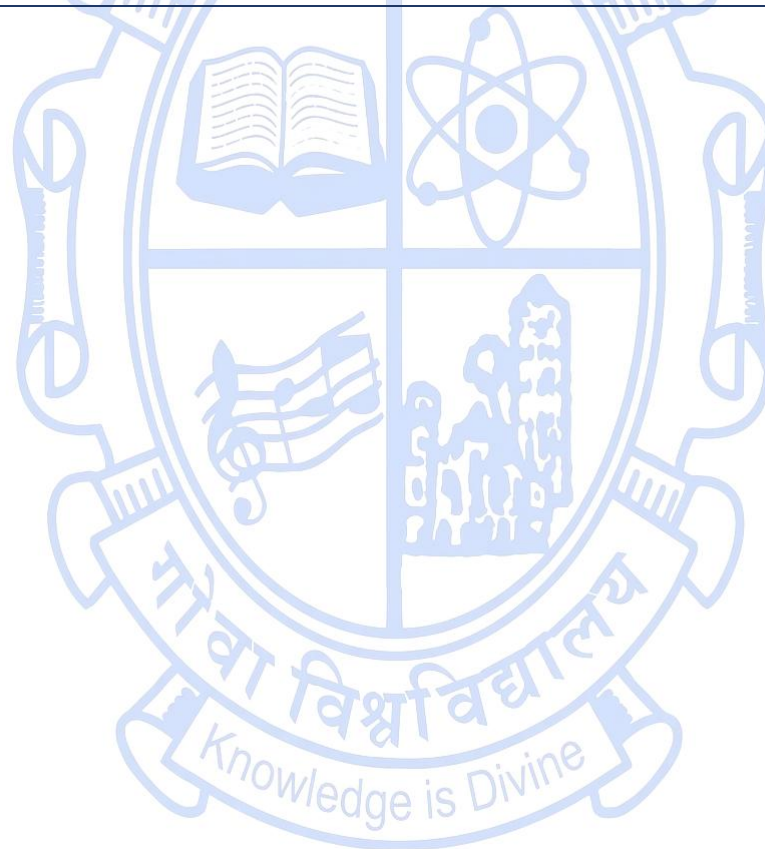
	CO 2. differentiate between polarography, potentiometry, cyclic voltammetry, Stripping methods, and hydrodynamic voltammetry.		PSO1, PSO2	
	CO 3. apply the knowledge of polarography, potentiometry, cyclic voltammetry, stripping methods, hydrodynamic voltammetry and solve numerical problems on electrochemistry.		PSO2	
	CO 4. analyze electrochemical data to interpret results and evaluate the performance of different electrochemical techniques.		PSO3	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Potentiometry with ion selective electrodes: General principles, Definitions: Reference electrode, working electrode, electrode and standard electrode potential, Reference electrode (saturated calomel and Ag-AgCl electrode) Membrane indicator electrodes. Classification of membranes, glass electrode for pH measurement, crystalline membrane electrodes, Liquid membrane electrodes, Ion selective FET, Molecular selective electrode systems (gas sensing probes, Biosensors), instrument for measuring cell potential, Direct potentiometric measurement, Potentiometric titrations</p>	8	CO1, CO2, CO3, CO4	K1, K2, K3,
Module 2:	<p>Cyclic Voltammetry Principle of cyclic Voltammetry, cyclic voltamogram of $K_3[Fe(CN)_6]$ and parathion (Fundamental studies), determination of analytes using cyclic voltammetry, criteria of reversibility of electrochemical reactions, quasireversible and irreversible processes</p>	10	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5
Module 3:	<p>Polarographic Methods of Analysis: Fundamental principle of Voltammetric analysis and electrode system for voltammetric analysis; Fundamental principle of Polarographic analysis and electrode system for polarographic analysis</p>	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5

	<p>Classification of Voltammetric Methods; Principle of Polarographic Analysis; Working Electrode in Polarographic Analysis; Dropping mercury electrode (DME); Construction and working Dropping mercury electrode (DME); Advantages of DME; Disadvantages of DME; Apparatus for polarographic analysis; Instrumentation of Polarography; Electrode system for polarographic cell containing analyte; System for removal of dissolved oxygen; Electrical circuit for application of linear DC potential; Recorder for obtaining polarogram; Working of Polarography; Qualitative and Quantitative Analysis by polarogram; Factors Affecting the Nature of the Polarographic Wave; Residual current; Migration current; Condenser or non-faradic current; Diffusion or faradic current; Half wave potential</p> <p>Applications of Polarography: Qualitative analysis/Identification of the electroactive species; Quantitative analysis by Ilkovic equation; Simultaneous determination of cations in the mixture; Polarographic determination of copper and zinc in the brass; Polarographic titration; Determination of dissolved oxygen; Analysis of organic compounds.</p>			
Module 4:	<p>Hydrodynamic Voltammetry</p> <p>Hydrodynamic voltammetry and applications of hydrodynamic voltammetry, voltammetric detectors in chromatography and flow injection analysis, voltammetric oxygen sensors, amperometric titration, problems</p>	6	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5
Module 5:	<p>Stripping Voltammetry</p> <p>Stripping voltammetry, principle, electrode system, anodic stripping voltammetry and cathodic stripping voltammetry, adsorptive stripping voltammetry and their applications, problems</p>	6	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5
Module 6:	<p>Electrochemical Impedance Spectroscopy EIS</p>	5	CO1, CO2, CO3,	K1, K2, K3, K4, K5

	Principles of EIS, sinusoidal signals, impedance in electrical circuits, Nyquist plot, equivalent electrical circuits, selected examples to corrosion, biosensing and energy related applications,		CO4	
Module 7:	Pulse Polarography Different types of excitation signals in pulse polarography, Differential pulse polarography, square wave polarography, Voltammetry with ultramicroelectrode, Applications of these techniques for determination Cu and Zn from tap water by differential pulse polarography and by square wave	10	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5
Pedagogy:	Mainly lectures and tutorials, Seminars / assignments / presentations / self- study or a combination of some of these can also be used. ICT mode should be preferred. Sessions shall be interactive in nature to enable peer group learning.			
Texts:	<ol style="list-style-type: none"> 1. D. A. Skoog, F. J. Holler, S. R. Crouch, Principles of Instrumental Analysis, 6th Ed., Brooks/Cole, Thomson Learning, Belmont, California, USA, 2007. 2. D. K. Gosser, Cyclic Voltammetry: Simulation and Analysis of Reaction Mechanisms, VCH, New York, USA, 1994. 3. G. H. Jeffery, J. Bassett, J. Mendham, R. C. Denney, Textbook of Quantitative Chemical Analysis, 5th Ed., ELBS, London, UK, 1989. 4. H. H. Willard, L. L. Merritt, J. A. Dean, F. A. Settle Jr., Instrumental Methods of Analysis, 6th Ed., CBS Publishing Company, New Delhi, India, 1986. 5. R. D. Braun, Introduction to Instrumental Analysis, Pharmamed Press, Hyderabad, India. 6. R. Kellner, J. M. Mermet, M. Otto, M. Valcárcel, H. M. Widmer (Eds.), Analytical Chemistry: A Modern Approach to Analytical Science, 2nd Ed., Wiley-VCH, Weinheim, Germany. 			
References/ Readings:	<ol style="list-style-type: none"> 1. A. J. Bard and Larry R. Faulkner, Electrochemical methods: Fundamentals and applications, 2nd Ed. John Wiley and Sons, New Jersey, 2001 2. D. K. Gosser, Cyclic Voltammetry: Simulation and Analysis of Reaction Mechanisms, VCH, New York, USA, 1994. 			

	<ol style="list-style-type: none">3. E. Barsoukov, J. R. Macdonald, Impedance Spectroscopy: Theory, Experiment, and Applications, John Wiley & Sons, New Jersey, 20054. J. O'M Bockris, A. K. N. Reddy, M. Gamboa-Aldeco, Modern Electrochemistry: Fundamentals of Electrodeics, Vol. 2A, 2nd Ed. Kluwer Academic Publishers, New York, 20025. R. Kellner, J. M. Mermet, O. Otto, M. Valcárcel, H. M. Widmer (Eds.), Analytical Chemistry: A Modern Approach to Analytical Science, 2nd Ed., Wiley-VCH, Weinheim, Germany, 1998.
Web Resources:	https://doi.org/10.1021/acs.jchemed.7b00361

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Title of the Course	Research Methodology	
Course Code	CHA-6005	
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 Courses	
Course Objectives:	<ol style="list-style-type: none"> 1. To understand literature review process, safe laboratory practices and ethics in research. 2. To learn isolation procedures for separation of natural product from mixtures 3. To apply different methodologies, basic characterization and data interpretation for material property investigation 4. To evaluate different analytical parameters for method development 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. apply fundamentals of research to facilitate dissertation work.	PSO1
	CO 2. practice the concepts of laboratory safety along with good laboratory practices.	PSO1

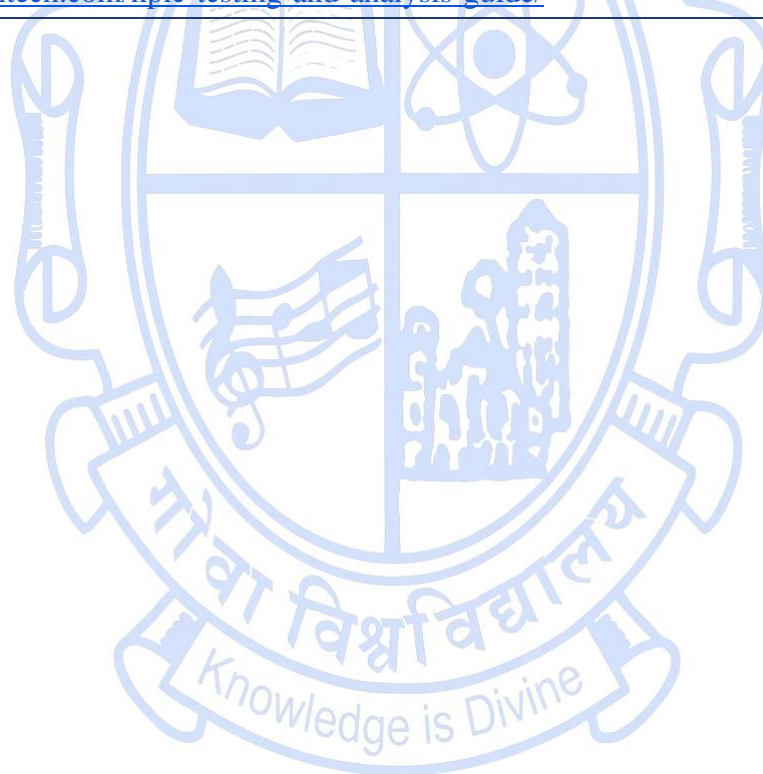
	CO 3. develop systematic approach to conduct experiments and data evaluation.		PSO1, PSO2, PSO3, PSO4	
	CO 4. apply methods for analysis of various chemical compositions.		PSO1, PSO2, PSO3, PSO4	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Literature Review, Academic Writing</p> <p>Brief introduction to research methodology, concept and purpose, logical format of dissertation, types and components.</p> <p>Sources for identifying research problem.</p> <p>Literature Review: types of literature, sources of literature review, primary sources, secondary sources, databases.</p> <p>Research methods: significance, purpose and characteristics of research, research process, necessity and scope.</p> <p>Academic Writing: purpose, types and features, common mistakes, conflicts of Interest, publication misconduct, redundant publications, predatory publishers and journals.</p> <p>Key aspects of ethics in scientific conduct.</p>	15	CO1	K1, K2, K3, K4
Module 2:	<p>Safe Laboratory Practices</p> <p>Instructions for safe working and use of personal protective equipment (PPE).</p> <p>The purpose and importance of Safety Data Sheet (SDS), classification and handling of Hazardous substances.</p> <p>Handling, storage, quenching, and disposal of chemicals, solvents and glassware.</p> <p>Experimental setup, choice of place and apparatus, precautions.</p> <p>Fire Hazards (Class A, B, C, D and K), fire extinguishers and</p>	05	CO2	K1, K2, K3, K4

	Emergency procedures.			
Module 3:	<p>Reaction setup and separation methods Setting up of reactions, reaction yields and mass balance.</p> <p>Methods of isolation and purification techniques for organic reaction intermediates and products.</p> <p>Solvent extraction: Batch extractions, continuous extractions, LLE extractions, counter current extraction techniques for isolation of organic compounds.</p> <p>Distillation techniques: Batch distillation, reduced pressure distillation, continuous distillation and wiping film distillation.</p> <p>Case studies for isolation of natural products (Quinine oil, cinnamon oil and capsaicin).</p>	10	CO3	K1, K2, K3, K4
Module 4:	<p>Syntheses, Characterization and Data Processing</p> <p>Synthetic methodologies, solution and solid-state synthesis, methods of preparation of crystalline solids, factors affecting product formation.</p> <p>Reaction setup, optimisation of reaction conditions. Selection of suitable solvent and analyte concentration</p> <p>Infra-red and UV-Visible Spectroscopy: Standard operating procedures, sample analysis, online reaction study using IR and UV analysis.</p> <p>Data conversion of the instrumental file into plottable format in excel, statistical tools for data processing, data visualization softwares</p>	15	CO3	K1, K2, K3, K4, K5
Module 5:	<p>Analytical method development and structure drawing</p> <p>HPLC method development - case studies with pharmaceuticals samples, cosmetic products, natural products, and other chemical compositions.</p> <p>GC method development - case studies with pharmaceuticals samples, essential oils, fragrances, and other chemical compositions.</p>	15	CO4	K3, K4, K5, K6

	Structure drawing software - Structures, reaction schemes, mechanisms.			
Pedagogy	Mainly lectures and tutorials, Seminars / assignments / presentations / self- study or a combination of some of these can also be used. ICT mode should be preferred. Sessions shall be interactive in nature to enable peer group learning.			
Texts:	<ol style="list-style-type: none"> 1. A. Bird, Philosophy of Science, Routledge, London, UK, 2006. 2. G. Christian, Analytical Chemistry, 6th Ed., Wiley, New York, USA, 2004. 3. J. Holler, S. R. Crouch, Principles of Instrumental Analysis, 7th Ed., Cengage Learning, Boston, USA, 2017. 4. M. Coghill & L. R. Garson, The ACS Style Guide: Effective Communication of Scientific Information, American Chemical Society, Washington, DC, USA & Oxford University Press, New York, USA, 2006. 5. M. Skoog, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry, 9th Ed., Cengage Learning, Boston, USA. 6. R. Carlson, Johan E. Carlson, Design and Optimization in Organic Synthesis, Elsevier, Amsterdam, Netherlands, 2005. 7. R. Kothari, Research Methodology: Methods & Techniques, New Age International Pvt. Ltd., New Delhi, India, 2004. 8. R. Manglik, Research Techniques in Organic Chemistry, Edu Gorilla Publication, 2024. 9. S. Furniss, A. J. Hannaford, P. W. G. Smith & A. R. Tatchell, Vogel's Textbook of Practical Organic Chemistry, 5th Ed., Longmans, London, UK, 1989. 10. S. Kromidas, More Practical Problem Solving in HPLC, Wiley, Germany, 2005. 11. S. Kromidas, Practical Problem Solving in HPLC, Wiley, Germany, 2004. 12. V. R. Meyer, Practical High-Performance Liquid Chromatography, 5th Ed., Wiley, Chichester, UK, 2010. 13. Y. K. Singh, Fundamentals of Research Methodology & Statistics, New Age International Pvt. Ltd., New Delhi, India, 2006. 			
References / Readings:	1. Indian Pharmacopeia, 2007, Volumes 1, 2, and 3, Indian Pharmacopoeia Commission, Ghaziabad, India.			

	<ol style="list-style-type: none">2. Manual of Methods of Analysis of Foods, Food Safety and Standards Authority of India, Ministry of Health and Family Welfare, Government of India, New Delhi, India, 2015.3. National Research Council, Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards, The National Academies Press, Washington, DC, USA, 2011.
Web Resources:	<ol style="list-style-type: none">1. www.merck-chemicals.com/analytical-hplc2. https://doi.org/10.1016/j.mex.2020.1010833. https://doi.org/10.1186/s13065-019-0595-64. https://lab-training.com/wp-content/uploads/2014/11/HPLC-E-Book.pdf5. https://torontech.com/hplc-testing-and-analysis-guide/

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Discipline Specific Vocational Elective (DSVE) Courses

Title of the Course	Calibration, Validation and Method Development
Course Code	CHA-6401
Number of Credits	4 (2T+2P)
Theory/Practical	Theory and 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 Courses
Course Objectives:	<ol style="list-style-type: none">1. To understand the principles and importance of calibration, method development, and validation in analytical chemistry.2. To apply appropriate calibration techniques and validation protocols to ensure accuracy and reliability of analytical results.3. To develop and optimize analytical methods suited for specific sample matrices and instrumentation.4. To analyze analytical data and validate method performance to support decision-making in quality control and research.

Course Outcomes:	Students will be able to	Mapped to PSO		
	CO 1. understand the role of calibration, method development and validation in Analytical laboratories	PSO1		
	CO 2. apply / select particular method / instrumental parameters for analysis of given sample and give mathematical treatment to analytical data and able to interpret the results accurately.	PSO2		
	CO 3. analyze the results able to take the decision regarding quality of sample.	PSO3		
	CO 4. design, modify and validate new analytical method for chemical analysis of particular sample.	PSO4		
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1: (Theory)	<p>Calibration, and Statistical Treatment of Data</p> <p>Introduction: The vocabulary of analytical chemistry: Analysis, determination, and measurement; techniques, methods, procedures, and protocols. Classification of different types of errors in analysis</p> <p>Calibration in analytical chemistry: Importance and need for calibration, compensating for interferences (method blank), effects of the sample matrix on signal measurement, importance of the correlation coefficient, concept of curve fitting, linear regression of reliable data, linearity and sensitivity of instrumental measurements.</p> <p>Calibration methods: External standard, standard additions, and internal standard methods; case scenarios to illustrate the suitability of each method for a given analysis. Calibration of key analytical instruments: UV-visible spectrophotometer, FTIR spectrophotometer, conductivity meter, gas chromatograph (GC), and high-performance liquid chromatograph (HPLC).</p>	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5

	Statistical evaluation of analytical results: Classification of different types of errors, significance of the Gaussian distribution; probability distribution of errors. Confidence limits and intervals, tests of significance, detection of bias and outliers, and the use of control charts.			
Module 2: (Theory)	<p>Method Development and Validation</p> <p>Quality in Analytical Laboratories: Good laboratory practices, quality control, quality assurance, and accreditation systems.</p> <p>Validation and Qualification: Overview of installation, operation, and performance qualification (IQ, OQ, PQ) of analytical equipment.</p> <p>Method Validation in the Pharmaceutical Industry: Regulatory requirements for analytical method validation as per International Conference on Harmonization (ICH) guideline Q2R1; method validation parameters and timeframe according to ICH guidelines; linearity and range criteria and their role in instrumental method validation; detailed discussion on the roles of accuracy and precision in method validation; role of quantification limits and specificity, including Limit of Detection (LOD) and Limit of Quantification (LOQ) for a given method.</p> <p>Case Scenarios: Illustrative examples of method development in practical applications.</p>	15	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6
PRACTICAL (2 CREDIT)				
Module 3: (Practical)	<p>(ANY 5 TO BE PERFORMED)</p> <p>i. HPLC Analysis of Paracetamol or Acetylsalicylic acid (standard) with known method and Calculation of mean, standard deviation in retention time.</p> <p>ii. HPLC Calibration curve with known concentration of Paracetamol or Acetylsalicylic acid (standard) and assay of tablets.</p>	40	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5, K6

	<ul style="list-style-type: none"> iii. HPLC Standard addition method for assay of tablets of Paracetamol or Acetylsalicylic acid. iv. HPLC method development and validation for analysis of Pharmaceutical formulations containing paracetamol / ibuprofen / aspirin/ chlorpheniramine / phenylephrine, etc. v. HPLC method development and validation for analysis of cosmetic formulations containing hippuric acid or hydantoin, etc. vi. Solvent extraction for medicinal plants and HPLC method development for quantitative analysis of plant extracts. vii. GC Analysis of formaldehyde or aniline (standard) with known method and Calculation of mean, standard deviation in retention time. viii. GC Calibration curve with known concentration of formaldehyde or aniline (standard) and assay of samples. ix. GC Standard addition method for assay of commercial samples of formaldehyde or aniline. x. GC method development for analysis of VOCs like formaldehyde, aniline, Toluene, or xylenes, etc. 			
<p>Module 4: (Practical)</p>	<p>(ANY 5 TO BE PERFORMED)</p> <ul style="list-style-type: none"> i. UV method development for analysis of Paracetamol in pharmaceutical formulations. ii. UV method development for analysis of hydantoin in cosmetic creams. iii. AES method development for estimation of Fe in soil samples. iv. Colorimetry method development for estimation of Ni in coordination complexes. v. KF titrimetric method for analysis of moisture in paracetamol tablets. 	<p>20</p>	<p>CO1, CO2, CO3, CO4</p>	<p>K1, K2, K3, K4, K5, K6</p>

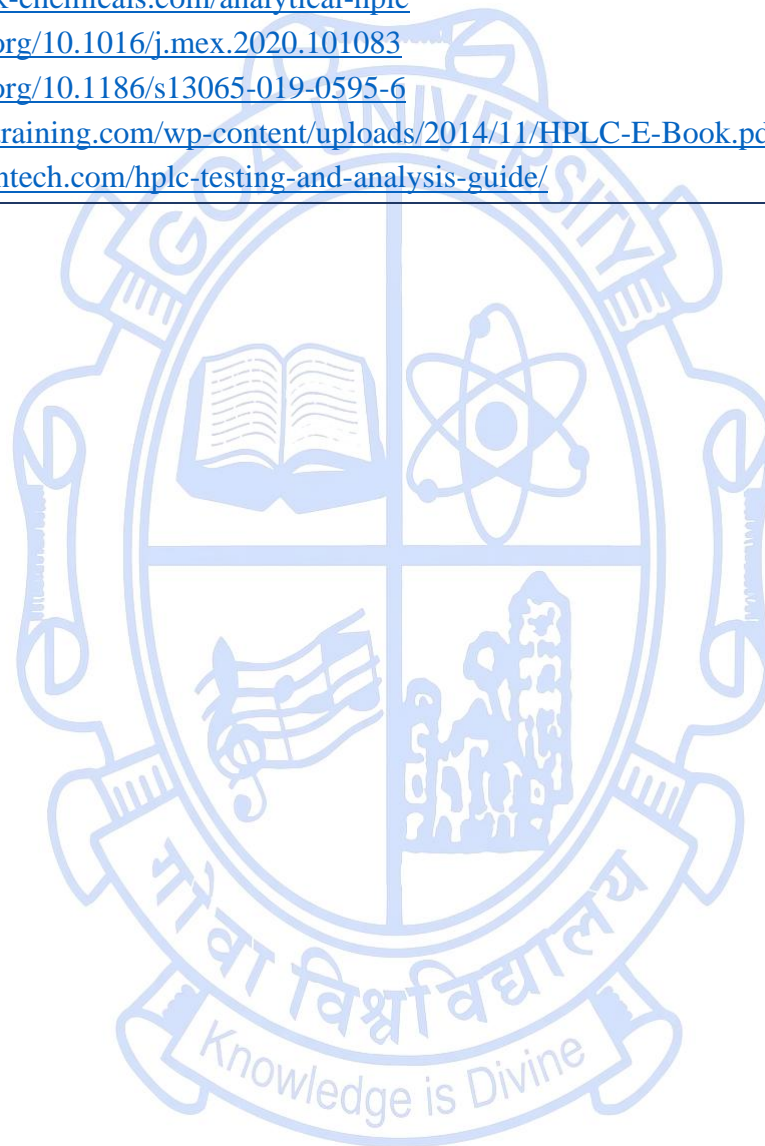
	<ul style="list-style-type: none"> vi. Determination of best pH for dye colour formation by UV-visible spectroscopy, and determination of λ_{max} for quantitative analysis vii. Determination of best pH for dye colour formation by colorimetry, and determination of λ_{max} for quantitative analysis viii. Determination of best pH for colour formation by UV-visible spectroscopy, and determination of λ_{max} for quantitative analysis using limited conc. of Cu or Co or Fe ion and large excess ligand. ix. Estimation of Cu or Co or Fe by calibration curve method with UV-Vis spectroscopy - validation of method by calibration curve method. x. Estimation of Cu or Co or Fe metal ion conc. at low conc. (near or below detection limit) by standard addition method - validation of method for standard addition method. (Cu(II) - R-nitroso salt; Co(II)-alfa-nitroso beta-naphthol; Co(II) - R-nitroso salt; Fe(III) – Salicylic acid) xi. Estimation of Glucose by Colorimetry Folin-Wu method or by Colorimetry oxidase peroxidase method. xii. Estimation of Glucose in saline/ glucose supplement by Polarimetry. xiii. Analysis of Riboflavin sample by calibration curve method by visible spectrometry or by fluorimetry with respect to linearity range and detection limit. xiv. Comparison of end point redox titration between $\text{K}_2\text{Cr}_2\text{O}_7$ and standard Fe(II) by potentiometry and by external indicator. 			
<p>Pedagogy</p>	<p>Theory: Mainly lectures and tutorials. Prelab excersise/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>			

<p>Texts:</p>	<ol style="list-style-type: none"> 1. A. H. Wachter, R. A. Nash, Pharmaceutical Process Validation, Marcel Dekker Inc, 2003. 2. B. P. Kafle, Chemical Analysis and Material Characterization by Spectrophotometry, Elsevier, Amsterdam, Netherlands, 2022. 3. D. T. Plummer, An Introduction to Practical Biochemistry, 3rd Ed., Tata McGraw-Hill Publishing Company Ltd., New Delhi, India, 2001. 4. G. H. Jeffery, J. Bassett, J. Mendham, R C. Denney, Vogel's Text Book of Quantitative Chemical Analysis, 5th Ed. Wiley, 1989. 5. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, B. Sivasankar, Vogel's Textbook of Quantitative Inorganic Analysis, 6th Ed., Pearson Education, New Delhi, India, 2009. 6. L. Validation and Qualification in Analytical Laboratories, Informa Healthcare USA Inc; 2007. 7. M. E. Swartz, I. S. Krull, Analytical method development & validation, CRC Press book, 1997. 8. R. B. Baird, A. D. Eaton, E. W. Rice, Standard Methods for the Examination of Water and Wastewater, 23rd Ed., American Public Health Association, American Water Works Association, Water Environment Federation, Washington, D.C., USA, 2017. 9. S. Gorog, Ultraviolet and Visible Spectrophotometry in Pharmaceutical Analysis, CRC Press, Taylor & Francis Group, Boca Raton, Florida, USA, 2010. 10. S. Sadashivam, A. Manickam, Biochemical Methods, 3rd Ed., New Age International Publishers, New Delhi, India, 2008. 11. S. Suzanne Nielsen (Ed.), Food Analysis, 4th Ed., Springer, New York, USA, 2010. 12. Z. Marczenko, M. Balcerzak, Separation, Preconcentration and Spectrophotometry in Inorganic Analysis, Analytical Spectroscopy Library – Vol. 10, Elsevier, Amsterdam, Netherlands, 2000.
<p>References / Readings:</p>	<ol style="list-style-type: none"> 1. Indian Pharmacopoeia, Vol. 1, 2, 3, Indian Pharmacopoeia Commission, Ghaziabad, India, 2007. 2. Manual of Methods of Analysis of Foods, Food Safety and Standards Authority of India, Ministry of Health and Family Welfare, Government of India, New Delhi, India, 2015. 3. S. Kromidas, More Practical Problem Solving in HPLC, Wiley-VCH, Weinheim, Germany, 2005. 4. S. Kromidas, Practical Problem Solving in HPLC, Wiley-VCH, Weinheim, Germany, 2004. 5. V. R. Meyer, Practical High-Performance Liquid Chromatography, 5th Ed., Wiley, Chichester, UK, 2010.

Web Resources:

1. www.merck-chemicals.com/analytical-hplc
2. <https://doi.org/10.1016/j.mex.2020.101083>
3. <https://doi.org/10.1186/s13065-019-0595-6>
4. <https://lab-training.com/wp-content/uploads/2014/11/HPLC-E-Book.pdf>
5. <https://torontech.com/hplc-testing-and-analysis-guide/>

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Title of the Course	Chemical Crystallography
Course Code	CHA-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 introduce basic concepts of crystallography. 2. To impart knowledge of single crystal and powder X-ray diffraction methods. 3. To analyse materials and understand the structure. 4. To familiarize students with various applications of crystallography 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. explain fundamental concepts of crystallography.	PSO1
	CO 2. describe and compare single crystal and powder X-ray diffraction methods	PSO1, PSO2
	CO 3. apply X-ray diffraction techniques to characterize materials	PSO2

	CO 4. analyze and correlate crystal structures with materials properties.		PSO3, PSO4	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1: (Theory)	<p>Single Crystal X-Ray Diffraction</p> <p>Basics of crystallography: Crystalline state, crystallographic directions, planes, crystallographic point groups and space groups, the Laue classes, International Tables.</p> <p>Crystals and their properties: crystallization, growing and choosing crystals, microscopic observation</p> <p>Data collection techniques for single crystals, diffractometer geometry, measurement of the integrated intensities, data collection with area detectors</p> <p>Data reduction: Lorentz correction, polarization correction, absorption corrections, radiation damage corrections, relative scaling.</p> <p>Solution and refinement of crystal structures: Wilson plot, the heavy atom method, Direct methods, phase determination procedures, figures of merit,</p> <p>Completing and refining the structure: difference Fourier method, least-squares method, absolute configuration.</p> <p>Introduction to crystallographic softwares (e.g. APEX 4, WINGX, Olex2 etc) and IUCr validation of the data (CIF)</p>	15	CO1, CO2, CO3	K1, K2, K3, K4, K5
Module 2: (Theory)	<p>Powder X-Ray Diffraction</p> <p>Scattering of X-rays by an electron, atom, atomic scattering factor, temperature factor, scattering by unit cell</p> <p>Diffraction by crystals, structure factor, Bragg's law, the reflection and the limiting spheres, symmetry in reciprocal space, systematic absences, diffraction intensities</p>	15	CO1, CO2, CO3	K1, K2, K3, K4, K5

	<p>Origin of powder diffraction pattern, position, shape, and intensity of powder diffraction peaks</p> <p>Powder diffractometry: beam conditioning, goniometer design, nonambient powder diffractometry</p> <p>Collecting quality powder diffraction data: sample preparation, data acquisition, quality of data, data processing</p> <p>Introduction to powder diffraction software's for indexing, unit cell refinement and powder diffraction database.</p> <p>Introduction to the Rietveld method.</p>			
PRACTICAL (2 CREDIT)				
Module 3: (Practical)	<p>(ANY 5 TO BE PERFORMED)</p> <ol style="list-style-type: none"> i. Growing single crystals of organic/Inorganic Compounds using slow evaporation/cooling/vapor diffusion e.g. Benzoic acid/acetylsalicylic acid and Potassium alum/copper(II) sulfate pentahydrate. ii. Selection and mounting (on loop) of a single crystals for X-ray diffraction studies. iii. Determination of unit cell parameters of a single crystal (e.g., copper(II) sulfate pentahydrate/sodium chloride) using software. iv. To demonstrate the process of single-crystal X-ray diffraction data collection for benzoic acid/copper(II) sulfate pentahydrate. v. Structure solution and refinement of aspirin/glycine/ or a small metal complex like $[\text{Cu}(\text{en})_2]\text{SO}_4$. using direct methods with Olex2 software. vi. Absolute Configuration Determination of Chiral compound like menthol derivative or (-)-camphor 	30	CO3, CO4	K1, K2, K3, K4, K5, K6

	<p>vii. To generate a crystallographic information file (CIF) and validate it for publication(WINGX/OLEX2)</p> <p>viii. To visualise and to do the crystal structure analysis (bond angles/bond lengths, atomic coordination) of NaCl/Quartz/Pervoskites(CaTiO₃) using structure visualization softwares such as VESTA/DIAMOND</p>			
Module 4: (Practical)	<p>(ANY 5 TO BE PERFORMED)</p> <p>i. Determination of lattice parameters for tetragonal, or hexagonal crystals</p> <p>ii. Calculation of crystallite size using Scherrer equation and study of effect of particle size on peak broadening</p> <p>iii. Determination of phase purity and quantitative phase analysis.</p> <p>iv. Analysis of solid solutions by peak shifts (Vegard's rule)</p> <p>v. Identification of polymorphs of a compounds (e.g. paracetamol, caffeine, etc.)</p> <p>vi. Determination of crystallinity percentage (e.g. polyethylene terephthalate (PET) or polyethylene (PE) etc.)</p> <p>vii. Powder X-ray diffraction pattern analysis (peak search, background subtraction, alpha2 stripping etc)</p> <p>viii. Lattice Parameter Refinement Using Least Squares Fit</p> <p>ix. Automated Phase Identification Using databases and quantitative Phase Analysis</p> <p>x. Analysis of pharmaceutical formulations such as Aspirin-Caffeine, Paracetamol-Chlorpheniramine maleate -Phenylephrine hydrochloride-Caffeine, etc.</p>	30	CO3, CO4	K1, K2, K3, K4, K5, K6
Pedagogy	<p>Theory: Mainly lectures and tutorials. Prelab excersise/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</p>			

	theoretical aspects of laboratory experiments prior to the conduct of each experiment.
Texts:	<ol style="list-style-type: none"> 1. A. Hofmann, S. Clokie, Wilson and Walkers Principles and Techniques of Biochemistry and Molecular Biology, 8th Ed., Cambridge University Press, Cambridge, UK, 2018. 2. A. R. West, Solid State Chemistry and Its Applications, 2nd Ed., Wiley, Hoboken, New Jersey, USA, 2022. 3. B. He, Two-dimensional X-ray Diffraction, 1st Ed., Wiley, Hoboken, New Jersey, USA, 2009. 4. C. Hammond, The Basics of Crystallography and Diffraction (International Union of Crystallography Texts on Crystallography), 4th Ed., Oxford University Press, Oxford, UK, 2015. 5. D. Sherwood, Crystals, X-rays and Proteins: Comprehensive Protein Crystallography, 1st Ed., Oxford University Press, Oxford, UK, 2015. 6. F. Hoffmann, Introduction to Crystallography, 1st Ed., Springer, Cham, Switzerland, 2020. 7. M. Milanese, G. Zanotti, G. Gilli, M. Catti, H. Monaco, G. Ferraris, G. Artioli, P. Gilli, D. Viterbo, C. Giacovazzo, Fundamentals of Crystallography, 3rd Ed., Oxford University Press, Oxford, UK, 2015. 8. R. Young, The Rietveld Method, 1st Ed., Oxford University Press, Oxford, UK, 1995. 9. V. Pecharsky, P. Zavalij, Fundamentals of Powder Diffraction and Structural Characterization of Materials, 2nd Ed., Springer, New York, USA, 2009. 10. W. David, K. Shankland, L. McCusker, C. Bärlocher, Structure Determination from Powder Diffraction Data, 1st Ed., Oxford University Press, Oxford, UK, 2006.
References / Readings:	<ol style="list-style-type: none"> 1. R. Dinnebier, S. Billinge, Powder Diffraction: Theory and Practice, 1st Ed., Royal Society of Chemistry, Cambridge, UK, 2008. 2. W. Massa, Crystal Structure Determination, 2nd Ed., Springer, Berlin, Germany, 2010.
Web Resources:	<ol style="list-style-type: none"> 1. https://doi.org/10.1107/S0021889808042726 2. https://www.iucr.org 3. http://www.crystallography.net/cod/ 4. https://www.ccdc.cam.ac.uk/ 5. https://www.rcsb.org/

Title of the Course	Forensic Analytical Chemistry	
Course Code	CHA-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 Courses	
Course Objectives:	<ol style="list-style-type: none"> 1. To learn concepts of forensic chemistry. 2. To learn the techniques used for forensic analysis. 3. To study various types of forensic evidences. 4. To gain experimental skills for forensic analysis. 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. explain concepts of forensic chemistry.	PSO1, PSO2, PSO3, PSO4
	CO 2. apply techniques / methods of forensic analysis.	PSO1, PSO2, PSO3, PSO4
	CO 3. evaluate drug and poison case studies based on gained knowledge.	PSO1, PSO2, PSO3, PSO4
	CO 4. analyse chemical evidences in forensic science.	PSO1, PSO2, PSO3, PSO4

Content:		No of hours	Mapped to CO	Cognitive Level
Module 1: (Theory)	Introduction to Forensic Science, Forensic Serology, Fingerprint Forensics, Forensic Ballistics, Forensic Toxicology, Forensic Pathology.	5	CO1	K1, K2, K3
Module 2: (Theory)	Sample Preparation: Types of forensic samples, Extraction, Preparation techniques for forensic samples for instrumental analyses, sample preparation for inorganic analyses, DNA Profiling. Presumptive Testing: drugs, firearms discharge residue, explosive residue, non-chemical.	5	CO2, CO3	K2, K3, K4
Module 3: (Theory)	Forensic Analysis of Arson and Explosives (GCMS, DSC), Analysis of Fire Debris (Total Ion Chromatography), Forensic Examination of Soils (Particle size distribution, Microscope, SEM, XRD, FTIR, Raman spectroscopy), Analysis of Paint Evidence (Microscopic examination, IR, Raman, GCMS, SEM-EDX), Forensic Examination of Writing and Printing Inks (optical examination, TLC, GCMS). Chemical analytical techniques used for the analysis of evidence, Case studies with above samples.	10	CO2, CO3	K2, K3, K4
Module 4: (Theory)	Blood Identification: Immunochromatographic assays, Crossed-Over Immunoelectrophoresis. Saliva Identification: Starch-Iodine assay, Phadebas assay, Immunochromatographic assays, RNA based assay. Forensic DNA Analysis: sample collection and DNA extraction, DNA quantification, problems encountered in Short Tandem Repeats analysis. Alcohol Analysis: blood alcohol concentration, field sobriety tests, blood alcohol measurements - enzymatic methods, headspace gas chromatography, breath alcohol testing, postmortem determination of alcohol. Postmortem Toxicology (GC, HPLC, AAS). Case studies with above techniques.	10	CO2, CO3	K2, K3, K4
PRACTICAL (2 CREDIT)				

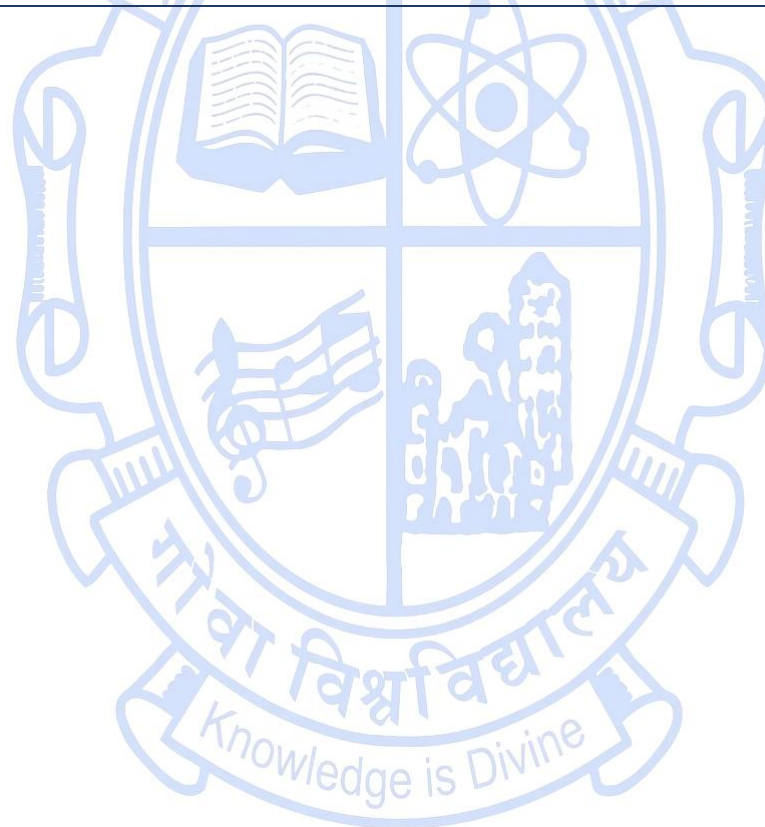
<p>Module 5: (Practical)</p>	<p>ANY 5 experiments (with representative sample prepared in lab)</p> <ol style="list-style-type: none"> i. Analysis of Petroleum Products and their residue forensic sample by GC ii. Analysis of alcohol forensic sample by GC iii. Detection of drugs forensic sample (caffeine) by HPLC iv. Detection of toxins forensic sample (aflatoxins) by HPLC v. Analysis of explosives (picric acid) forensic samples using FTIR. vi. Analysis of physical (paint and questionable materials such as cloth, paper), forensic samples using FTIR. vii. Detection of toxic metals by AES/AAS/ICPMS. viii. Analysis of chemical (drug) forensic samples using UV-visible spectrophotometry ix. Analysis of biological (DNA in blood and saliva) forensic samples using UV-visible spectrophotometry x. Analysis of chemical (drug such as caffeine) forensic samples using MS. xi. Analysis biological forensic samples (saliva and blood) using fluorescence spectroscopy. xii. Analysis of morphological details of biological (diatoms) forensic samples using AFM. xiii. Study of morphological details of biological (hair) forensic samples using SEM xiv. Study of morphology of physical (paint chips) forensic samples using optical microscopy xv. Analysis of chemical (drugs and dyes) forensic samples using NIR spectroscopy 	<p>30</p>	<p>CO2, CO3, CO4</p>	<p>K3, K4, K5, K6</p>
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Module 6:(Practical)	<p>ANY 5 experiments (with representative sample prepared in lab)</p> <ul style="list-style-type: none"> i. Chemical test for identification of Sesame oil ii. Chemical test for identification of Palmolein in Groundnut oil iii. Chemical test for identification of Linseed oil iv. Detection of Castor oil in edible oils by TLC v. Detection of Argemone oil in edible oils TLC vi. Detection of Mineral oils in edible oils by TLC vii. Detection of Phenolphthalein indicator in trap case examination by TLC 	20	CO2, CO3, CO4	K3, K4, K5, K6
Module 7:(Practical)	Field trip to Forensic science Lab in Goa.	10	CO2, CO3, CO4	K3, K4
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>			
Textbooks	<ol style="list-style-type: none"> 1. C. M. Hussain, D. Rawtani, G. Pandey, M. Tharmavaram, Handbook of Analytical Techniques for Forensic Samples: Current and Emerging Developments, Elsevier, Amsterdam, Netherlands, 2021. 2. D. Rawtani, C. M. Hussain, Technology in Forensic Science: Sampling, Analysis, Data and Regulations, 1st Ed., Wiley, Hoboken, New Jersey, USA, 2020. 3. L. Kobilinsky, Forensic Chemistry Handbook, Wiley, Hoboken, New Jersey, USA, 2012. 4. R. Saferstein, Forensic Science Handbook, Vol. I, Prentice Hall, Upper Saddle River, New Jersey, USA, 2002. 5. R. Wolstenholme, S. Jickells, S. Forbes, Analytical Techniques in Forensic Science, Wiley, Hoboken, New Jersey, USA, 2021. 			

	6. Working Procedure Manual: Chemistry, Directorate of Forensic Science Services, Ministry of Home Affairs, New Delhi, India, 2021.
References	<ol style="list-style-type: none"> 1. A. I. Vogel, Textbook of Practical Organic Chemistry including Qualitative Organic Analysis, ELBS, London, UK, 1971. 2. A. K. Jaiswal, T. Millo, Handbook of Forensic Analytical Toxicology, 2nd Ed., Jaypee Brothers Medical Publishers Ltd., New Delhi, India, 2022. 3. A. van Asten, Chemical Analysis for Forensic Evidence, 1st Ed., Elsevier, Amsterdam, Netherlands, 2022. 4. B. Bassett, Vogel's Textbook of Quantitative Inorganic Analysis, 4th Ed. Longman, London, UK, 1978. 5. B. H. Stuart, Forensic Analytical Techniques - Analytical Techniques in the Sciences, 1st Ed., Wiley, Hoboken, New Jersey, USA, 2012. 6. D. A. Skoog, D. M. West, F. J. Holler, Analytical Chemistry: An Introduction, Saunders College Publishing, Fort Worth, Texas, USA, 1994. 7. G. Biswas, Review of Forensic Medicine and Toxicology, 3rd Ed., Jaypee Brothers Medical Publishers Ltd., New Delhi, India, 2015. 8. G. Svehla (Ed.), Vogel's Qualitative Inorganic Analysis, Longman, London, UK, 1998. 9. Indian Pharmacopoeia, Vols. 1, 2, 3, Indian Pharmacopoeia Commission, Ghaziabad, India, 2007. 10. J. A. Siegel, P. J. Saukko, G. C. Knupfer, Encyclopaedia of Forensic Sciences, Academic Press, San Diego, California, USA, 2000. 11. M. Bassett, Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed., Longman, Essex, UK, 1989. 12. Manual of Methods of Analysis of Foods, Food Safety and Standards Authority of India, Ministry of Health and Family Welfare, Government of India, New Delhi, India, 2015. 13. P. Shrivastava, J. A. Lorente, A. Srivastava, A. Badiye, N. Kapoor, Textbook of Forensic Science, Springer Nature, Singapore, 2023. 14. S. A. Iqbal, Textbook of Forensic Chemistry, 1st Ed., Discovery Publishing Pvt. Ltd., New Delhi, India, 2011. 15. S. Bell, Forensic Chemistry, Pearson Prentice Hall, Upper Saddle River, New Jersey, USA, 2006.

	<p>16. S. Kromidas, More Practical Problem Solving in HPLC, Wiley-VCH, Weinheim, Germany, 2005.</p> <p>17. S. Kromidas, Practical Problem Solving in HPLC, Wiley-VCH, Weinheim, Germany, 2004.</p> <p>18. T. R. L. C. Paixão, W. K. T. Coltro, M. O. Salles, Detection Science - Forensic Analytical Methods, Royal Society of Chemistry, Cambridge, UK, 2019.</p> <p>19. V. R. Meyer, Practical High-Performance Liquid Chromatography, 5th Ed., Wiley, Chichester, UK, 2010.</p>
Web Resources:	<ol style="list-style-type: none">1. https://lab-training.com/wp-content/uploads/2014/11/HPLC-E-Book.pdf2. https://torontech.com/hplc-testing-and-analysis-guide/

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SEMESTER IV

Generic Elective (GE) Courses

Title of the Course	Trends in Analytical Chemistry	
Course Code	CHA-6201	
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 Courses	
Course Objectives:	<ol style="list-style-type: none">1. Familiarity with concepts of automation in the analytical measurements2. Learn artificial intelligence in analytical chemistry3. Understand different sensors for chemical analysis.4. Acquaint with concept of flow chemistry	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. explain automation in the analytical measurements	PSO1
	CO 2. apply AI in drug discovery and food.	PSO1, PSO2

	CO 3. choose appropriate method for sensing of analytes		PSO1, PSO2	
	CO 4. apply flow chemistry for process technology		PSO1, PSO2	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Automation in Measurement and Artificial Intelligence (AI) Principles of automation, automatic and automated devices, Process control: off-line, at-line and on-line analysis. Continuous and discrete analyzers, feed- back mechanism</p> <p>Flow injection analysis (FIA), principles, dispersion coefficient, factors affecting peak height-sample volume, channel length, flow rate and channel geometry, applications of FIA (chloride and phosphate determination), FIA acid-base titration, stopped flow measurements and gradient FIA. Laboratory Information Management Systems (LIMS). Artificial Intelligence (AI) in analytical chemistry, applications in drug discovery and food science</p>	20	CO1, CO2	K1, K2, K3, K4, K5
Module 2:	<p>Sensors Chemical sensors: Introduction, definitions, classification of chemical sensors, descriptions of chemical sensors (electrochemical sensors, potentiometric sensors, Voltametric chemical sensors, sensors based on conducting properties). Optical sensors - light guides, the evanescent wave, design of fibre optic sensor, indicator mediated sensor. Calorimetric sensors - catalytic gas sensor, thermal conductivity sensor. Mass sensor - piezoelectric quartz crystal resonator, surface acoustic wave sensor, applications</p> <p>Biosensors in analysis: Introduction, producing biological surface, methods of immobilization, Achievement of biotransduction (amperometric, potentiometric, optical), applications</p>	20	CO3	K1, K2, K3, K4, K5, K6
Module 3:	Flow chemistry	20	CO1,	K1, K2, K3, K4,

	<p>Introduction, advantages and challenges of flow processes.</p> <p>Instrumentation, Batch vs Flow, Flow Reactors - Types and Design, Reaction Kinetics and Thermodynamics in Flow, Flow Chemistry Techniques, Automation, Control, and Optimization,</p> <p>Microreactor technology and process intensification, process analytical technology (PAT) in Flow, safety in flow</p> <p>Applications in multistep synthesis and scalability.</p>		CO4	K5
Pedagogy	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.			
Texts:	<ol style="list-style-type: none"> 1. F. Darvas, G. Dormán, G., V. Hessel, S. V. Ley, De Gruyter, Flow Chemistry – Fundamentals, Berlin, 2021. 2. T. Wirth, Microreactors in Organic Synthesis and Catalysis, John Wiley & Sons, Germany, 2008 			
References / Readings:	<ol style="list-style-type: none"> 1. B. R. Eggins, Chemical Sensors and Biosensors, John Wiley, England, 2004. 2. G. D. Christian, Analytical chemistry, 7th Ed., Willey, USA, 2014. 3. G. Harsanyi, Sensors in Biomedical Applications – Fundamentals, Technology and applications, CRC Press, Boca Ratan, 2000. 4. J. Martinez-Calatayud. Flow injection analysis of pharmaceuticals: automation in the laboratory. 1st Ed., Taylor and Francis, London, 1996. 5. M. Mutlu, Biosensors in Food Processing, Safety and Quality Control, CRC Press, Boca Ratan, 2010. 			
Web Resources:	<ol style="list-style-type: none"> 1. https://doi.org/10.1016/j.aca.2021.338403 2. https://doi.org/10.1002/slct.202404446 			

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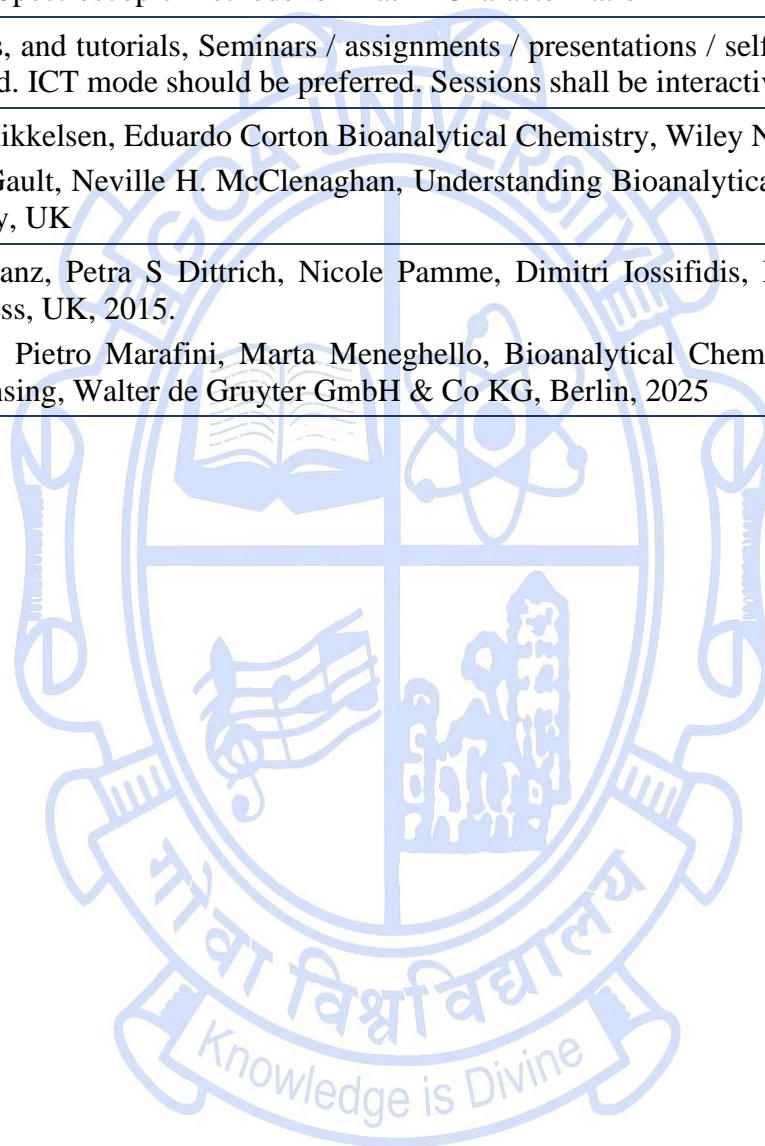
Title of the Course	Bioanalytical Chemistry
Course Code	CHA-6202
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Level 400 Courses	
Course Objectives:	<ol style="list-style-type: none"> 1. To understand the fundamental role of enzymes in bioanalytical chemistry and their applications in biological assays and diagnostics. 2. To apply the principles of electrophoresis for the separation, identification, and analysis of biomolecules in complex biological systems. 3. To integrate core biochemical knowledge with biosensor technologies for the development and application of effective biosensing systems. 4. To evaluate and compare various qualitative and quantitative methods used in modern bioanalysis, including spectroscopic, chromatographic, and electrochemical techniques. 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. understand the role of enzymes in bioanalytical chemistry.	PSO1, PSO2

	CO 2. explain the principles and techniques of electrophoresis for separation and analysis of biomolecules in bioanalytical chemistry.		PSO1, PSO2	
	CO 3. apply biochemical knowledge to develop and utilize biosensing methods.		PSO1, PSO2	
	CO 4. analyze various bioanalytical methods for effective biomolecule detection and quantification.		PSO1, PSO2, PSO3	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	Enzymes Enzymes in Bioanalytical Chemistry, Enzyme Kinetics, Enzyme Activators, Enzyme Inhibitors, Enzyme Units and Concentrations, Quantitation of Enzymes and Their Substrates, Immobilized Enzymes. Antibodies, Quantitative Immunoassays with Labels.	15	CO1	K1, K2, K3, K4, K5
Module 2:	Electrophoresis Electrophoretic support media, detection of proteins and nucleic acids after electrophoretic separation. Zone Electrophoresis: Determination of protein net charge and molecular weight using PAGE, diagnosis of genetic (inherited) disease, DNA sequencing with the maxam–gilbert method, immunoelectrophoresis Isoelectric Focusing: Carrier ampholytes, immobilized pH gradients, two-dimensional electrophoresis, Capillary Electrophoresis: Electroosmosis, detectors for capillary electrophoresis, capillary polyacrylamide gel electrophoresis, capillary isoelectric focusing.	15	CO2	K1, K2, K3, K4
Module 3:	Biosensors Response of Enzyme-Based Biosensors, Examples of Biosensor Configurations, Directed Evolution for the design of Macromolecular Bioassay Reagents.	15	CO3	K1, K2, K3, K4
Module 4:	Analytical Techniques for Biomolecular Separation and Characterization Centrifugation Methods, Chromatography of Biomolecules, Mass Spectrometry of	15	CO4	K2, K3, K4, K5

	Biomolecules. Spectroscopic Methods for Matrix Characterization			
Pedagogy	Mainly lectures, and tutorials, Seminars / assignments / presentations / self- study or a combination of some of these can also be used. ICT mode should be preferred. Sessions shall be interactive in nature to enable peer group learning.			
Texts:	<ol style="list-style-type: none"> 1. Susan R. Mikkelsen, Eduardo Corton Bioanalytical Chemistry, Wiley NJ, 2004. 2. Victor A. Gault, Neville H. McClenaghan, Understanding Bioanalytical Chemistry - Principles and applications, 2009, Wiley, UK 			
References / Readings:	<ol style="list-style-type: none"> 1. Andreas Manz, Petra S Dittrich, Nicole Pamme, Dimitri Iossifidis, Bioanalytical Chemistry 2nd Ed, Imperial College Press, UK, 2015. 2. Paolo Ugo, Pietro Marafini, Marta Meneghello, Bioanalytical Chemistry: From Biomolecular Recognition to Nanobiosensing, Walter de Gruyter GmbH & Co KG, Berlin, 2025 			

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Title of the Course	Applied analytical Chemistry
Course Code	CHA-6203
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 Courses	
Course Objectives:	<ol style="list-style-type: none"> To understand the basic importance of Quality in industrial products. To develop a basic understanding of clinical chemistry in medical laboratories To evaluate the compliance of product packaging with regulatory standards. To apply computational tools for basic chemical simulations and data management. 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. explain the importance of quality in industrial products and apply the knowledge in Quality Control (QC) and Quality Assurance (QA) processes.	PSO1
	CO 2. explain the principles of packaging and regulatory requirements and apply them in the food, drug, and cosmetics industries in compliance with relevant standards	PSO1, PSO2

	CO 3. describe the fundamental concepts and techniques of clinical chemistry used in medical laboratories.		PSO1	
	CO 4. explain the applications of computers in chemistry, including chemical data analysis, modeling, and laboratory automation.		PSO3	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Introduction to Quality Control and Quality Assurance</p> <p>Basic concepts; quality assurance; aspect of specification and tolerance; quality acceptance; sampling reality; cost aspect of quality decisions; quality control in raw materials; production; finished product;</p> <p>Law related to quality control; case studies of quality control in various industries like agrochemicals, petrochemicals, pharmaceuticals, dyes, plastics and polymers.</p>	8	CO1	K1, K2, K3, K4
Module 2:	<p>Packaging and Regulatory Aspects</p> <p>Introduction; types of packing material and regulations acts in Food and Pharmaceutical industries; testing of material for packing; legal consideration in packing; regulatory aspects of food, drugs and cosmetics;</p> <p>The Drug and Cosmetic Act, 1940; the Drug and Cosmetic Rules 1945; prevention of food adulteration; the Prevention of Food Adulteration Act, 1954; Fruit Product Order; Meat Product Order; I.S.I., Agmark and other standard for foods and Cosmetic particularly with reference the testing of foods, drug and cosmetic and the raw material concerned;</p> <p>The Government authorities concerned with the testing-their qualification, duties, powers and procedure to be followed; Record to be maintain under the Acts; C.G.M.P. and C.G.L.P.S. requirements of QC; Department of 'WHO' certification.</p>	12	CO2	K1,K2,K3,K4
Module 3:	Computers in Chemistry:	10	CO3	

	<p>PC and run standard programs and packages like MS-WORD, EXCEL, SIGMA PLOT, and CHEM SKETCH</p> <p>Chemistry numerical (numerical taken preferably from Physical Chemistry for plotting first and second derivative curves, linear plots); numerical from Analytical Chemistry, Chemical Kinetics, Electrochemistry, Spectroscopy and other related topics; writing the structures of inorganic and organic molecules, chemical equations, and other applications</p>			
Module 4:	<p>Clinical Chemistry</p> <p>Composition body fluid; detection of abnormal levels of certain constituents leading to diagnosis of diseases; sample collection and preservation of physiological fluids.</p> <p>Analysis of physiological fluids - blood, urine and serum; estimation of blood glucose, cholesterol, urea, haemoglobin; urine-urea, uric acid, albumin, globulins, barbiturates, acid and alkaline phosphates.</p> <p>Estimation of enzymes, carbohydrates, essential amino acids, proteins and lipids.</p>	15	CO4	K1, K2, K3, K4
Module 5:	<p>Food Analysis, Processing and Preservation:</p> <p>Analysis of food such as milk, milk products, tea, coffee and beverages (soft drinks, alcoholic drinks), Flour, starch, honey, jams and edible oils. Analysis of preservatives, colouring matter, micronutrients.</p> <p>Food processing and food preservation: Refining milling, canning, concentration, freezing drying, pasteurization sterilization irradiation.</p>	15	CO2	K1, K2, K3, K4
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. E. Prichard, Quality in the Analytical Chemistry Laboratory; John Wiley and Sons, NY, 1997 2. F. W. Fifield and D. Kealy, Principles and Practice of Analytical Chemistry; 5th Ed. Backwell Science Ltd. London, UK, 2020. 			

	<ol style="list-style-type: none"> 3. G. D. Christian, Analytical chemistry, 5th Ed., Wiley, 1994. 4. H. Kaur, Instrumental Methods of Chemical Analysis; Pragati Prakashan, 2012 5. Indian Pharmacopeia; Volume I and II, 2018 6. J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas, B. Sivasankar, Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed., Pearson Education, Asia 2009. 7. W. Funk, V. Dammann, G. Donnevert, Quality Assurance in Analytical Chemistry; VCH Weinheim, 1995
<p>References / Readings:</p>	<ol style="list-style-type: none"> 1. A. H. Beckett, J.B. Stenlake, Practical Pharmaceutical Chemistry (Part-1), 4th Ed. CBS publisher, 2006. 2. C. S. James, Analytical Chemistry of Foods, Blackie Academic and Professional Publisher, UK, 1995. 3. D. A. Skoog, D. M. West, F. J. Holler, S. R. Crouch, Fundamentals of Analytical Chemistry; 9th Ed. Brooks Cole Publisher, 2013 4. D. White, N. Lawson, P. Masters, D. McLaughlin, Clinical Chemistry, CRC press, 2016 5. Encyclopaedia of Analytical Chemistry, Volume 3, Academic Press, 1995. 6. Government of India Publications of Food Drug Cosmetic Acts and Rules. https://cdsco.gov.in/opencms/opencms/en/Acts-Rules/ 7. K. V. Raman, Computers in chemistry, Tata Mc.Graw-Hill, 1993. 8. M. B. Jacob, Chemical Analysis of Food and Food Products, 3rd Ed. CBS publisher, 2013. 9. M. L. Mehra, The Handbook of Drug Laws, Univ. Book Agency, 1997. 10. Modern Packaging Encyclopedia and planning guide, McGraw- Hill Publications, 1972. 11. Modern Packaging Encyclopedia, Volume 3 McGraw-Hill Publisher, 1957. 12. R. C. Gribbin, Principals of package Development, 2nd Ed. Springer, 2012. 13. R. L. Nath, Practical Biochemistry in Clinical Medicine, 2nd Ed. Academic Publishers, 1990. 14. S. K. Pundir, A. Bansal, Computers for Chemists, Pragati prakashan, 2018. 15. S. R. Mikkelsen, E. Corton, Bioanalytical Chemistry, 2nd Ed. John Wiley and Sons, 2016. 16. V. Malik, Drug and Cosmetics Act, 25th Ed. Eastern book company, 2016. 17. W. J. Marshall, M. Lapsley, A. Day, K. Shipman, Clinical Chemistry, Elsevier, 2020.

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Title of the Course	Microscopic and Imaging Techniques
Course Code	CHA-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 Courses	
Course Objectives:	<ol style="list-style-type: none"> 1. To understand working principles of various instrumental techniques for analysis 2. To learn application of microscopic and imaging techniques 3. To apply various microscopic techniques for understanding materials 4. To apply various imaging techniques for diagnosis 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. explain theory and instrumentation of various instrumental methods of analysis	PSO1
	CO 2. judge suitability of different instrumental methods for microscopic analysis and imaging	PSO1
	CO 3. understand and will be able to apply microscopic techniques for understanding materials	PSO3

	CO 4. apply various imaging techniques for diagnosis		PSO3	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Optical Microscopy Optical principles, instrumentation, specimen preparation.</p> <p>Imaging modes: Bright-Field and Dark-Field Imaging, Phase-Contrast Microscopy, Polarized-Light Microscopy, Nomarski Microscopy, Fluorescence Microscopy</p> <p>Confocal Microscopy: Working Principles and Three-Dimensional Images</p>	15	CO1, CO2, CO3	K1, K2, K3, K4, K5
Module 2:	<p>Electron microscopy Electron Microscopy: Electron Sources, Electromagnetic Lenses, Electron-Specimen Interactions</p> <p>Scanning Electron Microscopy: Instrumentation, Contrast Formation, Operational Variables, Specimen Preparation, Electron Backscatter Diffraction.</p> <p>Transmission Electron Microscopy: Instrumentation, Specimen Preparation, Image Modes, Selected-Area Diffraction, Images of Crystal Defects, Scanning transmission electron microscopy.</p>	15	CO1, CO2, CO3	K1, K2, K3, K4, K5, K6
Module 3:	<p>3D Imaging Techniques X-ray imaging and Computed Tomography: Introduction to X-ray and CT Imaging Principles, CT Scanners and Applications</p> <p>Magnetic Resonance Imaging: Introduction to Nuclear Magnetic Resonance and Magnetic Resonance Imaging, Basic MRI Techniques.</p> <p>Positron Emission Tomography: Nuclear medicine Imaging, Radiotracers and Detection Systems, Tomographic Reconstruction Methods, Clinical Applications.</p> <p>Ultrasound Imaging: Principles of Ultrasound Imaging, Instrumentation, Ultrasound Scanning, Imaging Techniques and Applications.</p>	20	CO1, CO2, CO4	K1, K2, K3, K4, K5
Module 4:	Other Imaging Techniques	10	CO1,	K1, K2,

	Scanning Probe Microscopy: Scanning Tunnelling Microscopy and Atomic Force Microscopy - Theory, Instrumentation, Operational Modes and Applications. Raman and Infrared (IR) Imaging: Principle, Instrumentation, Raman and Infrared (IR) Mapping / Imaging and Applications.		CO2, CO3, CO4	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. K. Iniewski, Medical Imaging: Principles, Detectors, and Electronics, 1st Ed., Wiley-Interscience, Hoboken, New Jersey, USA, 2009. 2. N. B. Smith, A. Webb, Introduction to Medical Imaging: Physics, Engineering and Clinical Applications, 1st Ed., Cambridge University Press, Cambridge, UK, 2010. 3. R. West, Solid State Chemistry and Its Applications, 2nd Ed., Wiley, Chichester, UK, 2014. 4. T. G. Rochow, E. G. Rochow, An Introduction to Microscopy by Means of Light, Electrons, X-Rays, or Ultrasound, 2nd Ed., Springer, Berlin, Germany, 2012. 5. Y. Leng, Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, 2nd Ed., Wiley-VCH, Weinheim, Germany, 2013. 			
References / Readings:	<ol style="list-style-type: none"> 1. R. F. Egerton, Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM, 2nd Ed., Springer, New York, USA, 2016. 2. R. Salzer, Infrared and Raman Spectroscopic Imaging, 2nd Ed., Wiley-VCH Verlag GmbH, Weinheim, Germany, 2014. 			

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Title of the Course	Practical course in Industrial Analytical Chemistry-I
Course Code	CHA-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

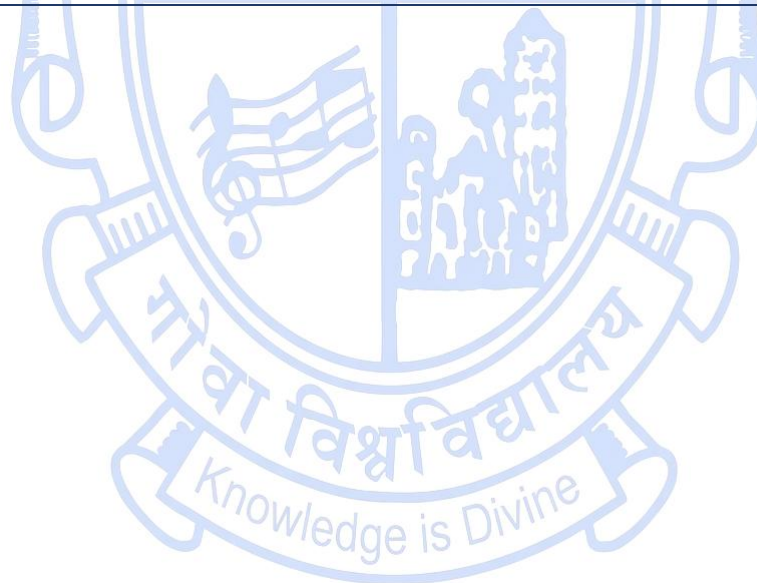
Pre-requisites for the Course:	Level 400 Courses	
Course Objectives:	<ol style="list-style-type: none"> 1. To study various experimental techniques for analysis. 2. To learn data analysis, handling and interpretation of spectra. 3. To understand different techniques for the analysis of pharmaceutical products. 4. To interpret data for the sample analysis 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. choose various techniques for raw materials and finished products analysis.	PSO1, PSO4
	CO 2. interpret data for identification, quality tests and assay of pharmaceutical raw materials and finished products.	PSO3, PSO4
	CO 3. solve numerical problems on analysis chemical analysis of pharmaceuticals.	PSO3, PSO4
	CO 4. analyse data and provide reports for analysis.	PSO4

Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Analysis of aspirin/Ibuprofen as per Indian Pharmacopeia. (Any 5)</p> <ul style="list-style-type: none"> i. Identification (B and C test); Appearance of solution; Clarity of solution in alkali; Sulphated Ash. ii. Limit tests: a) Heavy metals, b) Chlorides, c) Sulphates, d) Readily carburizable substances, e) Salicylic acid. iii. Loss on drying and assay. iv. Analysis of magnesium hydroxide as per Indian Pharmacopeia. v. Identification; Appearance of solution; heavy metals, iron and chloride vi. Tests: Sulphate; calcium; soluble substances; substances insoluble in acetic acid; vii. Loss on drying and assay viii. Analysis of calcium phosphate as per Indian Pharmacopeia. ix. Identification, acid insoluble substances, Heavy metals, Barium. x. Carbonate, chloride, nitrate and Monocalcium and tricalcium phosphates, Reducing substances xi. Loss on ignition and assay (calibration of acid solution must be performed) 	40	CO1, CO2, CO4	K1, K2, K3, K4, K5
Module 2:	<p>Identification test for Paracetamol tablet and tablet dissolution test on Paracetamol according to Indian Pharmacopeia</p> <ul style="list-style-type: none"> i. Identification test for Paracetamol table (according to IP); Dissolution and other tests. Average wt. of 20 tablets and UV absorbance based assay of Paracetamol tablet using specific absorbance as per Pharmacopeia. 	16	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5

	<p>ii. Analysis of Ca-Gluconate or calcium carbonate tablet or any Ca-supplementary tablet with respect to identification test, average wt. of 20 tablet, and Ca(II) content per tablet as per Indian Pharmacopeia.</p>			
Module 3:	<p>(Any 8)</p> <p>i. Interpretation of IR spectra of caffeine and assay of caffeine by non-aqueous titration method according to IP.</p> <p>ii. Interpretation of IR spectra of and assay of nicotine amide by non-aqueous titration method according to IP.</p> <p>iii. Identification test for dextrose i.e. glucose (anhydrous or monohydrate); determination of a) specific optical rotation and b) water by Karl Fischer Method.</p> <p>iv. Determination of NaCl and dextrose content in DNS saline solution: a) Cl by potentiometric titration and b) Dextrose by polarimetry</p> <p>v. Determination of refractive index of four liquids as per IP. b) Viscosity of ethyl cellulose by Oswald viscometer (use viscometer which comply specification of IP).</p> <p>vi. Identification and Assay of nicotinamide from tablets or capsules (UV-spectroscopy)</p> <p>vii. Optical rotation and assay of ascorbic acid from tablet or from vit-C pure material by iodimetric titration (vit-C).</p> <p>viii. Tablet friability and disintegration test; capsule disintegration test</p> <p>ix. Related substances in paracetamol syrup or in paracetamol tablet by thin layer chromatography.</p> <p>x. Assay of paracetamol in paracetamol syrup by liquid chromatography.</p>	64	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5

	<ul style="list-style-type: none"> xi. Related substances in paracetamol syrup or in paracetamol tablet by liquid chromatography xii. Interpretation of IR spectra of at least three pharmaceutical compounds. xiii. Calibration UV-Visible spectrophotometer as per IP. 			
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:	<ul style="list-style-type: none"> 1. Indian Pharmacopoeia, Vol. 1, The Indian Pharmacopoeia Commission (IPC), Ghaziabad, India, 2007. 2. Indian Pharmacopoeia, Vol. 2, The Indian Pharmacopoeia Commission (IPC), Ghaziabad, India, 2007. 3. Indian Pharmacopoeia, Vol. 3, The Indian Pharmacopoeia Commission (IPC), Ghaziabad, India, 2007. 			
References / Readings:	<ul style="list-style-type: none"> 1. Kar, Pharmaceutical Drug Analysis, 2nd Ed., New Age International Pvt. Ltd. Publishers, New Delhi, India, 2005. 2. S. Pedersen-Bjergaard, B. Gammelgaard, T. G. Halvorsen, Introduction to Pharmaceutical Analytical Chemistry, 2nd Ed., Wiley, Hoboken, New Jersey, USA, 2012. 			

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Title of the Course	Practical course in Industrial Analytical Chemistry-II
Course Code	CHA-6206
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

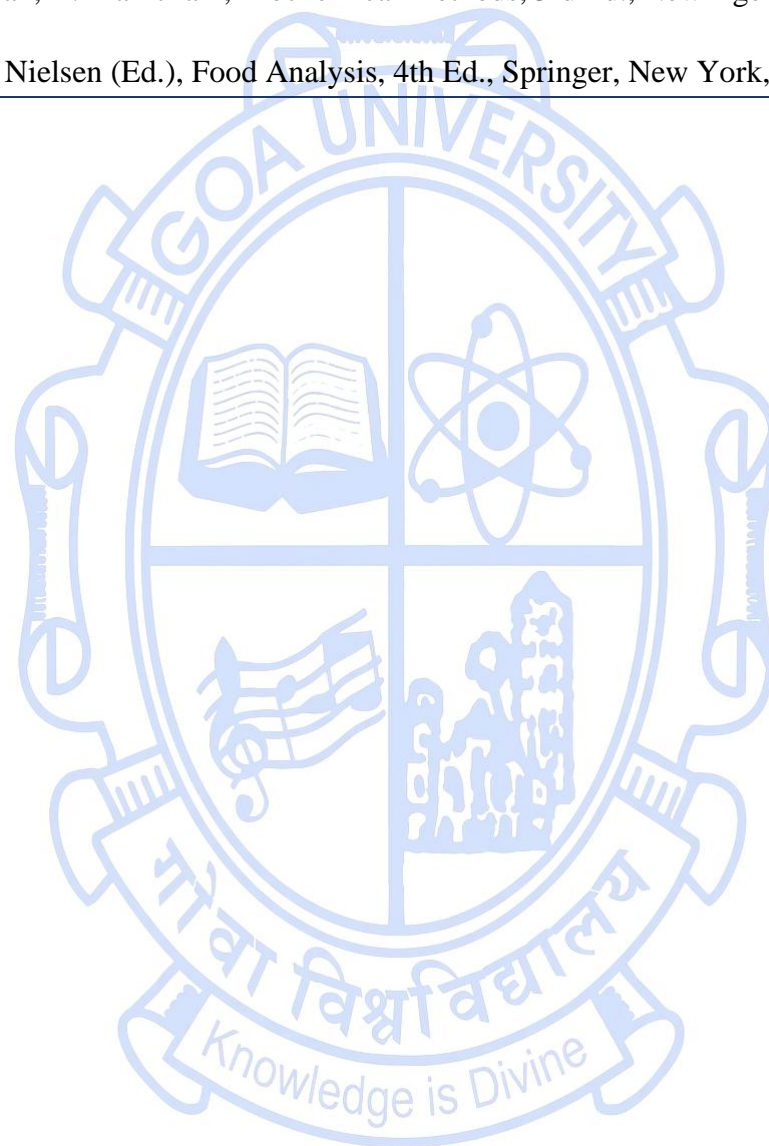
Pre-requisites for the Course:	Level 400 Courses	
Course Objectives:	<ol style="list-style-type: none"> 1. To study various experimental techniques for food analysis. 2. To learn data analysis, handling and interpretation of spectra data. 3. To understand different techniques for the analysis of food samples. 4. To interpret data for food sample analysis 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. choose various analytical techniques for food product analysis.	PSO1, PSO4
	CO 2. describe basic principles of various methods of food analysis.	PSO3, PSO4
	CO 3. apply appropriate methods for sample treatment for particular analysis of food.	PSO3, PSO4
	CO 4. evaluate the quality of the food and provide reports for analysis.	PSO4

Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Non-instrumental methods (Any 8)</p> <ul style="list-style-type: none"> i. Determination of total ash and acid insoluble ash in tea green tea. ii. Determination of water-soluble ash and alkalinity in tea green tea. iii. Caffeine content in tea: Extraction of Caffeine from tea, its purification by crystallization, weigh it. Characterize the caffeine by UV visible and IR spectroscopy. iv. Determination of a) saponification value and acid value of an edible oil sample. v. Determination of a) Iodine Value and b) Rancidity of an edible oil sample. vi. Detection (qualitative tests) of Adulterants in Milk (tests for any six adulterants). vii. Determination of moisture and fat content in dried milk products. viii. Determination of Milk Protein in Casein/Caseinates (Kjeldahl's method) ix. Isolation of casein from milk thereby gravimetric estimation of casein from milk. x. Method for qualitative test for Vitamin A in Vanaspati ghee: Antimony trichloride method and Determination of carotenoid content of raw palm oil. xi. Determination of Vit-C in lemon or in Vit-C supplement by indophenol or iodimetric method. xii. Determination of dietary fibres in food sample. 	64	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5
Module 2:	<p>Instrumental Methods (Any 7)</p> <ul style="list-style-type: none"> i. Quantitative Estimation of Urea in Milk. ii. Gas Chromatography-FID Method of Alcohol Estimation. iii. Determination of Ethyl Alcohol Content - Dichromate Oxidation Method. 	56	CO1, CO2, CO3, CO4	K1, K2, K3, K4, K5

	<ul style="list-style-type: none"> iv. Determination of Lead by Atomic Absorption Spectrophotometric (AAS) Method v. Determination of Calcium by Atomic Absorption or flame emission Spectrophotometric (AAS) Method. vi. Total carbohydrates in food sample by Anthrone or by phenol sulphuric acid method. vii. Reducing sugar in food sample by Nelson Somyogi or DNSA method viii. Determination phosphate in food sample ix. Determination iron in food sample x. Determination of Riboflavin in food sample by photofluorimetry. xi. Determination of purity of Sugar (Sucrose) and Dextrose (d-glucose) by polarimetry xii. Separation and identification of amino acids in food sample by two-dimensional TLC. 			
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:	<ol style="list-style-type: none"> 1. FSSAI Manual of Methods of Analysis for Alcoholic Beverages, Food safety and standards Authority of India, 2019. 2. FSSAI Manual of Methods of Analysis for Beverages Tea, Coffee and Chicory, Food safety and standards Authority of India, 2023. 3. FSSAI Manual of Methods of Analysis for Milk and Milk products, Food safety and standards Authority of India, 2015. 4. FSSAI Manual of Methods of Analysis for Oil and Fats, Food safety and standards Authority of India, 2016. 			
References / Readings:	<ol style="list-style-type: none"> 1. D. T. Plummer, An Introduction to Practical Biochemistry, 3rd Ed., Tata McGraw-Hill, New Delhi, India, 2017. 			

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| | <ol style="list-style-type: none">2. S. Sadashivan, A. Manickam, Biochemical Methods, 3rd Ed., New Age International Publishers, New Delhi, India, 2008.3. S. Suzanne Nielsen (Ed.), Food Analysis, 4th Ed., Springer, New York, USA, 2010. |
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Title of the Course	Practical Course in Environmental Analytical Chemistry
Course Code	CHA-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

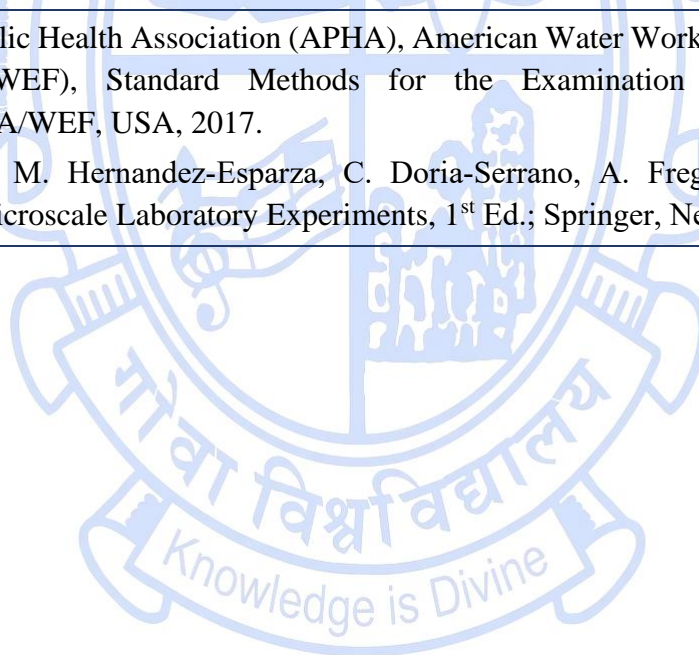
Pre-requisites for the Course:	Level 400 Course	
Course Objectives:	<ol style="list-style-type: none"> To understand and apply methods for sampling and analysis of environmental pollutants. To analyze air, water, and soil samples for common contaminants. To use instrumental methods (UV-Vis, AAS, AES, GC etc.) for pollutant determination. To interpret and report environmental data accurately using appropriate quality control measures. 	
Course Outcomes:	Students will be able to	Mapped to PSO
	CO 1. describe and explain various experimental techniques used in environmental analysis (titrimetry, spectrophotometry, and instrumental analysis).	PSO1
	CO 2. measure and determine physicochemical parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), BOD, COD, and nutrient levels in soil and water samples.	PSO1, PSO2

	CO 3. analyze and estimate the concentration of pollutants (e.g., SO ₂ , NO _x , heavy metals, nitrates, chlorides) in air, water, and soil using standard methods and instruments.		PSO3	
	CO 4. use analytical instruments (e.g., UV-Vis spectrophotometer, AAS, pH meter, air samplers) and evaluate environmental data with appropriate quality control and validation.		PSO4	
Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	<p>Analysis by Titrimetry (Any 3)</p> <ul style="list-style-type: none"> i. Determination of alkalinity of surface, ground and sea water sample using titrimetric analysis. ii. Determination of acidity of surface, ground and sea water sample using titrimetric analysis. iii. Estimation of total residual chlorine in water samples. iv. Estimation of total, permanent and temporary hardness of water samples. v. Determination of chemical oxygen demand of water sample. vi. Determination of Biological oxygen demand of water sample. vii. Estimation of hydrogen sulfide in waste waters. viii. Determination anionic detergents from waste water. ix. Determination of aqueous carbonate equilibria and corrosiveness. x. Determination of dissolved CO₂ in water. 	24	CO1, CO2, CO3	K1, K2, K3, K4, K5
Module 2:	<p>Other Analysis Techniques (Any 3)</p> <ul style="list-style-type: none"> i. Determination of pH, electrical conductivity and Total Dissolved Solids in water samples. ii. Determination of moisture content of soil using gravimetry, pH and conductivity of soil samples. 	24	CO1, CO2, CO3	K1, K2, K3, K4, K5

	iii. Estimation of organic matter in soil by Loss on Ignition method			
Module 3:	Solvent extraction (Any 3) <ol style="list-style-type: none"> Estimation of available phosphates in soil sample. Estimation of total nitrogen in soil and water. Determination of available sulphur in a soil sample. Estimation of oil and grease from soil/water sample. 	24	CO1, CO2, CO3	K1, K2, K3, K4, K5
Module 4:	Spectrophotometric Method (Any 3) <ol style="list-style-type: none"> Determination of nitrite in water sample using colorimetry. Estimation of phosphate in water by colorimetry Determination of chromium in water sample by UV-Visible spectrophotometry. Determination of adsorption capacity of activated charcoal for various coloured water samples. Determination of heavy metals (Mn, Fe, Cu, Zn, Mo) in environment sample by spectrophotometry. 	24	CO1, CO3, CO4	K1, K2, K3, K4, K5
Module 5:	Other Instrumental Techniques (Any 3) <ol style="list-style-type: none"> Estimation of sulphate in water samples (tap water) by turbidimetry. Determination of fluoride in Drinking Water Using an Ion-Selective Electrode. Determination of Na and K content in soil by flame photometry. Determination of elements (Fe/Mn/Zn/Pb/Cd etc) in air using high volume sampler. Determination of micronutrient content in soil by AAS/AES. (Mn, Fe, Cu, Zn, Mo). 	24	CO1, CO3, CO4	K1, K2, K3, K4, K5

	<ul style="list-style-type: none"> vi. Determination of SO₂ in ambient air by colorimetry. vii. Estimation of coagulant dose/ electrolyte using JAR test. viii. Determination of organic contaminants in environmental sample by UV-visible spectrophotometer/HPLC/ Gas chromatography 			
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:	<ul style="list-style-type: none"> 1. A. K. Dey, Environmental Chemistry, 7th Ed.; New Age International Publishers, India, 2010. 2. E. W. Rice, R. B. Baird, A. D. Eaton, L. S. Clesceri, Standard Methods for the Examination of Water and Wastewater Analysis, 22nd Ed.; American Public Health Association, USA, 2012. 3. G. H. Jeffery, J. Bassett, J. Mendham, R. C. Denney, Vogel's Textbook of Quantitative Chemical Analysis, 5th Ed.; Longman Scientific & Technical, UK, 1989. 			
References / Readings:	<ul style="list-style-type: none"> 1. American Public Health Association (APHA), American Water Works Association (AWWA), Water Environment Federation (WEF), Standard Methods for the Examination of Water and Wastewater, 23rd Ed.; APHA/AWWA/WEF, USA, 2017. 2. J. G. Ibanez, M. Hernandez-Esparza, C. Doria-Serrano, A. Fregoso-Infante, M. M. Singh, Environmental Chemistry: Microscale Laboratory Experiments, 1st Ed.; Springer, New York, USA, 2008. 			

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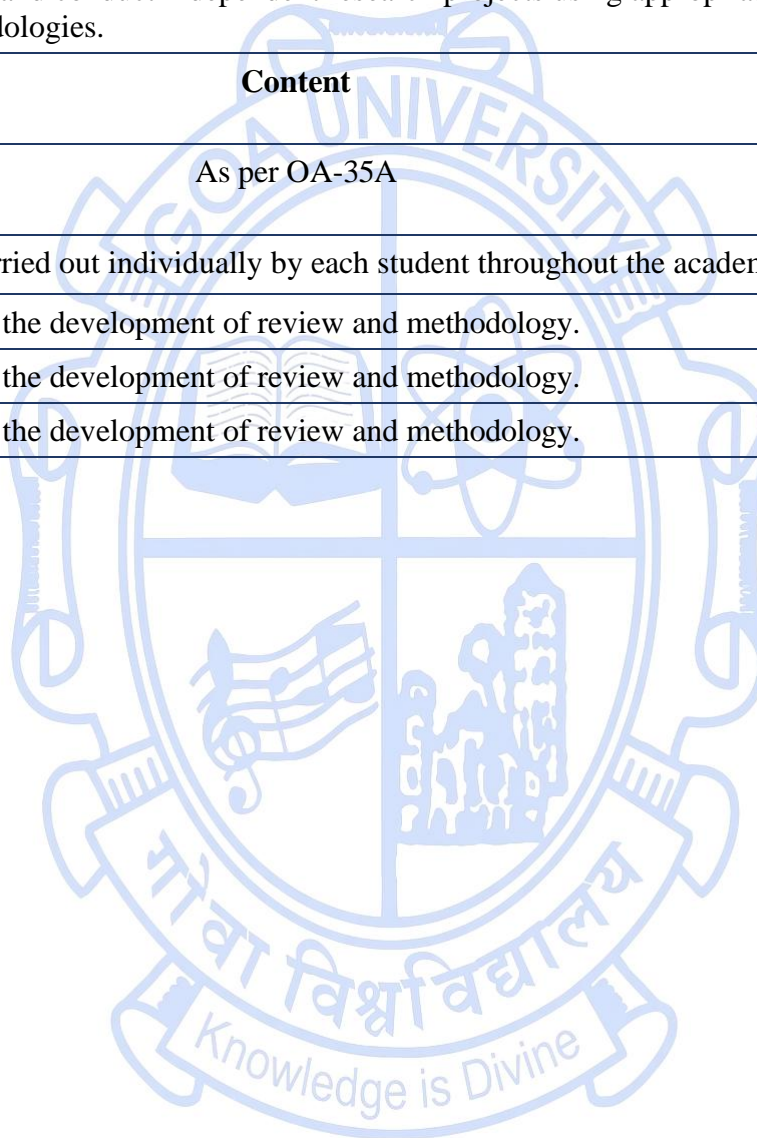


DISSERTATION (40 Credits)

Title of the Course	Discipline Specific Dissertation (DSD)	
Course Code	CHA-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.	PSO1
	CO 2. use appropriate chemical tools and methods to solve experimental problems.	PSO2
	CO 3. analyze and interpret experimental data to draw meaningful conclusions.	PSO3

	CO 4. design and conduct independent research projects using appropriate chemical methodologies.		PSO4	
	Content	No of hours	Mapped to CO	Cognitive Level
	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.			
Reference/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	CHA-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.	PSO1
	CO 2. use appropriate chemical tools and methods to solve experimental problems.	PSO2
	CO 3. analyze and interpret experimental data to draw meaningful conclusions.	PSO3

	CO 4. design and conduct independent research projects using appropriate chemical methodologies.		PSO4	
	Content	No of hours	Mapped to CO	Cognitive Level
	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.			
Reference/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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