Department of Chemistry
Cooch Behar Panchanan Barma University
Syllabus under NEP

SEMESTER III

Course Code	**Major 3**
Credit Hours	**4+2**
Course Overview	To impart basic knowledge about Chemical Thermodynamics, Chemical Kinetics, Surface Chemistry, Alcohols, Phenols, Ethers, Epoxide, carbonyl compounds and Aromatic Hydrocarbons
Course Outcome	This course aims to provide students with a solid foundation in chemical thermodynamics, kinetics, surface chemistry, and organic chemistry, equipping them with the knowledge, skills, and analytical tools necessary for further study and careers in chemistry and related fields.

Course Overview

Part A: Physical Chemistry

Module-1: Chemical Thermodynamics **18 Lectures**

Intensive and extensive variables; state and path functions; cyclic rule; 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 under isothermal and adiabatic conditions; Joule's experiment and its consequence.

Thermochemistry: Laws of thermochemistry; Standard states; Heats of reaction; enthalpy of formation and its applications; Heat of neutralization; bond dissociation energy and resonance energy, Kirchhoff's equations and enthalpy of reactions; Adiabatic flame temperature.

Need for a Second law; statement of the second law; heat reservoirs and heat engines; Carnot cycle; Physical concept of Entropy; Carnot engine and refrigerator; Kelvin – Planck and Clausius statements; Carnot's theorem; Clausius inequality; Entropy and unavailable work; Free energy

functions (G and A) and their variation with T, P and V; Criteria for spontaneity and equilibrium; Maxwell's relations; Gibbs-Helmholtz equation, Equations of states; Joule-Thomson experiment; inversion temperature; Joule-Thomson coefficient for a van der Waals gas.
Partial molar quantities and their significance; Gibbs- Duhem equation, chemical potential of ideal mixtures; variation in thermodynamic functions in mixing of ideal gases; Fugacity function and its physical significance.

Module-2: Reaction Kinetics **08 Lectures**

Introduction of rate law; Extent of reaction; rate constants; Order and molecularity; Forms of rates of zero, first, second and n^{th} order reactions; Pseudo first order reactions; Determination of order of a reaction; Opposing reactions, consecutive reactions and parallel reactions (first order step only). Rate-determining step and steady-state approximation; Temperature dependence of rate constant, Arrhenius equation, energy of activation and its physical significance; Chain reaction.

Module-3: Chemistry of Interfaces **06 Lectures**

Physical and chemical adsorption; Heat of adsorption; Freundlich and Langmuir adsorption isotherms; BET isotherm (only qualitative); Gibbs's adsorption isotherm; surfactant and surface excess; surface pressure; surface area of adsorbent.
Lyophobic and lyophilic sols; Origin of charge of colloids; Zeta potential and Stern double layer (qualitative idea); flocculation value and mechanism of coagulation; Schultz-Hardy rule; Tyndall effect; Electrokinetic phenomena (qualitative only); Micelle formation.

Part B: Organic Chemistry

Module -1: Alcohols, Phenols, Ethers and Epoxides **10 Lectures**

Properties, Preparation from alkenes, and carbonyl compounds, Relative reactivity of 1°, 2°, 3° alcohols, Bouveault-Blanc reduction, Lucas test, Oxidation of alcohols (H_2CrO_4, PDC/PCC, $KMnO_4$, Swern oxidation, DMP, and Oppenauer oxidation). Glycols: Properties and preparation of glycols (OsO_4, $KMnO_4$, from epoxide, Woodward and Prévost reaction), Oxidation by periodic acid and lead tetraacetate, Pinacol-Pinacolone, semipinacol and Tiffeneau-Demjanov rearrangement. Phenols: Properties, preparation, acidity, and factors effecting it. Ring substitution reactions: Kolbe–Schmidt Reaction, Reimer–Tiemann formylation, Houben-Hoesch acylation, Dienonephenol rearrangement, Fries and Claisen rearrangements. Ethers and Epoxides: Preparations, ether cleavage, and reactions of epoxides with alcohols, ammonia derivatives and LAH.

Module-2: Carbonyl Compounds **12 Lectures**

Preparation of carbonyls – mechanism, equilibrium and kinetic control. Nucleophilic additions: reactions with HCN, bisulfite, Nucleophilic addition-elimination reactions with alcohols, amines, thiols. Reaction with ylides: Wittig and Corey-Chaykovsky reaction. Benzoin condensation, Cannizzaro, and Benzil-Benzilic acid rearrangements. Baeyer-Villiger oxidation, α-substitution reactions, oxidations, reductions (Clemmensen, Wolff-Kishner, LAH, NaBH4, MPV, PDC and PCC). Active methylene compounds: Keto-enol tautomerism. Preparation and synthetic applications of diethyl malonate and ethyl acetoacetate. Formation of enols and enolates, kinetic and thermodynamic enolates, Haloform reaction. Condensation reactions: Aldol and Knoevenagel.

Module-3 Aromatic Hydrocarbons **8 Lectures**

Aromatic character of arenes, cyclic carbocations/carbanions, Electrophilic and Nucleophilic aromatic substitutions: halogenation, nitration, sulphonation, Friedel-Craft's alkylation/acylation, SNAr, Benzyne mechanism and Directing effects of the groups.

Practical **30 Lectures**

Physical Chemistry

1. Determination of the Specific heat of a metal (iron) using coffee cup calorimeter.
2. Determination of rate constant of acid-catalysed hydrolysis of methyl acetate
3. Determination of rate constant for the decomposition of H_2O_2 by KI
4. Study the adsorption of acetic acid on charcoal by Freundlich's adsorption isotherm

Organic Chemistry

Qualitative Analysis of Single Solid Organic Compounds

1. Solubility and classification (solvents: H2O, 5% HCl, 5% NaOH and 5% NaHCO3)
2. Detection of the following functional groups by systematic chemical tests:
3. Aromatic amino ($-NH_2$), aromatic nitro ($-NO_2$), amido ($-CONH_2$, including imide), phenolic –OH, carboxylic acid (-COOH), carbonyl (-CHO and >C=O); only one test for each functional group is to be reported.
4. Preparation, purification and melting point determination of a crystalline derivative of the given compound.

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 four) organic compounds.

Suggested Textbooks

1. Physical Chemistry, 7th Edition, P. C. Rakshit, 2020, Levant Books.

2. Physical Chemistry, 9th Edition, P. W. Atkins, WH Freeman & Co.
3. Morrison, R. T. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
4. Finar, I. L. *Organic Chemistry* (*Volume 1*), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
5. Graham Solomons, T.W. *Organic Chemistry,* John Wiley & Sons, Inc.

Reference Books for Practical

1. Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).
2. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. Experiments in Physical Chemistry 8th Ed.; McGraw-Hill: New York (2003).
3. An Advanced Course in Practical Chemistry by Nad, Mahapatra & Ghosal, New Central Book Agency (P) Limited, 2014.
4. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry,* Pearson Education (2009)
Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5th Ed.,* Pearson (2012).
5. Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis,* University Press (2000).

Course Code	Major 4
Credit Hours	4+2
Course Overview	To impart basic knowledge about Covalent bonding using MO approach, study the chemistry of s and p block elements, nuclear chemistry and some fundamental concepts and application of mathematics in chemistry
Course Outcome	This course aims to provide students with a solid foundation in covalent bonding, the chemistry of s and p block elements, nuclear chemistry, and mathematical concepts relevant to chemistry, preparing them for further study and careers in chemistry, materials science, and related fields.

Course Overview

Part A: Inorganic Chemistry

Module-1 Covalent Bonding: MO Approach **14 Lectures**

Covalent bonding, 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) and heteronuclear diatomic molecules such as CO and NO. Metallic Bond: Qualitative idea of valence bond and band theories. Semiconductors and insulators
Weak Chemical Forces: Hydrogen bonding: theories of hydrogen bonding, valence bond treatment, receptor-guest interactions

Module-2 Introduction to Nuclear Chemistry **16 Lectures**

Classification of nuclides based on the number of nucleons- Isotopes, Isobars, Isotones; Nuclear Isomer and isomeric transition; Radius and Density of Nucleus; Nuclear Spin; Shape of Nucleus; Nuclear Stability; Nuclear Fission; Nuclear Fusion; Mass-energy relations; The Neutron to Proton Ratio and Different Modes of Decay; Fajans & Soddy's Group Displacement Law; Nuclear Reactions; Nuclear Reaction Cross Section; Nuclear Binding Energy and Nuclear Stability; Radioactive Decay Kinetics; Application of Radioactivity in Age Determination.

Part B: Mathematics & Statistics for Chemists

Module 1: Functions **6 Lectures**

Single-valued functions and multi-valued functions, Domain and range of a functions, Different types of functions, Applications in Chemistry

Module 2: Differentiation and Integrations **10 Lectures**

Differentiation with single variable function, Differentiation with multivariable function, Application in Chemistry, L'Hospital rule and its use in chemistry, Order and degree of differential equations, Exact and Inexact differential equations, Construction and solution of differential equation. Some theorems of Integration, Definite integral represents an area under the curve, Improper Integrals: Gamma and Beta Functions, Application in Chemistry. Integrating Factor, Hermite Functions.

Module 3: Series, Transformation, & Matrix **08 Lectures**

Mean value theorem, Taylor Series, Infinite series, Legendre Transformation, Euler's Theorem, Matrix, Concept of Permutation and Combination.

Module 4: Statistics and Probability **06 Lectures**

Definition of probability, counting probability, Probability distribution function. Mean, median, mode, Standard deviation, accuracy and precision, Significant figures.

Practical **30 Lectures**

1. Estimation of available chlorine in bleaching powder iodometrically.
2. Estimation of Fe(III) and Fe(II) mixture based on permanganometry.
3. Estimation of Fe(III) and Cu(II) in a mixture using Standard $K_2Cr_2O_7$.
4. Data plotting using Microsoft Excel- Linear and non-linear method.
5. Data interpretation and calculation of mean, median, standard deviation using Microsoft Excel.

Suggested Textbooks

1. Catherine E. Housecroft and Alan G. Sharpe, Inorganic Chemistry. 2nd ED. Pearson Education Limited, Essex CM20 2JE, England, 2005 (ISBN: 0130-39913-2)
2. General and Inorganic Chemistry by Ramaprasad Sarkar- Volume 1 and II
3. Concise Inorganic Chemistry by J D Lee (5th Edition)
4. G. L. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Edition, Pearson India, 2008.
5. Mathematics & Statistics for Chemists, Nabakumar Bera, 2020, Techno World.

Reference Books for Practical

1. G. N. Mukherjee, Hand Book of Inorganic Analysis, U. N. Dhar & sons (P) LTD, 2014.
2. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.

SEMESTER IV

Course Code	**Major 5**
Credit Hours	**4+2**
Course Overview	To impart knowledge about Chemical Equilibrium, Colligative properties, fundamental concepts of Quantum chemistry, organometallics, sulfur containing organic compounds, nitrogen containing functional groups, carboxylic acids, and polynuclear hydrocarbons.
Course Outcome	This course aims to provide students with a comprehensive understanding of chemical equilibrium, quantum chemistry, organometallics, and the chemistry of sulfur-containing and nitrogen-containing compounds, preparing them for further study and careers in chemistry, chemical engineering, materials science, and related fields.

Course Overview

Part A: Physical Chemistry

Module-1: Chemical equilibrium **07 Lectures**

Laws of mass action; Thermodynamic conditions for equilibrium; degree of advancement of reaction; variation of equilibrium constant with addition to inert gas; van't Hoff's reaction isotherm; 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; Le Chatelier's principle; van't Hoff's reaction isobar and isochore; Shifting of equilibrium due to change in external parameters; equilibrium constant in terms of degree of dissociation.

Module-2: Dilute solution and Colligative properties **08 Lectures**

Dilute solutions; Vapour pressure of solution; Raoult's and Henry's Laws; Excess thermodynamic functions; Clapeyron equation; Clausius-Clapeyron equation; Troutons' rule; Thermodynamic derivation using chemical potential to derive relations between the four colligative properties i.e., (i) relative lowering of vapour pressure, (ii) elevation of boiling point, (iii) Depression of freezing point, (iv) Osmotic pressure; Applications in calculating molar masses of solute; vant Hoff factor; Abnormal colligative properties; Nernst's distribution law: its derivation and applications; solvent extraction.

Module-3: Foundation of Quantum Mechanics **12 Lectures**

Black body radiation; Planck's quantum theory; Photoelectric and Compton effects; Wave-particle duality; de-Broglie hypothesis; Uncertainty principle; Wilson-Sommerfeld quantum theory.

Wave function; acceptability conditions imposed on the wave functions; Properties of wave functions (normalisation, orthogonality, probability distribution); and probability interpretations of wave function. Elementary concepts of operators; eigenfunctions and eigenvalues; Linear operators; Commutation of operators, commutator and uncertainty relation; Expectation value; Hermitian operator; Postulates of Quantum Mechanics.

Schrödinger equation and its application to free particle and "particle-in-a-box" (rigorous treatment); quantization of energy levels, zero-point energy and Heisenberg Uncertainty principle; wavefunctions; probability distribution functions, nodal properties; Extension to two- and three-dimensional boxes; separation of variables; degeneracy.

Part B: Organic Chemistry

Module-1: Organometallics **08 Lectures**

Grignard reagent; Organolithiums; Gilman cuprates: preparation and reactions addition of Grignard and organolithium to carbonyl compounds; substitution on -COX; 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.

Module-2: Sulphur containing compounds **02 Lectures**

Preparation and reactions of thiols, thioethers and sulphonic acids.

Module-3: Nitrogen Containing Functional Groups **06 Lectures**

Preparation and important reactions of nitro and compounds, nitriles and isonitriles.

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 their synthetic applications.

Module-4: Carboxylic Acids and their Derivatives: **10 Lectures**

Preparation, physical properties and reactions of monocarboxylic acids: Typical reactions of dicarboxylic acids, hydroxy acids and unsaturated acids: succinic/phthalic, lactic, malic, tartaric, citric, maleic and fumaric acids.

Preparation and reactions of acid chlorides, anhydrides, esters and amides; Comparative study of nucleophilic substitution at acyl group -Mechanism of acidic and alkaline hydrolysis of esters, Claisen condensation, Dieckmann and Reformatsky reactions, Hofmannbromamide degradation and Curtius rearrangement.

Module-5: Polynuclear Hydrocarbons **04 Lectures**

Reactions of naphthalene phenanthrene and anthracene. Structure, Preparation and structure elucidation and important derivatives of naphthalene and anthracene; Polynuclear hydrocarbons.

Practical **30 Lectures**

Physical Chemistry

1. Determination of partition coefficient for the distribution of I_2 between water and CCl_4.
2. Determination of partition coefficient for the distribution of I_2 between water and $CHCl_3$.
3. Determination of equilibrium constant of equilibrium $KI + I_2 \rightleftharpoons KI_3$ by partition method.

Organic Preparations

1. Bromination of acetanilide by conventional methods or green approach (Bromate-bromide method).
2. Hydrolysis of amides and esters.
3. Benzil-Benzilic acid rearrangement.

Suggested Textbooks

1. Physical Chemistry, 7th Edition, P. C. Rakshit, 2020, Levant Books.
2. Physical Chemistry, Volume IV, Nabakumar Bera, 2022, Techno World.
3. Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
4. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
5. Graham Solomons, T.W. Organic Chemistry, John Wiley & Sons, Inc.

Practical Reference Books

1. Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).
2. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. Experiments in Physical Chemistry 8th Ed.; McGraw-Hill: New York (2003).
3. An Advanced Course in Practical Chemistry by Nad, Mahapatra & Ghosal, New Central Book Agency (P) Limited, 2014.
4. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry,* Pearson Education (2009)
5. Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis,* University Press (2000).

Course Code	Major 6
Credit Hours	4+2
Course Overview	To impart knowledge about s and p block elements, oxidation and reduction reaction in Inorganic chemistry, general principles of metallurgy and the basic concept of Analytical Chemistry, Optical method of analysis and separation techniques.
Course Outcome	The course aims to provide students with a comprehensive understanding of key topics in inorganic chemistry, analytical chemistry, metallurgy, and separation techniques, preparing them for further study or professional applications in related fields.

Course Overview

Part A: Inorganic Chemistry

Module-1 Chemistry of *s* and *p* Block Elements (14 Lectures)

Inert pair effect, Relative stability of different oxidation states, diagonal relationship and anomalous behavior of first member of each group. Allotropy and catenation. Complex formation tendency of s and p block elements. Hydrides and their classification- ionic, covalent and interstitial. Basic beryllium acetate and nitrate.

Study of the following compounds with emphasis on structure, bonding, preparation, properties and uses. Boric acid and borates, boron nitrides, borohydrides (diborane), carboranes and graphitic compounds, silanes, Oxides and oxoacids of nitrogen, Phosphorus and chlorine. Peroxo acids of Sulphur, interhalogen compounds, polyhalide ions, pseudohalogens, basic properties of halogens.

Module- 2 Oxidation and Reduction (8 Lectures)

Elementary idea on standard redox potentials with sign convention, Nernst equation. Influence of complex formation, precipitation and change of pH on redox potentials, formal potential. Feasibility of a redox titration, redox potential at the equivalence point, redox indicators, redox potential diagram (Latimer and Frost) of common elements and their applications. Disproportionation and comproportionation reactions (typical examples).

Module-3 General Principles of Metallurgy (8 Lectures)

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.

Part B: Analytical Chemistry

Module-1: Quantitative Analytical methods **12 Lectures**

Accuracy and Precision, Errors, Systematic and Random errors, Standard Deviation, Concept of Confidence level and interval, Student's t-test, G-Test, F-test, Calibration method, matrix effect, method of standard addition, method of internal standard, Limit of detection, Limit of quantitation, Selectivity, Specificity and Sensitivity.

Module-2: Optical methods of analysis **08 Lectures**

Origin of spectra, interaction of radiation with matter, fundamental laws of spectroscopy and selection rules, validity of Beer-Lambert's law. UV-Visible Spectrometry: Basic principles of instrumentation (choice of source, monochromator and detector) for single and double beam instrument. Determination of composition of metal complexes using Job's method of continuous variation and mole ratio method.

Module-3: Separation Techniques **10 Lectures**

Solvent extraction: Classification, principle and efficiency of the technique. Mechanism of separation: adsorption, partition & ion exchange. Development of chromatograms: frontal, elution and displacement methods. Affinity Chromatography, Paper Chromatography, Thin-layer Chromatography, Column Chromatography, Size-Exclusion Chromatography, Gel-electrophoresis.

Practical

Inorganic Chemistry-Gravimetric Analysis:

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

Analytical Chemistry

1. Separation of Co^{2+}, Ni^{2+}, Fe^{3+} using Thin Layer Chromatography and calculation of R_f value.
2. Separation of two amino acids using Paper Chromatography and calculation of R_f value.
3. Job's method to determination the composition of iron-salicylic acid complex.

Textbooks

1. Lee, J.D. Concise Inorganic Chemistry, ELBS, 1991.
2. Atkin, P. Shriver & Atkins' Inorganic Chemistry 5th Ed. Oxford University Press (2010).
3. R. P. Sarkar, General and Inorganic Chemistry (Vol. 1), New Central Book Agency, ed. 3, 2011

4. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson, 2006.
5. Quantitative Chemical Analysis, Daniel C Harris: 10th Edition, W H Freeman and Company
6. Fundamental of Analytical Chemistry, Skoog and West, 10th Edition

Reference Books for Practical

1. Vogel, A.I. A text book of Quantitative Analysis, ELBS 1986.

2. Practical Analytical Chemistry, Dr. G Devala Rao, 2010, Birla Publications P Limited.

3. An Advanced Course in Practical Chemistry, Nad, Mahapatra & Ghosal, New Central Book Agency (P) Limited, 2014.

SEMESTER V

Course Code	**Major 7**
Credit Hours	**4+2**
Course Overview	To impart knowledge about important concepts related to Physical Chemistry. This will cover the conductance of solution, properties of ionic solution, basic electrochemistry, chemical thermodynamics, phase equilibrium, and solid-state chemistry.
Course Outcome	This course aims to provide students with a solid foundation in physical chemistry concepts and their applications, preparing them for further study and careers in chemistry, chemical engineering, materials science, and related fields.

Course Overview

Module-1: Phase Equilibria **12 Lectures**

Definitions of phase; component and degrees of freedom; Phase rule and its derivations; Phase diagram for water, CO_2 and Sulphur.

Liquid vapour equilibrium for two component systems. Three component systems; water-chloroform-acetic acid system, triangular plots.; Duhem-Margules equation; Positive and negative deviations from ideal behaviour; Azeotropic solution; Principle of fractional distillation; Konowaloff's rule; Liquid-liquid phase diagram using phenol-water system; Solid-liquid phase diagram; Eutectic mixture; congruent and incongruent melting points.

Module-2: Properties of Ionic Solution **04 Lectures**

Chemical potential of an ion in solution; Activity and activity coefficients of ions in solution; Debye-Hückel limiting law (qualitative) for ion-ion atmosphere interaction potential; activity coefficient for electrolytes; mean ionic activity coefficient and its applications.

Module-3: Conductance **12 Lectures**

Arrhenius theory of electrolytic dissociation; Ion conductance; Conductivity, equivalent and molar conductivity; Variation of specific and equivalent conductance with dilution for strong and weak electrolytes; Kohlrausch's law of independent migration of ions; Debye-Hückel theory of ion atmosphere (qualitative)-asymmetric effect, relaxation effect and electrophoretic effect; Wien effect; Debye- Falkenhagen effect; Debye-Hückel-Onsager equation; Ionic mobility; Application of conductance measurement; Conductometric titrations; Transport number; Principles of Hittorf's and Moving-boundary method; Walden's rule.

Module-4: Electrochemical Cell **20 Lectures**

Electrochemical cell, galvanic cell, electrolytic cell, rules of oxidation/reduction of ions based on half-cell potentials, Chemical cells, reversible and irreversible cells; Faraday's laws of electrolysis; Electromotive force of a cell and its measurement; Nernst equation; Standard electrode 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; determination of activity coefficients and transference numbers; Potentiometric titrations (acid-base, redox, precipitation).

Module-5: Dipole Moment and Polarizability **04 Lectures**

Polarizability of atoms and molecules; dielectric constant and polarisation; molar polarisation for polar and non-polar molecules; Clausius-Mosotti equation and Debye equation and their application; Determination of dipole moments.

Module-6: Solid State **08 Lectures**

Forms of solids; crystal systems, unit cells and Bravais lattice; 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 (qualitative treatment only); Relation between molar mass and unit cell dimension for cubic system; Packing fraction; Schottky and Frenkel defects in crystals.

Practical

1. Conductometric titration of strong acid against strong base.
2. Conductometric titration of weak acid against strong base.
3. Conductometric titration of mixture of strong acid and weak acid against strong base.
4. Conductometric titration dibasic acid against strong base.
5. pH-metric titration of strong acid against strong base.
6. pH-metric titration of weak acid against strong base.

Textbooks

1. Physical Chemistry, 9th Edition, P. W. Atkins, WH Freeman & Co.
2. Physical Chemistry Concepts and Models, Volume III, Nabakumar Bera, 2022, Techno World.
3. Physical Chemistry, 7th Edition, P. C. Rakshit, 2020, Levant Books.

Reference for Practical

1. Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).

2. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. Experiments in Physical Chemistry 8th Ed.; McGraw-Hill: New York (2003).
3. An Advanced Course in Practical Chemistry by Nad, Mahapatra & Ghosal, New Central Book Agency (P) Limited, 2014.

Course Code	Major 8
Credit Hours	4+2
Course Overview	To impart knowledge about important concepts related to Organic Chemistry. This will cover cycloalkanes and conformational analysis, Heterocyclic compounds and biochemistry.
Course Outcome	This course aims to provide students with a solid foundation in organic chemistry concepts and their applications, preparing them for further study and careers in chemistry, biochemistry, materials science, and related fields.

Course Overview

Module-1: Cycloalkanes and Conformational Analysis **16 Lectures**

Types of cycloalkanes and their relative stability, Baeyer strain theory, Conformation analysis of alkanes: Relative stability: Energy diagrams of cyclohexane: Chair, Boat and Twist boat forms; Relative stability with energy diagrams. Dynamic stereochemistry involving cyclohexane ring.

Module-2: Heterocyclic Compounds **16 Lectures**

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

Module-3: Amino Acids, Peptides and Proteins **14 Lectures**

Preparation of amino acids by Strecker and Gabriel phthalimide synthesis. Zwitterion, Isoelectric point and Electrophoresis. Reactions of amino acids: esterification, of $-CO_2H$, acetylation of $-NH_2$, complexation, ninhydrin test. Overview of primary, secondary, tertiary and quaternary structures of proteins, Determination of primary structure of peptides by degradation – Edmann degradation (N-terminal), with thiohydantoin and carboxypeptidase enzyme (C-terminal). Synthesis of simple peptides (upto dipeptides) by N-protection (^{t}butyloxycarbonyl and phthaloyl) and C-activating groups and Merrifield solid-phase synthesis.

Module-4: Carbohydrates **14 Lectures**

Monosaccharides – Constitution and absolute configuration of glucose and fructose, epimers

and anomers, mutarotation, determination of ring size of glucose and fructose. Haworth projections and conformational structures, Interconversions of aldoses and ketoses, Kiliani- Fischer synthesis, Ruff degradation, Osazone formation, Oxidation and Reduction. Disaccharides – Structure elucidation of maltose, lactose and sucrose.

Textbooks

1. Barrow, G. M. *Physical Chemistry,* Tata McGraw-Hill (2007).
2. Berg, J.M., Tymoczko, J.L. and Stryer, L. (2006) Biochemistry. VIth Edition. W. H. Freeman and Co.
3. Nelson, D.L., Cox, M.M. and Lehninger, A.L. (2009) Principles of Biochemistry. IV Edition. W.H. Freeman and Co.
4. Morrison, R. T. & Boyd, R. N. Organic Chemistry, 7th Ed., Pearson Education India (2011).

Practical

1. Estimation of aromatic amine (aniline) by bromination (Bromate-Bromide) method
2. Estimation of phenol by bromination (Bromate-Bromide) method
3. Preparation of urea formaldehyde.
4. Preparation of methyl orange.
5. New preparation
6. Two step synthesis-

Reference Books for Practical:

1. Manual of Biochemistry Workshop, 2012, Department of Chemistry, University of Delhi.
2. Arthur, I. V. Quantitative Organic Analysis, Pearson.

Course Code	Major 9
Credit Hours	4+2
Course Overview	This inorganic chemistry course incorporates the concept of coordination chemistry, chemistry of Transition elements, f-block elements and the basic knowledge about bioinorganic chemistry.
Course Outcome	The course aims to provide students with a comprehensive understanding of key topics in inorganic chemistry, including coordination chemistry, transition elements, f-block elements, and their relevance to biological systems.

Course Overview

Module-1 Coordination Chemistry (24 Lectures)

Werner's theory, IUPAC nomenclature of coordination compounds, isomerism in coordination compounds. Stereochemistry of complexes with 4 and 6 coordination numbers. valence bond theory (inner and outer orbital complexes), electroneutrality principle and back bonding. Crystal field theory, measurement of 10 Dq (Δo), CFSE in weak and strong fields, pairing energies, factors affecting the magnitude of 10 Dq (Δo, Δt). Octahedral vs. tetrahedral coordination, tetragonal distortions from octahedral geometry Jahn-Teller theorem, square planar geometry. Qualitative aspect of Ligand field and MO Theory. Orbital and spin magnetic moments, spin only moments of dn ions and their correlation with effective magnetic moments, including orbital contribution; quenching of magnetic moment: super exchange and ferromagnetic/antiferromagnetic interactions (elementary idea with examples only); d-d transitions; L-S coupling; qualitative Orgel diagrams for 3dl -3d9 ions and their spectroscopic ground states; selection rules for electronic spectral transitions; spectrochemical series of ligands; charge transfer spectra (elementary idea). Chelate effect, polynuclear complexes, Labile and inert complexes.

Module-2 Transition Elements (6 Lectures)

General comparison of 3d, 4d and 5d elements; Electronic configuration; Oxidation state; Redox properties; Atomic radii; Ionization potentials; Metallic nature; Atomization energy;
Coordination chemistry and catalytic properties

Module-3 *f* block elements (14 Lectures)

f block elements and their comparison with d block. Lanthanides: Lanthanide contraction; Electronic configuration; Oxidation states; Atomic/Ionic radii; Ionization energy; Complex formation; Isomerization; Basicity; Hydration of Ln (III) ions; Organometallics compounds and their applications; Separation of lanthanides by ion exchange method. Actinides: Actinide

contraction; Electronic configuration; Oxidation states; Atomic/Ionic radii; Ionization energy; Complex formation and Organometallic compounds.

Module-4 Bioinorganic Chemistry (16 Lectures)

Elements of life: essential, major, trace and ultratrace elements. Basic chemical reactions in the biological systems and the role of metal ions (specially Na^{+}, K^{+}, Mg^{2+}, Ca^{2+}, $Fe^{3+/2+}$, $Cu^{2+/+}$, and Zn^{2+}). Ionophores, Sodium potassium pump. Biological functions of hemoglobin and myoglobin, cytochromes and ferredoxins, carboxypeptidase, carbonic anhydrase. Biological nitrogen fixation, Photosynthesis: Photo system-I and Photosystem-II. Toxic metal ions and their effects, chelation therapy, Pt and Au complexes as drugs (examples only), metal dependent diseases.

Practical

Preparation of

1. Tetraamminecopper (II) sulphate, $[Cu(NH_3)_4]SO_4.H_2O$.
2. Potassium tris(oxalate)ferrate (III)

Suggested Textbook

1. R. L. Dutta & G.S. De, Inorganic Chemistry (Vol. 1), The New Book Stall, 1973.
2. Purcell, K.F & Kotz, J.C. Inorganic Chemistry W.B. Saunders Co, 1977.
3. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.
4. Lippard, S.J. & Berg, J.M. Principles of Bioinorganic Chemistry Panima Publishing Company 1994.
5. Cotton, F.A. & Wilkinson, G, Advanced Inorganic Chemistry Wiley-VCH, 1999.

Reference Book for Practical

1. Marr & Rockett Practical Inorganic Chemistry. John Wiley & Sons 1972.
2. An Advanced Course in Practical Chemistry by Nad, Mahapatra & Ghosal, New Central Book Agency (P) Limited, 2014.
3. Vogel, A.I. A text book of Quantitative Analysis, ELBS 1986.

SEMESTER VI

Course Code	**Major 10**
Credit Hours	**4+2**
Course Overview	To impart knowledge about important concepts related to Physical Chemistry. This will cover Quantum chemistry, molecular spectroscopy, Photochemistry, Statistical Thermodynamics, Concept of Dipole moment and Macromolecules.
Course Outcome	This course aims to provide students with a solid foundation in physical chemistry concepts and their applications, preparing them for further study and careers in chemistry, chemical engineering, materials science, and related fields.

Course Overview

Module-1: Kinetics and Catalysis **07 Lectures**

Collision theory; Lindemann theory of unimolecular reaction; outline of Transition State theory (classical treatment); Types of catalyst; Homogeneous catalysis; acid-base catalysis; Enzyme catalysis; Michaelis-Menten equation; Lineweaver-Burk plot; Heterogenous catalysis (single reactant); unimolecular surface reactions; Primary kinetic salt effect.

Module-2: Introduction to Quantum Chemistry **12 Lectures**

Qualitative treatment of simple harmonic oscillator model of vibrational motion; Setting up of Schrödinger equation and discussion of solution and wavefunctions; Vibrational energy, and zero-point energy; Schrödinger equation in Cartesian and spherical polar coordinates (without derivation); Separation of variables; Rigid rotator model of rotation of diatomic molecule; Spherical harmonics. Qualitative treatment of hydrogen atom and hydrogen-like ions; setting up of Schrödinger equation in spherical polar coordinates, radial part, quantization of energy (only final energy expression); average and most probable distances of electron from nucleus.

Module-3: Statistical Thermodynamics **08 Lectures**

Macrostates, microstates and configuration; Thermodynamic probability, Entropy and probability; Boltzmann distribution law; Partition function; translational, rotational and vibrational partition functions; Thermodynamic properties in terms of partition function. Nernst heat theorem; Planck's formulation of third law of thermodynamics; Concept of residual entropy and absolute entropy of molecules.

Module-4: Molecular Spectroscopy **26 Lectures**

Interaction of electromagnetic radiation with molecules and various types of spectra; Born-Oppenheimer approximation

Rotation spectroscopy: Selection rules; intensities of spectral lines; determination of bond lengths of diatomic and linear triatomic molecules; isotopic substitution

Vibrational spectroscopy: Classical equation of vibration; computation of force constant; amplitude of diatomic molecular vibrations; anharmonicity; Morse potential; dissociation energies; fundamental frequencies; overtones; hot bands; degrees of freedom for polyatomic molecules; modes of vibration; concept of group frequencies

Vibration-rotation spectroscopy: diatomic vibrating rotator, P, Q, R branches.

Electronic spectroscopy: Franck-Condon principle; electronic transitions; singlet and triplet states; fluorescence and phosphorescence; Jablonski diagram; dissociation and predissociation; calculation of electronic transitions of polyenes using free electron model.

Raman spectroscopy: Qualitative treatment of Rotational Raman effect; Effect of nuclear spin; Vibrational Raman spectra; Stokes and anti-Stokes lines; rule of mutual Exclusion

Module-5: Photochemistry **07 Lectures**

Lambert-Beer's law and its limitations; physical significance of absorption coefficients; Laws of photochemistry; quantum yield; low and high quantum yields; chemiluminescence; actinometry; photochemical equilibrium and the differential rate of photochemical reactions; HI decomposition; H_2-Br_2 reaction, photosensitized reactions; photostationary states; dimerization of anthracene;

List of Practical

1. Verification of Lambert-Beer's Law for $K_2Cr_2O_7$ solution.
2. Verification of Lambert-Beer's Law for $KMnO_4$ solution.
3. Verification of Lambert-Beer's Law for $CuSO_4$ solution.
4. Determination of pH of unknown buffer using spectrophotometrically.

Textbooks

1. Physical Chemistry, 9th Edition, P. W. Atkins, WH Freeman & Co.
2. Fundamentals of Molecular Spectroscopy, Banwell, 4th Edition, 2017, McGraw Hill Edu.
3. Physical Chemistry, 7th Edition, P. C. Rakshit, 2020, Levant Books.

Reference for Practical

1. Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).
2. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. Experiments in Physical Chemistry 8th Ed.; McGraw-Hill: New York (2003).
3. An Advanced Course in Practical Chemistry by Nad, Mahapatra & Ghosal, New Central Book Agency (P) Limited, 2014.

Course Code	Major 11
Credit Hours	4+2
Course Overview	To impart knowledge about important concepts related to Organic Chemistry. This will cover Pericyclic chemistry, Organic spectroscopy and some important biomolecules.
Course Outcome	This course aims to provide students with a solid foundation in organic chemistry concepts and their applications, preparing them for further study and careers in chemistry, biochemistry, materials science, and related fields.

Course Overview

Module-1: Pericyclic reactions **15 Lectures**

Mechanism, stereochemistry, regioselectivity in case of Electrocyclic reactions: FMO approach involving 4π- and 6π-electrons (thermal and photochemical) and corresponding cyclo reversion reactions. Cycloaddition reactions: FMO approach, Diels-Alder reaction, photochemical [2+2] cycloadditions. Sigmatropic reactions: FMO approach, sigmatropic shifts and their order; [1,3]- and [1,5]-H shifts and [3,3]-shifts with reference to Claisen and Cope rearrangements.

Module-2: Organic Spectroscopy **35 Lectures**

General principles; Introduction to absorption and emission spectroscopy.

UV Spectroscopy: Types of electronic transitions, λmax, Chromophores and auxochromes, Bathochromic and hypsochromic shifts, Intensity of absorption, Application of Woodward rules to calculate λmax for the following systems: α,β-unsaturated aldehydes, ketones, carboxylic acids, esters, conjugated dienes (alicyclic, homoannular and heteroannular), extended conjugated systems (aldehydes, ketones and dienes), and distinction between cis- and trans-isomers.

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

NMR Spectroscopy: Basic principles of Proton Magnetic Resonance, chemical shift, shielding and deshielding mechanisms, Anisotropic effects in alkene, alkyne, aldehydes and aromatics, equivalence and non-equivalence of protons, Spin–Spin coupling, notation for spin systems, coupling constant, and its variation with stereochemistry, Structural application of ^{1}H NMR, aromaticity, antiaromaticity and homoaromaticity of organic molecules and related problems. Applications of IR, UV and NMR for identification of simple organic molecules.

Nucleic Acids and Enzymes **15 Lectures**

Components of nucleic acids, Nucleosides and nucleotides; Structure and nomenclature of: Adenine, Guanine, Cytosine, Uracil and Thymine; Structure of polynucleotides, molecular biology of DNA and RNA: structure, properties and types of DNA (A, B and Z) and RNA (hn RNA, mRNA, tRNA and rRNA). DNA replication.

Enzymes

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

Textbooks

1. Kemp, W. *Organic Spectroscopy*, Macmillan India (2019).
2. Pavia, D. L. *Introduction to Spectroscopy,* 5th Ed., Cengage India Pvt. Ltd. (2015).
3. Fleming, I. *Pericyclic Reactions,* 2nd Ed., Oxford University Press (2015).

Practical

Solid mixture separation

1. Separation based upon solubility, by using common laboratory reagents like water (cold, hot), dil. HCl, dil. NaOH, dil. $NaHCO_3$, etc., of components of a binary solid mixture; purification of the separated components by crystallization and determination of its melting point. The composition of the mixture may be of the following types: Benzoic acid/p-Toluidine; p Nitrobenzoic acid/p-Aminobenzoic acid; p-Nitrotoluene/p-Anisidine; etc.

Chromatography separation:

1. Separation of a mixture of two amino acids by ascending and horizontal paper chromatography

2. Separation of a mixture of o-and p-nitrophenol or o-and p-aminophenol by thin layer chromatography (TLC)

3. Column chromatographic separation of mixture of dyes.

Reference Books:

1. Vogel, A.I. *Quantitative Organic Analysis,* Part 3, Pearson (2012).
2. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry,* Pearson Education (2009)

Course Code	**Major 12**
Credit Hours	**4+2**
Course Overview	This inorganic chemistry describes some important inorganic reaction mechanism and kinetics, general idea about the organometallic chemistry and some catalytic process using organometallic compounds.
Course Outcome	The course aims to provide students with a solid foundation in inorganic chemistry, with a focus on reaction mechanisms, kinetics, organometallic chemistry, and catalysis.

Course Overview

Module-1 Inorganic Reaction Mechanism and Kinetics **18 Lectures**

Stability of complexes in solution. Stepwise and overall formation constants and their relations. Trends in stepwise formation constants, factors affecting the stability of metal complexes with reference to the nature of the metal ions and ligands. Statistical and non-statistical factors influencing stability of complexes in solution. Introduction to inorganic reaction mechanisms. Thermodynamic and Kinetic stability, Kinetics of octahedral substitution, Ligand field effects and reaction rates, Mechanism of substitution in octahedral complexes. Substitution reactions in square planar complexes, Trans- effect, theories of trans effect, Mechanism of nucleophilic substitution in square planar complexes,

Module-2 Organometallic compounds **30 Lectures**

Definition and classification of organometallic compounds on the basis of bond type. Concept of hapticity of organic ligands. Metal carbonyls: 18 electron rules, electron count of mononuclear, polynuclear and substituted metal carbonyls of 3d series. General methods of preparation (direct combination, reductive carbonylation, thermal and photochemical decomposition) of mono and binuclear carbonyls of 3d series. Structures of mononuclear and binuclear carbonyls of Cr, Mn, Fe, Co and Ni using VBT. π-acceptor behaviour of CO (MO diagram of CO to be discussed), synergic effect and use of IR data to explain extent of back bonding. Zeise's salt: Preparation and structure, evidences of synergic effect and comparison of synergic effect with that in carbonyls. Metal Alkyls: Important structural features of methyl lithium (tetramer) and trialkyl aluminium (dimer), concept of multicentre bonding in these compounds. Role of triethylaluminium in polymerisation of ethene (Ziegler – Natta Catalyst). Species present in ether solution of Grignard reagent and their structures, Schlenk equilibrium. Ferrocene: Preparation and reactions (acetylation, alkylation, metallation, Mannich Condensation). Structure and aromaticity. Comparison of aromaticity and reactivity with thatof benzene.

Module-3 Catalysis by Organometallic Compounds **12 Lectures**

Study of the following industrial processes and their mechanism:

1. Alkene hydrogenation (Wilkinson's Catalyst)
2. Hydroformylation (Co salts)
3. Wacker Process
4. Synthetic gasoline (Fischer Tropsch reaction)
5. Synthesis gas by metal carbonyl complexes.

Practical 30 Lectures

Qualitative semi micro analysis of mixtures containing four radicals. Emphasis should be given to the understanding of the chemistry of different reactions. The following radicals are suggested: CO_3^{2-} , NO_2^-, S^{2-} , SO_3^{2-} , $S_2O_3^{2-}$, CH_3COO^-, F^-, Cl-, Br-, I-, NO_3^-, BO_3^{3-} , $C_2O_4^{2-}$, PO_4^{3-}, NH_4^+, K^+, Pb^{2+}, Cu^{2+}, Cd^{2+}, Bi^{3+}, Sn^{2+}, Sb^{3+}, Fe^{3+}, Al^{3+}, Cr^{3+}, Zn^{2+}, Mn^{2+}, Co^{2+}, Ni^{2+}, Ba^{2+}, Sr^{2+}, Ca^{2+}, Mg^{2+}. Mixtures should preferably contain one interfering anion, or insoluble component ($BaSO_4$, $SrSO_4$, $PbSO_4$, CaF_2 or Al_2O_3) or combination of anions e.g. CO_3^{2-} and SO_3^{2-} , $NO_2^-$and NO_3^-, Cl^- and Br^-, Cl^- and I^-, Brand I^-, NO^{3-} and Br^-, NO^{3-} and I^-. Spot tests should be done whenever possible.

Suggested Textbook

1. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.
2. Powell, P. Principles of Organometallic Chemistry, Chapman and Hall, 1988.
3. Basolo, F. & Pearson, R. Mechanisms of Inorganic Reactions: Study of Metal Complexes in Solution 2nd Ed., John Wiley & Sons Inc; NY.
4. Purcell, K.F. & Kotz, J.C., Inorganic Chemistry, W.B. Saunders Co. 1977
5. Crabtree, R. H. The Organometallic Chemistry of the Transition Metals. j New York, NY: John Wiley, 2000.
6. Essentials of Nuclear Chemistry by H. J. Arnikar
7. Fundamental Concepts of Inorganic Chemistry, Vol-1, 2 and 3 by Asim K. Das

Reference Books for Practical

1. Vogel's Qualitative Inorganic Analysis, Revised by G. Svehla. Pearson Education, 2002.
2. Marr & Rockett Practical Inorganic Chemistry. John Wiley & Sons 1972.