

Indrashil University



Department of Chemistry
School of Science

M.Sc. 2026-2028 Sem I-II

Analytical Chemistry

Course Profile

Academic Year 2026-2027

Course Structure M.Sc. Chemistry Semesters I to II

SEMESTER: I	MINIMUM SEMESTER CREDIT REQUIRED: 20 CUMULATIVE SEMESTER CREDITS REQUIRED: 20		
SUBJECT NO.	SUBJECT NAME	L-T-P	CREDITS
CH4 101	ORGANIC CHEMISTRY – I: LOGICS IN ORGANIC REACTION AND MECHANISM	3-0-0	3
CH4 102	INORGANIC CHEMISTRY – I: COORDINATION CHEMISTRY & MAGNETIC MATERIALS	3-0-0	3
CH4 103	PHYSICAL CHEMISTRY – I: MOLECULAR THERMODYNAMICS AND SOLID-STATE PROPERTIES	3-0-0	3
CH4 104	ANALYTICAL CHEMISTRY – I: INSTRUMENTAL METHODS OF ANALYSIS	3-0-0	3
CH4 105	QUANTUM MECHANICS FOR CHEMISTS	3-0-0	3
CH4 106	BASIC ORGANIC CHEMISTRY LABORATORY	0-0-8	4
CH4 107	INORGANIC CHEMISTRY LABORATORY	0-0-8	4
Total		15L-16P	23

SEMESTER: II	MINIMUM SEMESTER CREDIT REQUIRED: 43 CUMULATIVE SEMESTER CREDITS REQUIRED: 23		
SUBJECT CODES	SUBJECT NAME	L-T-P	CREDITS
CH4 201	ORGANIC CHEMISTRY – II: REACTIONS, REAGENTS, AND REARRANGEMENTS	3-0-0	3
CH4 202	INORGANIC CHEMISTRY – II: MAIN GROUP AND ORGANOMETALLIC COMPOUNDS	3-0-0	3
CH4 203	PHYSICAL CHEMISTRY – II: SURFACE AND INTERFACIAL CHEMISTRY	3-0-0	3
CH4 204	BIOORGANIC CHEMISTRY:	3-0-0	3
CH4 205	SPECTROSCOPY – I: MOLECULAR STRUCTURE DETERMINATION	3-0-0	3
CH4 206	ANALYTICAL TECHNIQUES LABORATORY	0-0-8	4
CH4 207	PHYSICAL CHEMISTRY LABORATORY	0-0-8	4
Total		15L-16P	23

SEMESTER I DETAILED SYLLABUS

CH4 101: ORGANIC CHEMISTRY-I: LOGICS IN ORGANIC REACTION AND MECHANISM (L-T-P-C: 3-0-0-3)

Program: M. Sc. Chemistry	Semester: I
Course code: CH4 101	Course name: ORGANIC CHEMISTRY-I: LOGICS IN ORGANIC REACTION AND MECHANISM

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
3/week	-	3	45	Lecture	CCE, ESE	100	35

Course Objectives:

- Understand and apply the fundamental principles of structure and reactivity
- Analyze and compare reaction mechanisms
- Develop proficiency in stereochemical concepts and conformational analysis

Course Outcome: At the end of this course, the students will be able to

CO 1: Familiarize with types of reactions, their mechanisms, and reactivity of organic reactive intermediates

CO 2: Understand the Hammett equation, Hammond's postulate, Curtin-Hammett principle, and HSAB Principle.

CO 3: Get an idea about S_NAr, S_{RN}1, and benzyne mechanism, the NGP, and anchimeric assistance.

CO 4: Be able to understand Classical and non-classical carbocations. Aromatic electrophilic substitution reactions, arenium ion mechanism, the ortho/para ratio, ipso attack,

CO 5: Knowledge of Basic principles of Stereochemistry, chirality, Prochiral relationship, and optical activity in biphenyls, spiranes, allenes, and helical structures. Stereochemistry of compounds containing Nitrogen, Sulphur, and Phosphorus.

Syllabus

Units	Contents	Hours
Unit I: Structure and Reactivity	Structure and Reactivity: Chemical bonding; Bond Polarity and Dipole Moment, Resonance and, Various Electronic Delocalization and its Role in Stability; Steric Effects Aromaticity; Hard and Soft Acids and Bases (HSAB Principle); Frontier Molecular Orbital Theory (HOMO-LUMO Concepts); Thermodynamic vs. Kinetic Control; Hammond's Postulates; Reactive Intermediates: Carbocations, Carbanions, Free Radicals, Carbenes and Nitrenes; Transition State Theory and Curtin-Hammett Principle; Energy profiles and reaction coordinate, Energy profiles and reaction; Coordinate Diagrams for Catalysed and Un-catalysed Reactions; Effect of Solvent Polarity; Substituent Effects on Reactivity; Molecular Strain and reactivity; Ring Strain and Bredt's Rule; Baeyer Strain Theory	15
Unit II: Organic Reaction Mechanism	Organic Reaction Mechanism: Bond cleavage: homolytic vs. heterolytic cleavage Types of Reactions and their mechanism: Nucleophilic Substitution Reactions: S _N 1 and S _N 2 mechanisms; Stereoelectronic Control): kinetics, stereochemistry, and energy diagrams; Neighboring group participation (NGP); Ambident nucleophiles Elimination Reactions: E ₁ , E ₂ , and E1cb mechanisms; Hofmann vs. Zaitsev elimination; Base strength and solvent effects; Stereoelectronic requirements Addition Reactions: Electrophilic, nucleophilic, and radical additions; Markovnikov vs. anti-Markovnikov additions; Stereochemistry in <i>syn/anti</i> additions; Addition to carbon-heteroatom multiple bonds (e.g., C=O, C=N) Aromatic Substitution Mechanisms: Electrophilic aromatic substitution (EAS); Nucleophilic aromatic substitution (NAS): S _N Ar, benzyne mechanism	15

Unit III: Stereochemistry and Conformational Analysis	Stereochemistry: Isomerism; Constitutional vs. Stereoisomerism; Types of Stereoisomers: Enantiomers, Diastereomers, Meso Compounds; Optical Activity: Chirality, Specific Rotation, Optical Purity; Absolute and Relative Configuration: CIP Rule for R/S Nomenclature; Stereoselective vs. Stereospecific Reactions Projection Formulas and Interconversion; Define Fischer, Sawhorse, Newman, Representations; Interconversion of different projections; Stereochemical assignment; Conformational Analysis of Acyclic and Cyclic Systems; Conformations of ethane, butane: eclipsed, staggered, gauche, anti; Cyclohexane; conformations: chair, boat, twist-boat; conformational preference; Energy barriers and conformational equilibrium; Effect of substituents on conformational stability	15
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CO-PO Mapping

	P01	P02	P03	P04	P05	P06	P06
C01	3	2	1	2	-	-	-
C02	3	3	2	2	-	-	1
C03	3	3	2	2	1	-	-
C04	3	2	2	1	1	-	-
C05	3	3	2	2	1	-	1

CO-PO Mapping Justification

CO	Justification
CO 1	Understanding structure, bonding, electronic effects, aromaticity, and molecular orbital concepts strengthens advanced chemical knowledge (P01), analytical thinking and problem-solving skills (P02), supports interpretation of molecular behavior (P03), and provides a foundation for research-oriented studies (P04).
CO 2	Evaluation of reaction energetics, intermediates, and mechanistic pathways develops critical thinking and advanced knowledge (P01), enhances problem-solving abilities (P02), strengthens analytical skills (P03), supports research aptitude (P04), and promotes scientific integrity in data interpretation (P07).
CO 3	Mechanistic analysis enhances conceptual understanding (P01), develops logical reasoning and problem-solving abilities (P02), supports analytical expertise (P03), contributes to research and industrial applications (P04), and improves scientific communication skills (P05).
CO 4	Application of stereochemical concepts strengthens subject knowledge (P01), develops analytical and problem-solving skills (P02), supports structural characterization (P03), provides a basis for advanced synthesis and research (P04), and enhances scientific communication through stereochemical representations (P05).
CO 5	Prediction of stereochemical and conformational behavior develops advanced disciplinary knowledge (P01), strengthens problem-solving capabilities (P02), enhances analytical expertise (P03), supports research-oriented learning (P04), improves communication of scientific findings (P05), and encourages responsible interpretation of scientific results (P07).

Reading references:

1. E. L. Eliel. *Stereochemistry of Carbon Compounds*. TATA McGraw-Hill Publishing Company Ltd., New Delhi. 1962, 1st Ed.
2. D. Nasipuri. *Stereochemistry of Organic Compounds*. New Age International (P) Ltd., Publishers, New Delhi. 1994, 2nd Ed.
3. P. S. Kalsi. *Stereochemistry: Conformation and Mechanism*. New Age International (P) Ltd., Publishers, New Delhi. 2019, 10th Ed.
4. J. March. *March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure*. Wiley-Interscience, A John Wiley & Sons, Inc., New York. 2006, 6th Ed.
5. P. Sykes. *A Guidebook to Reaction Mechanisms in Organic Chemistry*. Longman Scientific & Technical, Essex. 1986, 6th Ed.
6. S. M. Mukherji; S. P. Singh. *Reaction Mechanism in Organic Chemistry*. Macmillan India Ltd., New Delhi. 1976, Revised Ed.
7. L. G. Wade Jr. *Organic Chemistry*. Pearson Education, New Delhi. 2011, 8th Ed.
8. F. A. Carey; R. J. Sundberg. *Advanced Organic Chemistry, Part A and Part B: Structure and Mechanisms*. Springer, New York. 2007, 5th Ed.
9. J. Clayden; N. Greeves; S. Warren; P. Wothers. *Organic Chemistry*. Oxford University Press, Oxford. 2014, 2nd Ed.

**CH4 102: INORGANIC CHEMISTRY-I: COORDINATION CHEMISTRY & MAGNETIC MATERIALS
(L-T-P-C: 3-0-0-3)**

Program: M. Sc. Chemistry	Semester: I
Course code: CH4 102	Course name: INORGANIC CHEMISTRY-I: COORDINATION CHEMISTRY & MAGNETIC MATERIALS

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
3/week	-	3	45	Lecture	CCE, ESE	100	35

Course Objectives:

- Learn about different types of isomers, coordination polyhedra and molecular symmetry.
- Understand redox reactions, the Nernst equation
- Comprehend inorganic reaction mechanisms
- Have a concept of magnetic materials, calculation of magnetic moment

Course Learning Outcomes: At the end of this course, students will be able to

CO 1: Identify different coordination isomers.

CO 2: Compare different strengths of acids and bases.

CO 3: Classify the molecular symmetry by using the group theory concept.

CO 4: Develop the concept of a redox reaction, the Nernst equation, and Inorganic reaction mechanisms.

Syllabus

Units	Content	Hours
Unit I: Isomerism	Principles of Inorganic Chemistry: Isomerism, Structural and stereoisomerism of tetrahedral, square planar and octahedral complexes, facial and meridional isomers, methods to distinguish cis and trans isomers, the concept of ligand- ambidentate, chelating, innocent, non-innocent and bridging ligand, flexidentate behavior of polydentate ligand, Chelate complex, EDTA.	15
UNIT-II Molecular Symmetry, Structure, and Reactivity	Symmetry and Group Theory: Definitions and theorems of group theory, subgroups, Classes Molecular symmetry and symmetry groups – symmetry elements and operations. Symmetry planes, reflections, inversion centre, proper/ improper axes of rotation, products of symmetry operations, equivalent symmetry elements and atoms, symmetry elements and optical isomerism, symmetry point groups, classes of symmetry operations. Inorganic Reaction Mechanisms: Substitution reactions - Dissociative and associative interchange - trans-effect: polarization theory, pi-complexing theory, cis effect, and -redox reactions, concept of oxidant and reductant, disproportionation and comproportionation reaction, std electrode potential and electrochemical series, formulation of Nernst equation, calculation of k value for given inorganic reaction, Latimer diagram, redox indicator, Z-R solutions.	15
III Magnetism and Inorganic Compounds	Magnetic Properties: Classification of magnetic materials; Cooperative phenomena – Diamagnetism, Paramagnetism, ferro, anti-ferro and ferrimagnetism, Magnetic permeability, Magnetic moment, quenching of magnetic moment: 1. By super exchange process, 2) by metal-metal direct bond formation (compounds of Cr and Cu), Curie equation, effect of orbital contribution to spin magnetic moment in oct. and tet-field for d ⁿ ion and calculation of effective magnetic moment.	15

CO-PO Mapping Table

	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	1	2	-	-

CO 2	3	2	2	-	-
CO 3	3	2	3	1	-
CO 4	3	3	3	1	-
Average	3	2.00	2.50	1	-

Correlation levels:**1 - Low, 2 - Moderate, 3 - High****Justification for CO-PO Mapping**

COs	Justification
CO 1	Develops fundamental knowledge of coordination chemistry and isomerism while strengthening analytical skills for identifying coordination compounds (PO1, PO2, PO3).
CO 2	Enhances understanding of acid–base behavior and chemical reactivity, promoting analytical reasoning and problem-solving skills (PO1, PO2, PO3).
CO 3	Develops knowledge of molecular symmetry and group theory with applications in structural analysis, fostering analytical thinking and research orientation (PO1, PO3, PO4)
CO 4	Strengthens understanding of redox chemistry, the Nernst equation, inorganic reaction mechanisms, and magnetic properties while developing quantitative analysis and scientific problem-solving abilities (PO1, PO2, PO3, PO4).

Reading references:

1. P. Atkins; T. Overton; J. Rourke; M. Weller; F. Armstrong. *Shriver and Atkins' Inorganic Chemistry*. W. H. Freeman and Company, New York. 2009, 5th Ed.
or
D. F. Shriver; P. W. Atkins. *Inorganic Chemistry*. W. H. Freeman and Company, New York. 1999, 3rd Ed.
2. C. Housecroft; A. G. Sharpe. *Inorganic Chemistry*. Prentice Hall/Pearson Education, Harlow. 2008, 3rd Ed.
or
C. Housecroft; A. G. Sharpe. *Inorganic Chemistry*. Prentice Hall/Pearson Education, Harlow. 2012, 4th Ed.
3. F. A. Cotton; G. Wilkinson. *Advanced Inorganic Chemistry*. John Wiley & Sons, New York. 1988, 5th Ed.
or
F. A. Cotton; C. A. Murillo; M. Bochmann; R. N. Grimes. *Advanced Inorganic Chemistry*. John Wiley & Sons, New York. 1999, 6th Ed.
4. J. E. Huheey; E. A. Keiter; R. L. Keiter. *Inorganic Chemistry: Principles of Structure and Reactivity*. Prentice Hall, New Jersey. 1997, 4th Ed.
5. G. L. Miessler; D. A. Tarr. *Inorganic Chemistry*. Pearson Education, New Delhi. 2004, 3rd Ed.
6. G. Wulfsberg. *Inorganic Chemistry*. University Science Books, Sausalito. 2000, 2nd Ed.

**CH4 103: PHYSICAL CHEMISTRY-I: MOLECULAR THERMODYNAMICS AND SOLID-STATE PROPERTIES
(L-T-P-C: 3-0-0-3)**

Program: M. Sc. Chemistry	Semester: I
Course code: CH4 103	Course name: PHYSICAL CHEMISTRY-I: MOLECULAR THERMODYNAMICS AND SOLID-STATE PROPERTIES

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
3/week	-	3	45	Lecture	CCE, ESE	100	35

Course Objective: This course aims to provide advanced understanding of statistical thermodynamics, chemical kinetics, and solid-state chemistry. Students will learn the principles of partition functions, statistical distributions, reaction kinetics, crystal structures, and thermal and electrical properties of materials. The course develops analytical thinking, mathematical interpretation, and problem-solving skills for understanding molecular behaviour, reaction mechanisms, semiconductors, superconductors, and modern materials relevant to research and technological applications.

Course Outcomes: At the end of this course students will be able to

CO 1: Recall the concepts of statistical thermodynamics, chemical kinetics, crystallography, and solid-state properties.

CO 2: Explain statistical distributions, reaction mechanisms, crystal structures, and thermal and electrical behaviour of materials.

CO 3: Apply thermodynamic, kinetic, and solid-state principles to solve chemical and material science problems.

CO 4: Analyze reaction kinetics, crystal defects, conductivity, and superconducting behaviour using theoretical models.

CO 5: Evaluate the properties and behaviour of materials, reactions, and solid-state systems for scientific and technological applications.

Syllabus

Units	Content	Hours
Unit I: Statistical Thermodynamics and Applications in Chemistry	Statistical Thermodynamics: Limitations of classical thermodynamics. Introduction to terms like microstates, macrostates, ensemble, population, degeneracy. Maxwell-Boltzmann's distribution law, equipartition of energy, partition function, molar partition function, Electronic, Translational, Rotational, and Vibrational partition functions. Applications of statistical thermodynamics- Heat capacity behavior of solid and calculation of equilibrium constant, variation in equilibrium constant with temperature and pressure, Le Chatelier's Principle. Relationship between entropy and probability, Statistical interpretation of chemical equilibrium.	15
Unit II: Chemical Kinetics and Dynamics	Chemical Kinetics: Basics of simple chemical kinetics. Reactions approaching equilibrium, steady state approximation, Complex Reactions: Rate laws for consecutive, opposing, parallel, chain reactions. Comparison between gas phase and solution reactions, factors determining rates in solution. Reaction between ions, reactions involving dipoles, reactions in solution. Kinetics of enzyme-catalyzed reactions: Michaelis-Menten mechanism, Lineweaver-Burk plot, Applications of kinetic isotope effects in reaction mechanism studies. Basics of simple collision theory. <i>Activated complex theory:</i> Reaction coordinate and the transition state theory, potential energy surface, rate constant derivation. Reaction coordinate diagrams and activation parameters ($\Delta H^\ddagger$, $\Delta S^\ddagger$, $\Delta G^\ddagger$).	15
Unit III: Crystalline Materials: From Lattice to	Solid State Chemistry: Crystallography- Diffraction properties of crystals. Symmetry elements, space groups. Concept of crystal planes, Miller indices. Ionic crystals. Determination of crystal	15

Device	structure. Imperfection in crystals- point defects (Thermodynamic treatment) and line defects. Crystal growth, engineering, polymorphism, and drug polymorphism regulatory issues. Thermal Properties: Lattice vibrations - phonon spectrum; Lattice heat capacity; Thermal expansion; Thermal conductivity. Electrical Properties: Band theory - band gap - metals and semiconductors - intrinsic and extrinsic semiconductors; Temperature dependence on conductivity. Organic semiconductors, conducting polymers, and perovskites.	
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CO-PO Mapping Table

	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	1	1	-	-
CO 2	3	3	2	-	1
CO 3	2	2	3	-	1
CO 4	2	3	3	1	2
Average	2.5	2.25	2.25	0.25	1.0

Correlation levels:

1 - Low, 2 - Moderate, 3 - High

Justification for CO-PO Mapping

COs	Justification
CO 1	This CO develops fundamental understanding of electrochemistry and surface chemistry concepts, strengthening scientific knowledge and basic analytical understanding (PO1, PO2, PO3).
CO 2	This CO enhances conceptual understanding of statistical distributions, reaction mechanisms, and material properties while improving analytical reasoning skills (PO1, PO2, PO3).
CO 3	This CO develops the ability to apply thermodynamic, kinetic, and solid-state concepts for solving advanced chemical and material science problems (PO2, PO3).
CO 4	This CO strengthens analytical and research-oriented thinking through the study of reaction kinetics, crystal defects, conductivity, and superconductivity (PO2, PO3).
CO 5	This CO improves evaluation of materials and solid-state systems for scientific, technological, and interdisciplinary applications (PO3, PO4, PO5).

Reading references:

1. M. C. Gupta. *Statistical Thermodynamics*. New Age International Publishers, New Delhi. 1998, Revised Printing.
2. T. L. Hill. *An Introduction to Statistical Thermodynamics*. Dover Publications, New York. 1986, 1st Ed.
3. B. N. Roy. *Fundamentals of Classical and Statistical Thermodynamics*. Wiley, New Delhi. 2002, 1st Ed.
4. K. J. Laidler. *Chemical Kinetics*. Pearson Education, Noida. 1987, 3rd Ed.
5. R. D. Levine. *Molecular Reaction Dynamics*. Cambridge University Press, New York. 2009, Paperback Ed.
6. Raja Ram; J. C. Kuriacose. *Kinetics and Mechanism of Chemical Transformations*. Macmillan India Ltd., New Delhi. 1993, 1st Ed.
7. S. Glasstone. *Textbook of Physical Chemistry*. Macmillan Publishers, London. 1942, 2nd Ed.
8. P. Atkins. *Physical Chemistry*. Oxford University Press, Oxford. 2018, 8th Ed.
9. M. M. Woolfson. *An Introduction to X-ray Crystallography*. Cambridge University Press-Vikas Publishing House, New Delhi. 1980, 2nd Ed.
10. W. Cochran. *Dynamics of Atoms in Crystals*. Edward Arnold, London. 1973. (pp. 24-37).
11. P. M. A. Sherwood. *Vibrational Spectroscopy of Solids*. Cambridge University Press, Cambridge. 1972. (pp. 1-45).
12. C. N. R. Rao; K. J. Rao. *Phase Transitions*. Cambridge University Press, Cambridge. 1st Ed.
13. G. H. Stout; L. H. Jenson. *X-ray Structure Determination: A Practical Guide*. Macmillan Publishing Co. Inc. and Collier Macmillan Publishers, New York. 1989, 2nd Ed.

14. Gurdeep Raj. *Advanced Physical Chemistry*. Krishna Prakashan Media Pvt. Ltd., Meerut. 2022, 1st Ed.

CH4 104: ANALYTICAL CHEMISTRY-I: INSTRUMENTAL METHODS OF ANALYSIS (L-T-P-C: 3-0-0-3)

Program: M. Sc. Chemistry	Semester: I
Course code: CH4 104	Course name: ANALYTICAL CHEMISTRY-I: INSTRUMENTAL METHODS OF ANALYSIS

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
3/week	-	3	45	Lecture	CCE, ESE	100	35

Course Objectives:

- This course covers the basics of Analytical Chemistry.
- They will understand the importance of analytical science in real-world applications.
- Learn fundamental knowledge of spectrophotometric techniques
- This course enhances scientific understanding and prepares students for industry roles.
- Students will also learn most of the chromatographic techniques and their principles

Course Learning Outcomes: At the end of this course, students will be able to

CO 1: Know the importance of Analytical science in the Research & Development of an industry.

CO 2: Operate several analytical instruments within a very short period.

CO 3: Understand several analytical data representation techniques.

CO 4: Learn the techniques to analyze unknown samples.

CO 5: Be familiar with several computer-based data plots.

Syllabus

Unit	Content	Hours
Unit I: Principles, Errors, and Quality Assurance	Scope of analytical chemistry, Qualitative and quantitative analysis, Accuracy and precision, Types of errors and their causes; Significant figures, Control charts, Confidence limit, Mean deviation, Standard deviation, Coefficient of variance, Rejection of a result- the Q-test. Good Laboratory Practice (GLP), Standard operating procedures, Quality assurance and quality control, Finding the best straight line-least square regression, correlation coefficient; Calibration curves, Concept of reference material internal standards, Measurement uncertainty, traceability, and calibration of analytical instruments.	15
Unit II: Spectrophotometric Methods and Optical Techniques in Chemical Analysis	Properties of light, absorption of light, interaction of light with matter and origin of spectra. The spectrophotometer- calibration, sources of light, monochromators and detectors. Beer's law in chemical analysis, optical rotatory dispersion and circular dichroism, Stoichiometry-method of continuous variation-the Jobs plot, Photometric titrations. Atomic absorption spectroscopy. UV-Visible spectroscopy: instrumentation, applications and quantitative analysis. Introduction to fluorescence spectroscopy and its analytical applications. Factors affecting Beer-Lambert law and causes of deviations.	15
Unit-III: Chromatographic Techniques: Principles, Methods, and Instrumentation	Principles of chromatography, Classification and mechanism of different chromatographic methods, Paper chromatography, Thin layer chromatography, Column chromatography, High-performance thin-layer chromatography, Fast protein liquid chromatography. High performance liquid chromatography, Gas chromatography, Detectors. Applications of chromatographic techniques in pharmaceutical, food and environmental analysis.	15

Reading references:

1. D. A. Skoog; D. M. West; F. J. Holler; S. R. Crouch. *Fundamentals of Analytical Chemistry*. Brooks/Cole Publishing, Belmont. 2013, 9th Ed.

2. E. Prichard; V. Barwick. *Analytical Chemistry by Open Learning (Set of 34 Titles)*. Wiley India, New Delhi. 2008, 1st Ed.
3. D. A. Ray; Underwood. *Quantitative Analysis*. Prentice-Hall International Ltd., New Delhi. 1991, 6th Ed.
4. G. H. Jeffery; J. Bassett; J. Mendham; R. C. Denny. *Vogel's Textbook of Quantitative Inorganic Analysis*. Longman Scientific & Technical, Essex. 1989, 5th Ed.
5. G. D. Christian. *Analytical Chemistry*. John Wiley & Sons Inc., New York. 1994, 6th Ed.
6. G. R. Chatwal; S. K. Anand. *Instrumental Methods of Chemical Analysis*. Himalaya Publishing House, Mumbai. 2016, 5th Revised and Enlarged Ed.
7. H. H. Willard; L. L. Merritt; J. A. Dean. *Instrumental Methods of Analysis*. Van Nostrand Reinhold, New York. 1974, 5th Ed.
8. H. Kaur. *Analytical Chemistry*. Pragati Prakashan, Meerut. 2021, Paperback Ed.
9. D. C. Harris. *Quantitative Chemical Analysis*. W. H. Freeman and Company, New York. 1998, 5th Ed.
10. G. D. Christian. *Analytical Chemistry*. John Wiley & Sons Inc., New Jersey. 2004, 6th Ed.
11. D. A. Skoog. *Principles of Instrumental Analysis*. Holt Saunders International Edition, New York. 2016, 7th Ed.
12. G. W. Ewing. *Instrumental Methods of Chemical Analysis*. International Student Edition, New York. 1975, 4th Ed.

CH4 105: QUANTUM MECHANICS FOR CHEMISTS (L-T-P-C: 3-0-0-3)

Program: M. Sc. Chemistry	Semester: I
Course code: CH4 105	Course name: QUANTUM MECHANICS FOR CHEMISTS

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
3/week	-	3	45	Lecture	CCE, ESE	100	35

Course Description: In this course, students will learn the basics and advanced part of mathematical tools which generally used to understand the concept of quantum chemistry which will help them to understand the Chemistry of different kind of atoms and molecules. This course will help them to understand the basics of any kind of molecular structure as well as their energy. They will understand the concept and also the approach for different kind of atoms with many electron systems by studying the hydrogen atom and hydrogen-like ions. Students will understand the concept of chemical bonding and different theories for their molecular orbitals.

Course Learning Outcomes: At the end of this course students will be able to

CO 1: Remember the concept of different mathematical tools and their applications.

CO 2: Understand the concept of postulates of quantum, Schrodinger equation and its application, Heisenberg Uncertainty principle, Pauli exclusion principle to understand the basics.

CO 3: Apply the concept on different types of problems such as 1D box, harmonic oscillator, hydrogen atom, etc.

CO 4: Analyze the concept to evaluate the eigenvalues and eigenfunction of different molecular structures.

CO 5: Interpret molecular orbital and valence bond theories, Huckel MO theory and its application

Detailed Syllabus

	Content	Hours
Unit I: Linear Vector Space and Structure of Quantum Chemistry	Linear vector space, Matrix representation of Observables and states, Determination of eigenvalues and eigenstate for observables using matrix representations, applications of differential calculus, application of integral calculus, the postulates of quantum mechanics Operators and observables, operators as matrices, significance of eigenvalues and eigenfunctions, Commutation relations, Uncertainty principle.	15
Unit II: Schrödinger Equation and 1D problems	The Schrodinger equation to some model system- particle in a box, the Harmonic oscillator, the rigid rotator, the hydrogen atom, Angular momentum: ordinary angular momentum, generalized angular momentum, Eigen functions for angular momentum, eigenvalues of angular momentum, operator using ladder operators	15
Unit III: Spherically Symmetric Potentials	Pauli matrices and spinors, Identical particles: Indistinguishability, symmetric and antisymmetric wave functions, incorporation of spin, Pauli exclusion principle. Born-Oppenheimer approximation, VB and MO theory, H ₂ ⁺ , H ₂ molecule problem, Hückel molecular orbital theory and its application	15

CO-PO Mapping Table

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	2	-	-	-
CO 2	3	3	-	-	-
CO 3	-	3	3	-	-
CO 4	3	3	3	-	-
CO 5	3	-	-	2	2
Average	2.4	2.2	1.2	0.4	0.4

Justification for CO-PO Mapping

CO	Justification
CO 1	Understanding mathematical tools used in quantum chemistry develops advanced theoretical knowledge and strengthens logical and critical thinking required for scientific problem solving. (PO1, PO2)
CO 2	Comprehension of quantum mechanical postulates, Schrödinger equation, uncertainty principle, and exclusion principle enhances conceptual understanding and analytical reasoning for solving chemical problems. (PO1, PO2)
CO 3	Application of quantum concepts to model systems such as particle in a box, harmonic oscillator, and hydrogen atom develops problem-solving ability and analytical expertise in scientific calculations. (PO2, PO3)
CO 4	Analysis of eigenvalues and eigenfunctions for molecular systems requires advanced theoretical understanding, critical evaluation, and quantitative analytical skills essential for chemistry research. (PO1, PO2, PO3)
CO 5	Interpretation of molecular orbital, valence bond, and Hückel theories provides foundational knowledge for research-oriented studies, molecular design, and effective scientific communication of chemical concepts. (PO1, PO4, PO5)

Reading references:

1. P. Tebbutt. *Basic Mathematics for Chemists*. Wiley, New York. 1998, 2nd Ed.
2. B. Singh. *Mathematics for Chemists*. Pragati Prakashan, Meerut. 2015, 1st Ed.
3. I. N. Levine. *Quantum Chemistry*. Tata McGraw-Hill Publishing Company Ltd., New Delhi. 2002, 5th Ed.
4. A. K. Chandra. *Introductory Quantum Chemistry*. Tata McGraw-Hill Publishing Company Ltd., New Delhi. 1995, 4th Ed.
5. H. C. Verma. *Quantum Physics*. Surya Publications, Ghaziabad. 2009, 2nd Ed.
6. P. W. Atkins. *Molecular Quantum Mechanics: An Introduction to Quantum Chemistry*. Clarendon Press, Oxford. 1970, 1st Ed.
7. D. A. McQuarrie. *Quantum Chemistry*. University Science Books, Sausalito. 2007, 2nd Ed.

CH4 106: BASIC ORGANIC CHEMISTRY LABORATORY (L-T-P-C: 0-0-8-4)

Program: M. Sc. Chemistry	Semester: I
Course code: CH4 106	Course name: BASIC ORGANIC CHEMISTRY LABORATORY

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
-	8/week	4	120	Lab	CCE, ESE	100	35

Course Objectives:

- To separate and purify mixture of organic acids and bases.
- To understand and apply synthetic planning and experimental execution of one or two step synthesis.
- To characterize the organic compounds by use of various analytical techniques like IR, NMR and mass.

Course Outcomes: At the end of this course, students will be able to

CO 1: Explain the separation and purification techniques used in organic synthesis.

CO 2: Illustrate the experimental techniques for one or two step synthesis.

CO 3: Apply chromatographic techniques in monitoring and analyzing reaction progress.

CO 4: Evaluate the analytical techniques line IR and NMR for characterization of products.

CO 5: Demonstrate the synthesis and characterization of a compound

Detailed Syllabus

Sr. No.	Name of the Experiment	Hours
1	To Analyse mixture of organic compounds • Analysis of individual components • Ether-soluble component • Ether-insoluble component	12
2	To estimate organic compounds • phenol • aniline • glucose	12
3	To perform thin layer chromatography and determine Retention factor	12
4	To Perform one step synthesis: Benzoin from benzaldehyde	12
5	To prepare and characterize Methyl orange by Diazotization method	12
6	To prepare and characterize aldol condensation product by reaction with benzaldehyde and acetophenone	12
7	To prepare and characterize dibenzalacetone	12
8	To prepare and characterize benzyl alcohol from benzaldehyde by sodium borohydride	12
9	To synthesize and characterize phenylacetic acid by hydrolysis of Benzyl cyanide	12
10	To prepare and characterize benzoic acid by oxidation of benzaldehyde	12

Reading references:

1. I. Vogel; B. S. Furniss. *Vogel's Textbook of Practical Organic Chemistry*. Longman Scientific & Technical, Essex. 1989, 5th Ed.
2. F. G. Mann; B. C. Saunders. *Practical Organic Chemistry*. Longman Scientific & Technical, London. 1960, 4th Ed.
3. N. K. Vishnoi. *Advanced Practical Organic Chemistry*. Vikas Publishing House, New Delhi. 2010, 3rd Ed.
4. R. K. Bansal. *Laboratory Manual of Organic Chemistry*. New Age International Publishers, New Delhi. 1983, 5th Ed.

CH4 107: INORGANIC CHEMISTRY LABORATORY (L-T-P-C: 0-0-8-4)

Program: M. Sc. Chemistry	Semester: I
Course code: CH4 107	Course name: INORGANIC CHEMISTRY LABORATORY

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
-	8/week	4	120	Lab	CCE, ESE	100	35

Course Objectives: The laboratory course focuses on

- Quantitative analysis by gravimetric method
- Emphasize the principles of different redox titrimetric analyses like a) permanganometry, b) dichrometry, c) iodometry

Course Outcomes: At the end of this course students will be able to

CO 1: Demonstrate practical execution of redox titrimetric estimations of different metal ions based on a)

Permanganometry, b) Dichromatometry, c) Iodometry

CO 2: Estimation of different ions based on complexometric EDTA titration.

CO 3: Determination of different metal ions quantitatively by Gravimetric estimation.

CO 4: Separation of different ions in a mixture like brass or Dolomite by volumetric estimation

Syllabus

Sr. No.	Name of the Experiment	Hours
1.	Estimation of Fe(II) in a given solution (Permanganometry). Estimation of Fe(II) with $K_2Cr_2O_7$ (dichromatometry/dichrometry). Estimation of oxalic acid in a given solution by potassium permanganate titration (Permanganometry).	15
2.	Estimation of Cu(II) in a solution (Iodometry). Estimation of total hardness of water using EDTA by complexometric method	15
3.	Estimate the amount of magnesium present per liter of the given solution of magnesium sulfate To determine the percentage of iron in hematite ore	15
4.	To estimate the mass of nickel in the whole of the given nickel ammonium sulfate solution	15
5.	Synthesis and analysis of 3d metal complexes. Synthesis and analysis of rare earth metal complexes	15
6.	Gravimetric estimation of Cu from a mixture of Cu and Fe solution. Gravimetric determination of Fe in Fe and Cr solution. Gravimetric determination of Ni in Cu and Ni solution.	15
7.	Volumetric estimation of Cu in Cu and Ni (German silver). Volumetric estimation of Ca and Mg in Dolomite solution.	15
8.	Volumetric estimation of Fe in Cu and Fe solution. Volumetric estimation of Zn in Brass Volumetric estimation of Ni in Ni and Zn solution.	15

CO-PO Mapping Table

	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	2	3	3	-	1
CO 2	2	3	3	-	1
CO 3	3	3	3	1	1

CO 4	2	3	3	1	1
Average	2.25	3	3	0.5	1

Correlation levels:**1 - Low, 2 - Moderate, 3 - High****Justification for CO-PO Mapping**

COs	Justification
CO 1	Develops practical skills in redox titrimetric analysis and quantitative estimation of metal ions, strengthening analytical and problem-solving abilities (P02, P03).
CO 2	Enhances competency in complexometric EDTA titrations for quantitative analysis, promoting technical proficiency and analytical reasoning (P02, P03).
CO 3	Develops expertise in gravimetric estimation and synthesis of coordination compounds, reinforcing scientific knowledge, laboratory skills, and research aptitude (P01, P02, P03, P04).
CO 4	Strengthens the ability to separate and quantitatively estimate metal ions in mixed samples using volumetric methods, improving analytical thinking and scientific investigation skills (P02, P03, P04).

Reading references:

1. G. H. Jeffery; J. Bassett; J. Mendham; R. C. Denny. *Vogel's Textbook of Quantitative Chemical Analysis*. Longman Scientific & Technical, Essex. 1989, 5th Ed.
2. G. Svehla. *Vogel's Textbook of Macro and Semimicro Qualitative Inorganic Analysis*. Orient Longman, Hyderabad. 1982, 5th Ed.

SEMESTER II

DETAILED SYLLABUS

CH4 204: ORGANIC CHEMISTRY-II REACTIONS, REAGENTS AND REARRANGEMENTS (L-T-P-C: 3-0-0-3)

Program: M. Sc. Chemistry	Semester: II
Course code: CH4 201	Course name: ORGANIC CHEMISTRY-II REACTIONS, REAGENTS, AND REARRANGEMENTS

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
3/week	-	3	45	Lecture	CCE, ESE	100	35

Course Objectives:

- Develop a mechanistic understanding of redox processes
- Explore the reactivity and synthetic utility of organometallic and selective reagents
- Analyze diverse organic rearrangements and reaction pathways

Course Outcomes: At the end of this course, students will be able to:

CO 1: Explain the mechanisms and stereochemical aspects of organic reactions.

CO 2: Analyze molecular rearrangements and their significance in organic chemistry.

CO 3: Identify and describe the synthesis, reactions, and properties of heterocyclic compounds.

CO 4: Apply knowledge of reaction mechanisms to solve problems in synthesis.

CO 5: Demonstrate the applications of heterocyclic compounds in pharmaceuticals, agrochemicals, and materials science.

Syllabus

Unit	Content	Hours
Unit I: Organic Reaction Mechanisms – Oxidations and Reductions	Fundamentals of Redox Reactions in Organic Chemistry: Electron transfer vs. hydride transfer vs. atom transfer; Redox potential and selectivity; Mechanistic Insights: Electron flow (arrow-pushing); Stereoselectivity and chemo/regioselectivity; Transition states, intermediates, catalytic cycles Oxidation Mechanisms: Alcohols → Aldehydes/Ketones/Acids: PCC, PDC, Dess–Martin, Swern, Jones, KMnO ₄ , TEMPO; Alkenes and Alkynes: Epoxidation (m-CPBA, peracids), Dihydroxylation (OsO ₄ , KMnO ₄), Oxidative cleavage (ozonolysis, KMnO ₄) Reduction Mechanisms: Carbonyl compounds: NaBH ₄ , LiAlH ₄ , DIBAL-H; Reductive amination, Birch reduction, Clemmensen, Wolff–Kishner; Selective reductions: Rosenmund, Lindlar, Meerwein Ponndorf–Verley Asymmetric Oxidations and Reductions (Brief Introduction): Sharpless epoxidation, Corey–Bakshi–Shibata (CBS) reduction	15
Unit II: Reagents in Organic Synthesis	Classification of reagents; about air and moisture sensitive reagents; handling, storage and precaution. Reagent role in stepwise mechanism; Stereocontrol and functional group compatibility; Concept of functional group interconversion (FGI); Chemoselectivity, regioselectivity, and protecting group strategies Organometallic Reagents: Grignard, organolithium, organocuprates, Gilman reagents Applications in C–C bond formation; Transition-metal catalysts (Pd, Ru, Rh) and other cross-coupling reagents Hypervalent iodine reagents- Various types of hypervalent iodine reagents and their preparation; application in organic transformation, selectivity, sensitivity and reactivity; Peptide coupling reagents and their applications. Functional group protecting agents – Different types of protecting/masking agents; Selective and Protective Reagents: Silyl protecting groups (TBDMS, TMS), Acetals, Carbamates, PMP protection and their deprotection after completion of	15

	reaction; Electrophilic halogenating agents (NBS, NCS), sulfonation, acylation reagents. Phase-transfer Catalysts	
Unit III: Molecular Rearrangements	Intramolecular vs. Intermolecular; Pericyclic, ionic, and radical pathways; Rearrangement vs. Isomerization; Importance of Rearrangements in installation of Stereocenters and importance of conformational aspects in this regard Rearrangements Involving Carbocations: Wagner–Meerwein, Pinacol–Pinacolone, Tiffeneau–Demjanov Benzilic acid and related 1,2-shifts Rearrangements Involving Carbanions and Ylides: Favorskii, Wittig, Stevens, Sommelet–Hauser, Ireland–Claisen Rearrangements Involving Nitrenes: Curtius, Hofmann, Lossen, Schmidt, Beckmann Pericyclic Rearrangements (Concerted): Cope and Claisen rearrangements; Aza–Claisen, Oxy–Cope, Sigmatropic shifts Oxidative Rearrangements: Baeyer–Villiger, Dienone–Phenol rearrangement	15

Reading references:

1. R. K. Mackie; D. M. Smith; R. A. Aitken. *Guidebook to Organic Synthesis*. Addison-Wesley Longman Ltd., Harlow. 1990, 2nd Ed.
2. H. O. House. *Modern Synthetic Reactions*. W. A. Benjamin, Menlo Park. 1972, 2nd Ed.
3. M. B. Smith. *Organic Synthesis*. Editorial Staff, Boca Raton. 2016, 4th Ed.
4. S. N. Sanyal. *Reactions, Rearrangements, and Reagents*. Bharti Bhawan Publishers, Patna. 2020, 4th Ed.
5. F. A. Carey; R. J. Sundberg. *Advanced Organic Chemistry: Part A Structure & Mechanism*. Springer, New York. 2007, 5th Ed.
6. R. K. Bansal. *Heterocycles*. New Age International Publishers, New Delhi. 2022, 7th Ed.
7. I. L. Finar. *Organic Chemistry Vol. I & II*. ELBS Publication, London. 2002, 5th Ed.
8. M. C. Ray. *Reaction Mechanisms in Organic Chemistry*. MTG Learning Media, New Delhi. 2021, Revised Ed.
9. J. J. Li. *Name Reactions*. Springer, New York. 2018, 4th Ed.
10. C. M. Rojas. *Molecular Rearrangements in Organic Synthesis*. Wiley, Hoboken. 2015, 1st Ed.
11. R. K. Bansal. *Organic Reaction Mechanisms*. New Age International, New Delhi. 2012, 4th Ed.
12. J. March. *Advanced Organic Chemistry*. Wiley India Pvt. Ltd., New Delhi. 2007, 6th Ed.
13. L. M. Harwood. *Advanced Organic Chemistry*. Oxford University Press, Oxford. 1992, 1st Ed.
14. P. S. Kalsi. *Organic Reactions and Their Mechanisms*. New Age International, New Delhi. 2020, 3rd Ed.
15. R. M. Acheson. *An Introduction to the Chemistry of Heterocyclic Compounds*. Wiley Student Edition, New York. 2008, 3rd Ed.
16. J. A. Joule; K. Mills. *Heterocyclic Chemistry*. Wiley, Chichester. 2010, 5th Ed.
17. T. L. Gilchrist. *Heterocyclic Chemistry*. Pearson Education, Harlow. 2005, 3rd Ed.
18. R. R. Gupta; M. Kumar; V. Gupta. *Heterocyclic Chemistry*. Springer, Berlin. 1998, 1st Ed.

**CH4 202: INORGANIC CHEMISTRY-II MAIN GROUP AND ORGANOMETALLIC COMPOUNDS
(L-T-P-C: 3-0-0-3)**

Program: M. Sc. Chemistry	Semester: II
Course code: CH4 202	Course name: INORGANIC CHEMISTRY-II MAIN GROUP AND ORGANOMETALLIC COMPOUNDS

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
3/week	-	3	45	Lecture	CCE, ESE	100	35

Course Description:

- This course deals with the understanding of different periodic properties and periodic anomalies.
- This course provides a detailed study of s- and p-block group elements. This course also focuses on EAN rule and various Carbonyl, nitrosyl metal complexes.

Course Outcomes: At the end of this course students will be able to

CO 1: Define periodic properties and anomalies

CO 2: Elaborate discussion of s & p-block group (1-2 & 13-18) elements

CO 3: Calculate the EAN value of different organometallic compounds

CO 4: Summarize bonding, structure and property of different carbonyl-nitrosyl compounds

Syllabus

Units	Content	Hours
Unit I: Periodic trends, structure, bonding	Periodic Trend: Radius, Ionization enthalpy, electron gain enthalpy, electronegativity. Relativistic effects on chemical properties. Hydrogen and its compounds: H-bond and its influence on the structure and properties of crystals. Hydrides, classification: electron deficient, electron precise and electron rich hydrides. Concept of ortho and para hydrogen, Alkali and alkaline earth metals: Solutions in liquid ammonia - Synthesis, properties, uses and structures of crown ether complexes, Group 13 elements: Borides, borates, boron halides, boranes, carboranes and metallocarboranes, BN compounds, Lewis Base adducts of AlR ₃ compounds, Group 14 elements: Allotropes of Carbon- C ₆₀ and its compounds (fullerenes) - carbon nanotubes: synthesis and properties - Intercalation compounds of graphite - Pure Silicon, silica and silicates, Silicones - Low coordinated and hypervalent Silicon compounds - Brief survey of Ge, Sn, and Pb chemistry- Organo-germanium, -tin, and -lead compounds Group 15 elements: P(V) compounds (structure, bonding, reactivity)-P(III) compounds: diphosphenes, phosphalkenes, iminophosphanes - P-containing ring systems (phosphabenzene, phosphole), phosphazenes, Oxo-acids of Phosphorous. Comparison of basicity, reducing property of oxoacids. Group 16 elements: Sulfurpolycationic and anionic species - SN compounds.	15
Unit II: Halogens and Noble gases	Group 17 elements: Charge-transfer complexes of halogens, inter-halogen compounds, halogen oxides and oxygen fluorides, pseudo halogens. Group 18 elements: Physical properties and reactivity, Xenon compounds: preparation, bonding and structure, noble gas clathrates	15
Unit III: Metal carbonyl and nitrosyl complexes	Organometallic Chemistry: Complexes with pi-acceptor and sigma-donor ligands - 16 electron and 18 electron rules- Stability and Reactivity -synergic effect, preparation, Structure, and property of carbonyl, evidence for multiple bonds in Carbonyl compounds, nature of bonding, stretching frequency and ligand effect, Ferrocene.	15

CO-PO Mapping Table

	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	2	2	-	1
CO 2	3	2	2	-	1
CO 3	3	3	3	-	1
CO 4	3	2	3	1	1
Average	3.00	2.25	2.50	0.25	1.00

Correlation levels:**1 - Low, 2 - Moderate, 3 - High****Justification for CO-PO Mapping**

COs	Justification
CO 1	Develops a strong understanding of periodic properties and periodic anomalies while enhancing analytical interpretation of elemental trends (PO1, PO2, PO3).
CO 2	Strengthens knowledge of the chemistry of s- and p-block elements and their compounds, promoting scientific understanding and analytical skills (PO1, PO2, PO3).
CO 3	Develops the ability to calculate EAN values and analyze the stability of organometallic compounds, enhancing quantitative reasoning and problem-solving skills (PO1, PO2, PO3).
CO 4	Enhances understanding of the bonding, structure, and properties of carbonyl and nitrosyl complexes, fostering analytical thinking and introducing research-oriented concepts in organometallic chemistry (PO1, PO3, PO4).

Reading references:

1. A. G. Massey. *Main Group Chemistry*. Wiley, Chichester. 2000, 2nd Ed.
2. N. N. Greenwood; A. Earnshaw. *Chemistry of the Elements*. Pergamon Press, Oxford. 1989, 1st Ed.
3. P. Atkins; T. Overton; J. Rourke; M. Weller; F. Armstrong. *Shriver and Atkins' Inorganic Chemistry*. W. H. Freeman and Company, New York. 2009, 5th Ed.
or
D. F. Shriver; P. W. Atkins. *Inorganic Chemistry*. W. H. Freeman and Company, New York. 1999, 3rd Ed.
4. C. Housecroft; A. G. Sharpe. *Inorganic Chemistry*. Prentice Hall/Pearson Education, Harlow. 2008, 3rd Ed.
or
C. Housecroft; A. G. Sharpe. *Inorganic Chemistry*. Prentice Hall/Pearson Education, Harlow. 2012, 4th Ed.
5. F. A. Cotton; G. Wilkinson. *Advanced Inorganic Chemistry*. John Wiley & Sons, New York. 1988, 5th Ed.
or
F. A. Cotton; C. A. Murillo; M. Bochmann; R. N. Grimes. *Advanced Inorganic Chemistry*. John Wiley & Sons, New York. 1999, 6th Ed.
6. J. E. Huheey; E. A. Keiter; R. L. Keiter. *Inorganic Chemistry: Principles of Structure and Reactivity*. Prentice Hall, New Jersey. 1997, 4th Ed.

CH4 203: PHYSICAL CHEMISTRY-II: SURFACE AND INTERFACIAL CHEMISTRY (L-T-P-C: 3-0-0-3)

Program: M.Sc. Chemistry	Semester: II
Course code: CH4 203	Course name: PHYSICAL CHEMISTRY-II SURFACE AND INTERFACIAL CHEMISTRY

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
3/week	-	3	45	Lecture	CCE, ESE	100	35

Course Objectives: This course aims to provide advanced understanding of surface chemistry, electrochemistry, and catalysis. Students will learn adsorption phenomena, surfactants, electrochemical interfaces, corrosion, catalyst preparation, and characterization techniques while developing analytical and problem-solving skills related to industrial and research applications.

Course Outcomes: At the end of this course students will be able to

CO 1: Explain the principles of adsorption, surface tension, micellization, and interfacial phenomena.

CO 2: Apply electrochemical theories and equations to analyze ionic interactions and electrode processes.

CO 3: Analyze catalytic mechanisms, catalyst deactivation, and characterization techniques used in surface chemistry.

CO 4: Evaluate the importance of electrochemical and catalytic systems in industrial and environmental applications.

CO 5: Design approaches for catalyst preparation and characterization using modern analytical techniques.

Syllabus

Units	Content	Hours
Unit I: Surface Sciences	Surface phenomena: surface tension, capillary action pressure difference across curved surface (Laplace equation), vapour pressure of droplets (Kelvin equation), Gibbs adsorption isotherm, Langmuir and Freundlich Adsorption Isotherms, estimation of surface area (BET equation), Catalytic activity at surfaces. Micelles- Surface active agents, classification of surface-active agents, micellization, hydrophobic interaction, critical micellar concentration (CMC), factors affecting the CMC of surfactants, solubilisation, micro emulsion, reverse micelles. Colloidal systems: classification, stability, and applications. Applications of surfactants and colloids in pharmaceuticals, cosmetics, food science, detergents, and nanomaterials.	15
Unit II: Electrochemical Interfaces and Applications	Electrochemistry of solutions: ionic conductance, electrode potentials, and the Nernst equation. Electroanalytical techniques: cyclic voltammetry, polarography (Ilkovic equation, half-wave potential, and its significance), and their applications in qualitative and quantitative analysis. Electrochemical sensors and biosensors: principles of potentiometric, amperometric, and voltammetric sensors. Applications of electrochemistry in organic synthesis, pharmaceutical analysis, and environmental monitoring. Introduction to corrosion: types, monitoring, and prevention methods.	15
Unit III: Heterogeneous Catalysis	Mechanism of surface reactions. Surface heterogeneity, catalytic activity, selectivity, deactivation, and regeneration of catalysts. Catalyst promotion and poisoning. Zeolites and zeolite-like materials: structure, synthesis, and applications. Basic catalyst characterization techniques (BET surface area, XRD, SEM, and FTIR). Catalysis in Green Chemistry and Sustainability. Nanocatalysis: role of particle size, shape, and support effects. Applications of catalysis in organic synthesis, pharmaceutical manufacturing, and environmental remediation.	15

CO-PO Mapping Table

	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	2	1	1	1
CO 2	3	3	2	1	1
CO 3	2	3	3	1	1
CO 4	2	2	3	2	2
CO 5	2	3	3	2	2
Average	2.4	2.6	2.4	1.4	1.4

Correlation levels:**1 - Low, 2 - Moderate, 3 - High****Justification for CO-PO Mapping**

COs	Justification
CO 1	This CO develops understanding of adsorption, interfacial phenomena, and surface chemistry concepts, strengthening scientific and analytical knowledge (PO 1, PO 2).
CO 2	This CO enhances the application of electrochemical principles and equations for solving problems related to ionic interactions and electrode processes (PO 2, PO 3).
CO 3	This CO develops analytical and research-oriented thinking through the study of catalytic mechanisms and surface characterization techniques (PO 2, PO 3).
CO 4	This CO improves evaluation and problem-solving skills regarding industrial and environmental applications of electrochemical and catalytic systems (PO 3, PO 4, PO 5).
CO 5	This CO promotes innovation and technical competency in catalyst preparation and characterization using modern analytical methods (PO 2, PO 3, PO 4).

Reading references:

1. M. J. Schick. *Non-ionic Surfactants*. Surfactant Science Series, Marcel Dekker, New York. 1985, Vol. 72.
2. P. Ghosh. *Colloids and Interface Science*. PHI Learning Pvt. Ltd., New Delhi. 2009, 1st Ed.
3. M. J. Rosen. *Surfactants and Interfacial Phenomena*. John Wiley & Sons, New Jersey. 2004, 3rd Ed.
4. M. R. Porter. *Handbook of Surfactants*. Chapman and Hall, London. 1994, 2nd Ed.
5. A. W. Adamson. *Physical Chemistry of Surfaces*. John Wiley & Sons, New York. 1997, 6th Ed.
6. J. O'M. Bockris; A. K. N. Reddy. *Modern Electrochemistry, Vol. II*. Springer, New York. 2018, 2nd Ed.
7. A. Tager. *Physical Chemistry of Polymers*. Mir Publishers, Moscow. 1978, 1st Ed.
8. H. S. Harned; B. B. Owen. *The Physical Chemistry of Electrolytic Solutions*. Reinhold Publishing, New York. 1950, 1st Ed.
9. S. Glasstone. *Textbook of Physical Chemistry*. Macmillan Publishers, London. 1948, 2nd Ed.

CH4 204: BIOORGANIC CHEMISTRY (L-T-P-C: 3-0-0-3)

Program: M. Sc. Chemistry	Semester: II
Course Code: CH4 204	Course name: BIOORGANIC CHEMISTRY

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
3/week	-	3	45	Lecture	CCE, ESE	100	35

Course Objectives:

- To understanding the role of biological molecules used in daily life.
- To know and analyze the structure and function of proteins and carbohydrates.
- To discuss the structure, synthesis and application of nucleic acids, lipids and enzymes.

Course Outcomes: At the end of this course, students will be able to

CO 1: Understand the structure and classification of proteins, lipids, carbohydrates and nucleic acid.

CO 2: Learn various structural determination techniques of biomolecules.

CO 3: Apply the knowledge of biomolecules in the progression of diseases.

CO 4: Demonstrate the role of biomolecules in drug discovery and development.

Syllabus

Units	Content	Hours
Unit I: Protein and Carbohydrates	Peptides and Proteins: Building blocks to the Quaternary structure of proteins, structure-stabilizing interactions in secondary structures. α -helix, β -sheets, secondary structures, triple helix structure of collagen. Tertiary structure of protein-folding and domain structure, Peptidomimetics, Carbohydrates: Classification and structure of simple and complex carbohydrates. Isomerization in monosaccharides, reducing non reducing sugars, anomers, mutarotation, Structural polysaccharides-cellulose and chitin. Storage polysaccharides-starch and glycogen. Structure and biological function of glucosaminoglycans or mucopolysaccharides.	15
Unit II: Nucleic Acids and Lipids	Nucleic Acids: Detailed Structure of nucleic acids, Different types of DNA, the double helix model of DNA, and forces responsible for holding it. Chemical and enzymatic hydrolysis of nucleic acids. Chemical synthesis of mono and tri-nucleosides. Lipids: Classification, chemical structure, and biological functions of lipids, glycerol phospholipids, sphingolipids, cholesterol, bile acids, prostaglandins, Lipoproteins-composition and function, role in atherosclerosis. Properties of lipid aggregates-micelles, bilayers, liposomes, and their possible biological function.	15
Unit III: Enzymes	Enzymes, Coenzymes, enzyme-kinetics, metalloenzymes, applications of enzymes in organic synthesis, enzyme-models and applications. Enzyme-catalyzed carboxylation and decarboxylation reactions. Enzyme inhibition and drug design, Molecular recognition, chiral recognition, crown ethers, cryptands, host-guest chemistry.	15

Reading references:

1. L. Lehninger. *Principles of Biochemistry*. Worth Publishers, New York. 2007, 7th Ed.
2. L. Stryer. *Biochemistry*. W. H. Freeman and Company, New York. 2019, 5th Ed.
3. D. Voet; J. G. Voet. *Biochemistry*. John Wiley & Sons, New York. 2010, 3rd Ed.
4. J. L. David; J. Rawn. *Biochemistry*. Neil Patterson Publishers, North Carolina. 1989, International Ed.
5. E. E. Conn; P. K. Stumpf. *Outlines of Biochemistry*. John Wiley & Sons, New York. 2006, 5th Ed.
6. T. Palmer. *Understanding Enzymes*. Prentice Hall, London. 1995, 2nd Ed.

7. C. H. Collins; J. Suckling. *Enzyme Chemistry: Impact and Applications*. Chapman and Hall, London. 1990, 2nd Ed.
8. U. Satyanarayana; U. Chakrapani. *Essentials of Biochemistry*. Elsevier Health Sciences, New Delhi. 2021, 3rd Ed.
9. R. K. Murray; V. W. Rodwell; D. Bender; K. M. Botham; P. A. Weil; P. J. Kennelly. *Harper's Illustrated Biochemistry*. McGraw Hill Professional, New York. 2009, 28th Ed.

CH4 205: SPECTROSCOPY-I: MOLECULAR STRUCTURE ELUCIDATION (L-T-P-C: 3-0-0-3)

Program: M. Sc. Chemistry	Semester: II
Course Code: CH4 205	Course name: SPECTROSCOPY-I: MOLECULAR STRUCTURE ELUCIDATION

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
3/week	-	3	45	Lecture	CCE, ESE	100	35

Course Description:

- Understand the principles, instrumentation, and interpretive strategies of UV-Vis, IR, NMR (^1H and ^{13}C), and mass spectrometry
- To correlate spectral data with molecular structure and functional groups
- Apply spectroscopic techniques to differentiate isomers, elucidate structures, and analyze mixtures
- To train students in the application of spectroscopic techniques for qualitative and quantitative analysis in chemistry, pharmaceuticals, materials science, and related research areas.

Course Outcomes: At the end of this course students will be able to

CO 1: Remember the basic concept of Vibrational, UV, IR, ^1H and Mass spectroscopy

CO 2: Analyze and assign ^1H NMR and ^{13}C NMR spectra, including chemical shifts, coupling patterns, integration, stereochemical effects, and structure determination of organic compounds.

CO 3: Apply mass spectrometric principles to determine molecular weight, molecular formula, isotopic patterns, and fragmentation pathways of organic

CO 4: Analyze the UV, IR, ^1H NMR and Mass spectra

Syllabus

Units	Content	Hours
Unit I: UV and IR Spectroscopy	UV, and IR Spectroscopy – UV Spectroscopy: Origin of electronic spectra, Lambert-Beer's absorption law, Types of electronic transitions. Principle of UV spectroscopy and instrumentation. Effect of solvent, substituent, and conjugation on electronic transitions. Factors affecting the position and intensity of bands and λ_{max} , Chromophores and auxochromes, Benzene and its substituted derivatives. Applications of UV-visible spectroscopy in analysis (qualitative/quantitative) of polyenes/aromatic (hetero & homo) systems, geometrical isomers, keto-enol tautomer's, components of a mixture. Woodward-Fieser rules for calculating absorption maximum in dienes, trienes, α , β -unsaturated carbonyl compounds and aromatic compounds. Applications of UV-Vis spectroscopy in reaction kinetics, photochemistry, pharmaceuticals, sensors, and materials chemistry. IR Spectroscopy: Instrumentation–sources-sampling techniques. Factors influencing IR spectroscopy, Characteristic vibrational frequencies of alkanes, alkenes, alkynes, aromatic compounds, alcohols, ethers, phenols and amines. Detailed study of vibrational frequencies of carbonyl compounds (ketones, aldehydes, esters, amides, acids, anhydrides, lactones, lactams and conjugated carbonyl compounds). Effect of hydrogen bonding and solvent effect on vibrational frequencies, overtones, combination bands and Fermi resonance. Differentiation of compounds/isomers by IR. Application of IR spectroscopy and limitations. Introduction to fluorescence spectroscopy	15
Unit II: NMR Spectroscopy	^1H NMR Spectroscopy: Introduction, Definition, Chemical shift and factor affecting chemical shift, spin-spin interaction, shielding and deshielding mechanism, mechanism of measurement, chemical shift values and correlation for protons bonded to carbon (aliphatic, olefinic, carbonyl and aromatic) and other nuclei (alcohols, phenols, enols, carboxylic acids, amines, amides & mercapto), coupling constants – vicinal, geminal, long	15

	range and virtual couplings, Intensity of signal (Peak area or integration) the effect of deuteration, Solvent effects in NMR, Practical aspects of sample preparation. complex spin-spin interaction between two, three nuclei. Stereochemistry, hindered rotation, Karplus curve variation of coupling constant with dihedral angle. ¹³C NMR Spectroscopy: ¹³ C NMR, introduction to FT technique, relaxation phenomena, NOE effects, ¹ H and ¹³ C chemical shifts to structure correlations. Chemical shift and (Aliphatic, olefinic, Alkyne, Aromatic, Heteroaromatic and carbonyl carbon), Coupling constants. To identify structure from ¹³ C NMR data; Use of ¹³ C spectra in differentiating compounds/isomers. Difference between ¹ H NMR and ¹³ C NMR	
Unit III: Mass Spectrometry	Mass Spectrometry - Origin of mass spectrum, principles of EI mass spectrometer-Instrumentation. Preliminary account of chemical ionization, Soft ionization techniques: Chemical Ionization (CI), Electrospray Ionization (ESI), and MALDI. Types of fragments: odd electron and even electron containing neutral and charged species (even electron rule, Nitrogen rule, isotopic peaks, metastable ion peaks, determination of molecular formula and High-resolution mass spectrometry. Salient features of the fragmentation pattern of organic compounds- α-cleavage, β cleavage, McLafferty rearrangement, Fragmentation patterns of important functional groups such as hydrocarbons, aromatic compounds, alcohols, ethers, aldehydes, ketones, carboxylic acids, esters, amides, amines, and halo compounds.	15

Reading references:

1. C. N. Banwell; E. M. McCash. *Fundamentals of Molecular Spectroscopy*. McGraw-Hill Education, New Delhi. 2011, 4th Ed.
2. G. Aruldas. *Molecular Structure and Spectroscopy*. Prentice Hall of India, New Delhi. 2004, 2nd Ed.
3. R. M. Silverstein; F. X. Webster; D. J. Kiemle; D. L. Bryce. *Spectroscopic Identification of Organic Compounds*. John Wiley & Sons, New York. 2014, 8th Ed.
4. Y. R. Sharma. *Elementary Organic Spectroscopy*. S. Chand & Company Ltd., New Delhi. 2007, Revised Ed.
5. R. Kakkar. *Atomic and Molecular Spectroscopy*. Cambridge University Press, Cambridge. 2015, 1st Ed.
6. W. Kemp. *Organic Spectroscopy*. Macmillan, London. 1994, 3rd Ed.
7. D. H. Williams; I. Fleming. *Spectroscopic Methods in Organic Chemistry*. McGraw-Hill Education, London. 1995, 5th Ed.
8. A. B. Derome. *Modern NMR Techniques for Chemistry Research*. Pergamon Press, Oxford. 1987, Reprinted Ed.
9. D. L. Pavia. *Introduction to Organic Spectroscopy*. Cengage India Pvt. Ltd., New Delhi. 2015, 5th Ed.
10. G. C. Levy; O. L. Nelson. *Carbon-13 NMR for Organic Chemists*. Wiley, New York. 1980, 2nd Ed. and
Atta-ur-Rahman. *Nuclear Magnetic Resonance: Basic Principles*. Springer-Verlag, New York. 2011, 1st Ed.
11. P. S. Kalsi. *Spectroscopy of Organic Compounds*. New Age International Pvt. Ltd., New Delhi. 2020, 8th Ed.

CH4 206: ANALYTICAL TECHNIQUES LABORATORY (L-T-P-C: 0-0-8-4)

Program: M. Sc. Chemistry	Semester: II
Course code: CH4 206	Course name: ANALYTICAL TECHNIQUES LABORATORY

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
-	8 per week	4	120	Lab	CCE, ESE	100	35

Course Objectives:

- To understand and learn analytical techniques in biochemical studies.
- To separate and identify biomolecules such as amino acids, carbohydrates, and proteins.
- To determine the iodine value of lipids
- To determine the concentration of biomolecules in tea and coffee

Course Learning Outcomes: At the end of this course students will be able to

CO 1: Demonstrate proficiency in techniques for the separation and identification of biomolecules, including amino acids and sugars.

CO 2: Quantify biomolecules using standard methods like Anthrone and Lowry's techniques.

CO 3: Evaluate lipid properties through determination of iodine and acetyl numbers.

CO 4: Analyze organic compounds using spectroscopic methods, including UV-visible and IR spectroscopy.

CO 5: Compare and interpret shifts in electronic absorption spectra under varying chemical conditions.

Syllabus

Sr. No.	Name of the Experiment	Hours
1.	Determination of Isoelectric point (PI) of Amino acid by titration method.	8
2.	Characterize mono- and disaccharides by recrystallization, solubility, melting points, and crystal morphology.	8
3.	Estimation of total sugar in biological samples using the Anthrone method involving spectrophotometric detection.	8
4.	Estimation of amino acids using Ninhydrin-Anthrone method involving colorimetric analysis.	8
5.	Estimation of protein by Lowery's method	8
6.	Determination of Iodine number and acetyl number of Lipid molecules.	8
7.	Separation of amino acids by paper chromatography	8
8.	Study the bathochromic shift of p-nitrophenol in UV-Vis spectra under alkaline vs. neutral conditions to assess pH-dependent resonance effects.	8
9.	Study the hypsochromic shift in aniline by comparing its UV-Vis spectra in neutral and acidic media.	8
10.	Compare IR spectra of acetone and benzophenone to distinguish aliphatic and aromatic ketones based on key vibrations.	8
11.	Comparative IR Analysis of Aromatic and aliphatic Nitro compounds, Amines, Nitriles and Amides	8
12.	Analyze unknown organic samples to identify alcohols, acids, amines, or esters based on diagnostic IR bands	8
13.	UV-Vis Spectrophotometric Analysis of caffeine and benzoic acid in soft drinks via Beer's Law.	8
14.	Assign ^1H NMR peaks of common compounds using chemical shift, splitting, and integration with software or spectra.	8
15.	Record and analyze spectra of complexes like $[\text{Cu}(\text{NH}_3)_4]^{2+}$ or $[\text{Fe}(\text{SCN})]^{2+}$ to observe d-d transitions and ligand effects.	8

Reading references:

1. R. Katoch. *Analytical Techniques in Biochemistry and Molecular Biology*. Springer, New York. 2011, 1st Ed.

2. H. Martin. *Basic Methods for the Biochemical Lab*. Springer, Berlin. 2007, 1st Ed.
3. K. Wilson; J. Walker. *Principles and Techniques in Biochemistry and Molecular Biology*. Cambridge University Press, Cambridge. 2010, 7th Ed.
4. J. A. A. Chambers; D. Rickwood. *Biochemistry Lab Fax*. Blackwell Science, Oxford. 1993, 1st Ed.
5. T. S. Work; E. Work. *Laboratory Techniques in Biochemistry and Molecular Biology, Vol. I & II*. North-Holland Publishing Company, Amsterdam. 1970, 1st Ed.
6. R. K. Bansal. *Practical Organic Chemistry*. New Age International Pvt. Ltd., New Delhi. 2008, 5th Ed.
7. D. Field; S. Sternhell; J. R. Kalman. *Organic Structures from Spectra*. John Wiley & Sons Ltd., Chichester. 2008, 4th Ed.
8. F. G. Mann; B. C. Saunders. *Practical Organic Chemistry*. Pearson Education India, New Delhi. 2009, 4th Ed.
9. W. Kemp. *Organic Spectroscopy*. Macmillan, London. 1994, 3rd Ed.
10. P. S. Kalsi. *Spectroscopy of Organic Compounds*. New Age International Publishers, New Delhi. 2007, 6th Ed.
11. Y. R. Sharma. *Elementary Organic Spectroscopy – Principles and Chemical Applications*. S. Chand & Company Ltd., New Delhi. 1992, 5th Ed.

CH4 207: PHYSICAL CHEMISTRY LABORATORY (L-T-P-C: 0-0-8-4)

Program: M. Sc. Chemistry	Semester: II
Course code: CH4 207	Course name: PHYSICAL CHEMISTRY LABORATORY

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
-	8/week	4	120	Lab	CCE, ESE	100	35

Course Objectives: This laboratory course aims to provide practical knowledge of electrochemistry, surface chemistry, conductometry, potentiometry, kinetics, and related physical chemistry techniques. Students will develop experimental, analytical, and data interpretation skills through laboratory experiments and modern instrumental methods.

Course Outcomes: At the end of this course, students will be able to

CO 1: Explain the principles of conductometry, potentiometry, viscometry, spectroscopy, and electrochemistry used in laboratory experiments.

CO 2: Perform quantitative analysis and kinetic studies using modern physical chemistry experimental techniques.

CO 3: Analyze experimental data to determine thermodynamic, kinetic, and electrochemical parameters.

CO 4: Evaluate the accuracy and reliability of experimental observations using appropriate error analysis and interpretation methods.

CO 5: Design and execute laboratory experiments related to solution chemistry, surfactants, and reaction kinetics.

Syllabus

Sr. No.	Name of the Experiment	Hours
1.	Conductometric Determination of the Percentage Composition of Strong and Weak Acids in a Mixture	8
2.	Conductometric Determination of the Rate Constant and Activation Energy for the Hydrolysis of Methyl Acetate	8
3.	To determine the relative strengths of the given strong acids by studying the kinetics of inversion of cane sugar using the polarimetric method.	8
4.	Determination of the Viscosity Average Molecular Weight of a Polymer Using Ostwald's Viscometer	8
5.	To determine the Redox potential of Fe(II)/Fe(III) system by potentiometric method. (pH metry) Or, Potentiometric Determination of KCl and KI Concentrations in a Mixture Using Standard AgNO ₃ Solution	8
6.	Potentiometric Determination of the Strength of an Unknown Silver Nitrate (AgNO ₃) Solution	8
7.	pH-Metric Determination of the Dissociation Constants (pK ₁ and pK ₂) of a Dibasic Acid	8
8.	Conductometric Determination of the Solubility Product (K _{sp}) of Barium Sulfate and Silver Chloride.	8
9.	Potentiometric Determination of the Dissociation Constants of Monobasic Acids: Acetic Acid, Benzoic Acid, and Salicylic Acid	8
10.	Kinetic study of the esterification of an alcohol by NMR Spectroscopy. (Chemical kinetics)	8
11.	Determination of Critical Micelle Concentration (CMC) and Thermodynamics of Micellization	8
12.	Conductometric Determination of the Critical Micelle Concentration (CMC) of Sodium Dodecyl Sulfate (SDS)	10
13.	Characterization of a catalyst or nanomaterial using available instrumentation (FTIR, XRD, UV-Vis, or SEM data interpretation). Adsorption isotherm of acetic	10

	acid or oxalic acid on activated charcoal (Langmuir/Freundlich isotherm).	
14.	Evaluation of the catalytic activity of a heterogeneous catalyst (e.g., MnO_2 decomposition of H_2O_2 or KI-catalyzed reaction).	10

CO-PO Mapping Table

	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	2	1	1	1
CO 2	2	3	2	3	2
CO 3	2	3	3	2	2
CO 4	1	2	3	3	2
CO 5	1	3	3	3	3
Average	2.0	2.5	2.25	2.25	2.0

Correlation levels:

1 - Low, 2 - Moderate, 3 - High

Justification for CO-PO Mapping

COs	Justification
CO 1	This CO develops understanding of experimental principles and physical chemistry laboratory techniques, strengthening scientific and analytical knowledge (PO 1, PO 2).
CO 2	This CO enhances practical laboratory competency and application of physical chemistry techniques for quantitative analysis and kinetic studies (PO 2, PO 4).
CO 3	This CO develops analytical and interpretation skills through the analysis of thermodynamic, kinetic, and electrochemical experimental data (PO 2, PO 3).
CO 4	This CO strengthens evaluation and problem-solving abilities through error analysis and interpretation of laboratory observations (PO 3, PO 4).
CO 5	This CO promotes innovation and experimental design skills related to solution chemistry, surfactants, and reaction kinetics (PO 3, PO 4, PO 5).

Reading references:

1. B. D. Khosla; V. C. Garg. *Senior Practical Physical Chemistry*. R. Chand & Co., New Delhi. 2018, 18th Ed.
2. B. Viswanathan; P. S. Raghavan. *Practical Physical Chemistry*. Viva Books Pvt. Ltd., Navi Mumbai. 2017, 1st Ed.
3. A. K. Nad; B. Mahapatra; A. Ghoshal. *An Advanced Course in Practical Chemistry*. New Central Book Agency Pvt. Ltd., Kolkata. 2012, 3rd Ed.
4. J. N. Gurtu; A. Gurtu. *Advanced Physical Chemistry Experiments*. Pragati Prakashan, Meerut. 2008, 1st Ed.

~:The End::~

Indrashil University



Department of Chemistry School of Science

M.Sc. 2026-2028 Sem III-IV

Analytical Chemistry

Course Profile

Academic Year 2026-2027

Course Structure M.Sc. Analytical Chemistry Semesters III and IV

SEMESTER: III	MINIMUM SEMESTER CREDIT REQUIRED: 24 CUMULATIVE SEMESTER CREDITS REQUIRED: 67		
SUBJECT CODES	SUBJECT NAMES	L-T-P	CREDITS
CH5 AN101	ANALYTICAL CHEMISTRY - II: PHARMACEUTICAL ANALYSIS AND MEASUREMENTS	3-0-0	3
CH5 AN102	ANALYTICAL CHEMISTRY - III: ELECTROANALYTICAL TECHNIQUES	3-0-0	3
CH5 AN103	ANALYTICAL CHEMISTRY-IV: QUALITY MEASUREMENTS IN ANALYSIS	3-0-0	3
CH5 104	SPECTROSCOPY-II	3-0-0	3
CH5 105	SPECTROSCOPIC ANALYSIS AND DATA INTERPRETATION LABORATORY	0-0-8	4
CH5 AN106	ANALYTICAL CHEMISTRY LABORATORY	0-0-8	4
	<u>ELECTIVE-I</u>	2-0-0	2
	<u>ELECTIVE-II</u>	2-0-0	2
Total		19L-16P	24

SEMESTER: IV	MINIMUM SEMESTER CREDIT REQUIRED: 15 CUMULATIVE SEMESTER CREDITS REQUIRED: 82		
SUBJECT CODES	SUBJECT NAMES	L-T-P	CREDITS
CH5 AN201	RESEARCH OR INDUSTRIAL PROJECT	0-0-20	10
CH5 AN202	PROJECT REPORT	3-0-0	3
CH5 AN203	PROJECT PRESENTATION	2-0-0	2
Total		5L-20P	15

Semester III: LIST OF AVAILABLE SUBJECTS FOR ELECTIVE I, II

SUBJECT CODES	SUBJECT NAMES	L-T-P	CREDIT
CH5 EAN1	SEPARATION METHODS	2-0-0	2
CH5 EAN2	APPLICATIONS OF COMPUTER IN CHEMISTRY	2-0-0	2
CH5 EAN3	SUPRAMOLECULAR CHEMISTRY	2-0-0	2
CH5 EAN4	APPLIED ANALYSIS AND GREEN ANALYTICAL CHEMISTRY	2-0-0	2

SEMESTER III**SYLLABUS WITH COURSE LEARNING OUTCOME (CLO)****CH5 AN101: ANALYTICAL CHEMISTRY II: PHARMACEUTICAL ANALYSIS AND MEASUREMENTS****(L- T-P-C: 3-0-0-3)**

Program: M. Sc. Chemistry (Analytical)	Semester: III
Course code: CH5 AN101	Course name: ANALYTICAL CHEMISTRY II: PHARMACEUTICAL ANALYSIS AND MEASUREMENTS

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
3 per week	-	3	45	Lecture	CCE, ESE	100	35

Course Description:

This course provides a comprehensive introduction to the fundamental principles of Analytical Chemistry, emphasizing its significance and diverse applications in scientific research and industrial sectors. It covers the theoretical foundations and practical aspects of major analytical techniques, with particular focus on spectrophotometric methods and their applications in qualitative and quantitative analysis. The course also introduces the principles and applications of major chromatographic techniques used for the separation, identification, and quantification of chemical substances. By integrating theoretical knowledge with practical relevance, the course enhances students' understanding of modern analytical methods employed in chemical, pharmaceutical, environmental, and industrial laboratories.

Course Outcomes: At the end of this course students will be able to

CO 1: Know the importance of Analytical science in Research & Development of an industry.

CO 2: Operate several analytical instruments within a very short span of time.

CO 3: Understand several analytical data representation techniques.

CO 4: Unknown sample determination techniques.

CO 5: Be familiarizing with several computer-based data plot.

Syllabus

Unit	Content	Hours
Unit I: Automation in Measurements	Principles of automation, Process control: off-line, at-line and on-line analysis. Flow injection analysis, principles, dispersion coefficient, factors affecting peak height-sample volume, channel length, flow rate and channel geometry. Applications of FIA, stopped flow measurements and gradient FIA. Introduction to Laboratory Automation Systems (LAS) and Laboratory Information Management Systems (LIMS). Basics of Process Analytical Technology (PAT) in chemical and pharmaceutical industries.	15
Unit II: Pharmaceutical analysis	Introduction to food analysis, regulations and international standards related to food analysis, nutritional labelling, sample collection and sample preparation. Compositional analysis of foods for moisture, proteins, fat, fibres, ash, vitamins and minerals. Adulteration of fats and oils; milk and milk products. Heavy metal ion analysis in pharmaceuticals. Importance of UV-Visible spectrophotometry, IR spectroscopy and HPLC with UV, fluorescence and photodiode array detection in pharmaceutical industry. Overview of Good Laboratory Practices (GLP) and Good Manufacturing Practices (GMP).	15
Unit-III: Pesticides, soaps and fertilizers	Classification of pesticides. Pesticide residue monitoring in food and environmental samples. LC-MS/MS and GC-MS techniques. Classification of soaps and detergents with suitable examples. Characterization of soaps and detergents. Types of fertilizers and analysis of different elements like, nitrogen, phosphates, calcium, sodium, potassium and ammonia.	15

Reference Books:

1. G. D. Christian. *Analytical Chemistry*. John Wiley & Sons Inc., New Jersey. 2007, 6th Ed.
2. D. A. Skoog. *Principles of Instrumental Analysis*. Holt-Saunders International Edition, New York. 2016, 7th Ed.
3. J. Martinez Calatayud. *Flow Injection Analysis of Pharmaceuticals: Automation in the Laboratory*. Taylor & Francis, London. 1996, 1st Ed.
4. S. S. Nielsen. *Food Analysis*. Springer, New York. 2003, 3rd Ed.
5. S. S. Nielsen. *Food Analysis Laboratory Manual*. Springer, New York. 2003, 3rd Ed.
6. P. D. Sethi. *Quantitative Analysis of Drugs in Pharmaceutical Formulation*. CBS Publishers, New Delhi. 2008, 3rd Ed.
7. S. Ahuja; S. Scypinski. *Handbook of Modern Pharmaceutical Analysis*. Academic Press, San Diego. 2001, Vol. 3.
8. F. J. Welcher. *Standard Methods of Chemical Analysis, Vols. 1, 2 & 3, Part Two*. Van Nostrand Reinhold Company, New York. 1917, 6th Ed.

CH5 102: ANALYTICAL CHEMISTRY III: ELECTROANALYTICAL TECHNIQUES (L-T-P-C: 3-0-0-3)

Program: M. Sc. Chemistry	Semester: III
Course code: CH5 AN102	Course name: ANALYTICAL CHEMISTRY-III: ELECTROANALYTICAL TECHNIQUES

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
3 per week	-	3	45	Lecture	CCE, ESE	100	35

Course Objectives:

- Understanding of different electrogravimetric analyses.
- Explains the principles of potentiometry, voltammetry, Polarography, and Cyclic Voltammetry.
- Delivers the idea about different kinds of electrodes used in different techniques

Course Outcomes: At the end of this course students will be able to

CO 1: State different techniques used for electrogravimetry analysis

CO 2: Summarize the working principle of different techniques.

CO 3: Identify the different types of electrodes used in different techniques

CO 4: Analyze different electroanalytical titration used for the separation method.

Syllabus

Units	Content	Hours
Unit I: Electrochemical measurements	Basic revision of electrochemistry, Idea about electrode, working principal of different electrode: SHE, reference electrode, glass electrode, type-I/II electrode, saturated calomel electrode, advantages and disadvantages of different electrode, gravimetric analysis, classification: precipitation, volatilization, electroanalytical, extraction and chromatographic method, determination of ions by gravimetric method, Faraday's law of electrolysis, electrogravimetry: principle and instrumentation, method: constant current electrolysis, constant potential electrolysis, determination of Cu ion by electrogravimetry.	15
Unit II: Potentiometry, Voltammetry, Polarography	Potentiometry: Fundamentals, indicator and ion-selective electrodes, Instrumentation, types of potentiometric titration: acid-base, redox, complexometric and precipitation titration, determination of end point and analytical application. Voltammetry: principle, instrumentation, Randles-Sevick equation, modified voltammetry, cyclic voltammetry, quantitative applications of voltammetry. Polarography: introduction, principle, ILKOVIC Equation & instrumentation, construction and working of dropping mercury electrode, application of polarography in qualitative and quantitative analysis.	15
Unit III: Coulometry	Coulometry: Introduction: principles, instrumentation, coulometry at constant current and controlled potential, coulometric titration, advantages of coulometric titration, applications.	15

CO-PO Mapping Table2

	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	2	1	-	1
CO 2	3	3	2	-	1
CO 3	3	3	3	1	1
CO 4	2	3	3	1	1
Average	2.75	2.75	2.25	0.50	1.00

Correlation levels:**1 - Low, 2 - Moderate, 3 - High****Justification for CO-PO Mapping**

COs	Justification
CO 1	Develops fundamental knowledge of electrochemical measurements and electrode systems (PO1) while introducing analytical concepts (PO2).
CO 2	Enhances understanding of gravimetric and electrogravimetric techniques (PO1) and strengthens quantitative analytical skills (PO2, PO3).
CO 3	Provides knowledge of potentiometry, voltammetry, and polarography (PO1) and develops analytical reasoning and problem-solving abilities in chemical analysis (PO2, PO3, PO4).
CO 4	Develops understanding of coulometric methods and their applications (PO1), while improving analytical competency and interpretation of electrochemical data (PO2, PO3, PO4).

Reading references:

1. P. T. Kissinger; W. R. Heineman. *Laboratory Techniques in Electroanalytical Chemistry*. Marcel Dekker Inc., New York. 1996, 2nd Ed.
2. B. H. Vassos; G. W. Ewing. *Electroanalytical Chemistry*. John Wiley & Sons, New York. 1983, 1st Ed.
3. A. J. Bard; L. R. Faulkner. *Electrochemical Methods – Fundamentals and Applications*. John Wiley & Sons, New York. 2001, 2nd Ed.
4. D. C. Harris. *Quantitative Chemical Analysis*. W. H. Freeman and Company, New York. 2015, 9th Ed.
5. I. M. Kolthoff; P. J. Elving. *Treatise on Analytical Chemistry*. Wiley-Interscience, New York. 1968, 1st Ed.
6. B. R. Eggins. *Chemical Sensors and Biosensors*. John Wiley & Sons, New York. 2002, 1st Ed.

CH5 AN103: ANALYTICAL CHEMISTRY IV: QA QC VALIDATION (L-T-P-C: 3-0-0-3)

Program: M. Sc. Chemistry	Semester: III
Course code: CH5 AN103	Course name: ANALYTICAL CHEMISTRY-IV: QUALITY MEASUREMENTS IN ANALYSIS

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
3 per week	-	3	45	Lecture	CCE, ESE	100	35

Course Description:

This course provides a comprehensive understanding of the principles and practices of Quality Assurance (QA) and Quality Control (QC) in Analytical Chemistry, emphasizing their critical role in ensuring the reliability and accuracy of analytical results. It introduces the concepts of accuracy, precision, uncertainty, and quality management systems, along with the importance and application of certified reference materials in analytical measurements. The course also covers the fundamentals of analytical method development and validation in accordance with standard regulatory guidelines. By integrating theoretical concepts with industrial practices, the course equips students with the knowledge and skills required for quality control and analytical laboratories, particularly in the pharmaceutical, chemical, food, and environmental industries.

Course Outcomes: At the end of this course students will be able to

CO 1: Know the importance of Analytical science in Research & Development of an industry.

CO 2: Operate several analytical instruments within a very short span of time.

CO 3: Understand several analytical data representation techniques.

CO 4: Quantitative determination of unknown sample using various techniques.

Syllabus

Unit	Content	Hours
Unit I: Quality Assurance and Quality Control	Industrial Analysis: Quality characteristics of chemical analysis, errors occurring at the start, during or by the end of analysis, Shewhart Chart, CUSUM chart, Quality Management Systems (ISO/IEC 17025 and ISO 9001) in analytical laboratories. Laboratory accreditation and documentation. Measurement uncertainty and risk assessment in analytical laboratories. Clinical Analysis: Introduction, analytical responsibilities, Managerial responsibilities, practical approaches to QA, Internal QC, near-patient testing and QC. Water Industry: Water quality field sampling QA/QC program, QA/QC documentation, sampling frequency and sample size, Water quality sampling, bacterial sample collection, sample handling, preservation, storage and transport, chain of custody,	15
Unit II: Reference Materials	Analytical standards, primary and secondary standards, high purity substances, reference materials, Role of certified reference materials (CRMs), Traceability of analytical measurements. Proficiency testing and inter-laboratory comparison studies. Calibration procedures and instrument qualification (IQ, OQ and PQ). Selection and application of reference materials in pharmaceutical, environmental and food analysis.	15
Unit-III: Method development and validation	Analytical method development: Theory and factors affecting resolution separation factor (selectivity), retention factor (capacity factor) and column efficiency). Ion-exchange and size-exclusion chromatography. Modern detector selection, Gradient/isocratic operation, selecting the column for analysis, Troubleshooting of HPLC methods and analytical instrumentation. Basic introduction to UPLC and hyphenated analytical	15

	techniques. Forced degradation (stress testing) of drug substance.	
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Reading references:

1. D. A. Skoog; D. M. West; F. J. Holler. *Fundamentals of Analytical Chemistry*. Saunders College Publishing, Philadelphia. 1991, 2nd Ed.
2. R. A. Day; A. L. Underwood. *Quantitative Analysis*. Prentice-Hall of India Pvt. Ltd., New Delhi. 1993, 6th Ed.
3. I. A. Fowles. *Gas Chromatography*. Analytical Chemistry Series, Open Book Learning, Oxford. 1995, 2nd Ed.
4. L. Hargis. *Analytical Chemistry: Principles and Techniques*. Pearson Education, New Delhi. 1988, Facsimile Ed.
5. S. Ahuja; S. Scypinski. *Handbook of Modern Pharmaceutical Analysis, Vol. 3*. Academic Press, San Diego. 2001, 1st Ed.
6. F. J. Welcher. *Standard Methods of Chemical Analysis, Vols. 1, 2 & 3*. Van Nostrand Reinhold Company, New York. 1963, 6th Ed.

CH5 104: SPECTROSCOPY II: ADVANCED NMR AND MOLECULAR SPECTROSCOPY (L-T-P-C: 3-0-0-3)

Program: M. Sc. Chemistry	Semester: III
Course code: CH5 104	Course name: SPECTROSCOPY II ADVANCED NMR AND MOLECULAR SPECTROSCOPY

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
3 per week	-	3	45	Lecture	CCE, ESE	100	35

Course Objectives:

- Students will learn the basic Principles of NMR, ^{13}C NMR, Raman, and Mössbauer spectroscopy.
- Student will learn the Interpretation of first-order and second-order NMR spectra and methods for their simplification.
- The course will cover the analysis and structure elucidation of organic compounds using 2D NMR techniques.
- Students will learn the fundamentals and applications of rotational and vibrational Raman spectra and mössbauer spectroscopy in chemical analysis.

Course Outcomes: At the end of this course, students will be able to

CO 1: Remember the basic concept of ^1H and ^{13}C , Raman and Mossbauer spectroscopy

CO 2: Interpret the ^1H and ^{13}C NMR spectra for molecular structure determination.

CO 3: Apply the knowledge of advanced NMR for the structure elucidation of an organic compound.

CO 4: Analyze the ^1H , ^{13}C NMR, Raman and Mossbauer Spectroscopy ~~IR to~~ obtain molecular and electronic structural information.

Syllabus

Units	Content	Hours
Unit I: Proton NMR Spectroscopy	^1H NMR Spectroscopy -Pople notation and spin assignments; chemical shift equivalence and magnetic equivalence; Differences between first order and Second order effects, examples of AB, AX, A2X2, AX2, AA'XX', AMC and ABX systems, Simplification of second order spectrum: selective decoupling, use of chemical shift reagents for stereochemical assignments, Proton exchange, Deuterium exchange, Nuclear Overhauser Effect (NOE); Differentiation of compounds/ isomers by PMR; To identify structure from PMR data, Study of dynamic processes by VT NMR, restricted rotation (DMF, DMA, biphenyls, annulenes), cyclohexane ring inversion, NMR applications in natural product and pharmaceutical structure elucidation.	15
Unit II: Carbon NMR Spectroscopy	^{13}C NMR Spectroscopy - To identify structure from ^{13}C NMR data; Use of ^{13}C spectra in differentiating compounds/isomers; 2D NMR Spectroscopy: Principles and applications of homonuclear and heteronuclear 2D NMR techniques (COSY); two-dimensional NMR spectroscopy. COSY, HMBC, HMQC, NOESY. Editing techniques: INEPT and DEPT methods, Time scale- Multinuclear, Introduction to NMR of nuclei other than proton and carbon- ^{19}F NMR, ^{31}P NMR, ^{15}N NMR, and ^{11}B NMR.	15
Unit III: Raman and Mossbauer Spectroscopy	Raman spectroscopy - Quantum theory of Raman effect, Classical theory of Raman effect, Pure rotational Raman spectra, Raman activity of vibrations, Vibrational Raman spectra, polarization of light and Raman effect, applications., Mutual exclusion principle Mossbauer Spectroscopy: Basic principles, spectral parameters and spectrum display. Isomer shift, quadrupole splitting, magnetic hyperfine splitting. Application of the technique to the studies of (1) bonding and structures of Fe+2 and Fe+3 compounds including those of intermediate spin, (2) Sn+2 and Sn+4 compounds- nature of M-L bond, structure and detection of oxidation state and in equivalent MB atoms. Applications in nanomaterials, catalysts, and bioinorganic systems.	15

Reading references:

1. R. M. Silverstein; G. C. Bassler; T. C. Morrill. *Spectrometric Identification of Organic Compounds*. John Wiley & Sons,

- New York. 1991, 5th Ed.
2. R. J. Abraham; J. Fisher; P. Loftus. *Introduction to NMR Spectroscopy*. Wiley, Chichester. 1992, 1st Ed.
 3. J. R. Dyer. *Application of Spectroscopy of Organic Compounds*. Prentice Hall, Englewood Cliffs, N.J. 1965, 1st Ed.
 4. D. H. Williams; I. Fleming. *Spectroscopic Methods in Organic Chemistry*. Tata McGraw-Hill, New Delhi. 1968, 7th Ed.
 5. J. L. McHale. *Molecular Spectroscopy*. CRC Press, Boca Raton. 2017, 2nd Ed.
 6. D. L. Pavia. *Introduction to Organic Spectroscopy*. Cengage India Pvt. Ltd., New Delhi. 2015, 5th Ed.
 7. D. N. S. Narayana. *Handbook of Molecular Spectroscopy*. J. K. International Publishers, New Delhi. 2015, 1st Ed.
 8. Y. R. Sharma. *Elementary Organic Spectroscopy*. S. Chand & Company Ltd., New Delhi. 2007, Revised Ed.
 9. D. A. Skoog. *Principles of Instrumental Analysis*. Holt Saunders International Edition, New York. 2016, 7th Ed.
 10. R. Kakkar. *Atomic and Molecular Spectroscopy*. Cambridge University Press, Cambridge. 2015, 1st Ed.

CH5 105: SPECTROSCOPY ANALYSIS & DATA INTERPRETATION LABORATORY (L-T-P-C: 0-0-8-4)

Program: M. Sc. Chemistry (Analytical)	Semester: III
Course code: CH5 105	Course name: SPECTROSCOPY ANALYSIS & DATA INTERPRETATION LABORATORY

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
-	8 per week	4	120	Lab	CCE, ESE	100	35

Course Objectives:

- The objective of the practical course is to make students understand the spectral analysis of various organic compounds which are synthesized in laboratory and chemical industries.
- Students will also learn various software used in analysis of data in NMR and IR spectroscopy.
- Students will learn structural prediction and confirmation of compounds through their spectral analysis.

Course Outcomes: At the end of this course students will be able to

CO 1: Understand the analysis of ^1H and ^{13}C -NMR spectra with analysis

CO 2: Explain the IR spectra analysis for functional group determination

CO 3: Apply the knowledge of spectral analysis in structural characterization

CO 4: Demonstrate the application of software for NMR analysis

CO 5: Demonstrate the knowledge of spectroscopy in analysis of drug molecules

Syllabus

S. No.	Name of Experiment	Hours
1	To learn Chem Draw, Chems sketch, ISIS Draw tools	12
2	To Draw the Structure of Simple aliphatic, aromatic, and heterocyclic compounds in ChemDraw with different substituents. Get the correct IUPAC Name and predict the ^1H -NMR Spectra.	12
3	To learn sample preparation and data analysis of UV spectroscopy	12
4	To Determine the Effect of alkaline and acidic media on the organic compound using UV-Vis spectroscopy	12
5	To Determine the Bathochromic shift in Alkaline medium of p- Nitrophenol Compared to p-Nitrophenol. Determination of Hypsochromic shift in acidic medium of Aniline compared to Aniline.	12
6	Structure elucidation using ^1H and ^{13}C NMR spectra	24
7	To Learn Mestronova software for structure analysis	12
8	Solving structure elucidation problems using multiple spectroscopic data sheets (NMR, MS, IR, and UV-Vis) on at least 10 examples	24

Reading references:

- R. K. Bansal. *Practical Organic Chemistry*. New Age International Pvt. Ltd., New Delhi. 2008, 5th Ed.
- D. Field; S. Sternhell; J. R. Kalman. *Organic Structures from Spectra*. John Wiley & Sons Ltd., Chichester. 2008, 4th Ed.
- F. G. Mann; B. C. Saunders. *Practical Organic Chemistry*. Pearson Education India, New Delhi. 2009, 4th Ed.
- W. Kemp. *Organic Spectroscopy*. Macmillan, London. 1994, 3rd Ed.
- P. S. Kalsi. *Spectroscopy of Organic Compounds*. New Age International Pvt. Ltd., New Delhi. 2020, 8th Ed.
- Y. R. Sharma. *Elementary Organic Spectroscopy – Principles and Chemical Applications*. S. Chand & Company Ltd., New Delhi. 1992, 5th Ed.

CH5 AN106: ANALYTICAL CHEMISTRY LABORATORY (L-T-P-C: 0-0-8-4)

Program: M. Sc. Chemistry (Analytical)	Semester: III
Course code: CH5 AN106	Course name: ANALYTICAL CHEMISTRY LABORATORY

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
-	8 per week	4	120	Lab	CCE, ESE	100	35

Course Objectives:

This laboratory course aims to provide comprehensive hands-on training in modern analytical chemistry by integrating classical, spectroscopic, electrochemical, and instrumental techniques used in research and industrial laboratories. The course enables students to determine important physicochemical parameters such as moisture content, acid dissociation constants (pKa), complex stability constants, and redox characteristics using Karl Fischer titration, UV-Visible spectrophotometry, conductometry, ion-selective electrodes, fluorescence spectroscopy, and cyclic voltammetry. Students will develop practical skills in the quantitative analysis of pharmaceutical formulations, environmental water samples, and metal ions, while gaining experience in electrochemical investigations of redox systems, cyclic voltammetric analysis, and spectrophotometric method development. The course further emphasizes experimental design, data acquisition, interpretation, and quality assurance practices, preparing students for advanced research and professional careers in analytical, pharmaceutical, environmental, and industrial laboratories.

Course Learning Outcomes: At the end of this course, students will be able to

CLO1: Understand the potentiometric analysis of chemical compounds

CLO2: Explain the use of pH meter in sample analysis of acid and base

CLO3: Apply the knowledge of conductometry in analysis of metal complexes

CLO4: Demonstrate the application of polarography and electrogravimetry

Syllabus

Sr. No.	Name of the Experiment	Hours
1	Determination of moisture content in pharmaceutical samples using Karl Fischer Titration	8
2	Determination of pKa values of: (i) Ethylenediamine, (ii) Glycine, (iii) Histidine	8
3	Determination of $\lambda_{\max}$ and quantitative estimation of an analyte (e.g., KMnO_4 , Cu^{2+} , Fe^{3+} or aspirin) using UV-Visible Spectrophotometry.	8
4	Determination of stability constant for ternary o-Phen-Ni(II)-His complex	8
5	Determination of the redox behavior of potassium ferricyanide using Cyclic Voltammetry.	8
6	Estimation of aspirin using KOH titration with pH or conductometric end-point	8
7	Quantitative determination of a given compound (such as quinine or fluorescein) using Fluorescence Spectrophotometry.	8
8	Ion-selective electrode (ISE) method for nitrate determination in water	8
9	Electrochemical determination of ascorbic acid (or paracetamol) using cyclic voltammetry.	8
10	Conductometric determination of complex composition: Cu(II)-oxine and Cu(II)-EDTA	8
11	Spectrophotometric determination of phosphate or nitrate in environmental water samples using UV-Visible spectroscopy	8
12	Determination of iron(II) by the 1,10-phenanthroline method using UV-Visible spectrophotometry.	8
13	Ion-selective electrode (ISE) method for fluoride estimation in water	8
14	Study of the ferricyanide/ferrocyanide redox system using cyclic voltammetry	8
15	Determination of pKa of an indicator or weak acid using UV-Visible Spectrophotometric method.	4

16	Study the effect of scan rate on the cyclic voltammogram of the ferri/ferrocyanide redox couple.	4
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Reading references:

1. J. H. Kennedy. *Analytical Chemistry Practice*. Saunders College Publishing, Philadelphia. 1990, 2nd Ed.
2. J. Mendham. *Vogel's Textbook of Quantitative Chemical Analysis*. Pearson Education, New Delhi. 2002, 6th Ed.
3. A. I. Vogel. *A Textbook of Quantitative Inorganic Analysis*. ELBS Publication, London. 1969, 3rd Ed.
4. A. E. Martell; R. J. Motekaitis. *Determination and Use of Stability Constants*. VCH Publishers Inc., New York. 1988, 2nd Ed.
5. A. E. Martell; R. D. Hancock. *Metal Complexes in Aqueous Solutions*. Plenum Press, New York. 1996, 1st Ed.
6. G. D. Christian. *Analytical Chemistry*. John Wiley & Sons Inc., New York. 1994, 6th Ed.

CH5 EAN1: SEPARATION METHODS (L-T-P-C: 2-0-0-2)

Program: M. Sc. Chemistry	Semester: III
Course code: CH5 EAN1	Course name: SEPARATION METHODS

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
2 per week	-	2	30	Lecture	CCE, ESE	50	18

Course Objectives:

- Understand the principles and mechanisms of solvent extraction and chromatographic techniques
- Explore the use of organic reagents in inorganic analysis
- Gain theoretical insight into advanced separation techniques

Course Learning Outcomes: At the end of this course students will be able to

CO 1: Explain the role of partition coefficient in solvent extraction

CO 2: Classify various solvent systems for extraction of natural and synthetic products

CO 3: Apply the knowledge in recovery and recycling of solvents

CO 4: Demonstrate the working principle of supercritical fluid extraction

Syllabus

Units	Content	Hours
Unit I:	Solvent Extractions: The distribution coefficient, distribution ratio, relation between KD& D, and the percent extracted. Solvent extraction of metals – ion association complexes, metal chelates, the effect of pH and reagent concentration, the extraction process, separation efficiency of metal chelates, analytical separations – multiple counter current distribution, solid phase extraction, solvent extraction of flow injection analysis. Supercritical fluid extraction. Organic reagents in Inorganic analysis: Extraction of metal ions by the use of organic reagents – acetylacetone, thionyl-trifluoro acetone, tri-n-octyl phosphine oxide. Applications to extractions of metal ions by chelating agent (Dithizone, 8-hydroxy quinoline, and cupferron) Determination of salts of organic acids and bases, determination of alkaloids in crude drugs	15
Unit II:	Supercritical Fluid chromatography (SFC) and Electrophoresis: Instrumentation of SFC stationary and mobile phases used in SFC, Detectors, Advantages of SFC. Technique and applications of SFC. Size Exclusion Chromatography: Principle of Gel Chromatography, Filtration Chromatography, Instrumentation, retention behavior, resolution, selection of gel type – applications. Ion Exclusion – Principle and applications. Ultra-Performance Liquid Chromatography: Principle, Instrumentation Electrophoresis: Introduction, Definition Paper Electrophoresis: Principle, Experimental Requirements, Technique, Factors governing the migration of ions, Applications Capillary Electrophoresis: Electro osmotic flow, migration in CE, instrumentation, control of separation, applications Gel Electrophoresis: Principle, instrumentation, separation mechanism, agarose and polyacrylamide gel electrophoresis, visualization techniques, and applications.	15

CO-PO Mapping Table

	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	2	2	-	-
CO 2	3	2	2	-	1
CO 3	2	3	3	1	1

CO 4	3	3	2	1	1
Average	2.75	2.50	2.25	0.50	0.75

Correlation levels:**1 - Low, 2 - Moderate, 3 - High****Justification for CO-PO Mapping**

COs	Justification
CO 1	Develops understanding of solvent extraction principles and partition coefficients (PO1) while enhancing analytical interpretation skills (PO2, PO3).
CO 2	Strengthens knowledge of different solvent systems and extraction methods (PO1) and develops analytical competency in selecting suitable separation techniques (PO2, PO3).
CO 3	Enhances technical and analytical skills related to solvent recovery and recycling (PO2) and promotes problem-solving abilities in sustainable chemical processes (PO3, PO4).
CO 4	Develops understanding of supercritical fluid extraction and advanced separation techniques (PO1), while strengthening analytical skills and introducing research-oriented applications (PO2, PO4).

Reading references:

1. M. N. Sastri. *Separation Methods*. Himalaya Publishing House, Mumbai. 1991, 1st Ed.
2. D. A. Skoog; F. J. Holler; T. A. Nieman. *Principles of Instrumental Analysis*. Harcourt College Publishers, Orlando. 1998, 5th Ed.
3. G. D. Christian. *Analytical Chemistry*. John Wiley & Sons Inc., New York. 1994, 6th Ed.
4. R. A. W. Johnstone; M. E. Rose. *Mass Spectrometry for Chemists and Biochemists*. Cambridge University Press, Cambridge. 1996, 2nd Ed.
5. E. A. V. Ebsworth; D. W. H. Rankin; S. Cradock. *Structural Methods in Inorganic Chemistry*. ELBS Publications, London. 1988, 2nd Ed.
6. R. P. W. Scott. *Introduction to Analytical Gas Chromatography*. Marcel Dekker Inc., New York. 1988, 2nd Ed.

CH5 EAN4: APPLIED ANALYSIS AND GREEN ANALYTICAL CHEMISTRY (L-T-P-C: 2-0-0-2)

Program: M. Sc. Chemistry	Semester: III
Course code: CH5 EAN4	Course name: APPLIED ANALYSIS AND GREEN ANALYTICAL CHEMISTRY

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
2 per week	-	2	30	Lecture	CCE, ESE	50	18

Course Objectives: To provide a comprehensive understanding of the scope and real-world significance of applied analytical chemistry across the pharmaceutical, clinical, agricultural, and forensic sectors. The course aims to build advanced competence in monitoring environmental and food quality indices, including BOD, COD, and trace toxicities, using specialized classical and instrumental procedures. Furthermore, it instills a strong foundational focus on the pillars of Green Analytical Chemistry (GAC), empowering students to design, optimize, and evaluate eco-friendly solvents, miniaturized architectures, and sustainable analytical practices that align with global regulatory frameworks.

Course Outcomes: At the end of this course students will be able to

CO 1: Understand the commercial scope, industrial significance, and operational workflow of applied analytical chemistry across pharmaceutical, environmental, agricultural, forensic, and clinical sectors.

CO 2: Explain the foundational chemistry, standard operating protocols, and diagnostic limits of analytical assays used in drug screening, water quality testing, food adulteration tracking, and forensics.

CO 3: Apply classical and modern instrumental techniques to isolate and precisely quantify trace metals, toxins, bio-macromolecules, and key environmental metrics like COD, BOD, and TDS.

CO 4: Describe the twelve principles of Green Analytical Chemistry (GAC), evaluating green extraction protocols, micro-sampling formats, eco-friendly solvents, and waste-reduction dynamics.

CO 5: Evaluate and audit analytical workflows against global sustainability development goals, regulatory safety compliance, and eco-scale assessment criteria.

Syllabus

Units	Content	Hours
Unit I: Applied Analysis	Introduction to Applied Analysis (Definition and scope, role of analytical chemists in industry and research), pharmaceutical applications (assay and impurity profiling, dissolution testing and drug release studies, stability testing and validation protocols), Environmental and Water Analysis (analysis of trace metals and pollutants, Water quality parameters - COD, BOD, TDS), Food and Agricultural Analysis (Nutrient profiling - Detection of adulterants, preservatives, pesticides), Forensic and Clinical Applications: Analysis of toxins, drugs, and biological fluids. ICH guidelines, ISO/IEC 17025 laboratory accreditation	15
Unit II: Green Analytical Chemistry	Introduction to Green Analytical Chemistry: 12 principles and importance of Green Chemistry, Greening sample preparation: solvent-free methods: SPME, MAE, SFE, Solid-phase extraction (SPE) and microextraction, green solvents and miniaturization, Green instruments: Use of spectroscopic techniques (UV-Vis, FTIR, NIR, Raman), Electroanalytical methods (voltammetry, amperometry), Green chromatography and electrophoresis, Flow injection analysis (FIA) . Case studies involving green analytical technique in food analysis, pharmaceuticals, environmental monitoring. Role of GAC in sustainable development goal. Assessment of greenness of analytical methods (Analytical Eco-Scale, GAPI, AGREE). Miniaturization and automation in Green Analytical Chemistry. Circular economy and waste minimization in analytical laboratories.	15

CO-PO Mapping Table

	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	2	3	1	2	-
CO 2	3	3	3	-	-
CO 3	2	3	2	1	3
CO 4	3	3	2	2	-
CO 5	3	3	3	-	1
Average	2.60	3.00	2.20	1.00	0.80

Correlation levels:

1 - Low, 2 - Moderate, 3 - High

Justification for CO-PO Mapping

COs	Justification
CO 1	Mapping out the analytical needs of varied industries builds an expansive, integrated scientific baseline (PO 1). Recognizing how cross-sector labs run shapes systematic thinking (PO 3) and alerts students to professional collaboration demands in multi-disciplinary fields (PO 4, PO 5).
CO 2	Explaining the mechanics behind complex forensic and drug assays directly bridges core chemical principles with targeted field applications (PO 1, PO 3). Disseminating these standard methods cleanly builds systematic reporting skills (PO 4) while highlighting legal and civic safety responsibilities (PO 5).
CO 3	Assaying trace environmental parameters like Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Dissolved Solids (TDS) demands highly specialized experimental proficiency (PO 2). Executing these validation frameworks drives independent scientific deduction (PO 3) and directly protects environmental ecosystems (PO 5).
CO 4	Studying Green Analytical Chemistry (GAC) frameworks expands core chemical knowledge (PO 1) into modern engineering loops. Optimizing miniaturized, low-solvent sample preparation lines translates theory into advanced laboratory problem-solving (PO 3), pushing directly toward green, low-waste sustainability goals (PO 5).
CO 5	Auditing industrial protocols against global eco-scales and strict safety thresholds forces students to critically evaluate chemical processes (PO3). Managing these regulatory baselines develops professional leadership and corporate ethics (PO 4), directly contributing to responsible innovation and environmental sustainability (PO 5).

Reading references:

1. G. D. Christian. *Analytical Chemistry*. John Wiley & Sons Inc., New York. 1994, 6th Ed.
2. H. Marck; J. Rekniz. *Kinetics Methods of Analysis*. Marcel Dekker Inc., New York. Volume 25.
3. A. H. Beckett; J. B. Stenlake. *Practical Pharmaceutical Chemistry, Vol. 1 & Vol. 2*. CBS Publishers & Distributors, New Delhi. 1986, 3rd Ed.
4. M. De La Guardia; S. Armenta. *Green Analytical Chemistry: Theory and Practice*. Elsevier, Amsterdam. 2010, 1st Ed.
5. M. Koel; M. Kaljurand. *Green Analytical Chemistry*. RSC Publishing, Cambridge. 2010, 1st Ed.
6. A. Gałuszka; Z. Migaszewski; J. Namieśnik. *The 12 Principles of Green Analytical Chemistry. TrAC Trends in Analytical Chemistry*, Elsevier, Amsterdam. 2013, Vol. 50, pp. 78–84.

SEMESTER IV**SYLLABUS WITH COURSE LEARNING OUTCOME (CLO)****CH5 AN201: RESEARCH OR INDUSTRIAL PROJECT (L-T-P-C: 0-0-20-10)**

Program: M. Sc. Chemistry	Semester: IV
Course code: CH5 AN201	Course name: RESEARCH OR INDUSTRIAL PROJECT

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
-	20 per week	10	150	Lab	CCE, ESE	100	35

Course Description: This is a compulsory course performed in the final semester where the students get a semester-long exposure to research.

- Students who work on research and industrial projects gain valuable training and experience that can help them in their future careers.
- Students can work on real-world research projects proposed by industry or public sector sponsors.
- This course helps to train individuals who contribute to human resources required in the chemical/pharmaceutical industry.
- The research work may lead to academic research articles as well.
- They also learn about patents, scientific publications, and literature search tools

Course Learning Outcomes: At the end of this course students will be able to

CO 1: Understand the real-world academic/industrial research problems

CO 2: Apply the knowledge gained during various theoretical and practical courses

CO 3: Design different projects with the knowledge of chemistry to solve existing problems in society

CO 4: Understand data interpretation and data analysis

CO 5: Learn to reboot any experimental problems.

Syllabus: Lab-specific research topics.

CH5 AN202: PROJECT REPORT (L-T-P-C: 2-0-0-2)

Program: M. Sc. Chemistry	Semester: IV
Course code: CH5 AN202	Course name: PROJECT REPORT

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
2 per week	-	2	30	Lecture	CCE, ESE	100	35

Course Description: In this course, the students learn to summarise their learning experiences.

- They learn the proper ways to write a 'project thesis'.
- This contains a comprehensive overview of a project's objectives, progress, team performance, and milestone accomplishments.
- It also gives an account of the challenges faced during a project's execution, solutions devised to tackle them, and the lessons learned during the process.
- They also learn about different communication medium like Microsoft word, chemdraw etc.

Course Learning Outcomes: At the end of this course students will be able to

CO 1: Understand how to report a practical work into a thesis

CO 2: Learn to publish their research results after the program **CLO3:**

Learn the art of written scientific communications

Syllabus: Depends on the research performed in respective labs.

CH5 AN203: PROJECT PRESENTATION (L-T-P-C: 3-0-0-3)

Program: M. Sc. Chemistry	Semester: IV
Course code: CH5 AN203	Course name: PROJECT PRESENTATION

Lecture (Hours)	Practical (Hours)	Credits	Total Hours	Evaluation Scheme			
				Component	Exam	Max. Marks	Passing %
3 per week	-	3	45	Lecture	CCE, ESE	100	35

Course Description: In this course, the students mainly learn to communicate their work performed to the audience.

- They learn to use different communication mediums (for example Microsoft PowerPoint) and convince their audience about the research findings.
- This course helps students to increase confidence, presence, and enjoyment of public speaking.
- The students also learn to use vocal techniques; use tone, range, articulation, power, pace, and pausing to make an impact.
- The students learn the use of body language and gestures to create credibility.

Course Learning Outcomes: At the end of this course students will be able to

CO 1: Develop proper communication skills.

CO 2: Defend their accomplished research in front of experts.

CO 3: Gain confidence in facing job interviews.

Syllabus: Depends on the research performed in respective labs.

~:The End:

