Structure and Detailed Syllabus of the Four Year Undergraduate Programme (FYUGP)
of
MAJOR COURSE (MJ)
under NEP-2020

Department of Chemistry
JAGANNATH BAROOAH UNIVERSITY
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This syllabus for the Four-Year Undergraduate Programme (FYUGP) in Chemistry (Major Course) at Jagannath Barooah University, is designed to equip students with a robust understanding and practical skills in chemistry.

The overarching aim is to foster a firm foundation in the fundamentals and applications of current chemical and basic sciences, including Physical, Organic, Inorganic, and Analytical Chemistry, as well as the chemistry of life.

Program Outcomes (PO)

Upon successful completion of the B.Sc. in Chemistry program, students will be able to:

- **PO 1: Foundational Knowledge:** Demonstrate a firm foundation in the fundamental principles and applications across various branches of chemistry, including physical, organic, inorganic, analytical chemistry, and bio-chemistry.
- **PO 2: Research Aptitude:** Develop awareness of major issues in chemical research and acquire competence in initiating, developing, and pursuing scientific research.
- **PO 3: Information Management & Lifelong Learning:** Acquire the ability to seek new knowledge and skills, and effectively manage relevant scientific information.
- **PO 4: Laboratory Proficiency:** Work effectively and safely in a laboratory environment, both independently and as part of a team, demonstrating practical expertise.
- **PO 5: Experimental Design & Analysis:** Design and execute scientific experiments, critically analyze experimental data, and draw logical and sound inferences.

These program outcomes are further supported by specific learning outcomes for each semester and individual courses, ensuring a progressive development of knowledge and skills throughout the undergraduate program.

Semester-wise Course structure

Semester	Course No	Paper Code	Paper title	Course Type	Credit	Total Marks
SEM-I	C-01	CHMMJ-011	General Chemistry-I	Theory	4	100
SEM-II	C-02	CHMMJ-021	General Chemistry-II	Theory	4	100
SEM-III	C-03	CHMMJ-031	Inorganic Chemistry-I	Theory	4	100
	C-04	CHMMJ-032	Organic Chemistry-I	Theory	4	100
	C-05	CHMMJ-033	Practical Chemistry-I	Practical	4	100
SEM-IV	C-06	CHMMJ-041	Inorganic Chemistry-II	Theory	4	100
	C-07	CHMMJ-042	Organic Chemistry-II	Theory	4	100
	C-08	CHMMJ-043	Physical Chemistry-I	Theory	4	100
	C-09	CHMMJ-044	Practical Chemistry-II	Practical	4	100

SEM-V	C-10	CHMMJ-051	Inorganic Chemistry-III	Theory	4	100
	C-11	CHMMJ-052	Organic Chemistry-III	Theory	4	100
	C-12	CHMMJ-053	Physical Chemistry-II	Theory	4	100
	C-13	CHMMJ-054	Practical Chemistry-III	Practical	4	100
SEM-VI	C-14	CHMMJ-061	Inorganic Chemistry-IV	Theory	4	100
	C-15	CHMMJ-062	Organic Chemistry-IV	Theory	4	100
	C-16	CHMMJ-063	Physical Chemistry-III	Theory	4	100
	C-17	CHMMJ-064	Quantum Chemistry-I	Theory	2	50
	C-18	CHMMJ-065	Practical Chemistry-IV	Practical	4	100
SEM-VII	C-19	CHMMJ-071	Inorganic Chemistry-IV	Theory	4	100
	C-20	CHMMJ-072	Organic Chemistry-IV	Theory	4	100
	C-21	CHMMJ-073	Physical Chemistry-III	Theory	4	100
	C-22	CHMMJ-074	Research Methodology	Theory	2	50
	C-23	CHMMJ-075	Practical Chemistry-IV	Practical	4	100
SEM-VIII	C-24	CHMMJ-081	Analytical Methods in Chemistry	Theory	4	100
	C-25	CHMMJ-082	Organic Chemistry-II	Theory	4	100

SEMESTER-I

Paper Title : **GENERAL CHEMISTRY-I (THEORY)**
Paper Code : **CHMMJ-011**
Course No : **C- 01**
Credits : **04**
No. of Classes : **60**
Total Theory Marks : **100 (End Semester: 70; In Semester: 30)**

Course Objectives:

- To understand the important features of the quantum mechanical model of atom.
- To know the position and properties of elements, predict chemical reactions, understand trends in periodic properties among different elements.
- To introduce with a variety of structural aspects of organic molecules that are designed to lay the foundations for the study of the organic molecule.
- To impart basic knowledge of the gaseous state of matter; to understand the basic properties of liquids and their application.

Course Outcome: Students will gain an understanding of

- Quantum mechanical model of atom; concept of wave function, contour diagram, probability diagram etc.
- Properties of elements, atomic radii, ionic radii, size effect of ionic bond, solvation energy, covalent character of ionic bond, redox equations etc.
- Organic compounds, their classification, nomenclature; reaction of aliphatic hydrocarbons.
- Kinetic molecular model of a gas, behaviour of real gases etc.; various physical properties of liquids with special reference to surface tension and viscosity.

SECTION A: INORGANIC CHEMISTRY - I

UNIT-I: Atomic Structure: Bohr's theory, its limitations and atomic spectrum of hydrogen atom. Wave mechanics: de Broglie equation, Heisenberg's Uncertainty Principle and its significance, Schrödinger's wave equation, significance of ψ and ψ^2. Quantum numbers and their significance. Normalized and orthogonal wave functions. Sign of wave functions. Radial and angular wave functions for hydrogen atom. Radial and angular distribution curves. Shapes of s, p, d and f orbitals. Contour boundary and probability diagrams. Pauli's Exclusion Principle, Hund's rule of maximum multiplicity, Aufbau's principle and its limitations, Variation of orbital energy with atomic number.

(10 Lectures; Marks: 13)

UNIT-II: Periodicity of Elements: Modern periodic table. s, p, d, f block elements, Detailed discussion of the following properties of the elements, with reference to s and p-block. Effective nuclear charge, shielding or screening effect and their variation, Slater rules, Atomic

radii (van der Waals), Ionic and crystal radii, Covalent radii (octahedral and tetrahedral), Ionization enthalpy, Successive ionization enthalpies and factors affecting ionization energy. Applications of ionization enthalpy, Electron gain enthalpy, trends of electron gain enthalpy. Electronegativity, Pauling's/ Mulliken's/ Allred Rachow's/ and Mulliken-Jaffé's electronegativity scales. Variation of electronegativity with bond order, partial charge, hybridization, group electronegativity. Sanderson's electron density ratio. Covalent character in ionic compounds, Polarising power and polarizability, Fajan's rules and consequences of polarization, Ionic character in covalent compounds: Bond moment and dipole moment. Percentage ionic character from dipole moment and electronegativity difference.

(10 Lectures; Marks: 10)

SECTION B: ORGANIC CHEMISTRY- I

UNIT-III: **Basics of Organic Chemistry:** Organic Compounds: Classification, and Nomenclature, Hybridization and shapes of molecules. Electronic effects: (Inductive, resonance and hyperconjugation) and steric effect their applications (acid/base property). Homolytic and Heterolytic fission with suitable examples. Electrophiles and Nucleophiles; Nucleophlicity and basicity; Chemistry of reactive intermediates (carbocations, free radical, carbenes and nitrene). Elementary idea on types of organic reactions. Aromaticity: Benzenoids and Hückel's rule. Electrophilic aromatic substitution: halogenation, nitration, sulphonation and Friedel-Craft's alkylation/acylation with their mechanism. Directing effects of the groups.

(10 Lectures; Marks: 12)

UNIT-IV: Chemistry of Aliphatic Hydrocarbons: Chemistry of alkanes: Formation of alkanes, Wurtz Reaction, Wurtz-Fittig Reactions, Free radical substitutions: Halogenation - relative reactivity and selectivity. Carbon-Carbon pi Bonds: Formation of alkenes and alkynes by elimination reactions, Mechanism of E1, E2, E1cb reactions. Saytzeff and Hofmann eliminations. Reactions of alkenes: Electrophilic additions their mechanisms (Markownikoff/ Anti Markownikoff addition), mechanism of oxymercuration-demercuration, hydroborationoxidation, ozonolysis, reduction (catalytic and chemical), syn and anti-hydroxylation (oxidation) with simple effect of stereo selectivity and specificity. 1,2-and 1,4-addition reactions in conjugated dienes and, Diels-Alder reaction; Allylic and benzylic bromination and mechanism, e.g. propene, 1- butene, toluene, ethyl benzene. Reactions of alkynes: Acidity, Electrophilic and Nucleophilic additions. Hydration to form carbonyl compounds, Alkylation of terminal alkynes.

(10 Lectures; Marks: 12)

SECTION C: PHYSICAL CHEMISTRY – I

UNIT-V: Gaseous State: Kinetic molecular model of a 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 from η; variation of viscosity with temperature

and pressure. Maxwell distribution and its use in evaluating molecular velocities (average, root mean square and most probable) and average kinetic energy, law of equipartition of energy, degrees of freedom and molecular basis of heat capacities. Behaviour of Real Gases: Deviations from ideal gas behaviour, compressibility factor, Z, and its variation with pressure for different gases. Causes of deviation from ideal behaviour. Van der Waals equation of state, its derivation and application in explaining real gas behaviour, mention of other equations of state (Berthelot, Dietrici); virial equation of state; van der Waals equation expressed in virial form and calculation of Boyle temperature. Isotherms of real gases and their comparison with van der Waals isotherms, continuity of states, critical state, relation between critical constants and van der Waals constants, law of corresponding states.

(15 Lectures; Marks: 17)

UNIT- VI: Liquid State: Molecular forces and general properties of liquids. **Surface Tension:** surface tension, surface energy, effect of temperature on surface tension, shapes of liquid drops and soap bubbles, capillary action, determination of surface tension by capillary rise method, drop weight and drop number methods using stalagmometer. Effect of temperature on surface tension. Parachor, Additive and constitutive properties: atomic and structural parachor. Elucidation of structure of benzene and benzoquinone. **Viscosity:** Definition, viscosity coefficient, fluidity, molecular viscosity, relative viscosity and absolute viscosity, determination of coefficient of viscosity using Ostwald viscometer. Effect of temperature, size, weight, shape of molecules and intermolecular forces.

(5 Lectures; Marks: 6)

Text Books:

- Lee, J.D. *Concise Inorganic Chemistry* ELBS, 1991.
- Finar, I. L. *Organic Chemistry (Volume 1)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Atkins, P. W. & Paula, J. de *Atkin's Physical Chemistry* 10th Ed., Oxford University Press (2014).

Reference Books:

- Douglas, B.E. and McDaniel, D.H. *Concepts & Models of Inorganic Chemistry* Oxford, 1970.
- Day, M.C. and Selbin, J. *Theoretical Inorganic Chemistry*, ACS Publications, 1962.
- Morrison, R. N. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- McMurry, J.E. *Fundamentals of Organic Chemistry*, 7th Ed. Cengage Learning India Edition, 2013.
- Ball, D. W. *Physical Chemistry* Thomson Press, India (2007).
- Kapoor, K. L. *A Textbook of Physical Chemistry*, Vol. 1

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SEMESTER-II

Paper Title : **GENERAL CHEMISTRY-II (THEORY)**
Paper Code : **CHMMJ-021**
Course No : **C- 02**
Credits : **04**
No. of Classes : **60**
Total Theory Marks : **100 (End Semester: 70; In Semester: 30)**

Course Objectives:

- To understand the different types of bonds formed by atoms and their chemical approaches of bonding and shape of molecules.
- To impart basic knowledge on transition metals and their applications.
- To impart knowledge on stereochemistry and importance of alkyl and aryl halides.
- To introduce with a variety of laws of thermodynamics, thermo-chemistry and their applications.

Course Outcome: Students will gain an understanding of

- Molecular geometries, physical and chemical properties of the molecules; Current bonding models for simple inorganic and organic molecules in order to predict structures and important bonding parameters.
- Catalytic, magnetic and redox properties of transition elements.
- Stereochemistry; 2D, 3D structures of molecules and their interconversion; E/Z, R/S nomenclature, Conformational analysis of alkanes.
- Chemistry of alkyl halides aryl halides; their preparation and reactions.
- Different thermodynamic functions; First, second & third law of thermodynamics.

SECTION A: INORGANIC CHEMISTRY - II

UNIT-I: Chemical Bonding: Ionic Bonding: General characteristics, types of ions, size effects, radius ratio rule and its limitations. Packing of ions in crystals. Born-Landé and Kapustinskii expression and its application (no derivation). Madelung constant, Born-Haber cycle and its application, Solvation energy. Covalent Bonding: Lewis structure, Valence Bond theory (Heitler-London approach). Energetics of hybridization, equivalent and non-equivalent hybrid orbitals. Bent's rule, Resonance and resonance energy, Molecular orbital theory. Molecular orbital diagrams of diatomic and simple polyatomic molecules N_2, O_2, C_2, B_2, F_2, CO, NO, and their ions; HCl, BeF_2, CO_2, (idea of s-p mixing and orbital interaction to be given). Formal charge, Valence shell electron pair repulsion theory (VSEPR), shapes of simple molecules and ions containing lone pairs and bond pairs of electrons, multiple bonding (σ and π bond approach) and bond lengths. Metallic Bonding: Qualitative idea of valence bond and band theories. Semiconductors and insulators, defects in solids. Weak Chemical Forces: van der Waals forces, ion-dipole forces, dipole-dipole interactions, induced dipole interactions,

Instantaneous dipole-induced dipole interactions. Repulsive forces, Hydrogen bonding (theories of hydrogen bonding, valence bond treatment) Effects of chemical force, melting and boiling points, solubility energetics of dissolution processes.

(12 Lectures; Marks: 16)

UNIT-II: Transition Elements: General group trends with special reference to electronic configuration, colour, variable valency, magnetic and catalytic properties, ability to form complexes. Stability of various oxidation states and e.m.f. (Latimer & Bsworth diagrams). Difference between the first, second and third transition series. Chemistry of Ti, V, Cr Mn, Fe and Co in various oxidation states (excluding their metallurgy)

(08 Lectures; Marks: 8)

SECTION B: ORGANIC CHEMISTRY- II

UNIT-III: **Stereochemistry:** Fischer, Newmann and Sawhorse Projection formulae and their interconversions; Geometrical isomerism: *cis–trans* and, *syn-anti* isomerism, E/Z notations with C.I.P rules. Optical Isomerism in compounds with or without chiral centers (allenes, spirans and biphenyls): Optical Activity, Specific Rotation, Enantiomers, Molecules with two or more chiral-centres, Distereoisomers, meso structures, Racemic mixture, resolution and enantiomeric excess. Relative and absolute configuration.
Conformational Analysis: Types of cycloalkanes and their relative stability, Baeyer strain theory, Conformation analysis of alkanes (ethane and n-butane): Relative stability: Energy diagrams of cyclohexane; Relative stability of cyclohexanes, monosubstituted cyclohexanes.

(12 Lectures; Marks: 14)

UNIT-IV: Alkyl and Aryl Halides: Alkyl Halides (Upto 5 Carbons) Types of Nucleophilic Substitution (S_N1, S_N2 and S_Ni) reactions. Preparation: from alkenes and alcohols. Reactions: hydrolysis, nitrite & nitro formation, nitrile & isonitrile formation. Williamson's ether synthesis: Elimination vs substitution. Aryl Halides Preparation: (Chloro, bromo and iodo-benzene case): from phenol, Sandmeyer & Gattermann reactions. Reactions (Chlorobenzene): Aromatic nucleophilic substitution (replacement by –OH group) and effect of nitro substituent. Benzyne Mechanism: KNH_2/NH_3 (or $NaNH_2/NH_3$). Reactivity and Relative strength of C-Halogen bond in alkyl, allyl, benzyl, vinyl and aryl halides.

(08 Lectures; Marks: 9)

SECTION C: PHYSICAL CHEMISTRY– II

UNIT-V: Chemical Thermodynamics: Intensive and extensive variables; state and path functions; isolated, closed and open systems; zeroth law of thermodynamics. **First law:** Concept of heat, q, work, w, internal energy, U, and statement of first law; enthalpy, H, relation between heat capacities, calculations of q, w, U and H for reversible, irreversible and free expansion of gases (ideal and van der Waals) under isothermal and adiabatic conditions.

Thermochemistry: Heats of reactions: standard states; enthalpy of formation of molecules and ions and enthalpy of combustion and its applications; calculation of bond energy, bond dissociation energy and resonance energy from thermochemical data, effect of temperature (Kirchhoff's equations) and pressure on enthalpy of reactions. Adiabatic flame temperature, explosion temperature. **Second Law:** Concept of entropy; thermodynamic scale of temperature, statement of the second law of thermodynamics; molecular and statistical interpretation of entropy. Calculation of entropy change for reversible and irreversible processes. **Third Law:** Statement of third law, concept of residual entropy, calculation of absolute entropy of molecules

(20 Lectures; Marks: 23)

Text Books:

- Lee, J.D. *Concise Inorganic Chemistry* ELBS, 1991.
- Finar, I. L. *Organic Chemistry (Volume 2: Stereochemistry and the Chemistry of Natural Products)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Kapoor K. L. *A Textbook of Physical Chemistry* Sixth Ed., Vol. 2, Macmillan, India

Reference Books:

- Douglas, B.E. and McDaniel, D.H. *Concepts & Models of Inorganic Chemistry* Oxford, 1970
- Rodger, G.E. *Inorganic and Solid State Chemistry*, Cengage Learning India Edition, 2002.
- Eliel, E. L. & Wilen, S. H. *Stereochemistry of Organic Compounds*, Wiley: London, 1994.
- Kalsi, P. S. *Stereochemistry Conformation and Mechanism*, New Age International, 2005.
- McMurry, J.E. *Fundamentals of Organic Chemistry*, 7th Ed. Cengage Learning India Edition, 2013.
- McQuarrie, D. A. & Simon, J. D. *Molecular Thermodynamics* Viva Books Pvt. Ltd.:New Delhi (2004).
- Levine, I .N. *Physical Chemistry* 6th Ed., Tata Mc Graw Hill (2010).

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SEMESTER-III

Paper Title : **INORGANIC CHEMISTRY-I**
Paper Code : **CHMMJ-031**
Course No. : **C- 03**
Credits : **04**
No. of Classes : **60**
Total Theory Marks : **100 (End Semester: 70; In Semester: 30)**

Course Objectives:

- To introduce students to the various theories of acid and bases, hard and soft concept of ions & molecules and acid – base indicators
- To understand the principle and application of oxidation and reduction
- To enable students with diverse range of principles underlying qualitative and quantitative analysis, separation of cations, impact of interfering radicals etc.
- To introduce the principle of volumetric and gravimetric analysis with application
- To give basic concept of polymer chemistry with special reference to inorganic polymer and its applications
- To introduce the main group chemistry of hydrides, compounds of boron and their applications

Course Outcome: Students will gain an understanding of

- Acid-Base concepts, principle of oxidation- reduction.
- Analysis of inorganic salt mixture including interfering radicals.
- Principle of volumetric and gravimetric analysis and its application.
- Basics of polymer chemistry including inorganic polymer and its diverse application in modern sciences

UNIT-I: Acid-Base Concepts: Arrhenius Definition, Lewis Definition, Bronsted-Lowry Definition, Lux Flood Definition, Solvent System Definition, Solvated Proton, Relative Strength of Acids, Leveling Solvents, Types of Acid-Base Reactions, Pearson's Hard and Soft Acids and Bases (HSAB) Concept, Application of HSAB Principle, Theory of Acid-Base Indicators, Selection of Indicators and their Limitations.

(12 Lectures; 14 Marks)

UNIT-II: Oxidation-Reduction: Oxidation and Reduction Reactions, Oxidation Number Concept, Balancing Redox Equations by Oxidation Number Method and Ion-electron Method, Equivalent Weight of Oxidizing and Reducing agents, Standard Electrode Potential and its Application to Inorganic Reactions. Redox Stability in Water – Disproportionation and Comproportionation, Frost and Latimer diagrams

(08 Lectures; 08 Marks)

UNIT-III: Theoretical Principles in Qualitative Analysis (H_2S Scheme): Basic Principles Involved in Analysis of Cations and Anions, Different types of equilibrium, solubility products, common ion effect (with example). Confirmatory test for chlorie, bromide, nitrate, Principles involved in separation of cations into groups and choice of group reagents. Interfering anions

(fluoride, borate, oxalate and phosphate: Detection and removal) and need to remove them after Group II. Detection of anions with mixture (Carbonate & Sulphite), (Nitrate & Bromide), (Bromide & Iodide).

(12 Lectures; 12 Marks)

UNIT-IV: Principles of Volumetric Analysis and Gravimetric Analysis: Principle involved in volumetric (Redox & Complexometry) and Gravimetric analysis. Application in analytical chemistry: Estimation of Ni (II) by DMG, Al (III) as oxinate in a given solution, Estimation of Ca (II), Mg (II) and Zn (II) by complexometric titrations using EDTA. Hardness of a given sample of water by complexometric titration. Iodometry and Iodimetry.

(06 Lectures; 10 Marks)

UNIT-V: Inorganic Polymers: Types of inorganic polymers, comparison with organic polymers, synthesis, structural aspects and applications of silicones and siloxanes. Borazines, silicates and phosphazenes, and polysulphates.

(05 Lectures; 06 Marks)

UNIT-VI: Nuclear Chemistry & Radioactivity: Definition, Natural Radioactivity, Nature of Radioactive rays, Unit of Radioactivity,Laws of radioactivity, Law of Radioactive disintegration, Half – life period, Average life period, Stability of nucleus: Mass defect and nuclear binding energy, Packing fraction., n/p ratio, Meson theory, Nuclear shell model, Chain reaction: Nuclear fission and fusion, Nuclear Reactor, Breeder Reactions, Artificial Nuclear Transmutation or Transformation.

(07 Lectures; 08 Marks)

UNIT-VII: Hydrides & Chemistry of Group 13 Elements: Definition and their classification ionic, covalent and interstitial. Basic beryllium acetate and nitrate**. Chemistry of Group 13 Elements:** The elements and their properties; Chemistry of Boron; Borides; Boron hydrides (Preparation, structure, bonding, reactions and properties); Wade's rule, Boron halides, Boron-Nitrogen chemistry; Boron-Oxygen chemistry, borane, carborane, metalloborane and metallocarboranes.

(10 Lectures; 12 Marks)

Text Books:

- Huheey, J. E.; Keiter, E.A. & Keiter, R.L. *Inorganic Chemistry,* Pearson,2006
- Atkin, P. *Shriver & Atkins' Inorganic Chemistry,* 5th Ed., Oxford University Press (2010)
- Lee, J. D. *Concise Inorganic Chemistry,* 5th Ed.*,* Wiley India Pvt. Ltd., 2008

Reference Books:

- Douglas, B.E. and McDaniel, D.H. *Concepts & Models of Inorganic Chemistry* Oxford, 1970.
- Cotton, F.A., Wilkinson, G. and Gaus, P.L., *Basic Inorganic Chemistry 3rd Ed.;* Wiley India.
- Sharpe, A.G., *Inorganic Chemistry*, 4th Ed. Indian Reprint (Pearson Education) 2005.
- Mingos, D.M.P., *Essential trends in inorganic chemistry*. Oxford University Press (1998)
- General and Inorganic Chemistry (Part-1 & 2) , RP Sarkar, NCBA, 2015

- Harvey, B. G. Nuclear Chemistry. Prentice-Hall (1965)
- SWAYAM
- N-LIST
- E-PATHSALA

Paper Title : ORGANIC CHEMISTRY-I (THEORY)
Paper Code : CHMMJ-032
Course No : C- 04
Credits : 04
No. of Classes : 60
Total Theory Marks : 100 (End Semester: 70; In Semester: 30)

Course Objectives:

- To impart basic knowledge on chemistry of alcohols, phenols and ethers,
- To understand chemistry of Thiols & Thioethers.
- To gain insight in carbonyl compounds, carboxylic acids and their derivatives.
- To understand chemistry of different classes nitrogen containing compounds.

Course Outcome: Students will gain an understanding of

- An idea of alcohols, phenols, carbonyl compounds, acids and their derivatives etc.
- The prediction of mechanism for organic reactions.
- How to describe and classify organic compounds in terms of their functional groups and reactivity.
- Identification and classification of different types of N-based derivatives

Unit-I: Alcohols, Phenols, Ethers and Epoxides: Alcohols: preparation, properties and relative reactivity of 1°, 2°, 3° alcohols, Bouvaelt-Blanc Reduction; Preparation and properties of glycols: Oxidation by periodic acid and lead tetraacetate, Pinacol-Pinacolone rearrangement. Phenols: Preparation and properties; Acidity and factors effecting it, Ring substitution reactions, Reimer–Tiemann and Kolbe's-Schmidt Reactions, Fries and Claisen rearrangements with mechanism; Ethers and Epoxides: Preparation (Simmons-Smith reaction) and reactions with acids. Reactions of epoxides with alcohols, ammonia derivatives and $LiAlH_4$.
Sulphur containing compounds: Thiols & Thioethers: Preparation and reactions

(16 Lectures; Marks: 20)

Unit-II: Carbonyl Compounds: Structure, reactivity and preparation; Nucleophilic additions, Nucleophilic addition-elimination reactions with ammonia derivatives with mechanism; Mechanisms of Aldol, Benzoin, Knoevenagel condensation, Claisen-Schmidt, Darzens, McMurray, Perkin, Cannizzaro and Wittig reaction, Beckmann, Favorskii, Wolff and Benzil-Benzilic acid rearrangements, haloform reaction and Baeyer Villiger oxidation, α-substitution reactions, oxidations and reductions (Clemmensen, Wolff-Kishner, $LiAlH_4$, $NaBH_4$, MPV, PDC and PGC); Addition reactions of unsaturated carbonyl compounds: Michael addition.

Active Methylene Compounds: Keto-enol tautomerism. Preparation and synthetic applications of diethyl malonate and ethyl acetoacetate.
Organometallic compounds of Mg and Li: Use in synthesis of organic compounds.

(16 Lectures: Marks: 20)

Unit-III: Carboxylic Acids and their Derivatives: Preparation, physical properties and reactions of monocarboxylic acids: Typical reactions of dicarboxylic acids, hydroxy acids and unsaturated acids: succinic/phthalic, lactic, malic, tartaric, citric, maleic and fumaric acids; Preparation and reactions of acid chlorides, anhydrides, esters and amides; Comparative study of nucleophilic sustitution at acyl group -Mechanism of acidic and alkaline hydrolysis of esters, Claisen condensation, Dieckmann and Reformatsky reactions, Hofmann and Curtius rearrangement.

(14 Lectures; Marks: 16)

Unit-IV: **Nitrogen Containing Functional Groups**: Preparation and important reactions of nitro compounds, nitriles and isonitriles. Amines: Effect of substituent and solvent on basicity; Preparation and properties: Gabriel phthalimide synthesis, Carbylamine reaction, Mannich reaction, Lossen rearrangement, Hofmann's exhaustive methylation, Hofmann-elimination reaction; Distinction between 1°, 2° and 3°amines with Hinsberg reagent and nitrous acid.
Diazonium Salts: Preparation and their synthetic applications.

(16 Lectures; Marks: 14)

Text Book(s):

- Clayden, J.; Greeves, N.; Warren, S.; Wothers, P. *Organic Chemistry*, 2nd Edn., Oxford University Press, 2012.
- Morrison, R. T.; Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Finar, I. L. *Organic Chemistry* (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Graham Solomons, T.W. *Organic Chemistry*, John Wiley & Sons, Inc.

Reference Book(s):

- Keeler, J.; Wothers, P. *Chemical Structure and Reactivity – An Integrated approach*, Oxford University Press.
- Smith, J. G. *Organic Chemistry*, Tata McGraw-Hill Publishing Company Ltd.
- Carey, F. A.; Sundberg, R. J. *Advanced Organic Chemistry: Reactions and Synthesis* (Part B), Springers.

Paper Title : PRACTICAL CHEMISTRY -I (Practical)
Paper Code : CHMMJ-034
Course No : C- 05
Credits : 04

No. of Classes : 120
Total Theory Marks : 100 (End Semester: 70; In Semester: 30)

Section A (Inorganic Chemistry) (40 Lectures; Marks: 24)

Unit-I: Qualitative semimicro analysis of mixtures containing 5 radicals. The following radicals are suggested:
CO_3^{2-}, NO_2^-, S^{2-}, SO_3^{2-}, $S_2O_3^{2-}$, CH_3COO^-, F^-, Cl^-, Br^-, I^-, NO_3^-, BO_3^{3-}, $C_2O_4^{2-}$, PO_4^{3-}, NH_4^+, K^+, Pb^{2+}, Cu^{2+}, Cd^{2+}, Bi^{3+}, Sn^{2+}, Sb^{3+}, Fe^{3+}, Al^{3+}, Cr^{3+}, Zn^{2+}, Mn^{2+}, Co^{2+}, Ni^{2+}, Ba^{2+}, Sr^{2+}, Ca^{2+}, Mg^{2+}

Mixtures should preferably contain one interfering anion, or Insoluble component.

Unit-II: Acid-Base Titrations
1. Estimation of carbonate and hydroxide present together in mixture.
2. Estimation of carbonate and bicarbonate present together in a mixture.

Section B (Organic Chemistry) (40 Lectures; Marks: 23)

Unit I:

1. Purification of organic compound and determination of melting point: Purification of organic compounds by crystallization using the following solvents: Water, Alcohol, Alcohol-Water.

2. Estimation of Glucose

Unit II: Chromatography:
1. Separation of a mixture of two amino acids by ascending and horizontal paper chromatography.
2. Separation of a mixture of two sugars by ascending paper chromatograph.
3. Separation of a mixture of o-and p-nitrophenol or o-and p-aminophenol by thin layer chromatography (TLC)

Section C (Physical Chemistry) (40 Lectures; Marks: 23)

Unit-I: Surface Tension and Viscosity
1. Surface tension measurements: Determine the surface tension by (i) drop number (ii) drop weight method.
2. Viscosity measurement using Ostwald's viscometer:

Unit-II: pH Metry
1. Study the effect on pH upon addition of HCl/NaOH to solutions of acetic acid, sodium acetate and their mixtures.
2. Preparation of buffer solutions of different pH: (i) Sodium acetate-acetic acid (ii) Ammonium chloride-ammonium hydroxide
3. pH metric titration of (i) strong acid vs. strong base, (ii) weak acid vs. strong base.

Determination of dissociation constant of a weak acid.

Text Books:

- Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.
- Furniss, B. S., Ford, A. J. H., Smith, P. W. H., Tatchell, A. R. Vogel's Textbook of Practical Organic Chemistry, 5th Edn., (Wiley, 1989).
- Jadav, J. B. Advanced Practical Physical Chemistry, (Krishna Prakashan, 2015).
- Mendham, J., Danney, R. C., Barnes, J. D., Thomas, M. Vogel's Textbook of
- Quantitative Chemical Analysis, 6th Edn., (Prentice Hall, 2009).
- Gurdeep, R. Advanced Practical Inorganic Chemistry, (Krishna Prakashan, 2013).

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SEMESTER-IV

Paper Title : **INORGANIC CHEMISTRY-II**
Paper Code : **CHMMJ-041**
Course No : **C- 06**
Credits : **04**
No. of Classes : **60**
Total Theory Marks : **100 (End Semester: 70; In Semester: 30)**

Course Objectives:

- To introduce concept of coordination complex, its developmental theory, ligands, nomenclature and isomerism
- To understand various bonding theories of coordination complexes, and their applications in different geometries and the chelate effect and its applications
- To understand the magnetic properties, colour in complexes, charge transfer complexes and L-S coupling
- To give basic concept of lanthanoids and actinoids, their separation techniques and applications
- To introduce the main group chemistry of 14^{th} and 15^{th} group elements and their applications

Course Outcome: Students will gain an understanding of

- Coordination complexes, their bonding, magnetic properties.
- d-d transition, L-S coupling.
- Chemistry of inner transition elements and their applications
- Chemistry of 14^{th} and 15^{th} group elements

UNIT-I: Coordination Chemistry-I: Coordinate bonding: double and complex salts. Werner's theory of coordination complexes, Classification of ligands, Ambidentate ligands, chelates, Coordination numbers, IUPAC nomenclature of coordination complexes (up to two metal centers), Isomerism in coordination compounds, constitutional and stereo isomerism, Geometrical and optical isomerism in square planar and octahedral complexes.

Valence Bond Theory (inner and outer orbital complexes) and its limitations, Electroneutrality principle and back bonding, Elementary Crystal Field Theory: splitting of d^n configurations in octahedral, square planar and tetrahedral fields, crystal field stabilization energy (CFSE) in weak and strong fields; pairing energy. Spectrochemical series. Jahn- Teller distortion. Chelate effect, polynuclear complexes, Labile and inert complexes.

(20 Lectures, 20 Marks)

UNIT-II: Coordination Chemistry-II: Metal-ligand bonding (MO concept, elementary idea) Magnetism and Colour: Orbital and spin magnetic moments, spin only moments of d^n ions and their correlation with effective magnetic moments, including orbital contribution; quenching of magnetic moment: super exchange and anti-ferromagnetic interactions (elementary idea with examples only); d-d transitions; L-S coupling; qualitative Orgel diagrams for $3d^1$ to $3d^9$ ions. Racah parameter. Selection rules for electronic spectral transitions; spectrochemical series of ligands; charge transfer complexes and spectra (elementary idea).

(15 Lectures, 20 Marks)

UNIT-III: Lanthanoids and Actinoids: General Comparison on Electronic configuration, oxidation states, colour, spectral and magnetic properties; lanthanide contraction, separation of lanthanides (including ion-exchange method). Analytical applications

(07 Lectures, 08 Marks)

UNIT-IV: Chemistry of Group 14 Elements: The elements and their properties; Allotropy of Carbon: Diamond, Graphite, and Fullerenes; Intercalation; Carbides; Carbon halides and oxides; Compounds with C-N and C-S bonds; Silane reagents.

(06 Lecture, 08 Marks)

UNIT-V: Chemistry of Group 15 Elements: The elements and properties, Nitrogen compounds- Nitrides, Ammonia, Hydrazine, Oxides of Nitrogen, Oxo acids and anions, nitrogen compounds as ligands, Halides of Phosphorous, Oxides of Phosphorous, Phosphonium, P– N Compounds. Organic compounds of Phosphorous, Compounds with element-element bonds, Oxo anions of Phosphorous, Phosphate in bio systems, Phosphorous compounds as ligands, Compounds of As, Sb and Bi.

(12 Lectures, 14 Marks)

Text Books:

- Lee, J. D. *Concise Inorganic Chemistry,* 5th Ed.*,* Wiley India Pvt. Ltd., 2008.
- Coordination Chemistry, Ajai Kumar, Aaryush Educations, Ghaziabad, 2014
- Atkin, P. *Shriver & Atkins' Inorganic Chemistry,* 5th Ed., Oxford University Press (2010)

Reference Books:

- Cotton, F.A., Wilkinson, G. and Gaus, P.L., *Basic Inorganic Chemistry 3rd Ed.;* Wiley India.
- Sharpe, A.G., *Inorganic Chemistry*, 4th Ed. Indian Reprint (Pearson Education) 2005.
- Huheey, J. E.; Keiter, E.A. & Keiter, R.L. *Inorganic Chemistry,* Pearson,2006
- Mingos, D.M.P., *Essential trends in inorganic chemistry*. Oxford University Press (1998)
- General and Inorganic Chemistrty, RP Sarkar, NCBA, 2015
- SWAYAM
- N-LIST
- E-PATHSALA

Paper Title : **ORGANIC CHEMISTRY-II (THEORY)**
Paper Code : **CHMMJ-042**
Course No : **C- 07**
Credits : **04**
No. of Classes : **60**
Total Theory Marks : **100 (End Semester: 70; In Semester: 30)**

Course Objectives:

- To deal in detail the different aspects of the chemistry of heterocyclic compounds.
- To understand Isolation and Structure elucidation and synthesis of alkaloids.
- To understand Structure elucidation and synthetic application of terpenoids
- Classification, structure, reactivity and chemical properties of polymers anf pharmaceutical compounds.
- To understand chemistry of dyes and polynuclear hydrocarbons.

Course Outcome: Students will gain an understanding of

- Classification, nomenclature and Structure of Heterocyclic Compounds.
- Reaction and mechanism of substitution reactions in heterocyclic compounds.
- General structural features, Isolation and Structure elucidation of alkaloids and terpenoids
- Synthesis and different types of reactions of alkaloids and terpenoids.
- Classification, structure, reactivity and chemical properties of polymers.
- Preparation of polynuclear hydrocarbons and their reactions.

Unit-I: Heterocyclic Compounds: Classification and nomenclature, Structure, aromaticity in 5-numbered and 6-membered rings containing one heteroatom; Synthesis, reactions and mechanism of substitution reactions of: Furan, Pyrrole (Paal-Knorr synthesis, Knorr pyrrole synthesis, Hantzsch synthesis), Thiophene, Pyridine (Hantzsch synthesis), indole, Fischer indole synthesis and Madelung synthesis), Structure elucidation of quinoline and isoquinoline, Skraup synthesis, Friedlander's synthesis, Knorr quinoline synthesis, Doebner-Miller synthesis, Bischler-Napieralski reaction, Pictet-Spengler reaction.

(16 Lectures; Marks: 14)

Unit-II: Alkaloids: Natural occurrence, General structural features, Isolation and their physiological action Hoffmann's exhaustive methylation, Emde's modification, Structure elucidation and synthesis of Hygrine and Nicotine. Medicinal importance of Nicotine, Hygrine, Quinine, Morphine, Cocaine, and Reserpine.

(12 Lectures; Marks: 10)

Unit-III: Terpenoids: Occurrence, classification, isoprene rule; Elucidation of structure and synthesis of Citral, Neral and α-terpineol.

(8 Lectures; Marks: 8)

Unit-IV: Pharmaceutical Compounds: Classification, structure and therapeutic uses of antipyretics: Paracetamol (with synthesis), Analgesics: Ibuprofen (with synthesis),

Antimalarials: Chloroquine (with synthesis). An elementary treatment of Antibiotics and detailed study of chloramphenicol and sulpha drugs (Preparation and mechanism of action), Medicinal values of curcumin (haldi), azadirachtin (neem), vitamin C and antacid (ranitidine).

(10 Lectures; Marks: 10)

Unit-V: Dyes: Classification, Colour and constitution; Mordant and Vat Dyes; Chemistry of dyeing; Synthesis and applications of: Azo dyes-Methyl Orange and Congo Red (mechanism of Diazo Coupling); Triphenyl Methane Dyes -Malachite Green, Rosaniline and Crystal Violet; Phthalein Dyes-Phenolphthalein and Fluorescein; Natural dyes-structure elucidation and synthesis of Alizarin and Indigotin; Edible Dyes with examples.

(10 Lectures; Marks: 12)

Unit-VI: **Polynuclear Hydrocarbons:** Structure, preparation and reactions of Reactions of naphthalene, phenanthrene and anthracene.

(4 Lectures; Marks: 8)

Unit-VII: Polymers: Metallocene-based Ziegler-Natta polymerisation of alkenes; Preparation and applications of plastics-thermosetting (phenol-formaldehyde, Polyurethanes) and thermosoftening (PVC, polythene); Fabrics-natural and synthetic (acrylic, polyamido, polyester); Rubbers-natural and synthetic: Buna-S, Chloroprene and Neoprene; Vulcanization; Polymer additives; Introduction to liquid crystal polymers; Biodegradable and conducting polymers with examples.

(5 Lectures; Marks: 8)

Text Book(s):

- Morrison, R. T.; Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Finar, I. L. *Organic Chemistry (Volume 1)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Finar, I. L. *Organic Chemistry (Volume 2: Stereochemistry and the Chemistry of Natural Products)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

Reference Book(s):

- Clayden, J.; Greeves, N.; Warren, S.; Wothers, P. *Organic Chemistry*, Oxford University Press.
- Singh, J.; Ali, S.M.; Singh, J. *Natural Product Chemistry*, Prajati Parakashan (2010).
- Graham Solomons, T.W. *Organic Chemistry*, John Wiley & Sons, Inc.
- Kalsi, P. S. *Textbook of Organic Chemistry*, 1st Ed., New Age International (P) Ltd. Pub.

Paper Title	**: PHYSICAL CHEMISTRY-I (THEORY)**
Paper Code	**: CHMMJ-043**
Course No	**: C- 08**
Credits	**: 04**
No. of Classes	**: 60**

Total Theory Marks : 100 (End Semester: 70; In Semester: 30)

Course Objectives:

- To understand the solid states of matter.
- To gain insight on interactions of ions in solution.
- T gain knowledge on surface phenomena of solids.
- To understand thermodynamic free energy functions.

Course Outcome: Students will gain an understanding of

- Arrangement of constituent particles of solids, diffraction methods of analyzing the structure of solids and various types of defects present in solids
- Ionization of electrolytes in solution, ionization constant, pH scale, buffer solution, solubility of salts, solubility product and its application, theory of acid base titration and indicators.
- Adsorption on solid surface and adsorption isotherms.
- Free energy functions and systems of variable compositions.

Unit-I: Solid State: Nature of the solid state, law of constancy of interfacial angles, law of rational indices, Miller indices, elementary ideas of symmetry, symmetry elements, discussion of various symmetry elements of a cubical crystal, Crystallographic terms, Space lattice or crystal lattice, crystal structure and unit cell, calculation of interplanar separation for cubic systems, qualitative idea of point and space groups, seven crystal systems and fourteen Bravais lattices; X-ray diffraction, Bragg's law, a simple account of rotating crystal method and powder pattern method. Analysis of powder diffraction patterns of NaCl. Density of cubic crystals, Closest packing, Packing in ionic solids, Effect of ion size on crystal structure – radius ratio, Void, Defects in crystals, Semiconductor and Band theory, Super cooled liquids and liquid crystals.

(15 Lectures; Marks: 16)

Unit-II: Ionic Equilibria: Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water. Ionization of weak acids and bases, pH scale, common ion effect; dissociation constants of mono-, di-and triprotic acids (exact treatment). Salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts. Buffer solutions; derivation of Henderson equation and its applications; buffer capacity, buffer range, buffer action and applications of buffers in analytical chemistry and biochemical processes in the human body. Solubility and solubility product of sparingly soluble salts – applications of solubility product principle.

(15 Lectures; Marks: 18)

Unit-III: Surface Chemistry and Colloids: Physical adsorption, chemisorption, adsorption isotherms- Langmuir & Freundlich. nature of adsorbed state, BET Theory

The colloidal systems, Preparation of lyophobic colloidal solutions, Properties of colloidal systems, zeta potential, DLVO theory, Micelles, Critical Micelle Concentration (CMC).

(10 Lectures; Marks: 14)

Unit IV: Free Energy Functions: Gibbs and Helmholtz energy; variation of S, G, A with T, V, P; Free energy change and spontaneity. Relation between Joule-Thomson coefficient and other thermodynamic parameters; inversion temperature; Gibbs-Helmholtz equation; Maxwell relations; thermodynamic equation of state.

(10 Lectures; Marks: 14)

Unit-V: Systems of Variable Composition: Partial molar quantities, dependence of thermodynamic parameters on composition; Gibbs-Duhem equation, chemical potential of ideal mixtures, change in thermodynamic functions in mixing of ideal gases.

(10 Lectures; Marks: 8)

Text Books:

- Atkins, P. Paula, J., et al.; *Physical Chemistry International Edition* (2018).
- West, A. R.; *Solid State Chemistry and its Applications*. Wiley (2014).

Reference Books:

- Butler, J. N.; *Ionic Equilibrium: Solubility and pH Calculations*. Wiley-Interscience (1998).
- Levine, I.N. *Physical Chemistry 6th Ed*., Tata Mc Graw Hill (2010).
- Pathania, P. S.; *Physical Chemistry. 48th Edition* (2021).
- Kapoor K. L. *A Textbook of Physical Chemistry Sixth Ed*., Vol. 2, Macmillan, India

Paper Title	**: PRACTICAL CHEMISTRY -II (Practical)**
Paper Code	**: CHMMJ-044**
Course No	**: C- 09**
Credits	**: 04**
No. of Classes	**: 120**
Total Theory Marks	**: 100 (End Semester: 70; In Semester: 30)**

Section A (Inorganic Chemistry) **(40 Lectures; 23 Marks)**

Unit-I: Titration

Oxidation-Reduction

1. Estimation of Fe (II) and oxalic acid using standardized $KMnO_4$ solution.
2. Estimation of oxalic acid and sodium oxalate in a given mixture.

Iodo / Iodimetric Titrations

(i) Estimation of Cu(II) and $K_2Cr_2O_7$ using sodium thiosulphate solution iodimetrically.
(ii) Estimation of available chlorine in bleaching powder iodometrically.

Unit-II: Inorganic Preparations

(i) Cuprous Chloride, Cu_2Cl_2
(ii) Preparation of Manganese (III) phosphate, $MnPO_4.H_2O$

(iii) Preparation of Aluminium potassium sulphate $KAl(SO_4)_2.12H_2O$ (Potash Alum) or Chrome alum.

Section B (Organic Chemistry) (40 Lectures; 24 Marks)

Unit-I: Qualitative Organic analysis

1. Detection of extra elements in organic compounds (up to two extra elements).
2. Functional group test for nitro, amine and amide groups.

Unit-II: Organic Preparations:

1. Acetylation of one of the following compounds: amines (aniline, o-, m -, p- toluidines and o-, m-, p-anisidine) and phenols (β-naphthol, vanillin, salicylic acid).
2. Benzolyation of one of the following amines (aniline, o-, m-, p- toluidines and o-, m-, panisidine) and one of the following phenols (β-naphthol, resorcinol, p-cresol) by Schotten-Baumann reaction.
3. Nitration of Acetanilide/nitrobenzene.
4. Selective reduction of metadinitrobenzene to m-nitroaniline.
6. Benzil-benzilic rearrangement

Section C (Physical Chemistry) (40 Lectures; 23 Marks)

Unit-I: Phase Equilibria:

1. Determination of critical solution temperature and composition of the phenol-water system and to study the effect of impurities on it.
2. Distribution of acetic/ benzoic acid between water and cyclohexane.
3. Study the equilibrium of at least one of the following reactions by the distribution method:

(i) $I_{2(aq)} + I^- \rightarrow I_3^-{}_{(aq)}$

(ii) $Cu^{2+}{}_{(aq)} + nNH_3 \rightarrow Cu(NH_3)_n$

Unit-II: Study the kinetics of the following reactions.

A. Initial rate method: Iodide-persulphate reaction

B. Integrated rate method: (i) Acid hydrolysis of methyl acetate with hydrochloric acid. (ii) Saponification of ethyl acetate.

Unit-III: Adsorption: Verify the Freundlich and Langmuir isotherms for adsorption of acetic acid on activated charcoal.

Text Books:

- Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.
- Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A. J., Smith, P. W. G., Textbook of Practical Organic Chemistry, 5th Edn., (Prentice-Hall, 1996).
- Jadav, J. B. Advanced Practical Physical Chemistry, (Krishna Prakashan, 2015)
- Halpern, A. M. & McBane, G. C. Experimental Physical Chemistry 3rd Ed.; W.H. Freeman & Co. New York (2003).

SEMESTER-V

Paper Title : **INORGANIC CHEMISTRY-III**
Paper Code : **CHMMJ-051**
Course No : **C- 10**
Credits : **04**
No. of Classes : **60**
Total Theory Marks : **100 (End Semester: 70; In Semester: 30)**

Course Objectives:

- To introduce students to the concept of organometallic chemistry: Bonding, heptacity, electron count, preparation, structure and bonding in 3d series compounds, preparation, structure and reactions of ferrocene and Zeise salt
- To understand mechanism of organometallic reactions and applications of organometallic catalyst in industry
- To give basic concept of halogens and noble gases and their applications
- To introduce the need of metal ions in biology, function, structure of metallo proteins and metalloenzymes, metal poisoning and chelate therapy

Course Outcome: Students will gain an understanding of

- Organometallic chemistry and their applications.
- Chemistry of halogens and noble gases.
- The role of inorganic elements in biology.

UNIT-I: Organometallic Chemistry: Definition and classification of organometallic compounds on the basis of bond type. Concept of hapticity of organic ligands. 18-electron and 16-electron rules (pictorial MO approach). Applications of 18-electron rule to metal carbonyls, nitrosyls, cyanides. General methods of preparation of mono and binuclear carbonyls of 3d series. Structures of mononuclear and binuclear carbonyls of Cr, Mn, Fe, Co and Ni. pi-acceptor behaviour of CO, synergic effect and use of IR data to explain extent of back bonding. Zeise's salt: Preparation, structure, evidences of synergic effect. Ferrocene: Preparation and reactions (acetylation, alkylation, metallation, Mannich Condensation). Structure and aromaticity. Comparison of aromaticity and reactivity with that of benzene, Organometallic compounds of Mg and Li –Use in synthesis of organic compounds. Schlenk equilibrium, σ, π donor/π acceptor ligands – olefin complexes, Metal–Metal bonds and transition metal clusters (brief idea).

(22 Lectures; 25 Marks)

UNIT-II: Reactions of Organometallic Complexes and Organometallic Catalysis: Oxidative addition**,** reductive elimination, insertion, nucleophilic and electrophilic attack of coordinated ligands substitution, Study of the following industrial processes and their mechanism: Alkene hydrogenation (Wilkinson's Catalyst), Hydroformylation, Wacker Process, Synthetic gasoline (Fischer Tropsch reaction), Ziegler-Natta catalysis for olefin polymerization

(10 Lectures; 15 Marks)

UNIT-III: Halogen Family: Electronic structure and valences, preparation, interhalogen compounds, polyhalides, pseudohalogens,fluorocarbons, charge transfer complexes of halogens, oxides and oxoacids of halogens.

(05 Lectures; 07 Marks)

UNIT-IV: Noble Gases: Occurrence separation and uses, rationalization of inertness of noble gases, Clathrates; preparationand properties of XeF_2, XeF_4 and XeF_6. Nature of bonding in noble gas compounds (Valence bond treatment for XeF_2 and XeF_4, MO treatment for XeF_2). Xenon-oxygen compounds. Molecular shapes of noble gas compounds (VSEPR theory).

(07 Lectures; 08 Marks)

UNIT-V: Bioinorganic Chemistry: Elements of life: essential and beneficial elements, major, trace and ultratrace elements, the role of metal ions (specially Na, K, Mg, Ca, Fe, Cu, and Zn) in biological system. Metal ion transport across biological membrane Na/ K-ion pump. Metal ions in biological systems: Heme proteins-hemoglobin, myoglobin, Non-Heme Iron Proteins: Iron storage and transfer-ferritin, transferrin; electron transfer (Iron-sulfur protein)-rubredoxin, ferredoxin; O_2 transport-hemerythrin, Copper proteins and Enzymes-Hemocyanin, superoxide dismutase, ceruloplasmin, cytochrome coxidase; Zinc and Cobalt enzymes-carbonic anhydrase, carboxypeptidase, Vitamin B_{12} and and Nitrogen fixation Metals in medicines and therapy. Pt and Au complexes as drugs (examples only), metal dependent diseases (examples only), Toxic metal ions and their effects (Hg, Pb, Cd and As), chelation therapy (examples only),

(16 Lectures; 15 Marks)

Text Books:

- Lee, J. D. *Concise Inorganic Chemistry,* 5th Ed., Wiley India Pvt. Ltd., 2008.
- Organometallic and Bioinorganic Chemistry, Ajai Kumar, Aaryush Educations, 2014
- Atkin, P. *Shriver & Atkins' Inorganic Chemistry,* 5th Ed., Oxford University Press (2010)
- Huheey, J. E.; Keiter, E.A. & Keiter, R.L. *Inorganic Chemistry,* Pearson,2006

Reference Books:

- Cotton, F.A., Wilkinson, G. and Gaus, P.L., *Basic Inorganic Chemistry 3rd Ed.;* Wiley India.
- Sharpe, A.G., *Inorganic Chemistry*, 4th Ed. Indian Reprint (Pearson Education) 2005.
- Mingos, D.M.P., *Essential trends in inorganic chemistry*. Oxford University Press (1998)
- Bioinorganic Chemistry, K Hussain Reddy, New Age International, 2003
- SWAYAM
- N-LIST
- E-PATHSALA

Paper Title : **ORGANIC CHEMISTRY-III (THEORY)**
Paper Code : **CHMMJ-052**
Course No : **C- 11**
Credits : **04**
No. of Classes : **60**
Total Theory Marks : **100 (End Semester: 70; In Semester: 30)**

Course Objectives:

- To impart basic knowledge on chemistry of biomolecules such as nucleic acids, amino acids, peptides, proteins, enzymes, lipids and that work within biological systems.
- To understand chemistry and energetics of biological system.
- To gain knowledge on carbohydrate chemistry.
- To understand art of retro synthetic analysis.
- To impart basic knowledge on chemistry of polymers.

Course Outcome: Students will gain an understanding of

- The structure, synthesis, chemical properties and importance of nucleic acids in biological systems.
- The chemical properties and structure of amino acids and proteins and enzymes
- Concepts of energetics of biological systems.
- Classification, structure and biological importance of Lipids & carbohydrates.
- Organic synthesis, retro synthesis and concept of FGI, FGA and synthon.
- Identification of Biodegradable polymer, colour and constitution of dyes and applications of different dyes.

Unit-I: Nucleic Acids: Components of nucleic acids, Nucleosides and nucleotides; Structure, synthesis and reactions of: Adenine, Guanine, Cytosine, Uracil and Thymine; Structure of polynucleotides.

(5 Lectures; Marks: 8)

Unit-II: Amino Acids, Peptides and Proteins: Amino acids, Peptides and their classification. α-Amino Acids - Synthesis, ionic properties and reactions. Zwitterions, pKa values, isoelectric point and electrophoresis; Study of peptides: determination of their primary structures-end group analysis, methods of peptide synthesis. Synthesis of peptides using N-protecting, C-protecting and C-activating groups - Solid-phase synthesis.

(10 Lectures; Marks: 14)

Unit-III: Enzymes: Introduction, classification and characteristics of enzymes. Salient features of active site of enzymes. Mechanism of enzyme action (taking trypsin as example), factors affecting enzyme action, coenzymes and cofactors and their role in biological reactions, specificity of enzyme action (including stereospecificity), enzyme inhibitors and their importance, phenomenon of inhibition (competitive, uncompetitive and non-competitive inhibition including allosteric inhibition.

(8 Lectures; Marks: 10)

Unit-IV: Lipids: Introduction to oils and fats; common fatty acids present in oils and fats, Hydrogenation of fats and oils, Saponification value, acid value, iodine number. Reversion and rancidity.

(6 Lectures; Marks: 6)

Unit-V: Concept of Energy in Biosystems: Cells obtain energy by the oxidation of foodstuff (organic molecules). Introduction to metabolism (catabolism, anabolism). ATP: The universal currency of cellular energy, ATP hydrolysis and free energy change. Agents for transfer of electrons in biological redox systems: NAD^+, FAD. Conversion of food to energy: Outline of catabolic pathways of carbohydrate- glycolysis, fermentation, Krebs cycle.

(6 Lectures; Marks: 8)

Unit-VI: Carbohydrates: Occurrence, classification and their biological importance. Monosaccharides: Constitution and absolute configuration of glucose and fructose, epimers and anomers, mutarotation, determination of ring size of glucose and fructose, Haworth projections and conformational structures; Interconversions of aldoses and ketoses; Killiani-Fischer synthesis and Ruff degradation; Disaccharides – Structure elucidation of maltose, lactose and sucrose. Polysaccharides – Elementary treatment of starch, cellulose and glycogen.

(10 Lectures; Marks: 14)

Unit-VII: Planning of Organic Synthesis I: Disconnection, functional group interchange (FGI), functional group addition (FGA), synthons and synthetic equivalent, simple example of reactions (Corey House, witting and aldol condensation), retrosynthesis of monofunctionalized compounds.

(10 Lectures; Marks: 10)

Text Book(s):

- Bruice, P. Y. *Organic Chemistry*, Pearson, 3rd Edn., 2013.
- Warren, S. *Organic Synthesis: The disconnection approach*, Wiley, 2nd Edn., 2009.
- McMurry, J.E. Fundamentals of Organic Chemistry, 7th Edn. Cengage Learning India Edn., 2013.

Reference Books:

- Kalsi, P.S. *Organic Synthesis through Disconnection Approach*, MedTech Science Press, 2nd Edn., 2022.
- Nelson, D.L.; Cox, M. M. and Lehninger A.L. *Principles of Biochemistry*, 4th Edn., W.H. Freeman and Co., 2009.
- Berg, J.M.; Tymoczko, J.L. and Stryer, L. *Biochemistry*. 6th Edn., W.H. Freeman and Co. 2006.
- Billmeyer, F. W. *Textbook of Polymer Science*, John Wiley & Sons, Inc.
- Graham Solomons, T.W. *Organic Chemistry*, John Wiley & Sons, Inc.

Paper Title	**: PHYSICAL CHEMISTRY-II (THEORY)**
Paper Code	**: CHMMJ-053**
Course No	**: C- 12**
Credits	**: 04**
No. of Classes	**: 60**
Total Theory Marks	**: 100 (End Semester: 70; In Semester: 30)**

Course Objectives:

- To understand kinetics of chemical reactions.
- To impart knowledge on catalytic activity of chemicals.
- To gain understanding of the basic thermodynamics of chemical equilibrium.
- To understand different spectroscopic technique and their application.

Course Outcome: After completion of the course, the learner shall be able to understand:

- Rate laws, kinetics of different types of reactions and theories of reaction rates.
- The basic principles involved in the interaction of electromagnetic radiation with matter
- Different types of spectra of CO_2: Spectroscopic techniques like IR, UV-Vis, NMR and the theory involved.
- Use of the spectroscopy in deducing the chemical structure.

Unit I: I: Chemical Kinetics: Order and molecularity of a reaction, rate laws in terms of the advancement of a reaction, differential and integrated form of rate expressions up to second order reactions, experimental methods of the determination of rate laws, kinetics of complex reactions (integrated rate expressions up to first order only): (i) Opposing reactions (ii) parallel reactions and (iii) consecutive reactions and their differential rate equations (steady-state approximation in reaction mechanisms) (iv) chain reactions. Temperature dependence of reaction rates; Arrhenius equation; activation energy. Collision theory of reaction rates, Lindemann mechanism, qualitative treatment of the theory of absolute reaction rates.

(16 Lectures; Marks: 18)

Unit II: Catalysis: Types of catalyst, specificity and selectivity, mechanisms of catalyzed reactions at solid surfaces; effect of particle size and efficiency of nanoparticles as catalysts. Enzyme catalysis, Michaelis-Menten mechanism, acid-base catalysis.

(7 Lectures; Marks: 8)

Unit III: Chemical Equilibrium: Criteria of thermodynamic equilibrium, degree of advancement of reaction, chemical equilibria in ideal gases, concept of fugacity. Thermodynamic derivation of relation between Gibbs free energy of reaction and reaction quotient. Coupling of exoergic and endoergic reactions. Equilibrium constants and their quantitative dependence on temperature, pressure and concentration. Free energy of mixing and spontaneity; thermodynamic derivation of relations between the various equilibrium constants K_p, K_c and K_x. Le Chatelier principle (quantitative treatment); equilibrium between ideal gases and a pure condensed phase.

(7 Lectures; Marks: 9)

Unit IV: Molecular Spectroscopy: Interaction of electromagnetic radiation with matter and various types of spectroscopy, Born-Oppenheimer approximation.
Rotation Spectroscopy: Selection rules, intensities of spectral lines, determination of bond lengths of diatomic and linear triatomic molecules, isotopic substitution.

Vibrational Spectroscopy: Classical equation of vibration, computation of force constant, amplitude of diatomic molecular vibrations, anharmonicity, Morse potential, dissociation energies, fundamental frequencies, overtones, hot bands, Fermi resonance, degrees of freedom for polyatomic molecules, modes of vibration, concept of group frequencies.
Vibration-rotation Spectroscopy: diatomic vibrating rotator, P, Q, R branches. Raman Spectroscopy: Qualitative treatment of Rotational Raman effect; Effect of nuclear spin,
Vibrational Raman spectra, Stokes and anti-Stokes lines; their intensity difference, rule of mutual exclusion.
Electronic Spectroscopy: Franck-Condon principle, electronic transitions, singlet and triplet states, fluorescence and phosphorescence, dissociation and predissociation, calculation of electronic transitions of polyenes using free electron model.
Nuclear Magnetic Resonance (NMR) Spectroscopy: Principles of NMR spectroscopy, Larmor precession, chemical shift and low-resolution spectra, different scales, spin-spin coupling and high-resolution spectra.
Electron Spin Resonance (ESR) Spectroscopy: Its principle, hyperfine structure, ESR of simple radicals.

(30 Lectures; Marks: 35)

Text Books:

- Pathania, P. S.; *Principles of Physical Chemistry*. 48th Edition (2021).
- Banwell, C.N.; *Fundamentals of Molecular Spectroscopy*, 4th Edition. Mc-Graw Hill (1994).

Reference Books

- Kapoor K. L. *A Textbook of Physical Chemistry Sixth Ed*., Vol. 2, Macmillan, India.
- Mukerjee, R.C.; *Modern Approach to Physical Chemistry 1*, BB Bharati Bhawan (P & D) (2022).
- Levine, I.N. *Physical Chemistry 6th Ed*., Tata Mc Graw Hill (2010).
- Pavia, D.L.; *Introduction to Spectroscopy*, 5th Edition Cengage India Private Limited (2015).

Paper Title : PRACTICAL CHEMISTRY-III (Practical)
Paper Code : CHMMJ-054
Course No : C- 13
Credits : 04
No. of Classes : 120
Total Theory Marks : 100 (End Semester: 70; In Semester: 30)

Section A (Inorganic Chemistry) (40 Lectures; 23 Marks)

UNIT-I: Gravimetric Analysis:

1. Estimation of Nickel (II) using Dimethylglyoxime (DMG)
2. Estimation of iron as Fe_2O_3 by precipitating iron as $Fe(OH)_3$

UNIT-II: Inorganic Preparations:

1. Tetraamminecopper (II) sulphate, $[Cu(NH_3)_4]SO_4.H_2O$
2. *Cis* and *trans* $K[Cr(C_2O_4)_2.(H_2O)_2]$ Potassium dioxalatodiaquachromate (III)
3. Tetraamminecarbonatocobalt (III) ion $[Co(NH_3)_4(CO_3)]^+$
4. Potassium tris(oxalate)ferrate (III) $K_3[Fe(C_2O_4)_3]$

Section B (Organic Chemistry) (40 Lectures; 23 Marks)

Unit-I:

1. Preparation of urea formaldehyde.
2. Preparation of Aspirin and its analysis.
3. Preparation of Paracetamol and its analysis.

Unit-II:

1. Estimation of glycine by Sorenson's formalin method.
2. Study of the titration curve of glycine.
3. Estimation of proteins by Lowry's method.
4. Saponification value of an oil or a fat.
5. Determination of Iodine number of an oil/ fat.

Section C (Physical Chemistry) (40 Lectures; 24 Marks)

Unit-I: UV/Visible spectroscopy

1. Study the 200-500 nm absorbance spectra of $KMnO_4$ and $K_2Cr_2O_7$ (in 0.1 M H_2SO_4) and determine the λ_{max} values. Calculate the energies of the two transitions in different units (J molecule^{-1}, kJ mol^{-1}, cm^{-1}, eV).
2. Study the pH-dependence of the UV-Vis spectrum of $K_2Cr_2O_7$ in the range 200-500 nm.

Unit-II: Colorimetry

1. Verify Lambert-Beer's law and determine the concentration of $CuSO_4$/$KMnO_4$/$K_2Cr_2O_7$ in a solution of unknown concentration.
2. Determine the concentrations of $KMnO_4$ and $K_2Cr_2O_7$ in a mixture.
3. Determine the amount of iron present in a sample using 1,10-phenathroline.
4. Determine the dissociation constant of an indicator (phenolphthalein)

Text Books

- Svehla, G. Vogel's Qualitative Inorganic Analysis, 7th Edn., (Prentice Hall, 1996).
- Vishnoi, R. Advanced Practical Organic Chemistry, 2nd Revised Edn., (Vikas Publisher, 2007).
- Gurdeep, R. Advanced Practical Inorganic Chemistry, (Krishna Prakashan, 2013).
- Yadav, J. B. Advance Practical Physical Chemistry, (Goel Publishing House- Meerut, 2008).

SEMESTER-VI

Paper Title : **INORGANIC CHEMISTRY-IV**
Paper Code : **CHMMJ-061**
Course No : **C- 14**
Credits : **04**
No. of Classes : **60**
Total Theory Marks : **100 (End Semester: 70; In Semester: 30)**

Course Objectives:

- To introduce students to the concept of general metallurgical process, its types, thermochemistry, purification techniques, purification of ultra pure metals
- To give basic idea on chemical data handling, errors, descriptive statistics, regression analysis etc.
- To understand the principle of solvent extraction and chromatography and its application in laboratory and industry
- To give basic concept of symmetry elements and group theory and correlate the concept to molecules

Course Outcome: Students will gain an understanding of

- Principle of meal extraction process.
- Data handling in laboratory and its descriptive statistics.
- Separation by solvent extraction and chromatography.
- Group theory and its application.

UNIT-I: General Principle of Metallurgy: Occurrence of metals based on standard electrode potential, methods of concentration of ores, reduction to free metal, electrometallurgy, hydrometallurgy and pyrometallurgy, synthesis of ultrapure elements. Refining of metals, electrolytic, ion exchange, zone refining, vapour phase refining and oxidative refining. Thermodynamics of the oxidation of metals to metaloxides- Ellingham diagrams. Extractive metallurgy of Fe, Al, Th, Ti. Kroll process, Parting process, van Arkel-de Boer process and Mond's process, Zone refining, Ferrous metallurgy – manufacture of steel by open hearth process-Alloys-composition and uses of German silver, Brass, Bronze, Gunmetal etc.

(15 Lectures; 20 Marks)

UNIT-II: Errors and Statistics in Data Analysis: Significant figures, Accuracy, Precision, Error, Types of errors- Determinate and Indeterminate errors, Distribution of random errors, Mathematical Expression for error- Absolute and Relative error, Methods to reduce error, Statistical tools for expressing precision- Standard deviation, Relative standard deviation, Variance, Comparison of results- Students t test, f test, Criteria for rejecting a value-Q test, Confidence interval, Correlation and Regression, Linear regression analysis.

(15 Lectures; 20 Marks)

UNIT – III: Separation Techniques: Mechanism of extraction: extraction by solvation and chelation. Technique of extraction: batch, continuous and counter current extractions. Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from

aqueous solution, extraction of organic species from the aqueous and nonaqueous media. **Chromatography**: Classification, principle and efficiency of the technique. Mechanism of separation: adsorption, partition & ion exchange. Development of chromatograms: frontal, elution and displacement methods. Qualitative and quantitative aspects of chromatographic methods of analysis: GLC, GPC, TLC and HPLC. Paper chromatographic separation of following metal ions: Ni (II) and Co (II) and Fe (III) and Al (III)

(15 Lectures; 15 Marks)

UNIT – IV: Symmetry and Group Theory: Symmetry as a universal theme, Molecular symmetry, Symmetry elements and operations, Point groups, Matrix representation of symmetry operations, character, Definition of a mathematical group, Abelian group, Cyclic group, symmetry operations as group elements, symmetry and isomerism, Symmetry classification of molecules into point groups (Schoenflies symbol). Group multiplication table. Reducible and irreducible representations, Great Orthogonality Theorem and its consequences, character tables, reduction formula, construction of character tables for point groups with order 6, interpretation of character tables

(15 Lectures; 15 Marks)

Text Books:

- General and Inorganic Chemistry (Part-2), RP Sarkar, NBCA, 2002.
- Molecular Symmetry in Chemistry, Agarwalla, Nigam, and Karla,
- Basic Concepts of Analytical Chemistry, 4th Ed. SM Khopker, New Age International

Reference Books:

- Metallurgical Engineering, Arvind Kumar, Khanna Publisher, 1998
- Material Science and Metallurgy, OP Khanna, Dhanpat Rai Publications
- Basic Statistics, BL Agarwal, New Age International
- SWAYAM
- N-LIST
- E-PATHSALA

Paper Title	**: ORGANIC CHEMISTRY-IV (THEORY)**
Paper Code	**: CHMMJ-062**
Course No	**: C- 15**
Credits	**: 04**
No. of Classes	**: 60**
Total Theory Marks	**: 100 (End Semester: 70; In Semester: 30)**

Course Objectives:

- To understand different types of Spectroscopic techniques used in organic chemistry.
- To gain knowledge on different types of pericyclic reactions.
- To familiarize students with various greener approaches in chemical transformations.

Course Outcome: The course introduces the learner to

- The basics principles of organic spectroscopy.
- The different spectroscopic techniques and their applications in organic chemistry.
- UV-Visible, IR spectroscopy, Raman Spectroscopy, NMR & Mass Spectroscopy as tools for identifying and characterizing organic compounds.
- Different types of pericyclic reactions, orbital symmetry and FMO method.
- The different aspects of Green Chemistry.

Unit-I: Organic Spectroscopy:

IR Spectroscopy: Fundamental and non-fundamental molecular vibrations; IR absorption positions of O, N and S containing functional groups; Effect of H-bonding, conjugation, resonance and ring size on IR absorptions; Fingerprint region and its significance; application in functional group analysis.

UV Spectroscopy: Types of electronic transitions, λ_{max}, Chromophores and Auxochromes, Bathochromic and Hypsochromic shifts, Intensity of absorption; Application of Woodward Rules for calculation of λmax for the following systems: α, β unsaturated aldehydes, ketones, carboxylic acids and esters; Conjugated dienes: alicyclic, homoannular and heteroannular; Extended conjugated systems (aldehydes, ketones and dienes); distinction between cis and trans isomers.

NMR Spectroscopy: Basic principles of Proton Magnetic Resonance, chemical shift and factors influencing it; Spin-Spin coupling and coupling constant; Anisotropic effects in alkene, alkyne, aldehydes and aromatics, Interpretation of NMR spectra of simple compounds.

Mass Spectrometry: Principle, molecular ion peak, base peak, metastable ion, nitrogen rule, and even electron rule.

Applications of **IR**, **UV, NMR** and **Mass** for identification of simple organic molecules.

(24 Lectures; Marks: 30)

Unit-II: Pericyclic Reactions I: Definition and classification, Orbital symmetry and HOMO-LUMO approach (FMO method), Cycloaddition reactions ([2+2] and [4+2]), electro-cyclic reactions and sigma-tropic rearrangement (Cope and Claisen).

(12 Lectures; Marks: 10)

Unit-III: Introduction to Green Chemistry:

Green Chemistry and Green Technology, Need for Green Chemistry; Goals of Green Chemistry; Limitations/ Obstacles in the pursuit of the goals of Green Chemistry.

Principles of Green Chemistry and Designing a Chemical synthesis:

Twelve principles of Green Chemistry with their explanations and examples and special emphasis on the following: Designing a Green Synthesis using these principles, Prevention of Waste/ byproducts, maximum incorporation of the materials used in the process into the final products, Atom Economy: calculation of atom economy of the rearrangement, addition, substitution and elimination reactions, Prevention/ minimization of hazardous/ toxic products reducing toxicity, risk factor, Green solvents, Energy requirements for reactions, catalytic reagents, biocatalysis in Organic synthesis, inherent safer design-principle of ISD, Bhopal Gas Tragedy, Flixiborough accident.

(24 Lectures; Marks: 30)

Text Book(s):

- Banwell, C. N.; McCash, E. M. *Fundamentals of Molecular Spectroscopy* 4th Ed., Tata McGraw-Hill: New Delhi 2006.
- Bruice,P. Y. *Organic Chemistry*, Pearson, 3rd Ed., 2013.
- Ahluwalia,V. K.; Kidwai M. R. *New Trends in Green Chemistry*, Anamalaya Publishers, 2012.
- Anastas, P. T., Warner, J. K. *Green Chemistry - Theory and Practical*, Oxford University Press, 2005.
- Cann, M.C.; Connely, M. E. *Real-World cases in Green Chemistry*, American Chemical Society, Washington, 2000.

Reference Book(s):

- Kemp, W. Organic Spectroscopy, Palgrave.
- Silverstein, Spectrometric Identification of Organic Compounds, 7th Ed., John Wiley & Sons, 2005.
- Chandra, S. Molecular Spectroscopy, Narosa, 2009.
- McMurry, J.E. *Fundamentals of Organic Chemistry*, 7th Ed. Cengage Learning India Edition, 2013.
- Fleming, I. *Molecular Orbitals and Organic Chemical Reactions*, Oxford University Press, 2010.
- Sankararaman, S. *Pericyclic reactions—a textbook: reactions, applications and theory*, 1st Edn., Wiley VCH, 2005.
- Matlack, A. S. *Introduction to Green Chemistry*, 2nd Ed., Marcel Dekker, 2010.
- Ryan, M. A.; Tinnesand, M. *Introduction to Green Chemistry*, American Chemical Society, Washington, 2002.
- Lancaster, M. *Green Chemistry: An Introductory Text*, 2nd Ed., RSC Publishing, 2010

Paper Title	**: PHYSICAL CHEMISTRY-III (THEORY)**
Paper Code	**: CHMMJ-063**
Course No	**: C- 16**
Credits	**: 04**
No. of Classes	**: 60**
Total Theory Marks	**: 100 (End Semester: 70; In Semester: 30)**

Course Objectives:

- To understand phase, phase rule and phase diagram.
- To impart knowledge on conductivity of electrolytes in solution or molten state.
- To understand theory and application of conductance measurement, chemical cells.
- To develop understanding of colligative properties of solutions.

Course Outcome: Students will gain an understanding of

- Phase, phase rule and phase diagram of one component system, phase diagram for systems of solid liquid equilibria.
- Conductivity and different theories to explain conductivity of electrolytes and application of conductance measurement.
- Laws of electrolysis, electrochemical cells, EMF of cells, its measurement and applications of EMF measurement.
- Colligative properties of dilute solutions and thermodynamics.

UNIT I: Phase Equilibria: Concept of phases, components and degrees of freedom, derivation of Gibbs Phase Rule for nonreactive and reactive systems; Clausius-Clapeyron equation and its applications to solid-liquid, liquid-vapour and solid-vapour equilibria, phase diagram for one component systems, with applications. Phase diagrams for systems of solid-liquid equilibria involving eutectic, congruent and incongruent melting points, solid solutions. Three component systems, water-chloroform-acetic acid system, triangular plots. Binary Solutions: Gibbs-Duhem-Margules equation, its derivation and applications to fractional distillation of binary miscible liquids (ideal and nonideal), azeotropes, lever rule, partial miscibility of liquids, CST, miscible pairs, steam distillation. Nernst distribution law: its derivation and applications.

(18 Lectures; Marks: 20)

UNIT II: Conductance: Arrhenius theory of electrolytic dissociation. Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Molar conductivity at infinite dilution. Kohlrausch law of independent migration of ions. Debye-Huckel-Onsager equation, Wien effect, Debye-Falkenhagen effect, Walden's rules. Ionic velocities, mobilities and their determinations, transference numbers and their relation to ionic mobilities, determination of transference numbers using Hittorf and Moving Boundary methods. Applications of conductance measurement: (i) degree of dissociation of weak electrolytes, (ii) ionic product of water (iii) solubility and solubility product of sparingly soluble salts, (iv) conductometric titrations, and (v) hydrolysis constants of salts.

(16 Lectures; Marks: 17)

UNIT III: Electrochemistry: Quantitative aspects of Faraday's laws of electrolysis, rules of oxidation/reduction of ions based on half-cell potentials, applications of electrolysis in metallurgy and industry. Chemical cells, reversible and irreversible cells with examples.

Electromotive force of a cell and its measurement, Nernst equation; Standard electrode (reduction) potential and its application to different kinds of half-cells. Application of EMF measurements in determining (i) free energy, enthalpy and entropy of a cell reaction, (ii) equilibrium constants, and (iii) pH values, using hydrogen, quinone-hydroquinone, glass and SbO/Sb_2O_3 electrodes. Concentration cells with and without transference, liquid junction potential; determination of activity coefficients and transference numbers. Qualitative discussion of potentiometric titrations (acid-base, redox, precipitation).

(18 Lectures; Marks: 22)

UNIT IV: Solutions and Colligative Properties: Dilute solutions; lowering of vapour pressure, Raoult's and Henry's Laws and their applications. Thermodynamic derivation using chemical potential to derive relations between the four colligative properties [(i) relative lowering of vapour pressure, (ii) elevation of boiling point, (iii) Depression of freezing point, (iv) osmotic pressure] and amount of solute. Applications in calculating molar masses of normal, dissociated and associated solutes in solution.

(8 Lectures; Marks: 11)

Text Books:

- Kapoor K. L. *A Textbook of Physical Chemistry Sixth Ed*., Vol. 2, Macmillan, India.
- Pathania, P. S.; *Principles of Physical Chemistry*. 48th Edition (2021).
- Negi, A.S., Anand S.C.; *A Textbook of Physical Chemistry*, New Age International (P) Publishers (2004).

Reference Books:

- Gurdeep, R. *Advanced Practical Inorganic Chemistry*, (Krishna Prakashan, 2013).
- Levine, I.N. *Physical Chemistry 6th Ed*., Tata Mc Graw Hill (2010).
- Bockris, J.; *Modern Electrochemistry-Volume 1-Ionics 2nd Edition*, Springer (2018).
- Laidler, K.J.; *Chemical Kinetics 3rd Edition*, Pearson (2003).

Paper Title : QUANTUM CHEMISTRY-I (THEORY)
Paper Code : CHMMJ-064
Course No : C- 17
Credits : 02
No. of Classes : 30
Total Theory Marks : 50 (End Semester: 35; In Semester: 15)

Course Objectives:

- To understand inadequacy of classical mechanics.
- To understand postulates of quantum mechanics,
- To develop understanding of concept of wave function, Valence bond theory and Molecular orbital theory.

Course Outcome: Students will gain an understanding of

- Drawbacks of classical mechanics and the origin of quantum theory
- Postulates of quantum mechanics. concept of wave functions, operators and eigen value equation
- Valence bond and molecular orbital theory
- Approximation methods for the solution of the Schordinger equation for many body systems.

Quantum Chemistry: Origin of the quantum theory of matter: Franck- Hertz experiment, Photoelectric effect, Compton Effect, Black body radiation, Planck's law, Wein's law, Bohr's theory and atomic spectra. Matter wave: Wave-particle duality, uncertainty principle. Operators and wave functions in quantum mechanics: Operator principles, Hamiltonian and Hermitian operators, postulates of quantum mechanics, Schrödinger equation, free particle, particle in a box (one and three dimensional). Wave mechanics of simple systems: One dimensional harmonic oscillator, rigid rotator, the hydrogen atom, angular momentum, electron spin, spin-orbit coupling. Molecular orbital theory: Born-Oppenheimer approximation, LCAO approximation, LCAO MO of H_2 and H_2^+, VB Theory, comparison of VB and MO. Approximate methods: Basic idea of variation and perturbation theory.

(40 Lectures; Marks: 35)

Text Books:

- Kapoor, K. L.; *A Textbook of Physical Chemistry Sixth Ed., Vol. 4*, Macmillan, India.
- Sen, BK; *Quantum Chemistry-Including Spectroscopy*, 4th Edition Kalyani (2011).
- Prasad, R.K.; *Quantum Chemistry, 4th Edition*, New Age (2020).

Reference Books:

- Levine, I. N.; *Quantum Chemistry, 7th Edition*, Pearson (2014).
- McQuarrie, D. A.; *Quantum Chemistry, 2nd Edition*, Viva Books (2011).

Paper Title : PRACTICAL CHEMISTRY-IV (Practical)
Paper Code : CHMMJ-065
Course No : C- 18
Credits : 04
No. of Classes : 120
Total Theory Marks : 100 (End Semester: 70; In Semester: 30)

Section A (Inorganic Chemistry) **(40 Lectures; Marks: 23)**

Unit-I:

UNIT-I: Chromatography of Metal Ions:

1. Principles involved in chromatographic separations. Paper chromatographic separation of following metal ions:
i. Ni (II) and Co (II) ii. Fe (III) and Al (III)

Unit-II
1.Measurement of 10 Dq by spectrophotometric method
2. Verification of spectrochemical series
3. Controlled synthesis of two copper oxalate hydrate complexes: kinetic vs thermodynamic factors.
4. Preparation of acetylacetanato complexes of Cu^{2+}/Fe^{3+}. Find the λ_{max} of the complex.

Unit-III:
1. Determination of dissolved oxygen in water.
2. Percentage of available chlorine in bleaching powder.
3. Measurement of chloride, sulphate and salinity of water samples by simple titration method ($AgNO_3$ and potassium chromate).
4. Estimation of total alkalinity of water samples (CO_3^{2-}, HCO_3^-) using double titration method.

Section B (Organic Chemistry) (40 Lectures; Marks: 24)

Unit-I:
1. Qualitative analysis of unknown organic compounds containing monofunctional groups carbohydrates, aryl halides, aromatic hydrocarbons) and simple bifunctional groups, for e.g. salicylic acid, cinnamic acid, nitrophenols etc.

2. Analysis of Carbohydrate: aldoses and ketoses, reducing and non-reducing sugars.
3. Preparation of methyl orange.

Unit-II: Green Chemistry
1. Preparation of biodiesel from vegetable/ waste cooking oil.
2. Calculation of atom economy of organic reaction.
3. Benzoin condensation using Thiamine Hydrochloride as a catalyst instead of cyanide.
4. Preparation of Manganese (III) acetylacetonate, $Mn(acac)_3$
5. Synthesis of dihydropyrimidone.
6. Synthesis of 1,1-bis(2-naphthol)

Section C (Physical Chemistry) (40 Lectures; Marks: 23)

Unit-I: Conductometry
1. Determination of cell constant
2. Determination of equivalent conductance, degree of dissociation and dissociation constant of a weak acid.

Conductometric Titrations
a. Strong acid vs. strong base
b. Weak acid vs. strong base
c. Strong acid vs. weak base

Unit-II: Potentiometry
i. Strong acid vs. strong base
ii. Weak acid vs. strong base
iii. Dibasic acid vs. strong base
iv. Potassium dichromate vs. Mohr's salt

Text Books:
1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.
2. Furniss, B. S., Ford, A. J. H., Smith, P. W. H., Tatchell, A. R. Vogel's Textbook of Practical Organic Chemistry, 5th Edn., (Wiley, 1989).
2. Jadav, J. B. Advanced Practical Physical Chemistry, (Krishna Prakashan, 2015).
3. Mendham, J., Danney, R. C., Barnes, J. D., Thomas, M. Vogel's Textbook of Quantitative Chemical Analysis, 6th Edn., (Prentice Hall, 2009).
4. Gurdeep, R. Advanced Practical Inorganic Chemistry, (Krishna Prakashan, 2013).

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SEMESTER-VII

Paper Title : **INORGANIC CHEMISTRY-V**
Paper Code : **CHMMJ-071**
Course No : **C- 19**
Credits : **04**
No. of Classes : **60**
Total Theory Marks : **100 (End Semester: 70; In Semester: 30)**

Course Objectives:

- To understand Physical Techniques in Inorganic Chemistry,
- To understand Electron spin resonance spectroscopy,
- To gain knowledge on Nanomaterials and their Synthetic Methods
- To understand Chemistry of Water, Soil and Air Pollution, Industrial Gases & Chemicals

Course Outcome: Students will gain an understanding of

- Basic techniques and applications of NMR, ESR in inorganic molecules
- Nonmaterial, types, their synthesis and applications
- Causes and measures of soil, air and water pollution, solid waste management.
- Industrially Important gases, preparation and storage and handling, Industrial chemicals and their preparation and applications

UNIT-I: Physical Techniques in Inorganic Chemistry: Applications to inorganic Compounds – Spin-spin coupling involving different nuclei (^{1}H, ^{19}F, ^{31}P, ^{13}C) Effect of quadrupolar nuclei (^{2}H, ^{10}B, ^{11}B) on the ^{1}H NMR 4 spectra, Satellite spectra. Systems with chemical exchange–evaluation of thermodynamic parameters in simple systems – study of fluxional behaviour of molecules – an elementary treatment of second order spectra – examples – NMR of paramagnetic molecules – isotopic shifts contact and pseudo-contact interactions – Lanthanide shift reagent, Charge transfer spectra – electronic spectra of $[Ru(bipy)_3]^{2+}$.

Electron spin resonance spectroscopy: Basic principles – comparison between esr and nmr spectra – hyperfine splitting – factors affecting the magnitude of g values – calculation of unpaired electron density on an atom in a delocalized system – applications to organic free radicals. Spectra of V(II), Mn(II), Fe(II), Co(II), Ni(II) and Cu(II) complexes – Applications of EPR to a few biological molecules containing Cu(II) and Fe(III) ions.

UNIT-II: Nanomaterials – An Introduction and Synthetic Methods: Definition of non-dimensional materials - Historical milestone - Unique properties due to nano size - Quantum dots. Classification of nanomaterials. General methods for the synthesis of nanometerials - hydrothermal synthesis - solvothermal synthesis, microwave irradiation, sol-gel and precipitation technologies, combustion flame-chemical vapour condensation process, gas phase condensation synthesis. Reverse micelle synthesis, polymer mediated synthesis - Protein microtube mediated synthesis. Synthesis of nanomaterials using microorganisms and other biological agents. Sonochemical synthesis - Hydrodynamic cavitation. Inorganic nanomaterials - Typical examples - TiO_2/ZnO/CdO/CdS. Reactions in nanospace / Nano-confinement/ Nano-capsules - Cavitands, Cucurbiturils, Zeolites, MOF.s, Pours sillicon, nanocatalysis. Characterization and formation of nanomaterials using microscopy, Nanostructures and properties, One-dimensional control: carbon nanotubes and inorganic nanowires, Two-dimensional control: graphene, quantum wells, and solid-state superlattices, Three-

dimensional control: mesoporous materials and composites, Special optical properties of nanomaterials.

UNIT-III: Chemistry of Water, Soil and Air Pollution: Environmental pollution and pollutants and monitoring: Concept, definition and characteristics. Air pollution: Natural and anthropogenic sources and types of air pollutants, photochemical reactions, acid rains, PAN, concept of Fog and Smog, effect of air pollution on human beings, plants and animals. Air quality standards, vehicular pollution. Water pollution: Sources and types of water pollutants, Effect of water pollutants on living organisms, water pollution linked human diseases, ground water pollution, heavy metals and their effects on biota, thermal pollution, characteristics of industrial effluents. Solid wastes: Source and generation of solid wastes; composition, classification and disposal techniques of solid wastes, municipal and industrial wastes, biomedical wastes, Electronic wastes, and their environmental effects. Pesticides: Classification, properties, effects on living organisms. Basic concepts of WQI and AQI; Introduction to Soil Chemistry; Soil pH and Buffering Capacity: Factors affecting soil pH, Role of carbonates, organic matter, Acidic vs. alkaline soils and liming.

UNIT –V: Industrial Gases & Chemicals: Large scale production, uses, storage and hazards in handling of the following gases: oxygen, nitrogen, argon, neon, helium, hydrogen, acetylene, carbon monoxide, chlorine, fluorine, sulphur dioxide and phosgene. PSA**. Inorganic Chemicals:** Manufacture, application, analysis and hazards in handling the following chemicals: hydrochloric acid, nitric acid, sulphuric acid, caustic soda, common salt, borax, bleaching powder, sodium thiosulphate, hydrogen peroxide, potash alum, chrome alum, potassium dichromate and potassium permanganate

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Paper Title **: ORGANIC CHEMISTRY-V**
Paper Code **: CHMMJ-072**
Course No **: C- 20**
Credits **: 04**
No. of Classes **: 60**
Total Theory Marks **: 100 (End Semester: 70; In Semester: 30)**

Course objectives:

- To provide students the fundamental knowledge on structure, reactivity and reaction mechanism of organic compounds.
- Students will be able to appreciate/demonstrate/explain the unique features of organic reactions mechanism, reaction intermediates,
- stereochemistry and
- application of NMR spectroscopic technique for compound characterization.

Course Outcome: Students will gain an understanding of

- Various types of bonding and their implications in reactivity and properties of organic compound.

- Organic reaction mechanism
- Reactive Intermediates: Structure & Reactivity
- Stereochemistry of organic molecules, prostereogenic elements and asymmetric synthesis
- Characterization of organic compounds using NMR spectroscopy.

Unit I: Structure and Bonding: Reactivity of organic molecules, aromaticity, n-annulenes and hetero-annulenes, fullerenes (C60), Graphene, Cryptans, bonds weaker than covalent: addition compounds, inclusion compounds and rotaxenes.

(4 Lectures) Marks: 7

Unit II: Thermodynamics and Kinetics: Acids and bases, concept of hard and soft acids and bases, symbiosis, labeling and kinetic isotope effects, Hammett equation, ς–ρ relationship, non-classical carbenuim ion (or carbocation), kinetic and thermodynamic control, Hammand principle, Curtin-Hammett principle, transition state and intermediates.

(4 Lecture) Marks: 7

Unit III: Organic reaction mechanism: Transition state vs. Reaction intermediate, Energy profile of multistep reaction, Significance of rate limiting step in multistep reactions, Catalysed and uncatalysed reactions, Kinetic vs. Thermodynamic control, Kinetic and non-kinetic methods of studying organic reaction mechanism; Isotope labeling studies and kinetic isotope effects, Cross-over experiment. Reactivity - selectivity principle: Chemoselectivity, regioselectivity, stereoselectivity and stereospecificity in substitution, elimination and addition reactions.

(10 Lecture) Marks: 12

Unit IV: Reactions & Intermediates: Structure & Reactivity I (12h) • Carbanions: enolates and enamines, Kinetic and thermodynamic enolates, lithium and boron enolates in aldol and Michael reactions, alkylation and acylation of enolates; name reactions under carbanion chemistry-Claisen, Dieckmann, Knoevenegal, Stobbe, Darzen, Acyloin condensations, Shapiro reaction, Julia olefination, Brook rearrangement, Sakurai reaction, Henry reaction, Kulinkovich reaction, Nef reaction, Baylis-Hillman reaction. Ylids: Chemistry of phosphorous and sulfur ylids-Wittig and related reactions, Peterson olefination. Carbocation: structure and stability of carbocations, classical and non-classical carbocations, neighbouring group participation and rearrangements including Wagner-Meerwein, pinacol-pinacolone, semi-pinacol rearrangement, C-C bond formation involving carbocations, oxymercuration, halo-lactonisation, Tishchenko reaction, Ritter reaction, Prins reaction.
Free radicals, carbenes, benzynes and nitrenes.

(22 Lecture) Marks: 20

Unit V: Stereochemistry II: Conformational Analysis of mono and disubstituted cyclohexanes: chair, boat and twist boat forms, Concept of prostereoisomerism and prochirality – Homotopic and heterotopic ligands and faces; Optical purity and enantiomeric excess; Classification of stereoselective synthesis: diastereoselective and enantioselective reactions; Stereo-differentiating approach, Nucleophilic addition to aldehydes and acyclic ketones: Cram

and Felkin-Ahn model. Enantioselective synthesis-Use of chiral reagent, chiral catalyst and chiral auxillary. Resolution – optical and kinetic.

(Lecture 10) Marks: 12

Unit VI: NMR spectroscopy: Chemical shift, factors affecting chemical shift, spin- spin interaction, Coupling constant and Factors affecting, relaxation processes, NOE.
Nuclear magnetic double resonance, shift resonance, spin tickling; ^{1}H and ^{13}C NMR spectroscopy of simple organic & Inorganic molecules, living systems – MRI.

(Lecture 10) Marks: 12

Text Book:

1. Kalsi, P. S. Stereochemistry, Conformation and Mechanism (New Age international Publishers, 2009).
2. Sengupta, S. Basic Stereochemistry of Organic Molecules, 1st Edn., (Oxford University Press, 2014).

Reference Book(s):

1. Eliel, E. L., Wilen, S. H. and Doyle, M. P. Basic Organic Stereochemistry, 1st Edn., (Wiley-Interscience, 2001)

Paper Title	**: PHYSICAL CHEMISTRY-IV (THEORY)**
Paper Code	**: CHMMJ-073**
Course No	**: C- 21**
Credits	**: 04**
No. of Classes	**: 60**
Total Theory Marks	**: 100 (End Semester: 70; In Semester: 30)**

Course Objectives:

- To understand the application of statistical thermodynamics.
- To develop basic knowledge on photochemical reactions.
- To impart knowledge on criteria and assumptions of non-equilibrium thermodynamics.
- To understand the concepts of dynamic electrochemistry.

Course Outcomes: Students will gain an understanding of

- Statistical thermodynamics to understand complex systems
- Thermodynamic and kinetic aspects of Electrochemistry.
- Basics of non-equilibrium thermodynamics.
- Basics of dynamic electrochemistry.

Uni I: Statistical Thermodynamics: Probability and most probable distribution, distinguishable and indistinguishable particles, Concept of ensembles, partition functions and distributions, microcanonical, canonical and grand canonical ensembles, Boltzmann distribution, Elementary idea of Fermi-Dirac and Bose-Einstein distributions.

Ideal gases: Canonical partition function in terms of molecular partition function of noninteracting particles, Translational, rotational and vibrational partition functions. Absolute values of thermodynamic quantities (U,H,S,A) for ideal monoatomic and diatomic gases, heat capacity (Cv, Cp) of an ideal gas of linear and nonlinear molecules, chemical equilibrium. Mono atomic Crystals - Einstein and Debye models. T3 dependence of heat capacity of solids at low temperatures. Numerical calculations of thermodynamic quantities for monoatomic, diatomic and polyatomic molecules.

(18 Lectures; Marks: 20)

Unit-II: Photochemistry: Characteristics of electromagnetic radiation, Lambert-Beer's law and its limitations, physical significance of absorption coefficients. Laws of photochemistry, quantum yield, actinometry, examples of low and high quantum yields, photochemical equilibrium and the differential rate of photochemical reactions, photosensitized reactions, quenching. Role of photochemical reactions in biochemical processes, photostationary states, chemiluminescence.

(**12 Lectures; Marks: 16**)

Unit-III: Irreversible Thermodynamics: Non-equilibrium thermodynamics, thermodynamic criteria for non-equilibrium states, Assumptions of non-equilibrium thermodynamics, uncompensated heat, entropy production and entropy flow, entropy balance, Onsager formalism, relation between forces and fluxes, transformations of generalized fluxes and forces, microscopic reversibility and Onsager's reciprocity relations. Electrokinetic phenomena, diffusion, electric conduction, irreversible thermodynamics for biological systems, coupled reactions

(**16 Lectures; Marks: 18**)

Unit-IV: Dynamic Electrochemistry: Ion-solvent interaction- the Born model, Thermodynamic parameters of ion solvent interactions- structural treatment, the ion-dipole model-its modifications, ion-quadrupole and ion-induced dipole interactions, Primary solution-determination of hydration number, compressibility method and viscosity-mobility method, Debye-Huckel theory of ion-ion interactions-derivation, validity and limitations, extended Debye-Huckel-Onsager equation. The random walk model of ionic diffusion-Einstein Smoluchowski reaction.

(**14 Lectures; Marks: 16**)

Text Books:

- P. Atkins, J. Paula, Physical Chemistry, 9th Edition, Oxford University Press, Oxford 2010.
- R. Levine, Physical chemistry, 6th Edition, Mcgraw Hill Education, 2011.
- D. A. McQuarrie, J. D. Simon, Physical Chemistry: A Molecular Approach, Viva Student Edition, 1st Edition, 2011.
- R. S. Berry, S. A. Rice and J. Ross, Physical Chemistry, 2nd Edition, Oxford University Press, Oxford 2007.
- D. A. McQuarrie, Statistical Mechanics, University Science Books, California, 2005
- J. O. Bockris, A. K. N. Reddy, Modern Electrochemistry Part 1, 2A and 2B, 2nd Edition, Springer
- A. J. Bard, L. R. Faulkner, Electrochemical Methods Fundamentals and Applications, 2nd edition, Willy India, 2006.

Paper Title	**: RESEARCH METHODOLOGY**
Paper Code	**: CHMMJ-074**
Course No	**: C- 22**
Credits	**: 02**
No. of Classes	**: 30**
Total Theory Marks	**: 50 (End Semester: 35; In Semester: 15)**

Course objectives:

- To understand some basic concepts of research and its methodologies.
- To identify appropriate research topics, select and define appropriate research problem and parameters
- To prepare a project proposal, organize and conduct research in a more appropriate manner

Course Outcomes: Students will be able to

- Develop ability to apply multidisciplinary concepts, tools and techniques in research.
- Identify and formulate research problems.
- Write a good research proposal.
- Identify and use appropriate research methodology.

Course Objectives:

UNIT I:

Research: concept, meaning, objective and process; Types of research: Basic and Applied; Inter- disciplinary and Multi-disciplinary; Qualitative and Quantitative approaches; research methods versus research methodology.

(10 Lectures; Marks: 10)

UNIT II: Literature Search Technique: Introduction to chemical abstracts –Subject Index, Substance Index, Author Index, Formula Index and other indices-Uses of these indices with examples, current contents, organization methods of using the titles and index –other similar abstracts for special topics related to chemistry. Use of computer browsing for literature search and downloading basics of internet services various sources of abstracts, articles and papers of browsing and downloading, Techniques of conversion from one format to another Structure drawing programs and their uses searches through structure. Use of Literature, Knowledge of National and International Journals, Impact Factor, Citation-Index, h-Index, SCI Journals, Plagiarism.

(20 Lectures; Marks: 15)

Unit III: Research Ethics and Safety (10 Lectures, 10 Marks)

Ethical issues in research, responsible conduct of research, misconduct; Laboratory safety rules, chemical handling, waste management.

(10 Lectures, 10 Marks)

Text Books

- C. R. Kothari and Gaurav Garg, Research Methodology Methods and Techniques, New Age International.
- Gopal, M. H. (1992). *An Introduction to Research Procedure in Social Science*. New Delhi: Vikas.
- O. R. Krishnaswami, (1993). *Methodology of Research in Social Sciences*. Bombay: Himalaya. Lewis - Beck, Michael S. (1995). *Data analysis: an introduction*. Thousand Oaks: Sage.

Paper Title	**: PRACTICAL CHEMISTRY LAB-V (Practical)**
Paper Code	**: CHMMJ-075**
Course No	**: C- 23**
Credits	**: 04**
No. of Classes	**: 120**
Total Theory Marks	**: 100 (End Semester: 70; In Semester: 30)**

Section A (Inorganic Chemistry) **(40 Lectures; 23 Marks)**

Preparation and characterization (viz. conductivity measurement, IR, UV-Vis) of the following complexes:

1. Potassium chromioxalate, $K_3[Cr(C_2O_4)_3]$
2. Reinecke's salt
3. Tris-(thiourea) copper(I) sulphate, $[Cu(tu)_3]2SO_4.2H_2O$
4. Potassium chromithiocyanate
5. Chloropentamine Cobalt (III) chloride $[Co(NH_3)_5Cl]Cl_2$
6. NitropentamineCobalt(III) chloride $[Co(NO_2)(NH_3)_5]Cl_2$

Section B (Organic Chemistry) **(40 Lectures; 23 Marks)**

UNIT-I: Organic Estimation:

i) Estimation of glucose and sucrose in a mixture.
ii) Estimation of acetone by iodoform method.
iii) Estimation of hydroxyl and amino groups by acetylation method.

UNIT-II: Chromatographic separation:

(i) Qualitative TLC separation and identification.
(ii) Column chromatographic separation of a mixture of compounds.

UNIT-III: Qualitative analysis: Binary mixture analysis (solid-solid)

Section C (Physical Chemistry) **(40 Lectures; 24 Marks)**

Unit I: Chemical Kinetics:

1) Determination of kinetics of hydrolysis of ethyl acetate by NaOH.
2) Study the kinetics of the reaction between iodine and acetone in acidic medium.
3) Study of the autocatalytic reaction between oxalic acid and KMnO4 and determination of the order of the reaction.

Unit II: Conductometric Titrations:

1) Comparison of the relative strength of acetic acid and monochloroacetic acid by conductance measurement.
2) Determination of the composition of a mixture of acetic acid and hydrochloric acid by conductometric titrations.
3) Determination of the degree of hydrolysis and hydrolysis constant of CH_3COONa of NH_4Cl by conductance measurement.
4) Determination of the concentration of $AgNO_3$ by conductometric titration against KCl solution.

Unit III: Experiments of Spectrophotometry etc.

1) Verify Beers law and determine concentration of (a) $K_2Cr_2O_7$ (b) Organic dyes like methylene blue, Rhodamine B (c) $CuSO_4$
2) Investigation of the complex ion formation between Ni^{2+} and o-phenanthroline.
3) To titrate Fe(II) with $KMnO_4$ spectrophotometrically.
4) Investigation of the reaction between acetone and iodine by colorimetry

Text Books

- Mendham, J., Denney, R. C., Barnes, J. D., Thomas, M. and Sivasankar, B. Vogel's Quantitative Chemical Analysis, 6th Edn., (Pearson Education, 2009).
- Marr, G., Rockett, B. W. Practical Inorganic Chemistry, (Van Nostrand, 1972).
- B. S. Furniss, A. J. Hannaford, P. W. G. Smith, Vogel's Textbook of Practical Organic Chemistry, Pearson, 2012.
- V. K. Ahluwalia, S. Dhingra, Comprehensive Practical Organic Chemistry, University Press.
- Yadav, J. B. Advanced Practical Physical Chemistry, (Goel Publishing House- Meerut, 2008).
- J. N. Gurtu and A. Gurtu, Advanced Physical Chemistry Experiments, PragatiPrakashan, 6th Edition, 2014.
- 3. M. Halpern, Experimental Physical Chemistry, 2nd Edition, Prentice Hall, Upper Saddle River, NJ 07458

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SEMESTER-VIII

Paper Title : **ANALYTICAL METHODS IN CHEMISTRY**
Paper Code : **CHMMJ-081**
Course No : **C- 24**
Credits : **04**
No. of Classes : **60**
Total Theory Marks : **100 (End Semester: 70; In Semester: 30)**

Course Objectives:

- To introduce modern analytical and non-spectroscopic approaches.
- To develop understanding of thermal analysis and X-diffraction studies.
- To impart basic knowledge on chromatographic separation techniques.
- To develop understanding of microscopic technique for analysis.

Course Outcome: Students will be able to

- Describe and illustrate how various analytical methods are used in chemistry.
- Understand the basic principle and instrumentation of different analytical techniques.

Unit I: Optical methods of analysis:
UV-Visible Spectrometry: Basic principles of instrumentation (choice of source, monochromator and detector) for single and double beam instrument; Basic principles of quantitative analysis: estimation of metal ions from aqueous solution, geometrical isomers, keto-enol tautomers. Determination of metal complex composition using Job's method of continuous variation and mole ratio method.
Infrared Spectroscopy: Basic principles of instrumentation (choice of source, monochromator & detector) for continuous wave and Fourier transform spectrometers; sampling techniques. Structure elucidation through interpretation of data. Effect and importance of isotope substitution.
Flame Atomic Absorption and Emission Spectrometry: Basic principles of instrumentation (choice of source, monochromator, and detector, choice of flame and Burner designs. Techniques of atomization and sample introduction. Method of background correction, sources of chemical interferences and their method of removal. Techniques for the quantitative estimation of trace level of metal ions from water samples.

(20 Lectures, Marks: 18)

Unit-II: Thermal methods of analysis: Theory of thermogravimetry (TG), basic principle of instrumentation. Theory and basic principle of DSC. Techniques for quantitative estimation of Ca and Mg from their mixture. (5 Lectures)

(06 Lectures, Marks: 08)

Unit-III: Separation techniques: Solvent extraction: Classification, principle and efficiency of the technique. Mechanism of extraction: extraction by solvation and chelation.
Technique of extraction: batch, continuous and counter current extractions.
Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from aqueous solution, extraction of organic species from the aqueous and nonaqueous media.

Chromatography: Classification, principle and efficiency of the technique. Mechanism of separation: adsorption, partition & ion exchange. Development of chromatograms: frontal, elution and displacement methods.
Qualitative and quantitative aspects of chromatographic methods of analysis: IC, GLC, GPC, TLC and HPLC. Stereoisomeric separation and analysis: Measurement of optical rotation, calculation of Enantiomeric excess (ee)/ diastereomeric excess (de) ratios and determination of enantiomeric composition using NMR, Chiral solvents and chiral shift reagents. Chiral chromatographic techniques using chiral columns (GC and HPLC).

(22 Lectures, Marks: 25)

Unit-IV: Microscopy:
Development of Microscopy, Optical microscopy, Reflectance, Transmittance, Fluorescence Microscopy, CLSM, Ultra-high-resolution microscopy.
Electron Microscopy: Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM): Technique, instrumentation, and applications
EDX, SAED

(08 Lectures, Marks: 12)

Unit-V: Diffraction Techniques:
Powder XRD: Technique, Instrumentation, Applications; *Single Crystal XRD*: Technique, Instrumentation, Applications

(04 Lectures, Marks: 07)

Text Books:

- J. M. Hollas, Modern Spectroscopy, John Wiley & Sons, 4thEd., 2004
- D.L. Pavia, G. M. Lampman, G. S. Kriz, Introduction to Spectroscopy, 4th Ed.,Cengage, 2001
- R. S. Drago, Physical Methods in Chemistry, 1992
- Mikes, O. and Chalmes, R.A. Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Ltd. London.1979
- Ditts, R.V. Analytical Chemistry: Methods of separation.Van Nostrand, New York, 1974.

Paper Title : QUANTUM CHEMISTRY-II
Paper Code : CHMMJ-081
Course No : C- 25
Credits : 04
No. of Classes : 60
Total Theory Marks : 100 (End Semester: 70; In Semester: 30)

Course objective:

- To familiarize students with the basic ideas and contemporary applications of quantum chemistry.

- To solve of the Schrodinger equation for different model systems and their correlation with real systems.
- To understand Born Oppenheimer approximation
- To impart knowledge on Hartree-Fock method for the solution of Schrodinger equation for many particle system
- To understand Models of chemical bonding-Molecular orbital (MO) and Valence bond (VB) theory and Hückel π-electron theory**.**

Course Outcome: Students will gain an understanding of

- The theories and principles of quantum chemistry as well as explain its theoretical underpinnings.
- The validity of several approximation formalisms in explaining experimental phenomena will be compared by the students.

Unit-I: Wavepackets and Operators:

Black-body radiation, the photoelectric and Compton effects, atomic spectra, the duality of matter, Dirac bra-ket notation, review of vectors and vector spaces; Hermitian operators, matrix elements, The diagonalization of the Hamiltonian, wave-packets, wave functions of one particle and many particles system, the equation for the wave function, the separation of the Schrodinger equation, Born interpretation, expectation values of observable properties, complementarity and complementary observable, uncertainty principle, general angular momentum operators, step-up and step-down operators, theoretical basis of the L-S and J-J coupling schemes.

(20 Lectures; Marks: 24)

Unit-II: 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; Huckel Molecular Orbital theory and its application to unsaturated carbon compounds, elements of band theory.

(16 Lectures; Marks: 18)

Unit-III: Approximate Methods

Time-independent perturbation theory of a two-level system (up to second order), the first order correction to the energy and wave function, perturbation theory for degenerate states, the second order correction to the energy, time dependent behaviour of a two-level system, the Rabi formula, the effect of a slowly switched constant perturbation, the variation theorem, linear variation function-secular equation, the Rayleigh ratio.

(12 Lectures; Marks: 14)

Unit-IV: 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)

(12 Lectures; Marks: 14)

Text Books:

- Atkins, P. W., Friedman, R. S., *Molecular Quantum Mechanics*, (Oxford University Press, 1997).
- Levine, I. N *Quantum Chemistry*, (Pearson Education, 2004).
- McQuarrie, D. A. *Quantum Chemistry* 2nd Edn., (University Science Books, 2007).
- Prasad, R. K. *Quantum Chemistry* (New Age, 2010)

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