CURRICULUM FRAMEWORK FOR

CHEMISTRY

FOUR YEAR UNDERGRADUATE PROGRAMME (FYUP)

UNDER

NEW EDUCATION POLICY (NEP), 2020

(1st TO 8th SEMESTER)

Date of approval by the Academic Council:

Semester 1-2: Sept 23, 2023

Semester 3-8: May 30, 2024

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CHE-100 INTRODUCTORY CHEMISTRY-I
(Contact Hours: 75, Credits: 4)
Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objective: *The contents, assignments and assessments of this course are aligned to understand the fundamental concepts in chemistry. The students will also learn the qualitative analysis technique to identify the acidic and basic radicals present in inorganic salts.*

Course Outcomes: *The main objective of this course is to demonstrate scientific understanding of the structure of matter and its physical and chemical transformations so that students will be able to apply appropriate theories to predict chemical structure, reactivity and physical properties. It would also provide students with hands-on training in qualitative analysis of various inorganic ions.*

PART-A (Theory)

Unit I: Inorganic Chemistry-I **Marks: 7 (In-Sem.): 18 (End Sem.)** **(15 hours)**

(a) Structure of Atom: Bohr's atomic model and its limitations, Dual nature of matter and radiation, De-Broglie's matter waves, Heisenberg's Uncertainty principle, Schrodinger's wave equation, and its importance, Radial and angular wave function, Physical concept of Ψ and Ψ^2, Quantum numbers, Shapes of s, p and d orbitals, Principles of electronic configuration: Aufbau, Pauli's exclusion and Hund's rules of maximum multiplicity, Screening effect and effective nuclear charge.
(5 marks, 5 hours)

(b) Chemical Periodicity: Long form of periodic table, Modern periodic law, Types of elements on the basis of electronic configuration, periodic variation in properties: atomic and ionic radii, ionization enthalpy, electron gain enthalpy, electronegativity, Diagonal relationships.
(5 marks, 4 hours)

(c) Chemical Bonding-I: Valence shell electron pair repulsion (VSEPR) theory and shapes of molecules and ions: BeF_2, CO_2, BF, BO_3^{3-}, O_3, H_3O^+, NH_3, H_2O, PCl_3, PCl_5, SF_4 and SF_6, Basic concept of valence bond theory, Formation of Hydrogen molecule and its Limitations, Salient features of hybridization. Concept of hybridization of orbitals and its implications on bond length, bond energy, bond angles shapes of molecules with the following examples: BeF_2, CO_2, BF_3, BO_3^{3-}, O_3, H_3O^+, NH_3, H_2O, PCl_3, PCl_5, SF_4, SF_6, $AlCl_3$, CLF_3, I^{3-}, Polarity of covalent bonds and dipole moment, Percentage ionic character, Dipole moments and structure of molecules, Polarizing power, Polarizability of ions, Fazan's rules, Concept of Lattice energy and Born-Haber cycle (NaCl).
(8 marks, 6 hours)

Unit II: Organic Chemistry-I **Marks: 6 (In-Sem.): 19 (End Sem.)** **(15 hours)**

(a) Nomenclature, Structure, Bonding and Properties: Nomenclature of organic molecules (hydrocarbons, halogen compounds, aldehydes, ketones, alcohols, ethers, amines, carboxylic acids, esters, amides and nitro compounds). Hybridization and its implications on the bond length, bond energy, bond angles, shape of the molecules with following examples: (i) CH_4, CH_3^-, RNH_2 (ii) C_2H_4, CH_3^+, carbonyl compounds (C=O) and (iii) C_2H_2, R-C≡N, ketene. Nature of covalent bond and its orbital representation in molecules listed above, Electronegativity, Inductive effect, Effect of H-bonding on boiling point and solubility of organic compounds, Conjugation, Resonance, Hyperconjugation (propene and toluene), Heterolytic and homolytic bond cleavage, Electrophiles and nucleophiles, Reactive intermediates: carbocations, carbanions and free radicals.
(8 marks, 6 hours)

(b) Alkanes and Cycloalkanes: Methods of preparation of alkanes (with special reference to mechanism of Kolbe, Würtz, Würtz-Fittig and Corey-House reactions), Chemical reactivity

(oxidation and cracking). Mechanism of chlorination, Relative reactivity of halogens towards different types of alkanes. General methods of preparation of cycloalkanes (up to cyclohexane) and their reactions with halogens and HX, Baeyer's strain theory – modifications and its limitations.

(5 marks, 4 hours)

(c) Alkenes and Alkynes: Synthesis and reactivity of alkenes, Markownikoff's rule and anti-Markownikoff's rule, Mechanism of hydrogenation, bromination, hydration, halo-hydration, hydroboration, oxidation, epoxidation, ozonolysis, hydroxylation and polymerization, Comparative acidity of ethane, ethane and ethyne, Synthesis and reactivity of alkynes: electrophilic addition reactions (halogenation, hydration, HX and HOX), ozonolysis; alkynides (Na, Cu and Ag) and polymerization.

(6 marks, 5 hours)

Unit III: Physical Chemistry-I Marks: 6 (In-Sem.): 19 (End Sem.) (15 hours)

(a) State of Matter: (i) Gaseous State-I: Postulates of kinetic theory of gases, Collisions and gas pressure, Average kinetic energy, Root mean square velocity and absolute temperature of gas, Boltzmann constant, Gas laws and kinetic theory, Liquification of CO_2 gas, Real gases - deviation from ideality, Compressibility factor and its variation with pressure and temperature for different gases, and van der Waals equation of state.

(7 marks, 6 hours)

(ii) Liquid State-I: Qualitative description of the structure of liquids, Physical properties of liquids: vapour pressure, Surface tension, Viscosity, Refractive index (definitions and descriptions). Effect of additive (sodium chloride and ethanol) on surface tension and viscosity of liquid.

(4 marks, 3 hours)

(iii) Solid State-I: Elementary discussion on the types of unit cells, Crystal systems, Crystal defects, Bragg's law.

(3 marks, 2 hours)

(b) Chemical Kinetics-I: Rate of reaction and rate constant, Molecularity and order of a reaction, Zero-order reaction, Differential and integrated forms of rate equations of first and second order reactions, Pseudo-first order reactions, Determination of order of reactions, Effect of temperature on reaction rates and energy of activation, Effect of catalyst.

(5 marks, 4 hours)

PART-B (Practical)

Unit-IV: Laboratory work (Inorganic) Marks: 6 (In-Sem.): 19 (End Sem.) (30 hours)

Experiment: Qualitative analysis of inorganic mixtures containing at least five radicals/ions (from the list given below) to be completed-one of the radicals/ions must be interfering (borate, chromate or phosphate).

List of ions /radicals

Cations: Pb^{2+}, Cu^{2+}, Bi^{3+}, As^{3+}, Sn^{2+}, Sn^{4+}, Fe^{2+}, Fe^{3+}, Al^{3+}, Ba^{2+}, Cr^{3+}, Zn^{2+}, Mn^{2+}, Co^{2+}, Ni^{2+}, Ca^{2+}, Sr^{2+}, Mg^{2+}, K^{+}, NH^{4+},

Anions: Cl^{-}, Br^{-}, I^{-}, SO_4^{2-}, BO_3^{3-}, PO_4^{3-}, CrO_4^{2-}

Interfering radicals/ions: BO_3^{3-}, PO_4^{3-}, CrO_4^{2-}

Marks Distribution	***In-semester***	***End-semester***	***Exam duration***
1. Experiment	2	12	6 hours
2. Viva voce	2	5	
3. Laboratory records	2	2	

CHE-150 INTRODUCTORY CHEMISTRY-II
(Contact Hours: 75, Credits: 4)
Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objectives: *The primary objective of this course is to prove a broad foundation in chemistry that stresses scientific understanding and reasoning along with problem solving aptitude with a molecular perspective. It would also provide the students with the skills required to analyze and comprehend the chemical composition of organic compound.*

Course Outcomes: *Upon successful completion of this course, the students will have firm foundation in the fundamentals and application of current chemical, nuclear and basic scientific theories including those in inorganic, organic and physical chemistries. They will also know the techniques to identify the functional groups and analyze the organic samples*.

PART-A (Theory)

Unit I: Inorganic Chemistry-II **Marks: 6 (In-Sem.): 19 (End Sem.)** **(15 hours)**

(a) Nucleus and Radioactivity: Elementary nuclear particles and concept of mesons and pions, Size of nucleus and nuclear forces, Magic numbers, Mass defect and nuclear binding energy, Packing fraction, Q value of nuclear reactions, Neutron-proton ratio and its implications, Natural and artificial radioactivity, Radioactive disintegration series(4n, 4n+1 and 4n+2), First order kinetics of radioactive disintegration, Half-life period and average half-life period, Group displacement law, Radioactive equilibrium, Types of nuclear reactions, Chain reaction and critical mass, Elementary concept of fusion and fission, Principles of separation of isotopes - gaseous diffusion, electrolysis and electromagnetic separation methods, , Application of radioisotopes as tracers, Detection and measurement of radioactivity (GM counter), Basic principles and types of nuclear reactors.

(10 marks, 8 hours)

(b) Redox reactions: Elementary concept of oxidation and reduction, Oxidation number, Common oxidants and reductants, Calculations of equivalent weights of oxidants and reductants, Balancing of redox reactions by ion electron method.

(4 marks, 3 hours)

(c) Acids and Bases: Arrhenius concept, Bronsted–Lowry concept, Solvent system concept and its limitations, Franklin concept, Lewis concept, Differentiating and levelling effect, Effect of solvents in the relative strengths of acids and bases (pK_a and pH concept). Classification of acids and bases as hard and soft, Pearson's SHAB principle and its application, Symbiosis, Basis of hard-hard and soft-soft interactions.

(5 marks, 4 hours)

Unit II: Organic Chemistry-II **Marks: 7 (In-Sem.): 18 (End Sem.)** **(15 hours)**

(a) Organic Stereochemistry-I: Concept of isomerism, Types of isomerism, Configurational and conformational isomerism (ethane and butane), Fischer, Newman and Sawhorse projections with suitable examples, Geometrical isomerism, Configuration of geometrical isomers, E and Z nomenclature (including oximes), Optical isomerism: optical activity, chiral carbon atom, enantiomers, diastereomers, R/S nomenclature (with one chiral carbon atom only)

(5 marks, 5 hours)

(b) Aromatic Hydrocarbons and Aromaticity: Molecular orbital picture of benzene, Resonance energy, Aromaticity, Hückel's (4n+2) rule and its application to simple molecules and ions, Electrophilic substitution reactions in aromatic hydrocarbons and general pattern of the mechanism, Effect of substituent groups (activating and deactivating groups, directive influence): mechanism of nitration, sulphonation, halogenation (nuclear and side-chain), formylation (Gattermann and Gattermann - Koch), Friedel - Craft's alkylation and acylation.

(5 marks, 4 hours)

(c) Nucleophilic Substitution Reactions: Nucleophile, Ambident nucleophile (KCN, AgCN, KNO_2, $AgNO_2$), Difference between nucleophiles and bases, SN1, SN2, NGP, SNi, Factors affecting substitution reactions (structure of substrate, nature of nucleophile, solvent and role of leaving group), Mechanism and stereochemistry of substitution reactions.

(5 marks, 4 hours)

(d) Elimination reactions: E^1, E^2, E^1cB mechanism, Orientation in elimination reactions (Saytzeff's and Hoffmann rules).

(3 marks, 2 hours)

Unit III: Physical Chemistry-II Marks: 6 (In-Sem.): 19 (End Sem.) (15 hours)

(a) Thermodynamics-I: Concept of system and surrounding, types of systems, Intensive and extensive properties, Types of processes: isothermal, adiabatic, isobaric, reversible, irreversible and cyclic processes; Thermodynamic functions: state variables and exact differentials, Path functions and inexact differentials, Zeroth law of thermodynamics, Reversibility and maximum work in ideal gas expansion. First law of thermodynamics: Statement, internal energy, enthalpy, Heat capacity at constant pressure (C_p) and volume (C_v), Concept of heat, Relation between C_p and C_v, Spontaneous processes, Entropy, Second law of thermodynamics, Joule-Thomson coefficient and inversion temperature.

(10 marks, 8 hours)

(b) Thermochemistry: Exothermic and endothermic reactions, Hess's law of constant heat summation, Enthalpy of formation, Standard state, Enthalpy of combustion, Enthalpy of neutralization, Enthalpy of solution, Enthalpy of dilution, Kirchhoff's equations: influence of temperature on H and U of a reaction.

(5 marks, 4 hours)

(c) Adsorption and Surface Phenomena: Physisorption and chemisorption, Adsorption isotherms: derivation and application of Freundlich and Langmuir adsorption isotherm.

(4 marks, 3 hours)

PART-B (Practical)

Unit IV: Laboratory work (Organic) Marks: 6 (In-Sem.): 19 (End Sem.) (30 hours)

Experiment: Systematic qualitative analysis of organic compounds containing one functional group.

(a) Detection of elements (N, Cl, Br and I)

(b) Determination of one of the following functional groups present in a single organic compound (with systematic reporting)

-COOH, -OH (phenolic), -CHO, >C=O, $-NH_2$ and $-NO_2$

(c) Preparation of the derivative.

Marks Distribution	*In-semester*	*End-semester*	*Exam duration*
1. Experiment	2	12	6 hours
2. Viva voce	2	5	
3. Laboratory records	2	2	

CHE-200: INTERMEDIATE CHEMISTRY-I
(Contact Hours: 60, Credits: 4)
Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objectives: *To provide students with a comprehensive understanding of inorganic chemistry principles, including main group elements, transition metals, and related compounds, along with the application of mathematical and thermodynamic concepts relevant to chemistry. Additionally, the course aims to explore the properties of dilute solutions and chemical equilibria to deepen students' understanding of solution chemistry and dynamic chemical systems.*

Course outcomes: *Learner of this course will acquire a comprehensive understanding of inorganic chemistry principles, encompassing main group elements, transition metals, and related compounds, alongside proficiency in applying mathematical and thermodynamic concepts relevant to chemistry. Furthermore, they will also demonstrate the ability to analyze the properties of dilute solutions and chemical equilibrium.*

PART-A (Inorganic) **Marks: 12 (In-Sem.): 38 (End Sem.)** **(30 hours)**

Unit I: Main group elements

(a) s- and p-block elements and their Compounds: Group discussion of the elements with respect to their position in the periodic table, electronic configuration, Atomic and ionic radii, Ionization enthalpy, Electron gain enthalpy, Electronegativity, Oxidation states, Variation of acidic and basic properties of their oxides and oxy-acids, Inert -pair effect and catenation.
Preparation, important reactions, structure and use of the following compounds: sodium thiosulphate, potassium iodide, quick lime, bleaching powder, diborane, boric acid, aluminium chloride, lithium aluminium hydride, hydrazine, hydroxylamine, hydrazoic acid and lead tetra-acetate.

(12 marks, 10 hours)

(b) Interhalogens, Polyhalides and Pseudohalides: Definition of interhalogen, polyhalide and pseudohalide compounds, Different types of interhalogens and their reactivity, polyhalides of iodine; preparation and reactivity of pseudohalides: cyanogen, and thiocynogen, structure of ClF_3, BrF_3, BrF_5, and IF_7.

(7 marks, 5 hours)

Unit II: Transition metals

(a) d- and f-block elements and their Compounds: Transition metals - Definition and characteristic features of transition metals, electronic configuration of d-block elements, General characteristics of transition metals: Atomic and ionic radii, Melting and boiling point, Ionization energies, oxidation states, colour, reducing and catalytic properties, and magnetic properties. Variation of properties in first, second and third row transition metals.
Lanthanides and Actinides: Electronic configuration of lanthanides and actinides, oxidation states of lanthanides and actinides, variation in their atomic and ionic radii – lanthanide contraction, separation of lanthanides: solvent method and ion exchange method of separation only, synthetic elements, synthesis of Np and Pu only
Preparation, important reactions, structures and uses of nickel tetra-carbonyl, potassium ferricyanide, potassium dichromate, potassium permanganate, sodium nitroprusside, sodium cobaltinitrite, Nessler's reagent and uranium hexafluoride

(12 marks, 10 hours)

(b) Chemical Bonding-II: Molecular orbital Theory (MOT): Salient features of molecular orbital theory, Formation of molecular orbitals: Linear combination of atomic orbitals, Conditions for the

combination of atomic orbitals, Shapes of molecular orbitals, Applications of MOT to homo and heteronuclear diatomic molecules : H_2, N_2, N_2^+, N_2^{2+}, N_2^-, N_2^{2-}, O_2, O_2^+, O_2^{2+}, O_2^-, O_2^{2-}, Cl_2, CO and NO). Electronic configuration of molecules and molecular behavior viz. bond order, bond length, nature of the bond, and magnetic nature.

(7 marks, 5 hours)

PART-B (Physical) Marks: 13 (In-Sem.): 37 (End Sem.) (30 hours)

Unit III: Fundamental Mathematics and Concepts of Thermodynamics

(a) Mathematics for Chemistry-I: Mathematical functions, polynomial expressions, logarithms, the exponential function, units of a measurement, interconversion of units, constants and variables, equation of a straight line, plotting graphs; Basic Trigonometric functions; differentiation: Functions, limits, derivative, physical significance, basic rules of differentiation, maxima and minima, partial differentiation, cyclic rule; Integration: rules of integration, definite and indefinite integrals.

(9 marks, 7 hours)

(b) Thermodynamics-II: Limitations of the first law, statements of second law, spontaneous processes. Carnot cycle and its efficiency, Carnot's theorem, Entropy (S) as a state function, entropy changes of ideal gases in different processes. Gibbs function (G) and Helmholtz function (A), criteria for thermodynamic equilibrium and spontaneity, variation of G and A with pressure, volume and temperature, Gibbs-Helmholtz equation, Clausius-Clapeyron equation, Trouton's rule.

(9 marks, 8 hours)

Unit IV: Solution Chemistry and Equilibrium

(a) Dilute Solutions: Raoult's law and Henry's law; Colligative properties: relative lowering of vapour pressure, elevation in boiling point, depression in freezing point, osmosis, osmotic pressure and its determination; relation between colligative properties and molecular mass, determination of molecular mass, van't Hoff factor, abnormal molar mass, Reverse osmosis and its applications.

(10 marks, 8 hours)

(b) Chemical Equilibria: Law of mass action, equilibrium constant (K) from thermodynamic considerations, temperature and pressure dependence of equilibrium constants (K_p and K_c - van't Hoff equation, relation of K_p and K_c, equilibria in homogeneous and heterogeneous systems, Le Chatelier's principle, effect of addition inert gases on equilibrium constant.

(9 marks, 7 hours)

CHE-201: ORGANIC CHEMISTRY LABORATORY
(Contact Hours: 120, Credits: 4)
Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objectives*: To provide hands-on experience in the separation of the organic binary mixture based on the acid-base concept and compound synthesis.*

Course outcomes*: Upon successful completion of this course, students will know separation techniques, functional group detection, derivative preparation, and melting point measurement. Moreover, they will also know the preparation of organic compounds following green chemistry principles.*

Laboratory Course (Organic)

1. Separation of Mixtures

(a) Separation of binary organic mixtures based on acid-base concept.
(b) Analysis and preparation of derivatives, determination of melting points of compounds and derivatives, identification of compounds

2. Organic Preparation

Preparation of the following compounds:
(a) Phthalimide (from phthalic anhydride)
(b) *m*-Dinitrobenzene (from nitrobenzene)
(c) Picric acid (from phenol)
(d) *p*-Bromoacetanilide (from acetanilide)
(e) Benzilic acid (from benzil)

3. Green method of synthesis of the following compounds

(a) benzilic acid
(b) *p*-bromoacetanilide
(c) acetanilide (acetylation of primary amines)
(d) α,β-unsaturated ester/nitrile (Knoevenagel condensation)

Marks Distribution	***In-semester***	***End-semester***	***Exam duration***
1. Separation of mixtures	15	40	
2. Organic Preparation	5	10	
3. Green method of synthesis	-	10	18 hours
4. Viva voce	3	10	
5. Laboratory records	2	5	

CHE-250: INTERMEDIATE CHEMISTRY-II
(Contact Hours: 60, Credits: 4)
Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objectives: *The main objective about this course is to make the students aware about different basic concepts of the bonding principles responsible for the energetics and structure of the coordination and organometallic chemistry. In this course, they will also learn about the theories of analytical chemistry used in different analytical techniques and to interpret the experimental data by using statistical methods.*

Course Outcomes: *The students will be benefited from this course by knowing more about the compounds formed by the metals in a complex form. The critical analytical thinking of the learner will also improve in respect of the analytical and statistical procedures after completion of this course.*

Unit I: Analytical Chemistry-I

Standard solutions : Primary and secondary, Concentrations of standard solutions, Applications of chemical equilibrium to analytical separations and estimations : equilibrium constants, activity coefficients, acid-base equilibrium, solubility equilibrium, distribution equilibria, complex ion equlibria and stability constants, Basic theories of systematic qualitative analysis : solubility product, common ion effect, pH and buffer actions, complex formation, Volumetric analysis : permanganatometry, dichromatometry, iodometric and iodimetric analysis, Complexometric titrations with special emphasis on EDTA titrations, Theory of indicators, Gravimetric analysis: theory of precipitation, fractional precipitation, co-precipitation and post precipitation.

(19 marks, 15 hours)

Unit II: Coordination Chemistry-I

Double salts an complex salts, Werner's Coordination theory, Coordination number, Ligands and their classification , Chelation and its applications of chelate formation, Nomenclature of coordination compounds(mono and poly-nuclear), Determination of composition of complexes by spectrophotometric method, Effective atomic number rule, Factors influencing the detection of complex formation, Isomerism in coordination compounds : structural isomerism: Ionization, hydrate, linkage, coordination, coordination position, ligand, conformational and polymerization isomerism and stereoisomerism: geometrical and optical isomerism in 4-and 6- coordinate complexes only

(19 marks, 15 hours)

Unit III: Organometallic Chemistry-I

Definition and classification of organometallic compounds, Nomenclature of organometallic compounds, General characteristics of organometallic compounds: Ionic bonded, Sigma bonded and electron deficient bridged compounds, Synthesis, properties, nature of bonds, structure and application of one organometallic compound each of lithium (LiR; R= alkyl or aryl), Methyl Lithium), magnesium (RMgX and MgR_2).

Organic reagents in Inorganic analysis: Oxine, 1-Niroso-2-napthol, Cupferron, Cupron, Dithizone, Acetylacetone, Dimethylglyoxime, Salicyladoxime, Alizarin –S, Rhodamine-B.

(19 marks, 15 hours)

Unit IV: Data Analysis

Significant figures, Accuracy and precision, Errors (determinate and indeterminate), Ways of expressing errors, Normal distribution of indeterminate errors, Propagation of errors-addition and subtraction, multiplication and division, Minimization of errors, Significant figures and propagation of error, Average mean deviation, Standard deviations, Coefficient of correlation and variance, Method of least squares, Rejection of data: Q-test, Test for significance: the F-test and t-test.

(18 marks, 15 hours)

CHE-251: INTERMEDIATE CHEMISTRY-III
(Contact Hours: 60, Credits: 4)
Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objectives: *To provide a solid foundation on various aromatic, aliphatic compounds and organometallic reagents.*

Course outcome: *On successful competition of this course, students will be able to know more about the properties and applications of different organic compounds including functional group inter-conversions.*

Unit I: Functional Groups in Organic Chemistry

(a) Aromatic Halogen Compounds**:** Introduction, preparation and chemical reactivity, nuclear and side chain halogenation, electrophilic and nucleophilic substitution in aromatic halogen compounds (bimolecular displacement, benzyne mechanism). Role of ring substituents in nucleophilic substitutions. Relative reactivity of alkyl, allyl, aryl, benzyl and vinyl halides towards nucleophilic substitution.
(b) Alcohols**:** Classification, method of preparation (hydration, hydroboration-oxidation and oxymercuration-reduction, reaction of alcohols, distinction between primary, secondary and tertiary alcohols (Victor Meyer's test, Lucas's test, Oxidation by $K_2Cr_2O_7$ and metallic Cu), preparation and chemical reactions of glycol (HNO_3, HCl, PX_3, terephthalic acid, oxidation) and glycerol (HNO_3, HI, oxalic acid, $KHSO_4$).
(c) Epoxides: Properties of epoxides and reactions with alcohols, HCN, NH_3, amines & $LiAlH_4$.
(d) Phenols**:** Nomenclature, Preparation (from benzene diazonium salts, benzene sulphonic acids and cumene), physical properties and acidic character, comparison of acid strength of phenols with alcohols, effect of substituents on acidity of phenols, chemical reactions: nitration, halogenation, sulphonation, Kolbe's reaction, Reimer-Tiemann reaction, phenol-formaldehyde resin.

(19 marks, 15 hours)

Unit II: Carbonyl Compounds and their Derivatives

(a) Aldehydes and Ketones**:** Method of preparation of aldehydes and ketones (from alcohols, Rosenmund reduction, Gattermann-Koch), Structure and reactivity of carbonyl group, mechanism of nucleophilic additions and addition-elimination reactions with HCN, $NaHSO_3$, NH_2OH, NH_2-NH_2, $C_6H_5NHNH_2$, 2,4-DNPH, $NH_2CONHNH_2$); Formation and acid-assisted cleavage of acetals and ketals; acidity of α-hydrogen in carbonyl compounds and formation of enolates, aldol condensation, Perkin reaction, Cannizzaro reaction, reactions with Grignard reagents, benzoin condensation, oxidation reactions (haloform reaction, Tollen's reagent, Fehling's solution, bromine water) and reduction reactions (Clemmensen and Wolff-Kishner reductions),.
(b) Carboxylic Acids and their Derivatives**:** Structure and bonding, effect of substituents on the acidity of aliphatic and aromatic carboxylic acids, methods of preparation (oxidation of alcohols and aldehydes, acid hydrolysis of nitriles), chemical reactions (reduction using $LiAlH_4$, Hell Volhard Zelinsky reaction), Preparation and reactions of succinic acid, citric acid, tartaric acid, maleic acid and fumaric acid. Preparation and reactions of esters, acid chlorides, acid anhydrides, and amides, comparison of the chemical reactivity of these derivatives.

(18 marks, 15 hours)

Unit III: Nitrogen-containing Compounds
(a) Nitro Compounds (Aliphatic and Aromatic): Preparation, properties (aliphatic) α–hydrogen acidity, reaction with HNO_2, carbonyl compounds in the presence of NaOH, Nef reaction and halogenations of nitro-aromatics.

(b) Amines (Aliphatic and Aromatic): Preparation of amines (reduction of nitro compounds and Gabriel phthalimide synthesis), basicity and effect of substituents on basicity, reaction with acetyl chloride, benzoyl chloride, nitrous acid, CS_2, $CHCl_3$/KOH (carbylamine reaction), carbonyl groups and ring substitution. Distinction between primary, secondary, and tertiary amines (Hinsberg and Hoffmann).

***(c) Diazo Compounds*:** Preparation and stability of diazo compounds (aliphatic and aromatic). Reactions of benzene diazonium chloride (Sandmeyer, diazo coupling, and arylation). Preparation and reactions of diazomethane.

***(d) Urea*:** Preparation of urea, reactions of urea with HNO_3, H_2O, HNO_2, NaOBr, CH_3COCl, C_2H_5OH, NH_2NH_2 and diethyl malonate, formation of biuret.

(19 marks, 15 hours)

Unit IV: Specialized Organic Compounds

(a) Organometallic Compounds: Grignard reagent and its application in the synthesis of alkanes, alcohols, acids, aldehydes, ketones, and amines with mechanism. Organolithium compounds: preparation and reactions with H_2O, CO_2 & epoxide.

***(b) Active Methylene Compounds*:** Active methylene group, keto-enol tautomerism. Preparation of ethyl acetoacetate and diethyl malonate, application of ethyl acetoacetate and diethyl malonate in the synthesis of butanoic acid, succinic acid, cinnamic acid, crotonic acid, ethyl methyl ketone and barbituric acid;

***(c) Interconversions*:** Interconversion involving the following functional groups (mechanism not required): -OH. –CHO, -CO, -COOH, -COOR, -$CONH_2$, -NH_2, NHR, -NO_2, -CN, SO_3H, X (Cl, Br, I), (aliphatic to aliphatic and aromatic to aromatic).

(19 marks, 15 hours)

CHE-252: INTERMEDIATE CHEMISTRY-IV
(Contact Hours: 60, Credits: 4)
Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objectives: *To equip students with advanced knowledge of mathematical foundations, ionic equilibrium, gaseous state principles, and electrochemical concepts for comprehensive understanding.*

Course Outcomes: *Students will demonstrate proficiency in mathematical tools, grasp principles of ionic equilibrium, comprehend gaseous state phenomena, and apply electrochemical principles effectively.*

Unit I: Mathematics for Chemistry-II

Fundamentals of Permutations and combinations; Probability meaning and definition, Events, Trial, Random experiment, mutually likely events, mutually exclusive events, Favorable cases to an event; Algebraic operations on real scalar variables, Quadratic equation and their solutions; Mathematical series: Power series, Maclaurin, Taylor series; Mathematical relations: vectors (Vectors, dot, cross and triple products), matrices (3×3), determinants (3×3), Stirling approximation.

(15 marks, 12 hours)

Unit II: Ionic Equilibrium

Arrhenius theory of electrolyte dissociation and its limitations. Ostwald's dilution law and its uses, dissociation equilibria of weak electrolytes, dissociation constant of weak acids (K_a) and weak bases (K_b), ionic product of water (K_w), hydrogen ion concentration and pH scale, buffer solutions and buffer activity, hydrolysis constant (K_h), relation between K_a, K_w and K_b, derivation of hydrolysis constant for salts of (i) strong acid and weak base, (ii) weak acid and strong base and (iii) weak acid and weak base. Solubility product, common ion effect.

(15 marks, 12 hours)

Unit III: Gaseous State-II

Maxwell's distribution law of molecular speeds, molecular speeds and energy distribution as a function of temperature, calculation of the most probable, average and root mean square speeds of molecules, degrees of freedom of motion, principle of equipartition of energy, collision diameter, collision cross-section, collision frequency and mean free path, viscosity of gases, Boyle temperature, critical phenomena-critical constants, P-V isotherm of carbon dioxide, continuity of state, law of corresponding states and reduced equation of state.

(15 marks, 12 hours)

Unit IV: Electrochemistry-I

Electrical transport - conduction in metals and in electrolyte solutions, specific conductance, equivalent and molar conductance and their determination, variation of equivalent and specific conductance with concentration of strong and weak electrolytes. Migration of ions and Kohlrausch law and application, transport numbers and their determination using Hittorf's and moving boundary methods. Conductometric titrations (acids – bases).

(15 marks, 12 hours)

Unit V: Electrochemistry-II

Electrochemical cells; Half cells: types and examples; types of reversible electrodes; Electrode reactions; Nernst equation and standard electrode potentials; reference electrodes (Hydrogen and calomel electrodes); sign conventions; electrochemical series. Application of EMF measurements in determining (i) free energy, enthalpy and entropy of a cell reaction, (ii) equilibrium constants.

(15 marks, 12 hours)

CHE-253: INORGANIC CHEMISTRY LABORATORY

(Contact Hours: 120, Credits: 4)

Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objectives: *Learn quantitative estimation of elements in inorganic salts and synthesis of coordination compounds.*

Course Outcomes: *On completion of the course the students will know principles of analysis of compounds and practical methods of analysis through various titrimetric techniques and gravimetric methods. In this practical they will also master the synthesis of inorganic complexes.*

Laboratory Course (Inorganic)

1. Volumetric Analysis:
(a) Redox titrations involving potassium permanganate, oxalic acid and potassium dichromate for estimation of iron and calcium, iodometric estimation of Cu^{2+}.
(b) Estimation of the following constituents from the mixtures: Iron-Calcium; Copper-Iron; Calcium-Barium; Copper-Zinc.

2. Complexometric Titration using EDTA: Ca^{2+}, Mg^{2+} and Zn^{2+}

3. Gravimetric methods: Estimation of Zn^{2+}, Ba^{2+} Mg^{2+} and Pb^{2+}

4. Preparation of the following inorganic complexes: Tris (thiourea) copper (I) sulphate; Hexammine cobalt (III) chloride; potassium trioxalato chromate and Potassium chlorochromate.

Marks Distribution	***In-semester***	***End-semester***	***Exam duration***
1. Estimation of mixture	15	40	18 hours
2. Preparation of coordination compound	5	15	
3. Viva voce	3	15	
3. Laboratory records	2	5	

CHE-300: HIGHER-LEVEL CHEMISTRY-I
(Contact Hours: 60, Credits: 4)
Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objectives: *This course will deal with molecular symmetry and its applications to solve complex problems related to molecular structure. Students will also learn the metallurgical techniques in the extraction of metals with special reference to iron, copper and aluminum. In this course, the importance of using non-aqueous solvent will be taken up extensively. They will also learn about inorganic polymers regarding their synthesis, characterization and properties. In addition, basic concept of molecular spectroscopy, liquid state properties, photochemical reactions and chemical kinetics will also be provided.*

Course Outcomes: *The students will be able to detect the symmetry of molecules and apply that in understanding the molecular structure and properties. They will also be conversant with the basics of extraction of metals, use of non-aqueous solvents, inorganic polymers, molecular spectroscopic techniques, liquid state properties, photochemical reactions, and theories of reaction rate analysis.*

PART-A (Inorganic) **Marks: 13 (In-Sem.): 37 (End Sem.)** **(30 hours)**

Unit I: Symmetry of molecules

(a) Molecular Symmetry: Symmetry elements and symmetry operations, symmetry planes and its classification, inversion centre, proper axis and proper rotations, improper axis and improper rotations, Deduction of other symmetry elements(Cn and Sn where n=odd or even), molecular point group, , systematic classification of molecules into point groups with examples (i) molecules with low symmetry (ii) molecules with high symmetry, (iii) molecules with special symmetry (linear and cubic point groups), Determination of molecular symmetry viz. H_2O, H_2O_2, BF_3, NH_3, $XeOF_4$, XeF_4, PF_5, SbF_5, B_2H_6, $B(OH)_3$, C_2H_2, ferrocene, $PtCl_4^{2-}$, $Co(NH_3)_4Cl_2$, cyclohexane (chair and boat forms), benzene, borazole, $[Fe(py)_6]^{2+}$

(12 marks, 10 hours)

(b) Non aqueous solutions: Characteristic properties of a solvent, Classification of solvents, Reactions in liquid ammonia and liquid sulphur dioxide (neutralization, redox, precipitation, complex formation and solvolysis reactions), Action of metals in liquid ammonia.

(7 marks, 5 hours)

Unit II: Metallurgy and Polymers

(a) Metals and Metallurgy: Minerals and ores, Types of ores, Metallurgy: pulverization of ore, concentration of ores : electromagnetic separation, hydraulic washing, leaching, froth-floatation, calcination and roasting of ores, Various methods of reductions : Gold Schmidt's aluminothermic process, thermite welding process, reduction by coke or coal, electrolytic reductions, smelting, flux and slag, Refining and purifications methods : liquation, process, zone refining process, fractional distillation process, Parke's process, electrolytic process, amalgamation process, Extraction of copper from copper pyrites , Iron from haematite and Aluminium from bauxite.

(12 marks, 10 hours)

(b) Inorganic Polymers: General characteristics of inorganic polymers and comparison with organic polymers, Synthesis, structural aspects and applications of the following inorganic polymers: silicones, polyphospazenes, tetrasulphurtetranitride.

(6 marks, 5 hours)

PART-B (Physical) Marks: 12 (In-Sem.): 38 (End Sem.) (30 hours)

Unit III: Molecular Spectroscopy and Liquid Properties

(a) Molecular Spectroscopy-I: Introduction: electromagnetic radiation and interaction with molecules (Absorption and emission), regions of the spectrum, Born-Oppenheimer approximation (statement only), degrees of freedom. Rotational (rigid rotor) and Vibrational (S.H.O.) spectra of diatomic molecules: frequency expressions, selection rules and applications to estimate molecular properties; isotope effect in vibrational spectrum. Anharmonicity and Morse Potential.

(12 marks, 10 hours)

(b) Liquid State-II: Determination of surface tension, viscosity and refractive index of liquids. Physical properties and chemical constitution- additive and constitutive properties, molar volume, parachor, specific and molar refraction. Polar and non-polar liquids, dielectric constant, dipole moment, structure of molecules, polarization, Clausius-Mossotti equation.

(7 marks, 5 hours)

Unit IV: Photochemistry and Chemical Kinetics

(a) Photochemistry: Difference between thermal and photochemical reactions, Grotthus-Draper law, Beer-Lambert's law, Stark-Einstein law of photochemical equivalence and quantum yield, Jablonski diagram; Fluorescence and phosphorescence. photochemical reactions – decomposition of ammonia, hydrogen iodide and acetaldehyde, photochemical equilibrium – photodimerization of anthracene, photosensitized reactions, actinometry, chemiluminescence.

(7 marks, 6 hours)

(b) Chemical Kinetics-II: Complex reactions – opposite, parallel, consecutive and chain reactions (formation of HBr, decomposition of acetaldehyde), Theory of Reaction rates – collision theory, transition state theory. Catalyzed reactions – rate determining step, steady state approximation, enzyme catalysis - Michaelis-Menten mechanism (including LB plot, MM constant).

(12 marks, 9 hours)

CHE-301: HIGHER-LEVEL CHEMISTRY-II
(Contact Hours: 60, Credits: 4)
Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objectives*: To introduce carbohydrates, proteins, vitamins, polynuclear hydrocarbons, and polymers. Students shall also learn the stereochemistry of cyclic compounds and polymer chemistry.*

Course Outcome*: Upon successful completion of the course, students will have a clear understanding of the properties, reactivity, application, and stereochemical aspects of carbohydrates, proteins, vitamins, cyclic compounds, and polynuclear hydrocarbons. Students will also have idea about the synthesis, applications, and properties of polymers.*

Unit I: Carbohydrates and Polysaccharides

Carbohydrates: Classification, D/L nomenclature, reducing/non-reducing sugars, aldoses and ketoses, monosaccharides - Glucose and fructose, Fischer Projection formula, Reaction of glucose and fructose with Br_2-water, HCN, Tollen's reagent, Fehling's solution, hydroxylamine, phenylhydrazine, HNO_3 and osazone formation. Determination of ring size by HIO_4 method. Haworth projection formula, conformational structures of glucose and fructose. Epimerization, inter-conversion of glucose and fructose. Ascending (Kiliani) and descending series (Wohl).
Disaccharides: Sucrose and maltose; elucidation of structure, hydrolysis.
Polysaccharides: structure of cellulose, starch (details not required), preparation of cellulose nitrate, cellulose acetate, cellophane and rayon.

(18 marks, 15 hours)

Unit II: Amino acids, Peptides, Proteins and Vitamins

(a) Amino Acids, Peptides and Proteins: Amino acids - Classification, D/L nomenclature, physical properties, isoelectric points and zwitterionic structure, synthesis of α-haloacids and Gabriel syntheses of glycine, alanine, phenyl alanine; glutamic and aspartic acids.
Peptides - Definition and preparation of di- and tripeptides from α-amino acids.
Proteins - Introduction, classification, structure of proteins - primary, secondary (α- and β-proteins, helical and sheet structures), tertiary and quaternary; denaturation of proteins.
(b) Vitamins**:** – Definition and biological importance of vitamins. Carotenoids – occurrence, isolation and synthesis of β-carotene, synthesis of vitamin A_1 and ascorbic acid.

(19 marks, 15 hours)

Unit III: Organic synthesis and Rearrangements

(a) ***Organic Synthesis:*** Formation of carbon-carbon bond, electrophilic and nucleophilic carbon species, acid-assisted reaction (Friedel Crafts alkylation and acylation, Gattermann-Koch formylation), base assisted condensations (Knoevenagel, Michael, Wittig reaction, Claisen reaction, Claisen-Schmidt reaction, Mannich reaction, Dieckmann), Reformatsky reaction.
(b) Rearrangements: Carbocation rearrangements – pinacole-pinacolone, Wagner-Meerwein, dienone-phenol. Beckmann, Wolff, Hofmann, Curtius, Lossen, Schmidt, benzil-benzilic acid, benzidine-semidene, Favorskii, Fries and Claisen rearrangements.
(c) Inorganic Reagents in Organic Synthesis: $NaBH_4$, $LiAlH_4$, B_2H_6, Na/liq.NH_3, aluminium isopropoxide (MPV reduction and Oppenauer oxidation), $KMnO_4$, $K_2Cr_2O_7$, HIO_4, Lead tetraacetate, peracids.

(19 marks, 15 hours)

Unit IV: Aromatic hydrocarbons, Stereochemistry and Polymers

***(a) Polynuclear Aromatic Hydrocarbons*:** Introduction; molecular orbital structure of naphthalene; resonance; Preparations, reactions, mechanism and orientation of electrophilic substitution. Preparations and reactions of α- and β-naphthols (azo-coupling, reactions with HNO_2 and $FeCl_3$. Preparation and reactions of anthracene.

(b) Organic Stereochemistry-II: Relative and absolute configuration, nomenclature of enantiomers (R and S); inversion, retention, conformation and conformational isomerism in ethane and *n*-butane; conformation of cyclic compounds – cyclohexane, mono-substituted and disubstituted cyclohexanes (1,2-, 1,3-, 1,4-) with reference to their relative stability; stereochemical aspects of addition of bromine to alkenes.

(c) Polymers: Types of polymers and polymerization processes. Addition (chain-growth) polymerization; free radical vinyl polymerization; ionic vinyl polymerization, Ziegler–Natta polymerization. Condensation (step-growth) polymerization, polyesters (Dacron), polyamides (Nylon-6, Nylon-6,6), urea-formaldehyde resins (Bakelite), polyurethanes. Natural and synthetic rubbers (Neoprene, Buna-S, Butyl rubber), vulcanization process.

(19 marks, 15 hours)

CHE-302: GENERAL CHEMISTRY-I

(Contact Hours: 75, Credit: 4)

Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objectives: *This course will cover a wide range of chemistry topics, including industrial and environmental chemistry, pharmaceuticals, phase equilibria, and physical chemistry principles. Students will explore industrial processes, environmental pollutants, drug classifications, properties of fats and oils, phase diagrams, and macromolecules. In the practical component, they will conduct experiments to reinforce the theoretical concepts.*

Course Outcomes: *Upon completion, students will possess a comprehensive understanding of inorganic, organic, and physical chemistry concepts. They will be able to analyze industrial processes, identify environmental pollutants, synthesize pharmaceuticals, interpret phase diagrams, and conduct laboratory experiments effectively, enhancing their practical skills in chemistry.*

PART-A (Theory)

Unit I: Inorganic Chemistry-III **Marks: 6 (In-Sem.): 19 (End Sem.)** **(15 hours)**

(a) Industrial Chemistry: (i) Fertilizers: Nitrogenous fertilizer-manufacture of ammonia and urea, Phosphatic fertilizers- calcium superphosphate, phosphatic slag and nitrophosphate, Mixed fertilizer: NPK fertilizers;
(ii) Cement: constituents, manufacture and setting process, role of Gypsum;
(iii) Paints and pigments: different parts of paints, classification of pigments.

(8marks, 7 hours)

(b) Environmental Chemistry: (i) Chemistry of air environment: Classification of air pollutants, Air pollutants and their effects, Particle size and chemical nature of air pollutants, Oxides of carbon, sulphur, nitrogen and hydrocarbon- their health hazards and environmental effects, Photochemical smog and its constituents, Environmental effects of ozone and fluorocarbons, greenhouse effect, Acid rains.
(ii) Chemistry of water environment: Classification of water pollutants, Characterization of waste waters, Problems caused by pollutants like soaps, detergents, phosphates and waste chemicals related to mercury and lead compounds.
(iii) Chemistry of soil environment: Sources of soil pollution, Effect of pesticides, synthetic fertilizers, industrial effluents and urban waste on environment.

(11 marks, 8 hours)

Unit II: Organic Chemistry-III **Marks: 6 (In-Sem.): 19 (End Sem.)** **(15 hours)**

(a) Drugs: Antipyretic, analgesic, antibacterial, antiviral, antibiotic, sulpha drugs and tranquilizer with examples. Synthesis and use of aspirin, paracetamol, sulphaguanidine, barbituric acid.

(6 marks, 5 hours)

(b) Fats, Oils, Soaps and Detergents: Animal and vegetable oils, drying and non-drying oils, hydrogenation, iodine value, RM value and saponification value, soaps and detergents, mechanism of cleansing action of soap and detergents.

(6 marks, 5 hours)

***(c) Dyes*:** Relationship between colour and constitution, chromophore and auxochrome, classification of dyes (based on structure and application), syntheses of methyl orange, Bismarck brown, Malachite green and phenolphthalein.

(7 marks, 5 hours)

Unit III: Physical Chemistry-III **Marks: 7 (In-Sem.): 18 (End Sem.)** **(15 hours)**

(a) Phase Equilibria-I: Phase rule and meaning of the terms phase, components and degrees of freedom, equilibrium between phases, phase diagram for one component systems (water and sulphur systems), Typical phase diagrams of two component systems involving eutectic ($KI-H_2O$), congruent (phenol-aniline) and incongruent ($NaCl-H_2O$) melting points.

(6 marks, 6 hours)

(b) Macromolecules: Characteristics of macromolecules; degree of polymerization; calculation of number and weight average molecular mass; determination of molecular mass by osmometry, viscometry.

(3 marks, 2 hours)

(c) Solid State-II: Law of constancy of interfacial angles, Law of rational indices, Miller Indices, relationship between interplanar spacing with Miller indices, Bravais lattice, Symmetry elements in crystals-plane of symmetry, axis of symmetry, centre of symmetry, X-ray diffraction of crystals, crystal structure determination-Laue's method and powder method.

(5 marks, 4 hours)

(d) Colloids: Classification of colloids, preparation of colloids – peptization, Bredig's method and condensation methods, purification of colloids, properties of colloids – Tyndall effect, Brownian movement, electrophoresis and electro-osmosis, protective colloids, gold number.

(4 marks, 3 hours)

PART-B (Practical)

Unit V: Laboratory work (Physical) **Marks: 6 (In-Sem.): 19 (End Sem.)** **(30 hours)**

Experiments:

(1) Determination of the heat of neutralization of a strong acid by a strong base.
(2) Determination of molecular weight by Rast's method
(3) Study of the heat of dilution of H_2SO_4 and then to determine the strength of an unknown acid.
(4) Determination of the velocity constant of the decomposition of hydrogen peroxide in presence of ferric chloride as catalyst by titrating against $KMnO_4$.
(5) Determination of the solubility of $BaCl_2$/NaCl at two different temperatures and to determine the heat of solution.
(6) Determination of the velocity constant of the hydrolysis of methyl acetate catalyzed by an acid.

Marks Distribution	***In-semester***	***End-semester***	***Exam duration***
1. Experiment	2	12	
2. Viva voce	2	5	6 hours
3. Laboratory records	2	2	

CHE-350: HIGHER-LEVEL CHEMISTRY-III
(Contact Hours: 60, Credits: 4)
Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objectives: *The main objective of this course is to make the students familiarize with the higher-level chemistry such as coordination, organometallic, bioinorganic chemistry. Students will also learn about the reactivity of coordination compounds with emphasis on mechanism and their rate laws.*

Course Outcomes: *The students will know more about the coordination compounds and their reactivity with special emphasis on metals containing organic group. The learners shall have idea on special topic of bioinorganic chemistry.*

Unit I: Coordination Chemistry-II

Valence bond theory and its limitations, Basic principle of crystal field theory, d-Orbital splitting in electrostatic field(octahedral, tetrahedral and square planar), Crystal field stabilizing energy(10 Dq values), Factors affecting the magnitude of crystal field splitting energy, Spectrochemical series, Structural and thermodynamic effects of d-orbital splitting- variation of ionic radii, hydration and lattice energies of the first row transition metal ions, Jahn - Teller effect , Adjusted CFT and molecular orbital theory for octahedral complexes.

(19 marks, 15 hours)

Unit II: Organometallic Chemistry-II

General method of preparation of organometallic compounds, Reaction mechanism of organometallic reactions: oxidative addition and reductive elimination, nucleophilic and electrophilic addition, insertion and abstraction, Umplong effect, Synthesis, nature of bonds, structure, properties and application of organometallic compounds of iron (ferrocene) and tin (R_3SnX, R_2SnX_2 types), π-acid ligands, Mononuclear and dinuclear carbonyls and nitrosyls and the nature of bonding in them - their uses in metallurgy, Effective atomic number rule in metal carbonyls and metal nitosyls compounds, Important applications of organometallic compounds in heterogeneous catalysis – alkene polymerization, hydrogenation of alkenes using Wilkinson's catalyst and synthesis of acetic acid using rhodium carbonyl iodide catalyst.

(19 marks, 15 hours)

Unit III: Bioinorganic Chemistry-I

Essential and trace elements in biological processes, Criteria of essential elements, Metalloporphyrin, Structure and functions and physiological behavior of haemoglobin and myoglobin, Cooperatively of dioxygen binding, Chlorophyll and its functions, Vitamin B_{12} and role of Co in vitamin B_{12}, Metalloenzymes, Carbonic anhydrase and carboxypeptidase their characteristics and functions, pH of biological fluids, Non-complexing cations in biochemical processes: Na^+-K^+ pump; Toxic effects of metal ions with reference to mercury, lead, beryllium and aluminium; Deficiency of Fe, Ca, Mg and iodine; Platinum complexes as anticancer drugs.

(19 marks, 15 hours)

Unit IV: Coordination Chemistry-III

Reactivity of Coordination Compounds, Stability of complex ions, Factors effecting the stability of a complex ion, Thermodynamic stability and kinetic stability, Lability and inertness of complexes, Stepwise formation constant, Mechanism of ligand substitution reactions in octahedral and square planar complexes, Mechanisms of acid and base hydrolysis reactions in octahedral complexes, Mechanism and rate law of nucleophilic substitution reaction in square planar complexes, The trans effect.

(19 marks, 15 hours)

CHE-351: HIGHER-LEVEL CHEMISTRY-IV
(Contact Hours: 60, Credits: 4)
Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objectives*: To get an idea on heterocyclic molecules, biomolecules, natural products, spectroscopy, green chemistry, and the influence of heat and light on organic reactions.*

Course Outcome*: Students will know about nomenclature, synthesis, properties, and reactivities of various heterocycles, natural products, and biomolecules, selectivity and reactivity of various organic molecules under the influence of heat and light energy. They will have ideas on green chemistry principles, various greener techniques for synthesis, etc. This course will also provide a clear knowledge of the principle and application of various spectroscopic techniques*.

Unit I: Heterocyclic Compounds

Structure and reactivity, Paal-Knorr synthesis of pyrrole, furan and thiophene, Knorr pyrrole synthesis, synthesis of furan from pentose and pyrrole from furan, comparative reactivity in Diels Alder and diazo coupling reaction, electrophilic substitution reactions (nitration, sulphonation, Friedel-Crafts) of pyrrole, furan and thiophene. Structure, synthesis (Hantzsch synthesis) and reactions of pyridine (electrophilic, and nucleophilic substitutions). Condensed five- and six-membered heterocycles, preparation and reactions of indole (with special reference to Fischer-Indole synthesis, Madelung synthesis). Preparation and reactions of quinoline and isoquinoline (with special reference to Knorr, Skraup and Bischler-Napieralski syntheses). Comparative basicity of pyrrole/pyridine, pyrrole/pyrrolidine and pyridine/piperidine.

(18 marks, 15 hours)

Unit II: Natural Products, Bioorganic chemistry, and Green Chemistry

(a) Natural Products: (i) Terpenoids: Introduction, isoprene rule, classification, structural elucidation of citral and geraniol; synthesis of citral, geraniol and α-Terpeniol. (ii) Alkaloids: Introduction, classification, physiological action and syntheses of nicotine and cocaine.
(b) Topics in Bioorganic Chemistry: (i) Enzymes: Introduction, nomenclature and characteristics. Mechanism of enzyme action (a general picture); mechanism of action of the enzyme chymotripsin as a peptidase.; co-enzyme, co-enzymes derived from niacin and thiamine, lipoic acid, co-enzyme A, energy production in biological system (role of ATP and ATP-ADP cycle), glycolysis and tricarboxylic acid cycle. *(ii) Nucleic acids*: Structure of purine and pyrimidine bases in nucleic acid (adenine, guanine, cytosine, uracil and thiamine) [no synthesis]. Structure of nucleosides, nucleotides, RNA and DNA.
(c) Green Chemistry: Definition, goals, principles and techniques (brief discussions); Solvent free reactions (Reformatsky, Dieckmann condensation), Ultrasound reactions (Heck reaction, Cannizaro reaction), Microwave assisted reactions (Biginelli reaction, Hoffmann elimination), reactions in aqueous media (Diels-Alder, Claisen rearrangement) and ionic liquid (Oxidation of benzyl alcohol using $KMnO_4$ in [bmim][BF_4], Diels-Alder reaction) – their advantages over conventional method (mechanism not required).

(19 marks, 15 hours)

Unit III: Pericyclic Reactions and Photochemistry

(a) Pericyclic Reactions**:** Definition and types of pericyclic reactions. (i) Electrocyclic **r**eactions; conrotatory and disrotatory ring closures and ring opening (simple examples like 1,4-disubstituted-1,3-buta-diene; 1,6-disubstituted-1,3,5-hexatriene), stereochemistry, Woodward-Hoffmann rules for electrocyclic reactions, frontier molecular orbital theory (correlation diagram not required). (ii)

Cycloaddition **r**eactions; Definition of dienes and dienophiles, *supra-supra* and *antara-antara* modes of cycloadditions ($\pi_s^4 + \pi_s^2$, $\pi_s^4 + \pi_a^2$, $\pi_s^2 + \pi_s^2$, $\pi_s^2 + \pi_a^2$) by taking examples of simple dienes and dienophiles. Woodward-Hoffmann rules for cycloaddition reactions, frontier molecular orbital theory (correlation diagram not required).

***(b) Organic Photochemistr*y:** Molecular energy and photochemical energy, excitation of molecules, Franck-Condon principle, dissipation of energy, Jablonski diagram, singlet-triplet states, fluorescence and phosphorescence, photosensitization and quenching, quantum yield. Introduction to photochemical reactions of carbonyl compounds: Norrish Type I and Type II cleavages, photoreduction, Paterno-Buchi reaction, *supra-supra* and *antara-antara* modes of cycloadditions ($\pi_s^4 + \pi_s^2$, $\pi_s^4 + \pi_a^2$, $\pi_s^2 + \pi_s^2$, $\pi_s^2 + \pi_a^2$) by taking examples of simple dienes and dienophiles. Woodward-Hoffmann rules for cycloaddition reactions, frontier molecular orbital theory (correlation diagram not required).

(19 marks, 15 hours)

Unit IV: Spectroscopy in Organic Chemistry

(a) Ultraviolet and Visible Spectroscopy: Basic principles of UV and visible spectroscopy, application to conjugated polyenes, carbonyl compounds and α, β-unsaturated carbonyl compounds, Woodward-Fieser rules.

(b) Infrared Spectroscopy: Basic principles, characteristic vibrational frequencies of simple organic compounds such as alcohols, phenols, carbonyl compounds and acid derivatives, amines, nitriles, alkynes and alkenes.

(c) Nuclear Magnetic Resonance Spectroscopy: Basic principles, chemical shifts, shielding and deshielding of protons, chemically equivalent protons, peak area and proton counting, Characteristics protons - chemical shifts and coupling constants of vicinal (ethyl alcohol, ethyl acetate, acetaldehyde), geminal (styrene), cis- & trans- (cinnamic acid), ortho-, meta-, para- protons (toluene, p- xylene, *o*-and *p*-nitrotoluene, anisole).

(d) Mass Spectrometry: Basic principles, molecular ion peak, base peak and metastable ion, fragmentation pattern, N-Rule, Simple applications in structure elucidation (butane, iso-pentane, ethanol, 2- butanol, ethyl propylamine, acetone, ethyl methyl ketone, ethyl benzene), McLafferty rearrangement (butanal, methyl pentanoate and hexanoic acid).

Application of UV, IR, NMR Spectroscopy and Mass Spectrometry in structure elucidation of simple organic molecules

(19 marks, 15 hours)

CHE-352: HIGHER-LEVEL CHEMISTRY-V
(Contact Hours: 60, Credits: 4)
Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objectives: *To impart students with a foundational understanding of Thermodynamics, Statistical Thermodynamics, Quantum Mechanics, Electrochemistry, and Phase Equilibria, encompassing pivotal concepts such as black-body radiation and the photoelectric effect.*

Course Outcomes: *Students will deepen their grasp of thermodynamics, electrochemistry, statistical thermodynamics, and quantum mechanics. They will apply principles to analyze chemical potential, ion activity, and molecular partition functions, gaining insights into molecular behavior.*

Unit I: Thermodynamics-III

Thermodynamic scale of temperature, Maxwell's relations, definition of chemical potential, concept of chemical potential, equilibrium between different phases, derivation of phase rule from the concept of chemical potential, partial molal quantities, variation of chemical potential with temperature and pressure, chemical potential of a component in an ideal mixture, Gibbs-Duhem equation. Nernst heat theorem, third law of thermodynamics and its application to the determination of entropy, concept of residual entropy.

(15 marks, 12 hours)

Unit II: Statistical Thermodynamics-I

Limitations of classical thermodynamics; concept of ensemble and its different types; concept of distribution; Thermodynamic probability, relationship between entropy and probability; Boltzmann distribution for non-degenerate and degenerate cases (with derivation); Partition function: definition, molecular partition functions, relation between molecular and molar partition functions. Thermodynamic parameters in term of partition function (without derivation).

(15 marks, 12 hours)

Unit III: Quantum Mechanics-I

Failure of classical mechanics: Black-body radiation, Planck's radiation law, photoelectric effect, Compton effect, heat capacity of solids, atomic and molecular spectra; Wave Particle Duality: de Broglie relation & Heisenberg's Uncertainty principle; Postulates of quantum mechanics; Schrodinger wave equation, Wave function and its significance, Normality and Orthogonality, Eigen value equation.

(15 marks, 12 hours)

Unit IV: Electrochemistry-III

Activity and ionic activity coefficient; mean ionic activity. Ion atmosphere; electrophoretic and relaxation effects; Onsager equation (qualitative); Wien and Debye-Falkenhagen effects; Debye-Huckel theory (qualitative) and the limiting law. Solubility of sparingly soluble salts and ionic strength of medium. Standard cells, concentration cells (with and without transport), liquid junction potentials. polarization and over potential. Applications of Hydrogen electrode, quinhydrone and glass electrodes in the determination of pH; potentiometric titrations with examples.

(15 marks, 12 hours)

Unit V: Phase Equilibria-II

Liquid-liquid mixtures, fractional distillation of binary miscible liquids, azeotropes (ethanol-water system), partial miscibility of liquids, lower and upper critical solution temperatures (triethylamine-water, phenol-water and nicotine-water systems), steam distillation, Nernst distribution law-derivation and its application. Three component system: Phase diagram of CO_2 system.

(15 marks, 12 hours)

CHE-353: PHYSICAL CHEMSITRY LABORATORY
(Contact Hours: 120, Credits: 4)
Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objectives: *To learn how to conduct experiments to reinforce physical chemistry principles, including titrations, colorimetry, conductometry, kinetics, thermodynamics, and adsorption studies.*

Course Outcomes: *Students will gain practical proficiency in experimental techniques, data analysis, and interpretation, enhancing their understanding of physical chemistry concepts.*

Part A (Instrumental Experiments) Marks: 12 (In-Sem.): 38 (End Sem.) (60 hours)

Experiments:

a) Conductometric titrations of an acid by a base (strong acid vs. strong base; weak acid vs strong base).
b) Acid-base titration using potentiometer (strong acid vs. strong base; weak acid vs strong base).
c) Verification of Beer-Lambert's law using $CuSO_4$ or $K_2Cr_2O_7$ solution colorimetrically and determination of the concentration of the supplied solution
d) Determination of pK_a value of different sets of buffers by pH-metric titration using glass electrode.
e) Determination of cell constant and hence the specific conductance of an electrolyte by conductometry.
f) pH-metric titration of (i) strong acid with strong base, (ii) weak acid with strong base and determination of dissociation constant of a weak acid.
g) Estimation of ferrous ammonium sulphate using standard potassium dichromate solution potentiometrically.

Part B (Non-instrumental Experiments) Marks: 13 (In-Sem.): 37 (End Sem.) (60 hours)

Experiments:

a) Determination of velocity constant for the decomposition of hydrogen peroxide using ferric chloride as catalyst; and to determine the activation energy.
b) Determination of the heat of solution of solid calcium chloride and to determine lattice with the help of Born-Haber cycle.
c) Determination of the critical solution temperature of the phenol-water system.
d) Study on the kinetics of the reaction between potassium persulfate and potassium iodide at two temperatures with determination of activation energy
e) Study of the adsorption of oxalic acid on charcoal and verification of Freundlich's adsorption isotherm.
f) Determination of surface tension of a liquid/solution by drop-weight method.
g) To obtain the viscosity–composition (v/v) curve of ethanol-water/ glycerol- water/ methanol water system and to determine the composition (v/v) of a given unknown mixture.
h) Determination of partition coefficient of a solute between two immiscible solvents (e.g., iodine in water/organic solvent; benzoic acid in water/benzene).
i) To study the kinetics of iodine clock reaction.

Marks Distribution		***In-semester***	***End-semester***	***Exam duration***
PART- A	1. Experiment	7	25	
	2. Viva voce	3	8	6 hours
	3. Laboratory records	2	5	
PART -B	1. Experiment	8	24	

	2. Viva voce 3. Laboratory records	3 2	8 5	6 hours

CHE-400: RESEARCH METHODOLOGY AND PROPOSAL WRITING
(Contact Hours: 60, Credits: 4)
Marks: 25 (In-Sem.): 75 (End Sem.)

***Learning Objectives**: This course equips students with fundamental research methodology skills, covering research types, approaches, and methods, alongside ethical considerations and data handling. It also emphasizes laboratory safety protocols and introduces analytical tools like chromatography and electrochemistry.*

***Course Outcomes:** Upon completion, students will adeptly identify research problems, conduct literature reviews, and adhere to ethical standards in research. They will demonstrate proficiency in presenting findings, understanding publication ethics, and practicing laboratory safety measures. Additionally, they will be equipped with analytical tools such as separation methods, electrochemistry, and thermoanalytical methods for data analysis.*

Unit I: Research methodology
Definitions, Purpose of Research, Types of research, Research approaches, Research Methods, Stages of the research process, Background reading & information gathering: Literature survey, Hypothesis: Identification of Research Problem; Data collection, Data recording and reproducibility, Importance of documentation.

(19 marks, 15 hours)

Unit II: Research and Publication ethics
Presentation of research findings: Elements and types of research publications; Seminar presentation; Patent; Paper writing; Journal impact factor, i10 index, h-index; Publication quality Vs quantity; Ethical issues in research, review process.

(19 marks, 15 hours)

Unit III: Laboratory safety
General health and safety concerns; Do's and Don'ts in the laboratory; Emergency measures against splash/cut/fire/burn; Chemical hazards, commonly used hazardous laboratory chemicals (azide, perchlorate, nBuLi, acid chlorides, bromine, cyanide, mercury, etc.), Personal protective equipment, Environmental safety issues: Fume hood safety, Safety data sheet, Waste handling, Disposal of chemical and plastic-waste; precautionary measure for the maintenance of laboratory equipment.

(19 marks, 15 hours)

Unit IV: Analytical Tools in Research
Separation and Purification techniques: Crystallization, Chromatography (TLC, LC, HPLC, GC, Ion)
Electrochemistry: Principles, instrumentation and application in cyclic voltammetry.
Thermoanalytical methods: Principles, instrumentation, and applications of thermo-analytical methods (TGA, DTA and DSC).

(19 marks, 15 hours)

CHE-401: ADVANCED CHEMISTRY-I
(Contact Hours: 60, Credits: 4)
Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objectives: *This course aims to impart a thorough understanding of symmetry and group theory, metal-ligand equilibria, reaction mechanisms of transition metal complexes, magnetochemistry, and the electronic structure of transition metal complexes. By the end of the course, students will be proficient in analyzing symmetry elements, interpreting magnetic properties, and understanding electronic absorption spectra and IR spectroscopy in coordination compounds.*

Course Outcomes: *Upon completion, students will demonstrate mastery in identifying symmetry elements, analyzing metal-ligand equilibria, elucidating reaction mechanisms of transition metal complexes, and interpreting magnetic properties and electronic absorption spectra. They will also develop skills in applying group theory concepts to molecular vibration and analyzing IR spectra, enhancing their competency for research and practical applications.*

Unit I: Symmetry and Group Theory

Symmetry elements and operations; equivalent symmetry elements and equivalent atoms; Identification of symmetry point groups with examples from inorganic compounds; groups of very high symmetry; molecular dissymmetry and optical activity; systematic procedure for symmetry classification of molecules and illustrative examples; molecular symmetry for compounds having co-ordination numbers 2 to 9; Brief review of matrix representation of group, reducible and irreducible representations; Application to molecular vibration.

(19 marks, 15 hours)

Unit II: Coordination Chemistry-III

(a) Metal-Ligand Equilibria in Solution: Stepwise and overall formation constants; trends in stepwise formation constants; determination of binary formation constant by spectrophotometry; factors affecting stability of metal complexes and chelate effect.

(10 marks, 7 hours)

(b) Reaction Mechanism of Transition Metal Complexes: Discussion on general reactivity of metal complexes, Labile and inert complexes; mechanisms of ligand-replacement reactions; ligand displacement reactions in square planar and octahedral complexes; trans effect; electron transfer reactions: outer sphere and inner sphere, atom transfer; isomerization and racemization of tris-chelate complexes; stereochemical nonrigidity and fluxional molecules.

(10 marks, 8 hours)

Unit III: Magnetochemistry

Brief review of different types of magnetic substance and magnetic behavior, Magnetic susceptibility and its measurement by Gouy and Faraday method , origin of paramagnetic moment, electron spin moment and orbital angular moment, Curie Law, Curie - Weiss law, Magnetic moment for single and multi-electron system, L-S and j-j coupling, Ground State Term symbols for metal ions; R-S coupling and Lande intervals, Spin-orbit coupling, Thermal energy and magnetic property: temperature-independent paramagnetism, Magnetic moment of first row transition metal ions, spin crossover, quenching of orbital magnetic moment.

(18 marks, 15 hours)

Unit IV: Spectroscopy of Transition Metal Complexes

(a) Electronic absorption spectra and colour of octahedral and tetrahedral complexes, Free ion terms symbols and their splitting in octahedral symmetry, selection rules, Orgel diagrams, Tanabe-Sugano diagrams, calculation of Dq, B and β values, band intensities and band widths, spectra of high-spin octahedral and tetrahedral complexes of d^1 to d^9 systems, Spectrochemical series; Adjusted crystal field theory, Nephelauxetic series, Molecular orbital theory of complexes, MO diagrams for octahedral and tetrahedral complexes and charge-transfer spectra, optical properties of Lanthanides and Actinides.

(b) IR Spectroscopy: Basic principles, spectral studies of coordination compounds containing following molecules or ions as ligands: H_2O, CN^-, CO, SO_4^{2-} and halides (F, Cl, Br, I).

(18 marks, 15 hours)

CHE-402: ADVANCED CHEMISTRY-II
(Contact Hours: 60, Credits: 4)
Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objectives: *This course aims to explore advanced topics in organic chemistry synthesis, emphasizing the use of metals and reactive intermediates. Students will learn about organoboranes, organosilicon, and transition metal catalysis, along with C-H bond activation and fluorination reactions.*

Course Outcomes: *By the end of the course, students will develop a deep understanding of metal-mediated organic synthesis, stereochemistry, and reactive intermediates. They will gain proficiency in designing complex synthetic routes, predicting reaction outcomes, and analyzing reaction mechanisms involving metal and radical processes.*

Unit I: Metal in Organic chemistry

(a) Uses of metal in Organic chemistry synthesis: Organoboranes in carbon-carbon bond forming reactions, application of organosilicon in organic synthesis. Principle of C-H bond activation, radical mediated C-H bond activation, mechanism of Pd and Ru catalyzed C-H activation.

(b) Reactive Intermediates-I: Concept, generation, stereochemical aspects, and important name reactions of carbenes, nitrenes, and arynes.

(19 marks, 15 hours)

Unit II: Stereochemistry

Axial and planar chirality, helicity; topicity and prostereoisomerism; Racemic modification and optical purity; Conformational analysis of acyclic, cyclic (C5, C6 and decalin), heterocyclic (one heteroatom system); Effects of conformation on reactivity.

(19 marks, 15 hours)

Unit III: Aromatic Systems and Intermediates Species

(a) Aromaticity and Reaction mechanisms: Concept and application of aromaticity, Aromaticity in benzenoid and non-benzenoid compounds, n-annulenes, hetero-annulenes, fullerenes, cryptates. Concept of E, Z geometry of enolates, kinetic vs thermodynamic control of enolates, stereoselective enolate reactions – alkylation and aldol condensation (Zimmerman models).

(b) Reactive Intermediates-II: Concept, generation, stability and stereochemical aspects of free radicals; Barton reaction and Hoffmann-Loefller-Freytag reaction.

(19 marks, 15 hours)

Unit IV: Reactions and Reagents

Stereochemistry and application of catalytic hydrogenation, hydride reduction, hydroboration, dissolving metal reductions, and carbonyl reduction with hydrazine derivatives; Oxidation of alcohol with PCC, PDC, Collin's reagent, Swern oxidation, IBX, Dess-Martin periodinane, MnO_2, Ag_2CO_3; oxidation of alkene with metal/alkyl hydroperoxides, Sharpless asymmetric epoxidation and asymmetric dihydroxylation, dioxiranes, I_2/Ag^+ ; periodates, LTA, SeO_2; Photo-Fries rearrangement of esters and anilides; di-π-methane rearrangement; Photooxygenation - Singlet molecular oxygen reactions.

(18 marks, 15 hours)

CHE-403: ADVANCED CHEMISTRY-III
(Contact Hours: 60, Credits: 4)
Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objectives: *To impart students with a comprehensive understanding of quantum mechanics, chemical bonding, molecular spectroscopy, and non-equilibrium thermodynamics. Through rigorous study, students will delve into quantum mechanical operators, model systems and approximation methods. They will explore chemical bonding theories, spectroscopic techniques including Raman and electronic spectra, and delve into non-equilibrium thermodynamics concepts such as entropy production and electro-kinetic phenomena.*

Course Outcomes: *By the end of the course, students will be proficient in applying quantum mechanics principles to model systems and will understand the intricacies of chemical bonding theories. Additionally, students will be proficient in molecular spectroscopic techniques and comprehend the principles of non-equilibrium thermodynamics.*

Unit I: Quantum Mechanics-II

Expectation values, Quantum mechanical operators, Hamiltonian operator, Hermitian operators, angular momentum operator, Important theorems in Quantum mechanics.

Model systems: Particle in one-dimensional-box (with complete derivation of wavefunction & energy expression); Construction of Hamiltonian (H) operator and Energy expression of S.H.O., rigid rotor and hydrogen atom (without derivation). Approximation methods: Variation and time-independent perturbation methods (up to 2^{nd} order) and simple applications.

(19 marks, 15 hours)

Unit II: Chemical Bonding

Many-electron functions and anti-symmetry principle. Born-Oppenheimer Approximation. Valence bond (VB) and Molecular Orbital (MO) approaches for diatomic molecules, LCAO-MO treatment of hydrogen molecule ion, hydrogen molecule. Bonding and Anti-bonding orbital. Comparison of LCAO-MO and VB treatments of H_2 and their limitations. Excited states of H_2 singlet and triplet. Term symbols. Hybridization. Huckel MO treatment for conjugated π-electron systems.

(18 marks, 15 hours)

Unit III: Molecular Spectroscopy-II

(a) Raman Spectra: concept of polarizability, classical theory of Raman effect, selection rule, mutual exclusion rule.

(b) Electronic spectra: Frank-Condon principle, qualitative description of σ, π and n MOs, their relative energy levels and respective transitions, examples of conjugated molecules. Fate of electronically excited states – radiative and non-radiative decay. Vibronic transitions, Spectra of organic compounds, $\pi \rightarrow \pi^*$, $n \rightarrow \pi^*$ transitions.

(19 marks, 15 hours)

Unit IV: Non-equilibrium Thermodynamics

Entropy of irreversible processes – Clausius inequality; entropy production (heat flow, chemical reactions, electrochemical reactions) and entropy flow; Entropy production in open systems; Rate of entropy production – generalized forces and fluxes; Phenomenological equations, Onsager reciprocity relation; Electrokinetic phenomena; Stationary non-equilibrium states -states of minimum entropy production.

(19 marks, 15 hours)

CHE-404: GENERAL CHEMISTRY-II
(Contact Hours: 60, Credits: 4)
Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objectives: *This course aims to provide a thorough understanding of diverse chemistry branches, covering coordination, organometallic, analytical, organic, and physical chemistry. Students will delve into complex concepts like ligands, chelation, isomerism, and chemical reactions, fostering a comprehensive grasp of fundamental principles and applications across these fields.*

Course Outcomes: *In this paper, students will emerge equipped with in-depth knowledge of coordination chemistry, organometallic compounds, analytical techniques, and organic chemistry reactions. Additionally, they will master concepts such as chemical kinetics, ionic equilibria, solid-state chemistry, metallic and hydrogen bonding, and liquid crystals, enabling them to analyze and address real-world challenges in chemistry and allied domains.*

Unit-I: Inorganic Chemistry-IV **Marks: 6 (In-Sem.): 19 (End Sem.)** **(15 hours)**

(a) Coordination Chemistry-I: Double salts an complex salts, Werner's Coordination theory, coordination number, ligands and their classification , chelation, applications of chelate formation, nomenclature of coordination compounds(mono and poly-nuclear), determination of composition of complexes by spectrophotometric method, effective atomic number rule, factors influencing complex formation, isomerism in coordination compounds: structural and stereoisomerism : geometrical and optical isomerism in 4-and 6- coordinate complexes only.

(7 marks, 5 hours)

(b) Organometallic Chemistry-I: Definition and classification of organometallic compounds, Nomenclature of organometallic compounds, General characteristics of organometallic compounds: Ionic bonded, Sigma bonded and electron deficient bridged compounds, Synthesis, properties, nature of bonds, structure and application of one organometallic compound each of lithium (LiR; R=alkyl or aryl), Methyl Lithium), magnesium (RMgX and MgR_2)

(6 marks, 5 hours)

(c) Analytical Chemistry: Standard solutions: Primary and secondary, Concentrations of standard solutions, applications of chemical equilibrium to analytical separations and estimations: equilibrium constants, activity coefficients, acid-base equilibrium, solubility equilibrium, distribution equilibria, complex ion equilibria and stability constants. basic theories of systematic qualitative analysis: solubility product, common ion effect, pH and buffer actions, complex formation, Volumetric analysis: permanganatometry, dichromatometry, iodometric and iodimetric analysis, Complexometric titrations with special emphasis on EDTA titrations, theory of indicators, gravimetric analysis: theory of precipitation, fractional precipitation, co-precipitation and post precipitation.

(6 marks, 5 hours)

Unit II: Organic Chemistry-IV **Marks: 6 (In-Sem.): 19 (End Sem.)** **(15 hours)**

(a) Aromatic Halogen compounds: Introduction, preparation and chemical reactivity, nuclear and side chain halogenations, electrophilic and nucleophilic substitution in aromatic halogen compounds (bimolecular displacement, benzyne mechanism. Role of ring substituents in nucleophilic substitutions. Reactivity of alkyl, allyl, aryl, benzyl and vinyl halides towards nucleophilic substitution.

(b) Alcohols: Classification, methods of preparation (hydration, hydroboration-oxidation and oxymercuration), Reaction of alcohols, distinction between primary, secondary and tertiary alcohols (Victor-Meyer's test, Lucas test, oxidation by $K_2Cr_2O_7$ and metallic copper). Preparation and

chemical reactions of glycol (HNO_3, HCl, PX_3, terepthalic acid, oxidation), and glycerol (HNO_3, HI, oxalic acid and $KHSO_4$)

(c) Epoxides: Reactions of epoxides with alcohols, HCH, NH_3, amines and $LiAlH_4$.

(d) Phenols: Nomenclature, Preparation (from benzene diazonium salts, benzene sulphonic acids and cumene), physical properties and acidic character, comparison of acid strength of phenols with alcohols, effect of substituents on acidity of phenols, chemical reactions: Nitration, halogenations, sulphonation, Kolbes reaction, Reimer – Tiemann Reaction, phenol – formaldehyde resin,

Unit III: Physical Chemistry-IV **Marks: 6 (In-Sem.): 19 (End Sem.)** **(15 hours)**

(a) Chemical Kinetics-II: Equilibrium and Steady state approximations; Complex reactions – opposite, parallel, consecutive and chain reactions (formation of HBr, decomposition of acetaldehyde). Catalyzed reactions: enzyme catalysis (Michaelis-Menten equation).

(10 marks, 8 hours)

(b) Ionic Equilibria: Arrhenius theory of electrolyte dissociation and its limitations. Ostwald's dilution law and its uses, dissociation equilibria of weak electrolytes, dissociation constant of weak acids (K_a) and weak bases (K_b), ionic product of water (K_w), hydrogen ion concentration and pH scale, buffer solutions and buffer activity.

(9 marks, 7 hours)

Unit IV: Solid State and Molecular Interactions

Marks: 7 (In-Sem.): 18 (End Sem.)(15 hours)

(a) Solid State: Classification of solids, Lattices and unit cells, Number of atoms in a unit cell, Voids and types of voids, Radius ratio effect, Packing and efficiency of packing in metallic crystals, Ionic structures, Electrical, magnetic and dielectric properties of solids. Imperfection in solids.

(7 marks, 6 hours)

(b) Metallic Bonding and Hydrogen Bonding: Metallic Bonding, Qualitative idea of free electron model and molecular orbital approach for metallic bonding, Conductors, insulators and semiconductors, Types of semiconductors, Intermolecular forces: Dipole-dipole, Ion-dipole, induced dipole-induced dipole, Vander Waal's forces, Hydrogen bonding: concept and types of hydrogen bonding and its application to molecules.

(7 marks, 6 hours)

(c) Liquid Crystals: Definition, Vapour Pressure- Temperature Diagrams, Types of Liquid Crystals, Polymorphism in Liquid Crystals, Molecular arrangement in various states of Liquid Crystals.

(4 marks, 3 hours)

CHE-450: ADVANCED CHEMISTRY-IV
(Contact Hours: 60, Credits: 4)
Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objectives*: This course aims to impart knowledge in green chemistry, nanochemistry, resonance spectroscopy, and statistical methods with computer applications. Students will learn sustainable chemical practices, nanomaterial synthesis, spectroscopic data analysis, and statistical interpretation. Through theoretical learning and practical exercises, they'll develop proficiency in environmentally friendly processes, nanomaterial synthesis, spectral analysis, and statistical tools.*

Course Outcomes: *Upon completion, students will proficiently apply green chemistry principles, nanochemistry synthesis techniques, and advanced spectroscopic methods. They will assess the environmental impact of chemical processes, propose greener alternatives, synthesize and characterize nanomaterials, and interpret nuclear and electron spin resonance spectra. Additionally, they will effectively utilize statistical methods and computational tools for data analysis, enhancing their problem-solving abilities for research and industrial applications in chemistry.*

Unit I: Green Chemistry

Definition of green solvents, specific health and environmental requirements, criteria to evaluate solvents, life cycle analysis and assessment of solvents, green industrial solvents, alternative solvents for separation processes. Reactions in aqueous phase, ionic liquids, supercritical fluids and fluorinated systems, Solid state and enzyme catalyzed reactions.

(19 marks, 15 hours)

Unit II: Nanochemistry and nanomaterials

General introduction to nanomaterials and emergence of nanotechnology, Types of nanomaterials, Synthesis of nanoparticles with reference to gold, platinum and silver, Properties of nanoparticles (optical, semiconductor, electrical and magnetic), Important applications of nanoparticles, Nanocomposites, Nanocrystals, Nanostructures and types of nano-structure, Quantum dots: production and its application.

(19 marks, 15 hours)

Unit III: Resonance Spectroscopy

(a) Nuclear Magnetic Resonance: Nuclear spin and nuclear spin states in magnetic field, resonance phenomenon, relaxation processes, NMR line shapes and saturation, shielding and de-shielding of magnetic nuclei, chemical shift, Factors (electron density, electronegativity, functional groups) influencing chemical shift with examples, ^{1}H NMR analysis of simple organic compounds, Basics of ^{13}C, ^{19}F, and ^{31}P NMR spectroscopy.

(b) Electron Spin Resonance: Basic principles, factors affecting g values, hyperfine coupling, Operational differences between EPR and NMR.

(19 marks, 15 hours)

Unit IV: Statistical Methods and Computer Applications in Chemistry

Errors, precision and accuracy; Average Mean Deviation, Standard Deviation, Variance, Chi-square Test. Curve Fitting, Straight Line Fitting, Interpolation in solving chemical problems.

Applications of commonly used Computer softwares, such as Chemdraw, Chemoffice, Mercury, Origin, Excel, etc.

Computational chemistry and molecular modelling softwares: GAUSSIAN, GAMESS, GROMACS, AUTO DOCK.

Visualization softwares: Gaussview, pymol, VMD, Avogadro.

(18 marks, 15 hours)

CHE-451: GENERAL CHEMISTRY-III
(Contact Hours: 60, Credits: 4)
Marks: 25 (In-Sem.): 75 (End Sem.)

Objectives: *This course aims to delve into various aspects of chemistry, including chemical bonding, nanochemistry, metallurgy, organic reactions, thermodynamics, chemical equilibria, and solution chemistry. Through comprehensive study, students will gain a deeper understanding of these fundamental principles and their applications in different chemical systems.*

Learning Outcomes: *Upon completion of the course, students will acquire a solid foundation in molecular orbital theory, nanoparticle synthesis, metallurgical processes, organic synthesis techniques, thermodynamics, chemical equilibria, and solution chemistry. They will develop analytical and problem-solving skills essential for addressing challenges across diverse chemical disciplines.*

Unit I: Inorganic Chemistry-V Marks: 6 (In-Sem.): 19 (End Sem.) (15 hours)

(a) Chemical Bonding-II: Molecular orbital Theory (MOT): Salient features of Molecular orbital theory, Formation of molecular orbitals: Linear combination of atomic orbitals, Conditions for the combination of atomic orbitals, Types of molecular orbitals, Applications of MOT to homo and heteronuclear diatomic molecules : H_2, N_2, N_2^+, N_2^{2+}, N_2^-, N_2^{2-}, O_2, O_2^+, O_2^{2+}, O_2^-, O_2^{2-}, Cl_2, CO and NO). Electronic configuration of molecules and molecular behavior viz. bond order, bond length, nature of the bond, and magnetic nature.

(6 marks, 5 hours)

(b) Nanochemistry and nanomaterials: General introduction to nanomaterials and emergence of nanotechnology, types of nanomaterials, types of synthesis of nanoparticles with reference to gold, platinum and silver, properties of nanoparticles (optical, semiconductor, electrical and magnetic), important applications of nanoparticles.

(6 marks, 5 hours)

(c) Metals and Metallurgy: Minerals and ores, types of ores, metallurgy: pulverization of ore, concentration of ores : electromagnetic separation, hydraulic washing, leaching, froth-floatation, calcination and roasting of ores, various methods of reductions : Gold Schmidt's aluminothermic process, thermite welding process, reduction by coke or coal, electrolytic reductions, smelting, flux and slag, refining and purifications methods : liquation, process, zone refining process, fractional distillation process, Parke's process, electrolytic process, amalgamation process, extraction of copper from copper pyrites , iron from haematite and aluminium from bauxite.

(7 marks, 5 hours)

Unit II: Organic Chemistry-V Marks: 6 (In-Sem.): 19 (End Sem.) (15 hours)

(a) Aldehydes and ketones: Structure of the carbonyl group, methos of preparation of aldehydes and ketones (from alcohols, Rodsenmund Reduction, Gattermann – Koch), chemical reactivity of carbonyl group, mechanism of nucleophilic additions and addition elimination reactions with KCN, $NaHSO_3$, NH_2OH, NH_2NH_2, $C_6H_5NH_2NH_2$, 2,4 – DNPH, $NH_2CONHNH_2$) and Cannizzaro reaction. Formation of acid - assisted cleavage of acetals and ketals; acidity of alpha hydrogen in carbonyl compounds and formation of enolates, aldol condensation, Perkin reaction and reactions with Grignard reagents, benzoin condensation, oxidation reactions (haloform reaction, Tollen's reagent, Fehling's solution, bromine – water, reduction reactions (Clemmensen's reduction and Wolf – Kishner reductions)

(10 marks, 8 hours)

(b) Carboxylic acids and their derivatives: Structure and bonding, effect of substituents on the acidity of aliphatic and aromatic carboxylic acids, methods of preparation (oxidation of alcohols and aldehydes, acid hydrolysis of nitriles), chemical reactions (reduction using $LiAlH_4$, Hell – Volhard – Zelinsky reaction). Preparation and reactions of succinic acid, citric acid, tartaric acid, maleic acid and fumaric acid. Preparation and reactions of esters, acid chlorides, acid anhydrides and amides,

comparison of chemical reactivity of these derivatives.

(9 marks, 7 hours)

Unit III: Physical Chemistry-V Marks: 6 (In-Sem.): 19 (End Sem.) (15 hours)

(a) Thermodynamics-II: Limitations of the first law, statements of second law, spontaneous processes. Carnot cycle and its efficiency, Carnot's theorem, Entropy (S) as a state function, entropy changes of ideal gases in different processes. Gibbs function (G) and Helmholtz function (A), criteria for thermodynamic equilibrium and spontaneity, variation of G and A with pressure, volume and temperature, Gibbs-Helmholtz equation, Clausius-Clapeyron equation, Trouton's rule.

(10 marks, 8 hours)

(b) Chemical Equilibria: Law of mass action, equilibrium constant (K) from thermodynamic considerations, temperature and pressure dependence of equilibrium constants (Kp and Kc – van't Hoff equation, relation of Kp and Kc, equilibria in homogeneous and heterogeneous systems, Le Chatelier's principle, effect of addition inert gases on equilibrium constant.

(9 marks, 7 hours)

Unit IV: Properties of reactive species and dilute solution

Marks: 7 (In-Sem.): 18 (End Sem.) (15 hours)

(a) Active methylene Compounds: Active methylene group**,** structure of active methylene compounds, tautomerism, difference between tautomerism and resonance (keto – enol tautomerism). Preparation of ethyl acetoacetate and diethyl malonate, application of ethyl acetoacetate and diethyl malonate in the synthesis of butanoic acid, succinic acid, cinnamic acid, crotonic acid, ethyl methyl ketone and barbituric acid; Refrormatsky reaction.

(9 marks, 8 hours)

(b) Dilute Solutions: Raoult's law and Henry's law; Colligative properties and their relation with molecular mass; Osmotic pressure and its determination; van't Hoff factor; Reverse osmosis and its application.

(9 marks, 7 hours)

CHE-452: RESEARCH PROJECT
(Contact Hours: 180, Credits: 12)
Marks: 75 (In Sem.): 225 (End Sem.)

Learning Objectives: *The Research Project course aims to foster independent research skills in chemistry, guiding students in formulating hypotheses, designing experiments, and analyzing data to address specific research questions.*

Course Outcomes: *Upon completion, students will demonstrate proficiency in conducting scientific research, including critical literature evaluation, experimental design, precise execution of laboratory techniques, data analysis, and effective communication of findings through written reports and oral presentations.*

Marks and Credits distribution:

In-semester	**Marks**	**Credits**
Proposal writing and literature review	50	2
Presentation	25	1
Total	***75***	***3***
End semester	**Marks**	**Credits**
Dissertation	100	4
Seminar	75	3
Viva voce	50	2
Total	***225***	***9***

CHE-453: ADVANCED INORGANIC CHEMISTRY

(Contact Hours: 60, Credits: 4)

Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objectives: *To learn a wide diversity of reactions, unusual structures and practical applications in organic synthesis and industrial catalysis by the organometallic compounds.*

Course Outcomes: *Student shall be motivated to study organometallic chemistry that finds applications in commercially relevant organic reactions catalyzed by organometallic compounds.*

Unit I: Organometallic Chemistry

Application of 18-electron and 16-electron rules to transition metal organometallic complexes, Ligands in organometallic chemistry; Synthesis, bonding and reactivity of Metal-alkyl, -alkene, -alkyne, -allyl, -carbene complexes, Agostic interaction, Stereochemical non-rigidity and fluxional behavior of organometallic compounds with typical examples; Catalytic applications: Oxidative addition, Reductive elimination, Hydroformylation (Oxo process), Wacker oxidation (Pd-catalyzed), Polymerization of olefins, Ziegler-Natta catalyst.

(19 marks, 15 hours)

Unit II: Bioinorganic Chemistry-II

Biologically important compounds amino acids, proteins, nucleotides, carbohydrates and lipids, Bioenergetic principle and role of ATP and ADP; Biological membranes; mechanism of ion transport across membranes, ionophores; channel and pump; O2-uptake proteins: haemoglobin, myoglobin, hemerythrin and hemocyanin, structure, function and model study. Electron transport protein: Fe-S proteins (Rubredoxin and ferredoxins), cytochromes, Metal ions transport and storage proteins: ferritin, transferin, ceruloplasmin. Coordination chemistry in medicine: chelation therapy, metal complexes as radiodiagnostics agents, gold compounds and rheumatoid arthritis, anticancer drugs.

(19 marks, 15 hours)

Unit III: Metal carbonyls, clusters and Metal-metal multiple bond

Synthesis, structure and reactivity of metal carbonyls; Metal cluster: Low nuclearity and high nuclearity carbonyl clusters; Boron clusters: Structure and bonding of boranes and Lipscomb's topology, styx system of numbering, nomenclature; Synthesis and structure of carboranes, metalloboranes, metallocarboranes; Skeletal electron counting, Wade's rule. Metal-metal multiple bonds, quadruple bond, structures and bonding (MO).

(19 marks, 15 hours)

Unit IV: Inorganic Supramolecular Chemistry

Origin of supramolecular chemistry. Concepts and terminology of supramolecular chemistry. Types of supramolecular interactions (Hydrogen bonding, van der Waal's interaction, π-stacking, CH-π, anion-π interaction). Supramolecular chemistry in inorganic perspective: Inorganic crystal engineering and design principle of metal organic framework (MOF) and inorganic-organic hybrid material. Application of supramolecular chemistry in catalysis, drug delivery, and recognition/sensing.

(18 marks, 15 hours)

CHE-454: ADVANCED ORGANIC CHEMISTRY

(Contact Hours: 60, Credits: 4)

Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objectives: *This course aims to impart a comprehensive understanding of organic reactions and reagents, including Aza-Cope and Aza-Wittig reactions, Julia olefination, and stereoselective olefination. It also aims to learn heterocyclic nomenclature, synthesis, and properties, alongside name reactions such as Mukaiyama, Heck, and Ring closing metathesis. Additionally, it explores dynamic stereochemistry and the classification, structure, and synthesis of alkaloids and steroids.*

Course Outcomes: *Students will gain proficiency in various organic reactions, mastering their mechanisms and stereochemical implications. They will be able to name and synthesize heterocycles, understanding their properties and significance. Furthermore, they will apply name reactions effectively in synthesis and comprehend dynamic stereochemistry's role in determining reaction outcomes. Lastly, they will classify alkaloids and steroids, describing their structures and synthesis pathways, enriching their knowledge of natural product chemistry.*

Unit I: Reaction and reagents

Aza-Cope and Aza-Wittig reactions, Corey–Fuchs reaction, Julia olefination, Baylis-Hillman reaction, BINOL and BINAP assisted reactions, TADDOL assisted reactions, Buchwald-Hartwig coupling, Hiyama Coupling, Peterson's stereoselective olefination, Jacobsen epoxidation, Ireland Claisen rearrangement, Meyer–Schuster rearrangement, Simmons–Smith reaction, Pauson–Khand reaction, C-H oxidations using metal complexes, Chan–Lam coupling, Sonogashira reaction, Bergman cyclization, Evans aldol reaction.

(19 marks, 15 hours)

Unit II: Heterocycles

Hantzsch-Widman nomenclature for monocyclic, fused and bridged heterocycles; concept, property, and synthesis of aziranes, oxiranes; azetidines, oxetanes; pyrazole, isoxazole; imidazoles, thiazoles and oxazoles, indole; quinolines, isoquinolines, carbazoles, pteridines, azepines, diazepines.

(19 marks, 15 hours)

Unit III: Name reactions

Concept, stereochemical aspect and application of Mukaiyama reaction, Henry reaction, Wittig reaction and Horner-Wordwoth-Emmons reaction; Peterson's olefinantion, Prins reaction, Heck reaction, Stille coupling, Suzuki coupling, Chan Lam Coupling, reactions of allylsilane, Biginelli reaction, Hantzsch reaction, Passerini reaction, Ugi reaction, Ring closing metathesis (RCM) - Grubb's reaction, Mitsonobu reaction, Nef reaction, Umpolung effect.

(19 marks, 15 hours)

Unit IV: Stereochemistry and Natural Products

(a) Dynamic stereochemistry: Conformation, reactivity, and mechanism of acyclic, cyclic, and fuse ring systems for addition, elimination, alkylation, halogenations, and reduction reactions. Acyclic stereoselection - addition of nucleophiles, enolates and allyl metals to carbonyl compounds; Diastereoselectivity in cyclic systems - nucleophilic addition, alkylation, hydrogenation, and cyclisation.

(b) Alkaloids: Classification of alkaloids (with example); structure and synthesis of strychnine, lysergic acid, nicotine, morphine.

(c) Steroids: Classification of steroids (with example); structure and synthesis of cholesterol, estrogens, and progesterones.

(18 marks, 15 hours)

CHE-455: ADVANCED PHYSICAL CHEMISTRY
(Contact Hours: 60, Credits: 4)
Marks: 25 (In-Sem.): 75 (End Sem.)

Learning Objectives: *This course aims to introduce advanced concepts in physical chemistry, encompassing electrochemistry, chemical kinetics, statistical thermodynamics, and surface chemistry. Students will explore ion-ion and ion-solvent interactions, electrodics, kinetics of chemical reactions, statistical thermodynamics, and surface phenomena.*

Course Outcomes: *By the course end, students will proficiently analyze electrochemical processes, kinetics, statistical thermodynamics principles, and surface chemistry phenomena. They will demonstrate an understanding of complex concepts such as ion-solvent interactions, electrodics, and surface tension, applying them to real-world scenarios.*

Unit I: Electrochemistry-IV

Ion-ion interaction: Poison equation, Linearized Poisson–Boltzmann equation; ionic cloud and chemical potential change; activity coefficients and mean ionic activity coefficients; expression of mean ionic activity coefficients in terms of ionic strength.

Ion-solvent interaction: free energy changes due to ion-solvent interactions; Born model; enthalpy and entropy of ion-solvent interactions.

Electrodics: processes at electrodes, electrical double layer; Helmholtz-Perrin model; Gouy-Chapman diffuse charge model and Stern model. The basic electrodic equation: Butler–Volmer equation; overpotential; polarizable and nonpolarizable interfaces, Corrosion.

(19 marks, 15 hours)

Unit II: Chemical Kinetics-III

Lindemann, Hinshelwood and the RRKM theories for unimolecular reactions, Reactions in solutions: Diffusion controlled & activation-controlled reactions; Thermodynamic formulation of rate constant: effect of pressure & ionic strength. Reaction in surfaces: Langmuir adsorption isotherm; kinetics of surface catalyzed unimolecular & bimolecular reactions; Concept of potential energy surface for a reaction.

(19 marks, 15 hours)

Unit III: Statistical Thermodynamics-II

Calculation of partition function: Translational partition function, rotational partition function for linear and non-linear molecules; vibrational partition function, electronic partition function, reference state of zero energy for evaluating partition function, Thermodynamic properties of Ideal monatomic gas.

Application of statistical thermodynamics: equipartition theorem, heat capacity behavior of crystals. Introduction to quantum statistics: Distribution law for fermions (Fermi-Dirac statistics) and for bosons (Bose-Einstein statistics), and its applications (No derivation necessary).

(19 marks, 15 hours)

Unit IV: Surface Chemistry

Surface tension and surface free energy; Pressure across an interface: Laplace equation, Kelvin equation; Wetting: Young-Dupre equation; Adsorption in liquid systems: Gibbs adsorption isotherm.

Surfactants, classification of surfactants, hydrophobic interaction, aggregation/micellization of surfactants, critical micelle concentration (cmc), factors affecting the cmc, thermodynamics of micellization: phase separation and mass action models. Sols of surface-active reagents, electrical properties of colloidal systems, size determination of colloidal particles.

(18 marks, 15 hours)

SUGGESTED BOOKS

A. Inorganic Chemistry

1. Advanced Inorganic Chemistry, F. A. Cotton, G. Wilkinson, C. A. Murillo and m. Bochmann, 6th Ed., John Wiley & Sons (Asia) Pvt. Ltd., (2009).
2. General and Inorganic Chemistry, Vol. I and II, Dr P. K. Dutt and Prof. P. K. Dutt, 10th Ed, Sarat Book House, (1990).
3. Advanced Inorganic Chemistry, Vol. II, Satya Prakash, G. D. Tuli, S. K. Basu and R. D. Madan, S. Chand and Company Ltd., revised (2005).
4. Inorganic Chemistry, R. L. Dutta (Vol-II), 2rd Ed, The New Book Stall, (1987).
5. Inorganic Chemistry, 3rd Ed., Cengage Learning, Indian reprint (2016).
6. Concise Coordination Chemistry, R. Gopalan and V. Ramalingam, 2nd Ed., Vikas Publishing House Pvt. Ltd., (2006).
7. Principles of Inorganic Chemistry, B. R. Puri, L. R. Sharma & K. C. Kalia, Vishal Publishing Co., (2019-2020).
8. Basic Concepts of Analytical Chemistry, S. M. Khopkar, 2nd Ed., New Age International (P) Ltd., (1998).
9. University Practical Chemistry, P. C. Khamboj, Vishal Publishing Co., (2009-2010).
10. Quantitative Analysis, R. A. Day & A.L. Underwood, 5th Ed., Prentice Hall of India Private Ltd., (1988).
11. Analytical Chemistry, Gary D. Christian, 6th Ed., John Wiley & Sons (Asia), Pvt. Ltd., reprint (2011)
12. Analytical chemistry, S. Usha Rani, MacMillian, Delhi
13. Symmetry and Spectroscopy of Molecules, K. Verra Reddy, New Age International(P) Ltd., (2002).
14. Chemical Applications of Group Theory, F. A. Cotton, 2nd Edn., Wiley Eastern Ltd., (1992)
15. A Text Book of Inorganic Polymers, A. K. Bhagi, G. R. Chatwal, 1st Edn., Himalaya Publishing House, (2001).
16. Industrial Chemistry, Part-I, R. K. Das, Kalyani Publishers, 1st Edn., 1994.
17. Elements of Magnetochemistry, R. L. Dutta & A. Syamal, Affiliated East-West Press Pvt. Ltd., 2nd Edn., 2021.
18. Principles of Nanotechnology, N. Phani Kumar, Scitech Publications (India)Pvt. Ltd.
19. Organometallic Chemistry- A Unified Approach, R. C. Mehrotra & A. Singh, New Age International(P) Ltd., 2nd Edn., 2009.
20. A Textbook of Coordination Chemistry, K. Somasekhara Rao & B. N. Krishna Vani, Kalyani Publishers, 5th Edn., 2009.
21. Bioinorganic and Supramolecular Chemistry, A. K. Bhagi & G.R. Chatwal, Himalaya Publishing House., 1st Edn., 2003.
22. Bioinorganic Chemistry, K. Hussian Reddy, New Age International Publishers, 1st Edn., 2007.
23. Introduction to Ligand Fields., B. N. Figgis, Interscience Publishers, 1966
24. Inorganic Chemistry- Principles of Structure and Reactivity, J. E. Huheey, E. A. Keiter, R. A. Keiter & O. K. Medhi, Pearson Education, 4th Edn., 2009.
25. A Text book of Environmental Chemistry and Pollution Control, S. S. Dara & D. D. Mishra, S. Chand & Co. Ltd., 1st Edn., 2012
26. Industrial Chemistry, Part-II, R. K. Das, Kalyani Publishers, 1st Edn., 1994,
27. Application Oriented Chemistry, R. K. Gangopadhyay, Book Syndicate Pvt. Ltd., Kolkata, (2002).
28. Environmental Chemistry, Anil K. De and Arnab K. De, New Age International (P) Ltd., (2001)

Practical Books

1. Vogel's Textbook of Qualitative Inorganic Analysis, J. Bassett, R.C. Denney, G.H. Jeffery & J. Mendham, 4th Ed., ELBS, Longman Group Ltd., 1985

2. A Manual of Practical Chemistry, R. C. Bhattacharjee, 10th Ed., Book Sellers and Publishers, Calcutta, 1980.
3. Comprehensive Experimental Chemistry, 1st Ed., New Age International (P) Ltd., reprint-2009.

B. Organic Chemistry

1. A. I. Vogel, *A Text Book of Practical Organic Chemistry*, Longmans.
2. B. S. Bahl and A. Bahl, *Advanced Organic Chemistry*, S. Chand & Co., New Delhi.
3. G. R. Chatwal, *Reaction mechanism and Reagents in Organic Chemistry*, Himalaya Publishing House.
4. J. Singh & J. Singh, *Photochemistry and Pericyclic Reactions*, New Age international publishers.
5. M. K. Jain and S. C. Sharma Vishal, *Modern Organic Chemistry*, Publishing Co. Jalandhar.
6. O. P. Agarwal, *Organic Natural Products - Vol 1&2*, Krishna's
7. O. P. Agarwal, *Chemistry of Organic Natural products Vol. I*, Goel Publishing House Meerut.
8. P. S. Kalsi, *Organic Reactions and their Mechanisms*, New Academic Science Limited (2010)
9. P. S. Kalsi, *Spectroscopy of Organic Compounds*, 4th ed., New Age International, New Delhi.
10. P. S. Kalsi, *Stereochemistry*, 4th ed., New Age International, New Delhi.
11. P. T. Anastas and J. K. Warner, *Oxford Green Chemistry – Theory and Practical*, Oxford University Press.
12. R. K. Bansal, *Heterocyclic chemistry*, 7th ed., New Age Int.(P)Ltd, New Delhi.
13. R. T. Morrison and R. N. Boyd, *Organic Chemistry*, 5th ed., Prentice-Hall of India, New Delhi.
14. S. M. Mukherjee and S. P. Singh, *Reactions Mechanism in Organic Chemistry*, Macmillan.
15. S. M. Mukherjee, S. P. Singh and R. P. Kapoor, *Organic Chemistry, Vol I, II & III*, Wiley Eastern Ltd., New Delhi.
16. S. N. Sanyal, *Reactions Rearrangements and Reagents*, Bharati Bhawan Publishers
17. V. K. Ahluwalia & M. R. Kidwai, *New Trends in Green Chemistry*, Anamalaya Publishers.
18. V. K. Ahluwalia, R. K. Parashar, *Organic Reaction Mechanisms*, Alpha Science International (2006)
19. V. Kumar, *An Introduction to Green Chemistry*, Vishal Publishing Co. Jalandhar.
20. Y. R. Sharma, *Elementary Organic Spectroscopy: Principles and Chemical Applications*, S. Chand & Company Pvt. Ltd. (2013)
21. Y. R. Sharma, *Organic Absorption Spectroscopy*, S. Chand & Company Pvt. Ltd., Delhi.
22. Subrata Sen Gupta, *Basic Stereochemistry of Organic Molecules*, Oxford University Press.
23. A, K, Nad, B, Mahapatra, A, Ghoshal, *An Advanced Course In Practical Chemistry*, New Central Book Agency P Ltd.
24. Ratan Kumar Kar, Frontier Orbital and Symmetry Controlled Pericyclic Reactions, Book & Allied Ltd.

Reference Books

1. C. Bandyopadhyay, *An Insight into Green Chemistry*.
2. D. L. Pavia, G. M. Lampman, G. S. Kriz, and J. R. Vyvyan, *Introduction to Spectroscopy*, Cengage Learning (2013)
3. D. Nasipuri, *Stereochemistry*, 2nd ed., New Age International, New Delhi.
4. G. Marc Loudon, *Organic Chemistry*, Oxford Univ. Press.
5. J. Clayden, N. Greeves, S. Warren and P. Wothers, *Organic Chemistry*, Oxford Univ. Press.
6. J. G. Smith, *Organic Chemistry*, McGraw Hill (2018)
7. J. J. Li, *Name Reactions: A Collection of Detailed Mechanisms and Synthetic Applications*, Springer-Verlag Berlin Heidelberg (2021)
8. J. March, *Advanced Organic Chemistry*, 3rd ed., McGraw Hill, New York.
9. L. Finar, *Organic Chemistry, Vol. I & II*, 5th ed., Pearson Edu. Ltd., Delhi.
10. M. Loudon, J. Parise, *Organic Chemistry*, Macmillan Learning (2021)

11. R. Bruckner, *Organic Mechanisms: Reactions, Stereochemistry and Synthesis*, Springer-Verlag Berlin Heidelberg (2010)
12. T. Laue and A. Plagenns, *Named Organic*, John Wiley & Sons Ltd (2005)
13. T. W. G. Solomons, *Organic Chemistry*, 13th ed., John Wiley & Sons.
14. V. K. Ahluwalia, *Green Chemistry A Textbook*, Narosa Publishing House.
15. W. Kemp, *Organic Spectroscopy*, Palgrave Publishers Ltd (2002)

C. **Physical Chemistry**

1. A. S. Negi, S. C. Anand, A Text book of Physical Chemistry, New Age International Publishers, N. Delhi.
2. N. B. Singh, S. S. Das, & Ram Ji Singh, Physical Chemistry, New Age International Publishers, N. Delhi.
3. Arun Bhal, B. S. Bhal & G. D. Tuli, Essential of Physical Chemistry, S. Chand & Co.
4. P. Atkins & de Paula, Atkins' Physical Chemistry, 7th ed., Oxford Univ. Press.
5. P. C. Rakshit (revised by S. C. Rakshit), Physical Chemistry, 6th ed., Sarat Book, Kolkata.
6. B. R. Puri, L.R. Sharma & M. S. Pathania, Principles of Physical Chemistry, S. L. N. Chand & Co., Jalandhar.
7. V. D. Athawale & P. Mathur, Experimental Physical Chemistry, New Age International Publ., New Delhi
8. J. N. Gurtu & R. Kapoor, Advanced Experimental Chemistry, Vol. I, S. Chand & Co., New Delhi.
9. McQuarrie, D. A. Mathematics for Physical Chemistry University Science Books, 2008.

Reference Books

1. G. Raj, Advanced Physical Chemistry, Goel Pub. House, Meerut.
2. R. S. Barry, S. A. Rice and J. Ross, Physical Chemistry, Oxford Univ. Press.
3. D. A. McQuarries and J. D. Simon, Physical Chemistry, Viva Books Pvt. Ltd., New Delhi.
4. G. W. Castellan, Physical Chemistry, Narosa Pub. House,Delhi .
5. S. Glasstone, Textbook of Physical Chemistry, Macmillan India Ltd., Madras.
6. W. J. Moore, Basic Physical Chemistry, Prentice Hall of India, New Delhi.
7. G. M. Barrow, Physical Chemistry, McGraw Hill, New York.
8. R. A. Alberty, Physical Chemistry 6th ed., Wiley Eastern Ltd., New Delhi
9. S. Glasstone, An Introduction of Electrochemistry, (Reprint), Affiliated East- West Press, New Delhi.
10. J. B. Yadav, Advanced Practical Physical Chemistry, 20th ed., Goel Publ. House, Meerut.
11. P. Atkins and R. Friedman, Molecular Quantum Chemistry P. Atkins Oxford University Press, 2011.
12. Mortimer, R. Mathematics for Physical Chemistry. 3rd ed. Elsevier, 2005.
13. Yates, P. Chemical Calculations. 2nd ed. CRC Press, 2007.

Practical Books

1. B. D. Khosla, V. C. Garg, A. Gulati, Senior Practical Physical Chemistry, R. Chand & Co, 2015.
2. V. K. Ahluwalia, S. Dhingra, College Practical Chemistry, University Press, 2005.
3. K. L. Kapoor, A Textbook of Physical Chemistry, Vol. 7, 1st ed., McGraw Hill Education, 2019.
4. W. C. Garland, J. W. Nibler, D. P. Shoemaker, Experiments in Physical Chemistry, 8th ed., McGraw Hill, New York.

MARKING SCHEME

1st Semester				
Course code	***Total marks***	***Sections***	***In-semester***	***End-semester***
CHE-100	**100**	**Introductory Chemistry-I**		
		Part A: Theory		
		Unit I: Inorganic Chemistry-I		
		(a) Structure of atom	7	5
		(b) Chemical Periodicity		5
		(c) Chemical bonding-I		8
		Unit II: Organic Chemistry-I		
		(a) Nomenclature, Structure, bonding and Properties	6	8
		(b) Alkanes and Cycloalkanes		5
		(c) Alkenes and Alkynes		6
		Unit III: Physical Chemistry-I		
		(a) States of Matter		
		(i) Gaseous State-I	6	7
		(ii) Liquid State-I		4
		(iii) Solid State-I		3
		(b) Chemical Kinetics-I		5
		Part B: Practical ***(Duration: 6 hours)***		
		Unit IV: Laboratory Work (Inorganic)		
		1. Experiment	2	12
		2. Viva voce	2	5
		3. Lab records	2	2
		Total	25	75

2nd Semester				
Course code	***Total marks***	***Sections***	***In-semester***	***End-semester***
CHE-150	100	**Introductory Chemistry-II**		
		Part A: Theory		
		Unit I: Inorganic Chemistry-II		
		(a) Nucleus and Radioactivity	6	10
		(b) Redox reactions		4
		(c) Acid-base Concept		5
		Unit II: Organic Chemistry-II		
		(a) Organic Stereochemistry-I	7	5
		(b) Aromatic Hydrocarbons and Aromaticity		5
		(c) Nucleophilic Substitution reactions		5
		(d) Elimination reactions		3
		Unit III: Physical Chemistry-II		
		(a) Thermodynamics-I	6	10
		(b) Thermochemistry		5
		(c) Adsorption and Surface Phenomena		4
		Part B: Practical ***(Duration: 6 hours)***		
		Unit IV: Laboratory Work (Organic)		
		1. Experiment	2	12
		2. Viva voce	2	5
		3. Lab records	2	2
		Total	25	75

3rd Semester				
Course code	***Total marks***	***Sections***	***In-semester***	***End-semester***
CHE-200	100	**Intermediate Chemistry-I**		
		Part A: Inorganic chemistry		
		Unit I: Main group elements		
		(a) *s*- and *p*-block elements and their compounds		12
		(b) Interhalogens, Polyhalides & Pseudohalides	12	7
		Unit II: Transition Metals		
		(a) *d*- and *f*-block elements and their compounds		12
		(b) Chemical Bonding-II		7
		Part B: Physical Chemistry		
		Unit III: Mathematical Fundamentals and Thermodynamics concepts		
		(a) Mathematics for Chemistry-I		9
		(b) Thermodynamics-II	13	9
		Unit IV: Solution chemistry and Equilibrium		
		(a) Dilute Solutions		10
		(b) Chemical Equilibria		9
		Total	25	75
CHE-201	100	**Organic Laboratory (Duration: 18 hours)**		
		1. Separation of mixtures	15	40
		2. Organic Preparation	5	10
		3. Green method of synthesis		10
		4. Viva voce	3	10
		5. Laboratory records	2	5
		Total	25	75
4th Semester				
Course code	***Total marks***	***Sections***	***In-semester***	***End-semester***
CHE-250	100	**Intermediate Chemistry-II**		
		Unit I: Analytical Chemistry-I	25	19
		Unit II: Coordination Chemistry-I		19
		Unit III: Organometallic Chemistry-I		19
		Unit IV: Data Analysis		18
		Total	25	75
CHE-251	100	**Intermediate Chemistry-III**		
		Unit I: Functional group in Organic Chemistry		19
		(a) Aromatic halogen Compounds		
		(b) Alcohols		
		(c) Epoxides		
		(d) Phenols		
		Unit II: Carbonyl Compounds and their derivatives		18
		(a) Aldehydes and Ketones		
		(b) Carboxylic Acids and their Derivatives		
		Unit III: Nitrogen-containing compounds		19
		(a) Nitro Compounds		

		(b) Amines	25	
		(c) Diazo Compounds		
		(d) Urea		
		Unit IV: Specialized Organic compounds		19
		(a) Organometallic Compounds		
		(b) Active Methylene Compounds		
		(c) Interconversions		
		Total	25	75
CHE-252	100	**Intermediate Chemistry-IV**		
		Unit I: Mathematics for chemistry-II		15
		Unit II: Ionic Equilibrium		15
		Unit III: Gaseous State-II	25	15
		Unit IV: Electrochemistry-I		15
		Unit V: Electrochemistry-II		15
		Total		
CHE-253	100	**Inorganic Laboratory (Duration: 18 hours)**		
		1. Estimation of mixture	15	40
		2. Preparation of coordination compound	5	15
		3. Viva voce	3	15
		4. Laboratory records	2	5
		Total	25	75
5th Semester				
Course code	***Total marks***	***Sections***	***In-semester***	***End-semester***
CHE-300	100	**Higher-level Chemistry-I**		
		Part A: Inorganic chemistry		
		Unit I: Symmetry of molecule		
		(a) Molecular Symmetry		12
		(b) Non-aqueous solution	13	7
		Unit II: Metallurgy and Polymers		
		(a) Metals and Metallurgy		12
		(b) Inorganic Polymers		6
		Part B: Physical chemistry		
		Unit III: Molecular Spectroscopy and Liquid Properties		
		(a) Molecular Spectroscopy-I		12
		(b) Liquid State-II	12	7
		Unit IV: Photochemistry and Chemical Kinetics		
		(a) Photochemistry		7
		(b) Chemical Kinetics-II		12
		Total	25	75
CHE-301	100	**Higher-level Chemistry-II**		
		Unit I: Carbohydrates and Polysaccharides		18
		Unit II: Amino acids, Peptides, Proteins and Vitamins		19
		(a) Amino Acids, Peptides and Proteins		
		(b) Vitamins		
		Unit III: Organic synthesis and Rearrangements		19
		(a) Organic synthesis	25	
		(b) Rearrangements		

		(c) Inorganic Reagents in Organic Synthesis		
		Unit IV: Aromatic hydrocarbons, Stereochemistry and Polymers		19
		(a) Polynuclear Aromatic Hydrocarbons		
		(b) Organic Stereochemistry-II		
		(c) Polymers		
		Total	25	75
CHE-302	100	**General Chemistry-I**		
		Part A: Theory		
		Unit I: Inorganic Chemistry-III		
		(a) Industrial Chemistry	6	8
		(b) Environmental Chemistry		11
		Unit II: Organic Chemistry-III		
		(a) Drugs		6
		(b) Fats, Oils, Soaps and Detergents	6	6
		(c) Dyes		7
		Unit III: Physical Chemistry-III		
		(a) Phase Equilibria-I		6
		(b) Macromolecules	7	3
		(c) Solid State-II		5
		(d) Colloids		4
		Part B: Practical **(Duration: 6 hours)**		
		Unit IV: Laboratory Work (Physical)		
		1. Experiment	2	12
		2. Viva voce	2	5
		3. Lab records	2	2
		Total	25	75
6th Semester				
Course code	***Total marks***	***Sections***	***In-semester***	***End-semester***
CHE-350	100	**Higher-level Chemistry-III**		
		Unit I: Coordination Chemistry-II		19
		Unit II: Organometallic Chemistry-II	25	19
		Unit III: Bioinorganic Chemistry-I		19
		Unit IV: Coordination Chemistry-III		18
		Total	25	75
CHE-351	100	**Higher-level Chemistry-IV**		
		Unit I: Heterocyclic Compounds		18
		Unit II: Natural products, Bioorganic chemistry and Green Chemistry		19
		(a) Natural Products		
		(b) Topics in Bioorganic Chemistry		
		(c) Green Chemistry		
		Unit III: Pericyclic reactions and Photochemistry	25	19
		(a) Pericyclic Reactions		
		(b) Organic Photochemistry		
		Unit IV: Spectroscopy in Organic chemistry		19
		(a) Ultraviolet and Visible Spectroscopy		
		(b) Infrared Spectroscopy		
		(c) Nuclear Magnetic Resonance Spectroscopy		

		(d) Mass Spectrometry		
			25	75
CHE-352	100	**Higher-level Chemistry-V**		
		Unit I: Thermodynamics-III		15
		Unit II: Statistical Thermodynamics-I	25	15
		Unit III: Quantum Mechanics-I		15
		Unit IV: Electrochemistry-III		15
		Unit V: Phase Equilibria-II		15
		Total	25	75
CHE-353	100	**Physical Laboratory**		
		Part A–Instrumental Experiments **(Duration: 6 hours)**		
		Experiment	7	25
		Viva voce	3	8
		Laboratory records	2	5
		Part B–Non-instrumental Experiments **(Duration: 6 hours)**		
		Experiment	8	24
		Viva voce	3	8
		Laboratory records	2	5
		Total	25	75
7th Semester				
Course code	***Total marks***	***Sections***	***In-semester***	***End-semester***
CHE-400	100	**Research Methodology and Proposal Writing**		
		Unit I: Research Methodology		19
		Unit II: Research and Publication Ethics	25	19
		Unit III: Laboratory Safety		18
		Unit IV: Analytical tools in Research		19
		Total	25	75
CHE-401	100	**Advanced Chemistry-I**		
		Unit I: Symmetry and Group Theory		19
		Unit II: Coordination Chemistry-III		
		(a) Metal-Ligand equilibria in Solution	25	10
		(b) Reaction mechanism of transition metal complexes		10
		Unit III: Magnetochemistry		18
		Unit IV: Electronic structure of transition metal complexes		18
		Total	25	75
CHE-402	100	**Advanced Chemistry-II**		
		Unit I: Metal in organic chemistry synthesis		19
		(a) Uses of metal in organic chemistry synthesis		
		(b) Reactive Intermediates-I		
		Unit II: Stereochemistry	25	19
		Unit III: Aromatic systems and Intermediate species		19
		(a) Aromaticity and Reaction mechanisms		
		(b) Reactive Intermediates-II		
		Unit IV: Reactions and Reagents		18
		Total	25	75
CHE-403	100	**Advanced Chemistry-III**		
		Unit I: Quantum Mechanic-II		19
		Unit II: Chemical Bonding	25	18
		Unit III: Molecular Spectroscopy-II		19

		Unit IV: Resonance Spectroscopy		19
		Total	25	75
CHE-404	100	**General Chemistry-II**		
		Unit I: Inorganic Chemistry-IV		
		(a) Coordination Chemistry-I		7
		(b) Organometallic Chemistry-I	6	6
		(c) Analytical Chemistry		6
		Unit II: Organic Chemistry-IV	6	19
		(a) Aromatic Halogen compounds		
		(b) Alcohols		
		(c) Epoxides		
		(d) Phenols		
		Unit III: Physical Chemistry-IV		
		(a) Chemical Kinetics-II	6	10
		(b) Ionic Equilibria		9
		Unit IV: Solid State and Molecular Interactions		
		(a) Solid State		7
		(b) Metallic Bonding and Hydrogen Bonding	7	7
		(c) Liquid Crystals		4
			25	75
8th Semester				
Course code	***Total marks***	***Sections***	***In-semester***	***End-semester***
CHE-450	100	**Advanced Chemistry-IV**		
		Unit I: Green Chemistry		19
		Unit II: Nanochemistry	25	19
		Unit IV: Resonance Spectroscopy		19
		Unit V: Statistical Methods and computer applications		18
		Total	25	75
CHE-451	100	**General Chemistry-III**		
		Unit I: Inorganic Chemistry-V		
		(a) Chemical Bonding-II		6
		(b) Nanochemistry and nanomaterials	6	6
		(c) Metals and Metallurgy		7
		Unit II: Organic Chemistry-V		
		(a) Aldehydes and Ketones	6	10
		(b) Carboxylic acids and their derivatives		9
		Unit III: Physical Chemistry-V		
		(a) Thermodynamics-II	6	10
		(b) Chemical Equilibria		9
		Unit IV: Properties of reactive species and dilute solution		
		(a) Active methylene compounds	7	9
		(b) Dilute Solutions		9
		Total	25	75
CHE-452	300	**Research Project**		
		Proposal writing and literature review	50	
		Presentation	25	
		Dissertation		100
		Seminar		75
		Viva voce		50
			75	225

CHE-453	100	**Advanced Inorganic Chemistry**		
		Unit I: Organometallic Chemistry		19
		Unit II: Bioorganic Chemistry-II	25	19
		Unit III: Metal Carbonyls, Cluster and Metal-Metal bond		19
		Unit IV: Inorganic Supramolecular chemistry		18
		Total	25	75
CHE-454	100	**Advanced Organic Chemistry**		
		Unit I: Reaction and Reagents	25	19
		Unit II: Heterocycles		19
		Unit III: Name Reactions		19
		Unit IV: Dynamic stereochemistry, Alkaloids, Steroids		18
		Total	25	75
CHE-455	100	**Advanced Physical Chemistry**		
		Unit I: Electrochemistry-IV		19
		Unit II: Chemical Kinetics-III	25	19
		Unit III: Statistical Thermodynamics-II		19
		Unit IV: Surface Chemistry		18
		Total	25	75