Draft Syllabus of

3-Year/4-Year B.Sc. Chemistry

(Disciplinary Minor Course)

Revised 2024

As Per NEP 2020

(Up-to 8th Semester)

University of Gourbanga

Malda – 732 101

West-Bengal

Semester Wise Course Distribution

Semester	Interdisciplinary Minor Course	Level
SEM-I	**DCM-10**: Inorganic-I + Organic-I	**100 level**
SEM-II	**DCM -20**: Inorganic Chemistry-II + Physical Chemistry-I	
SEM-III	**DCM -30**: Physical Chemistry-II + Organic Chemistry-II	**200 level**
SEM-IV	**DCM -40**: Inorganic Chemistry-III + Organic Chemistry-III	
SEM-V	**DCM -50**: Physical Chemistry-III + Environmental Chemistry	**300 level**
SEM-VI	**DCM -60**: Organic Chemistry-IV + Inorganic Chemistry-IV	
SEM-VII	**DCM -70**: Analytical and Industrial Chemistry	**400 Level**
SEM-VIII	**DCM -80**: Physical Chemistry-IV + Basic Nano Technology	

Chemistry (Disciplinary Minor)
[Credit: Theory -03, Practical – 01], T=Theory, P=Practical

SEMESTER-I

Paper: **DCM-10 (Inorganic Chemistry-I + Organic Chemistry-I)**
Theory: 45 L (45 Hours)

Objectives

1. Understand Bohr's theory and atomic spectra of hydrogen.
2. Learn quantum numbers and the Pauli exclusion principle.
3. Analyze chemical periodicity and element classification.
4. Explore electronic displacements and bond cleavage in organic chemistry.
5. Study types of isomerism, chirality, and optical activity.
6. Examine aliphatic hydrocarbons and their reactions mechanisms.
7. Conduct practical estimations of inorganic compounds.
8. Identify pure organic compounds through experimentation.

Learning Outcomes

After completion of this course the student will learn to:

1. Bohr's theory and atomic spectra for hydrogen atoms.
2. Quantum numbers and their significance.
3. Pauli's exclusion principle and Hund's rule.
4. Electronic configuration and Aufbau principle.
5. Classification of elements based on electronic configuration.
6. Variations of atomic, ionic radii, ionization potential, electron affinity, and electronegativity.
7. Inductive effect, resonance and hyperconjugation in organic chemistry.
8. Different types of organic isomerism and chirality concepts.
9. Preparations and reactions of alkanes, alkenes, and alkynes.
10. Practical skills in inorganic and organic compound analysis.

Inorganic Chemistry-I

Atomic Structure (12 L)

Bohr's theory for hydrogen atom (simple mathematical treatment); Atomic spectra of hydrogen and Bohr's model; Sommerfeld's model; Quantum numbers and their significance; Pauli's exclusion principle; Hund's rule; Electronic configuration of many-electron atoms, Aufbau principle and its limitations.

Chemical Periodicity (10 L)

Classification of elements based on electronic configuration; General characteristics of s-, p-, d- and f-block elements. Positions of hydrogen and noble gases in the periodic table. Atomic and ionic radii, ionization potential, electron affinity, and electronegativity; periodic and group- wise variation of above properties in respect of s- and p- block elements

Organic Chemistry-I

Fundamentals of Organic Chemistry (05 L)

Electronic displacements: Inductive effect, resonance and hyperconjugation; cleavage of bonds: homolytic and heterolytic; structure of organic molecules based on VBT; nucleophiles and electrophiles; reactive intermediates:

carbocations, carbanions and free radicals

Basic Organic Stereochemistry **(05 L)**

Different types of isomerism; geometrical and optical isomerism; concept of chirality and optical activity (up to two carbon atoms); asymmetric carbon atom; elements of symmetry (plane and centre); interconversion of Fischer and Newman representations; enantiomerism and diastereomerism, mesocompounds; *threo* and *erythro*, D- and L-, *cis* and *trans* nomenclature; CIP Rules: R/S (up to 2 chiral carbon atoms) and *E/Z* nomenclature.

Aliphatic Hydrocarbons **(13 L)**

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structures.

Alkanes (up to 5 Carbons): Preparation: catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis, from Grignard reagent. Reactions: mechanism for free radical substitution: halogenation.

Alkenes: (up to 5 Carbons): Preparation: elimination reactions: dehydration of alcohols and dehydrohalogenation of alkyl halides; *cis*- alkenes (partial catalytic hydrogenation) and *trans*- alkenes (Birch reduction). Reactions: *cis*-addition (alkaline $KMnO_4$) and *trans*-addition (bromine) with mechanism, addition of HX [Markownikoff's (with mechanism) and *anti*-Markownikoff's addition], hydration, ozonolysis, oxymercuration-demercuration and hydroboration-oxidation reaction.

Alkynes: (up to 5 Carbons): Preparation: acetylene from CaC_2 and conversion into higher alkynes; by dehalogenation of tetra halides and dehydrohalogenation of vicinal dihalides. Reactions: formation of metal acetylides, addition of bromine and alkaline $KMnO_4$, ozonolysis and oxidation with hot alkaline $KMnO_4$.

Practical:

Inorganic

1. Estimation of sodium hydroxide and sodium carbonate present in a mixture.
2. Estimation of oxalic acid by titrating it with $KMnO_4$.

Organic

Identification of a pure organic compound

1. Solid compounds: oxalic acid, tartaric acid, succinic acid, resorcinol, urea, glucose, benzoic acid and salicylic acid.
2. Liquid Compounds: methyl alcohol, ethyl alcohol, acetone, aniline, dimethylaniline, benzaldehyde, chloroform and nitrobenzene.

Reference Books:

1. Lee, J.D. Concise Inorganic Chemistry ELBS, 1991.
2. Cotton, F.A., Wilkinson, G. & Gaus, P.L. Basic Inorganic Chemistry, 3rd ed., Wiley.
3. Douglas, B.E., McDaniel, D.H. & Alexander, J.J. Concepts and Models in Inorganic Chemistry, John Wiley & Sons.
4. Huheey, J.E., Keiter, E.A., Keiter, R.L. & Medhi, O.K. Inorganic Chemistry: Principles of Structure and Reactivity, Pearson Education Ind
5. Sethi, A. Conceptual Organic Chemistry; New Age International Publisher.
6. Parmar, V. S. A Text Book of Organic Chemistry, S. Chand & Sons.
7. Madan, R. L. Organic Chemistry, S. Chand & Sons.
8. Wade, L. G., Singh, M. S., Organic Chemistry.
9. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
10. Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
11. Eliel, E. L. & Wilen, S. H. Stereochemistry of Organic Compounds, Wiley: London, 1994.
12. Sengupta, Subrata. Basic Stereochemistry of Organic molecules

SEMESTER-II

Paper: **DCM-20 (Inorganic Chemistry-II + Physical Chemistry-I)**
Theory: 45 L (45 Hours)

Objectives

1. Understand balancing redox reactions using oxidation number and ion-electron methods.
2. Explore ionic bonding, lattice energy, and the Born-Haber cycle.
3. Analyze the kinetic theory of gases and real gas behavior using van der Waals equation.
4. Study surface tension and viscosity principles in liquid states.
5. Examine crystal structures, Bravais lattices, and crystallography laws.
6. Conduct practical estimations and measurements in inorganic and physical chemistry.

Learning Outcomes

After completion of this course the student will learn to:

1. Balance redox reactions using oxidation number and ion-electron methods.
2. Understand standard and formal electrode potentials.
3. Identify and use redox indicators and conduct redox titrations.
4. Describe characteristics and significance of ionic bonding.
5. Explain lattice and solvation energies in ionic compound stability.
6. Apply the Born-Haber cycle to ionic compounds.
7. Analyze gas behavior using kinetic theory and van der Waals equation.
8. Explain liquid properties like surface tension and viscosity.
9. Understand crystal systems and laws of Crystallography.
10. Conduct practical titrations and measure surface tension and viscosity.

Inorganic Chemistry-II

Redox Reactions **(07 L)**

Balancing of equations by oxidation number and ion-electron method, Standard electrode potential, formal potential, redox indicator and redox titrations.

Acids and Bases **(08 L)**

Brönsted–Lowry concept, conjugate acids and bases, relative strengths of acids and bases, effects of substituent and solvent, differentiating and levelling solvents, Lewis Acid-Base concept, classification of Lewis acids and bases, Lux-Flood concept and solvent system concept, hard and soft acids and bases (HSAB concept), applications of HSAB process, acidity and basicity of common organic compounds

Ionic Bonding (08 L)

Ionic Bonding: General characteristics of ionic bonding. Energy considerations in ionic bonding, lattice energy and solvation energy and their importance in the context of stability and solubility of ionic compounds. Statement of Born-Landé equation for calculation of lattice energy, Born-Haber cycle and its applications, polarizing power and polarizability. Fajan's rules, ionic character in covalent compounds, bond moment, dipole moment and percentage ionic character.

Physical Chemistry-I

Kinetic Theory of Gases and Real Gases **(12 L)**

a. Concept of pressure and temperature; Collision of gas molecules; Collision diameter; Collision number and mean free path; Frequency of binary collisions (similar and different molecules); Rate of effusion

b. Nature of distribution of velocities, Maxwell's distribution of speed and kinetic energy; Average velocity, root

mean square velocity and most probable velocity; Principle of equipartition of energy and its application to calculate the classical limit of molar heat capacity of gases

c. 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 behaviour; Existence of critical state, Critical constants in terms of van der Waals constants; Law of corresponding states
d. Viscosity of gases and effect of temperature and pressure on coefficient of viscosity (qualitative treatment only)

Solid & Liquid State **(10 L)**

Liquid State: Definition of Surface tension, its dimension and principle of its determination using stalagmometer; Viscosity of a liquid and principle of determination of coefficient of viscosity using Ostwald viscometer; Effect of temperature on surface tension and coefficient of viscosity of a liquid (qualitative treatment only).

Solid State: Forms of solids, crystal systems, unit cells, Bravais lattice types, Symmetry elements; Laws of Crystallography - Law of constancy of interfacial angles, Law of rational indices; Miller indices of different planes and interplanar distance, Bragg's law; Structures of NaCl, KCl and CsCl treatment only); Defects in crystals; Glasses and liquid crystals.

Practical:

Inorganic

1. Estimation of Cu in a solution of $CuSO_4.5H_2O$
2. Estimation of Fe (II) ions by titrating it with $K_2Cr_2O_7$.

Physical

1. Surface tension measurement: Study of the variation of surface tension with concentration
2. Viscosity measurement: Study of the variation of viscosity concentration of solute.

Reference Books:

1. Lee, J. D. Concise Inorganic Chemistry,5th Ed., Wiley India Pvt. Ltd., 2008.
2. Atkins, Overton, Rourke, Weller, Armstrong; Shriver & Atkins' Inorganic Chemistry, 5th Ed., Oxford University Press (2010).
3. Levine, I. N. Physical Chemistry, 6th Edition McGraw-Hill India, 2011
4. Castellan, G. W. Physical Chemistry, Narosa, 2004
5. Atkins, P. W. & Paula, J. de, Atkins' Physical Chemistry, 11th Edition, Oxford University Press, 2018
6. G. L. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Edition, Pearson India, 2008
7. R.P. Sarkar, General and Inorganic Chemistry (Part – I, 3rd Revised Edition; and Part-II), New Central Book Agency.
8. B. R. Puri, L. R. Sharma, M. S. Pathania, Principles of Physical Chemistry (48th Edition), Vishal Publishing Co.

SEMESTER-III

Paper: **DCM-30 (Physical Chemistry-II + Organic Chemistry-II)**
Theory: 45 L (45 Hours)

Objectives

1. Understand qualitative rate laws and reaction orders.
2. Derive rate expressions for various reaction orders.
3. Explore temperature effects using Arrhenius and Collision theories.
4. Apply Zeroth and First laws of Thermodynamics.
5. Calculate thermodynamic properties under various conditions.
6. Comprehend nucleophilic substitution and elimination mechanisms.
7. Study preparation and reactions of benzene and aryl halides.
8. Conduct practical experiments on kinetics and organic compound analysis.

Learning Outcomes

After completion of this course the student will learn to:

1. Understand qualitative rate laws, order, and molecularity in chemical kinetics.
2. Derive and apply rate equations for first, second, and nth order reactions.
3. Determine reaction order using half-life and differential methods.
4. Analyze temperature effects on rate constants using the Arrhenius equation.
5. Explain collision and transition state theories of reaction rates.
6. Apply the Zeroth and First Laws of Thermodynamics in various processes.
7. Calculate thermodynamic quantities (q, w, U, H) for gas expansions.
8. Understand and apply laws of thermochemistry and enthalpy concepts.
9. Differentiate between SN1, SN2, and SNi nucleophilic substitution reactions.
10. Explore electrophilic and nucleophilic substitution in aromatic compounds.
11. Conduct kinetics experiments on acid hydrolysis reactions.
12. Verify Ostwald's dilution law through practical applications.
13. Identify special elements and functional groups in organic compounds.

Physical Chemistry-II

Chemical Kinetics (10 L)

a. Introduction of qualitative rate law, order and molecularity; Extent of reaction; rate constants; Rates of First, second and nth order reactions and their Differential and integrated forms (with derivation); Pseudo first order reactions; Determination of order of a reaction by half-life and differential method; Opposing reactions, consecutive reactions and parallel reactions

b. Temperature dependence of rate constant; Arrhenius equation, energy of activation; Collision theory; Lindemann theory of unimolecular reaction; outline of Transition State theory (classical treatment).

Thermodynamics-I and Thermochemistry (12 L)

Zeroth and 1st law of Thermodynamics: Intensive and extensive variables; state and path functions; isolated, closed and open systems; zeroth law of thermodynamics; Concept of heat, work, internal energy and statement of first law; enthalpy, H; relation between heat capacities, calculations of q, w, U and H for reversible, irreversible and free expansion of gases (ideal and van der Waals) under isothermal and adiabatic conditions; Joule's experiment and its consequence.

Thermochemistry: Standard states; Heats of reaction; enthalpy of formation of molecules and ions and enthalpy of combustion and its applications; Laws of thermochemistry; bond energy, bond dissociation energy and resonance energy from thermochemical data, Kirchhoff's equations and effect of pressure on enthalpy of reactions.

Organic Chemistry-II

Substitution and Elimination Reactions (09 L)

Nucleophilic substitution reactions: substitution at sp^3 centre [systems: alkyl halides, allyl halides, benzyl halides, alcohols, ethers, epoxides, α-halocarbonyls]: mechanisms (with evidence), relative rates & stereochemical features: S_N1, S_N2, and SNi; effects of solvent, substrate structure, leaving group and nucleophiles (including ambident nucleophiles, cyanide & nitrite)

Elimination reactions: E1, E2, E1cB; formation of alkenes and alkynes; mechanisms (with evidence), reactivity, regioselectivity (Saytzeff/Hofmann) and stereoselectivity; comparison between substitution and elimination.

Aromatic Hydrocarbons (07 L)

Benzene: Preparation: from phenol, by decarboxylation, from acetylene. Reactions: electrophilic substitution reaction (general mechanism); nitration (with mechanism), sulphonation, halogenations (chlorination and bromination), and Friedel-Crafts reaction (alkylation and acylation) (up to 4 carbons on benzene).

Aryl Halides (07 L)

Aryl Halides: Preparation: (Chloro, bromo and iodo-benzene) from phenol, Sandmeyer& Gattermann reactions. Reactions (Chlorobenzene): Aromatic nucleophilic substitution (replacement by –OH group) and effect of nitro substituent. Benzyne Mechanism: KNH_2/NH_3 (or $NaNH_2/NH_3$). Reactivity and Relative strength of C-Halogen bond in alkyl, allyl, benzyl, vinyl and aryl halides.

Practical:

Physical

1. Kinetics of acid hydrolysis of methyl acetate/ethyl acetate
2. Verification of Ostwald's dilution law

Organic

1. Detection of special elements (N, Cl, and *S*) in organic compounds.
2. Detection of functional groups: Aromatic-NO_2, Aromatic-NH_2, -COOH, carbonyl (no distinction of –CHO and >C=O needed), -OH (phenolic) in solid organic compounds

Reference Books:

1. Barrow, G.M. Physical Chemistry Tata McGraw-Hill (2007).
2. Castellan, G.W. Physical Chemistry 4th Ed. Narosa (2004).
3. Kotz, J.C., Treichel, P.M. & Townsend, J.R. General Chemistry Cengage Learning India Pvt. Ltd., New Delhi (2009).
4. Mahan, B.H. University Chemistry 3rd Ed. Narosa (1998).
5. Ekambaram, S. General Chemistry, Pearson.
6. Petrucci, R.H. General Chemistry 5th Ed. Macmillan Publishing Co.: New York (1985).
7.Chugh, K.L., Agnish, S.L. A Text Book of Physical Chemistry Kalyani Publishers.
8. Bhattacharjee, P. Pathway to Organic Chemistry, Books and Allied
9. Palit, S. R., Elementary Physical Chemistry Book Syndicate Pvt. Ltd.
10. Mandal, A. K. Degree Physical and General Chemistry Sarat Book House.
11. Pahari, S., Physical Chemistry New Central Book Agency.
12. Pahari, S., Pahari, D., Problems in Physical Chemistry New Central Book Agency.
13. Sethi, A. Conceptual Organic Chemistry; New Age International Publisher.
14. Kalsi, P. S. and Oza R. S. R S Organic Reactions: Stereochemistry and Mechanism, New Age International Publishers
15. Madan, R. L. Organic Chemistry, S. Chand & Sons.
16. Wade, L. G., Singh, M. S., Organic Chemistry, Pearson.
17. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd.(Pearson Education).
18. Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
19. Bahl, A. & Bahl, B.S. Advanced Organic Chemistry, S. Chand, 2010.

SEMESTER-IV

Paper: **DCM-40 (Inorganic Chemistry-III + Organic Chemistry-III)**
Theory: 45 L (45 Hours)

Objectives

1. Understand covalent bonding using VSEPR and hybridization.
2. Apply MO theory to diatomic molecules with LCAO method.
3. Analyze weak chemical forces and their effects on properties.
4. Examine s- and p-block elements including trends and compounds.
5. Prepare and react alcohols using various methods.
6. Explore preparation and reactions of phenols and ethers.
7. Study preparation and reactions of aldehydes and ketones.
8. Estimate carbonate and bicarbonate in a mixture practically.
9. Perform organic reactions and analyze yields.
10. Purify crude organic products using crystallization.

Learning Outcomes

After completion of this course the student will learn to:
1. Explain shapes of inorganic molecules using VSEPR and hybridization.
2. Understand resonance in inorganic and organic compounds.
3. Apply LCAO method in molecular orbital theory.
4. Analyze molecular orbitals for homonuclear diatomic molecules.
5. Describe van der Waals and other weak chemical forces.
6. Discuss effects of chemical forces on physical properties.
7. Examine group trends of s- and p-block elements.
8. Prepare and react alcohols using various reagents.
9. Understand the preparation and reactions of phenols.
10. Synthesize ethers through Williamson's ether synthesis.
11. Prepare aldehydes and ketones from various sources.
12. Perform aldol condensation and Cannizzaro reactions with mechanisms.
13. Estimate carbonate and bicarbonate in mixtures.
14. Perform nitration and condensation reactions in the lab.
15. Purify organic compounds by crystallization techniques.

Inorganic Chemistry-III

Covalent Bonding, Molecular Orbital Approach, Weak Chemical Forces (14 L)

a. Covalent bonding: VB Approach: Shapes of some inorganic molecules and ions on the basis of VSEPR and hybridization with suitable examples from s and p block elements of linear, trigonal planar, square planar, tetrahedral, trigonal bipyramidal and octahedral arrangements. Concept of resonance and resonating structures in various inorganic and organic compounds.

b. MO Approach: Rules for the LCAO method, bonding and antibonding MOs and their characteristics for s-s, s-p and p-p combinations of atomic orbitals, nonbonding combination of orbitals, MO treatment of homonuclear diatomic molecules of 1st and 2nd periods (including idea of s- p mixing).

c. Weak Chemical Forces: van der Waals forces, ion-dipole forces, dipole-dipole interactions, induced dipole interactions, Instantaneous dipole-induced dipole interactions. Repulsive forces, Hydrogen bonding (theories of hydrogen bonding, valence bond treatment). Effects of chemical force, melting and boiling points, solubility energetics of dissolution process.

Chemistry of p-block Elements (13 L)

Relative stability of different oxidation states, diagonal relationship and anomalous behaviour of first member of each group. Group trends in electronic configuration, modification of pure elements, common oxidation states,

inert pair effect. Allotropy and catenation. Study of the following compounds with emphasis on structure, bonding, preparation, properties and uses: Boric acid and borates, boron nitrides, borohydrides (diborane) and graphitic compounds, silanes, Oxides and oxoacids of nitrogen, phosphorus, sulphur and chlorine.

Organic Chemistry-III

Alcohols, Phenols and Ethers (09 L)

Alcohols: (up to 5 Carbons). Preparation: 1°-, 2°- and 3°- alcohols: using Grignard reagent, reduction of aldehydes, ketones, carboxylic acid and esters; Reactions: With sodium, HX (Lucas test), oxidation (alkaline KMnO4, acidic dichromate, concentrated HNO3); Oppenauer oxidation;
Diols: Preparation (with OsO4); pinacol- pinacolone rearrangement (with mechanism) (with symmetrical diols only).
Phenols: Preparation: cumene hydroperoxide method, from diazonium salts; acidic nature of phenols; Reactions: electrophilic substitution: nitration and halogenations; Reimer-Tiemann reaction, Houben–Hoesch condensation, Schotten–Baumann reaction, Fries rearrangement and Claisen rearrangement.
Ethers: Preparation: Williamson's ether synthesis; Reaction: cleavage of ethers with HI.

Carbonyl Compounds (09 L)

Aldehydes and Ketones (aliphatic and aromatic): (Formaldehye, acetaldehyde, acetone and benzaldehyde): Preparation: from acid chlorides, from nitriles and from Grignard reagents; general properties of aldehydes and ketones; Reactions: with HCN, ROH, $NaHSO_3$, NH_2-G derivatives and with Tollens' and Fehling's reagents; iodoform test; aldol condensation (with mechanism); Cannizzaro reaction (with mechanism), Wittig reaction, benzoin condensation; Clemmensen reduction, Wolff-Kishner reduction and Meerwein-Pondorff-Verley (MPV) reduction.

Practical:

Inorganic Chemistry

1. Estimation of carbonate and bicarbonate present together in a mixture.
2. Estimation of Alkali content of antacid tablets/ Estimation of oxalic acid and sodium oxalate.

Organic Chemistry

The following reactions are to be performed, noting the yield of the crude product:
a. Nitration of aromatic compounds
b. Condensation reactions
c. Hydrolysis of amides/imides
Purification of the crude product is to be made by crystallization from water/alcohol.

Reference Books:

1. Lee, J.D. Concise Inorganic Chemistry ELBS, 1991.
2. Cotton, F.A., Wilkinson, G. & Gaus, P.L. Basic Inorganic Chemistry, 3rd ed., Wiley.
3. Douglas, B.E., McDaniel, D.H. & Alexander, J.J. Concepts and Models in Inorganic Chemistry, John Wiley & Sons.
4. Dutt, P. K. General and Inorganic Chemistry, Sarat Book House
5. Sethi, A. Conceptual Organic Chemistry; New Age International Publisher.
6. Parmar, V. S. A Text Book of Organic Chemistry, S. Chand & Sons.
7. Madan, R. L. Organic Chemistry, S. Chand & Sons.
8. Wade, L. G., Singh, M. S., Organic Chemistry.
9. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
10. Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
11. Eliel, E. L. & Wilen, S. H. Stereochemistry of Organic Compounds, Wiley: London, 1994.
12. Sengupta, Subrata. Basic Stereochemistry of Organic molecules

SEMESTER-V

Paper: **DCM-50 (Physical Chemistry-III + Environmental Chemistry)**
Theory: 45 L (45 Hours)

Objectives

1. Understand the concepts of heat reservoirs and heat engines, including Carnot cycle.
2. Explain entropy and its physical concept; analyze the efficiency of Carnot engines and refrigerators.
3. Learn about entropy changes in systems and surroundings for various transformations.
4. Study auxiliary state functions (G & A) and understand the criteria for spontaneity and equilibrium.
5. Explore conditions for chemical equilibrium and the variation of Gibbs free energy.
6. Relate equilibrium constants (K_P, K_C, K_X) and understand van't Hoff's reaction isotherm, isobar, and isochore.
7. Understand behavior of strong, moderate, and weak electrolytes including ionization concepts and their constants.
8. Comprehend pH scale, the effects of salt hydrolysis, and the relevance of buffer solutions.
9. Recognize environmental chemistry covering the role and composition of the atmosphere, hydrosphere, and lithosphere.
10. Engage in practical experiments, such as titrations and solubility studies to reinforce theoretical knowledge.

Learning Outcomes

After completion of this course the student will learn to:

1. Understand the concept of heat reservoirs and heat engines.
2. Analyze the Carnot cycle and its efficiency.
3. Explain the physical concept of entropy and its implications.
4. Apply criteria for spontaneity and equilibrium using state functions.
5. Determine thermodynamic conditions for chemical equilibrium.
6. Calculate equilibrium constants and standard Gibbs free energy changes.
7. Evaluate the effects of temperature and pressure on chemical equilibria.
8. Discuss the degree of ionization and its influencing factors.
9. Explain the pH scale, common ion effect, and buffer solutions.
10. Describe atmospheric composition and major air pollutants.
11. Analyze the environmental impact of pollutants in the hydrosphere.
12. Understand water pollution control measures and treatment processes.
13. Discuss soil pollution and waste management strategies.
14. Conduct experiments on solubility and pH-metric titration.
15. Perform qualitative analysis of inorganic mixtures and understand chemical reactions.

Physical Chemistry-III

Thermodynamics-II (07 L)

Concept of heat reservoirs and heat engines; Carnot cycle; Physical concept of Entropy; Carnot engine, refrigerator and efficiency; Entropy change of systems and surroundings for various processes and transformations; Auxiliary state functions (G and A) and Criteria for spontaneity and equilibrium.

Chemical Equilibrium (07 L)

Thermodynamic conditions for equilibrium, degree of advancement; Variation of free energy with degree of advancement; Equilibrium constant and standard Gibbs free energy change; Definitions of K_P, K_C and K_X and relation among them; van't Hoff's reaction isotherm, isobar and isochore from different standard states; Shifting of equilibrium due to change in external parameters e.g. temperature and pressure; variation of equilibrium constant with addition to inert gas; Le Chatelier's principle.

Ionic Equilibrium **(09 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, common ion effect; Salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts; Buffer solutions; Solubility and solubility product of sparingly soluble salts – applications of solubility product principle.

Environmental Chemistry

The Atmosphere **(09 L)**

The Atmosphere: composition and structure of the atmosphere; troposphere, stratosphere, mesosphere and thermosphere; ozone layer and its role; major air pollutants: CO, SO_2, NO_x and particulate matters – their origin and harmful effects; problem of ozone layer depletion; greenhouse effect; acid rain and photochemical smog; air pollution episodes: air quality standard; air pollution control measures: cyclone collector, electrostatic precipitator, catalytic converter.

The Hydrosphere **(09 L)**

The Hydrosphere: environmental role of water, natural water sources, water treatment for industrial, domestic and laboratory uses; water pollutants; action of soaps and detergents, phosphates, industrial effluents, agricultural runoff, domestic wastes; thermal pollution, radioactive pollution and their effects on animal and plant life; water pollution episodes: water pollution control measures: waste water treatment; chemical treatment and microbial treatment; water quality standards: DO, BOD, COD, TDS and hardness parameters; desalination of sea water: reverse osmosis, electrodialysis.

The Lithosphere **(04 L)**

The Lithosphere: water and air in soil, waste matters and pollutants in soil, waste classification, treatment and disposal; soil pollution and control measures.

Practical:

Physical Chemistry

1. Study of the solubility of benzoic acid in water.
2. Study of the solubility of sparingly soluble salt (KHTa) in water.
3. pH-metric titration of strong acid vs strong base.

Inorganic Chemistry

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-}, PO_4^{3-}, BO_3^{3-}, H_3BO_3.
Basic Radicals: Na^+, K^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Cr^{3+}, Mn^{2+}, Fe^{3+}, Ni^{2+}, Cu^{2+}, NH_4^+

Reference Books:

1. Barrow, G.M. Physical Chemistry Tata McGraw-Hill (2007).
2. Castellan, G.W. Physical Chemistry 4th Ed. Narosa (2004).
3. Kotz, J.C., Treichel, P.M. & Townsend, J.R. General Chemistry Cengage Learning India Pvt. Ltd., New Delhi (2009).
4. Samir Kr Banerjee, Environmental Chemistry 2Nd Edition, PHI
5. Ekambaram, S. General Chemistry, Pearson.
6. Dara and Misra, A Text Book of Environmental chemistry & Pollution Control, S. Chand
7. Chugh, K.L., Agnish, S.L. A Text Book of Physical Chemistry Kalyani Publishers.
8. Banerjee, S. P. A Text Book of Analytical Chemistry, The New Book Stall
9. Palit, S. R., Elementary Physical Chemistry Book Syndicate Pvt. Ltd.
10. Mandal, A. K. Degree Physical and General Chemistry Sarat Book House.
11. Pahari, S., Physical Chemistry New Central Book Agency.
12. Pahari, S., Pahari, D., Problems in Physical Chemistry New Central Book Agency.

SEMESTER-VI

Paper: **DCM-60 (Organic Chemistry-IV + Inorganic Chemistry-IV)**
Theory: 45 L (45 Hours)

Objectives

1. Learn preparation and reactions of nitro, nitrile, and isonitrile aliphatic and aromatic compounds.
2. Understand the basicity effects of substituents and solvents on amines.
3. Study the preparation properties and reactions specific to amines.
4. Master the preparation and applications of diazonium salts.
5. Understand the structures and transformations of D-glucose and monosaccharides.
6. Explore synthesis and reactions related to amino acids and peptides.
7. Gain knowledge about structures and properties of nucleic acid components.
8. Comprehend group trends and characteristics of transition metals.
9. Analyze complex formation and stability, isomerism, and crystal field theory in coordination chemistry.
10. Perform practical experiments in organic and inorganic preparations including synthesis and estimations.

Learning Outcomes

After completion of this course the student will learn to:

1. Synthesize and evaluate nitrogen compounds in aliphatic and aromatic groups.
2. Understand the effects of substituents and solvents on the basicity of amines and their distinguishability.
3. Explore synthesis and reactions of diazonium salts for synthetic applications.
4. Analyze the configurations, conformations, and chemical reactions of monosaccharides.
5. Synthesize amino acids and peptides with an understanding of their sequencing methods.
6. Gain a basic understanding of nucleic acids, their structures, and base-pairing.
7. Examine electronic configurations and properties of transition metals and lanthanoids/actinoids.
8. Explore coordination chemistry theories such as Werner's theory and Valence Bond Theory.
9. Study the effects and theories behind crystal field stabilization and distortions in coordination complexes.
10. Perform practical experiments to synthesize organic compounds and estimate metallic ions through complexometric titrations.

Organic Chemistry-IV

Nitrogen Compounds (09 L)

Preparation and important reactions of aliphatic and aromatic compounds of nitro, nitrile and isonitrile groups. Amines: Effect of substituent and solvent on basicity, Preparation and properties: Gabriel phthalimide synthesis, Carbylamine reaction, Mannich reaction, Hoffmann's exhaustive methylation, Hofmann-elimination reaction, Distinction between 1°, 2° and 3°- amines with Hinsberg reagent and nitrous acid. Diazonium salts: Preparation and synthetic applications.

Biomolecules (14 L)

D-glucose: (configuration & conformation); ring structure of monosaccharides (furanose and pyranose forms): Haworth representations and non-planar conformations; anomeric effect (including stereoelectronic 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.

Amino acids: Synthesis with mechanistic details: Strecker, Gabriel; acetamido malonic ester, azlactone.

Peptides: peptide linkage and its geometry; peptide sequence: C-terminal and N-terminal unit determination (Edman, Sanger).
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

Inorganic Chemistry-IV

Transition Metal Chemistry: A Basic Approach (**08 L**)

a. General group trends with special reference to electronic configuration, variable valency, colour, magnetic and catalytic properties, ability to form complexes and stability of various oxidation states (Latimer diagrams) for Mn, Fe and Cu.
b. Lanthanoids and actinoids: Electronic configurations, oxidation states, colour, magnetic properties, lanthanide contraction, separation of lanthanides (ion exchange method only).

Coordination Chemistry (VBT and CFT) (**14 L**)

a. Werner's coordination theory, Valence Bond Theory (VBT): Inner and outer orbital complexes of Cr, Fe, Co, Ni and Cu (coordination numbers 4 and 6). Structural and stereoisomerism in complexes with coordination numbers 4 and 6.
b. Crystal field effect, octahedral symmetry. Crystal field stabilization energy (CFSE), Crystal field effects for weak and strong fields. Tetrahedral symmetry. Factors affecting the magnitude of D. Spectrochemical series. Comparison of CFSE for Oh and Td complexes, Tetragonal distortion of octahedral geometry.
c. Jahn-Teller distortion, Square planar coordination.

Practical:

Organic

Preparation of the Following Compounds:
Benzanilide, Aspirin, Vitamin C, 7-Hydroxy-4-Methyl Coumarin,, Benzylidene acetone.
The following reactions are to be performed, noting the yield of the crude product:
a. Acetylation of aromatic amines
b. Benzoylation of aromatic amines

Inorganic Chemistry

1. Estimation of (i) Mg^{2+} or (ii) Zn^{2+} by complexometric titrations using EDTA.
2. Estimation of total hardness of a given sample of water by complexometric titration.

Reference Books

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2.Shriver, D.F. & Atkins, P.W. Inorganic Chemistry, Oxford University Press.
3.Wulfsberg, G. Inorganic Chemistry, Viva Books Pvt. Ltd.
4.Rodgers, G.E. Inorganic & Solid State Chemistry, Cengage Learning India Ltd., 2008.
5. Gangopadhyay, P. K. Application Oriented Chemistry, Book Syndicate.
6.Mondal, A. K & Mondal, S. Degree Applied Chemistry, Sreedhar Publications.
7. Wade, L. G., Singh, M. S., Organic Chemistry.
9. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
10. Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
11. Eliel, E. L. & Wilen, S. H. Stereochemistry of Organic Compounds, Wiley: London, 1994.
12. Sengupta, Subrata. Basic Stereochemistry of Organic molecules

SEMESTER-VII

Paper: **DCM-70 (Analytical and Industrial Chemistry)**
Theory: 45 L (45 Hours)

Objectives

1. Understand accuracy and precision in quantitative analysis.
2. Analyze determinate, indeterminate, systematic, and random errors.
3. Learn methods of least squares and standard deviations.
4. Introduction to components and functioning of computers.
5. Study binary numbers, arithmetic, and basic computer languages.
6. Overview of programming and operating systems.
7. Learn about the origin, classification, and chemical processes of fuels.
8. Study the manufacturing processes of various fertilizers.
9. Understand the manufacture and types of glasses, ceramics, and cements.
10. Perform practical experiments in estimation and determination related to chemistry.

Learning Outcomes

After completion of this course the student will learn to:-
1. Define and analyze errors in quantitative analysis such as accuracy, precision, systematic and random errors.
2. Apply methods such as least squares and calculation of standard deviations to manage data.
3. Understand the basic structure and functions of computers including hardware and software.
4. Grasp the basics of binary arithmetic and the workings of different input and output devices.
5. Classify fuels, understand their origin, and describe processes like carbonization and refining.
6. Learn the manufacture and application of fertilizers like ammonia and urea.
7. Describe the manufacturing processes of industrial materials such as glass, ceramics, and cement.
8. Understand and apply knowledge on surface coatings, including the composition of paints and the process of anodizing.
9. Identify types and components of batteries like Li-Battery and analyze their characteristics.
10. Perform practical experiments including estimation of chemicals in solutions and analysis of battery components.

Analytical

Error Analysis and Computer Applications (15 L)

a. Error analysis: accuracy and precision of quantitative analysis, determinate, indeterminate, systematic and random errors; methods of least squares and standard deviations.
b. Computer applications: general introduction to computers, different components of a computer; hardware and software; input and output devices; binary numbers and arithmetic; introduction to computer languages; programming and operating systems.

Industrial Chemistry (30 L)

a. Fuels: classification of fuel; heating values; origin of coal, carbonization of coal, coal gas, producer gas, water gas, coal-based chemicals; origin and composition of petroleum, petroleum refining, cracking, knocking, octane number, antiknock compounds, kerosene, liquefied petroleum gas (LPG), liquefied natural gas (LNG); petrochemicals (C1 to C3 compounds and their uses).
b. Fertilizers: manufacture of ammonia and ammonium salts, urea, superphosphate, biofertilizers.
c. Glass and Ceramics: definition and manufacture of glasses, optical glass and coloured glass; clay and feldspar, glazing and vitrification, glazed porcelein, enamel.
d. Cement: Portland cement: composition and setting of cement, white cement.

e. Surface Coatings: Objectives of coatings surfaces, preliminary treatment of surface, classification of surface coatings. Paints and pigments-formulation, composition and related properties. Oil paint, Vehicle, modified oils, Pigments, toners and lakes pigments, Fillers, Thinners, Enamels, emulsifying agents. Special paints (Heat retardant, Fire retardant, Eco-friendly paint, Plastic paint), Dyes, Wax polishing, Water and Oil paints, additives, Metallic coatings, metal spraying and anodizing.

f. Batteries: Primary and secondary batteries, battery components and their role, Characteristics of Battery. Working of following batteries: Pb acid, Li-Battery, Solid state electrolyte battery. Fuel cells, Solar cell and polymer cell

Practical:

1. Estimation of available chlorine in bleaching powder.
2. Estimation of acetic acid in commercial vinegar.
3. Estimation of Fe in Cement.
4. Estimation of Fe (III) in synthetic sample by reduction with $SnCl_2$

Reference Books

1. Stocchi E., Industrial Chemistry, Vol-I, Ellis Horwood Ltd. UK.
2. Sharma, B.K. & Gaur, H. Industrial Chemistry, Goel Publishing House, Meerut (1996).
3. P. C. Jain, M. Jain: Engineering Chemistry, Dhanpat Rai & Sons, Delhi.
4. Felder R.M. and Rousseau R.W., Elementary Principles of Chemical Processes, Wiley Publishers, New Delhi.
5. Dara S. S., A Textbook of Engineering Chemistry, S. Chand & Company Ltd. New Delhi.
6. A. Kent: Riegel's Handbook of Industrial Chemistry, CBS Publishers, New Delhi.
7. R. Gopalan, D. Venkappayya, S. Nagarajan: Engineering Chemistry, Vikas, Publications, New Delhi.
8. Christian, G.D, Analytical Chemistry, 6th Ed. John Wiley & Sons, New York, 2004.
9. Cooper, T.G. The Tools of Biochemistry, John Wiley and Sons, N.Y. USA. 16 (1977).
10. Day, R. A. & Underwood, A. L. Quantitative Analysis, Prentice Hall of India.
11. Dean, J. A. Analytical Chemistry Notebook, McGraw Hill.
12. Ditts, R.V. Analytical Chemistry, Methods of separation, van Nostrand, 1974.
13. Freifelder, D. Physical Biochemistry 2nd Ed., W.H. Freeman and Co., N.Y. USA (1982).
14. Harris, D.C.: Exploring Chemical Analysis, 9th Ed. New York, W.H. Freeman, 2016.
15. Khopkar, S. M., Basic Concepts of Analytical Chemistry, New Age (Second edition) 1998

SEMESTER-VIII

Paper: **DCM-80 (Physical Chemistry-IV + Basic Nano Technology**)
Theory: 45 L (45 Hours)

Objectives

1. Understand dilute solutions, vapor pressure lowering, Raoult's and Henry's Laws.
2. Explore colligative properties and their applications across various scenarios.
3. Determine molar masses using elevation of boiling point, depression of freezing point, and osmotic pressure.
4. Study conductance, cell constants, and applications including solubility product determination.
5. Learn Faraday's laws of electrolysis and apply them to metallurgy and chemical cell electromotive force.
6. Examine phase equilibria, Gibbs Phase Rule, and phase diagrams across systems.
7. Grasp fundamentals of nano-technology, types of nanocrystals, and their specific applications.
8. Perform practical experiments: Conductometric and potentiometric titrations, solubility curves, and pH determination.

Learning Outcomes

After completion of this course the student will learn to:
1. Understand dilute solutions, Raoult's and Henry's Laws along with applications.
2. Explain colligative properties and its calculations including elevation of boiling point and osmotic pressure.
3. Determine molar masses using abnormal colligative properties and Van't Hoff 'I' factor.
4. Study electrochemistry including conductance, cell EMF, and applications in industries.
5. Apply Faraday's laws of electrolysis and use the Nernst equation for thermodynamic calculations.
6. Analyze phase equilibria using the Phase Rule and Clausius-Clapeyron equation.
7. Recognize the development and challenges of nano-technology and different nanostructures.
8. Explore applications of nanotechnology in electronics, biology, and environmental sciences.
9. Perform conductometric titrations to analyze strong and weak acids and bases.
10. Conduct potentiometric titrations, conductometric titrations, pH-determination by simple color matching method including redox and precipitation reactions.

Physical Chemistry-IV

Dilute Solutions **(05 L)**

Dilute solutions, lowering of vapour pressure, Raoult's and Henry's Laws and their applications. Colligative properties of solutions, abnormal colligative properties, Van't Hoff 'I' factor. Elevation of boiling point, (iii) Depression of freezing point, (iv) osmotic pressure and amount of solute. Applications in calculating molar masses of normal, dissociated and associated solutes in solution. Azeotropes.

Electrochemistry (Conductance + Cell EMF) **(14 L)**

a. 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; Ostwald's dilution law; Application of conductance measurement (determination of solubility product and ionic product of water); Conductometric titrations (acid-base)

b. Faraday's laws of electrolysis, rules of oxidation/reduction of ions based on half-cell potentials, applications of electrolysis in metallurgy and industry; Chemical cells, reversible and irreversible cells with examples; Electromotive force of a cell and its measurement, Nernst equation; Standard electrode (reduction) potential; Electrochemical series; Thermodynamics of a reversible cell, calculation of thermodynamic properties: G, H and S from EMF data

c. Concentration cells with and without transference, liquid junction potential; pH determination using hydrogen electrode and quinhydrone; Qualitative discussion of potentiometric titrations (acid-base, redox, precipitation)

Phase Rule **(07 L)**

Phases, components and degrees of freedom of a system, criteria of phase equilibrium; Gibbs Phase Rule and its thermodynamic derivation; Derivation of Clausius – Clapeyron equation and its importance in phase equilibria; Phase diagrams of one-component systems (water and sulphur) and two component systems involving eutectics, congruent and incongruent melting points (lead-silver, $FeCl_3$-H_2O and Na-K only).

Basic Nano Technology

Background of Nano-Technology **(02 L)**

Emergence of nano-technology, challenges in nanotechnology, carbon age: New forms of carbon (from graphene to CNT).

Nucleation **(07 L)**

Influence of nucleation rate on size of the crystals, macroscopic and microscopic crystals and nano crystals, large surface to volume ratio, top-down and bottom-up approaches, self-assembly process, defects in nanocrystals, surface effects on the properties.

Types of Nano-Structures & Applications **(10 L)**

Definition of nano system, types of nanocrystals: One dimensional (1D), Two dimensional (2D), Three dimensional (3D). Molecular electronics and nanoelectronics, quantum electronic devices, CNT based transistor and Field Emission Display, biological applications, biochemical sensor, membrane-based water purification.

Practical:

1. Conductometric titrations (Strong acid *vs*. strong base)
2. Potentiometric titrations (Strong acid *vs*. strong base)
3. Mutual solubility curve for Phenol and Water by help of 'Phase Diagram'
4. Determination of pH of unknown solution by color matching method

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3. Steiner, E. The Chemical Maths Book Oxford University
4. Levie, R. de, How to use Excel in analytical chemistry and in general scientific data analysis, Cambridge Univ. Press (2001) 487 pages.
5. Noggle, J. H. Physical chemistry on a Microcomputer. Little Brown & Co. (1985).
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7. Nabakumar Bera, Subhasree Ghosh, Paulami Ghosh, Mathematics and Statistics for Chemists, Techno World. 8. Essentials of Physical Chemistry; A. Bhal, B.S. Bhal, G.D. Tuli; S. Chand and Company Limited.
9. Analytical Chemistry; G.D. Christian, P.K. Dasgupta, K.A. Schug; An Indian Adaptation (Wiley).
10. Fundamentals of Analytical Chemistry (Ninth Edition); D.A. Skoog, D.M. West, F.J. Holler, S.R. Crouch; Brooks/Cole Ceange Learning.
11. An Introduction to Nanomaterials and Nanoscience; A.K. Das, M. Das; CBS Publishers & Distributors Pvt. Ltd.