Syllabus of

3-Year/4-Year B.Sc. Chemistry (Major)

Revised 2024 (NEP NEW)

As Per NEP 2020

(Up-to 8th Semester)

University of Gourbanga

Malda – 732 101

West-Bengal

Semester Wise Course (Major) Distribution

Chemistry (Major)

Semester	Major Course	
SEM-I	CEMMJ DC-101 (For CEMMJ MC-01 & CEMMJ MC-02 Follow the Syllabus for NEP, OLD)	Organic-I + Physical-I
SEM-II	CEMMJ DC-201 (For CEMMJ MC-03 & CEMMJ MC-04 Follow the Syllabus for NEP, OLD)	Organic-II + Inorganic-I
SEM-III	CEMMJ DC-301 (CEMMJ MC-05) [For 2023-24 Admitted Batch]	Physical-II + Inorganic-II
	CEMMJ DC-302	Organic-III +Inorganic-III
SEM-IV	CEMMJ DC-401 (CEMMJ MC-06) [For 2023-24 Admitted Batch]	Organic-IV
	CEMMJ DC-402	Inorganic-IV
	CEMMJ DC-403 (CEMMJ MC-07) [For 2023-24 Admitted Batch]	Physical-III
SEM-V	CEMMJ DC-501 (CEMMJ MC-08) [For 2023-24 Admitted Batch]	Physical-IV
	CEMMJ DC-502 (CEMMJ MC-09) [For 2023-24 Admitted Batch]	Physical-V
	CEMMJ DC-503 (CEMMJ MC-10) [For 2023-24 Admitted Batch]	Organic-V
	CEMMJ DC-504 (CEMMJ MC-11) [For 2023-24 Admitted Batch]	Inorganic-V
SEM-VI	CEMMJ DC-601 (CEMMJ MC-12) [For 2023-24 Admitted Batch]	Organic-VI
	CEMMJ DC-602 (CEMMJ MC-13) [For 2023-24 Admitted Batch]	Inorganic-VI
	CEMMJ DC-603 (CEMMJ MC-14) [For 2023-24 Admitted Batch]	Inorganic-VII
	CEMMJ DC-604 (CEMMJ MC-15) [For 2023-24 Admitted Batch]	Physical-VI
SEM-VII	CEMMJ DC-701 (CEMMJ MC-16) [For 2023-24 Admitted Batch]	Organic-VII
	CEMMJ DC-702 (CEMMJ MC-17) [For 2023-24 Admitted Batch]	Organic-VIII
	CEMMJ DC-703 (CEMMJ MC-18) [For 2023-24 Admitted Batch]	Physical-VII
	CEMMJ DC-704 (CEMMJ MC-19) [For 2023-24 Admitted Batch]	Research Methodology for Chemists
SEM-VIII	CEMMJ DC-801 (CEMMJ MC-20) [For 2023-24 Admitted Batch]	Inorganic-VIII
	CEMMJ DC-802 (CEMMJ MC-21) [For 2023-24 Admitted Batch]	Physical-VIII
	CEMMJ DC-803 (CEMMJ MC-22) [For 2023-24 Admitted Batch]	Advanced Analytical Instrumental Techniques
	CEMMJ DC-804 (CEMMJ MC-23) [For 2023-24 Admitted Batch]	(Term paper)-field report/ literature review/book review

Chemistry (Major)
[Credit: 04. Theory:02 + Practical:01]

(FM:75// Th-30, Prac-20]
Attendance:05, CP:05, Presentation/Proj:10, Viva:05)
except CEMMJ DC-804/ CEMMJ MC-23)

Question Pattern vs Marks

(a) For the paper **which includes two types of groups** are there (e.g., **Group A**: Organic, **Group B**: Inorganic), the total number of questions in each group will be 15. That means for 30 Mark (FM) Question paper: Gr A-15 Mark + Gr B-15 Mark.

The division and distribution of questions for 15 marks (for each group, as and where applicable) will be as follows:

Very Short Answer Type Question (**01 Mark**): **2 Questions** to be attempted **out of 03 questions** = **02 Marks**
Short Answer Type Question (**02 Mark**): **3 Questions** to be attempted **out of 05 questions** = **06 Marks**
Long Answer Type Questions (**07 Mark**): **1 Question** to be attempted **out of 02 questions** = **07 Marks**
In this Case: Applicable for both Gr-A (Marks:15) & Gr-B (Marks:15), Total Marks =30

Q. 1 [(a) – (c)]: Very Short Answer Type Question (@ **01 Mark**): Attempt any **02 questions**
Q. 2 [(a) – (e)]: Short Answer Type Question (@ **02 Mark**): Attempt any **03 questions**
Q. 3 [(a) – (b)]: Long Answer Type Question (@ **10 Mark**): Attempt any **01 questions**

(b) Where there is no Group, the division and distribution of questions for 30 Mark (FM) Question paper will be as follows:

Very Short Answer Type Question (**01 Mark**): **4 Questions** to be attempted **out of 06 questions** = **04 Marks**

Short Answer Type Question (**02 Mark**): **6 Questions** to be attempted **out of 10 questions** = **12 Marks**

Long Answer Type Questions (**07 Mark**): **2 Questions** to be attempted **out of 04 questions** = **14 Marks**

In this Case: Total Marks =30

Q. 1 [(a) – (f)]: Very Short Answer Type Question (@ **01 Mark**): Attempt any **04 questions**
Q. 2 [(a) – (j)]: Short Answer Type Question (@ **02 Mark**): Attempt any **06 questions**
Q. 3 [(a) – (d)]: Long Answer Type Question (@ **10 Mark**): Attempt any **02 questions**

SEMESTER-I

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

Theory: 45 L (45 Hours)

Objectives

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 (m_{bond}, mlone-pair, mgroup, m_s, m_p, mzwitterionic), 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 p orbital system (C=C, conjugated diene, triene, allyl and pentadienyl systems), (ii) cyclic p 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 **(5 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 **(7 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. Peter Sykes, Guidebook To Mechanism In Organic Chemistry, Pearson Education
3. Smith, J. G. Organic Chemistry, Tata Mcgraw - Hill Publishing Company Limited.
4. Nasipuri , D. Stereochemistry of Organic Compounds, Wiley Eastern Limited.
5. Jerry March, Advanced Organic Chemistry, Wiley- Interscience . A John Wiley & Sons, Inc.
6. Anup Pathak & Anupa Saha, Organic Chemistry, Books & Allied (P) Ltd.
7. N. Tiwari, Advanced Organic Reaction Mechanism, Books & Allied (P) Ltd.
8. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
9. Finar , I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearson Education).
10. Fleming, I. Molecular Orbitals and Organic Chemical Reactions, Reference/Student Edition, Wiley, 2009.
11. Eames, J., Peach, J. M. Stereochemistry at A Glance, Blackwell Publishing, 2003.
12. Robinson, M. J., Stereochemistry, Oxford Chemistry Primer, Oxford University Press, 2005.

Gr-B: Physical-I

Thermodynamics-I **(8 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 Cp and Cv. 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. Kirchhoff's equation.

Chemical Kinetics- I: **(6 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: **(7 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 $\geq \varepsilon$, 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. K L Kapoor, Physical Chemistry, McGraw Hill
9. A L De, A De, Physical Chemistry, Books & Allied (P) Ltd
10. Mortimer, R. G. Physical Chemistry, Elsevier.
11. Laidler, K. J. Chemical Kinetics, Pearson.
12. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.
13. Rakshit, P.C., Physical Chemistry Sarat Book House.
14. Zemansky, M. W. & Dittman, R.H. Heat and Thermodynamics, Tata- McGraw-Hill.
15. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas.
16. Clauze& Rosenberg, Chemical Thermodynamics.

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

Practical: 30 Hours

Organic-I (Practical)

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 (Practical):

(a) Study of kinetics of acid-catalyzed hydrolysis of methyl acetate.

(b) Study of kinetics of decomposition of H_2O_2

(c) Determination of heat of solution of oxalic acid from solubility measurement

Reference Books:

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009
2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
3. Nad A. K., Mahapatra B. and Ghosal A. An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
4. Ghosh S., Das Sharma M., Majumder D and Manna S. Chemistry in Laboratory, Santra Publication Pvt Ltd
5. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic
6. Analysis, CBS Publishers and Distributors.
7. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)
8. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson
9. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
10. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency
11. University Hand Book of Undergraduate Chemistry Experiments, edited by
12. Mukherjee, G. N., University of Calcutta
13. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
14. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

SEMESTER-II

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

Theory: 45 L (45 Hours)

Objectives

1. Understand the fundamentals of bonding theories including VBT and MOT, and their applications in explaining molecular structures and properties.
2. Explore the influence of electronic displacements such as resonance and hyperconjugation on molecular stability and reactivity.
3. Gain a comprehensive understanding of stereochemistry, chirality, and the ability to depict and interrelate different forms of molecular projections.
4. Analyze reaction mechanisms involving various organic reaction intermediates and their roles in different organic transformations.
5. Study the thermodynamics and kinetics underlying chemical reactions and processes, including their temperature dependence and factors affecting reaction rates.
6. 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. Peter Sykes, Guidebook To Mechanism In Organic Chemistry, Pearson Education
3. Smith, J. G. Organic Chemistry, Tata Mcgraw - Hill Publishing Company Limited.
4. Nasipuri , D. Stereochemistry of Organic Compounds, Wiley Eastern Limited.
5. Jerry March, Advanced Organic Chemistry, Wiley- Interscience . A John Wiley & Sons, Inc.
6. Anup Pathak & Anupa Saha, Organic Chemistry, Books & Allied (P) Ltd.
7. N. Tiwari, Advanced Organic Reaction Mechanism, Books & Allied (P) Ltd.
8. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
9. Finar , I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearson Education).
10. Fleming, I. Molecular Orbitals and Organic Chemical Reactions, Reference/Student Edition, Wiley, 2009.
11. Eames, J., Peach, J. M. Stereochemistry at A Glance, Blackwell Publishing, 2003.
12. Robinson, M. J., Stereochemistry, Oxford Chemistry Primer, Oxford University Press, 2005.

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. James E. Huheey / Ellen A. Keiter/ Richard L. Keiter/ Okhil K. Medhi Inorganic Chemistry, Principles of Structure and Reactivity 5 th Ed., Pearson,2022.
2. J D Lee, Concise Inorganic Chemistry,5th Ed., Wiley India Pvt. Ltd., 2008
3. G.L. Meissler , P.J. Fischer and D.A. Tarr, Inorganic Chemistry, 5e, Pearson
4. F.A. Cotton, G.W. Wilkinson, C.A. Murillo, M. Bochmann, Advanced Inorganic Chemistry, Wiley, 6e, 1999.
5. R. H. Crabtree, The Organometallic Chemistry of the Transition Metals. NewYork , NY: John Wiley, 2000.
6. S. P. Banerjee, Comprehensive Coordination Chemistry, Books & Allied (P) Ltd
7. S. P. Banerjee, Advanced Inorganic Chemistry, Books & Allied (P) Ltd
8. R L Dutta & G S De, Inorganic Chemistry (Vol I & II), The New Book Stall. ·
9. B. Douglas, D Mcdaniell and J Alexander Concepts and Models in Inorganic Chemistry, 3e,
10. Shriver & Atkins' Inorganic Chemistry, Atkins, Overton, Rourke, Weller, Armstrong; 6th Ed.,Oxford University Press, 2010 .
11. J. P. Collman et al. Principles and Applications of OrganotransitionMetalChemistry , Mill Valley, CA: University Science Books, 1987.

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

Practical: 30 Hours

Organic-II (Practical):

(a) The following reactions are to be performed, noting the yield of the crude product:

i. Nitration of aromatic compounds
ii. Condensation reactions
iii. Hydrolysis of amides/imides/esters
iv. Acetylation of phenols/aromatic amines
v. Benzoylation of phenols/aromatic amines

Students must also calculate percentage yield, based upon isolated yield (crude) and theoretical yield.

(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 (Practical):

(a) Standardization of NaOH by standard oxalic acid solution

(b) Estimation of Fe(III) using standard K2Cr2O7 solution.

(d) Estimation of Fe(II) and Fe(III) in a given mixture using standard K2Cr2O7 solution

Reference Books:

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009
2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
3. Nad A. K., Mahapatra B. and Ghosal A. An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
4. Ghosh S., Das Sharma M., Majumder D and Manna S. Chemistry in Laboratory, Santra Publication Pvt Ltd
5. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic
6. Analysis, CBS Publishers and Distributors.
7. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)
8. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson
9. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
10. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency

11. University Hand Book of Undergraduate Chemistry Experiments, edited by
12. Mukherjee, G. N., University of Calcutta
13. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
14. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

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 §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.
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. K L Kapoor, Physical Chemistry, McGraw Hill
9. A L De, A De, Physical Chemistry, Books & Allied (P) Ltd
10. Mortimer, R. G. Physical Chemistry, Elsevier.
11. Laidler, K. J. Chemical Kinetics, Pearson.
12. Glasstone , S. & Lewis, G.N. Elements of Physical Chemistry.
13. Rakshit, P.C., Physical Chemistry Sarat Book House.
14. Zemansky, M. W. & Dittman, R.H. Heat and Thermodynamics, Tata- McGraw-Hill.
15. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas.
16. Clauze & Rosenberg, Chemical Thermodynamics.

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-Lande 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. James E. Huheey / Ellen A. Keiter/ Richard L. Keiter/ Okhil K. Medhi Inorganic Chemistry, Principles of Structure and Reactivity 5 th Ed., Pearson,2022.
2. J D Lee, Concise Inorganic Chemistry,5th Ed., Wiley India Pvt. Ltd., 2008
3. G.L. Meissler , P.J. Fischer and D.A. Tarr, Inorganic Chemistry, 5e, Pearson
4. F.A. Cotton, G.W. Wilkinson, C.A. Murillo, M. Bochmann, Advanced Inorganic Chemistry, Wiley, 6e, 1999.
5. R. H. Crabtree, The Organometallic Chemistry of the Transition Metals. NewYork , NY: John Wiley, 2000.
6. S. P. Banerjee, Comprehensive Coordination Chemistry, Books & Allied (P) Ltd
7. S. P. Banerjee, Advanced Inorganic Chemistry, Books & Allied (P) Ltd
8. R L Dutta & G S De, Inorganic Chemistry (Vol I & II), The New Book Stall. ·
9. B. Douglas, D Mcdaniell and J Alexander Concepts and Models in Inorganic Chemistry, 3e,
10. Shriver & Atkins' Inorganic Chemistry, Atkins, Overton, Rourke, Weller, Armstrong; 6th Ed.,Oxford University Press, 2010 .
11. J. P. Collman et al. Principles and Applications of OrganotransitionMetalChemistry , Mill Valley, CA: University Science Books, 1987.

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

Practical: 30 Hours

Physical-II (Practical)

(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 (Practical)

(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 $K_2Cr_2O_7$

Reference Books:

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009
2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
3. Nad A. K., Mahapatra B. and Ghosal A. An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
4. Ghosh S., Das Sharma M., Majumder D and Manna S. Chemistry in Laboratory, Santra Publication Pvt Ltd
5. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic
6. Analysis, CBS Publishers and Distributors.
7. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)
8. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson
9. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
10. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency
11. University Hand Book of Undergraduate Chemistry Experiments, edited by
12. Mukherjee, G. N., University of Calcutta

13. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
14. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

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 **(7 L)**

Electrophilic Aromatic Substitution

Mechanism (SE2, 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 (S_NAr)

Relative reactivity of alkyl, allyl, vinyl and benzyl, aryl halides towards nucleophilic substitution reactions, Evidences for S_NAr mechanism; S_NAr reactions involving various leaving groups, Reactions *via* Benzyne: Evidence and Structure of Benzyne; cine substitution. Regio-selection in the formation of aryne and its amination in substituted halobenzene, Aromatic Nucleophilic Substitutions with Rearrangements: von-Richter rearrangement, Sommelet-Hauser rearrangement, Bamberger 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 10 and 20 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-Tieman, 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. Quinhydrones (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. Wittig rearrangement

Stereochemistry-II (6 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. Peter Sykes, Guidebook To Mechanism In Organic Chemistry, Pearson Education
3. Smith, J. G. Organic Chemistry, Tata Mcgraw - Hill Publishing Company Limited.
4. Nasipuri , D. Stereochemistry of Organic Compounds, Wiley Eastern Limited.
5. Jerry March, Advanced Organic Chemistry, Wiley- Interscience . A John Wiley & Sons, Inc.
6. Anup Pathak & Anupa Saha, Organic Chemistry, Books & Allied (P) Ltd.
7. N. Tiwari, Advanced Organic Reaction Mechanism, Books & Allied (P) Ltd.
8. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
9. Finar , I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearson Education).

10. Fleming, I. Molecular Orbitals and Organic Chemical Reactions, Reference/Student Edition, Wiley, 2009.
11. Eames, J., Peach, J. M. Stereochemistry at A Glance, Blackwell Publishing, 2003.
12. Robinson, M. J., Stereochemistry, Oxford Chemistry Primer, Oxford University Press, 2005.

Gr-B: Inorganic-III

Acids and Bases: **(15 L)**

Acid-base concept: Arrhenius concept, theory of solvent system (in H_2O, NH_3, SO_2 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 **(7 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. James E. Huheey / Ellen A. Keiter/ Richard L. Keiter/ Okhil K. Medhi Inorganic Chemistry, Principles of Structure and Reactivity 5 th Ed., Pearson,2022.
2. J D Lee, Concise Inorganic Chemistry,5th Ed., Wiley India Pvt. Ltd., 2008
3. G.L. Meissler , P.J. Fischer and D.A. Tarr, Inorganic Chemistry, 5e, Pearson
4. F.A. Cotton, G.W. Wilkinson, C.A. Murillo, M. Bochmann, Advanced Inorganic Chemistry, Wiley, 6e, 1999.
5. R. H. Crabtree, The Organometallic Chemistry of the Transition Metals. NewYork , NY: John Wiley, 2000.
6. S. P. Banerjee, Comprehensive Coordination Chemistry, Books & Allied (P) Ltd
7. S. P. Banerjee, Advanced Inorganic Chemistry, Books & Allied (P) Ltd
8. R L Dutta & G S De, Inorganic Chemistry (Vol I & II), The New Book Stall. ·
9. B. Douglas, D Mcdaniell and J Alexander Concepts and Models in Inorganic Chemistry, 3e,
10. Shriver & Atkins' Inorganic Chemistry, Atkins, Overton, Rourke, Weller, Armstrong; 6th Ed.,Oxford University Press, 2010 .
11. J. P. Collman et al. Principles and Applications of OrganotransitionMetalChemistry , Mill Valley, CA: University Science Books, 1987.

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

Practical: 30 Hours

Organic-III (Practical)

(a) The following reactions are to be performed, noting the yield of the crude product:

i. Side Chain oxidation of aromatic compounds.
ii. Bromination of anilides using green approach (Bromate-Bromide method)

iii. Redox reaction including solid-phase method
iv. Green ‘multi-component-coupling’ reaction
v. Selective reduction of m-dinitrobenzene to m-nitroaniline

Students must also calculate percentage yield, based upon isolated yield (crude) and theoretical yield.

(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 (Practical)

(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

Reference Books:

1. Mendham, J., A. I. Vogel’s Quantitative Chemical Analysis 6th Ed., Pearson, 2009
2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
3. Nad A. K., Mahapatra B. and Ghosal A. An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
4. Ghosh S., Das Sharma M., Majumder D and Manna S. Chemistry in Laboratory, Santra Publication Pvt Ltd
5. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic
6. Analysis, CBS Publishers and Distributors.
7. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)
8. Mendham, J., A. I. Vogel’s Quantitative Chemical Analysis 6th Ed., Pearson
9. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
10. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency
11. University Hand Book of Undergraduate Chemistry Experiments, edited by
12. Mukherjee, G. N., University of Calcutta
13. Levitt, B. P. edited Findlay’s Practical Physical Chemistry Longman Group Ltd.
14. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

SEMESTER-IV

Paper: CEMMJ DC-401T/CEMMJ MC-06T (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) X_3C-CY_3 (b) YCH_2-CH_2Z, (c) Higher homologous alkanes, (d) Saturated chiral molecules (2-chlorobutane), (e) RX-CH_2Y (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)

General methods of synthesis of carboxylic acids. Preparation of Acyl halides, Esters, Anhydrides and Amides from Carboxylic acids. Mechanism (with evidence): *B*AC2, *A*AC2, *A*AC1, *A*AL1 (in connection to esterification of and hydrolysis of ester); Comparisons of reactivity and hydrolysis of Amides, Anhydrides, Acyl-halides and esters.

Organometallics (5 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 **(5 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 λmax 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 λmax considering conjugative effect, steric effect, solvent effect, effect of pH.

Reference Books:

1. Clayden, J., Greeves, N. & Warren, S. Organic Chemistry, Second Edition, Oxford University Press, 2012.
2. Peter Sykes, Guidebook To Mechanism In Organic Chemistry, Pearson Education
3. Smith, J. G. Organic Chemistry, Tata Mcgraw - Hill Publishing Company Limited.
4. Nasipuri , D. Stereochemistry of Organic Compounds, Wiley Eastern Limited.
5. Jerry March, Advanced Organic Chemistry, Wiley- Interscience . A John Wiley & Sons, Inc.
6. Anup Pathak & Anupa Saha, Organic Chemistry, Books & Allied (P) Ltd.
7. N. Tiwari, Advanced Organic Reaction Mechanism, Books & Allied (P) Ltd.
8. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
9. Finar , I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearson Education).
10. Fleming, I. Molecular Orbitals and Organic Chemical Reactions, Reference/Student Edition, Wiley, 2009.
11. Eames, J., Peach, J. M. Stereochemistry at A Glance, Blackwell Publishing, 2003.
12. Robinson, M. J., Stereochemistry, Oxford Chemistry Primer, Oxford University Press, 2005.
13. Pavia, D. L. et al. Introduction to Spectroscopy, 5th Ed. Cengage Learning India Ed. (2015)
14. Harwood, L. M., Polar Rearrangements, Oxford Chemistry Primer, Oxford University Press.
15. Dyer, J. Application of Absorption Spectroscopy of Organic Compounds, PHI Private Limited

Paper: CEMMJ DC-401P/ CEMMJ MC-06P (Organic-IV)

Practical: 30 Hours

Organic-IV (Practical)

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: H_2O, 5% HCl, 5% NaOH and 5% $NaHCO_3$)
3. Detection of the following functional groups by systematic chemical tests: $-CO_2R$, $-CO_2H$, Phenolic -OH, -CO-, -CHO, a-hydroxy carbonyl, $-CONH_2$ including imide, -CONHAr, Aromatic $-NH_2$, Aromatic $-NO_2$
5. Melting point of the given compound
6. Preparation, purification and determination of melting point of a crystalline derivative of the given compound
7. Prediction of the probable compound from literature survey.

Each student, during laboratory session, is required to carry out qualitative chemical tests for all the special elements and the functional groups with relevant derivatization in known and unknown (at least six) organic compounds.

Reference Books:

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009
2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
3. Nad A. K., Mahapatra B. and Ghosal A. An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
4. Ghosh S., Das Sharma M., Majumder D and Manna S. Chemistry in Laboratory, Santra Publication Pvt Ltd
5. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic
6. Analysis, CBS Publishers and Distributors.

7. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)
8. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson
9. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
10. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency
11. University Hand Book of Undergraduate Chemistry Experiments, edited by
12. Mukherjee, G. N., University of Calcutta
13. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
14. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

Paper: CEMMJ DC-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 H_2, Li_2, Be_2, B_2, C_2, N_2, O_2, F_2, and their ions wherever possible; Heteronuclear molecular orbitals: CO, NO, NO^+, CN^-, HF, BeH_2, CO_2 and H_2O. 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* p-p Stacking Interactions, N–H···π interactions, S–aromatic interactions. Effects of chemical force, melting and boiling points.

Radioactivity **(17 L)**

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. James E. Huheey / Ellen A. Keiter/ Richard L. Keiter/ Okhil K. Medhi Inorganic Chemistry, Principles of Structure and Reactivity 5 th Ed., Pearson,2022.
2. J D Lee, Concise Inorganic Chemistry,5th Ed., Wiley India Pvt. Ltd., 2008
3. G.L. Meissler , P.J. Fischer and D.A. Tarr, Inorganic Chemistry, 5e, Pearson
4. F.A. Cotton, G.W. Wilkinson, C.A. Murillo, M. Bochmann, Advanced Inorganic Chemistry, Wiley, 6e, 1999.
5. R. H. Crabtree, The Organometallic Chemistry of the Transition Metals. NewYork , NY: John Wiley, 2000.
6. S. P. Banerjee, Comprehensive Coordination Chemistry, Books & Allied (P) Ltd
7. S. P. Banerjee, Advanced Inorganic Chemistry, Books & Allied (P) Ltd
8. R L Dutta & G S De, Inorganic Chemistry (Vol I & II), The New Book Stall. ·
9. B. Douglas, D Mcdaniell and J Alexander Concepts and Models in Inorganic Chemistry, 3e,
10. Shriver & Atkins' Inorganic Chemistry, Atkins, Overton, Rourke, Weller, Armstrong; 6th Ed.,Oxford University Press, 2010 .
11. J. P. Collman et al. Principles and Applications of OrganotransitionMetalChemistry , Mill Valley, CA: University Science Books, 1987.
12. H. J. Arnikar, Essentials of Nuclear Chemistry, 5thEdition, New Age International Pvt, Ltd., 2022
13. Gillespie, R. J. and Hargittai , I., The VSEPR Model of Molecular Geometry, Prentice Hall

Paper: CEMMJ DC-402P (Inorganic-IV)

Practical: 30 Hours

Inorganic-IV (Practical)

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+}, Fe^{2+}/Fe^{3+}, Co^{2+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Pb^{2+}, Bi^{3+}, As^{3+}/As^{5+}, Sb^{3+}/Sb^{5+}.

Reference Books:
1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009
2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
3. Nad A. K., Mahapatra B. and Ghosal A. An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
4. Ghosh S., Das Sharma M., Majumder D and Manna S. Chemistry in Laboratory, Santra Publication Pvt Ltd
5. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic
6. Analysis, CBS Publishers and Distributors.
7. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)
8. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson
9. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
10. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency
11. University Hand Book of Undergraduate Chemistry Experiments, edited by
12. Mukherjee, G. N., University of Calcutta
13. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
14. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

Paper: CEMMJ DC-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 **(7 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 **(9 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 *dhkl*; 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 **(8 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 **(9 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.
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. K L Kapoor, Physical Chemistry, McGraw Hill.
9. A L De, A De, Physical Chemistry, Books & Allied (P) Ltd.
10. Mortimer, R. G. Physical Chemistry, Elsevier.
11. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.
12. Rakshit, P.C., Physical Chemistry, Sarat Book House.
13. Moore, W. J. Physical Chemistry, Orient Longman.
14. West, A. R. Solid State Chemistry and its Applications, Wiley India.
15. Klotz, Irving M. & Rosenberg, Robert M. Chemical Thermodynamics, Wiley India.
16. Negi, A. S. & Anand, S. C. A Textbook of Physical Chemistry, New Age International.

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

Practical: 30 Hours

Physical-III (Practical)

(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 the solubility product of $BaSO_4$ by conductivity method.

Reference Books:

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009
2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
3. Nad A. K., Mahapatra B. and Ghosal A. An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
4. Ghosh S., Das Sharma M., Majumder D and Manna S. Chemistry in Laboratory, Santra Publication Pvt Ltd
5. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic
6. Analysis, CBS Publishers and Distributors.
7. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)
8. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson
9. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
10. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency
11. University Hand Book of Undergraduate Chemistry Experiments, edited by
12. Mukherjee, G. N., University of Calcutta
13. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
14. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

SEMESTER-V

Paper: CEMMJ DC-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 L)**

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, CO_2, 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 **(8 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-I **(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: The time dependent Schrodinger equation. The time-independent Schrodinger equation; nature of the equation, acceptability conditions for the wave functions and probability interpretations of wave function. Vector representation of wave function. Dirac's bracket notation. Orthonormality of wave function.

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 Schrödinger Equation for one-dimensional well and its solution; Comparison with free particle eigenfunctions and eigenvalues. Properties of 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.
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. K L Kapoor, Physical Chemistry, McGraw Hill
9. A L De, A De, Physical Chemistry, Books & Allied (P) Ltd

10. Mortimer, R. G. Physical Chemistry, Elsevier.
11. Laidler, K. J. Chemical Kinetics, Pearson.
12. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.
13. Rakshit, P.C., Physical Chemistry Sarat Book House.
14. Zemansky, M. W. & Dittman, R.H. Heat and Thermodynamics, Tata- McGraw-Hill.
15. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas.
16. Clauze& Rosenberg, Chemical Thermodynamics.

Paper: CEMMJ DC-501P/ CEMMJ MC-8P (Physical-IV)

Practical: 30 Hours

Physical-IV (Practical)

(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 Ksp for AgCl by potentiometric titration of $AgNO_3$ solution against standard KCl solution

(d) Determination of solubility of sparingly soluble salt in water, in electrolyte with common ions and in neutral electrolyte (using common indicator)

Reference Books:

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009
2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
3. Nad A. K., Mahapatra B. and Ghosal A. An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
4. Ghosh S., Das Sharma M., Majumder D and Manna S. Chemistry in Laboratory, Santra Publication Pvt Ltd
5. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic
6. Analysis, CBS Publishers and Distributors.
7. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)
8. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson
9. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
10. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency
11. University Hand Book of Undergraduate Chemistry Experiments, edited by
12. Mukherjee, G. N., University of Calcutta
13. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
14. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

Paper: CEMMJ DC-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. Study adsorption phenomena through key isotherms and their applications in catalysis and surface chemistry.
3. Learn the laws and concepts of photochemistry, including quantum yields, excited states, and photochemical reaction mechanisms.
4. Gain a foundational understanding of molecular spectroscopy, including rotational and vibrational spectroscopy, and their applications in molecular structure determination.
5. 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. Apply adsorption isotherms such as Freundlich, Langmuir, and BET to interpret adsorption data and understand the role of adsorption in heterogeneous catalysis.
3. Understand the principles of photochemistry, including potential energy diagrams, excited-state dynamics, and quantum yield, and apply them to interpret photochemical processes and reactions.
4. 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.
5. 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.

Chemical Kinetics-II and Adsorption **(13 L)**

Kinetics: Kinetic control and thermodynamic control of reaction. Theories of reaction rate: simple collision theory (SCT); steric factor, activated complex theory (ACT); The Eyring Equation, thermodynamics of reaction rate and entropy of activation. Comparison of the two theories (qualitative treatment only). Lindemann theory of unimolecular reaction, the RRK model, 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; Heterogenous 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, H2-Br2 reaction, dimerization of anthracene; photosensitised reactions, quenching; Stern-Volmer equation, 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.
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. K L Kapoor, Physical Chemistry, McGraw Hill
9. A L De, A De, Physical Chemistry, Books & Allied (P) Ltd
10. Mortimer, R. G. Physical Chemistry, Elsevier.
11. Laidler, K. J. Chemical Kinetics, Pearson.
12. Glasstone , S. & Lewis, G.N. Elements of Physical Chemistry.
13. Rakshit, P.C., Physical Chemistry Sarat Book House.
14. Zemansky, M. W. & Dittman, R.H. Heat and Thermodynamics, Tata- McGraw-Hill.
15. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas.
16. Clauze & Rosenberg, Chemical Thermodynamics.

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

Practical: 30 Hours

Physical-V (Practical)

(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 $K_2Cr_2O_7$ solution.

(c) Determination of pH of unknown buffer, spectrophotometrically

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

Reference Books:

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009
2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
3. Nad A. K., Mahapatra B. and Ghosal A. An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
4. Ghosh S., Das Sharma M., Majumder D and Manna S. Chemistry in Laboratory, Santra Publication Pvt Ltd
5. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic
6. Analysis, CBS Publishers and Distributors.
7. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)

8. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson
9. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
10. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency
11. University Hand Book of Undergraduate Chemistry Experiments, edited by
12. Mukherjee, G. N., University of Calcutta
13. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
14. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

Paper: CEMMJ DC-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 S N 1, S N 2, S N 2′, S N 1′, S N i, E1, E2, and E1cB 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 (8 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: S_N1, S_N2, S_N2', S_N1' (allylic rearrangement), and SNi; 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 Ei (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 **(6 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. Alkylnitriles and isonitriles: preparation, Thorpe nitrile condensation, von Richter reaction. Diazonium salts: replacement of diazo group, Gomberg, Meerwein, and Japp–Klingermann reactions.

Rearrangements **(6 L)**

Mechanism, evidences (including crossover experiments), and stereochemical aspects of the following rearrangements:

Nucleophilic Rearrangement to electron-deficient Carbon: Wagner–Meerwein, Hydride shift, Pinacol, Semi-pinacol, dienone–phenol, Wolff rearrangement in Arndt–Eistert synthesis, Benzilic acid rearrangement, Homologation of ketones by diazomethane, Demjanov, and Tiffeneau–Demjanov rearrangements.

Rearrangement to electron-deficient Nitrogen: Hofmann, Curtius, Lossen, Schmidt, Neber, and Beckmann rearrangements.

Nucleophilic Rearrangement to electron-deficient oxygen: Baeyer–Villiger oxidation, Hydroperoxide rearrangement, and Dakin reaction.

A Few more Important Rearrangements: Stevens rearrangement, Favorskii rearrangement, Benzidine rearrangements, Hofmann-Martius rearrangement, Orton rearrangement, benzidine rearrangement, Fries rearrangement, Claisen rearrangement, Cope rearrangement, N-azo to C-azo, Bamberger 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.

Organic Synthesis-I: Retrosynthesis & Ring Synthesis **(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:

1. Clayden, J., Greeves, N. & Warren, S. Organic Chemistry, Second Edition, Oxford University Press, 2012.
2. Peter Sykes, Guidebook To Mechanism In Organic Chemistry, Pearson Education
3. Smith, J. G. Organic Chemistry, Tata Mcgraw - Hill Publishing Company Limited.
4. Nasipuri , D. Stereochemistry of Organic Compounds, Wiley Eastern Limited.
5. Jerry March, Advanced Organic Chemistry, Wiley- Interscience . A John Wiley & Sons, Inc.
6. Anup Pathak & Anupa Saha, Organic Chemistry, Books & Allied (P) Ltd.
7. N. Tiwari, Advanced Organic Reaction Mechanism, Books & Allied (P) Ltd.
8. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
9. Finar , I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearson Education).
10. Fleming, I. Molecular Orbitals and Organic Chemical Reactions, Reference/Student Edition, Wiley, 2009.
11. Eames, J., Peach, J. M. Stereochemistry at A Glance, Blackwell Publishing, 2003.
12. Robinson, M. J., Stereochemistry, Oxford Chemistry Primer, Oxford University Press, 2005.
13. Pavia, D. L. et al. Introduction to Spectroscopy, 5th Ed. Cengage Learning India Ed. (2015)
14. Harwood, L. M., Polar Rearrangements, Oxford Chemistry Primer, Oxford University Press.
15. Warren, S, Organic Synthesis the Disconnection Approach, John Wiley and Sons

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

Practical: 30 Hours

Organic-V (Practical)

(a) Preparation of organic compounds following green methodology

1. Benzoylation of anthranilic acid in the presence of base.
2. Preparation of dihydropyrimidinone.
3. Preparation of dibenzal propanone.
4. Preparation of benzilic acid from benzil
5. Preparation of benzoin from benzaldehyde
6. Preparation of azomethines using mechano-chemical protocol.
7. Preparation of 4-Nitrosalicylic Acid
8. Preparation of p-Bromo-acetanilide.
9. Preparation of 2-chlorobenzioc acid by Cannizaro method.
10. Preparation of Aspirin from Salicylic Acid

(b) Re-crystallization and determination of m.p. of the prepared compounds.

Reference Books:

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009
2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
3. Nad A. K., Mahapatra B. and Ghosal A. An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
4. Ghosh S., Das Sharma M., Majumder D and Manna S. Chemistry in Laboratory, Santra Publication Pvt Ltd
5. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic

6. Analysis, CBS Publishers and Distributors.
7. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)
8. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson
9. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
10. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency
11. University Hand Book of Undergraduate Chemistry Experiments, edited by
12. Mukherjee, G. N., University of Calcutta
13. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
14. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

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

Theory: 45 L (45 Hours)

Objectives

1. Understand the chemistry of s- and p-block elements (Groups 1, 2 and 13–18), including oxidation-state stability, diagonal relationships, anomalous behaviour of first members, allotropy and catenation.
2. Study the preparation, structure, bonding, properties and uses of important compounds of s- and p-block elements such as borates, diborane, borazines, silanes, silicones, silicates, zeolites, phosphazenes, oxoacids of N, P, S and Cl, interhalogens and pseudohalogens.
3. Explore the occurrence, inertness and compounds of noble gases, and rationalize the bonding and shapes of xenon fluorides and xenon–oxygen compounds using VSEPR, VB and MO treatments.
4. Compare 3d, 4d and 5d transition elements with respect to oxidation states, metal–metal bonding and redox behaviour, and study dinuclear and mixed-valence complexes.
5. Understand the general features of lanthanoids and actinoids, including electronic configuration, lanthanoid and actinoid contraction, separation methods and applications.
6. Learn the qualitative and quantitative aspects of chemical analysis, including sampling, evaluation of analytical data, errors, statistical tests and confidence intervals.

Learning Outcomes

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

1. Explain the trends in oxidation states, diagonal relationships and anomalous behaviour of the first member of each s- and p-block group, and correlate them with atomic structure.
2. Describe the preparation, structure, bonding and applications of important main-group compounds such as diborane, borazines, silicones, silicates, zeolites, phosphazenes and oxoacids of N, P, S and Cl.
3. Rationalize the inertness of noble gases and predict the structures and bonding of XeF2, XeF4, XeF6 and xenon–oxygen compounds.
4. Compare the chemistry of 3d, 4d and 5d series, Cu/Ag/Au and Zn/Cd/Hg groups, and explain metal–metal bonding in dinuclear complexes such as (Re2Cl8)2-.
5. Compare lanthanoids and actinoids in terms of electronic configuration, oxidation states, spectral and magnetic properties, and describe the ion-exchange separation of lanthanides and their applications.
6. Apply statistical tools such as F, Q and t tests, rejection rules and confidence intervals for the evaluation of analytical data in quantitative analysis.

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 XeF2, XeF4 and XeF6; Nature of bonding in noble gas compounds (Valence bond treatment and MO treatment for XeF2 and XeF4). 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. (Re2Cl8)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

Reference Books:

1. James E. Huheey/ Ellen A. Keiter/ Richard L. Keiter/ Okhil K. Medhi Inorganic Chemistry, Principles of Structure and Reactivity 5 th Ed., Pearson,2022.
2. J D Lee, Concise Inorganic Chemistry,5th Ed., Wiley India Pvt. Ltd., 2008
3. G.L. Meissler, P.J. Fischer and D.A. Tarr, Inorganic Chemistry, 5e, Pearson
4. F.A. Cotton, G.W. Wilkinson, C.A. Murillo, M. Bochmann, Advanced Inorganic Chemistry, Wiley, 6e, 1999.
5. R. H. Crabtree, The Organometallic Chemistry of the Transition Metals. NewYork, NY: John Wiley, 2000.
6. S. P. Banerjee, Comprehensive Coordination Chemistry, Books & Allied (P) Ltd
7. S. P. Banerjee, Advanced Inorganic Chemistry, Books & Allied (P) Ltd
8. R L Dutta & G S De, Inorganic Chemistry (Vol I & II), The New Book Stall. ·
9. B. Douglas, D Mcdaniell and J Alexander Concepts and Models in Inorganic Chemistry, 3e,
10. Shriver & Atkins' Inorganic Chemistry, Atkins, Overton, Rourke, Weller, Armstrong; 6th Ed.,Oxford University Press, 2010 .
11. J. P. Collman et al. Principles and Applications of OrganotransitionMetalChemistry, Mill Valley, CA: University Science Books, 1987.
12. Daniel C. Harris, Quantitative Chemical Analysis, 10thEdition, W.H. Freeman, 2020

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

Practical: 30 Hours

Inorganic-V (Practical)

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
7. Estimation of Cu(II) in brass

Reference Books:

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009
2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
3. Nad A. K., Mahapatra B. and Ghosal A. An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
4. Ghosh S., Das Sharma M., Majumder D and Manna S. Chemistry in Laboratory, Santra Publication Pvt Ltd
5. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic
6. Analysis, CBS Publishers and Distributors.
7. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)
8. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson
9. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
10. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency
11. University Hand Book of Undergraduate Chemistry Experiments, edited by
12. Mukherjee, G. N., University of Calcutta
13. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
14. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

SEMESTER-VI

Paper: CEMMJ DC-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 (6 L)

Synthetic methods including Haworth, Bardhan-Sengupta, Bogert-Cook and other useful syntheses (with mechanistic details). Structure(s), Stability, Canonical forms, Aromaticity of polybenzenoid hydrocarbons, Partial fixation of double bonds, Fries rule, Clar's rule. Reactions (with mechanism and comparison) of Naphthalene, Anthracene, Phenanthrene and their derivatives (Electrophilic substitution reactions, Oxidation and Reduction reactions, Bucherer reaction, Diels-Alder reaction, etc.).

Heterocyclic compounds (8 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 of different functional groups and factors influencing it; anisotropic effects in alkene, alkyne, aldehydes and aromatics (ring current effect); significance of the terms: up-/downfield, shielded and deshielded protons; spin coupling and coupling constant; First-order and Non-first-order spectra, relative intensities of first-order multiplets: Pascal's triangle; chemical and magnetic equivalence in NMR; 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, HNO_3 oxidation, selective oxidation of terminal $-CH_2OH$ 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 in common disaccharides (maltose, lactose, sucrose); reducing and non-reducing nature; concept of glycosidic bond formation by glycosyl donor-acceptor; structure of sucrose; inversion of cane sugar.

Amino acids, Peptides, Proteins & Nucleic Acids

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 Cyanogen bromide (CNBr), trypsine and chymotrypsine. Overview of Primary, Secondary, Tertiary and Quaternary structure of Proteins. Example(s) and function(s) of Fibrous protein and Globular proteins, Denaturation.

Nucleic Acids: pyrimidine and purine bases (only structure & nomenclature); nucleosides and nucleotides corresponding to DNA and RNA; elementary idea of double helical structure of DNA (Watson-Crick model); complimentary base–pairing in DNA

Reference Books:

1. Clayden, J., Greeves, N. & Warren, S. Organic Chemistry, Second Edition, Oxford University Press, 2012.
2. Peter Sykes, Guidebook To Mechanism In Organic Chemistry, Pearson Education
3. Smith, J. G. Organic Chemistry, Tata Mcgraw - Hill Publishing Company Limited.
4. Nasipuri , D. Stereochemistry of Organic Compounds, Wiley Eastern Limited.
5. Jerry March, Advanced Organic Chemistry, Wiley- Interscience . A John Wiley & Sons, Inc.
6. Anup Pathak & Anupa Saha, Organic Chemistry, Books & Allied (P) Ltd.
7. N. Tiwari, Advanced Organic Reaction Mechanism, Books & Allied (P) Ltd.
8. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
9. Finar , I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearson Education).
10. Fleming, I. Molecular Orbitals and Organic Chemical Reactions, Reference/Student Edition, Wiley, 2009.
11. Eames, J., Peach, J. M. Stereochemistry at A Glance, Blackwell Publishing, 2003.
12. Robinson, M. J., Stereochemistry, Oxford Chemistry Primer, Oxford University Press, 2005.
13. Pavia, D. L. et al. Introduction to Spectroscopy, 5th Ed. Cengage Learning India Ed. (2015)
14. Harwood, L. M., Polar Rearrangements, Oxford Chemistry Primer, Oxford University Press.
15. Warren, S, Organic Synthesis the Disconnection Approach, John Wiley and Sons
16. Dyer, J. Application of Absorption Spectroscopy of Organic Compounds, PHI Private Limited

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

Practical: 30 Hours

Organic-VI (Practical)

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≡C, C≡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

Reference Books:
1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009
2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
3. Nad A. K., Mahapatra B. and Ghosal A. An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
4. Ghosh S., Das Sharma M., Majumder D and Manna S. Chemistry in Laboratory, Santra Publication Pvt Ltd
5. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic
6. Analysis, CBS Publishers and Distributors.
7. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)
8. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson
9. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
10. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency
11. University Hand Book of Undergraduate Chemistry Experiments, edited by
12. Mukherjee, G. N., University of Calcutta
13. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
14. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

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

Theory: 45 L (45 Hours)

Objectives
1. Understand the basic principles of coordination chemistry, including theories, nomenclature, and types of isomerism in metal complexes.
2. 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 d^n 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. Experimental evidence for metal-ligand orbital overlap, and Nephelauxetic effect & Nephelauxetic Series. Tetragonal distortion from octahedral symmetry: Jahn-Teller distortion. Octahedral site stabilization energy (OSSE). Site selection in spinels, 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 3d1 to 3d9 ions. Racah parameter. Selection rules for electronic spectral transitions; vibronic coupling, band broadening, spin-orbit coupling, spin-forbidden transition, intensity stealing, 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 behaviour 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:

1. James E. Huheey / Ellen A. Keiter/ Richard L. Keiter/ Okhil K. Medhi Inorganic Chemistry, Principles of Structure and Reactivity 5 th Ed., Pearson,2022.
2. J D Lee, Concise Inorganic Chemistry,5th Ed., Wiley India Pvt. Ltd., 2008
3. G.L. Meissler , P.J. Fischer and D.A. Tarr, Inorganic Chemistry, 5e, Pearson
4. F.A. Cotton, G.W. Wilkinson, C.A. Murillo, M. Bochmann, Advanced Inorganic Chemistry, Wiley, 6e, 1999.
5. R. H. Crabtree, The Organometallic Chemistry of the Transition Metals. NewYork , NY: John Wiley, 2000.
6. S. P. Banerjee, Comprehensive Coordination Chemistry, Books & Allied (P) Ltd

7. S. P. Banerjee, Advanced Inorganic Chemistry, Books & Allied (P) Ltd
8. R L Dutta & G S De, Inorganic Chemistry (Vol I & II), The New Book Stall. ·
9. B. Douglas, D Mcdaniell and J Alexander Concepts and Models in Inorganic Chemistry, 3e,
10. Shriver & Atkins' Inorganic Chemistry, Atkins, Overton, Rourke, Weller, Armstrong; 6th Ed.,Oxford University Press, 2010 .
11. J. P. Collman et al. Principles and Applications of OrganotransitionMetalChemistry , Mill Valley, CA: University Science Books, 1987.
12. Greenwood, N.N. & Earnshaw A. Chemistry of the Elements, Butterworth- Heinemann, 1997
13. Daniel C. Harris, Quantitative Chemical Analysis, 10thEdition, W.H. Freeman, 2020
14. Lippard, S.J. & Berg, J.M. Principles of Bioinorganic Chemistry Panima Publishing Company 1994
15. Purecell , K.F. and Kotz, J.C., An Introduction to Inorganic Chemistry, Saunders: Philadelphia, 1980
16. Powell, P. Principles of Organometallic Chemistry, Chapman and Hall, 1988
17. Collman, J. P. et al. Principles and Applications of Organotransition Metal Chemistry. Mill Valley, CA: University Science Books, 1987

Paper: CEMMJ DC-602P/ CEMMJ MC-13P (Inorganic-VI)

Practical: 30 Hours

Inorganic-VI (Practical)

(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)

Reference Books:

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009
2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
3. Nad A. K., Mahapatra B. and Ghosal A. An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
4. Ghosh S., Das Sharma M., Majumder D and Manna S. Chemistry in Laboratory, Santra Publication Pvt Ltd
5. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic
6. Analysis, CBS Publishers and Distributors.
7. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)
8. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson
9. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
10. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency
11. University Hand Book of Undergraduate Chemistry Experiments, edited by
12. Mukherjee, G. N., University of Calcutta
13. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
14. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

Paper: CEMMJ DC-603T/ 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 (12 L)

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-I **(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+}, $Fe^{3+}/2^{+}$, $Cu^{2+}/1^{+}$, Zn^{2+} and $Mo^{3+}/4^{+}/6^{+}$) 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 (2Fe-2*S*, 4Fe-4*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 **(5 L)**

Zeise's salt: Preparation, structure, evidences of synergic effect. Ferrocene: Preparation and reactions (acetylation, alkylation, metalation, 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 5 th Ed., Pearson,2022.
2. J D Lee, Concise Inorganic Chemistry,5th Ed., Wiley India Pvt. Ltd., 2008
3. G.L. Meissler , P.J. Fischer and D.A. Tarr, Inorganic Chemistry, 5e, Pearson
4. F.A. Cotton, G.W. Wilkinson, C.A. Murillo, M. Bochmann, Advanced Inorganic Chemistry, Wiley, 6e, 1999.
5. R. H. Crabtree, The Organometallic Chemistry of the Transition Metals. NewYork , NY: John Wiley, 2000.
6. S. P. Banerjee, Comprehensive Coordination Chemistry, Books & Allied (P) Ltd
7. S. P. Banerjee, Advanced Inorganic Chemistry, Books & Allied (P) Ltd
8. R L Dutta & G S De, Inorganic Chemistry (Vol I & II), The New Book Stall. ·
9. B. Douglas, D Mcdaniell and J Alexander Concepts and Models in Inorganic Chemistry, 3e,
10. Shriver & Atkins' Inorganic Chemistry, Atkins, Overton, Rourke, Weller, Armstrong; 6th Ed.,Oxford University Press, 2010 .
11. J. P. Collman et al. Principles and Applications of OrganotransitionMetalChemistry , Mill Valley, CA: University Science Books, 1987.
12. Greenwood, N.N. & Earnshaw A. Chemistry of the Elements, Butterworth- Heinemann, 1997
13. Daniel C. Harris, Quantitative Chemical Analysis, 10thEdition, W.H. Freeman, 2020
14. Lippard, S.J. & Berg, J.M. Principles of Bioinorganic Chemistry Panima Publishing Company 1994
15. Purecell , K.F. and Kotz, J.C., An Introduction to Inorganic Chemistry, Saunders: Philadelphia, 1980
16. Powell, P. Principles of Organometallic Chemistry, Chapman and Hall, 1988
17. Collman, J. P. et al. Principles and Applications of Organotransition Metal Chemistry. Mill Valley, CA: University Science Books, 1987

Paper: CEMMJ DC-603P/ CEMMJ MC-14P (Inorganic-VII)

Practical: 30 Hours

Inorganic-VII (Practical)

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

Reference Books:

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009
2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
3. Nad A. K., Mahapatra B. and Ghosal A. An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
4. Ghosh S., Das Sharma M., Majumder D and Manna S. Chemistry in Laboratory, Santra Publication Pvt Ltd
5. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic
6. Analysis, CBS Publishers and Distributors.
7. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)
8. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson
9. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
10. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency
11. University Hand Book of Undergraduate Chemistry Experiments, edited by
12. Mukherjee, G. N., University of Calcutta
13. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
14. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

Paper: CEMMJ DC-604T/ 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 simple 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 Schultz-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 (15 L)

Configuration: Macro-states, 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*translation, *q*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. 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. K L Kapoor, Physical Chemistry, McGraw Hill
9. A L De, A De, Physical Chemistry, Books & Allied (P) Ltd
10. Mortimer, R. G. Physical Chemistry, Elsevier.
11. Laidler, K. J. Chemical Kinetics, Pearson.
12. Glasstone , S. & Lewis, G.N. Elements of Physical Chemistry.
13. Rakshit, P.C., Physical Chemistry Sarat Book House.
14. Zemansky, M. W. & Dittman, R.H. Heat and Thermodynamics, Tata- McGraw-Hill.
15. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas.
16. Clauze & Rosenberg, Chemical Thermodynamics.

Paper: CEMMJ DC-604P/ CEMMJ MC-15P (Physical-VI)

Practical: 30 Hours

Physical-VI (Practical)

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) Study of kinetics of $K_2S_2O_8$/KI reaction colorimetrically/spectrophotometrically
d) Determination of pKin of indicator (Bromocresol green) colorimetrically.

Reference Books:

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009
2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
3. Nad A. K., Mahapatra B. and Ghosal A. An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
4. Ghosh S., Das Sharma M., Majumder D and Manna S. Chemistry in Laboratory, Santra Publication Pvt Ltd
5. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic
6. Analysis, CBS Publishers and Distributors.
7. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)
8. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson
9. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
10. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency
11. University Hand Book of Undergraduate Chemistry Experiments, edited by
12. Mukherjee, G. N., University of Calcutta
13. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
14. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

SEMESTER-VII

Paper: CEMMJ DC-701T/ CEMMJ MC-16T (Organic-VII)

Theory: 45 L (45 Hours)

Objectives

1. Understand the principles, mechanisms, and stereochemical aspects of pericyclic reactions and apply orbital symmetry concepts to predict reaction outcomes.
2. Learn the Woodward–Hoffmann rules, frontier molecular orbital (FMO) approach, correlation diagrams, and Möbius–Hückel concepts for the rationalization of pericyclic processes.
3. Study the photochemical behavior of organic molecules, including carbonyl compounds, olefins, dienes, and aromatic systems, and understand the mechanistic pathways of photochemical reactions.
4. Develop an understanding of excited-state reactivity and the role of light in promoting organic transformations of synthetic importance.
5. Explore the principles of asymmetric synthesis and stereoselective reactions involving substrate, chiral auxiliary, and chiral reagent control.
6. Understand the theoretical basis of asymmetric induction and apply stereochemical models such as Cram's rule, Felkin–Anh model, and Prelog's rule in predicting stereochemical outcomes of organic reactions.

Learning Outcomes

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

1. Explain the mechanisms and stereochemical consequences of electrocyclic reactions, cycloadditions, sigmatropic rearrangements, cheletropic reactions, and related pericyclic processes.
2. Apply Woodward–Hoffmann selection rules, frontier molecular orbital theory, and correlation diagrams to predict the feasibility and stereochemistry of pericyclic reactions.
3. Interpret the photochemical behavior of carbonyl compounds, olefins, dienes, and aromatic compounds, and explain the mechanisms of important photochemical transformations.
4. Distinguish between ground-state and excited-state reactivity and evaluate the synthetic applications of photochemical reactions in organic chemistry.
5. Analyze stereochemical outcomes of reactions involving substrate-controlled, chiral auxiliary-controlled, and chiral reagent-controlled asymmetric synthesis.
6. Predict the configuration of products formed through asymmetric induction using Cram's rule, Felkin–Anh model, Prelog's rule, and related stereochemical principles, and appreciate their significance in modern synthetic chemistry.

Pericyclic Reactions **(15 L)**

The Woodward-Hoffmann selection rules and stereochemistry of electrocyclic reactions, cycloadditions, sigmatropic rearrangements, cheleotropic reactions and group transfer reaction, rationalization based on frontier MO approach, correlation diagrams, Dewer-Zimmermann approach, Mobius and Huckel systems, Sommelet-Hauser, Cope, aza-Cope and Claisen rearrangements, Ene reaction, Wittig rearrangement, suitable examples of [(2p+2p), (4p +2p), (4 p +4 p), (2p +2p +2p)] and metal catalysed cycloaddition reactions.

Photochemistry **(15 L)**

Photochemistry of carbonyl compounds- n-π*and π-π* transitions. Norrish type I and Norrish type II cleavages. Patterno-Buchi reactions, Photoreduction, Photo chemistry of α,ß-unsaturated ketones, photochemistry of enones and cyclohexadienones. Photochemistry of unsaturated systems (Olefins): cis-trans isomerization, dimerization, and addition. Acetylenes-dimerization. Photochemistry of 1,3-butadienes, di-π-methane rearrangement. Photochemistry of aromatic compounds – 1,2, 1,3, and 1,4- additions. Photo-Fries rearrangement, Photo- Fries reactions of anilides.

Organic Synthesis-II: Substrate Controlled Synthesis **(15 L)**

Fundamental Stereochemical Principles: Distinction between stereospecific and stereoselective reactions; quantitative assessment of stereoisomeric composition through enantiomeric excess (ee) and established methods for the determination of optical purity.
Strategies in Asymmetric Synthesis: Definition and representative examples of asymmetric synthesis; mechanistic paradigms for stereochemical control including substrate control, chiral auxiliary control, reagent control, asymmetric catalysis, kinetic resolution, and double asymmetric induction.
Enantioselectivity and Diastereoselectivity: Formal definition of enantioselectivity; formal definition of diastereoselectivity and predictive models for nucleophilic addition to carbonyl functionalities adjacent to a pre-existing stereogenic centre—the Felkin–Anh model, Cram's chelate model, and Prelog's rule.
Diastereoselective Aldol Condensation: The Zimmerman–Traxler transition-state model and its application to the diastereoselective aldol reaction mediated by lithium enolates.

Reference Books:

1. Some Modern methods of synthesis By Caruthers (Cambridge)
2. Organic synthesis by Robert & Ireland (Printce Hall of India)
3. Designing Organic Synthesis B staurt Warron, John Wiley & Sons
4. "Pericyclic reactions a mechanistic study" S.M. Mukheji
5. Synthetic approaches in Organic Chemistry " R.K. Bansal Narosa Publications
6. Advances in Organic Chemistry – Reaction mechanism and structure" by J. March (Mc Graw Hill).
7. 'Organic Photo chemistry and Pericyclic reactions' M.G. Arora Anmol Publications Pvt. Ltd.
8. Fundamentals of photochemistry by K.K. Rohatgi–Mukharjee Now Age international publishers.
9. Photochemistry by C W S Wells.
10. Organic Photochemistry by Turro.
11. Molecular Photo chemistry by Gilbert & Baggo.
12. Organic Photo chemistry by D Coyle.
13. Asymmetric synthesis by Nogradi.
14. Asymmetric organic reactions, J. D. Morrison and H. S. Moschcr.
15. Principles of Asymmetric synthesis, R. E. Gawley and J. Aube, 2nd Ed., Elsevier, 2012

Paper: CEMMJ DC-701P/ CEMMJ MC-16P (Organic-VII)

Practical: 30 Hours

Organic-VII (Practical)

1. Estimation of glycine by Sörensen's formol method
2. Estimation of glucose by titration using Fehling's solution
3. Estimation of sucrose by titration using Fehling's solution
4. Estimation of vitamin-C (reduced)
5. Estimation of aromatic amine (aniline) by bromination (Bromate-Bromide) Method

Reference Books:

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009
2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
3. Nad A. K., Mahapatra B. and Ghosal A. An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
4. Ghosh S., Das Sharma M., Majumder D and Manna S. Chemistry in Laboratory, Santra Publication Pvt Ltd
5. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic
6. Analysis, CBS Publishers and Distributors.
7. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)
8. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson
9. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
10. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency
11. University Hand Book of Undergraduate Chemistry Experiments, edited by
12. Mukherjee, G. N., University of Calcutta
13. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
14. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

Paper: CEMMJ DC-702T/ CEMMJ MC-17T (Organic-VIII)

Theory: 45 L (45 Hours)

Objectives

1. Understand the chemistry of terpenoids including the isoprene rule, structure elucidation by chemical and spectroscopic methods, synthesis and medicinal uses of representative acyclic, monocyclic and bicyclic monoterpenes.
2. Study the classification, structure elucidation, synthesis and biological activity of important alkaloids such as hygrine, nicotine, coniine and papaverine, and appreciate the medicinal importance of quinine, morphine, cocaine and reserpine.
3. Learn the principles, needs and goals of green chemistry, the twelve principles with emphasis on atom economy, green solvents, solvent-less synthesis and alternative energy sources such as microwave and ultrasound.
4. Understand linear free energy relationships, the Hammett equation, substituent and reaction constants, and their applications in studying reaction mechanisms.
5. Explore the chemistry of flavonoids, including coumarin and chromone scaffolds, structure determination, isolation, synthesis and biosynthetic origin via acetate and shikimate pathways.
6. Perform quantitative estimations of organic compounds such as phenol, formaldehyde, acetic acid, urea and saponification value of oils using standard titrimetric methods.

Learning Outcomes

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

1. Explain the isoprene rule and elucidate the structures of representative terpenoids using chemical and spectroscopic evidence, and describe their synthesis and medicinal applications.

2. Describe the classification, synthesis and structure elucidation of alkaloids and correlate their structures with biological and medicinal activity.
3. Apply the twelve principles of green chemistry, calculate atom economy, and compare green synthetic protocols (green solvents, MAOS, ultrasound) with conventional methods.
4. Use the Hammett equation and Hammett plots to calculate rate and equilibrium constants, interpret substituent and reaction constants, and analyze deviations from linearity.
5. Describe the synthesis, characteristic reactions, spectroscopic identification and biosynthesis of flavonoids and related natural products.
6. Carry out titrimetric estimation of phenol, formaldehyde, acetic acid in vinegar, urea and saponification value of oils/fats accurately in the laboratory.

Chemistry of Alkaloids and Terpenoids **(18 L)**

Terpenoids: Isoprene rule, structure elucidation (by chemical and spectroscopical methods), Synthesis and Medicinal Use of representative examples of acyclic (Citral), monocyclic (Camphor) and bicyclic monoterpenes (Caryophyllene); structural types: general concept and examples of sesqui-, di- and tri-terpenoids.

Alkaloids: Hoffmann's exhaustive methylation, Emde's modification, classifications, familiarity with methods (chemical and spectroscopic) for structure elucidation, synthesis and biological activity of hygrine, nicotine, coniine and papaverine. Medicinal importance of Nicotine, Hygrine, Quinine, Morphine, Cocaine and Reserpine.

Green Synthesis **(10 L)**

Green Chemistry: Introduction to Green chemistry, Definition, Needs and Goals. Twelve principles: Explanations with examples, Special emphasis on Prevention of waste, Maximum incorporation of starting materials and concept of 'Atom economy' with suitable examples and its calculation, Use of less hazardous chemicals, Catalysis.

Green solvents and Solvent less synthesis: Water, super critical fluids, PEG and basic ides of ionic liquids with few examples. Introduction to solvent less synthesis.

Alternative source of energy: Basic idea of using MAOS technique and use of Ultrasound Examples of some green synthesis in comparison with standard protocol: Synthesis of catechol, adipic acid and disodium imino diacetate.

Linear Free Energy Relationship & Hammett Equation **(7 L)**

Linear Free Energy Relationship: Introduction, Hammett Plots, Hammett equations: Substituent Constant (σ), Reaction Constant (ρ), Significance of σ and ρ, Concept of through- conjugation, Yukawa-Tsuno Equation. Use of Hammett Plots: Calculation of k and K values, Deviation from straight line plots- Acetolysis of 3-aryl-2-butyl brosylates, Cyclodehydration of 2-phenyltriarylmethanols.

Flavonoids **(10 L)**

Synthesis and characteristic reactions of coumarin and chromone scaffolds. Occurrence, systematic nomenclature, and general spectroscopic and chemical methods for the structure determination of flavonoids. Isolation and synthetic approaches to representative flavonoids and related natural products: apigenin, luteolin, quercetin, myricetin, quercetin 3-O-glucoside, vitexin, daidzein, butein, aureusin, cyanidin, cyanidin 7-O-arabinoside, and hirsutidin. Biosynthetic origin of flavonoids via the acetate and shikimate pathways.

Reference Books:

1. L. Finar, Organic Chemistry, vol-2, Pearson, 2009
2. S. K.Talapatra , B. Talapatra, Chemistry of Plant Natural Products, Springer, 2015
3. S. V. Bhat, B.A. Nagasampagi, M. Sivakumar, Chemistry of natural products, SpringerNarosa, 2005.
4. Bioorganic Chemistry: A Chemical Approach to Enzyme Action by H.Dugas and C.Penny
5. T. W. Graham Solomons, Organic Chemistry, John Wiley & Sons, 2016
6. Paula Yurkanis Bruice, Organic Chemistry, Pearson, 2017
7. O. P. Agarwal, Chemistry of Organic Natural Products, Vol. 1 & 2, Krishna Prakashan, 2014
8. Mann, Davidson, Hobbs, Banthorpe, Harborne, Natural Products: Their Chemistry and Biological Significance, Longman, 1994
9. V. K. Ahluwalia, Green Chemistry: Environmentally Benign Reactions, CRC Press, 2016
10. David L. Nelson and Michael M. Cox, Lehninger Principles of Biochemistry, W.H. Freeman, 2017
11. Jeremy M. Berg, John L. Tymoczko, Gregory J. Gatto, Biochemistry, W.H. Freeman, 2019
12. U. Satyanarayana and U. Chakrapani, Biochemistry, Elsevier, 2017

Paper: CEMMJ DC-702P/ CEMMJ MC-17P (Organic-VIII)

Practical: 30 Hours

Organic-VIII (Practical)

1. Estimation of phenol by bromination (Bromate-Bromide) method
2. Estimation of formaldehyde (Formalin)
3. Estimation of acetic acid in commercial vinegar
4. Estimation of urea (hypobromite method)
5. Estimation of saponification value of oil/fat/ester

Reference Books:

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009
2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
3. Nad A. K., Mahapatra B. and Ghosal A. An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
4. Ghosh S., Das Sharma M., Majumder D and Manna S. Chemistry in Laboratory, Santra Publication Pvt Ltd
5. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic
6. Analysis, CBS Publishers and Distributors.
7. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)
8. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson
9. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
10. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency
11. University Hand Book of Undergraduate Chemistry Experiments, edited by
12. Mukherjee, G. N., University of Calcutta
13. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
14. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

Paper: CEMMJ DC-703T/ CEMMJ MC-18T (Physical-VII)

Theory: 45 L (45 Hours)

Objectives

1. Understand the principles and applications of EPR and Mössbauer spectroscopy, including hyperfine interactions, isomer shift and quadrupole splitting, for probing spin and oxidation states.
2. Study excited-state and photoexcited processes, including the Born–Oppenheimer approximation, Jablonski diagram, Franck–Condon principle, fluorescence quenching, energy/electron transfer and principles of laser action.
3. Learn the fundamentals of group theory: symmetry elements and operations, point groups, matrix representations, character tables and the Great Orthogonality Theorem.
4. Apply group theoretical methods to molecular spectroscopy (IR and Raman activity), splitting of free-ion terms and construction of correlation diagrams.
5. Solve the Schrödinger equation for exactly solvable model systems: potential step and barrier, tunneling, harmonic oscillator, rigid rotator and the hydrogen atom.
6. Perform physical chemistry experiments on conductometric titration, distribution coefficient, coordination number, reaction kinetics and spectrophotometric estimation.

Learning Outcomes

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

1. Explain the principles of EPR and Mössbauer spectroscopy and interpret hyperfine splitting, isomer shifts and quadrupole interactions for 57Fe systems.
2. Describe radiative and non-radiative decay of excited states, static and dynamic fluorescence quenching, Marcus theory of electron transfer and solvation dynamics.
3. Identify symmetry elements and point groups of molecules and construct and use character tables and direct product representations.
4. Apply group theory to predict IR and Raman activity of normal modes and to analyze splitting of d1 and d2 free-ion terms using correlation diagrams.
5. Set up and solve the Schrödinger equation for potential steps, barriers, the quantum harmonic oscillator (including ladder operators), the rigid rotator and the hydrogen atom.
6. Conduct experiments such as conductometric titration of mixed halides, determination of distribution coefficients and coordination numbers, and spectrophotometric determination of copper.

EPR and Mössbauer Spectroscopy **(6 L)**

EPR Spectroscopy: Principle, comparison with NMR spectroscopy, line-width, nuclear hyperfine interactions, splitting constant, allowed transitions using energy diagram - $\dot{H}$, $\dot{C}H_3$, $Cu(acac)_2$, VO $(acac)_2$

Mössbauer Spectroscopy: Principle, Mössbauer energy levels with isomer shift, line-width, center shift, quadrupole interaction, quadrupole splitting and hyperfine interaction with reference to ^{57}Fe. Information of spin and oxidation states of Fe nuclei in variety of environments.

Excited State and Photoexcited Processes **(9 L)**

Nuclear and electronic motions in a molecule; Born–Oppenheimer approximation. Excitation of molecules—singlet and triplet states; radiative and non-radiative relaxations (Jablonski diagram construction); Franck–Condon principle. Absorption, emission and excitation spectra-mirror symmetry. Quenching of Fluorescence: Static and Dynamic. Excited state processes—proton transfer, electron transfer and energy transfer (Three distinct mechanisms). Marcus theory; Solvent effect in spectroscopy and solvation dynamics: Lippert–Mataga, Stokes shift, time-resolved Stokes shift. Non-linear optical processes (Susceptibility tensors, second-harmonic generation – an introductory approach); stimulated emission of radiation; principles of laser action and applications of lasers.

Group Theory **(18 L)**

Introduction to symmetry; symmetry elements and symmetry operations. Definition of a group; point symmetry groups; group multiplication tables; theorems of groups; conjugate elements and classes. Symmetry operators and their matrix representation; reducible and irreducible representations; equivalent representations; characters of representations. Great Orthogonality Theorem (Postulates only)— Construction of character tables, Mülliken symbols, Direct product representations, Interaction energy between states, Spectral intensity, Symmetries of the first excited states of normal modes and their application in spectroscopy (IR and Raman), Splitting of free-ion terms, Correlation diagrams ($d^1$and d^2 only).

Quantum Mechanics **(12 L)**

Exactly Solvable Systems-I: Potential step ($E>V_0$ and $E<V_0$), reflection and transmission coefficients; one-dimensional rectangular potential barrier, quantum mechanical tunneling; finite potential well, bound states (qualitative).

Exactly Solvable Systems-II: Quantum Harmonic Oscillator: one-dimensional Schrödinger Equation, wave functions, zero-point energy, classical turning points, expectation values, Hermite differential equation, algebraic/operator method (ladder operators). Rigid Rotator — angular momentum commutation relations, operators in spherical polar coordinates, quantization of L^2 and L_z, spherical harmonics.

Hydrogen Atom-Basics-Schrödinger Equation in spherical polar coordinates; separation of variables; angular part (spherical harmonics); energy quantization; quantum numbers; real wave functions.

Reference Books:

1. F. A. Cotton, Chemical Applications of Group Theory , John Wiley & Sons, 2008.
2. P. W. Atkins and R. S. Friedman, Molecular Quantum Mechanics , Oxford University Press, 2011.
3. I. N. Levine, Quantum Chemistry , Pearson, 2014.
4. D. A. McQuarrie, Quantum Chemistry , University Science Books, 2008.
5. C. N. Banwell and E. M. McCash, Fundamentals of Molecular Spectroscopy , McGraw-Hill Education, 2017.
6. J. M. Hollas, Modern Spectroscopy , John Wiley & Sons, 2004.
7. N. J. Turro, V. Ramamurthy and J. C. Scaiano, Principles of Molecular Photochemistry: An Introduction , University Science Books, 2009.
8. J. R. Lakowicz, Principles of Fluorescence Spectroscopy , Springer, 2006.
9. J. F. Watts and J. Wolstenholme, An Introduction to Surface Analysis by XPS and AES , John Wiley & Sons, 2019.
10. P. F. Bernath, Spectra of Atoms and Molecules , Oxford University Press, 2016.

Paper: CEMMJ DC-703P/ CEMMJ MC-18T (Physical-VII)

Practical: 30 Hours

Physical-VII (Practical)

1. Determination of the strength of mixed halides (HCl + KCl) by conductometric titration
2. Determination of distribution coefficient of benzoic acid between water and benzene.
3. Determination of coordination number of Cu(+2) in cuprammonium complex by partition method.
4. Comparison of the relative strength of HCl and H_2SO_4 by studying the kinetics of hydrolysis of an ester
5. Determination of copper by spectrophotometer Method

Reference Books:

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009
2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
3. Nad A. K., Mahapatra B. and Ghosal A. An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
4. Ghosh S., Das Sharma M., Majumder D and Manna S. Chemistry in Laboratory, Santra Publication Pvt Ltd
5. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic
6. Analysis, CBS Publishers and Distributors.
7. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)
8. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson
9. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
10. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency
11. University Hand Book of Undergraduate Chemistry Experiments, edited by
12. Mukherjee, G. N., University of Calcutta
13. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
14. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

Paper: CEMMJ DC-704T/ CEMMJ MC-19 (Research Methodology for Chemists)

Theory: 45 L (45 Hours)

Objectives

1. To make the students aware of fundamental but mandatory ethical practices in
2. chemistry.
3. To introduce the concept of data analysis.
4. To learn to perform literature survey in different modes.
5. To make the students aware of safety handling and safe storage of chemicals.
6. To make students aware about plagiarism and how to avoid it.
7. To teach the use of different e-resources.

Learning Outcomes

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

1. Follow ethical practices in chemistry
2. Do Data analysis
3. Literature survey in different modes
4. Use e-resources.
5. Avoid plagiarism, understand the consequences and how to avoid

Scope of Research **(3 L)**

Introduction, overview of research process: define research problem, review literature, formulate hypothesis, design research/experiment, collect and analyse data, interpret and report, scope and importance.

Scope of Research **(15 L)**

Print: Sources of information: Primary, secondary, tertiary sources; Journals: Journal abbreviations, Digital: Databases and their responsible use: Google Scholar, Web of science, Scopus, UGC INFONET, SciFinder, PubMed, ResearchGate, E-consortium, e-books; Search techniques: Phrase, Field, Boolean, Proximity, Concept, Limiting/Refining Search Results. Research metrics: Impact factor of Journal, h-index, i10 index, Altmetrics, Citation index. Author identifiers/or profiles: ORCID, Publons, Google Scholar, ResearchGate, VIDWAN

Communication in Science **(12 L)**

Types of technical documents: Full length research paper, book chapters, reviews, short communication, project proposal, Letters to editor, and thesis.

Thesis writing – different steps and software tools (Word processing, LaTeX, Chemdraw, Chemsketch etc) in the design and preparation of thesis, layout, structure (chapter plan) and language of typical reports, Illustrations and tables, bibliography, referencing: Styles (APA, Oxford etc), annotated bibliography, Citation management tools: Mendeley, Zotero and Endnote; footnotes. Oral presentation/posters – planning, software tools, creating and making effective presentation, use of visual aids, importance of effective communication, electronic manuscript submission, effective oral scientific communication and presentation skills.

Research and Publication ethics **(9 L)**

Scientific Conduct: Ethics with respect to science and research, Scientific Misconducts: falsification, fabrication and plagiarism, similarity index, software tools for finding plagiarism (Turnitin, Urkund etc), redundant publication

Publication Ethics: Introduction, COPE (Committee on Publication Ethics) guidelines; conflicts of interest, publication misconduct: problems that lead to unethical behaviour and vice versa, types, violation of publication ethics, authorship and contributorship, predatory publishers and journals

IPR - Intellectual property rights and patent law, commercialization, copy right, royalty, trade related aspects of intellectual property rights (TRIPS)

Statistical Analysis for Chemists **(6 L)**

Types of data, data collection-Methods and tools, data processing, hypothesis testing, Normal and Binomial distribution, tests of significance: t-test, F-test, chi- square test, ANOVA, multiple range test, regression and correlation.

Features of data analysis with computers and softwares -Microsoft Excel, Origin, SPSS

Paper: CEMMJ DC-704P/ CEMMJ MC-20P (Research Methodology for Chemists)

Practical: 30 Hours

Research Methodology for Chemists (Practical)

1. Collection of journal articles on a particular topic using Google Scholar and creating a database.
2. Collection of journal articles on a particular topic using Science Direct and creating a database.
3. Collection of journal articles on a particular topic using Scopus and creating a database.
4. Drawing chemical structure, reactions and mechanisms using Chemsketch or ISIS draw or any other software.
5. Collection of chemical structure using ChemSpider and creating a database.
6. Curve fitting using freely available softwares/apps (any one)
7. Making of power point presentation
8. Experimental learning of safe storage hazardous chemicals
9. Experimental learning of handling of hazardous chemicals
10. Technical writing on topics assigned.
11. Demonstration for checking of plagiarism using recommended software

Reference Books:

1. Kothari C.R. Garg Gaurav, Research Methodology –Methods and Techniques, New Age International Publisher,5th Edition, 2023
2. Kumar Ranjit, Research Methodology- A step-by step guide for beginners, SAGE Publications, 4th Edition, 2023
3. Dean, J. R., Jones, A. M., Holmes, D., Reed, R., Weyers, J. & Jones, A. (2011) Practical skills in chemistry. 2nd Ed. Prentice-Hall, Harlow.
4. Hibbert, D. B. & Gooding, J. J. (2006) Data analysis for chemistry. Oxford University Press.
5. Topping, J. (1984) Errors of observation and their treatment. Fourth Ed., Chapman Hall, London.
6. Harris, D. C. Quantitative chemical analysis. 6th Ed., Freeman (2007) Chapters 3-5.
7. Levie, R. de, how to use Excel in analytical chemistry and in general scientific data analysis. Cambridge Univ. Press (2001) 487 pages.
8. Chemical safety matters – IUPAC – IPCS, Cambridge University Press, 1992. OSU safety manual 1.01

SEMESTER-VIII

Paper: CEMMJ DC-801T/ CEMMJ MC-20T (Inorganic-VIII)

Theory: 45 L (45 Hours)

Objectives

1. Understand the synthesis, structure and bonding of ring, cage and cluster compounds including boranes, carboranes and metal carbonyl clusters using Wade's rules and polyhedral skeletal electron pair theory.
2. Study stereochemical non-rigidity and fluxional behaviour of organometallic complexes, isolobal and isoelectronic relationships, and bonding in metal–allyl, metal–alkyne, carbene and carbyne complexes.
3. Learn the molecular orbital treatment of octahedral and square-planar metal complexes, including ligand group orbitals, metal–ligand π interactions and charge-transfer transitions.
4. Explore advanced bioinorganic chemistry: ionophores, metal ion transport, bioenergetics, and the structure, function and mechanism of metalloenzymes such as carbonic anhydrase, carboxypeptidase, superoxide dismutase, catalase and peroxidase.
5. Understand photosynthesis, the role of chlorophyll and photosystems, vitamin B12 chemistry, metal ion toxicity, chelation therapy and metal complexes in medicine.
6. Carry out qualitative semi-micro analysis of mixtures containing six radicals including cations and anions derived from rare elements and insoluble materials.

Learning Outcomes

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

1. Apply Wade's rules and skeletal electron counting to predict the structures of higher boranes, carboranes, B–N clusters, metalloboranes and metal carbonyl clusters.
2. Interpret fluxional behaviour of organometallic complexes by 1H NMR, explain isolobal analogies, and describe bonding in Fischer and Schrock carbene/carbyne complexes and C–H activation by cyclometallation.
3. Construct simplified MO energy level diagrams for octahedral and square-planar complexes and explain the effect of metal–ligand π interaction on ligand field strength and charge-transfer spectra.
4. Describe the active-site structures and mechanisms of action of important metalloenzymes and the role of metal ions in biological transport and bioenergetics.
5. Explain the chemistry of photosynthesis and vitamin B12, the toxicity of As, Pb and Hg, chelation therapy and the medicinal applications of Pt, Rh, Ru and Au complexes.
6. Perform systematic qualitative analysis of complex mixtures containing six radicals, including rare elements (Ti, Zr, Ce, V, Mo, W) and insoluble compounds, with proper interpretation of the chemistry involved.

Ring, Cage and Cluster Compounds (16 L)

Diborane—synthesis and structure, nomenclature and the chemistry of boranes. Polyhedral skeletal electron pair theory (PSEPT)—Wade's rule, skeletal electron counting for higher boranes, carboranes and B-N clusters, vertices and cage structures, '*styx*' rule (Lipscomb's topological concept)-equation of balance, structures of higher boranes (neutral, cationic and anionic), metalloboranes and metallocarboranes. Structures of low nuclearity and high nuclearity carbonyl clusters—valence electron counting and metal–metal bonds.

Organometallic Chemistry-II (10 L)

Stereochemical non-rigidity and fluxional behaviour of $[Ti(\eta 1\text{-}Cp)_2(\eta 5\text{-}Cp)_2]$ (characterization with ^1H NMR). Isolobal and isoelectronic relationships with examples (MO approach). Structure and bonding (evidence from IR/bond length data) in metal-allyl, metal-alkyne complexes with typical examples: $[Ni(\eta 3\text{-}C_3H_5)_2]$, $[Co_2(CO)_6(C_2H_2)]$, $[(PPh_3)_2Pt(C_2Ph_2)]$ and

[$PtCl_2(ArNH_2)(C_2But_2)$]. MO diagram of ferrocene. C–H bond activation by organometallic complexes – cyclometallation reactions. Metal-Carbon bonding in Fischer and Schrock type carbene and carbyne complexes.

Molecular Orbital Treatment for Metal Complexes (7 L)

LCAO-MO approach for octahedral and square planar complexes: symmetry classification of metal valence orbitals and ligand group orbitals (LGOs) in O_h and D_{4h} fields; construction of qualitative MO energy level diagrams for σ-bonded and σ+π-bonded octahedral complexes; correlation of octahedral and square planar diagrams by descent in symmetry. Symmetry labels of metal–ligand σ and π molecular orbitals; effect of π-acceptor (CO, CN^-) and π-donor (halide, oxo) ligands on Δ_o and orbital energies; MO rationalization of the spectrochemical series and ligand field strength variations. Qualitative interpretation of charge-transfer transitions—ligand-to-metal (LMCT) and metal-to-ligand (MLCT)—using MO energy level diagrams; comparison with crystal field predictions.

Bioinorganic Chemistry-II (12 L)

Ionophores, Metal ion Transport (Na^+/K^+ ion). Na^+/K^+ ion pump. Bioenergetic principle and role of ATP. Active site structure, function, mechanism of action and synthetic model system for various metalloenzymes: carbonic anhydrase, carboxypeptidase, superoxide dismutase, catalase, peroxidase. Photosynthesis, Chlorophyll, PS-I, PS-II, photosynthetic electron transport chain. Vitamin B_{12}. Toxicity of metal ions (As, Pb, Hg) and their effects, LD_{50} (basic idea only), chelation therapy, Pt, Rh, Ru and Au complexes in medicine (examples only). Metal dependent diseases – Wilson’s and Alzheimer’s diseases

Reference Books:

1. J. E. Huheey , E. A. Keiter, R. L. Keiter and O. K. Medhi, Inorganic Chemistry: Principles of Structure and Reactivity , Pearson, 2006
2. Gary L. Miessler, Paul J. Fischer and Donald A. Tarr, Inorganic Chemistry , Pearson, 2017.
3. F. A. Cotton, G. Wilkinson, C. A. Murillo and M. Bochmann, Advanced Inorganic Chemistry , Wiley, 1999
4. A. K. Das, Fundamental Concepts of Inorganic Chemistry , CBS Publishers & Distributors, 2014.
5. Satya Prakash, G. D. Tuli, S. K. Basu and R. D. Madan, Advanced Inorganic Chemistry , S. Chand, 2018.
6. A. Syamal and R. L. Dutta, Elements of Magnetochemistry , S. Chand & Company.
7. B. N. Figgis and M. A. Hitchman, Ligand Field Theory and Its Applications , Wiley-VCH, 2000.
8. B. D. Gupta and A. J. Elias, Basic Organometallic Chemistry: Concepts, Syntheses and Applications , Universities Press, 2013
9. Robert H. Crabtree, The Organometallic Chemistry of the Transition Metals , Wiley, 2019.
10. Rosette M. Roat-Malone, Bioinorganic Chemistry: A Short Course , Wiley, 2007.
11. K. Hussain Reddy, Bioinorganic Chemistry , New Age International, 2008.
12. A. Earnshaw and N. N. Greenwood, Chemistry of the Elements , Butterworth-Heinemann, 2012

Paper: CEMMJ DC-801P/ CEMMJ MC-20P (Inorganic-VIII)

Practical: 30 Hours

Inorganic-VIII (Practical)

Qualitative/semimicro analysis of mixtures containing *six* radicals with composition.

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

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

Cation and anion radicals derived from some rare elements: Ti^{4+}, Zr^{4+}, Ce^{4+}, V^{5+}, Mo^{6+}, W^{6+}.

Insoluble Materials: Al_2O_3(ig), Fe_2O_3(ig), Cr_2O_3(ig), $SrSO_4$, $BaSO_4$, CaF_2, $PbSO_4$, TiO_2, ZrO_2, CeO_2.

The unknown mixture should contain two cations/anions derived from rare elements.

Reference Books:

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009
2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
3. Nad A. K., Mahapatra B. and Ghosal A. An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
4. Ghosh S., Das Sharma M., Majumder D and Manna S. Chemistry in Laboratory, Santra Publication Pvt Ltd
5. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic
6. Analysis, CBS Publishers and Distributors.
7. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)
8. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson
9. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
10. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency
11. University Hand Book of Undergraduate Chemistry Experiments, edited by
12. Mukherjee, G. N., University of Calcutta
13. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
14. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

Paper: CEMMJ DC-802T/ CEMMJ MC-20T (Physical-VIII)

Theory: 45 L (45 Hours)

Objectives

1. Understand the experimental and theoretical aspects of fast and ultrafast reaction kinetics, including stopped-flow, relaxation methods, flash photolysis and magnetic resonance line-shape analysis.
2. Study complex kinetic behaviour such as autocatalysis, non-linear dynamics and oscillating chemical systems, and the fundamentals of electrode kinetics including the Butler–Volmer and Tafel equations.
3. Explore surface chemistry and biophysical chemistry: curved surfaces, adsorption on solids, micelles, reverse micelles and microemulsions, thermodynamics of micellization and hydrophobic interactions.
4. Understand water structure, protein stabilization and denaturation, protein–lipid interactions and transport of ions and small molecules through membranes and ion channels.
5. Obtain the full analytical solution of the hydrogen atom, and learn approximation methods: variation theorem, linear variation principle and time-independent perturbation theory with application to the helium atom.
6. Study the electronic structure of diatomic molecules through the Born–Oppenheimer approximation, LCAO–MO and valence bond treatments, and perform related physical chemistry experiments.

Learning Outcomes

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

1. Describe and apply transient kinetic techniques (stopped-flow, temperature-jump, pressure-jump, flash photolysis) for the study of rapid reactions and interpret luminescence and energy-transfer processes.
2. Analyze oscillating reactions such as the Belousov–Zhabotinsky system and Lotka–Volterra models, and interpret electrode kinetics using Tafel plots derived from the Butler–Volmer equation.
3. Apply the Young–Laplace and Kelvin equations to curved surfaces and explain micellization, microemulsions and their applications.
4. Explain hydrophobic hydration, hydrophobic interactions and their role in protein stabilization/denaturation and membrane transport phenomena.
5. Solve the radial and angular parts of the hydrogen atom problem and compute average and most probable distances, and apply variation and perturbation methods to simple atoms and model systems.
6. Describe bonding in diatomic molecules using LCAO–MO and VB approaches, and carry out experiments on adsorption isotherms, critical solution temperature, CMC determination and kinetics of ester hydrolysis.

Chemical Kinetics- III (Fast and Ultrafast Reaction Kinetics) (13 L)

Experimental and theoretical aspects of rapid kinetic processes, including luminescence phenomena and energy-transfer mechanisms. Principles and applications of transient kinetic techniques: stopped-flow, relaxation methods (temperature-jump, pressure-jump), magnetic resonance line-shape analysis, and flash photolysis. Complex kinetic behaviour: autocatalysis, non-linear dynamics, oscillating chemical systems (Belousov–Zhabotinsky reaction), and Lotka–Volterra prey–predator models. Fundamentals of electrode kinetics: the Nernst equation, Butler–Volmer equation, Tafel equation, and their graphical representation via Tafel plots.

Surface Chemistry and Biophysical Chemistry (12 L)

Surface tension; curved surfaces; Young–Laplace and Kelvin equations. Adsorption on solids; micelles, reverse micelles and microemulsions; thermodynamics of micellization; applications of micelles and microemulsions. Hydrophobic hydration; micelle formation; hydrophobic interaction; stabilization and denaturation of proteins. Water structure; alternate theory of protein denaturation; protein–lipid interaction. Transport of ions and small molecules through membranes and ion channels.

Quantum Chemistry-II (20 L)

Hydrogen Atom-Full Analytical Solution: solution of radial equation (Laguerre polynomials); solution of angular part (spherical harmonics); quantization of energy; real wave functions; average and most probable distances.

Approximation Methods: variation theorem (applications to particle-in-box, harmonic oscillator, hydrogen atom); linear variation principle; secular determinant; time-independent perturbation theory (up to second order in energy); application to the helium atom; anti-symmetry and exclusion principle; Slater determinantal wave functions.

Electronic Structure of Diatomic Molecules: Born-Oppenheimer approximation; nuclear motion in diatomics; LCAO-MO approach (H_2^+ ground state; H_2); bonding and antibonding orbitals; VB treatment; electronic terms of diatomic molecules.

Reference Books:
1. Atkins, P. W. & Paula, J. de, Atkins' Physical Chemistry, Oxford University Press.
2. Atkins, P. W. & Friedman, R. S., Molecular Quantum Mechanics, Oxford University Press.
3. Levine, I. N., Quantum Chemistry, Pearson.
4. McQuarrie, D. A., Quantum Chemistry, University Science Books.
5. Laidler, K. J., Chemical Kinetics, Pearson Education.
6. Pilling, M. J. & Seakins, P. W., Reaction Kinetics, Oxford University Press.
7. Adamson, A. W. & Gast, A. P., Physical Chemistry of Surfaces, Wiley-Interscience.
8. Cantor, C. R. & Schimmel, P. R., Biophysical Chemistry, W.H. Freeman.
9. Chandra, A. K., Introductory Quantum Chemistry, Tata McGraw-Hill.
10. Prasad, R. K., Quantum Chemistry, New Age International.
11. K L Kapoor, Physical Chemistry (Vol. III & IV), McGraw Hill.
12. Rakshit, P.C., Physical Chemistry, Sarat Book House.

Paper: CEMMJ DC-802P/ CEMMJ MC-20P (Physical-VIII)

Practical: 30 Hours

Physical-VIII (Practical)

1. Study the adsorption of acetic acid on charcoal and analysis of the data on the basis of Langmuir and Freundlich adsorption isotherms.
2. Determination of critical solution temperature of phenol-water system and study the effect of electrolyte on CST.
3. Determination of co-ordination number of Cu^{+2} in cuprammonium complex by partition method.
4. Determination of HCl and KCl in a mixed halide by conductometry.
5. Determination of the CMC of a surfactant (Sodium Lauryl Sulfate) by conductometry.
6. Determination of the rate constant of basic hydrolysis of ethyl acetate by conductivity measurements

Reference Books:
1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.
2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
3. Nad A. K., Mahapatra B. and Ghosal A., An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
4. Ghosh S., Das Sharma M., Majumder D. and Manna S., Chemistry in Laboratory, Santra Publication Pvt Ltd.
5. Viswanathan, B. & Raghavan, P.S., Practical Physical Chemistry, Viva Books (2009).
6. Palit, S.R. & De, S. K., Practical Physical Chemistry, Science Book Agency.
7. Levitt, B. P. edited, Findlay's Practical Physical Chemistry, Longman Group Ltd.
8. Gurtu, J. N. & Kapoor, R., Advanced Experimental Chemistry, S. Chand & Co. Ltd.

Paper: CEMMJ DC-803T/ CEMMJ MC-21T (Advanced Analytical Instrumental Techniques)

Theory: 45 L (45 Hours)

Objectives

1. Understand the fine structure of one-electron and many-electron atoms, spin–orbit interaction, Russell–Saunders coupling, term symbols, and the Zeeman and Paschen–Back effects.
2. Learn the principles and applications of modern electroanalytical techniques including cyclic voltammetry, polarography, anodic stripping voltammetry, amperometry, coulometry and electrogravimetry.

3. Study 13C NMR spectroscopy: chemical shifts, spin–spin coupling, decoupling techniques and spectral editing using DEPT-135 for structure elucidation of organic compounds.
4. Understand the principles, instrumentation, ionization methods and fragmentation patterns in mass spectrometry, including the McLafferty rearrangement, for structural analysis of organic molecules.
5. Apply spectrophotometric and colorimetric methods for the determination of ligand field parameters (10Dq, λmax) and quantitative estimation of metal ions.
6. Develop practical skills in systematic qualitative analysis of organic liquids including derivatization and literature-based identification.

Learning Outcomes

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

1. Derive atomic term symbols using the L–S coupling scheme, apply Hund's rules to determine ground-state terms, and interpret Zeeman and Paschen–Back splitting patterns using the Landé g-factor.
2. Interpret cyclic voltammograms for reversible, quasi-reversible and irreversible processes using the Randles–Sevcik equation, and explain polarographic analysis using the Ilkovic equation and half-wave potentials.
3. Assign 13C NMR signals of aliphatic and aromatic compounds, distinguish CH3, CH2, CH and quaternary carbons using decoupling and DEPT-135 data, and elucidate structures from 13C spectral information.
4. Analyze mass spectra of alkanes, ethers, alcohols and carbonyl compounds, identify molecular ion, metastable and isotope peaks, and rationalize fragmentation pathways including the McLafferty rearrangement.
5. Determine 10Dq and λmax of coordination compounds and carry out colorimetric estimation of Fe, Mn, P and mixed-ion systems spectrophotometrically.
6. Perform systematic qualitative analysis of an unknown organic liquid, identify functional groups, prepare suitable crystalline derivatives and confirm identity through literature survey.

(Group-A)

Atomic Absorption Spectroscopy (AAS) and Atomic Emission Spectroscopy (AES)

(12 L)

Principles of atomic line spectra and Beer–Lambert law for atoms; AAS instrumentation—source (hollow cathode, electrodeless discharge), monochromator, detector, flame (air–acetylene, nitrous oxide–acetylene) and burner designs; AES instrumentation—ICP torch, nebulizer and polychromator. Atomization and sample introduction—flame nebulization, graphite furnace, cold vapour and hydride generation (arsine, AsH_3, via sodium borohydride reduction). Chemical interferences—refractory formation, ionization and matrix effects; removal by releasing agents, protective chelators, ionization suppressors and matrix modifiers. Background correction—continuum-source, Zeeman-effect and Smith–Hieftje methods. Quantitative methods—calibration curve, standard additions, detection limits; trace estimation of iron, calcium (phosphate interference and elimination) and arsenic (as AsH_3) in water. Comparison of AAS, AES and ICP-MS. Numerical problems in calibration, interference correction and detection-limit calculations.

Electrochemical Analysis (11 L)

Electrochemical Analyses: Mass transport and electrode kinetics underlying voltametric methods; cyclic voltammetry for reversible, quasi-reversible and irreversible processes, peak interpretation and the Randles–Sevcik equation. Polarography using the dropping mercury electrode, diffusion current, half-wave potential and the Ilkovic equation. Anodic stripping voltammetry involving preconcentration and anodic dissolution for trace metal determination. Amperometric methods including the Clark oxygen electrode and enzymatic biosensors. Coulometric analysis based on Faraday's laws, controlled-potential and controlled-current coulometric titrations.

Electrogravimetric determination of metals by controlled-potential electrolytic deposition, separation and weighing. Numerical problems in voltammetric, coulometric and electrogravimetric calculations.

(Group-B)

^{13}C Spectroscopy (11 L)

^{13}C NMR Spectroscopy: Chemical shift range of ^{13}C NMR (δ 0–220) and factors affecting carbon chemical shifts. Spin–spin coupling in ^{13}C spectra and principles of decoupling; broadband proton decoupling, gated decoupling and inverse-gated decoupling techniques. Assignment of CH_3, CH_2, CH and quaternary carbons in proton-decoupled ^{13}C NMR of aliphatic and aromatic systems. Preliminary principles of DEPT-135 for spectral editing and multiplicity determination. ^{13}C NMR spectra of isomeric dichlorobenzenes, toluene, cyclohexanol and cyclohexanone; structure elucidation using ^{13}C chemical shifts, coupling patterns and DEPT-135 data. Numerical problems involving ^{13}C NMR and DEPT-135.

Mass Spectroscopy (11 L)

Principles, instrumentation and applications of mass spectrometry. Methods of generation of ions in EI and CI. Detection of ions, ion analysis, ion abundance, molecular ion peak, metastable peak, isotopes, ion-molecule interaction and analysis of fragmentation patterns for: Alkane (linear & branched), ethers (with 1^0, 2^0, 3^0 alkyl chain), alcohols (1^0, 2^0, 3^0), benzyl alcohol, carbonyl compounds, toluene, xylenes; McLafferty rearrangement.

Reference Books:

1. Skoog, D. A., Holler, F. J. & Crouch, S. R., Principles of Instrumental Analysis, Cengage Learning.
2. Skoog, D. A., West, D. M., Holler, F. J. & Crouch, S. R., Fundamentals of Analytical Chemistry, Cengage Learning.
3. Willard, H. H., Merritt, L. L., Dean, J. A. & Settle, F. A., Instrumental Methods of Analysis, CBS Publishers.
4. Harris, D. C., Quantitative Chemical Analysis, W.H. Freeman.
5. Christian, G. D., Dasgupta, P. K. & Schug, K. A., Analytical Chemistry, Wiley.
6. Bard, A. J. & Faulkner, L. R., Electrochemical Methods: Fundamentals and Applications, Wiley.
7. Banwell, C. N. & McCash, E. M., Fundamentals of Molecular Spectroscopy, McGraw-Hill Education.
8. Silverstein, R. M., Webster, F. X., Kiemle, D. J. & Bryce, D. L., Spectrometric Identification of Organic Compounds, Wiley.
9. Pavia, D. L. et al., Introduction to Spectroscopy, Cengage Learning.
10. Kemp, W., Organic Spectroscopy, Palgrave (Macmillan).
11. Kalsi, P. S., Spectroscopy of Organic Compounds, New Age International.
12. Sharma, Y. R., Elementary Organic Spectroscopy, S. Chand & Company.

Paper: CEMMJ DC-803P/ CEMMJ MC-21P (Advanced Analytical Instrumental Techniques)

Practical: 30 Hours

Spectral Analysis: (i). Determination of 10Dq and (ii). Determination of λ_{max}

a) $[Cu(acac)_2]$
b) $[Ni(en)_3]Cl_2 . 2H_2O$
c) *cis*-$K[Cr(C_2O_4)_2(H_2O)_2]$

Colorimetric estimation

1. Iron as Fe(III)- thiocyanate complex
2. Manganese as permanganate
3. Phosphorous as phosphomolybdate blue complex
4. Fe(II) and Fe(III) mixture as Fe(II)-1,10-phenanthroline complex
5. MnO_4^- - $Cr_2O_7^{2-}$ mixture

***Note**: i) The experiments can be done spectrophotometrically / colorimetrically.*
ii) Graphs should be drawn by MS-Excel.

Systematic qualitative analysis of an organic liquid and its identification by derivatization and literature survey.

[Recording of the boiling point of the sample, Preliminary tests, Lassaigne's Test, Miscibility test and classification, Detection of nitrogenous functional groups (amide, anilide, nitrile, nitro,aromatic amines – 1^0, 2^0 and 3^0), Detection of non-nitrogenous functional groups (Phenolic-OH, carboxylic acid, carbonyl, ester, alcohol), Distinction between aldehyde and ketones to be performed, Literature survey, Preparation of suitable solid derivatives (crystallization and determination of melting point of the derivative included)]

At least 3 unknown to be reported in the practical notebook.

Reference Books:

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.
2. Svehla, G. & Sivasankar, B., Vogel's Qualitative Inorganic Analysis, 7th Ed., Pearson, 2012.
3. Furniss, B. S., Hannaford, A. J., Smith, P. W. G. & Tatchell, A. R., Vogel's Textbook of Practical Organic Chemistry, 5th Ed., Pearson.
4. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
5. Nad A. K., Mahapatra B. and Ghosal A., An Advanced Course in Practical Chemistry, New Central Book Agency (P) Ltd.
6. Ghosh S., Das Sharma M., Majumder D. and Manna S., Chemistry in Laboratory, Santra Publication Pvt Ltd.
7. Harris, D. C., Quantitative Chemical Analysis, 6th Ed., Freeman (2007).
8. Skoog, D. A., Holler, F. J. & Crouch, S. R., Principles of Instrumental Analysis, Cengage Learning.
9. Gurtu, J. N. & Kapoor, R., Advanced Experimental Chemistry, S. Chand & Co. Ltd.

Paper: CEMMJ DC-804/ CEMMJ MC-23 (TERM PAPER)-FIELD REPORT/ LITERATURE REVIEW/BOOK REVIEW

Term Paper: 60 L (60 Hours)

Evaluation Scheme:

- Continuous Evaluation (Term Work): 50 marks
- Presentation & Viva-Voce: 25 marks

This course is intended to introduce undergraduate chemistry students to the fundamentals of scientific inquiry, documentation, and communication. It emphasizes the development of analytical thinking, literature comprehension, experimental or field-based investigation, and academic writing consistent with accepted standards in chemical sciences. The course serves as a preparatory platform for advanced coursework, project work, and postgraduate studies in chemistry.

Objectives

1. Identify and formulate chemistry-related academic problems.
2. Apply appropriate theoretical, experimental, or analytical methodologies.
3. Compile, interpret, and present chemical data and literature.
4. Prepare a structured academic document adhering to professional scientific standards.
5. Communicate scientific ideas effectively through oral presentation and viva-voce.

Learning Outcomes

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

1. Demonstrate the ability to select and justify a chemistry-specific research topic.
2. Analyze chemical literature or data using appropriate scientific reasoning.
3. Present chemical concepts using equations, reaction mechanisms, and data representations.
4. Produce an original academic document with proper citation and ethical compliance.

MODES OF STUDY (ONE TO BE SELECTED)

Students shall opt for one of the following modes, subject to departmental approval:

Term Paper: Theoretical or analytical study on a chemistry-related topic involving critical discussion of concepts, mechanisms, or applications.

1. Literature Review: A critical review of peer-reviewed chemistry research articles focusing on trends, methodologies, and outcomes in a defined sub-discipline.
2. Field / Laboratory Report: Documentation and analysis of experimental, analytical, environmental, or industrial field work employing undergraduate-level chemical techniques.
3. Book Review: Critical review of an advanced standard chemistry textbook or monograph, focusing on conceptual depth, organization, and scientific contribution.

COURSE CONTENT AND TIME ALLOCATION (60 HOURS)

Unit	Description	Hours
I	Research methodology and scientific ethics in chemistry	**10**
II	Topic identification and proposal development	**8**
III	Literature survey, experimentation, or field investigation	**15**
IV	Scientific writing, data analysis, and interpretation	**15**
V	Finalization, revision, and presentation preparation	**12**
Total		**60**

EXECUTION FRAMEWORK

(a) **Topic Approval**

Each student shall submit a formal proposal outlining the title, objectives, methodology, and preliminary references. Approval shall be granted based on academic relevance and feasibility.

(b) **Supervised Academic Work**

Students shall undertake systematic literature review, experimental work, or field investigation under departmental guidance.

(c) **Drafting and Revision**

Interim drafts shall be reviewed to ensure scientific accuracy, coherence, and compliance with academic standards.

(d) **Final Submission**

The completed work shall be submitted in both hard and soft copy in the prescribed format.

DOCUMENT FORMAT AND TECHNICAL SPECIFICATIONS

- Length: 25–30 pages
- Font: Times New Roman, 12 pt
- Line spacing: 1.5
- Figures, tables, and chemical schemes: Properly labeled
- Referencing style: ACS (preferred)
- Plagiarism threshold: As per university regulations (normally ≤20%)

ASSESSMENT SCHEME

A] Continuous Evaluation (50 Marks)

Component	Marks
Topic relevance and objectives	**5**
Methodology and literature handling	**10**
Scientific content and depth	**15**
Data analysis and interpretation	**10**
Referencing and originality	**10**
Total	**50**

B] Presentation & Viva-Voce (25 Marks)

Mode: Oral presentation followed by viva-voce Duration: Presentation (8–10 minutes) + Viva-voce (5 minutes)

Evaluation Criteria and Marks Distribution

Sl. **No.**	**Evaluation Component**	**Description**	**Marks**
1	Conceptual Clarity	Understanding of fundamental chemical concepts, principles, reactions, mechanisms, or theories related to the topic	**8**
2	Organization & Presentation Quality	Logical structure of presentation, clarity of slides/visuals, use of equations, schemes, graphs, and overall coherence	**5**
3	Scientific Understanding & Application	Ability to explain data, results, interpretations, applications, and limitations of the study	**7**
4	Response to Questions (Viva-Voce)	Accuracy, confidence, and depth in answering questions during viva-voce	**5**
Total			**25**

EVALUATION NOTE (FOR RECORD):

- Emphasis shall be placed on chemical accuracy, scientific reasoning, and clarity of expression.
- Use of appropriate chemical representations (equations, mechanisms, spectra, tables) shall be positively weighted.
- Evaluation shall be conducted by internal examiners as per university norms.

VIVA-VOCE GUIDELINES (CHEMISTRY)

The viva-voce shall assess:

- Understanding of chemical principles involved
- Ability to explain reactions, mechanisms, or data
- Awareness of applications and limitations
- Academic integrity and originality

MAINTENANCE OF ACADEMIC RECORDS

Departments shall maintain records of:

- Approved proposals
- Plagiarism reports
- Final submissions
- Viva-voce evaluation sheets

These records shall be preserved for academic audit and accreditation purposes.

RECOMMENDED REFERENCE SOURCES (As Model Examples)

- Atkins, P. Physical Chemistry
- Clayden, J. et al. Organic Chemistry
- Lee, J. D. Concise Inorganic Chemistry
- Skoog et al. Principles of Instrumental Analysis
- ACS and RSC journal