Syllabus

M.Sc. in Chemistry

DEPARTMENT OF CHEMISTRY

KRISHNAGURU ADHYATMIK VISVAVIDYALAYA

2025

<u>Syllabus Contents</u>

Programme: Master of Science

Department: Chemistry

About the Department:

Established in 2023, the Department of Chemistry has been delivering higher education in chemistry through its active M.Sc. and Ph.D. programs. The department's curriculum is structured to ensure students develop a strong grasp of the subject. It has already built robust collaborations with prominent research institutes in the region for joint research efforts. Present research areas mainly include environmental chemistry, synthetic methodologies, and catalysis.

Academic Focus:

The Department concentrates on areas that demonstrate the latest advancements in current research, with a commitment to advancing teaching and research in these branches of chemistry. We work closely with various stakeholders and organizations to incorporate new perspectives and resources into our academic and research activities.

Career Scope:

The Department of Chemistry at **Krishnaguru Adhyatmik Visvavidyalaya** has designed its curriculum to offer students a strong foundation in both fundamental and applied aspects of chemistry. Career prospects for chemistry graduates span five primary sectors: industry, academia, government, non-profit organizations, and entrepreneurship.

Programme Details:

The Department of Chemistry provides a two-year Master of Science (M.Sc.) program structured across four semesters. Designed for students seeking careers in academia, industry, or research and development, the program imparts comprehensive knowledge, practical skills, and expertise to help students succeed in the field of chemistry.

Eligibility Criteria: B.Sc. 50 % marks.

Programme Objectives (PO)

The program provides essential scientific knowledge and skills needed for success in the field. It places a strong emphasis on teaching proper laboratory methods and safety procedures, equipping students for careers in higher education and research and development. Furthermore, the program helps students build solid scientific competencies while encouraging ethical conduct and social responsibility.

Programme Specific Outcomes (PSO)

Programme Name: Master of Science

Programme Code: M.Sc.

PSO-1: Gain a thorough understanding of the fundamental theories underlying the creation of new substances.

PSO-2: Effectively use techniques for qualitative and quantitative chemical analysis in both laboratory and industrial settings.

PSO-3: Develop analytical and problem-solving abilities that involve the application of chemical concepts.

PSO-4: Become acquainted with various branches of chemistry, including analytical, organic, inorganic, physical, spectroscopy, quantum, environmental, polymer, and biochemistry.

PSO-5: Build the capacity to conduct independent research.

PSO-6: Comprehend key environmental issues and explore sustainable solutions.

Programme Structure:

The M.Sc. programme is a two year program divided into four semesters. The programme is of 120 credits and for the award of degree a student will be required to complete the credits as per the University norm.

SEMESTER-I

Course Code	Course Title	Credit	Nature of course (T/P)	Marks Allotted		
				Internal	End Semester	Total
MSC-CHE-1016	Organic Chemistry-I	06	T	20	80	100
MSC-CHE-1026	Inorganic Chemistry-I	06	T	20	80	100
MSC-CHE-1036	Physical Chemistry-I	06	T	20	80	100
MSC-CHE-1046	Quantum Chemistry	06	T	20	80	100
MSC-CHE-1056	Organic Chemistry Practical	06	P	20	80	100
Total		**30**		**100**	**400**	**500**

VAC-1064	English Communication	04	T	20	80	100
SS-1011	Spiritual Studies	01	T	---	50	50

SEMESTER-II

Course Code	Course Title	Credit	Nature of course (T/P)	Marks Allotted		
				Internal	End Semester	Total
MSC-CHE-2016	Organic Chemistry-II	06	T	20	80	100
MSC-CHE-2026	Inorganic Chemistry-II	06	T	20	80	100
MSC-CHE-2036	Physical Chemistry-II	06	T	20	80	100
MSC-CHE-2046	Spectroscopy-I	06	T	20	80	100
MSC-CHE-2056	Inorganic Chemistry Practical	06	P	20	80	100
Total		**30**		**100**	**400**	**500**

VAC CHEM-2064	Environmental Chemistry	04	T	20	80	100
SS-2011	Spiritual Studies	01	T	---	50	50

SEMESTER-III

Course Code	Course Title	Credit	Nature of course (T/P)	Marks Allotted		
				Internal	End Semester	Total
MSC-CHE-3016	Organic Chemistry-III	06	T	20	80	100
MSC-CHE-3026	Inorganic Chemistry-III	06	T	20	80	100
MSC-CHE-3036	Physical Chemistry-III	06	T	20	80	100
MSC-CHE-3046	Spectroscopy-II	06	T	20	80	100
MSC-CHE-3056	Physical Chemistry Practical	06	P	20	80	100
Total		**30**		**100**	**400**	**500**

SEC CHEM-3064	Chemistry in Everyday Life	04	T	20	80	100
SS-3011	Spiritual Studies	01	T	---	50	50

SEMESTER-IV

Course Code	Course Title	Credit	Nature of course (T/P)	Marks Allotted		
				Internal	End Semester	Total
MSC-CHE-4016	Organic Chemistry-IV	06	T	20	80	100
MSC-CHE-4026	Inorganic Chemistry-IV	06	T	20	80	100
MSC-CHE-4036	Physical Chemistry-IV	06	T	20	80	100
MSC-CHE-4046	Project Dissertation	12	P	40	160	200
Total		**30**		**100**	**400**	**500**

DSE-CHEM-4054 or AEC-CHEM-4064	Green Chemistry and Sustainable Technology or Analytical Chemistry	04	T	20	80	100
SS-4011	Spiritual Studies	01	T	---	50	50

SEMESTER-I

Semester-I
Course Code: MSC-CHE-1016
Course Title: Organic Chemistry-I

Marks: 20+80=100
Total Credits: 06

Objective: To introduce fundamental principles of structure and reactivity in organic chemistry, mechanisms of substitution and elimination reactions, and foundational concepts in stereochemistry for analyzing and predicting organic reaction behavior.

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

1. Understand electronic effects, aromaticity, and reactive intermediates.
2. Analyze mechanisms of nucleophilic substitution, elimination, and electrophilic substitution reactions.
3. Interpret stereochemical representations and apply conformational analysis.
4. Evaluate stereoselective and asymmetric synthesis using models like Cram's and Felkin-Ahn.

Contents:

Unit I: Structure and Reactivity

Strength of acids and bases. Introduction to aromaticity in Benzenoid and non–Benzenoid compounds, Azulenes, Tropolenes, (4n+2) Huckel rule and it's applications, Frost diagram. Effect of structure on reactivity. The Hammett equation and linear free energy relationship, modifications of Hammett equation. Generation, structure, stability and reactivity of carbocations, carbanions, free radicals, carbenes, nitrenes, and benzynes.

Unit II: Reaction Mechanism I

Nucleophiles-definition, types-anionic, neutral, hard, soft, ambident. Reactivity effect of substrate structure, effect of attacking nucleophiles, leaving groups and reaction medium. Neighbouring group participation.

Nucleophilic substitution reactions – SN^1, SN^2 and SN^i mechanism and stereochemistry. Aromatic Nucleophilic Substitution: The SNAr, SN^1, benzyne and SRN^1 mechanisms.

Nucleophilic substitutions at an allylic, aliphatic trigonal and vinylic carbons. Isotope labeling and kinetic isotope effects.

Unit III: Reaction Mechanism II

Elimination reactions: E^1, E^2, E^{1CB}; mechanism, orientation and stereochemistry of Elimination, Protection-deprotection chemistry of selected functional groups such as aldehydes, ketone and -OH, –NH2.

Aromatic Electrophilic Substitution: The arenium ion mechanism, orientation and reactivity, energy profile diagrams. The ortho/para ratio, orientation in other ring system. Quantitative treatment of reactivity in substrates and electrophiles.

Unit IV: Stereochemistry

Fischer, Newman, Sawhorse and flying wedge projections and their interconversions. Conformational analysis of aliphatic organic molecules, cycloalkanes and decalins. Effect of conformation on reactivity in acyclic and cyclohexane systems. Molecules with more than one asymmetric centre e.g. erythro and threo compounds, D, L notations. R, S notations of biphenyles and allenes. Concepts of stereogenic centres – chirotopic and achirotopic centres, homotopic and heterotopic ligands and faces, optical purity and enantiomeric excess.

Chirality due to helical shape, a brief Study of dissymmetry of allenes, biphenyls and spiro compounds. Stereo specific and stereo selective reactions. Asymmetric synthesis, enantioselective and diastereoselective synthesis. Cram's and Prelog's rule, Cram model, Felkin-Ahn model.

References/ Text Books:

1. Organic Chemistry, Vols I and II – I. L. Finar, ELBS.
2. Organic Chemistry – R. T. Morrison, R. N. Boyd and S. K. Bhattacharjee, Prentice Hall India Limited
3. Organic Chemistry – Paula Yurkanis Bruice, Pearson

4. Advanced Organic Chemistry: Reaction Mechanism and Structure – Jerry March, Wiley Eastern

5. Stereochemistry and Mechanism through Solved Problems- P.S. Kalsi, New Age International Publishers.

6. Introduction to Spectroscopy – by Donald L. Pavia, Cengage Learning India Private Limited

7. Stereochemistry of Carbon Compounds–Subrata Sengupta, New Central Book agency, Kolkata

8. Organic Reaction Mechanism, Christine Willis and martin Willis, Oxford chemistry Primers (No. 74)

9. Disconnection Approach in Organic Synthesis – S. Warren, Wiley

10. Designing Organic Synthesis – S. Warren, Wiley, Chichester

11. The Logic of Organic Synthesis – E.J. Corey and Xue Min Chen, Wiley, New York

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Semester-I
Course Code: MSC-CHE-1026
Course Title: Inorganic Chemistry-I

Marks: 20+80=100
Total Credits: 06

Objective: To provide a comprehensive understanding of f-block elements, acid-base and redox chemistry, bioinorganic systems, and coordination chemistry, focusing on their structure, properties, and applications.

Course Outcome: Upon successful completion of the course, students will be able to:

1. Explain the properties and chemistry of lanthanides and actinides.
2. Understand acid-base theories, redox reactions, and electrochemical principles.
3. Analyze the roles of metal ions in biological systems and metalloproteins.
4. Apply coordination chemistry concepts, including bonding, isomerism, and crystal field theory.

Contents:

Unit I: The f-block elements-Lanthanides and Actinides

Electronic Configuration, Occurrence and recovery, General trends. Electronic, Optical and Magnetic properties. Coordination and organometallic compounds. Magnetic properties of Lanthanides and Actinides.

Unit II: Acid Base and Redox Chemistry

Acid-Base concepts, Measure of Acid-Base Strengths, Acid-Base in water. Non- aqueous solvent, aprotic solvent and super acids. Hard and Soft Acids and Bases, application of HSAB principle.

Half cell reaction, reduction potential, application of reduction potential data, electrochemical series; brief idea of corrosion and its prevention; Nernst equation. Latimer and Frost diagram (V, Mn Fe, Cu etc.), disproportionation reaction; cyclic voltammetry.

Unit III: Bioinorganic Chemistry I

Fundamentals of inorganic biochemistry, essential, non-essential and role of 3d block elements and non-metals in bio-systems. Natural and synthetic oxygen carriers, Porphyrins, model compounds for oxygen binding and carriers: Hemoglobin, myoglobin, hemerythrin, hemocyanin, Electron transfer protein: Cytochromes, Iron-Sulphur, Nitrogen fixation. Metalloenzymes, corrinoids (vitamin B12 and co-enzyme), carboxy-peptidases, chlorophyll and photosynthesis, Na-K or ATPase or sodium pump, crown ethers, futuristic aspects of organo-transition metal complexes in bioinorganic chemistry.

Unit IV: Coordination Chemistry

Coordination compounds, types of ligands, Werner's theory, IUPAC nomenclature and isomerism in coordination compounds. Stereochemistry of complexes with 4 and 6 coordination numbers.

Drawbacks of VBT. Crystal field effect, octahedral symmetry. Crystal field stabilization energy (CFSE), Crystal field effects for weak and strong fields. Tetrahedral symmetry. Factors affecting the magnitude of D. Spectrochemical series. Comparison of CFSE for Oh and Td complexes, Tetragonal distortion of octahedral geometry. Jahn-Teller distortion, Square planar coordination.

Reference/ Textbooks:

1. J. E. Huheey, E. A. Keiter, R. L. Keiter& O. K. Medhi. Inorganic Chemistry: Principles of Structure and Reactivity, Pearson Education (2006).
2. F. A. Cotton, G. Wilkinson, C. A. Murillo & M. Bochmann. Advanced Inorganic Chemistry (6th edition), John Wiley (1999).
3. M. Weller,T. Overton, J. Rourke, & F. Armstrong, Inorganic Chemistry, Oxford University Press , 6th edition.
4. J. D. Lee, Concise Inorganic Chemistry, Elbs, Chapman and Hall, 2006.
5. G. L.Meissler and D. A. Tarr; Inorganic Chemistry, 3rd. Edition, Pearson.
6. B. Douglas, D. McDaniel and J. Alexander. Concepts and Models of Inorganic Chemistry (3rd edn.), John Wiley & Sons (1994).
7. B. R. Puri, L. R. Sharma and K. C. Kalia; Principles of Inorganic Chemistry. Vishal Pub. 2016.

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Semester-I
Course Code: MSC-CHE-1036
Course Title: Physical Chemistry-I

Marks: 20+80=100
Total Credits: 06

Objective: To build a foundational understanding of chemical kinetics, thermodynamics, liquid state properties, and analytical data evaluation, with an emphasis on theoretical principles and practical applications.

Course Outcome: After completing this course, students should be able to:

1. Analyze reaction kinetics using rate laws and theoretical models like collision and transition state theory.
2. Apply thermodynamic principles to chemical equilibria, real systems, and phase behavior.
3. Understand and explain properties of liquids such as viscosity and surface tension.
4. Evaluate experimental data with appropriate error analysis and statistical tools.

Contents:

Unit I: Chemical Kinetics

The concept of reaction rate, Effect of temperature, pressure, Catalyst and other factors on reaction rate, Order and molecularity of reaction, Derivation of integrated rate equation of zero, first , second order reaction, Collision theory of reaction rates, collision cross-sections, rate coefficient, steric factor, Straight chain reactions, the hydrogen-oxygen reaction, explosion limit. Theory of absolute reaction rates, activated complex theory, thermodynamic interpretation, Arrhenius equations, Numerical Problems.

Unit II: Equilibrium Thermodynamics

Brief review of thermodynamic functions and laws of thermodynamics. Temperature dependence of thermodynamic functions. Gibbs-Helmholtz equation, partial molar properties: partial molar Gibbs free energy, partial molar volume, partial molar heat content and their significances. General methods of determination of partial molar properties – Gibbs-Duhem and Gibbs-

Duhem- Margules equation, excess thermodynamic functions. Third law of thermodynamics, calculation of entropy, Residual entropy.

Non-ideal system: thermodynamics of real gases and gas mixtures, fugacity and its determination, non-ideal solutions, activity and activity coefficient, Thermodynamic criteria of phase equilibrium, Gibbs phase rule and its application to one, two & three component systems - triangular plots-water- acetic acid-chloroform system.

Unit III: Liquid State:

Qualitative treatment of structure of liquid state, Physical properties of liquid, Vapor pressure, Surface tension, Viscosity, Co-efficient, Application of viscosity and surface tension, Explanation of cleansing action of detergent and soap, Temperature variation of viscosity of liquid and comparison.

Unit IV: Errors and Evaluation of Analytical Data

Definition of terms, Precision, deviation, mean deviation, standard deviation, accuracy, absolute errors, types of errors determinate, indeterminate and gross errors, sources of errors and their effect on final result, Methods of reporting analytical data, Indeterminate errors, Significant figures, Problems.

Reference/ Textbooks:

1. Principles of Physical Chemistry: by Puri, Sarma & Pathania, Vishal Publishing Co. **(2020)**
2. A Text Book of Physical Chemistry: by K. L. Kapoor, McGraw-Hill **(2020)**
3. A Textbook of Physical Chemistry: by A.S. Negi & S.C. Anand, New Age International (P) Ltd **(2016)**
4. Atkins Physical Chemistry: by Peter Atkins, OUP Oxford **(2019)**
5. A Textbook of Physical Chemistry: by K K Sharma & L K Sharama, VIKAS PUBLISHING (6^{th} edition).
6. Physical Chemistry: by IRA N. Levine, McGraw Hill Education **(2011)**

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Semester-I
Course Code: MSC-CHE-1046
Course Title: Quantum Chemistry

Marks: 20+80=100
Total Credits: 06

Objective: To introduce the foundational principles and mathematical formulations of quantum mechanics and apply them to molecular systems and spectroscopy.

Course Outcome: Students completing the course will gain the ability to:

1. Understand and apply the postulates of quantum mechanics to model systems.
2. Solve the Schrödinger equation for simple systems like particle in a box, harmonic oscillator, and hydrogen atom.
3. Analyze electronic structure using Born-Oppenheimer approximation and quantum mechanical operators.
4. Apply molecular orbital theories (HMO, extended Hückel) and understand the basics of band theory.

Contents:

Unit I: Principles of Quantum Mechanics

Review of the basic principles of quantum mechanics: Postulates, Schrödinger equation, normalization and orthogonalization of wave function. Expectation values, Quantum mechanical operators, Hamiltonian operator, Hermitian operators, angular momentum operator.

Unit II: Born-Oppenheimer Approximation

Born-Oppenheimer approximation, product wave-functions, complete many electron wave functions including electron spin, Pauli's anti-symmetry and exclusion principles, Singlet and triplet states, central field model of many electron atoms (He atom), Slater type orbitals, splitting of term energies in presence of electric and magnetic field (Stark effect and Zeeman effect).

Unit III: Model Systems

Translational Motion: Free particle and particle in a box (one, two and three dimensional) Qualitative treatment of simple harmonic oscillator model of vibrational motion: Setting up of

Schrödinger equation and discussion of solution and wavefunctions. Vibrational energy of diatomic molecules and zero-point energy. Hermite polynomials, rigid rotor, particle in a ring, quantum mechanical tunneling.

Unit IV: Solution of Eigenvalue Equations

Solutions of the energy eigenvalue equations for particles in a ring, Rigid Rotor, The angular momentum, QM treatment of H-atom.

QM treatment of Harmonic Oscillator, Free electron MO theory of benzene; HMO treatment for unsaturated carbon compounds, extended Hückel Theory, elements of band theory.

References/ Textbooks:

1. Introductory Quantum Chemistry, A. K. Chandra. Tata McGraw Hill, 1994.

2. Quantum Chemistry, I. N. Levine, Prentice Hall India, 2001.

3. Quantum Chemistry, B K Sen

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Semester-I
Course Code: MSC-CHE-1056
Course Title: Organic Chemistry Practical

Marks: 20+80=100
Total Credits: 06

Objective: To develop hands-on skills in chromatographic separation, qualitative analysis, and organic synthesis techniques, enabling students to identify, purify, and prepare organic compounds efficiently.

Course Outcome: The course outcomes include the ability to:

1. Perform chromatographic techniques (TLC, column, and paper chromatography) for purification and separation.
2. Systematically detect elements and functional groups in solid organic samples.
3. Carry out classical and modern organic synthesis reactions and identify the products.
4. Analyze mixtures and interpret R_f values to support compound identification and purity assessment.

Contents:

1.

a) Purification of binary mixtures by Thin Layer Chromatography (TLC) and Column Chromatography (CC).
b) Purification of tertiary mixtures of amino acids by Paper Chromatography.

2. Qualitative Analysis of solid organic sample

i. Detection of elements (N, Cl, Br, I, S), solubility test, unsaturation and aromaticity.
ii. Systematic Analysis to detect the functional groups:
Alcoholic/phenolic OH, carboxylic, aldehyde, ketone, ester, ether, nitro, amido, N-substituted amino, imido groups.

3. Organic preparations:

a) Esterification and saponification

b) Nucleophilic substitution

c) Cycloaddition reaction

d) Grignard reaction

e) Condensation reaction

f) Preparation of dyes

g) Aromatic electrophilic substitution

h) Heterocyclic synthesis

i) Pinacol-Pinacolone rearrangement

j) Benil-Benzilic acid rearrangement

k) Aspirin

4. Separation of mixtures by chromotohraphy; Measure the R_f value in each case (combination of two compounds to be given).

5. Extraction of Natural products: any one of the following - caffeine, nicotine, piperine, carotenoids.

References/ Textbooks:

1. R. K. Bansal, Laboratory of organic chemistry (3rd edn), Wiley-Eestern, 1994.
2. 2. R. K. Brewster & W. E. Mcwerdn. Unitized experimental organic chemistry (4th edn), East-West press (1977).
3. 3. A. I. Vogel, Practical organic chemistry (5th edn), Longman Group Ltd. (2009).
4. V K Ahluwalia, R Agarwal. Comprehensive Practical organic chemistry – preparation and quantitative analysis, University Press (2013)
5. O. Fitton & R. K. Smallery, Practicat heterocyclic chemistry.
6. R. L. Shriner & R. C. Fusion, Systematic Identification of organic compounds (5th edn.), John Wiley Sons (1964).

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SEMESTER-II

Semester-II
Course Code: MSC-CHE-2016
Course Title: Organic Chemistry-II

Marks: 20+80=100
Total Credits: 06

Objective: To provide foundational knowledge of heterocyclic compounds, biomolecules, photochemical reactions, and bioorganic chemistry, emphasizing their structure, reactivity, and biological relevance.

Course Outcome: Through this course, students will acquire the competence to:

1. Understand the structure, nomenclature, and reactivity of common heterocyclic compounds.
2. Explain the chemistry and biological importance of amino acids, peptides, and proteins.
3. Describe the principles and mechanisms of key photochemical reactions.
4. Analyze the structure, properties, and metabolism of carbohydrates and their role in biological systems.

Contents:

Unit-I: Chemistry of Heterocyclic compounds

Nomenclature of heterocyclic compounds: Five- membered ring- Furan, Pyrrole, Thiophene; Six-membered ring- Pyridine; Condensed five-membered heterocycles-Indole; Condensed six-membered heterocycles- Quinoline, Iso quinoline.

Unit-II: Chemistry of amino acids, peptides and proteins

Classification of amino acids, methods of preparations, reactions of amino acids. Isoelectric point of amino acids and its determination. Absolute configuration of amino acids. Peptides: peptide linkage, nomenclature of polypeptides, general principles of polypeptide synthesis, protection of amino and carboxylic groups. Determination of structure of peptides. Proteins: General properties, classification and detection of protein. Primary, tertiary, secondary and quaternary structures of proteins. Biosynthesis of amino acids.

Unit-III: Photochemistry

Principle of Photochemistry, Electronic excitation, Excited state, Modes of dissipation of energy, Energy transfer, Quantum efficiency, Photochemistry-Cis-trans isomerisation, Norrish type I & II reaction, Paterno-Buchi reaction, photo reduction of Ketones, dipimethane rearrangement, photochemistry of arenes, Barton reaction.

Unit-IV: Bioorganic Chemistry

Characteristics and properties of carbohydrates, monosaccharides, open chain and ring structure, Haworth and conformational representations, oxidation, determination of ring size, glycosides, anomeric effect; Oligosaccharides and Polysaccharides-sucrose and other oligosaccharides, starch, cellulose and other polysaccharides. Energy generation in living systems, metabolism of carbohydrate (Glucose), glycolysis and Kreb'scycle, Standard free energy change in biochemical reactions. ATP as biochemical currency, ATP-ADP cycle. cell membrane. transmembrane potential, active transport of ions through cell membranes, membrane equilibrium, muscular contraction.

References/ Textbooks:

1. Organic Chemistry: by I. L. Finar (Part I & II), Longman Group Ltd. (6^{th} edition), (2009)
2. Lehniger Principles of Biochemistry by David L. Nelson & Michael M. Cox, Macmillan Worth Publishers (2011).
3. Organic Chemistry of Natural Products (Vol. I & II) by Gurdeep R. Chatwal, Himalaya Publishing House (2013).
4. Pericyclic reactions: A mechanistic study by S. M. Mukherji, Macmillan Co. of India Ltd (2011)
5. Pericyclic reactions by Ian Fleming, Oxford Chemistry Primers, (2^{nd} edition), (2015)

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Semester-II
Course Code: MSC-CHE-2026
Course Title: Inorganic Chemistry-II

Marks: 20+80=100
Total Credits: 06

Course Objective: To impart a comprehensive understanding of organometallic reaction mechanisms, the chemistry and magnetic behavior of transition metals, and redox processes with applications in coordination and environmental chemistry.

Course Outcome: Upon successful completion of the course, students will be able to:

1. Explain the mechanisms of key organometallic reactions and their role in catalysis and polymerization.
2. Understand the structure, bonding, and reactivity of d-block elements, including metal carbonyls, clusters, and charge-transfer complexes.
3. Analyze magnetic properties of transition metal complexes using theoretical and experimental methods.
4. Apply redox concepts and electrochemical diagrams (Latimer, Frost, Pourbaix) to predict chemical behavior and environmental processes.

Contents:

Unit-I: Reactivity of Organometallic compounds

Organometallic reaction mechanisms-ligand substitution, oxidative addition, reductive elimination, Migration, insertion and deinsertion reactions and carbine involvement in metathesis and polymerization. Nucleophilic and electrophilic attack of coordinated ligands.

Unit-II: Chemistry of d-block elements

Definition and General Characteristics of Transition Metals, Oxidation state, Comparisons of First and Second and Third transition Series. Important Chemistry with reference to

(i) Polyoxometallates and heteropolyoxometallates of Mo and W.

(ii) Intermolecular charge transfer complex: Cruetz-Taubeion; tungsten bronze and ruthenium red.

(iii) Metal Carbonyls: Bonding and structure. Carbonyl Clusters-synthesis, Hetero atoms in clusters, Electron counting in medium size clusters, capping rule.

(iv) Dinitrogen and Nitrosyls complexes: Bonding and structure.

(v) Non-Carbonyl Clusters-halide clusters, Multiple Metal-Metalbonds, quadruple bonds.

Unit-III: Magnetic properties of transition metals

Study of different types of magnetic behavior, measurement of magnetic susceptibility using Gouy and Faraday methods, spin-orbit coupling, quenching of orbital angular momenta, temperature- independent paramagnetism, spincrossover, application of crystal field theory to explain magnetic properties.

Unit-IV: Oxidation and reduction:

Standard potential and spontaneity, Nernst equation, Influence of pH, Disproportionation and Comproportionation, influence of complexation, relation-chemical reduction, oxidation and electrochemical extraction between solubility and standard potentials. Latimer diagrams, Frost diagrams, Pourbaix diagrams. Application in environmental chemistry: natural waters, Chemical extraction of elements.

References/ Textbooks:

1. P. Atkins, T. Overton, J. Rourke, M. Welle R & F. Armstrong, Shriver and Atkins, Inorganic Chemistry, Oxford University Press (2006).
2. F. A. Cotton, Chemical Applications of Group Theory, (3rdedn.), John Wiley & Sons (1999).
3. F. A. Cotton, G. Wilkinson, C. A. Murillo & M. Bochmann, Advanced Inorganic Chemistry (6th edition), John Wiley (1999).
4. J. E. Huheey, E. A. Keiter, R. L. Keiter & O. K. Medhi, Inorganic Chemistry: Principles of Structure and Reactivity, Pearson Education (2006).
5. F. A. Cotton, G. Wilkinson, C. A. Murillo & M. Bochmann., Advanced Inorganic Chemistry (4th edition), John Wiley, 1993.
6. Principles of the Solid State, H. V. Keer, Wiley Eastern Limited, 2007.
7. Inorganic and Organometallic Reaction Mechanisms (2nd Edition), Jim D. Atwood, Wiley-VCH 8. Inorganic Reaction Mechanisms, R. K. Sharma, Discovery Publishing House, 2007.

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Semester-II
Course Code: MSC-CHE-2036
Course Title: Physical Chemistry-II

Marks: 20+80=100
Total Credits: 06

Objective: To introduce key concepts in photochemistry, electrochemistry, catalysis, and gas behavior, with emphasis on theoretical understanding and practical applications in chemical systems.

Course Outcome: Upon successful completion of the course, students will be able to:

1. Understand the fundamental principles of photochemical processes and their applications, including fluorescence, phosphorescence, and photodynamic therapy.
2. Analyze ion-solvent and ion-ion interactions using electrochemical theories such as the Debye-Hückel model.
3. Describe the types, mechanisms, and characterization techniques of catalysts, including phase transfer and heterogeneous catalysis.
4. Apply kinetic theory to explain the behavior of gases and deviations in real gases using viscosity and molecular interaction parameters.

Contents:

Unit-I: Photochemistry

Principle of photochemistry, Lambert's law, Beers's law, Quantum Yield or Quantum efficiency, Fluoresce, Quenching of fluorescence, Phosphorescence, Difference between Fluoresce and Phosphorescence, Chemiluminescence, Photosensitization, Photocatalysis, Example of photodynamic therapy of tumor.

Unit-II: Dynamic Electrochemistry

Ion-solvent interactions, the Born model, thermodynamic parameters of ion-solvent interactions, Debye-Huckel theory of ion-ion interactions, extended Debye-Huckel equation, Debye Huckel limiting law, Debye-Huckel-Onsagar treatment and its extension to ion-solvent interactions.

Unit-III: Catalysis

Catalysts, classification of catalysts. Characterization of catalysts: methods of surface analysis, surface area, pore size, void fraction, particle size, mechanical strength, surface chemical composition, surface acidity and reactivity.

Phase transfer catalysts, Heterogeneous catalysts, mechanism and kinetics of heterogeneous catalysis, shape and size selectivity of catalysts. Clays and zeolites.

Unit-IV: Gaseous state

Kinetic molecular model of gas: postulates and derivation of the kinetic gas equation, collision frequency; collision diameter; mean free Path and viscosity of gases, including their temperature and pressure dependence, relation between mean free path and coefficient of viscosity, calculation of σ, variation of viscosity with temperature and pressure. Behavior of real gases.

References/ Textbooks:

1. Fundamentals of Photochemistry, K. K. Rohtagi-Mukherjee, New Age International, New Delhi, 1986.
2. Photochemistry, J. G. Calvert and J. N. Pitts, Jr., John Wiley & Sons, New York, 1966.
3. Principles and Applications of Photochemistry, R. P. Wayne, Oxford Univ. Press, 1988.
4. Principles of Fluorescence Spectroscopy, 2nd Ed., J. F. L. Lakowicz, Plenum Pub., New York, 1999.

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Semester-II
Course Code: MSC-CHE-2046
Course Title: Spectroscopy-I

Marks: 20+80=100
Total Credits: 06

Course Objective: To equip students with fundamental and applied knowledge of molecular spectroscopy, including rotational, vibrational, IR, and NMR techniques, for structural analysis and interpretation of molecular properties.

Course Outcome*:* This course will equip students with the ability to:

1. Analyze rotational and rotational-Raman spectra to determine molecular geometry and dipole moments.
2. Interpret vibrational and vibrational-rotational spectra of diatomic and polyatomic molecules using group theory and normal coordinate analysis.
3. Identify functional groups and structural features using IR spectroscopy, including the effects of hydrogen bonding and FGI.
4. Apply NMR spectroscopy for structural elucidation, including chemical shift analysis, spin-spin coupling, signal integration, and advanced techniques like NOE, decoupling, and MRI basics.

Contents:

Unit I: Rotational (microwave) spectroscopy

(a) Classification of molecules according to their moments of inertia, rotational energy levels of HCl. Determination of molecular geometry by isotopic substitution effects on pure rotational spectrum, Stark effect, estimation of molecular dipole moments, Spectra of symmetric top and asymmetric top type molecules,

(b) Rotational Raman spectra-an isotropic polarizability, Specific selection rule in Raman spectroscopy, Stokes and anti-Stokes lines.

Unit II: Vibrational-rotational spectroscopy

(a) Diatomic molecules-force constants, Fundamental vibration frequencies, The anharmonicity of molecular vibrations and its effect on vibrational frequencies, second and high harmonics.

(b) Vibration-rotation spectrum of HCI - P, Q and R branches, Vibrational Raman spectra of diatomic molecules.

(c) Polyatomic molecules *(e.g.* CO_2, NH_3) - normal modes vibrations, symmetry of vibrations-group theoretical treatment. Elements of normal coordinate analysis for the CO_2 molecule.

Unit III: Infrared spectroscopy I

IR spectroscopy-Characteristic bands for different functional groups, change in band frequency due to FGI. Effects of hydrogen bonding on band frequency, Problem solving.

Unit IV: Nuclear Magnetic Resonance Spectroscopy I

Chemical shift and splitting patterns of signals, coupling constant and its distinction from chemical shift use of coupling constant in structural elucidation. Simplification of spectra by use of shift reagents and high magnetic field, integration and its use in proton count and molecular ratio determination of enantiomeric excess. Deuterium exchange technique and the determination of labile hydrogen, spin- decoupling and NOE, 13C NMR, complexity of 13 CNMR spectra and use of spin decoupling in its signification. CINDP and its application. Worked out example using application of NMR. Introduction to magnetic resonance imaging (MRI).

References/ Textbooks:

1. Introduction to Spectroscopy: by Donald L. Pavia, Cengage India Private Limited, 2015.

2. Fundamentals of Molecular Spectroscopy: by Colin N. Banwell, McGraw Hill Education, 2017.

3. Elementary Organic Spectroscopy: by Y. R. Sharma, S Chand, 2010.

4. Spectroscopy of Organic Compound: by P S Kalsi, New Age International Private Limited, 2016.

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Semester-II
Course Code: MSC-CHE-2056
Course Title: Inorganic Chemistry Practical

Marks: 20+80=100
Total Credits: 06

Objective: To develop practical skills in the synthesis of coordination complexes and the qualitative analysis of inorganic salt mixtures, including the identification of interfering radicals.

Course Outcome: Students who complete this course will gain the skills to:

1. Synthesize and isolate various coordination compounds with defined stoichiometry and geometry.
2. Perform systematic qualitative analysis of inorganic salt mixtures containing multiple radicals, including interfering ions.
3. Demonstrate understanding of coordination chemistry through practical techniques and observations.
4. Apply critical thinking to identify ions and compounds based on physical and chemical tests.

Contents:

1. Preparation of the following complexes:

a) Sodium ferrioxalate, $Na_3[Fe(C_2O_4)_3]$ $9H_2O$
b) Tetraamine Cu(II) sulphate, $[Cu(NH_3)_4]SO_4.H_2O$
c) Hexa-amine Ni(II) chloride $[Ni(NH_3)_6]Cl_2$
d) Sodium Cobaltinitrite $Na_3[Co(NO_2)_6]$
e) Nitrito Pentamine Cobalt (III) chloride, $[Co(NO_2)(NH_3)_5]Cl_2$
f) Hexamine Co(III) sulphatepentahydrate, $[Co(NH_3)_6]_2(SO_4)_3.5H_2O$
g) Potassium chromioxalate, $K_3[Cr(C_2O_4)_3]$
h) Reinecke’s salt
i) Tris-(thiourea) copper(I) sulphate, $[Cu(tu)_3]2SO_4.2H_2O$
j) Potassium chromithiocyanate

k) Chloropentamine Cobalt (III) chloride $[Co(NH_3)5Cl]Cl_2$

l) Nitropentamine Cobalt(III) chloride $[Co(NO_2)(NH_3)_5]Cl_2$

2. Qualitative analysis of inorganic salt mixtures containing a minimum of five radicals, including both basic and acidic radicals, with at least one interfering ion.

3. Quantitative estimation involving volumetric (redox and complexometry), gravimetric methods of analysis of constituents in three component mixtures.

References/ Textbooks:

1. *Advanced Practical Inorganic Chemistry*. Gurdeep Raj, Goal Publishing House, 2005.
2. Vogels Text Book of Quantitative Analysis. J. Mendahan, R.C. Danney and J.Mendhan, ELBS, 5th Ed, 2009.
3. *Practical Inorganic Chemistry*. G. Marr and B.W Rockett, Van Nostrand, 2001.
4. *Practical Inorganic Chemistry*. G. Pass and H. Sutcliffe, 2nd Ed, Chapman & Hill 2009.
5. *Inorganic Synthesis*. G.W. Parshall , Vol. 15, McGraw Hill, 2007.

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Semester-II
Course Code: VAC-CHEM-2064
Course Title: Environmental Chemistry

Marks: 20+80=100
Total Credits: 04

Course Objective: To introduce students to the fundamental concepts of environmental chemistry, focusing on the chemical processes in the atmosphere and water, pollution control, and the environmental impact of human activities.

Course Outcome: Upon successful completion of the course, students will be able to:

1. Understand the structure and components of the environment and the interdisciplinary nature of environmental science.
2. Explain atmospheric composition, structure, and chemical processes, including photochemical reactions.
3. Identify major air pollutants and describe their roles in climate change, acid rain, and global warming.
4. Analyze sources and effects of water pollution, understand eutrophication, and discuss relevant control and remediation strategies.

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Contents:

Unit I: Introduction to Environmental Chemistry

Definition, scope, and importance, Segments of the environment (atmosphere, hydrosphere, lithosphere, biosphere), Interdisciplinary nature of environmental science.

Unit II: Atmospheric Chemistry

Understanding the Atmosphere-Definition and Importance, Composition of the Atmosphere-Major Gases (Nitrogen, Oxygen, Argon, CO_2), Variable Components (Water Vapor, Ozone, Dust Particles), Structure of the Atmosphere, Chemical and photochemical reactions in the atmosphere, Atmospheric Pressure and Temperature.

Unit III: Air Pollution and Climate Change

Overview of Air Pollution and Climate Change, Primary vs. secondary pollutants, Major air pollutants: CO_2, SO_2, NO_x, particulate matter, ozone, Greenhouse gases and global warming, Acid Rain, Chemical reactions leading to acid rain (SO_2 and NO_x with water).

Unit IV: Water Pollution

Different water pollutants along with their chemistry, Probable health effects of drinking water pollutants-WHO's guideline values. Eutrophication- Definition and process, Role of nutrients, Ecological consequences: oxygen depletion, fish kills, Control measures and remediation.

References/ Textbooks:

1. Environmental Chemistry: by Anil Kumar Dey and Arnab Kumar De, New Age International Private Limited, Edition: Eleventh, 2023.

2. Textbook of Environmental Chemistry: by Balaram Pani, TechSar Pvt. Ltd, 2017.

3. Fundamentals of Environmental Chemistry: by Fouzia Ishaq and Amir Khan, Discovery Publishing House, 2015.

4. Textbook of Environmental Chemistry: by Dr. Reetu Singh, Wave Books, 2019.

5. A Textbook of Environmental Chemistry: by V. Subramanian, Dreamtech Press, 2020.

6. Baird, C. *Environmental Chemistry*. 5th Edition, W.H. Freeman, 2017.

7. Schwarzenbach, R. P., Gschwend, P. M., Imboden, D. M. *Environmental Organic Chemistry*. 2nd Edition, Wiley, 2003.

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SEMESTER-III

Semester-III
Course Code: MSC-CHE-3016
Course Title: Organic Chemistry-III

Marks: 20+80=100
Total Credits: 06

Objective: To provide in-depth knowledge of named organic reactions, pericyclic processes, and the chemistry of biomolecules such as nucleic acids and vitamins, emphasizing their mechanisms, structures, and biological significance.

Course Outcome: Upon successful completion of the course, students will be able to:

1. Understand the mechanisms and applications of key organic name reactions and rearrangements.
2. Analyze and predict pericyclic reactions using molecular orbital theory and the Woodward-Hoffmann rules.
3. Explain the structure, function, and synthesis of nucleic acids and their role in heredity.
4. Describe the classification, structure, and biochemical functions of vitamins, especially their roles as coenzymes.

Contents:

Unit I: Study of Organic Name Reactions and Rearrangements

Mukaiyama Aldol condensation, Perkin reaction, Darzen condensation, Mannich reaction, Robinson Annulation, Stork-Enamine reaction, HVZ reaction, Simmon smith reaction, Baylis-Hillman, Suzuki reaction, Heck reaction, Sonogashira coupling, Stille coupling.

Introduction to Molecular Rearrangement. Rearrangements to Electron deficient carbon: Wagner-Meerwein, Pinacol-pinacolone, Benzil-Benzilic acid, Arndt-Eistert synthesis. Rearrangements to Electron deficient nitrogen: Hoffman rearrangement, Curtius rearrangement, Schmidt and Lossen rearrangement, Beckmann rearrangement. Rearrangements to Electron rich carbon: Favorskii, Neber, Wittig, Stevens.

Unit II: Pericyclic Reaction

Molecular orbital symmetry, Frontier orbitals of ethylene, 1,3butadiene, 1,3,5-hexatriene and allyl system. Classification of pericyclic reactions. Woodward-Hoffmann rules, Correlation diagrams and FMO approach. Electrocyclic reactions - Conrotatory and disrotatory motions, 4n, (4n+2) and allyl systems.

Cycloaddition reactions - suprafacial and antarafacial additions, 4n and (4n+2) systems, thermal and photochemical processes, 1,3 dipolar cycloadditions and cheletropic reactions. Sigmatropic rearrangements - [i,j] shifts of C-H and C-C bonds; Sommelet Hauser, Claisen, thio-Claisen, Cope and aza-Cope rearrangements. Ene reaction.

Unit III: Nucleic Acids

Purine and pyrimidine of nucleic acids, base pairing via H – bonding. Structure of ribonucleic acids (RNA) and deoxyribonucleic acid (DNA), double helix model of DNA and forces responsible for holding it. Chemical and enzymatic hydrolysis of nucleic acids. The chemical basis for heredity, an overview of replication of DNA, transcription, translation and genetic code. Chemical synthesis of mono and poly nucleosides.

Unit IV: Vitamins

Classification of carotenoids, chemistry of β-carotene, lycopene and Xanthophiles. Provitamin A and food colouring properties of carotenes. Chemistry of thiamine, riboflavin, retinol, tocopherols, Vitamin C, pyridoxine, pentothenic acid and folic acid, role of Vitamins as coenzyme.

References/ Textbooks:

1. Organic Chemistry: by I. L. Finar (Part I & II), Longman Group Ltd. (6th edition), **(2009)**.
2. Pericyclic reactions: A mechanistic study by S.M. Mukherji, Macmillan Co. of India Ltd., **(2011).**
3. Organic Reactions Stereochemistry & Mechanism: by P S Kalsi & R S Oza, New Age International Publishers, **(2018)**.
4. Modern Methods of Organic Synthesis: by William Carruthers & Iain Coldham, Cambridge, **(2004)**.
5. Advanced General Organic Chemistry A Mordern Approach Part 1 & 2 (Set of 2 Books) By Sachin Kumar Ghosh, **(2019).**

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Semester-III
Course Code: MSC-CHE-3026
Course Title: Inorganic Chemistry-III

Marks: 20+80=100
Total Credits: 06

Objective: To introduce students to advanced concepts in coordination and organometallic chemistry of transition metals, their reaction mechanisms, and bioinorganic relevance, with a focus on medicinal and toxicological aspects of metal ions.

Course Outcome: Upon successful completion of the course, students will be able to:

1. Explain the kinetics and mechanisms of ligand substitution and electron transfer reactions in transition metal complexes.
2. Understand the structure, bonding, synthesis, and reactivity of various organometallic compounds, including metallocenes and carbenes.
3. Analyze the role of metals in medicine, including therapeutic and diagnostic applications, and assess their toxicity.
4. Describe the biological roles of metal ions in transport, storage, enzymatic processes, and signaling within living organisms.

Contents:

Unit I: Reaction Mechanism of Transition Metal Complexes

Complex formation in solution: Stability constants - overall and stepwise, factors affecting stability, Irving-Williams series, chelate and macrocyclic effects, steric effects and electron delocalization. Inert and labile complexes.

Kinetics and mechanisms of octahedral substitution, acid hydrolysis, base hydrolysis- conjugate base mechanism, anation reactions, substitution reactions in square planer complexes, the trans effect, mechanism of substitution reaction. Electron transfer reactions- outer- and inner-sphere mechanisms.

Unit II: Organometallic Compounds of Transition metals

MO theory and electron count rules for different types of organometallic compounds, synthesis, structure and bonding- alkyls, carbenes, carbynes and nonaromatic alkenes and alkynes, metallocenes, hapticity, multidecar compounds, phosphine and N-heterocyclic carbenes.

Fluxional organometallic compounds. Different methods for characterization of organometallic compounds.

Unit III: Applications and Toxicity of Metals

The chemistry of elements in medicine. Anticancer drugs (platinum complexes). Antiarthritis drugs (gold, copper and its complexes). Bismuth in the treatment of gastric ulcers, Lithium in Bipolar disorders, Organometallic drugs in malaria treatment, Cyclams as anti-HIV agents, Chelation therapy, Imaging agents. Toxicity of metal ions.

Unit IV: Bioinorganic Chemistry II

The inorganic compound of living organisms. Sodium and Potassium transport, Calcium signaling proteins, Zinc in transcription, Selective transport and storage of iron, Oxygen transport and storage, Electron transfer.

The Nitrogen cycle and Hydrogen cycle. Iron proteins as sensors, proteins that sense Cu and Zn levels. Common example of biominerals.

References/ Textbooks:

1. P. Atkins, T. Overton, J. Rourke, M. Welle R & F. Armstrong, Shriver and Atkins, Inorganic Chemistry, Oxford University Press **(2006).**

2. F. A. Cotton, Chemical Applications of Group Theory, (3rd edition), John Wiley & Sons **(1999).**

3. F. A. Cotton, G. Wilkinson, C. A. Murillo & M. Bochmann, Advanced Inorganic Chemistry (6th edition), John Wiley **(1999).**

4. J. E. Huheey, E. A. Keiter, R. L. Keiter & O. K. Medhi, Inorganic Chemistry: Principles of Structure and Reactivity, Pearson Education **(2006).**

5. F. A. Cotton, G. Wilkinson, C. A. Murillo & M. Bochmann., Advanced Inorganic Chemistry (4th edition), John Wiley, **(1993)**.

6. Inorganic and Organometallic Reaction Mechanisms (2nd Edition), Jim D. Atwood, Wiley-VCH 8. Inorganic Reaction Mechanisms, R. K. Sharma, Discovery Publishing House, **(2007).**

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Semester-III
Course Code: MSC-CHE-3036
Course Title: Physical Chemistry-III

Marks: 20+80=100
Total Credits: 06

Objective: To provide students with an in-depth understanding of surface and colloidal phenomena, phase equilibria, fuel cell technologies, and polymer chemistry, emphasizing both theoretical foundations and practical applications.

Course Outcome: Students completing the course will gain the ability to:

1. Explain surface and colloidal properties, adsorption phenomena, and the behavior of surfactants and micelles.
2. Apply the phase rule to one-, two-, and three-component systems and interpret heterogeneous equilibrium using phase diagrams.
3. Understand the working principles, classifications, and applications of various fuel cells and electrochemical supercapacitors.
4. Analyze the mechanisms and kinetics of different polymerization processes, evaluate molecular weight distributions, and understand the chemistry of copolymerization.

Contents:

Unit I: Surface Chemistry

Surface tension and surface free energy, capillary action. Pressure across an interface: Laplace equation, Kelvin equation; Wetting: Young-Dupre equation. Adsorption in liquid systems: Gibbs adsorption isotherm. Adsorption on solids: Langmuir isotherm, BET isotherm.

Sols, properties of sols, sols of surface active reagents, electrical properties of colloidal systems, coagulation of colloidal sols, electro-kinetic properties, electro-osmosis, size determination of colloidal particles.

Surfactants, classification of surfactants, hydrophobic interaction, aggregation /micellization of surfactants, solubilization, critical micelle concentration (cmc), reverse micelles, factors affecting the cmc, microemulsion.

Unit II: Heterogeneous Equilibrium

The distribution law, the phase rule – one component system – water, carbon dioxide, sulphur – enantiotropy & monotropy, Gibbs phase rule & its application to one, two & three component systems – triangular plots – water, acetic acid, chloroform system.

Unit III: Fuel Cells

Fuel cells: classification- alkaline fuel cells, solid polymer electrolyte fuel cells, phosphoric acid fuel cells, molten carbonate fuel cells and solid oxide fuel cells- brief description, reactions and applications of each type of fuel cell. Electrochemical supercapacitors: brief description, advantages and applications.

Unit IV: Polymers

Functionality and polymerization concept, Number average, weight average, viscosity average, sedimentation average molecular weights. Molecular weight distribution, polydispersity and degree of polymerization, End group Analysis. Chemistry of Polymerization: Free radical chain polymerization, kinetics of free radical polymerization, Cage effect and chain transfer reactions. Chemistry and kinetics of Condensation polymerization, Coarother's equation. Cationic and anionic polymerization chemistry, kinetics and degree of Polymerization. Copolymerization, types, copolymerization equation, monomer reactivity.

References/ Textbooks:

1. Principles of Physical Chemistry: by Puri, Sarma & Pathania, Vishal Publishing Co. **(2020)**
2. A Text Book of Physical Chemistry: by K. L. Kapoor, McGraw-Hill **(2020)**
3. A Textbook of Physical Chemistry: by A.S. Negi & S.C. Anand, New Age International (P) Ltd **(2016)**
4. Atkins Physical Chemistry: by Peter Atkins, OUP Oxford **(2019)**
5. A Textbook of Physical Chemistry: by K K Sharma & L K Sharama, VIKAS PUBLISHING (6^{th} edition).
6. Physical Chemistry: by IRA N. Levine, McGraw Hill Education **(2011)**

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Semester-III
Course Code: MSC-CHE-3046
Course Title: Spectroscopy-II

Marks: 20+80=100
Total Credits: 06

Objective: To equip students with fundamental knowledge and interpretative skills in modern spectroscopic techniques including Mass Spectrometry, IR, UV-Visible, and NMR spectroscopy for the structural elucidation of organic molecules.

Course Outcome: Upon completion of the course, students will be able to:

1. Analyze mass spectral fragmentation patterns and apply them in structural determination of organic compounds.
2. Interpret IR spectra to identify functional groups and assess the effects of conjugation, hydrogen bonding, and solvents.
3. Understand the principles and applications of electronic spectroscopy, including UV-Vis, fluorescence, and phosphorescence.
4. Apply ^{1}H and ^{13}C NMR spectroscopy, including 2D techniques like DEPT, NOESY, and INEPT, to elucidate detailed molecular structures.

Contents:

Unit I: Mass Spectrometry

Mass spectral fragmentation of organic compounds, common functional groups; molecular ion peak, fragmentation via retro-Diels-Alder reaction, McLafferty rearrangements, examples of mass spectral fragmentation of organic compounds with respect to their structure determination.

Unit II: Infrared Spectroscopy II

Characteristic vibrational frequencies of alkanes, alkenes, alkynes, aromatic compounds, alcohols, ethers, phenols, amines; detailed study of vibrational frequencies of carbonyl compounds (ketones, aldehydes, esters, amides, acid anhydrides, lactones, lactams, conjugated carbonyl compounds); effects of H-bonding and solvent effect on vibrational frequency, extension to various organic molecules for structural assignment.

Unit III: Electronic Spectroscopy

UV-visible spectroscopy: Electronic transitions, Franck-Condon principle, vertical transitions; Selection rules, parity, symmetry and spin selection rules. Instrumentation, Application in organic structure analysis; polarization of transitions

Fluorescence and phosphorescence spectroscopy: Jablonski Diagram, origin of fluorescence and phosphorescence processes, quantum yield, fluorescence quenching-static and dynamic. Instrumentation and applications.

Unit IV: Nuclear Magnetic Resonance Spectroscopy II

Approximate chemical shift values of various chemically non-equivalent protons and correlation to protons bonded to carbon (aliphatic, olefinic, aldehydic and aromatic); coupling constants; protons bonded to other nuclei (alcohols, phenols, enols, carboxylic acids, amines, amides, SH).

C-13 NMR: Basic difference with ^{1}H NMR, Chemical shift (aliphatic, olefinic, alkynes, aromatic, hetero-aromatic, carbonyl carbon); two-dimensional NMR spectroscopy, NOESY, DEPT and INEPT terminologies.

References/ Textbooks:

1. Introduction to Spectroscopy: by Donald L. Pavia, Cengage India Private Limited, **(2015).**

2. Fundamentals of Molecular Spectroscopy: by Colin N. Banwell, McGraw Hill Education, **(2017).**

3. Elementary Organic Spectroscopy: by Y. R. Sharma, S Chand, **(2010).**

4. Spectroscopy of Organic Compound: by P S Kalsi, New Age International Private Limited, **(2016).**

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Semester-III
Course Code: MSC-CHE-3056
Course Title: Physical Chemistry Practical

Marks: 20+80=100
Total Credits: 06

Objective: To provide hands-on experience in experimental techniques related to surface tension, viscosity, chemical kinetics, conductometry, pH-metry, and spectrophotometry, enabling students to understand physicochemical properties and quantitative analysis of chemical systems..

Course Outcome:

1. Perform accurate measurements of surface tension and viscosity of liquids and solutions, and analyze their concentration-dependent behavior.
2. Determine rate constants, activation energy, and reaction mechanisms through kinetic experiments.
3. Apply conductivity and pH-metric methods to analyze acid strength, degree of dissociation, and mixture composition.
4. Utilize spectrophotometric techniques for quantitative analysis and study of complex formation using Beer's law and Job's method.

Contents:

1. Surface tension measurement

a) Determination of surface tension of a liquid or a dilute solution using stalagmometer.

b) Study of variation of surface tension of a detergent solution with concentration.

2. Viscosity Measurements

a) Determination of relative and absolute viscosity of a liquid of dilute solution using an Ostwald s viscometer.

b) Study of variation of viscosity of an aqueous solution with concentration of solute.

3. Chemical kinetics

a) To determine the rate constant of hydrolysis of ethyl acetate catalyzed by an acid and also the energy of activation.

b) Study of reaction rate of iodine ion hydrogen peroxide at room temperature using different concentration of iodide ions.

c) Study of reaction rate of reaction between potassium iodate (KIO_3) & sodium sulphite (Na_2SO_3) using starch solution as indicator (clock reaction).

4. Conductivity

a) Determine the equivalent conductivity of acetic acid at infinite dilution by Kohlrausch's method and determine the degree of hydrolysis of the acid.
b) Determine the relative strength of chloroacetic acid and acetic acid by conductance measurements.

5. pH-metry

a) Determine the strength of the components of the mixtures: (i) HCl and acetic acid, (ii) H_2SO_4 and $CuSO_4$.
b) Determine the amount of components of the following mixtures: (i) HCl and acetic acid, (ii) HCl and oxalic acid, (iii) KCl and KBr and KI.

6. Spectrophotometry

a) Varify Beer's law and determine the concentration of solutions $KMnO_4/K_2Cr_2O_7$.
b) Determine the composition of iron-salicylic acid complex spectrophotometrically by Job's method of continuous variation.

References/ Textbooks:

1. Practical Physical Chemistry: by B. Viswanathan & P.S. Raghavan, MV Learning **(2015).**

2. Physical Chemistry Practical: by Dr. Kamala Rani Bhattacharyya, New Academic Publisher, (1st -edition**, 2016**).

3. Advanced Practical Physical Chemistry: by J. B. Yadav, KRISHNA PRAKASHAN MEDIA **(2016).**

4. Experimental Physical Chemistry by R.C. Das, B. Behera, Tata McGraw-Hill Publishing Company Limited.

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Semester-III
Course Code: SEC-CHEM-3064
Course Title: Chemistry in Everyday Life

Marks: 20+80=100
Total Credits: 04

Objective: To familiarize students with the role and applications of chemistry in daily life, focusing on food, agriculture, personal care products, and water treatment, while developing awareness of chemical safety, quality control, and environmental impacts.

Course Outcome: Upon successful completion of the course, students will be able to:

1. Understand the chemical basis of food components, additives, and food adulterants and their effects on health.
2. Analyze the role of chemistry in gardening through plant nutrition, fertilizers, pesticides, and composting.
3. Identify chemical constituents and functions of cosmetics and assess their potential health hazards.
4. Explain the chemical processes involved in swimming pool maintenance and evaluate the impact of chlorine on health and safety.

Contents:

Unit I: Chemistry in Kitchen

Nutritional value of foods, idea about food processing and food preservations. Definition and uses of food additives –Sweeteners, preservatives (sodium carbonate, sodium benzoate, sorbic acid), Flavouring agents (vanilla, isoamyl acetate, limonene, ethylpropionate , allyl hexanoate), Emulsifiers, Acidulants, Coloring Matter (Brilliant blue FCF, fast green FCF, tertrazine, sunset yellow FCF).

Food Adulteration: Introduction, Common adulterants in different foods- milk and milk products, vegetable oils, and fats, spices and condiments, cereals, pulses, sweetening agents and beverages. Harmful effects.

Unit II: Chemistry in Garden

Food for plants, nutrient deficiencies in plants, soil quality. Fertilizers: urea, superphosphate and NPK Pesticides: DDT, naphthalene, p-dichlorobenzene, nicotine, allethrin, and their toxicities. Manure and Composting.

Unit III: Chemistry in Cosmetics

Analysis of cosmetics: Major and minor constituents and their function, Composition of skin creams, hand lotions, nail paints, lip balm, conditioners, different kinds of Shampoos: antidandruff, anti lice, herbal and baby shampoos. Hazards of cosmetics.

Unit IV: Chemistry in Swimming pool

Chlorination of Swimming pool, effect of pH, chlorine stabilisers, super chlorination, effect of sunlight on chlorine. Side effects of chlorine in swimming pools on skin and measures to prevent it.

References/ Textbooks::

1. Vogel’s qualitative Inorganic analysis, Sixth Edition; G. Svehla & I. B. Sivankar; Prentice Hall, 2012.
2. Food Chemistry, Alex V Ramani, MJP Publisher, New Delhi, 2019,
3. Instrumental Methods of Analysis of Food Additives, H.Wincciam and Henry J Noebles; Interscience Publisher, New York, 1961.
4. The Chemical Analysis of Foods: Practical Treatise on the Examination of Food stuffs and the Detection of Adulterants; Fourth Edition; H. Edward, London, Churchill, 1950.
5. Chemical Analysis - A Series of Monographs on Analytical Chemistry and its Applications, J. J. Elving & I. M. Kolthoff; Inter Science- Vol. I to VII.
6. Aanalytical Agricultrual Chemistry, S.L. Chopra & J. S. Kanwar; Kalyani Publishers.

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SEMESTER-IV

Semester-IV
Course Code: MSC-CHE-4016
Course Title: Organic Chemistry-IV

Marks: 20+80=100
Total Credits: 06

Objective: To equip students with advanced knowledge of organic reagents, oxidation-reduction methodologies, photochemical and pericyclic reaction mechanisms, and the nomenclature, synthesis, and reactivity of heterocyclic compounds.

Course Outcome:

1. Understand the mechanisms and applications of oxidation reactions using Cr, Mn, DMSO, peroxides, and hypervalent iodine reagents.
2. Apply various reduction strategies including catalytic, metal hydride, dissolving metal, and organic-based methods in synthesis.
3. Analyze fundamental organic photochemical and pericyclic reactions using modern theories like Woodward-Hoffmann rules and FMO approach.
4. Classify and describe the synthesis, structure, and reactivity of common and fused heterocyclic systems with one or more heteroatoms.

Contents:

Unit I: Organic Reagents I

Cr and Mn oxidations: Oxidation of alcohols and aldehydes with Cr (VI) and Mn (VII) oxidants; oxidation of C=C and C-H bonds; uses of PCC, PDC, PFC and Collin's reagents. Peroxy oxidations: Alkene epoxidation by peracids and metal/alkyl hydroperoxides. Other methods of oxidations; DMSO and Swern oxidations; Oppenaur oxidatoion, Prevost and Woodward hydroxylation of alkenes.

Unit II: Organic Reagents II

Catalytic hydrogenation, Pd/C, PtO_2, H_2/catalyst, (stereochemistry and mechanism), Wilkinson's catalyst, Boranes and Hydroboration reactions, $NaBH_4$, $NaCNBH_3$, $Na(OAc)_3BH$, LAH, DIBAL, superhydrides, R_3SiH, Bu_3SnH, NH_2NH_2, MPV reduction, etc. reductions of conjugated systems, Birch reduction, reductive fission of alcohols, Pinacol coupling, McMurry coupling, deoxygenation of alcohols and carbonyl compounds such as Wolff Kisner, Shapiro reaction, Bamford-Stevens reaction, Clemmensons reduction.

Unit III: Photochemistry & Pericyclic Reactions

A. Photochemistry- Cis-trans isomerisation, Norrish type I & II reaction, Paterno-Buchi reaction, photoreduction of Ketones, dipimethane rearrangement, photochemistry of arenes, Barton reaction.

B. Pericyclic reactions-Main features of pericyclic reactions; Woodward-Hoffman rules, correlation diagram and FMO approaches; Electrocyclic reactions – conrotatory and disrotatory motions for 4n and [4n+2] systems. Cycloadditions– antarafacial and suprafacial additions, [2+2] and [4+2] reactions, 1,3-dipolar cycloadditions and chelotropic reactions; Sigmatropic [i, j] shifts of C-H and C-C bonds; Sommelet-Hauser, Claisen, thio-Claisen, Cope and aza-Cope rearrangements.

Unit IV: Nomenclature and classification of heterocycles

Structure, preparation and reactions of heterocyclic analogues of cyclopropane, cyclobutane, cyclopentadiene and benzene containing one or more heteroatoms (pyrrole, furan, thiophene, 1,2- and 1,3-azoles, triazoles, pyridine, diazines); fused heterocycles containing one or more heteroatoms (indoles, benzofurans, benzothiophene, quinolines, isoquinolines, benzopyrones).

References/ Textbooks:

1. P. S. Kalsi. Stereochemistry, Conformation and Mechanism (7th edn.), John Wiley (2008)
2. Stereochemistry of Organic Compounds: Principles and Applications by Nasipuri, John Wiley and Sons (6^{th} edn.) (2009)
3. Acheson, R. M. An Introduction to the Chemistry of Heterocyclic Compounds, 3rd Ed, Wiley India Pvt. Ltd, 2008.
4. Joule, J. A. and Mills, K. Heterocyclic Chemistry, Fifth Edition, Wiley, 2010.
5. Reagents in organic synthesis-(John Wiley) Fieser and Fieser (2008)

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Semester-IV
Course Code: MSC-CHE-4026
Course Title: Inorganic Chemistry-IV

Marks: 20+80=100
Total Credits: 06

Objective: To provide advanced knowledge of coordination chemistry, organometallics, bioinorganic systems, solid-state and materials chemistry, along with modern analytical and spectroscopic techniques used in inorganic chemistry.

Course Outcome: Upon successful completion of the course, students will be able to:

1. Interpret electronic spectra and magnetic properties of coordination complexes using Orgel and Tanabe-Sugano diagrams.
2. Understand mechanisms of metal complex reactions and their biological roles in metalloproteins and metal ion transport.
3. Apply principles of organometallic chemistry to catalysis and industrial processes.
4. Analyze the structure, properties, and applications of solid-state materials and nanomaterials.
5. Utilize spectroscopic techniques (UV-Vis, IR, Raman, NMR, EPR) for the characterization of inorganic compounds.

Contents:

Unit I: Coordination Chemistry and Bioinorganic Chemistry

Electronic spectra and magnetic properties of coordination compounds, Orgel and Tanabe-Sugano diagrams, Spectrochemical and nephelauxetic series, Jahn-Teller distortion, Thermodynamic and kinetic stability of coordination compounds, Reaction mechanisms of transition metal complexes: Substitution reactions in square planar and octahedral complexes, Electron transfer reactions (inner and outer sphere mechanisms).

Essential and trace elements in biological systems, Metalloproteins and metalloenzymes: hemoglobin, myoglobin, cytochromes, carbonic anhydrase, etc. Transport and storage of metal ions (Na^+, K^+, Ca^{2+}, Fe^{3+}), Metal toxicity and detoxification, Medicinal applications of inorganic compounds

Unit II: Organometallic Chemistry and Catalysis

EAN rule, hapticity, 18-electron rule, Metal carbonyls and nitrosyls, π-Complexes: olefins, alkynes, and aromatic compounds, Sandwich compounds: ferrocene and related metallocenes, Fluxional behavior in organometallics, Structure and bonding in organometallic complexes. Catalysis: Homogeneous catalysis, Hydrogenation (Wilkinson's catalyst), Hydroformylation, Olefin metathesis, Polymerization of alkenes, Heterogeneous catalysis – general principles, Industrial applications of organometallic catalysis.

Unit III: Solid State and Materials Chemistry

Crystal structures: Bravais lattices, unit cell parameters, Defects in solids: Schottky, Frenkel, Non-stoichiometric, Solid state reactions and synthesis methods, Electrical, magnetic, and optical properties of solids, Band theory of solids, Superconductivity: basic concepts and examples, Zeolites, clays, and other solid inorganic materials, Introduction to nanomaterials and their inorganic chemistry aspects.

Unit IV: Analytical and Spectroscopic Methods in Inorganic Chemistry

UV-Visible spectroscopy for transition metal complexes, Infrared and Raman spectroscopy, NMR spectroscopy for inorganic compounds, EPR spectroscopy – interpretation of spectra for paramagnetic complexes.

References/ Textbooks:

1. Inorganic Chemistry Principles of Structure and Reactivity-James E. Huheey, Pearson Education India.
2. Concise Inorganic Chemistry-J. D. Lee, Wiley.
3. Principles of Inorganic Chemistry-Puri, Sharma, and Kalia, Vishal Publishing Co.
4. Advanced Inorganic Chemistry-F. Albert Cotton, Geoffrey Wilkinson, Wiley.
5. Advanced Practical Inorganic Chemistry-Gurdeep Raj, Krishna Prakashan Media (P) Ltd.
6. Coordination Chemistry-Ajai Kumar, Aaryush Pub.
7. Basic Inorganic Chemistry- Ajai Kumar, Aaryush Education.
8. Organometallic & Bioinorganic Chemistry- Ajai Kumar

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Semester-IV
Course Code: MSC-CHE-4036
Course Title: Physical Chemistry-IV

Marks: 20+80=100
Total Credits: 06

Objective: To provide an in-depth understanding of chemical kinetics, reaction dynamics, theories of reaction rates, excited-state processes, and statistical thermodynamics, with emphasis on molecular-level interpretation and quantitative analysis of physical and chemical processes.

Course Outcome:

1. Understand transport properties and kinetics of complex reactions including enzyme catalysis and inhibition.
2. Apply theories of unimolecular and bimolecular reactions to interpret reaction mechanisms and energy surfaces.
3. Analyze excited state kinetics using Jablonski diagrams, photochemical rate processes, and energy/electron transfer mechanisms.
4. Evaluate thermodynamic properties of gases and solids using statistical mechanics and partition functions.

Contents:

Unit I: Kinetics and Reaction Dynamics

Transport properties: Diffusion, Thermal conductivity, Viscosity, Effusion, Drift velocity, Nernst-Einstein equation, Stokes-Einstein equation Complex reactionsChain reactions (free radical reaction, polymerization kinetics), Enzyme reaction, Inhibition kinetics.

Temperature dependence of reaction rate: Linear and non-linear Arrhenius equation, Interpretation of Arrhenius parameters.

Unit II: Theories of Reaction Rates

Various theories of unimolecular reactions (Lindemann Hinshelwood, RRK and RRKM theories), Potential energy surfaces for bimolecular reactions, Adiabatic and non-adiabatic curve crossing processes, Collision theory, Transition state theory, Activation/thermodynamic parameters, Erying equation

Unit III: Kinetics in the excited state

Jablonski diagram, Kinetics of Unimolecular and bimolecular photophysical and photochemical processes, Quantum yield calculation, Excited state lifetime-quenching constant, Resonance energy transfer rates (RET), Rate and efficiency of RET, Dynamics of electron transfer, Solvent re-organization energy, Marcus theory of electron transfer, Free energy and rate relation, RehmWeller behaviour, Marcus Inverted Region.

Unit IV: Statistical Thermodynamics

Canonical partition function in terms of molecular partition function of non-interacting particles, Translational, rotational and vibrational partition functions. Absolute values of thermodynamic quantities (U, H, S, A, G) for ideal monoatomic and diatomic gases, heat capacity (Cv, Cp) of an ideal gas of linear and nonlinear molecules, chemical equilibrium. Canonical partition function for interacting particles, intermolecular potential (Lennard-Jones, Hard-sphere and Square-well) and virial coefficients. Temperature dependence of the second virial coefficient. Thermodynamics of solids - Einstein and Debye models

References/ Textbooks:

1. P. Atkins and J. Paula, Physical Chemistry, 10th Edition, Oxford University Press, Oxford 2014
2. D. A. McQuarrie and J. D. Simon, Molecular Thermodynamics, University Science Books, California 2004
3. K. K. Rohatgi - Mukherjee, Fundamentals of Photochemistry, New Age International Pvt. Ltd.; 3rd edition, New Delhi 2014.
4. K. J. Laidler, Chemical Kinetics, 3rd edition, Harper & Row, New York 1998
5. J. I. Steindeld, J. S. Francisco, W. L. Hase, Chemical Kinetics and Dynamics, 2nd edition, Prentice Hall International Inc., New York 1989.

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Semester-IV
Course Code: MSC-CHE-4046
Course Title: Project Dissertation

Marks: 40+160=200
Total Credits: 12

Objective: Throughout the course, students will be introduced to various methods and techniques essential for conducting scientific research, with a focus on data collection and interpretation. They will also develop skills in reviewing scientific literature, compiling relevant information, and preparing research reports and publications.

Course Outcome: Upon successful completion of this course, students will be able to plan and execute a scientific research project effectively within a defined timeframe. They are expected to develop the ability to work independently while maintaining clear and accurate records of their experimental procedures.

Students will also gain hands-on experience in handling laboratory equipment and chemicals, as well as operating advanced analytical instruments for data collection and interpretation.

Furthermore, they will enhance their ability to critically evaluate scientific literature and strengthen their skills in scientific writing and communication.CO1: To give the practical knowledge of multistep synthesis.

1. To provide hands-on experience in performing multistep organic synthesis.
2. To develop practical skills in separation techniques for isolating compounds.
3. To impart knowledge and skills in the purification of chemical substances.
4. To train students in the characterization of compounds using various spectroscopic methods.
5. To enhance the ability to conduct comprehensive literature reviews.
6. To develop proficiency in scientific writing and presentation of research findings.
7. To introduce students to the use of scientific software tools such as ChemDraw, Origin, and others for data representation and molecular design.

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Semester-IV
Course Code: DSE-CHEM-4054
Course Title: Green Chemistry and Sustainable Technology

Marks: 20+80=100
Total Credits: 04

Objective: To introduce students to the principles of green chemistry and sustainable technologies aimed at minimizing environmental impact, conserving resources, and promoting the development of eco-friendly chemical processes and products.

Course outcome: Upon successful completion of the course, students will be able to:

1. Understand the core principles of green chemistry and apply them to real-world chemical processes.
2. Evaluate conventional vs. green technologies in terms of environmental, economic, and societal impact.
3. Design chemical processes and products that are more sustainable, energy-efficient, and less hazardous.
4. Analyze case studies of green technology innovations in industry and research.

Content:

Unit I: Introduction to Green Chemistry

Definition, principles and goals of Green Chemistry, Need for green chemistry in pollution prevention and sustainable development, Atom economy and E-factor, Metrics for evaluating greenness of chemical processes.

Unit II: Green Synthetic Methods

Green reagents and solvents: ionic liquids, supercritical CO_2, water, bio-based solvents, Alternative energy sources in synthesis: microwave-assisted, ultrasound-assisted synthesis, Green catalysts: biocatalysts, solid acid/base catalysts, phase-transfer catalysts, Case studies: green synthesis of adipic acid, ibuprofen, and paracetamol.

Unit III: Sustainable Industrial Processes

Waste minimization techniques, Life cycle assessment (LCA), Renewable feedstocks and raw materials, Sustainable technologies in polymer, textile, pharmaceutical and agrochemical industries, Design for degradation.

Unit IV: Green Chemistry in Daily Life and Future Trends

Green chemistry in agriculture: green pesticides, biofertilizers, Green chemistry in energy: biofuels, hydrogen economy, fuel cells, Water treatment and environmental remediation using green technologies, Future of green chemistry: circular economy, zero-waste processes, policy and regulation

References/ Textbooks:

1. **Paul T. Anastas and John C. Warner**, Green Chemistry: Theory and Practice, Oxford University Press, 1998. (The foundational text on green chemistry principles)
2. **V. K. Ahluwalia and M. Kidwai**, New Trends in Green Chemistry, Springer, 2004. (Focuses on green synthetic methodologies and solvents)
3. **M. Lancaster**, Green Chemistry: An Introductory Text, Royal Society of Chemistry, 2016 (2nd Ed.). (Student-friendly with examples and exercises)
4. **S. Mishra**, Green Chemistry for Environmental Remediation, Wiley-Scrivener, 2012. (Deals with real-world applications in pollution control and remediation)
5. **Suresh C. Ameta and Rakshit Ameta**, Green Chemistry: Fundamentals and Applications, CRC Press, 2013. (Covers industrial processes and sustainable technologies)
6. **D. M. Roundhill**, Green Technologies, Clean Technologies and Sustainable Development, Springer, 2018. (Broader view of green tech and sustainable practices)

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Semester-IV
Course Code: AEC-CHEM-4064
Course Title: Analytical Chemistry

Marks: 20+80=100
Total Credits: 04

Objective: This course aims to develop a foundational understanding of both classical and instrumental analytical techniques, focusing on the interpretation of analytical data, chemical equilibria, and the application of statistical and thermodynamic principles for solving analytical problems and evaluating real-world applications.

Course outcome: After successful completion of this course, students will be able to:

1. Evaluate and compare analytical techniques for accuracy, precision, and suitability.
2. Understand the theoretical foundation of gravimetric and volumetric analysis.
3. Apply chemical equilibrium concepts in complexometric, redox, and acid-base titrations.
4. Explain the principles behind spectroscopic, electrochemical, and chromatographic methods.

Content:

Unit I: Basic Concepts and Errors in Chemical Analysis

Introduction to analytical chemistry and its classification, Concepts of accuracy, precision, significant figures, and errors (systematic and random), Methods of error minimization, Statistical treatment of analytical data, Mean, median, standard deviation.

Unit II: Classical Methods of Analysis

A. **Gravimetric Analysis:** Principles, precipitation techniques, solubility product, co-precipitation, post-precipitation, peptization.
B. **Volumetric Analysis:** Principles of titrimetry, Types of titrations: acid-base, redox, complexometric, precipitation, Indicators and their selection.

Unit III: Electroanalytical Methods

Conductometry and conductometric titrations, Potentiometry and redox electrodes**,** Ion-selective electrodes and pH-metry**,** Coulometry and voltammetry: principles and applications.

Unit IV: Spectroscopic Techniques in Analysis

A. **UV-Visible Spectroscopy:** Principles, Beer-Lambert law, instrumentation, Quantitative analysis.
B. **Atomic Absorption and Emission Spectroscopy:** Principles, instrumentation, applications.

References/ Textbooks:

1. Analytical Chemistry" by G. D. Christian and P. K. Sharma; *(Adapted Indian edition; Sharma is Indian contributor)* Publisher: Wiley India.
2. "Instrumental Methods of Chemical Analysis" by B.K. Sharma; Publisher: Krishna Prakashan Media *(Comprehensive book with both theoretical and instrumental details).*
3. "Analytical Chemistry: Principles" by S. M. Khopkar; Publisher: New Age International Publishers *(Well-known for Indian university syllabi)*
4. "Textbook of Analytical Chemistry" by A. I. Vogel, adapted by G. H. Jeffery, J. Bassett, and Indian adaptations by S. S. Mendham and D. A. Sethi *(Classic text, often used in Indian universities; Indian edition available).*
5. "Fundamentals of Analytical Chemistry" by D. K. Sahu; Publisher: Narosa Publishing House
6. "Analytical Chemistry" by G. Chatwal and S. Anand; Publisher: Himalaya Publishing House.

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