

**Draft Syllabus of
3-Year/4-Year B.Sc. Chemistry
(Major)
Revised 2024
As Per NEP 2020
(Up-to 6th Semester)**



University of Gourbanga
Malda – 732 101
West-Bengal

Semester Wise Course (Major) Distribution

Semester	Major Course	
SEM-I	CEMDC-MJ-101	Organic-I + Physical-I
SEM-II	CEMDC-MJ-201	Organic-II + Inorganic-I
SEM-III	CEMDC-MJ-301 (CEMMJ-MC-5) [For 2023-24 Admitted Batch]	Physical-II + Inorganic-II
	CEMDC-MJ-302	Organic-III + Inorganic-III
SEM-IV	CEMDC-MJ-401 (CEMMJ-MC-6) [For 2023-24 Admitted Batch]	Organic-IV
	CEMDC-MJ-402	Inorganic-IV
	CEMDC-MJ-403 (CEMMJ-MC-7) [For 2023-24 Admitted Batch]	Physical-III
SEM-V	CEMDC-MJ-501 (CEMMJ-MC-8) [For 2023-24 Admitted Batch]	Physical-IV
	CEMDC-MJ-502 (CEMMJ-MC-9) [For 2023-24 Admitted Batch]	Physical-V
	CEMDC-MJ-503 (CEMMJ-MC-10) [For 2023-24 Admitted Batch]	Organic-V
	CEMDC-MJ-504 (CEMMJ-MC-11) [For 2023-24 Admitted Batch]	Inorganic-V
SEM-VI	CEMDC-MJ-601 (CEMMJ-MC-12) [For 2023-24 Admitted Batch]	Organic-VI
	CEMDC-MJ-602 (CEMMJ-MC-13) [For 2023-24 Admitted Batch]	Inorganic-VI
	CEMDC-MJ-603 (CEMMJ-MC-14) [For 2023-24 Admitted Batch]	Inorganic-VII
	CEMDC-MJ-604 (CEMMJ-MC-15) [For 2023-24 Admitted Batch]	Physical-VI

Total Marks for CEMDC-MJ-XXX => 75 = (Th. Exam:30 + Prac. Exam:20 + CA:25)

Total Marks for MJ-MC-XX=> 50 = (Th. Exam:25 + Prac. Exam:15 + IA:10)

Chemistry (Major)

[Credit: Theory -03, Practical – 01], T=Theory, P=Practical

SEMESTER-I

Paper: CEMMJ-DC-101T (Organic-I + Physical-I)

Theory: 45 L (45 Hours)

Objective

1. Understand the principles of valence bond theory, molecular orbital theory, and their correlation to molecular structure and bonding properties.
2. Explore the impact of electronic displacements like inductive, resonance effects on bond properties and molecular reactivity.
3. Comprehend the stereochemical aspects of organic molecules including chirality, stereoisomerism, and their representations in different projections.
4. Gain fundamental insights into reaction mechanisms, characteristics of reactive intermediates, and various types of organic reactions.
5. Apply thermodynamic principles and kinetics to evaluate chemical processes, reaction spontaneity, and rates of reaction.
6. Perform practical experiments to identify organic compounds and study reaction kinetics and thermodynamic properties to consolidate theoretical knowledge.

Learning Outcomes

After Completion of this course the student will be able to:

1. Apply molecular orbital and valence bond theories to predict molecular geometry and bonding properties effectively.
2. Evaluate the effects of electronic displacements on molecular stability and reactivity.
3. Determine the stereochemistry of organic compounds and predict the behavior of stereoisomers.
4. Analyze mechanisms of organic reactions and predict the outcome of various chemical reactions.
5. Relate the concepts of thermodynamics and kinetics to practical chemical phenomena and calculations.
6. Conduct experiments for identification of organic compounds and measure reaction rates and thermodynamic quantities.

Gr-A: Organic-I

Bonding and Physical Properties

(12 L)

VBT: Concept of hybridization, shapes and structures of molecules, double bond equivalent (DBE), Influence of hybridization on bond properties.

Electronic Effects: Charge distribution in molecules and ions, field effect & Inductive effect, electromeric, resonance and mesomeric effects, resonance energy, hyperconjugation and their applications, bond polarization and bond polarizability; steric effect, steric inhibition of resonance.

Physical Properties: Bond dissociation energy, bond energy, bond distances and bond angles. Various factors affecting bond length and bond energy. Factors affecting bond angle, bond polarity and dipole moment. Components of dipole moment (μ_{bond} , $\mu_{\text{one-pair}}$, μ_{group} , μ_{σ} , μ_{π} , $\mu_{\text{zwitterionic}}$), Understanding different types of stabilities, Understanding different types of strains: (a) angle strain, (b) torsional strain, (c) strain due to non-bonded interaction, dipole-dipole, and twisting. Impact of covalent and non-covalent intermolecular forces on m.p., b.p. and solubility. Heat of reaction (hydrogenation, combustion, and formation) and stability. Isodesmic and homodesmotic reaction.

MOT: Qualitative idea about molecular orbitals, bonding and antibonding interactions, idea about σ , σ^* , π , π^* , n – MOs; concept of HOMO, LUMO and SOMO; sketch and energy levels of π MOs of (i) acyclic π orbital system (C=C, conjugated diene, triene, allyl and pentadienyl systems), (ii) cyclic π orbital system (neutral systems: [4], [6] annulenes; charged systems: 3-,4-,5-,7- membered ring systems); Aromaticity, Antiaromaticity & Homoaromaticity, properties modified by aromaticity.

Stereochemistry-I

(05 L)

Bonding geometries of carbon compounds and representation of molecules: Tetrahedral nature of carbon; concept of asymmetry; concept of conformation and configuration; Fischer, sawhorse, flying wedge, and Newman projection formulae, and their interconversions.

Concept of chirality: Basic idea of the elements of chirality with suitable examples (chiral centre, chiral axis, chiral plane, helical chirality and conformational chirality) and the concept of non-superimposability (enantiomers and diastereomers); molecular chirality and centre of chirality; symmetry elements and point groups in molecules – asymmetric and dissymmetric molecules; concept of stereogenicity; possible stereoisomers with 1, 2, or 3 stereocenters.

Reaction Mechanism-I

(07 L)

Reactive intermediates: Generation, structure, stability, electrophilic/nucleophilic behavior of the reaction intermediates: carbocations, carbanions, carbon radicals, carbenes, nitrenes.

Elementary idea about reactions: Homolytic and heterolytic bond fission; homogenic and heterogenic bond formation; basic concepts of ionic, radical, and pericyclic reactions.

Types of reactions (definition and examples): Addition, elimination, substitution, rearrangement, oxidation–reduction, tautomerization, condensation, and polymerization.

Tautomerism: Prototropy: Keto–enol, nitro–aci-nitro, nitroso–oximino, diazo–amino, and enamine–imine systems. **Other types:** Valence tautomerism; ring–chain tautomerism. Equilibrium composition: In simple carbonyl compounds; 1,2- and 1,3-dicarbonyl systems; phenols and related systems. Factors affecting keto–enol tautomerism.

Reference Books:

1. Clayden, J., Greeves, N. & Warren, S. Organic Chemistry, Second Edition, Oxford University Press, 2012. 2. Smith, J. G. Organic Chemistry, Tata McGraw- Hill Publishing Company Limited. 3. Nasipuri, D. Stereochemistry of Organic Compounds, Wiley Eastern Limited. 4. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). 5. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearson Education). 6. Fleming, I. Molecular Orbitals and Organic Chemical Reactions, Reference/Student Edition, Wiley, 2009. 7. Eames, J., Peach, J. M. Stereochemistry at A Glance, Blackwell Publishing, 2003. 8. Robinson, M. J., Stereochemistry, Oxford Chemistry Primer, Oxford University Press, 2005.

Gr-B: Physical-I

Thermodynamics-I

(08 L)

Concept of systems (open, closed and isolated) and surroundings. State of a system; Intensive and extensive variables. Partial derivatives. Exact and inexact differentials. Path function and State function. Concept of heat and work. Zeroth law of thermodynamics. Concept of thermodynamic reversibility. Concept of internal energy and 1st law of thermodynamics. Enthalpy and heat capacity, Relations between C_p and C_v . Isothermal and Adiabatic processes; Calculations of ΔU , ΔH , q and w involving ideal gases in different processes.

Enthalpy of reaction. Hess's law. Enthalpy of formation and combustion. Kirchoff's equation.

Chemical Kinetics-I:

(06 L)

Concept of order and molecularity. Rate laws for zero, 1st and 2nd order reactions and in general for any n-th order reaction. Determination of order of a reaction by half-life and differential methods. Rate determining step and steady state approximation. Opposing, Consecutive and parallel reactions (first order steps only). Temperature dependence of the reaction rate, Arrhenius equation. Concept of pre-exponential factor, activation energy and their calculation.

Kinetic Theory and Gaseous state:**(07 L)**

Concept of pressure and temperature from kinetic theory of gas. Nature of distribution of velocities, Maxwell's distribution of speeds in one, two and three dimensions; Kinetic energy distribution in one, two and three dimensions, calculations of average, root mean square and most probable values in each case; Collision of gas molecules; Collision diameter; Collision number and mean free path; Frequency of binary collisions (similar and different molecules); Wall collision and rate of effusion Calculation of number of molecules having energy $\geq \epsilon$, Principle of equipartition of energy and its application to calculate the classical limit of molar heat capacity of gases

Reference Books:

1. Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press. 2. Castellan, G. W. Physical Chemistry, Narosa. 3. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press. 4. Engel, T. & Reid, P. Physical Chemistry, Pearson. 5. Levine, I. N. Physical Chemistry, Tata McGraw-Hill. 6. Maron, S. & Prutton Physical Chemistry. 7. Ball, D. W. Physical Chemistry, Thomson Press. 8. Mortimer, R. G. Physical Chemistry, Elsevier. 9. Laidler, K. J. Chemical Kinetics, Pearson. 10. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry. 11. Rakshit, P.C., Physical Chemistry Sarat Book House. 12. Zemansky, M. W. & Dittman, R.H. Heat and Thermodynamics, Tata- McGraw-Hill. 13. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas. 14. Clauze & Rosenberg, Chemical Thermodynamics.

Paper: CEMMJ-DC-101P (Organic-I + Physical-I)**Practical: 30 Hours****Organic-I (Prac)**

Identification of a Pure Organic Compound by chemical test(s): oxalic acid, tartaric acid, citric acid, succinic acid, resorcinol, urea, glucose, cane sugar, benzoic acid and salicylic acid, formic acid, acetic acid, methanol, ethanol, acetone, aniline, dimethyl aniline, benzaldehyde, chloroform and nitrobenzene.

Physical-I (Prac):

- Study of kinetics of acid-catalyzed hydrolysis of methyl acetate.
- Study of kinetics of decomposition of H_2O_2
- Determination of heat of solution of oxalic acid from solubility measurement

SEMESTER-II**Paper: CEMMJ-DC-201T (Organic-II + Inorganic-I)****Theory: 45 L (45 Hours)****Objectives**

- Understand the fundamentals of bonding theories including VBT and MOT, and their applications in explaining molecular structures and properties.
- Explore the influence of electronic displacements such as resonance and hyperconjugation on molecular stability and reactivity.
- Gain a comprehensive understanding of stereochemistry, chirality, and the ability to depict and interrelate different forms of molecular projections.
- Analyze reaction mechanisms involving various organic reaction intermediates and their roles in different organic transformations.
- Study the thermodynamics and kinetics underlying chemical reactions and processes, including their temperature dependence and factors affecting reaction rates.
- Perform practical experiments to synthesize, purify, and characterize organic compounds, including redox titration for quantitative estimation.

Learning Outcomes

After Completion of this course the student will be able to:

1. Predict and rationalize molecular shapes, bond properties, and reactivity using hybridization and orbital theory.
2. Interpret and apply stereochemical concepts to solve problems related to molecular symmetry, chirality, and stereoisomerism.
3. Identify and explain the formation and stability of different types of reactive intermediates in organic reactions.
4. Apply the principles of thermodynamics and kinetics to predict the feasibility and rate of chemical reactions.
5. Conduct various laboratory techniques for the synthesis of organic compounds, and quantitative estimation of Iron by redox titration.
6. Relate the electronic effects such as inductive, resonance effects, and other electronic displacements to the reactivity and properties of molecules.

Gr-A: Organic-II

Reaction Mechanism-II

(11 L)

Reaction thermodynamics: Free energy and equilibrium, Principle of reactivity and selectivity, enthalpy and entropy factor, calculation of enthalpy change *via* BDE, intermolecular & intramolecular reactions.

Concept of organic acids and bases: Effect of structure, substituent and solvent on acidity and basicity; proton sponge; gas-phase acidity and basicity; comparison between nucleophilicity and basicity; HSAB principle; application of thermodynamic principles in acid-base equilibria.

Reaction kinetics: Rate constant and free energy of activation; concept of order and molecularity; free energy profiles for one-step, two-step and three-step reactions; catalyzed reactions: electrophilic and nucleophilic catalysis; kinetic control and thermodynamic control of reactions; isotope effect: primary and secondary kinetic isotope effect (k_H/k_D); principle of microscopic reversibility; Hammond's postulate- Simple Applications.

Chemistry of Alkenes and Alkynes

(12 L)

Addition to C=C: Mechanism (with evidence wherever applicable), reactivity, regioselectivity (Markownikoff and anti-Markownikoff additions) and stereoselectivity; reactions: hydrogenation, halogenation, hydrohalogenation, hydration, oxymercuration-demercuration, hydroboration-oxidation, epoxidation, *syn* and *anti*-hydroxylation, ozonolysis, addition of singlet and triplet carbenes; Simmons-Smith cyclopropanation reaction; electrophilic addition to 1,3-butadiene; concept of kinetic and thermodynamic control of products; radical addition: HBr addition; mechanism of allylic and benzylic bromination in competition with bromination across C=C bond; use of NBS; interconversion of *E* and *Z* alkenes.

Addition to C≡C (in comparison to C=C): Mechanism, reactivity, regioselectivity (Markownikoff and anti-Markownikoff addition) and stereoselectivity; reactions: hydrogenation, Hg(II) ion catalyzed hydration, hydroboration-oxidation, dissolving metal reduction of alkynes (Birch); reactions of terminal alkynes by exploring its acidity.

Reference Books:

1. Clayden, J., Greeves, N., Warren, S. Organic Chemistry, Second edition, Oxford University Press 2012.
2. Sykes, P. A guidebook to Mechanism in Organic Chemistry, Pearson Education, 2003.
3. Smith, J. G. Organic Chemistry, Tata McGraw-Hill Publishing Company Limited.
4. Carey, F. A., Giuliano, R. M. Organic Chemistry, Eighth edition, McGraw Hill Education, 2012.
5. Loudon, G. M. Organic Chemistry, Fourth edition, Oxford University Press, 2008.
6. Norman, R.O. C., Coxon, J. M. Principles of Organic Synthesis, Third Edition, Nelson Thornes, 2003.
7. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
8. Finar, I. L. Organic Chemistry (Volume 1), Pearson Education.
9. Graham Solomons, T.W., Fryhle, C. B. Organic Chemistry, John Wiley & Sons, Inc.
10. March, J. Advanced Organic Chemistry, Fourth edition, Wiley.
11. Jenkins, P. R., Organometallic Reagents in Synthesis, Oxford Chemistry Primer, Oxford University Press.
12. Ward, R. S., Bifunctional Compounds, Oxford Chemistry Primer, Oxford University Press,

Gr-B: Inorganic-I

Extra Nuclear Structure of Atoms:

(12 L)

Wave-Particle duality; de Broglie hypothesis. Heisenberg's uncertainty principle. Introducing Schrödinger equation. Hydrogen and hydrogen like systems (detailed solution not required). Concept of Atomic Orbital; shapes of s, p and d orbitals. Radial and angular distribution curves. Extension to multi-electronic systems. Aufbau principle and its limitations; Pauli's exclusion principle; Hund's rules and multiplicity. Effective nuclear charge. Shielding and penetration; Slater's rule.

Periodicity:

(10 L)

Modern IUPAC Periodic table, Effective nuclear charge, screening effects and penetration, Slater's rules, atomic radii, ionic radii (Pauling's univalent), covalent radii, lanthanide contraction. Ionization potential, electron affinity and electronegativity (Pauling's, Mulliken's and Allred Rochow's scales) and factors influencing these properties, group electronegativities. Group trends and periodic trends in these properties in respect of s-, p- and d-block elements. Secondary periodicity, relativistic effect, inert pair effect.

Reference Books:

1. Lee, J. D. Concise Inorganic Chemistry, 5th Ed., Wiley India Pvt. Ltd., 2008. 2. Atkins, Overton, Rourke, Weller, Armstrong; Shriver & Atkins' Inorganic Chemistry, 5th Ed., Oxford University Press (2010). 3. G. L. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Edition, Pearson India, 2008. 4. R. Sarkar, General and Inorganic Chemistry Part-I, New Central Book Agency, 2014. 5. A. G. Sharpe, C. E. Housecroft, Inorganic Chemistry 3rd Edition, Pearson India, 2002. 6. J. E. Huheey, E. A. Keiter, R. L. Keiter, Okhil K. Medhi, Principles of Structure and Reactivity, 5th Edition, Pearson India, 2022. 7. A. K. Das, Fundamental Concepts of Inorganic Chemistry, (Vol. 1 & 3, Second Edition), CBS Publishers & Distributors Pvt. Ltd., 8. Principles of Inorganic Chemistry (33rd Edition), B.R. Puri, L.R. Sharma, K.C. Kalia, Vishal Publishing Co., 8. R. L. Dutta and G. S. De, Inorganic Chemistry, Pt – I, 7th Edn, 2013, The New Book Stall, 2013.

Paper: CEMMJ-DC-201P (Organic-II + Inorganic-I)

Practical: 30 Hours

Organic-II (Prac):

- (a) The following reactions are to be performed, noting the yield of the crude product:
- Nitration of aromatic compounds
 - Condensation reactions
 - Hydrolysis of amides/imides/esters
 - Acetylation of phenols/aromatic amines
 - Benzoylation of phenols/aromatic amines
- (b) Purification of the crude product is to be made by crystallization from water/alcohol.
- (c) Melting point of the purified product is to be noted.

Inorganic-I (Prac):

- Standardization of NaOH by standard oxalic acid solution
- Estimation of Fe(III) using standard $K_2Cr_2O_7$ solution.
- Estimation of Fe(II) and Fe(III) in a given mixture using standard $K_2Cr_2O_7$ solution

SEMESTER-III

Paper: CEMMJ-DC-301T/ CEMMJ-MC-5T (Physical-II + Inorganic-II)

Theory: 45 L (45 Hours)

Objectives

1. Develop a comprehensive understanding of the second law of thermodynamics and concepts such as entropy, Gibbs and Helmholtz functions, and their applications in various systems including biological systems.
2. Introduce the criteria for spontaneity and equilibrium in chemical reactions, along with Maxwell relations, and related thermodynamic equations.
3. Analyze systems of variable compositions, understand the determination of equilibrium, and learn the calculation of fugacity and activity coefficients.
4. Explore the various types and applications of chemical bonds, including ionic bonds and covalent bonds, along with theories and models explaining their formation and properties.
5. Learn how to balance redox reactions using the ion-electron method and understand the influence of different factors like complex formation and pH changes on redox potentials.
6. Conduct practical experiments to reinforce theoretical knowledge, explore real-world applications, and learn laboratory techniques such as conductometric titration, verification of Ostwald's law, and estimation of metal ions using standardized solutions.

Learning Outcomes

After Completion of this course the student will be able to:

1. Explain and apply the concepts of entropy and the second law of thermodynamics to predict the behavior of various systems.
2. Use thermodynamic principles to evaluate the spontaneity and equilibrium of reactions, understanding the use of Gibbs free energy and other related parameters.
3. Calculate partial molar quantities and understand the dependency of thermodynamic parameters on composition in variable composition systems.
4. Describe the nature and properties of chemical bonds, and predict molecular shapes and properties using principles like VSEPR and hybridization theories.
5. Apply redox theories and calculations in practical scenarios, accurately balance redox reactions considering different environmental influences.
6. Perform and interpret results from lab experiments such as conductometric titrations and estimations of metal ions, enhancing their experimental and analytical skills.

Gr-A: Physical-II

Thermodynamics-II:

(23 L)

2nd Law: Need for a Second law; statement of the second law of thermodynamics; Concept of heat reservoirs and heat engines; Carnot cycle; Carnot engine and refrigerator; Kelvin – Planck and Clausius statements and equivalence of the two statements with entropic formulation; Carnot's theorem; Values of $\int dQ/T$ and Clausius inequality; Physical concept of Entropy; Entropy is a measure of the microscopic disorder of the system. Entropy changes of systems and surroundings for various processes and transformations; Entropy and unavailable work; Temperature – Entropy diagram. Useful work and The Gibbs and Helmholtz function. Changes at constant T, P. Application to electric work. Criteria for spontaneity and equilibrium. Gibbs- Helmholtz equation, The Gibbs Function and useful work in biological systems. Gibbs free energy and spontaneous phase transition. Maxwell's relations; Joule-Thomson experiment and its consequences; inversion temperature; Joule-Thomson coefficient for a van der Waals gas; General heat capacity relations

Systems of Variable Compositions: State functions for system of variable compositions. Criteria of equilibrium and spontaneity in systems of variable composition. Partial molar quantities, dependence of thermodynamic parameters on composition; Chemical potential as an escaping tendency. Gibbs-Duhem equation, Entropy and

Gibbs function for mixing of ideal gases, the chemical potential of ideal mixtures. The Fugacity function of a pure real gas. Calculation of the fugacity of a van der Waals gas using compressibility factor. Definitions of Activities and activity coefficients. Choice of standard states. Dependence of Activity on pressure and temperature.

Reference Books:

1. Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press. 2. Castellan, G. W. Physical Chemistry, Narosa. 3. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press. 5. Levine, I. N. Physical Chemistry, Tata McGraw-Hill. 6. Rakshit, P.C., Physical Chemistry Sarat Book House. 7. Kapoor, K. L., A Text Book of Physical Chemistry, 6th Edn, McGraw-Hill.

Gr-B: Inorganic-II

Redox

(11 L)

Basic Principle of Redox Reactions: Ion-electron method of balancing equation of redox reaction. Elementary idea on standard redox potentials with sign conventions, Nernst equation (without derivation). Influence of complex formation, precipitation and change of pH on redox potentials; formal potential.

Applications: Feasibility of a redox titration, redox potential at the equivalence point, redox indicators. Redox potential diagrams (Latimer and Frost diagrams) of common elements and their applications. Pourbaix diagram for Iron and Manganese. Disproportionation, comproportionation reactions and auto-oxidations (typical examples). Disproportionation and comproportionation reactions (typical examples). Solubility product principle, common ion effect and their applications to the precipitation and separation of common metallic ions as hydroxides, sulfides, phosphates, carbonates, sulfates and halides.

Chemical Bonding-I:

(11 L)

Ionic bond: General characteristics, types of ions, size effects, radius ratio rule and its application and limitations. Packing of ions in crystals. Born-Landé equation with derivation and importance of Kapustinskii expression for lattice energy. Madelung constant, Born-Haber cycle and its application, Solvation energy. Defects in solids (elementary idea). Solubility energetic of dissolution process.

Covalent bond: Polarizing power and polarizability, ionic potential, Fajan's rules, Lewis structures, formal charge, Valence Bond Theory, The hydrogen molecule (Heitler-London approach), directional character of covalent bonds, hybridizations, equivalent and non-equivalent hybrid orbitals, Bent's rules, dipole moments, VSEPR theory, shapes of molecules and ions containing lone pairs (examples from main group chemistry) and multiple bonding (σ and π bond approach).

Shapes of f-orbitals, Ground state Term symbols of atoms and ions for atomic number up to 30.

Reference Books:

1. Lee, J. D. Concise Inorganic Chemistry, 5th Ed., Wiley India Pvt. Ltd., 2008. 2. Atkins, Overton, Rourke, Weller, Armstrong; Shriver & Atkins' Inorganic Chemistry, 5th Ed., Oxford University Press (2010). 3. G. L. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Edition, Pearson India, 2008. 4. R. Sarkar, General and Inorganic Chemistry Part-I, New Central Book Agency, 2014. 5. A. G. Sharpe, C. E. Housecroft, Inorganic Chemistry 3rd Edition, Pearson India, 2002. 6. J. E. Huheey, E. A. Keiter, R. L. Keiter, Okhil K. Medhi, Principles of Structure and Reactivity, 5th Edition, Pearson India, 2022. 7. A. K. Das, Fundamental Concepts of Inorganic Chemistry, (Vol. 1 & 3, Second Edition), CBS Publishers & Distributors Pvt. Ltd., 8. Principles of Inorganic Chemistry (33rd Edition), B.R. Puri, L.R. Sharma, K.C. Kalia, Vishal Publishing Co., 8. R. L. Dutta and G. S. De, Inorganic Chemistry, Pt - I, 7th Edn, 2013, The New Book Stall, 2013

Paper: CEMMJ-DC-301P/ CEMMJ-MC-5P (Physical-II + Inorganic-II)

Practical: 30 Hours

Physical-II (Prac)

- (a) Conductometric titration of an acid (strong, weak/ monobasic, dibasic) against strong base.
- (b) Study of saponification reaction conductometrically.
- (c) Verification of Ostwald's dilution law and determination of K_a of weak acid.

Inorganic-II (Prac)

- (a) Estimation of Fe (III) and Mn(II) in a mixture using standardized $KMnO_4$ solution
- (b) Estimation of Fe (III) and Cu(II) in a mixture using $K_2Cr_2O_7$.
- (c) Estimation of Fe (III) and Cr(III) in a mixture using $K_2Cr_2O_7$

Paper: CEMMJ-DC-302T (Organic-III + Inorganic-III)

Theory: 45 L (45 Hours)

Objectives

1. Understand the mechanisms and dynamics involved in electrophilic and nucleophilic aromatic substitution reactions.
2. Gain knowledge of the preparative methods and reactions of alcohols, ethers, and phenols up to five carbons.
3. Explore the relationship between chirotopicity and stereogenicity and understand optical activity, racemization, and resolution in stereochemistry.
4. Develop a fundamental understanding of acid-base concepts across different solvent systems and the methods used to evaluate acidity and basicity.
5. Learn about the general principles and purification methods in metallurgy with an emphasis on reduction, refining processes, and electrolytic methods.
6. Conduct practical experiments in organic and inorganic chemistry effectively, focusing on synthesis, characterization, and quantitative analysis of alkaline materials

Learning Outcomes

After Completion of this course the student will be able to:

1. Analyze and apply various types of aromatic substitution reactions to synthetic organic chemistry.
2. Synthesize alcohols, ethers, and phenols using advanced techniques and assess their reaction mechanisms/products with specificity.
3. Correlate molecular structure with optical activity and apply techniques for the separation and quantification of enantiomers.
4. Evaluate the strength of acids and bases using theoretical and practical approaches, and manipulate pH buffers and indicators effectively.
5. Apply theoretical knowledge in metallurgy to practical scenarios such as metal extraction and purification.
6. Perform precise organic synthetic reactions including environmentally friendly methods and accurately estimate the alkali materials in inorganic experiments.

Gr-A: Organic-III

Aromatic Substitution

(07 L)

Electrophilic Aromatic Substitution

Mechanism (S_E2 , arenium ion, energy profile, *etc.*) and Evidences (Isotope effect, Isolation of intermediate); Example(s) of S_E1 . Orientation and reactivity for mono-substituted benzene. Concept of orientation effect for di-substituted benzene. Reactions: Nitration, Nitrosation, Sulfonation, Halogenation, Friedel-Crafts reaction; one-carbon electrophiles (Reactions: chloromethylation, Gatterman-Koch, Gatterman, Houben-Hoesch, Vilsmeier-Haack, Reimer-Tiemann, Kolbe-Schmidt); Ipso- substitution.

Nucleophilic Aromatic Substitution (ArS_N)

Relative reactivity of alkyl, allyl, vinyl and benzyl, aryl halides towards nucleophilic substitution reactions, ArS_{N1} and ArS_{N2} Reactions: examples, mechanism, evidences in favour of the mechanism; Reactions *via* Benzyne: Evidence and Structure of Benzyne; cine substitution. Some Important name reactions involving aromatic nucleophilic substitution: von-Richter rearrangement, Sommelet-Hauser rearrangement, Smiles rearrangement

Chemistry of Alcohols, Ethers and Phenols

(10 L)

Alcohols: Structure and general properties of Alcohols: Boiling point, Polarity, Solubility, Acidity. Synthesis: Bouveault-Blanc reduction to 1^0 and 2^0 alcohols, Metallic hydride reduction ($NaBH_4$, LAH), Industrial preparation of Methanol (from CO and H_2), Concept of Fermentation of Carbohydrates for the formation of alcohols like ethanol. Reaction of alcohols: Hydrohalic acids, Oxidation to carbonyls and carboxylic acids (use of Chromic acid and/or Jones oxidation, $KMnO_4$, PCC, PDC). Differentiation of 1^0 , 2^0 and 3^0 alcohols by Oxidation, Lucas test and using heated Cu at 300^0C .

Phenols: Synthesis (from Halobenzene, Cumene, Diazonium salt, Sulphonic acid); Acidic character. Reactions: Ring substitution, Kolbe, Reimer-Tiemann, Formation of ether and Claisen rearrangement, Formation of ester and Fries rearrangement. Dihydric phenols: Dakin reaction, Formation of Quinol & Quinone. Reaction of p-benzoquinone: Addition reaction, Thiele acetylation. Quinhydrone (basic concept only).

Ethers: Boiling point, Polarity, Solubility, Usability as solvents. Synthesis and Reactions of Ethers: Synthesis from alcohols (in acidic medium, using diazomethane), Williamson's synthesis; Cleavage of Ethers by acids in hot and cold conditions. Hydrolysis of enol-ethers.

Stereochemistry-II

(06 L)

Chirotopicity and its relationship with stereogenicity; concept of pseudo-asymmetry for ABA type systems. Relative and absolute configuration: *R/S* descriptors; *erythro/threo* and *meso* nomenclature of compounds; *E/Z* descriptors for $C=C$, conjugated diene, triene, $C=N$ and $N=N$ systems, combination of *R/S*- and *E/Z* isomerism. Optical activity of chiral compounds: optical rotation, and specific rotation; racemic compounds, racemization (through cationic, anionic, radical intermediates and through Reversible Formation of Stable achiral Intermediates); resolution of acids, bases and alcohols via diastereomeric salt formation; optical purity and enantiomeric excess; invertomerism of chiral trialkylamines.

Reference Books:

1. Clayden, J., Greeves, N., Warren, S. Organic Chemistry, Second edition, Oxford University Press 2012. 2. Sykes, P. A guidebook to Mechanism in Organic Chemistry, Pearson Education, 2003. 3. Smith, J. G. Organic Chemistry, Tata McGraw-Hill Publishing Company Limited. 4. Carey, F. A., Guiliano, R. M. Organic Chemistry, Eighth edition, McGraw Hill Education, 2012. 5. Loudon,

G. M. Organic Chemistry, Fourth edition, Oxford University Press, 2008. 6. Norman, R.O. C., Coxon, J. M. Principles of Organic Synthesis, Third Edition, Nelson Thornes, 2003. 7. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). 8. Finar, I. L. Organic Chemistry (Volume 1), Pearson Education. 9. Graham Solomons, T.W., Fryhle, C. B. Organic Chemistry, John Wiley & Sons, Inc. 10. March, J. Advanced Organic Chemistry, Fourth edition, Wiley. 11. Jenkins, P. R., Organometallic Reagents in Synthesis, Oxford Chemistry Primer, Oxford University Press. 12. Ward, R. S., Bifunctional Compounds, Oxford Chemistry Primer, Oxford University Press, 13. Nasipuri, D. Stereochemistry of Organic Compounds, Wiley Eastern Limited.

Gr-B: Inorganic-III

Acids and Bases: (15 L)

Acid-base concept: Arrhenius concept, theory of solvent system (in H₂O, NH₃, SO₂ and HF), Bronsted-Lowry's concept, Pauling's rules. Lux-Flood concept, Lewis concept, group characteristics of Lewis acids, solvent levelling and differentiating effects. Factors affecting relative strength of acids and bases (different types), Thermodynamic acidity parameters, Drago-Wayland equation. Hammett acidity function. Super acids, Gas phase acidity and proton affinity; HSAB principle. Acid-base equilibria in aqueous solution (Proton transfer equilibria in water), pH, buffer, salt hydrolysis. Acid-base neutralization curves; indicator, choice of indicators.

General Principles of Metallurgy (07 L)

Chief modes of occurrence of metals based on standard electrode potentials. Ellingham diagrams for reduction of metal oxides using carbon and carbon monoxide as reducing agent. Electrolytic Reduction, Hydrometallurgy. Methods of purification of metals: Electrolytic Kroll process, Parting process, van Arkel-de Boer process and Mond's process, Zone refining.

Reference Books:

1. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson, 2006. 2. Greenwood, N.N. & Earnshaw A. Chemistry of the Elements, Butterworth-Heinemann, 1997. 3. Cotton, F.A., Wilkinson, G., Murrillo, C. A., Bochmann, M., Advanced Inorganic Chemistry 6th Ed. 1999., Wiley. 4. Miessler, G. L. & Donald, A. Tarr. Inorganic Chemistry 4th Ed., Pearson, 2010. 5. Lee, J. D. Concise Inorganic Chemistry ELBS, 1991. 6. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970. 7. Day, M.C. and Selbin, J. Theoretical Inorganic Chemistry, ACS Publications, 1962. 8. Atkins, P. Shriver & Atkins' Inorganic Chemistry 5th Ed. Oxford University Press (2010). 9. Cotton, F.A., Wilkinson, G. and Gaus, P.L., Basic Inorganic Chemistry 3rd Ed.; Wiley India. 10. Sharpe, A.G., Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005.

Paper: CEMDC-MJ-302P (Organic-III + Inorganic-III)

Practical: 30 Hours

Organic-III (Prac)

- (a) The following reactions are to be performed, noting the yield of the crude product:
- Bromination of anilides using green approach (Bromate-Bromide method)
 - Redox reaction including solid-phase method
 - Green 'multi-component-coupling' reaction
 - Selective reduction of m-dinitrobenzene to m-nitroaniline
- (b) Purification of the crude product is to be made by crystallization from water/alcohol.
- (c) Melting point of the purified product is to be noted.

Inorganic-III (Prac)

- (a) Estimation of carbonate and hydroxide present together in mixture
- (b) Estimation of carbonate and bicarbonate present together in a mixture.
- (c) Estimation of free alkali present in different soaps/detergents

SEMESTER-IV

Paper: CEMDC-MJ-401T/ CEMMJ-MC-6T (Organic-IV)

Theory: 45 L (45 Hours)

Objectives

1. Understand the various types of stereochemistry, including conformation and configuration in organic molecules.
2. Analyze the relative stability and reactivity of carbonyl containing compounds and their derivatives through mechanistic studies.
3. Learn the concepts and applications of nucleophilic addition reactions and substitutions at the sp² carbon of the carbonyl group.
4. Study alpha-hydrogen acidity in carbonyl compounds to understand enolate chemistry, enolates in alkylation and acylation reactions.
5. Understand UV-Visible spectroscopy principles and applications in organic chemistry for structure elucidation.
6. Develop practical skills in systematic qualitative analysis of organic compounds in the laboratory setting with precision.

Learning Outcomes

1. Explain the principles of stereochemistry including conformational analysis and differentiate between various stereoisomers.
2. Describe the mechanisms and outcomes of nucleophilic additions and substitutions involving carbonyl compounds.
3. Apply various organic reactions involving carbonyl compounds for synthetic purposes including aldol condensation and Michael reaction.
4. Utilize UV-Vis spectroscopy to predict and analyze organic molecular structures and transitions.
5. Perform systematic qualitative analysis of organic compounds, identifying functional groups and purity.
6. Integrate theoretical knowledge with practical lab skills to synthesize and characterize organic compounds, interpreting experimental data effectively.

Stereochemistry-III

(11 L)

Conformation of Acyclic Molecules

Conformational nomenclature: eclipsed, staggered, gauche, syn and anti; dihedral angle, torsion angle; Klyne-Prelog terminology; P/M descriptors; energy barrier of rotation, concept of torsional and steric strains, relative stability of conformers on the basis of steric effect, dipole-dipole interaction and H-bonding; butane gauche interaction; conformational analysis of the molecules of the type: (a) X₃C-CY₃ (b) YCH₂-CH₂Z, (c) Higher homologous alkanes, (d) Saturated chiral molecules (2-chlorobutane), (e) RX-CH₂Y (anomeric effect). conformation of conjugated systems (*s-cis* and *s-trans*).

Concept of Pro-stereoisomerism

Pro-stereogenic centre; concept of (pro)ⁿ chirality: topicity of ligands and faces (elementary idea); pro-R/pro-S, pro-E/pro-Z and Re/Si descriptors; pro-*r* and pro-*s* descriptors of ligands on pro-pseudo-asymmetric centre.

Chirality Arising Out of Stereo-Axis

Stereoisomerism of substituted cumulenes with even and odd number of double bonds; chiral axis in

allenes, spiro compounds, alkylidenecycloalkanes and biphenyls; related configurational descriptors (R_a/S_a and P/M); atropisomerism; racemization of chiral biphenyls; buttressing effect.

Chemistry of Carbonyl Compounds (24 L)

Nucleophilic Addition to C=O

Structure and reactivity of carbonyl compounds; mechanism (with evidence), reactivity, equilibrium and kinetic control; formation of hydrates, cyanohydrins and bisulphite adduct; nucleophilic addition-elimination reactions with alcohols, thiols and nitrogen-based nucleophiles; reactions: benzoin condensation, Cannizzaro and Tischenko reactions, reactions with ylides: Wittig and Corey-Chaykovsky reaction; Rupe rearrangement, oxidations and reductions: Clemmensen, Wolff-Kishner, $LiAlH_4$, $NaBH_4$, MPV redox equilibrium, acyloin condensation; oxidation of alcohols with PDC and PCC; periodic acid and lead tetraacetate oxidation of 1,2-diols.

Exploitation of acidity of α -H of C=O

Formation of enols and enolates; kinetic and thermodynamic enolates; reactions (mechanism with evidence): halogenation of carbonyl compounds under acidic and basic conditions, Hell-Volhard-Zelinsky (H.V.Z.) reaction, nitrosation, SeO_2 (Riley) oxidation; condensations (mechanism with evidence): Aldol, Tollens', Knoevenagel, Claisen-Schmidt, Claisen ester including Dieckmann; Mannich reaction, Perkin reaction; alkylation of active methylene compounds; synthetic applications of diethyl malonate and ethyl acetoacetate; specific enol equivalents (lithium enolates, enamines and silyl enol ethers) in connection with alkylation, acylation and aldol type reaction.

Nucleophilic addition to α,β -unsaturated carbonyl system

General principle and mechanism (with evidence); direct and conjugate addition, addition of enolates (Michael reaction), Robinson annulations reaction.

Substitution at sp^2 carbon (C=O system)

Mechanism (with evidence): B_{AC2} , A_{AC2} , A_{AC1} , A_{AL1} (in connection to acid and ester); acid derivatives: amides, anhydrides & acyl halides (formation and hydrolysis including comparison).

Organometallics (05 L)

Preparation and Reactions (mechanism with evidence); addition of Grignard and organolithium to carbonyl compounds; alkylation, substitution on $-COX$; directed ortho-metalation of arenes using organolithiums, conjugate addition by Gilman cuprates; Corey-House synthesis; abnormal behavior of Grignard reagents; comparison of reactivity among Grignard, organolithiums and organocopper reagents; Reformatsky reaction; Blaise reaction; concept of umpolung and base-nucleophile dichotomy in case of organometallic reagents.

Organic Spectroscopy-I: UV-Vis Spectroscopy (05 L)

UV- spectroscopy: Introduction; types of electronic transitions, end absorption; transition dipole moment and allowed/forbidden transitions; chromophores and auxochromes; Bathochromic and Hypsochromic shifts; intensity of absorptions (Hyper/Hypochromic effects); application of Woodward's Rules for calculation of λ_{max} for the following systems: conjugated diene, α,β -unsaturated aldehydes and ketones (alicyclic, homo-annular and hetero-annular); extended conjugated systems (dienes, aldehydes and

ketones); distinction between cis and trans isomers relative positions of λ_{\max} considering conjugative effect, steric effect, solvent effect, effect of pH.

Reference Books

1. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). 2. Finar, I. L. Organic Chemistry (Volume 2: Stereochemistry and the Chemistry of Natural Products), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). 3. Norman, R.O. C., Coxon, J. M. Principles of Organic Synthesis, Third Edition, Nelson Thornes, 2003. 4. Clayden, J., Greeves, N., Warren, S., Organic Chemistry, Second edition, Oxford University Press 2012. 5. Silverstein, R. M., Bassler, G. C., Morrill, T. C. Spectrometric Identification of Organic Compounds, John Wiley and Sons, INC, Fifth edition. 6. Kemp, W. Organic Spectroscopy, Palgrave. 6. Pavia, D. L. et al. Introduction to Spectroscopy, 5th Ed. Cengage Learning India Ed. (2015). 7. Dyer, J. Application of Absorption Spectroscopy of Organic Compounds, PHI Private Limited. 8. March, J. Advanced Organic Chemistry, Fourth edition, Wiley. 9. Harwood, L. M., Polar Rearrangements, Oxford Chemistry Primer, Oxford University Press. 10. Bailey, Morgan, Organonitrogen Chemistry, Oxford Chemistry Primer, Oxford University Press. Warren, S. Organic Synthesis the Disconnection Approach, John Wiley and Sons. Warren, S., Designing Organic Synthesis, Wiley India, 2009. 13. Carruthers, W. Modern methods of Organic Synthesis, Cambridge University Press. 14. Willis, C. A., Wills, M., Organic Synthesis, Oxford Chemistry Primer, Oxford University Press.

Paper: CEMDC-MJ-401P/ CEMMJ-MC-6P (Organic-IV)

Practical: 30 Hours

Organic-IV (Prac)

Systematic Qualitative Analysis of a Single Solid Organic Compound (Functional Groups to be considered):

1. Detection of special elements (N, S, Cl, Br) by Lassaigne's test
2. Solubility and classification (solvents: H₂O, 5% HCl, 5% NaOH and 5% NaHCO₃)
3. Detection of the following functional groups by systematic chemical tests: -CO₂R, -CO₂H, Phenolic -OH, -CO-, -CHO, α -hydroxy carbonyl, -CONH₂ including imide, -CONHAr, Aromatic -NH₂, Aromatic -NO₂
5. Melting point of the given compound
6. Preparation of one derivative of the given sample
7. Prediction of the probable compound from literature survey.

Paper: CEMDC-MJ-402T (Inorganic-IV)

Theory: 45 L (45 Hours)

Objectives

1. Understand the basic principles and applications of redox reactions, redox potential, and redox indicators.
2. Examine diagrams such as Latimer and Frost for understanding redox behaviors of elements, and Pourbaix diagrams for iron and manganese.
3. Learn the concepts and implications of nuclear stability, nuclear reactions, and energy production via nuclear processes.
4. Comprehend the principles and safety measures of radioactivity, including the practical applications in dating and isotope separation.
5. Understand the impact of physical properties of non-aqueous solvents on chemical reactions and categorize different types of solvents.
6. Carry out qualitative semimicro analysis of mixtures containing three radicals and learn the systematic approach in experimental inorganic chemistry.

Learning Outcomes

After Completion of this course the student will be able to:

1. Analyze and apply the knowledge of redox potentials and indicators for understanding and conducting redox titrations.
2. Utilize specialized diagrams like Latimer, Frost, and Pourbaix for predicting and rationalizing elemental behavior in different environments.
3. Describe and discuss the mechanisms and effects of nuclear reactions, including their applications in energy generation and safety protocols.
4. Implement radiochemical methods for determining the age of geological samples and understand the hazards associated with radiation.
5. Evaluate and explain how the properties of non-aqueous solvents influence the reactions that occur within them and determine the right solvent for specific reactions.
6. Skillfully carry out qualitative analysis of complex inorganic mixtures and draw conclusions according to experimental data.

Chemical Bonding-II

(28 L)

Molecular Orbital Theory

The approximations of the theory, Linear combination of atomic orbitals (LCAO) (elementary pictorial approach): sigma and pi bonds and delta interaction, multiple bonding. Orbital designations: gerade, ungerade, HOMO, LUMO. Orbital mixing, MO diagrams of H₂, Li₂, Be₂, B₂, C₂, N₂, O₂, F₂, and their ions wherever possible; Heteronuclear molecular orbitals: CO, NO, NO⁺, CN⁻, HF, BeH₂, CO₂ and H₂O. Bond properties: bond orders, bond lengths.

Metallic Bond

Qualitative idea of valence bond and band theories. Semiconductors and insulators, defects in solids.

Weak Chemical Forces

Hydrogen bonding (theories of hydrogen bonding, valence bond treatment), Non-covalent interactions – examples of Ion-Dipole Interactions, Dipole- Dipole interactions, Dipole-Induced Dipole and Ion-Induced Dipole interactions, van der Waals or Dispersion Interactions, Halogen bonding, Cation- interactions, Anion-pi interactions, pi – pi interactions, Aromatic-Aromatic Interactions: Edge-to-face (T-shaped interaction) *vs* π - π Stacking Interactions, N-H \cdots π interactions, S-aromatic interactions. Effects of chemical force, melting and boiling points.

Radioactivity

(17L)

Natural radioactivity, Radioactive decay law, half-life, average life, Soddy Fajan's Group displacement law, Radioactive equilibrium, Nuclear stability and nuclear binding energy. Nuclear forces: meson exchange theory. Nuclear models (elementary idea): Concept of nuclear quantum number, magic numbers, Nuclear Reactions, Artificial radioactivity, transmutation of elements, fission, fusion and spallation. Nuclear energy and power generation. Separation and uses of isotopes. Radiochemical methods: principles of determination of age of rocks and minerals, radio carbon dating, hazards of radiation and safety measures.

Reference Books

1. Lee, J. D. Concise Inorganic Chemistry 5th Ed., John Wiley and sons 2008.
2. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson, 2006.
3. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.
4. Porterfield, H. W., Inorganic Chemistry, Second Edition, Academic Press, 2005.
5. Purecell, K.F. and Kotz, J.C., An Introduction to Inorganic Chemistry, Saunders: Philadelphia, 1980.
6. Cotton, F.A., Wilkinson, G., & Gaus, P.L. Basic Inorganic Chemistry 3rd Ed.; Wiley India.
7. Gillespie, R. J. and Hargittai, I., The VSEPR Model of Molecular Geometry, Prentice Hall (1992).
8. Albright, T., Orbital interactions in chemistry, John Wiley and Sons (2005).
9. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).
10. Miessler, G. L., Fischer, P. J., Tarr, D. A., Inorganic Chemistry, Pearson, 5th Edition.
- H. J. Amikar, Essentials of Nuclear Chemistry, 5th Edition, New Age

Paper: CEMDC-MJ-402P (Inorganic-IV)

Practical: 30 Hours

Inorganic-IV (Prac)

Qualitative semi micro analysis of mixtures containing three radicals.

Emphasis should be given to the understanding of the chemistry of different reactions.

Acid Radicals: Cl^- , Br^- , I^- , NO_2^- , NO_3^- , S^{2-} , SO_4^{2-} , SO_3^{2-} ,

Basic Radicals: K^+ , Na^+ , NH_4^+ , Mg^{2+} , Ca^{2+} , Ba^{2+} , Sr^{2+} , Al^{3+} , Cr^{3+} , Mn^{2+} , $\text{Fe}^{2+}/\text{Fe}^{3+}$, Co^{2+} , Ni^{2+} , Cu^{2+} , Zn^{2+} , Pb^{2+} , Bi^{3+} , $\text{As}^{3+}/\text{As}^{5+}$, $\text{Sb}^{3+}/\text{Sb}^{5+}$.

Paper: CEMDC-MJ-403T/ CEMMJ-MC-7T (Physical-III)

Theory: 45 L (45 Hours)

Objectives

1. Understand the deviation of real gases from ideal behavior and various states of matter including solid, liquid, and gases.
2. Gain insight into theories and applications of fluid dynamics, including viscosity and surface tension experiments.
3. Explore the crystallographic structures and properties of solid materials, including the use of Bragg's law and Miller indices.
4. Comprehend the principles of chemical equilibrium, including Le Chatelier's principle and its applications in different reactions.
5. Learn and apply principles of electrolyte conductance and the applications of conductometric titrations.
6. Conduct practical experiments to understand the relationships between surface tension, viscosity, and solute concentrations as well as determining partition coefficients in chemistry.

Learning Outcomes

After Completion of this course the student will be able to:

1. Analyze and interpret the behavior of real gases using the Van der Waals equation and other state equations.
2. Understand and describe the concepts of viscosity and surface tension and their dependence on temperature and concentration.
3. Accurately define and utilize the laws of crystallography to determine crystal structures and their properties.
4. Apply thermodynamic concepts to predict and manipulate the conditions and outcomes of chemical reactions in equilibrium.
5. Conduct experiments to measure conductance and understand conductivity variations in different types of solutions.
6. Utilize experimental data to study the interactions between different substances and determine partition coefficients effectively.

Real gas and Virial equation

(07 L)

Deviation of gases from ideal behavior; compressibility factor; Boyle temperature; Andrew's and Amagat's plots; van der Waals equation and its features; its derivation and application in explaining real gas behavior, other equations of state ; Existence of critical state, Critical constants in terms of van der Waals constants; Law of corresponding states; virial equation of state; van der Waals equation expressed in virial form and significance of second virial coefficient; Intermolecular forces (Debye, Keesom and London interactions; Lennard-Jones potential - elementary idea).

Transport Processes and Liquid State

(09 L)

Diffusion and Viscosity

Fick's law, Flux, force, phenomenological coefficients & their inter-relationship (general form), different examples of transport properties

General features of fluid flow (streamline flow and turbulent flow); Newton's equation, viscosity coefficient; Poiseuille's equation; principle of determination of viscosity coefficient of liquids by falling sphere method and using Ostwald's viscometer. Temperature variation of viscosity of liquids and comparison with that of gases. Relation between viscosity coefficient of a gas and mean free path.

Surface tension and energy

Surface tension, surface energy, excess pressure, capillary rise and surface tension; Work of cohesion and adhesion, spreading of liquid over other surface; Temperature dependence of surface tension

Solid State

(12 L)

Bravais Lattice and Laws of Crystallography

Types of solid, Bragg's law of diffraction; Laws of crystallography (Haüy's law and Steno's law); Permissible symmetry axes in crystals; Lattice, space lattice, unit cell, crystal planes, Bravais lattice. Packing of uniform hard sphere, close packed arrangements (fcc and hcp); Tetrahedral and octahedral voids. Void space in cubic systems

Crystal plane

Distance between consecutive planes [cubic and orthorhombic lattices]; Indexing of planes, Miller indices; calculation of d_{hkl} ; Relation between molar mass and unit cell dimension for cubic system; Bragg's law (derivation). Determination of crystal structure: Powder method; Structure of NaCl and KCl crystals.

Chemical Equilibrium

(08 L)

Thermodynamic conditions for equilibrium, degree of advancement; *van't Hoff's* reaction isotherm (deduction from chemical potential); Variation of free energy with degree of advancement; Equilibrium constant and standard Gibbs free energy change; *van't Hoff's* reaction isobar and isochore from different standard states; Le Chatelier's principle and its derivation, variation of equilibrium constant under different conditions Nernst's distribution law; Application-(finding out K_{eq} using Nernst distribution law for $KI + I_2 = KI_3$ and dimerization of benzoic acid). Solvent Extraction.

Conductance

(09 L)

Ion conductance; Conductance and measurement of conductance, cell constant, specific conductance and molar conductance; Variation of specific and equivalent conductance with dilution for strong and weak electrolytes; Kohlrausch's law of independent migration of ions; Equivalent and molar conductance at infinite dilution and their determination for strong and weak electrolytes; Debye-Huckel theory of Ion atmosphere (qualitative)-asymmetric effect, relaxation effect and electrophoretic effect; Debye-Huckel limiting law-brief qualitative description. Estimation of activity coefficient for electrolytes using Debye-Huckel limiting law. Ostwald's dilution law; Ionic mobility; Application of conductance measurement (determination of solubility product and ionic product of water); Conductometric titrations. Transport number, Principles of Hittorf's and Moving-boundary method. Wien effect, Debye-Falkenhagen effect, Walden's rule

Reference Books:

1. Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press. 2. Castellan, G. W. Physical Chemistry, Narosa. 3. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press. 5. Levine, I. N. Physical Chemistry, Tata McGraw-Hill. 6. Rakshit, P.C., Physical Chemistry Sarat Book House. 7. Kapoor, K. L., A Text Book of Physical Chemistry, 6th Edn, McGraw-Hill.

Paper: CEMDC-MJ-403P/ CEMMJ-MC-7P (Physical-III)

Practical: 30 Hours

Physical-III (Prac)

- (a) Study of the variation of surface tension of a solution with concentration of the solute
- (b) Study of the variation of viscosity of a solution with concentration of the solute.
- (c) Determination of partition coefficient for the distribution of I₂ between water and Benzene.
- (d) Determination of K_{eq} using the partition coefficient between water and Benzene

SEMESTER-V

Paper: CEMDC-MJ-501T/ CEMMJ-MC-8T (Physical-IV)

Theory: 45 L (45 Hours)

Objectives

1. Understand the principles and thermodynamic derivations of colligative properties and their applications in determining molar masses of solutes.
2. Learn and interpret the phase rule and phase diagrams, including binary and ternary systems, and understand the behavior of real and ideal solutions.
3. Explore the fundamentals of electromotive force, electrode potentials, and their use in calculating thermodynamic properties and performing potentiometric titrations.
4. Develop a foundational understanding of quantum mechanics, including the origin, formulation, and application of Schrödinger's equation to physical systems.
5. Apply quantum mechanical principles to simple model systems such as the particle in a box and the hydrogen atom.
6. Perform practical experiments related to phase equilibria and electrochemical methods, reinforcing theoretical understanding through experimental analysis.

Learning Outcomes

After completion of this course, the student will be able to:

1. Derive and apply thermodynamic expressions for colligative properties, including boiling point elevation, freezing point depression, and osmotic pressure.
2. Analyze phase diagrams and use phase rule concepts to interpret single, binary, and ternary phase systems, including the application of Clapeyron and Clausius-Clapeyron equations.
3. Understand and apply concepts of ideal and non-ideal binary solutions, including Raoult's law, Henry's law, azeotropes, and eutectic mixtures.
4. Use EMF measurements to calculate thermodynamic quantities, equilibrium constants, and pH, and understand the functioning of different types of electrochemical cells.
5. Demonstrate a clear understanding of quantum mechanical concepts such as wave functions, operators, eigenvalues, and the postulates of quantum mechanics.
6. Solve the Schrödinger equation for a particle in a box and interpret the physical significance of quantum states, degeneracy, and uncertainty principles.
7. Conduct experiments involving potentiometric titrations and phase diagrams to apply theoretical principles in practical contexts.

Application of Thermodynamics – II

(17 Lectures)

Colligative properties

Vapour pressure of solution; Ideal solution, ideally dilute solution and colligative properties; Raoult's law. Thermodynamic derivations (using chemical potential) relating (i) Elevation of boiling point of an ideally dilute solution containing a non-volatile nonelectrolyte solute, (ii) Depression of freezing point of an ideally dilute solution containing a non-volatile non-electrolyte solute (iii) Osmotic pressure of an ideally dilute solution containing a non-volatile nonelectrolyte solute with the molality/molar concentration of solute in solution. Applications in calculating molar masses of normal, dissociated and associated solutes in solution; Abnormal colligative properties.

Phase rule:

Definitions of phase, component and degrees of freedom; Phase rule and its derivations; Definition of phase diagram; Phase diagram for water, CO₂, Sulphur. First order phase transition and Clapeyron equation; Clausius-Clapeyron equation derivation and use; Liquid vapour equilibrium for two component systems; Phenol- water system. Three component systems, water-chloroform-acetic acid system, triangular plots.

Binary solutions

Ideal solution at fixed temperature and pressure; Principle of fractional distillation; Duhem-Margules equation; Henry's law; Konowaloff's rule; Positive and negative deviations from ideal behavior; Azeotropic solution; Liquid- liquid phase diagram using phenol-water system; Solid-liquid phase diagram; Eutectic mixture.

Electromotive Force

(08 L)

Rules of oxidation/reduction of ions based on half-cell potentials, Chemical cells, reversible and irreversible cells with examples; Electromotive force of a cell and its measurement, Thermodynamic derivation of 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 and glass electrodes. Concentration cells with and without transference, liquid junction potential; Potentiometric Titration.

Quantum Chemistry

(20 L)

Beginning of Quantum Mechanics: Black-body radiation and Planck's theory of radiation; Light as particles: photoelectric and Compton effects; electrons as waves; Wave-particle duality: de Broglie hypothesis, Uncertainty relations (without proof).

Wavefunction: Schrödinger time-independent equation; nature of the equation, acceptability conditions imposed on the wave functions and probability interpretations of wave function (Postulate-I); Orthogonal and normal functions.

Concept of Operators: Elementary concepts of operators, eigenfunctions and eigenvalues; Linear operators; Commutation of operators, commutator and uncertainty relation; Expectation value; Hermitian operator; Postulates of Quantum Mechanics.

Particle in a box: Setting up of S.E. for one-dimensional well and its solution; Comparison with free particle eigenfunctions and eigenvalues. Properties of PB wave functions (normalization, orthogonality, probability distribution); Expectation values of x , x^2 , p_x and p_x^2 and their significance in relation to the uncertainty principle; Extension of the problem to two and three dimensions and the concept of degenerate energy levels.

Reference Books:

1. Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press. 2. Castellan, G. W. Physical Chemistry, Narosa. 3. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press. 5. Levine, I. N. Physical Chemistry, Tata McGraw-Hill. 6. Rakshit, P.C., Physical Chemistry Sarat Book House. 7. Kapoor, K. L., A Text Book of Physical Chemistry, 6th Edn, McGraw-Hill.

Paper: CEMDC-MJ-501P/ CEMMJ-MC-8P (Physical-IV)**Practical: 30 Hours****Physical-IV (Prac)**

- (a) Study of phenol-water phase diagram.
- (b) Potentiometric titration of Mohr's salt solution against standard $K_2Cr_2O_7$ solution
- (c) Determination of K_{sp} for AgCl by potentiometric titration of $AgNO_3$ solution against standard KCl solution

Paper: CEMDC-MJ-502T/ CEMMJ-MC-9T (Physical-V)**Theory: 45 L (45 Hours)****Objectives**

1. Understand the principles of ionic equilibrium in aqueous solutions, including acid-base dissociation, salt hydrolysis, and buffer systems.
2. Explore the fundamentals of macromolecules, including polymer types, polymerization mechanisms, and methods of molecular weight determination.
3. Study adsorption phenomena through key isotherms and their applications in catalysis and surface chemistry.
4. Learn the laws and concepts of photochemistry, including quantum yields, excited states, and photochemical reaction mechanisms.
5. Gain a foundational understanding of molecular spectroscopy, including rotational and vibrational spectroscopy, and their applications in molecular structure determination.
6. Perform practical experiments involving buffer preparation, pH analysis, and verification of spectroscopic laws to connect theoretical knowledge with laboratory techniques.

Learning Outcomes

After completion of this course, the student will be able to:

1. Analyze the ionization behavior of electrolytes, calculate pH of weak acids, bases, and salt solutions, and evaluate the action and capacity of buffer solutions using the Henderson equation.
2. Classify polymers based on structure and application, understand polymerization kinetics, and determine molecular weights using number and mass average methods.
3. Apply adsorption isotherms such as Freundlich, Langmuir, and BET to interpret adsorption data and understand the role of adsorption in heterogeneous catalysis.
4. Understand the principles of photochemistry, including potential energy diagrams, excited-state dynamics, and quantum yield, and apply them to interpret photochemical processes and reactions.
5. Explain and apply Lambert-Beer's law and the basics of molecular spectroscopy, including rotational and vibrational transitions, bond length determination, and vibrational mode analysis.
6. Conduct laboratory experiments involving preparation and analysis of buffer systems, verify Lambert-Beer's law using spectrophotometric techniques, and determine pH spectroscopically.

Ionic Equilibrium

(6 L)

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. Salt hydrolysis- calculation of hydrolysis constant, degree of hydrolysis and pH for different salts (exact Treatment). Determination of hydrolysis constant conductometrically. Buffer solutions; derivation of Henderson equation and its applications; buffer capacity, buffer range, buffer action. Theory of acid–base indicators; selection of indicators and their limitations.

Kinetics-II and Adsorption

(13L)

Kinetics: Theories of reaction rates: Collision theory and activated complex theory of bi-molecular reactions. Comparison of the two theories (qualitative treatment only). Unimolecular reaction: Lindemann mechanism. Types of catalysis – homogeneous and heterogeneous. Cause of catalytic effect on reaction rate. Introductory ideas of acid-base catalysis. Mechanism of catalysed reactions at solid surface, effect of particle size. Enzyme catalysis, its characteristics, Michaelis-Menten mechanism. Double reciprocal plot. Specificity and selectivity in enzyme catalysis.

Adsorption: Physical and chemical adsorption; Freundlich and Langmuir adsorption isotherms; multilayer adsorption and BET isotherm (no derivation required); Gibbs adsorption isotherm and surface excess; Heterogeneous catalysis (single reactant); Zero order and fractional order reactions.

Photochemistry and Molecular Spectroscopy-I

(26 L)

Lambert-Beer's law: Characteristics of electromagnetic radiation, Lambert-Beer's law and its limitations, physical significance of absorption coefficients; Laws of photochemistry, Stark-Einstein law of photochemical equivalence quantum yield, actinometry, examples of low and high quantum yields.

Photochemical Processes: Potential energy curves (diatomic molecules), Frank-Condon principle and vibrational structure of electronic spectra; Bond dissociation and principle of determination of dissociation energy (ground state); Decay of excited states by radiative and non-radiative paths; Pre-dissociation; Fluorescence and phosphorescence, Jablonski diagram.

Rate of Photochemical processes: Photochemical equilibrium and the differential rate of photochemical reactions, Photo-stationary state; HI decomposition, $\text{H}_2\text{-Br}_2$ reaction, dimerization of anthracene; photosensitized reactions, quenching; Role of photochemical reactions in biochemical processes, photo stationary states, chemiluminescence.

Rotational spectroscopy: Rotation of molecules, Classification of molecules based on principal moments of inertia, Example of prolate and oblate symmetric top molecules, Rigid rotor approximation and moment of inertia of a rigid diatomic molecule, selection rule and intensity of spectral lines, effect of centrifugal distortion and the spectrum of non-rigid rotor, determination of bond lengths of diatomic molecules, effect of isotopic substitution, principle of microwave oven.

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, degrees of freedom for polyatomic molecules, modes of vibration, concept of group frequencies; Diatomic vibrating rotator, P, Q, R branches.

Reference Books:

1. Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press. 2. Castellan, G. W. Physical Chemistry, Narosa. 3. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press. 5. Levine, I. N. Physical Chemistry, Tata McGraw-Hill. 6. Rakshit, P.C., Physical Chemistry Sarat Book House. 7. Kapoor, K. L., A Text Book of Physical Chemistry, 6th Edn, McGraw-Hill.

Paper: CEMDC-MJ-502P/ CEMMJ-MC-9P (Physical-V)

Practical: 30 Hours

Physical-V (Prac)

(a) Preparation of buffer solutions and find the pH of an unknown buffer solution by colour matching method (using following buffers).

(i) Sodium acetate-acetic acid

(ii) Ammonium chloride-ammonium hydroxide

(b) Verification of Beer and Lambert's Law for KMnO_4 and $\text{K}_2\text{Cr}_2\text{O}_7$ solution.

(c) Determination of pH of unknown buffer, spectrophotometrically

(d) Conductometric determination of CMC of SDS and effect of electrolytes.

Paper: CEMDC-MJ-503T/CEMMJ-MC-10T (Organic-V)

Theory: 45 L (45 Hours)

Objectives

1. Understand the stereochemistry and conformational behavior of alicyclic compounds and how they influence reaction mechanisms and reactivity.
2. Explore the mechanisms and stereoelectronic features of nucleophilic substitution and elimination reactions, including competition and selectivity between these pathways.
3. Study a wide range of organic rearrangements involving carbon, nitrogen, and oxygen centers, including evidence-based mechanisms and stereochemical aspects.
4. Learn about nitrogen-containing compounds including amines, nitro compounds, nitriles, and diazonium salts, along with their synthesis, separation, and key reactions.
5. Develop an ability to correlate structure, mechanism, and reactivity in organic transformations and predict products based on mechanistic pathways.
6. Gain practical experience in chromatographic techniques for separation and analysis of organic mixtures, reinforcing theoretical understanding.

Learning Outcomes

After completion of this course, the student will be able to:

1. Perform conformational analysis of cyclohexane and its derivatives and predict stereochemical outcomes in alicyclic systems based on steric and stereoelectronic effects.
2. Describe the mechanistic details and stereochemical aspects of $\text{S}_{\text{N}}1$, $\text{S}_{\text{N}}2$, $\text{S}_{\text{N}}2'$, $\text{S}_{\text{N}}1'$, $\text{S}_{\text{N}}\text{i}$, $\text{E}1$, $\text{E}2$, and $\text{E}1\text{cB}$ reactions and compare the factors influencing substitution and elimination processes.
3. Analyze organic rearrangement reactions involving electron-deficient carbon, nitrogen, and oxygen species, including key name reactions and their mechanisms.
4. Synthesize, identify, and differentiate between various nitrogenous compounds and understand their key reactions such as methylation, reductions, condensations, and coupling reactions.
5. Interpret and apply mechanistic reasoning to predict the behavior of organic molecules in complex transformation pathways.
6. Perform chromatographic techniques such as thin-layer chromatography (TLC) and paper chromatography for effective separation and identification of organic compounds, including amino acids and dyes.

Substitution and Elimination Reactions

(08 L)

Nucleophilic substitution reactions

Substitution at sp^3 centre [systems: alkyl halides, allyl halides, benzyl halides, alcohols, ethers, epoxides, α -halocarbonyls]: mechanisms (with experimental evidence), relative rates & stereochemical features: $\text{S}_{\text{N}}1$, $\text{S}_{\text{N}}2$, $\text{S}_{\text{N}}2'$, $\text{S}_{\text{N}}1'$ (allylic rearrangement), and $\text{S}_{\text{N}}\text{i}$; effects of solvent, substrate structure, leaving group, and

nucleophiles (including ambident nucleophiles such as cyanide & nitrite); substitutions involving neighboring group participation (NGP) with heteroatoms, π -systems, and phenyl groups; stereoelectronic effects; influence of steric hindrance and hyperconjugation; rearrangement during substitution; intramolecular substitution reactions.

Elimination reactions

E1, E2, E1cB and E_i (pyrolytic *syn* eliminations); formation of alkenes and alkynes; mechanisms (with evidence), reactivity, regioselectivity (Saytzeff / Hofmann) and stereoselectivity; comparison between substitution and elimination reactions, comparison between nucleophilicity and basicity.

Nitrogen compounds

(06 L)

Amines: Preparation, separation (Hinsberg's method), and identification of primary, secondary, and tertiary amines; Eschweiler–Clarke methylation, diazo coupling, reactions of phenylenediamines, diazomethane, and diazoacetic ester. **Nitro compounds:** preparation and reaction (with mechanism): reduction under different conditions; Nef carbonyl synthesis, Henry reaction and conjugate addition of nitroalkane anion, reaction with nitrous acid. **Alkyl nitriles and isonitriles:** preparation, Thorpe nitrile condensation, von Richter reaction. **Diazonium salts:** replacement of diazo group, Gomberg, Meerwein, and Japp–Klingermann reactions.

Rearrangements

(06 L)

Mechanism, evidences (including crossover experiments), and stereochemical aspects. **Rearrangement to electron-deficient carbon:** Wagner–Meerwein, pinacol, dienone–phenol, Wolff rearrangement in Arndt–Eistert synthesis, benzil–benzilic acid, Demjanov, and Tiffeneau–Demjanov rearrangements. **Rearrangement to electron-deficient nitrogen:** Hofmann, Curtius, Lossen, Schmidt, and Beckmann rearrangements. **Rearrangement to electron-deficient oxygen:** Baeyer–Villiger oxidation, cumene hydroperoxide–phenol rearrangement, and Dakin reaction. **Aromatic rearrangements**—migration from oxygen to ring carbon: Fries and Claisen rearrangements; migration from nitrogen to ring carbon: N-azo to C-azo, Bamberger, Orton, and benzidine rearrangements. Favorskii rearrangement, Piancatelli rearrangement.

Stereochemistry and Reactions of Alicyclic Compound

(10 L)

Relative stability of monocyclic alkanes (small, medium and large rings); Concept of I-strain, Cyclopropane, Cyclobutane, Cyclopentane.

Conformational analysis of cyclohexane and its mono-/disubstituted derivatives, with emphasis on symmetry, optical activity, ring size and ease of cyclisation; reactivity in cyclohexane system: consideration of steric and stereoelectronic requirements; elimination (E2, E1), nucleophilic substitution (S_N1, S_N2, S_Ni, NGP), merged substitution-elimination; rearrangements; oxidation of cyclohexanol, esterification, saponification, lactonization, epoxidation, pyrolytic *syn* elimination and fragmentation reactions.

Retrosynthetic analysis

(15 L)

Disconnections; synthons, donor and acceptor synthons; natural reactivity and *umpolung*; latent polarity in bifunctional compounds: illogical electrophiles and nucleophiles; synthetic equivalents; functional group interconversion and addition (FGI and FGA); C-C disconnections and synthesis: one-group and two-group (1,2- to 1,5-dioxygenated compounds), reconnection (1,6-dicarbonyl); protection-deprotection strategy (alcohol, amine, carbonyl, acid).

Strategy of ring synthesis: Thermodynamic and kinetic factors; synthesis of large rings, application of high dilution technique, Favorskii Rearrangement in relation to ring contraction.

Reference Books:

Finar, I. L. Organic Chemistry (Volume 1), Vol 1, 6th Edition (Pearson Education India), 2002, Morrison, R. N. & Boyd, R. N. and Bhattacharjee, Organic Chemistry, 7th Edition, Pearson Education, 2010, Eliel, E. L. & Wilen, S. H. Stereochemistry of Organic Compounds, Wiley: London, 1994, Sykes, P. A guidebook to Mechanism in Organic Chemistry, Pearson Education, 2003, Nasipuri, D. Stereochemistry of Organic Compounds, 4th Edition, New Age International Pvt Ltd, 2020, Clayden, J., Greeves, N. & Warren, S. Organic Chemistry, Second edition, Oxford University Press, 2012. Norman, R.O. C., Coxon, J. M. Principles of Organic Synthesis, Third Edition, March, J. Advanced Organic Chemistry, Fourth edition, Wiley, Organic Synthesis the Disconnection Approach, John Wiley and Sons. Warren, S., Designing Organic Synthesis, Wiley India, 2009,

Paper: CEMDC-MJ-503P/ CEMMJ-MC-10P (Organic-V)

Practical: 30 Hours

Organic-V (Prac)

Spectroscopic Analysis of Organic Compounds:

1. **Assignment** of labelled peaks in the ^1H NMR spectra of the known organic compounds explaining the relative δ -values and splitting pattern.
2. **Assignment** of labelled peaks in the IR spectrum of the same compound explaining the relative frequencies of the absorptions (C-H, O-H, N-H, C-O, C-N, C-X, C=C, C=O, N=O, C \equiv C, C \equiv N stretching frequencies; characteristic bending vibrations are included).

Chromatographic Separations

1. TLC separation of a mixture containing 2/3 amino acids
2. TLC separation of a mixture of dyes (fluorescein and methylene blue)
3. Paper chromatographic separation of a mixture containing 2/3 amino acid

Paper: CEMDC-MJ-504T/CEMMJ-MC-11T (Inorganic-V)

Theory: 45 L (45 Hours)

Objectives

1. Understand the stereochemistry and conformational analysis of alicyclic compounds, including their influence on reactivity in organic reactions.
2. Study the detailed mechanisms, stereochemical features, and influencing factors of nucleophilic substitution and elimination reactions.
3. Explore various molecular rearrangement reactions involving electron-deficient centers and their mechanistic pathways.
4. Learn the preparation, separation, and reactivity of nitrogen-containing compounds, including amines, nitro compounds, nitriles, and diazonium salts.
5. Develop skills to interpret mechanisms and predict the outcomes of complex organic transformations involving stereoelectronic effects and intermediate stability.
6. Conduct chromatographic experiments to separate and identify components in mixtures, reinforcing the practical application of organic separation techniques.

Learning Outcomes

After completion of this course, the student will be able to:

1. Analyze the conformations and stereoelectronic effects in alicyclic systems and predict their influence on substitution, elimination, and rearrangement reactions.
2. Understand and compare mechanisms such as SN_1 , SN_2 , SN_2' , SN_i , and NGP pathways in nucleophilic substitution reactions, and evaluate factors affecting reactivity and stereochemistry.
3. Explain the different types of elimination reactions, including E1, E2, and E1cB, and apply knowledge of regioselectivity and stereoselectivity in product prediction.
4. Describe and mechanistically analyze major organic rearrangements involving carbon, nitrogen, and oxygen centers, including key aromatic rearrangements.
5. Classify and characterize amines and other nitrogenous compounds, and understand their synthetic transformations and mechanistic behavior under various conditions.
6. Perform chromatographic techniques such as TLC and paper chromatography to effectively separate and analyze components in organic mixtures.

s- and p- Block Elements

(30 L)

Chemistry of s and p Block Elements (Group 1, 2, 13, 14 and 15)

Relative stability of different oxidation states, diagonal relationship and anomalous behavior of first member of each group. Allotropy and catenation. Study of the following compounds with emphasis on structure, bonding, preparation, properties and uses: Beryllium hydrides and halides. Boric acid and borates, boron nitrides, borohydrides (diborane) and graphitic compounds, silanes, Oxides and oxoacids of nitrogen, phosphorus. Synthesis, structural aspects and applications of silicones and siloxanes. Borazines, silicates, aluminosilicates, zeolites and phosphazenes.

Chemistry of p-Block Elements (Group 16, 17 and 18)

Relative stability of different oxidation states, diagonal relationship and anomalous behavior of first member of each group. Allotropy and catenation. Study of the following compounds with emphasis on structure, bonding, preparation, properties and uses: Oxides and oxoacids of Sulphur and chlorine. Peroxoacids of sulphur, sulphur-nitrogen compounds, inter-halogen compounds, polyhalide ions, pseudohalogens, fluorocarbons and basic properties of halogens.

Noble Gases:

Occurrence and uses, rationalization of inertness of noble gases, peculiar behavior of liquid helium, Clathrates; preparation and properties of XeF_2 , XeF_4 and XeF_6 ; Nature of bonding in noble gas compounds (Valence bond treatment and MO treatment for XeF_2 and XeF_4). Xenon-oxygen compounds. Molecular shapes of noble gas compounds (VSEPR theory).

d- and f- Block Elements

(9 L)

General comparison of 3d, 4d and 5d elements in terms of oxidation states, metal-metal bond, Structure and Bonding of Dinuclear Complexes: e.g. $(Re_2Cl_8)^{2-}$, Preliminary concept of Crutz Taube Complex (Mixed valence complexes), redox properties of Gr. 6-11, Comparative study of Cu, Ag and Au and Zn, Cd and Hg. General comparison of lanthanoids and actinoids in terms of electronic configuration, oxidation states, spectral and magnetic properties. Lanthanoid and actinoid contraction. Separation of lanthanides (ion-exchange method only). Uses of lanthanoids and actinoids in spectral, magnetic and theranostic applications.

Qualitative and quantitative aspects of analysis

(6 L)

Sampling, evaluation of analytical data, errors, accuracy and precision, methods of their expression, normal law of distribution of in determinate errors, statistical test of data; F, Q and t test, rejection of data, and confidence intervals. Reference

Books:

Concise Inorganic Chemistry, J. D. Lee, 5thEd., Wiley India Pvt. Ltd., 2008. Shriver & Atkins' Inorganic Chemistry, Atkins, Overton, Rourke, Weller, Armstrong; 6thEd., Oxford University Press, 2010. N. N. Greenwood, & A. Earnshaw, Chemistry of the Elements, Butterworth-Heinemann, 1997. F.A. Cotton, G.W. Wilkinson, C.A. Murillo, M. Bochmann, Advanced Inorganic Chemistry, Wiley, 6e, Douglas A. Skoog, D.M. West, F. James Holler, Stanley R. Crouch, Fundamentals of Analytical Chemistry, Cengage learning India Pvt Ltd. 10thEdition, 2022, Daniel C. Harris, Quantitative Chemical Analysis, 10thEdition, W.H. Freeman, 2020

Paper: CEMDC-MJ-504P/ CEMMJ-MC-11P (Inorganic-V)

Practical: 30 Hours

Inorganic-V (Prac)

1. Analysis of CaCO_3 and MgCO_3 in Dolomite
2. Analysis of Cr and Mn in steel
3. Analysis of Fe_2O_3 in Portland cement
4. Estimation (Gravimetry) of Ni(II) using dimethylglyoxime (DMG)
5. Estimation (Gravimetry) of Chloride
6. Estimation (Gravimetry) of Sulphate

SEMESTER-VI

Paper: CEMDC-MJ-601/ CEMMJ-MC-12T (Organic-VI)

Theory: 45 L (45 Hours)

Objectives

1. Understand the concepts and strategies of retrosynthetic analysis, including synthons, synthetic equivalents, and functional group transformations.
2. Learn protection–deprotection techniques and apply C–C disconnection approaches for the synthesis of complex organic molecules.
3. Explore synthetic and mechanistic aspects of ring formation, large-ring synthesis, and ring contraction reactions.
4. Study the synthesis, reactivity, and mechanistic pathways of polynuclear aromatic hydrocarbons and heterocyclic compounds.
5. Examine the preparation, reactivity, and applications of organometallic reagents in selective organic synthesis.
6. Develop skills in interpreting spectroscopic data (^1H NMR and IR) for the identification and characterization of organic compounds.

Learning Outcomes

After completion of this course, the student will be able to:

1. Apply retrosynthetic analysis to design synthetic routes using logical disconnections and functional group interconversions.
2. Use protection–deprotection strategies effectively in multi-step organic synthesis.
3. Analyze factors influencing ring formation and contraction, and design synthetic pathways accordingly.
4. Predict the reactivity, orientation, and mechanisms of reactions in polynuclear aromatic hydrocarbons and heterocycles.

5. Select appropriate organometallic reagents and apply them to achieve specific transformations with desired selectivity.
6. Interpret ¹H NMR and IR spectra to assign structural features and functional groups in organic compounds.

Polynuclear hydrocarbons and their derivatives (04 L)

Synthetic methods include Haworth, Bardhan-Sengupta, Bogert-Cook (with mechanistic details); fixation of double bonds and Fries rule; reactions (with mechanism) of naphthalene, anthracene and phenanthrene and their derivatives.

Heterocyclic compounds (10 L)

Heterocycles: 5- and 6-membered rings with one heteroatom; reactivity, orientation and important reactions (with mechanism) of furan, pyrrole, thiophene and pyridine; synthesis (including retrosynthetic approach and mechanistic details): pyrrole: Knorr synthesis, Paal-Knorr synthesis, Hantzsch synthesis; furan: Paal-Knorr synthesis, Feist-Benary synthesis and its variation; thiophenes: Paal-Knorr synthesis, Hinsberg synthesis; pyridine: Hantzsch synthesis; benzo-fused 5- and 6-membered rings with one heteroatom: reactivity, orientation and important reactions (with mechanistic details) of indole, quinoline and isoquinoline; synthesis (including retrosynthetic approach and mechanistic details): indole: Fischer, Madelung and Reissert; quinoline: Skraup, Doebner Miller, Friedlander; isoquinoline: Bischler-Napieralski synthesis

Organic Spectroscopy-II (12 L)

NMR Spectroscopy: Introduction to nuclear spin, NMR active molecules; basic principles of Proton Magnetic Resonance; equivalent and non-equivalent protons; chemical shift and factors influencing it; ring current effect; significance of the terms: up-/downfield, shielded and deshielded protons; spin coupling and coupling constant; relative intensities of first-order multiplets: Pascal's triangle; chemical and magnetic equivalence in NMR ; anisotropic effects in alkene, alkyne, aldehydes and aromatics; NMR peak area, integration; relative peak positions with coupling patterns of common organic compounds; rapid proton exchange; interpretation of NMR spectra of simple compounds.

IR Spectroscopy: Introduction; modes of molecular vibrations (fundamental and nonfundamental); IR active molecules; application of Hooke's law, force constant; fingerprint region and its significance; effect of deuteration; overtone bands; vibrational coupling in IR; characteristic and diagnostic stretching frequencies of C-H, N-H, O-H, CO, C-N, C-X, C=C (including skeletal vibrations of aromatic compounds), C=O, C=N, N=O, C≡C, C≡N; factors affecting stretching frequencies: effect of conjugation, electronic effects, mass effect, bond multiplicity, ring-size, solvent effect, H-bonding on IR absorptions; application in functional group analysis.

Problems to elucidate structures of simple organic molecules using combined spectral data (UV, IR and NMR)

Bio-Molecules (19 L)

Carbohydrates

Monosaccharides: Aldoses up to 6 carbons; structure of D-glucose & D-fructose (configuration & conformation); ring structure of monosaccharides (furanose and pyranose forms): Haworth representations and non-planar conformations; anomeric effect (including stereo-electronic explanation); mutarotation; epimerization; reactions (mechanisms in relevant cases): Fischer glycosidation, osazone formation, bromine water oxidation, HNO₃ oxidation, selective oxidation of terminal -CH₂OH of aldoses, reduction

to alditols, Lobry de Bruyn-van Ekenstein rearrangement; stepping-up (Kiliani-Fischer method) and stepping-down (Ruff's & Wohl's methods) of aldoses; end-group interchange of aldoses; acetonide (isopropylidene) and benzylidene protections; ring-size determination; Fischer's proof of configuration of (+)-glucose.

Disaccharides: Glycosidic linkages, concept of glycosidic bond formation by glycosyl donor-acceptor; structure of sucrose, inversion of cane sugar.

Amino acids, Peptides and Proteins

Amino acids: Synthesis with mechanistic details: Strecker, Gabriel, acetamido malonic ester, azlactone, Bücherer hydantoin synthesis, synthesis involving diketopiperazine; isoelectric point, isoionic point, zwitterions; electrophoresis, reaction (with mechanism): ninhydrin reaction, Dakin-West reaction; resolution of racemic amino acids.

Peptides and Proteins: Peptide linkage and its geometry; syntheses (with mechanistic details) of peptides using N-protection & C-protection, solid-phase (Merrifield) synthesis; peptide sequence: C-terminal (Carboxypeptidase, akabori and reduction methods) and N-terminal (Edman, Sanger & dansyl methods) unit determination; partial hydrolysis; specific cleavage of peptides: use of CNBr, trypsin and chymotrypsin, Structure of Proteins: Overview of Primary, Secondary, Tertiary and Quaternary structure. Example(s) and function(s) of Fibrous protein and Globular proteins, Denaturation.

Reference Books:

Finar, I. L. Organic Chemistry (Volume 1 & 2), 6th Edition (Pearson Education India), 2002, Morrison, R. N. & Boyd, R. N. and Bhattacharjee, Organic Chemistry, 7th Edition, Pearson Education, 2010, Eliel, E. L. & Wilen, S. H. Stereochemistry of Organic Compounds, Wiley: London, 1994, Sykes, P. A guidebook to Mechanism in Organic Chemistry, Pearson Education, 2003, Nasipuri, D. Stereochemistry of Organic Compounds, 4th Edition, New Age International Pvt Ltd, 2020, Clayden, J., Greeves, N. & Warren, S. Organic Chemistry, Second edition, Oxford University Press, 2012. Norman, R.O. C., Coxon, J. M. Principles of Organic Synthesis, Third Edition, March, J. Advanced Organic Chemistry, Fourth edition, Wiley,

Paper: CEMDC-MJ-601P/ CEMMJ-MC-12P (Organic-VI)

Practical: 30 Hours

Organic-VI (Prac)

Preparation of organic compounds following green methodology

- Benzoylation of aromatic amines sans alkali.
- Preparation of benzoic acid from benzil
- Preparation of azomethines using mechano-chemical protocol.
- Preparation of Benzanilide
- Preparation of Aspirin from Salicylic Acid

Paper: CEMDC-MJ-602/ CEMMJ-MC-13T (Inorganic-VI)

Theory: 45 L (45 Hours)

Objectives

- Understand the basic principles of coordination chemistry, including theories, nomenclature, and types of isomerism in metal complexes.
- Learn the valence bond theory (VBT) and crystal field theory (CFT) for various coordination geometries, and relate them to stability and properties of complexes.

3. Explore the concepts of crystal field stabilization energy (CFSE), pairing energy, Jahn–Teller distortion, and metal–ligand bonding using molecular orbital ideas.
4. Study the electronic spectra and magnetic properties of coordination complexes, including d–d transitions, Orgel diagrams, and magnetic moment calculations.
5. Examine the classification, preparation, structure, and bonding of organometallic compounds, including carbonyls, nitrosyls, and sandwich complexes.
6. Develop practical skills in synthesizing and characterizing coordination and organometallic complexes through laboratory experiments.

Learning Outcomes

After completion of this course, the student will be able to:

1. Identify and classify coordination compounds, apply IUPAC nomenclature, and determine possible isomers.
2. Apply VBT and CFT to explain the geometry, stability, and electronic configuration of metal complexes in various ligand fields.
3. Calculate CFSE, predict effects of Jahn–Teller distortion, and explain sigma and pi bonding interactions in coordination complexes.
4. Interpret electronic spectra of transition metal complexes, correlate magnetic properties with electronic configuration, and explain deviations due to orbital contributions.
5. Describe the synthesis, bonding, and reactivity of organometallic complexes, and relate their stability to the 18-electron rule.
6. Perform laboratory synthesis of selected coordination and organometallic complexes, and analyze their properties using suitable characterization techniques.

Coordination Chemistry

(30 L)

Basics of coordination chemistry

Werner's theory, ligands, IUPAC nomenclature, Isomerism (constitutional and stereo isomerism, Geometrical and optical isomerism in square planar and octahedral complexes)

Valence bond theory and crystal field theory

VB description and its limitations. Elementary Crystal Field Theory: splitting of dn configurations in octahedral, square planar, tetrahedral, trigonal bipyramidal (basic idea), square pyramidal (basic idea) and pentagonal bipyramidal (basic idea) fields; crystal field stabilization energy (CFSE) in weak and strong fields; pairing energy. Spectrochemical series. Jahn- Teller distortion. Octahedral site stabilization energy (OSSE). Metal-ligand bonding (MO concept, elementary idea), sigma- and pi-bonding in octahedral complexes (qualitative pictorial approach) and their effects on the oxidation states of transitional metals (examples).

Electronic spectra of complexes and magnetic properties

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 spectra (elementary idea). 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 antiferromagnetic interactions (elementary idea with examples only)

Complexometric Titrimetry

Theory, titration methods employing EDTA (direct, back, displacement and indirect determinations). Indicators for EDTA titrations - theory of metal ion indicators. Determination of hardness of water.

Numerical problems are to be solved wherever applicable.

Organometallic Chemistry

(15 L)

Definition and classification of organometallic compounds based on bond type. Concept of hapticity. 18-electron and 16-electron rules and its stability (pictorial MO approach). Applications of 18-electron rule to transition metal organometallic complexes. General methods of preparation of mono and binuclear carbonyls of 3d series. Structures of mono-, bi-, tri- and tetranuclear carbonyls. Different binding modes of CO and NO with examples. Comparison of σ -donor and π -acceptor behavior of CO, NO and CN-. Synergistic effect and its interpretation through IR spectra. Bonding of iron nitrosyl (brown ring) complex as a special case.

Reference Books

Lippard, S.J. & Berg, J.M. Principles of Bioinorganic Chemistry Panima Publishing Company 1994. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson, 2006. Greenwood, N.N. & Earnshaw A. Chemistry of the Elements, Butterworth- Heinemann, 1997. Cotton, F.A., Wilkinson, G., Murrillo, C. A., Bochmann, M., Advanced Inorganic Chemistry 6th Ed. 1999., Wiley. Bertini, I., Gray, H. B., Lippard, S.J., Valentine, J. S., Viva, 2007. Basolo, F, and Pearson, R.C. Mechanisms of Inorganic Chemistry, John Wiley & Sons, NY, 1967. Purecell, K.F. and Kotz, J.C., An Introduction to Inorganic Chemistry, Saunders: Philadelphia, 1980. Powell, P. Principles of Organometallic Chemistry, Chapman and Hall, 1988. Collman, J. P. et al. Principles and Applications of Organotransition Metal Chemistry. Mill Valley, CA: University Science Books, 1987. Crabtree, R. H. The Organometallic Chemistry of the Transition Metals. New York, NY: John Wiley, 2000.

Paper: CEMDC-MJ-602P/ CEMMJ-MC-13P (Inorganic-V)

Practical: 30 Hours

Inorganic-VI (Prac)

(A) Complexometric titration

1. Zn(II)
2. Ca(II) and Mg(II) in a mixture.
3. Total Hardness of water.

(B) Inorganic preparations

1. *Cis* and *trans* $K[Cr(C_2O_4)_2(H_2O)_2]$
2. Tetraamminecarbonatocobalt(III) ion
3. Potassiumtris(oxalato)ferrate(III)
4. Tris-(ethylenediamine) nickel(II) chloride.
5. $[Mn(acac)_3]$ and $[Fe(acac)_3]$ (acac= acetylacetonate)

Paper: CEMDC-MJ-603/ CEMMJ-MC-14T (Inorganic-VII)

Theory: 45 L (45 Hours)

Objectives

1. Understand the principles, classification, and mechanisms of solvent extraction and chromatographic separation techniques.
2. Learn qualitative and quantitative applications of separation methods, including modern instrumental techniques such as GC and HPLC.
3. Explore the role of essential and beneficial metal ions in biological systems and their involvement in biochemical processes.
4. Study the structure, function, and mechanism of metalloproteins involved in oxygen transport, storage, and electron transfer.
5. Examine the thermodynamic and kinetic stability of coordination complexes and their substitution and electron transfer reaction mechanisms.

6. Develop laboratory skills for qualitative semi-micro analysis of mixtures and understanding the underlying reaction chemistry.

Learning Outcomes

After completion of this course, the student will be able to:

1. Classify and explain the working principles of solvent extraction and chromatography, and compare their efficiencies.
2. Apply separation techniques, including GC and HPLC, for qualitative and quantitative analysis of chemical and biological samples.
3. Describe the biological roles of major, trace, and ultra-trace elements and explain their transport and function in living systems.
4. Analyze the structures and functions of metalloproteins involved in dioxygen management and electron transfer processes.
5. Interpret the kinetic and thermodynamic aspects of complex stability and predict reactivity using mechanistic pathways such as trans-effect and electron transfer.
6. Perform semi-micro qualitative analysis of mixtures, identify basic and acid radicals, and justify results based on chemical principles.

Separation techniques

(12L)

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.

Separation and analysis using GC and HPLC (dye and pesticide analysis)

Role of computers in instrumental methods of analysis

Bioinorganic Chemistry

(15 L)

Elements of life: essential and beneficial elements, major, trace and ultra trace elements. Basic chemical reactions in biological systems and the role of metal ions (specially Na^+ , K^+ , Mg^{2+} , Ca^{2+} , $\text{Fe}^{3+/2+}$, $\text{Cu}^{2+/1+}$, Zn^{2+} and $\text{Mo}^{3+/4+/6+}$) in biology. Metal Ions transport across biological membrane Na^+/K^+ -ion pump.

Hydrolytic enzymes: Carbonate bicarbonate buffering system and carbonic anhydrase and carboxyanhydrase A.

Dioxygen management proteins: Hemoglobin, Myoglobin, Hemocyanin and Hemerythrin.

Electron Transport Proteins: Ferredoxins ($2\text{Fe}\cdot 2\text{S}$, $4\text{Fe}\cdot 4\text{S}$, Reiske protein, Cytochrome C and Cytochrome C oxidase (Active Sites and Principle of Function)).

Reaction kinetics and mechanism

(13 L)

Thermodynamic and kinetic stability. Significance of LFAE, Inert and Labile complexes. Substitution reaction pathways. Mechanism of nucleophilic substitution in square planar and octahedral complexes. Trans- effect and trans influence and its application in complex synthesis. Explanation of trans-effect through MO approach. Electron transfer reactions (basic ideas of Inner sphere and Outer sphere mechanisms).

Applications of Organometallic Chemistry

(05 L)

Zeise's salt: Preparation, structure, evidences of synergic effect. Ferrocene: Preparation and reactions (acetylation, alkylation, metallation, Mannich Condensation). Reactions of organometallic complexes: substitution, oxidative addition, reductive elimination and insertion reactions with examples. Study of the following industrial processes: Alkene hydrogenation (Wilkinson's Catalyst), Wacker Process, Synthetic gasoline (Fischer Tropsch reaction), Ziegler-Natta catalysis for olefin polymerization.

Reference Books:

1. James E. Huheey/ Ellen A. Keiter/ Richard L. Keiter/ Okhil K. Medhi Inorganic Chemistry, Principles of Structure and Reactivity 5th Ed., Pearson, 2022. 2. G.L. Meissler, P.J. Fischer and D.A. Tarr, Inorganic Chemistry, 5e, Pearson 3.F.A. Cotton, G.W. Wilkinson, C.A. Murillo, M. Bochmann, Advanced Inorganic Chemistry, Wiley, 6e, 1999. R. H. Crabtree, The Organometallic Chemistry of the Transition Metals. New York, NY: John Wiley, 2000. B. Douglas, D McDaniel and J Alexander Concepts and Models in Inorganic Chemistry, 3e, Shriver & Atkins' Inorganic Chemistry, Atkins, Overton, Rourke, Weller, Armstrong; 6th Ed., Oxford University Press, 2010. J. P. Collman et al. Principles and Applications of Organotransition Metal Chemistry, Mill Valley, CA: University Science Books, 1987.

Paper: CEMDC-MJ-603P/ CEMMJ-MC-14P (Inorganic-V)

Practical: 30 Hours

Inorganic-VII (Prac)

Qualitative Analysis of Inorganic Samples: The sample should contain **four radicals** and interfering acid radicals and insoluble compounds are included. Probable composition should be mentioned.

Basic Radicals: K^+ , Na^+ , NH_4^+ , Mg^{2+} , Ca^{2+} , Ba^{2+} , Sr^{2+} , Al^{3+} , Cr^{3+} , Mn^{2+} , Fe^{2+}/Fe^{3+} , Co^{2+} , Ni^{2+} , Cu^{2+} , Zn^{2+} , Pb^{2+} , Cd^{2+} , Bi^{3+} , Sn^{2+}/Sn^{4+} , As^{3+}/As^{5+} , Sb^{3+}/Sb^{5+} .

Acid Radicals: F^- , Cl^- , Br^- , BrO_3^- , I^- , IO_3^- , SCN^- , S^{2-} , SO_4^{2-} , SO_3^{2-} , $S_2O_3^{2-}$, NO_3^- , NO_2^- , PO_4^{3-} , AsO_4^{3-} , BO_3^{3-} , CrO_4^{2-} , $Cr_2O_7^{2-}$, $Fe(CN)_6^{4-}$, $Fe(CN)_6^{3-}$

Insoluble Materials: Al_2O_3 (ignited), Fe_2O_3 (ignited), Cr_2O_3 (ignited), SnO_2 , SiO_2 , $PbSO_4$, $SrSO_4$, $BaSO_4$, CaF_2

Paper: CEMDC-MJ-604/ CEMMJ-MC-15T (Physical-VI)

Theory: 45 L (45 Hours)

Objectives

1. Understand the principles, theory, and applications of Raman, NMR, and ESR spectroscopy for molecular structure determination.
2. Learn the properties, classification, and stability mechanisms of colloids, and understand electrokinetic phenomena and micelle formation.
3. Study the fundamentals of statistical thermodynamics, including macrostates, microstates, Boltzmann distribution, and partition functions.
4. Apply statistical mechanics to relate microscopic molecular properties to macroscopic thermodynamic quantities.
5. Explore selected topics in solid-state thermodynamics, including specific heat, Einstein's and Debye's theories, and third law of thermodynamics.
6. Develop experimental skills in physical chemistry through laboratory work involving titrations, kinetics, and solubility determinations.

Learning Outcomes

After completion of this course, the student will be able to:

1. Explain the theoretical basis of Raman, NMR, and ESR spectroscopy, and interpret basic spectral data for chemical analysis.
2. Differentiate between lyophilic and lyophobic colloids, describe their stability, and explain related electrokinetic effects.
3. Calculate thermodynamic probabilities and entropy using Boltzmann statistics and apply partition functions to real systems.
4. Relate molecular-level statistical models to macroscopic thermodynamic behavior in gases, liquids, and solids.
5. Apply Einstein's and Debye's theories to predict specific heat variations and interpret the third law of thermodynamics in physical systems.
6. Perform physical chemistry experiments, analyze data from pH-metric titrations, reaction kinetics, and solubility studies, and draw scientific conclusions.

Molecular Spectroscopy- II

(15 L)

Raman spectroscopy: Qualitative treatment of Rotational Raman effect; Vibrational Raman spectra, Stokes and anti-Stokes lines. Effect of nuclear spin, their intensity difference, rule of mutual exclusion.

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, interpretation of PMR spectra of organic molecules.

Electron Spin Resonance (ESR) spectroscopy: Its principle, Hyperfine structure, ESR of simple radicals.

Colloids

(6 L)

Lyophobic and lyophilic sols, Origin of charge and stability of lyophobic colloids, coagulation and Schulz-Hardy rule, Zeta potential and Stern double layer (qualitative idea), Tyndall effect; Electrokinetic phenomena (qualitative idea only); Determination of Avogadro number by Perrin's method; Stability of colloids and zeta potential; Micelle formation.

Statistical Thermodynamics

(15L)

Configuration: Macrostates, microstates and configuration; calculation of microstates with harmonic oscillator and tossing of coins; variation of W with E ; equilibrium configuration

Boltzmann distribution: Thermodynamic probability, entropy and probability, Boltzmann distribution formula (with derivation); Applications to barometric distribution; Concept of ensembles - canonical ensemble and grand canonical ensemble.

Partition function: Molecular partition function and thermodynamic properties (U , H , S , CV , q , P); $q_{\text{translation}}$, $q_{\text{vibration}}$ and ideal gas equation. Maxwell's speed distribution, Gibbs' paradox.

Third-law of thermodynamics: Nernst heat theorem, Absolute entropy, Planck's law, Residual entropy, Adiabatic demagnetization.

Special selected topics

(9 L)

Specific heat of solid: Coefficient of thermal expansion, thermal compressibility of solids; Dulong -Petit's law; Perfect Crystal model, Einstein's theory - derivation from partition function, limitations. Debye's T^3 law - analysis at two extremes.

Dipole moment and polarizability: Polarizability of atoms and molecules, Clausius-Mosotti equation and Debye equation (both without derivation) and their application.

Reference Books:

1. Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press. 2. Castellan, G. W. Physical Chemistry, Narosa. 3. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press. 4. Levine, I. N. Physical Chemistry, Tata McGraw-Hill. 5. Rakshit, P.C., Physical Chemistry Sarat Book House. 6. Kapoor, K. L., A Text Book of Physical Chemistry, 6th Edn, McGraw-Hill.

Paper: CEMDC-MJ-604P/ CEMMJ-MC-15P (Physical-VI)**Practical: 30 Hours****Physical-VI (Prac)**

- a) pH-metric titration of acid (mono- and di-basic) against strong base.
- b) Effect of ionic strength on the rate of Persulphate–Iodide reaction.
- c) Determination of solubility of sparingly soluble salt in water, in electrolyte with common ions and in neutral electrolyte (using common indicator)
- d) Determination of pK_{in} of indicator (Bromocresol green) colorimetrically.