

TEST NAME: 311 - POLYMER SCIENCE

## PART-I CHEMISTRY

### SECTION – I: ORGANIC CHEMISTRY

#### 1. Structural theory in Organic Chemistry

Types of bond fission and organic reagents (Electrophilic, Nucleophilic, and free radical reagents including neutral molecules like H<sub>2</sub>O, NH<sub>3</sub> & AlCl<sub>3</sub>).

Bond polarization : Factors influencing the polarization of covalent bonds, electro negativity - inductive effect. Application of inductive effect (a) Basicity of amines (b) Acidity of carboxylic acids (c) Stability of carbonium ions. Resonance or Mesomeric effect, application to (a) acidity of phenol, and (b) acidity of carboxylic acids. Hyper conjugation and its application to stability of carbonium ions, Free radicals and alkenes, carbanions, carbenes and nitrenes. Types of Organic reactions : Addition - electrophilic, nucleophilic and free radical. Substitution - electrophilic, nucleophilic and free radical. Elimination- Examples.

#### 2. Acyclic Hydrocarbons

Alkenes - Preparation of alkenes. Properties: Addition of hydrogen - heat of hydrogenation and stability of alkenes. Addition of halogen and its mechanism. Addition of HX, Markonikov's rule, addition of H<sub>2</sub>O, HOX, H<sub>2</sub>SO<sub>4</sub> with mechanism and addition of HBr in the presence of peroxide (anti - Markonikov's addition). Dienes - Types of dienes, reactions of conjugated dienes - 1,2 and 1,4 addition of HBr to 1,3 - butadiene and Diel's - Alder reaction. Alkynes - Preparation by dehydrohalogenation of dihalides, dehalogenation of tetrahalides, Properties; Acidity of acetylenic hydrogen (formation of Metal acetylides). Preparation of higher acetylenes, Metal ammonia reductions, Physical properties. Chemical reactivity – electrophilic addition of X<sub>2</sub>, HX, H<sub>2</sub>O (Tautomerism), Oxidation with KMnO<sub>4</sub>, OsO<sub>4</sub>, reduction and Polymerisation reaction of acetylene.

#### 3. Alicyclic hydrocarbons (Cycloalkanes)

Nomenclature, Preparation by Freunds method, Wislicenus method. Properties - reactivity of cyclopropane and cyclobutane by comparing with alkanes, Stability of cycloalkanes - Baeyer's strain theory, Sachse and Mohr predictions and Pitzer's strain theory. Conformational structures of cyclobutane, cyclopentane, cyclohexane.

#### 4. Benzene and its reactivity

Concept of resonance, resonance energy. Heat of hydrogenation, heat of combustion of Benzene, mention of C-C bond lengths and orbital picture of Benzene. Concept of aromaticity - aromaticity (definition), Huckel's rule - application to Benzenoid (Benzene, Naphthalene) and Non - Benzenoid compounds (cyclopropenyl cation, cyclopentadienyl anion and tropylium cation)

Reactions - General mechanism of electrophilic substitution, mechanism of nitration, Friedel Craft's alkylation and acylation. Orientation of aromatic substitution - Definition of ortho, para and meta directing groups. Ring activating and deactivating groups with examples (Electronic interpretation of various groups like NO<sub>2</sub> and Phenolic). Orientation of (i) Amino, methoxy and methyl groups (ii) Carboxy, nitro, nitrile, carbonyl and sulphonic acid groups (iii) Halogens (Explanation by taking minimum of one example from each type)

## 5. Halogen compounds

Nomenclature and classification of alkyl (into primary, secondary, tertiary), aryl, aryl alkyl, allyl, vinyl, benzyl halides. Nucleophilic aliphatic substitution reaction- classification into  $S_N1$  and  $S_N2$  – reaction mechanism with examples – Ethyl chloride, t-butyl chloride and optically active alkyl halide 2-bromobutane.

## 6. Hydroxy compounds

Nomenclature and classification of hydroxy compounds.

Alcohols: Preparation with hydroboration reaction, Grignard synthesis of alcohols. Phenols: Preparation i) from diazonium salt, ii) from aryl sulphonates, iii) from cumene. Physical properties- Hydrogen bonding (intermolecular and intramolecular). Effect of hydrogen bonding on boiling point and solubility in water. Identification of alcohols by oxidation with  $KMnO_4$ , Ceric ammonium nitrate, Luca's reagent and phenols by reaction with  $FeCl_3$ .

Chemical properties:

a) Dehydration of alcohols.

b) Oxidation of alcohols by  $CrO_3$ ,  $KMnO_4$ .

c) Special reaction of phenols: Bromination, Kolbe-Schmidt reaction, Reimer-Tiemann reaction, Fries rearrangement, azocoupling, Pinacol-Pinacolone rearrangement.

## 7. Carbonyl compounds

Nomenclature of aliphatic and aromatic carbonyl compounds, structure of the carbonyl group. Synthesis of aldehydes from acid chlorides, synthesis of aldehydes and ketones using 1,3-dithianes, synthesis of ketones from nitriles and from carboxylic acids. Physical properties: Reactivity of carbonyl group in aldehydes and ketones.

Nucleophilic addition reaction with a)  $NaHSO_3$ , b)  $HCN$ , c)  $RMgX$ , d)  $NH_2OH$ , e)  $PhNHNH_2$ , f) 2,4-DNPH, g) Alcohols-formation of hemiacetal and acetal. Base catalysed reactions: a) Aldol, b) Cannizzaro's reaction, c) Perkin reaction, d) Benzoin condensation, e) Haloform reaction, f) Knoevenagel reaction. Oxidation of aldehydes- Baeyer-Villiger oxidation of ketones. Reduction: Clemmensen reduction, Wolf-Kishner reduction, MPV reduction, reduction with  $LiAlH_4$  and  $NaBH_4$ . Analysis of aldehydes and ketones with a) 2,4-DNPH test, b) Tollen's test, c) Fehling test, d) Schiff's test e) Haloform test (with equation)

## 8. Carboxylic acids and derivatives

Nomenclature, classification and structure of carboxylic acids. Methods of preparation by a) Hydrolysis of nitriles, amides b) Hydrolysis of esters by acids and bases with mechanism c) Carbonation of Grignard reagents. Special methods of preparation of aromatic acids by a) Oxidation of side chain. b) Hydrolysis by benzotrichlorides. c) Kolbe reaction. Physical properties: Hydrogen bonding, dimeric association, acidity- strength of acids with examples of trimethyl acetic acid and trichloroacetic acid. Relative differences in the acidities of aromatic and aliphatic acids. Chemical properties: Reactions involving H, OH and COOH groups- salt formation, anhydride formation, acid chloride formation, amide formation and esterification (mechanism). Degradation of carboxylic acids by Hunsdiecker reaction, decarboxylation by Schmidt reaction, Arndt-Eistert synthesis, halogenation by Hell-Volhard-Zelinsky reaction.

## 9. Active methylene compounds

(i) Acetoacetic ester: keto-enol tautomerism, preparation by Claisen condensation, Acid hydrolysis and ketonic hydrolysis. Preparation of a) monocarboxylic acids. b) Dicarboxylic acids. c) Reaction with urea

(ii) Malonic ester: preparation from acetic acid. Synthetic applications: Preparation of a) monocarboxylic acids (propionic acid and n-butyric acid). b) Dicarboxylic acids (succinic acid and adipic acid) c)  $\alpha,\beta$ -unsaturated carboxylic acids (crotonic acid). d) Reaction with urea.

### 10. Nitro hydrocarbons:

Nomenclature and classification-nitro hydrocarbons, structure -Tautomerism of nitroalkanes leading to aci and keto form, Preparation of Nitroalkanes, reactivity -halogenation, reaction with HONO (Nitrous acid),Nef reaction and Mannich reaction leading to Micheal addition and reduction.

### 11. Nitrogen compounds :

Amines (Aliphatic and Aromatic): Nomenclature, Classification into 1°, 2°, 3° Amines and Quarternary ammonium compounds. Preparative methods –

1. Ammonolysis of alkyl halides 2. Gabriel synthesis 3. Hoffman's bromamide reaction (mechanism).

Reduction of Amides and Schmidt reaction. Physical properties and basic character - Comparative basic strength of Ammonia, methyl amine, dimethyl amine, trimethyl amine and aniline - comparative basic strength of aniline, N-methylaniline and N,N-dimethyl aniline (in aqueous and non-aqueous medium), steric effects and substituent effects. Chemical properties: a) Alkylation b) Acylation c) Carbylamine reaction d) Hinsberg separation e) Reaction with Nitrous acid of 1°, 2°, 3° (Aliphatic and aromatic amines). Electrophilic substitution of Aromatic amines – Bromination and Nitration. Oxidation of aryl and Tertiary amines, Diazotization.

### 12. Heterocyclic Compounds

Introduction and definition: Simple five membered ring compounds with one hetero atom Ex. Furan. Thiophene and pyrrole - Aromatic character – Preparation from 1,4,- dicarbonyl compounds, Paul-Knorr synthesis.

Properties : Acidic character of pyrrole - electrophilic substitution at 2 or 5 position, Halogenation, Nitration and Sulphonation under mild conditions - Diels Alder reaction in furan. Pyridine – Structure - Basicity - Aromaticity - Comparison with pyrrole - one method of preparation and properties - Reactivity towards Nucleophilic substitution reaction.

### 13. Carbohydrates

Monosaccharides: (+) Glucose (aldo hexose) - Evidence for cyclic structure of glucose (some negative aldehydes tests and mutarotation) - Proof for the ring size (methylation, hydrolysis and oxidation reactions) - Pyranose structure (Haworth formula and chair conformational formula).

(-) Fructose (keto hexose) - Evidence of 2 - keto hexose structure (formation of pentaacetate, formation of cyanohydrin its hydrolysis and reduction by HI). Cyclic structure for fructose (Furanose structure and Haworth formula) - osazone formation from glucose and fructose – Definition of anomers with examples.

Interconversion of Monosaccharides: Aldopentose to Aldohexose (Arabinose to D- Glucose, D-Mannose) (Kiliani - Fischer method). Epimers, Epimerisation - Lobry de bruyn van Ekenstein rearrangement. Aldohexose to Aldopentose (D-Glucose to D- Arabinose) by Ruff degradation. Aldohexose to Keto hexose [(+) Glucose to (-) Fructose] and Keto hexose to Aldohexose (Fructose to Glucose)

### 14. Amino acids and proteins

Introduction: Definition of Amino acids, classification of Amino acids into alpha, beta, and gamma amino acids. Natural and essential amino acids - definition and examples, classification of

alpha amino acids into acidic, basic and neutral amino acids with examples. Methods of synthesis: General methods of synthesis of alpha amino acids (specific examples - Glycine, Alanine, valine and leucine) by following methods: a) from halogenated carboxylic acid b) Malonic ester synthesis c) strecker's synthesis.

Physical properties: Zwitter ion structure - salt like character - solubility, melting points, amphoteric character, definition of isoelectric point.

Chemical properties: General reactions due to amino and carboxyl groups - lactams from gamma and delta amino acids by heating peptide bond (amide linkage). Structure and nomenclature of peptides and proteins.

## **SECTION - II: INORGANIC CHEMISTRY**

### **1. p-block elements –I & II**

Group-13: Synthesis and structure of diborane and higher boranes ( $B_4H_{10}$  and  $B_5H_9$ ), boronnitrogen compounds ( $B_3N_3H_6$  and BN).

Group - 14: Preparation and applications of silanes and silicones.

Group - 15: Preparation and reactions of hydrazine, hydroxylamine.

Group - 16: Classifications of oxides based on (i) Chemical behaviour and (ii) Oxygen content.

Group-17: Inter halogen compounds and pseudo halogens.

### **2. Organometallic Chemistry**

Definition - classification of Organometallic compounds - nomenclature, preparation, properties and applications of alkyls of Li and Mg.

### **3. Chemistry of d-block elements:**

Characteristics of d-block elements with special reference to electronic configuration, variable valence, magnetic properties, catalytic properties and ability to form complexes. Stability of various oxidation states

### **4. Theories of bonding in metals:**

Metallic properties and its limitations, Valence bond theory, Free electron theory, Explanation of thermal and electrical conductivity of metals, limitations, Band theory, formation of bands, explanation of conductors, semiconductors and insulators.

### **5. Metal carbonyls :**

EAN rule, classification of metal carbonyls, structures and shapes of metal carbonyls of V, Cr, Mn, Fe, Co and Ni.

### **6. Chemistry of f-block elements:**

Chemistry of lanthanides - electronic structure, oxidation states, lanthanide contraction, consequences of lanthanide contraction, magnetic properties. Chemistry of actinides - electronic configuration, oxidation states, actinide contraction, comparison of lanthanides and actinides.

### **7. Coordination Chemistry:**

IUPAC nomenclature - bonding theories - Review of Werner's theory and Sidgwick's concept of coordination - Valence bond theory - geometries of coordination numbers 4-tetrahedral and square planar and 6-octahedral and its limitations, crystal field theory - splitting of d-orbitals in octahedral, tetrahedral and square-planar complexes - low spin and high spin complexes - factors affecting crystal-field splitting energy, merits and demerits of crystal-field theory. Isomerism in coordination compounds - structural isomerism and stereo isomerism, stereochemistry of complexes with 4 and 6 coordination numbers.

### **8. Spectral and magnetic properties of metal complexes:**

Types of magnetic behavior, spin-only formula, calculation of magnetic moments, experimental determination of magnetic susceptibility-Gouy method.

### **9. Stability of metal complexes:**

Thermodynamic stability and kinetic stability, factors affecting the stability of metal complexes, chelate effect, determination of composition of complex by Job's method and mole ratio method.

### **10. Reactivity of metal complexes:**

Labile and inert complexes, ligand substitution reactions -  $SN_1$  and  $SN_2$ , substitution reactions of square planar complexes - Trans effect and applications of trans effect.

### **11. Bioinorganic chemistry:**

Essential elements, biological significance of Na, K, Mg, Ca, Fe, Co, Ni, Cu, Zn and Cl-. Metalloporphyrins – Structure and functions of hemoglobin, Myoglobin and Chlorophyll.

## **SECTION – III: PHYSICAL CHEMISTRY**

### **1. Solidstate**

Symmetry in crystals. Law of constancy of interfacial angles. The law of rationality of indices. The law of symmetry. Definition of lattice point, space lattice, unit cell. Bravais lattices and crystal systems. X-ray diffraction and crystal structure. Bragg's law. Defects in crystals. Stoichiometric and non-stoichiometric defects.

### **2. Gaseous state**

Compression factors, deviation of real gases from ideal behavior. Vander Waal's equation of state. P-V Isotherms of real gases, Andrew's isotherms of carbon dioxide, continuity of state. Critical phenomena. The vander Waal's equation and the critical state. Law of corresponding states. Relationship between critical constants and vander Waal's constants. Joule Thomson effect.

### **3. Liquid state**

Structural differences between solids, liquids and gases. Liquid crystals, the mesomorphic state. Classification of liquid crystals into Smectic and Nematic. Differences between liquid crystal and solid/liquid. Application of liquid crystals as LCD devices.

### **4. Solutions**

Liquid-liquid - ideal solutions, Raoult's law. Ideally dilute solutions, Henry's law. Non-ideal solutions. Vapour pressure - composition and vapour pressure- temperature curves. Azeotropes- HCl-H<sub>2</sub>O, ethanol-water systems and fractional distillation. Partially miscible liquids- phenol-water, trimethylamine-water, nicotine-water systems. Effect of impurity on consolute temperature. Immiscible liquids and steam distillation.

Nernst distribution law. Calculation of the partition coefficient. Applications of distribution law.

### **5. Dilute solutions**

Colligative properties. Raoult's law, relative lowering of vapour pressure, its relation to molecular weight of non-volatile solute. Elevation of boiling point and depression of freezing point. Derivation of relation between molecular weight and elevation in boiling point and depression in freezing point. Experimental methods of determination. Osmosis, osmotic pressure, experimental determination. Theory of dilute solutions. Determination of molecular weight of non-volatile solute from osmotic pressure. Abnormal Colligative properties- Van't Hoff factor.

### **6. Electrochemistry-I & II**

Specific conductance, equivalent conductance. Variation of equivalent conductance with dilution. Migration of ions, Kohlrausch's law. Arrhenius theory of electrolyte dissociation and its

limitations. Ostwald's dilution law. Debye-Huckel-Onsagar's equation for strong electrolytes (elementary treatment only). Definition of transport number, determination by Hittorf's method.

Application of conductivity measurements- conductometric titrations.

Single electrode potential, sign convention, Reversible and irreversible cells Nernst Equation- Reference electrode, Standard Hydrogen electrode, calomel electrode, Indicator electrode, metal – metal ion electrode, Inert electrode, Determination of EMF of cell, Applications of EMF measurements - Potentiometric titrations.

### **7. Phase rule**

Concept of phase, components, degrees of freedom. Thermodynamic Derivation of Gibbs phase rule. Phase equilibrium of one component system - water system. Phase equilibrium of two component

system, solid-liquid equilibrium. Simple eutectic diagram of Pb-Ag system, simple eutectic diagram, desilverisation of lead., NaCl-Water system, Freezing mixtures.

### **8. Thermodynamics**

The first law of thermodynamics-statement, definition of internal energy and enthalpy. Heat capacities and their relationship. Joule-Thomson effect- coefficient. Calculation of  $w$ , for the expansion of perfect gas under isothermal and adiabatic conditions for reversible processes. State function. Temperature dependence of enthalpy of formation-Kirchoff's equation. Second law of thermodynamics. Different Statements of the law. Carnot cycle and its efficiency. Carnot theorem. Concept of entropy, entropy as a state function, entropy changes in reversible and irreversible processes. Entropy changes in spontaneous and equilibrium processes.

### **9. Chemical kinetics**

Rate of reaction - Definition of order and molecularity. Derivation of rate constants for first, second, third and zero order reactions and examples. Derivation for time half change. Methods to determine the order of reactions. Effect of temperature on rate of reaction, Arrhenius equation, concept of activation energy.

### **10. Photochemistry**

Difference between thermal and photochemical processes. Laws of photochemistry- Grothus-Draper's law and Stark-Einstein's law of photochemical equivalence. Quantum yield- Photochemical reaction mechanism- hydrogen- chlorine, hydrogen- bromine reaction. Qualitative description of fluorescence, phosphorescence, Photosensitized reactions- energy transfer processes (simple example)

## **SECTION – IV: SPECTROSCOPY**

### **1. Electronic spectroscopy:**

Interaction of electromagnetic radiation with molecules and types of molecular spectra. Energy levels of molecular orbitals ( $\sigma$ ,  $\pi$ ,  $n$ ). Selection rules for electronic spectra. Types of electronic transitions in molecules effect of conjugation. Concept of chromophore and auxochrome.

### **2. Infra red spectroscopy**

Different Regions in Infrared radiations. Modes of vibrations in diatomic and polyatomic molecules. Characteristic absorption bands of various functional groups. Interpretation of spectra-Alkanes, Aromatic, Alcohols carbonyls, and amines with one example to each.

### **3. Proton magnetic resonance spectroscopy ( $^1\text{H-NMR}$ )**

Principles of nuclear magnetic resonance, equivalent and non-equivalent protons, position of signals. Chemical shift, NMR splitting of signals - spin-spin coupling, coupling constants.

Applications of NMR with suitable examples - ethyl bromide, ethanol, acetaldehyde, 1,1,2-tribromo ethane, ethyl acetate, toluene and acetophenone.

## **PART-II: PHYSICS**

### **Section I: Mechanics & Properties of Matter**

#### **1. Vector Analysis**

Scalar and vector fields, gradient of a scalar field and its physical significance. Divergence and curl of a vector field with derivations and physical interpretation. Vector integration (line, surface and volume), Statement and proof of Gauss and Stokes theorems.

#### **2. Mechanics of particles**

Laws of motion, motion of variable mass system, Equation of motion of a rocket. Conservation of energy and momentum, Collisions in two and three dimensions, Concept of impact parameter, scattering cross-section, Rutherford scattering-derivation.

#### **3. Mechanics of Rigid bodies**

Definition of rigid body, rotational kinematic relations, equation of motion for a rotating body, angular momentum, Euler equations and its applications, precession of a top, Gyroscope, precession of the equinoxes.

#### **4. Mechanics of continuous media**

Elastic constants of isotropic solids and their relations, Poisson's ratio and expression for Poisson's ratio in terms of  $\nu$ ,  $n$ ,  $k$ . Classification of beams, types of bending, point load, distributed load, shearing force and bending moment, sign conventions.

#### **5. Central forces**

Central forces, definition and examples, characteristics of central forces, conservative nature of central forces, conservative force as a negative gradient of potential energy, equatglobalion of motion under a central force. Derivation of Kepler's laws. Motion of satellites, idea of Global Positioning System (GPS).

#### **6. Special theory of relativity**

Galilean relativity, absolute frames. Michelson-Morley experiment, negative result. Postulates of special theory of relativity. Lorentz transformation, time dilation, length contraction, addition of velocities, mass-energy relation. Concept of four-vector formalism.

### **Section II: Waves & Oscillations**

#### **1. Simple Harmonic oscillations**

Simple harmonic oscillator and solution of the differential equation-Physical characteristics of SHM, torsion pendulum-measurements of rigidity modulus, compound pendulum measurement of 'g', Principle of super position, beats, combination of two mutually perpendicular simple harmonic vibrations of same frequency and different frequencies.

Lissajous figures.

#### **2. Damped and forced oscillations**

Damped harmonic oscillator, solution of the differential equation of damped oscillator. Energy considerations, comparison with un-damped harmonic oscillator, logarithmic decrement, relaxation time, quality factor, differential equation of forced oscillator and its solution, amplitude resonance and velocity resonance.

### **3. Complex vibrations**

Fourier theorem and evaluation of the Fourier coefficients, analysis of periodic wave functions-square wave, triangular wave, saw tooth wave, simple problems on evolution of Fourier coefficients.

### **4. Vibrating strings:**

Transverse wave propagation along a stretched string, general solution of wave equation and its significance, modes of vibration of stretched string clamped at ends, overtones and harmonics. Energy transport and transverse impedance.

### **5. Vibrations of bars:**

Longitudinal vibrations in bars-wave equation and its general solution. Special cases (i) bar fixed at both ends (ii) bar fixed at the midpoint (iii) bar fixed at one end. Tuning fork.

### **6. Ultrasonics:**

Ultrasonics, properties of ultrasonic waves, production of ultrasonics by piezoelectric and magnetostriction methods, detection of ultrasonics, determination of wavelength of ultrasonic waves. Applications of ultrasonic waves.

## **Section III: Wave Optics**

### **1. Aberrations:**

Introduction – monochromatic aberrations, spherical aberration, methods of minimizing spherical aberration, coma, astigmatism and curvature of field, distortion. Chromatic aberration-the achromatic doublet. Achromatism for two lenses (i) in contact and (ii) separated by a distance.

### **2. Interference**

Principle of superposition – coherence-temporal coherence and spatial coherence-conditions for interference of light. Fresnel's biprism-determination of wavelength of light –change of phase on reflection. Oblique incidence of a plane wave on a thin film due to reflected and transmitted light (cosine law) –colors of thin films-

Interference by a film with two non-parallel reflecting surfaces (Wedge shaped film). Determination of diameter of wire, Newton's rings in reflected light. Michelson interferometer, Determination of wavelength of monochromatic light using Newton's rings and Michelson Interferometer.

### **3. Diffraction**

Introduction, distinction between Fresnel and Fraunhofer diffraction, Fraunhofer diffraction – Diffraction due to single slit-Fraunhofer diffraction due to double slit-Fraunhofer diffraction pattern with N slits (diffraction grating). Resolving power of grating, Determination of wavelength of light in normal incidence and minimum deviation methods using diffraction grating,

Fresnel's half period zones-area of the half period zones-zone plate-comparison of zone plate with convex lens-difference between interference and diffraction.

### **4. Polarisation:**

Polarized light: methods of polarization polarization by reflection, refraction, double refraction, scattering of light-Brewster's law-Mauls law-Nicol prism polarizer and analyzer- Quarter wave



plate, Half wave plate-optical activity, determination of specific rotation by Laurent's half shade polarimeter-Babinet's compensator - idea of elliptical and circular polarization

### **5. Lasers and Holography**

Lasers: introduction,spontaneous emission, stimulated emission. Population Inversion, Laser principle-Einstein coefficients-Types of lasers-He-Ne laser, Ruby laser- Applications of lasers. Holography: Basic principle of holography-Gabor hologram and its limitations, Applications of holography.

### **6. Fiber Optics**

Introduction- different types of fibers, rays and modes in an optical fiber, fiber material, principles of fiber communication (qualitative treatment only), advantages of fiber optic communication

## **Section IV: Thermodynamics & Radiation Physics**

### **1.Kinetic theory of gases**

Introduction –Deduction of Maxwell's law of distribution of molecular speeds, experimental verification. Transport phenomena – Mean free path - Viscosity of gases-thermal conductivity-diffusion of gases.

### **2. Thermodynamics**

Introduction- Isothermal and adiabatic process- Reversible and irreversible processes- Carnot's engine and its efficiency-Carnot's theorem-Second law of thermodynamics. Kelvin's and Clausius statements-Entropy, physical significance –Change in entropy in reversible and irreversible processes-Entropy and disorder-Entropy of Universe– Temperature-Entropy (T-S) diagram and its uses - Change of entropy of a perfect gas change of entropy when ice changes into steam.

### **3. Thermodynamic potentials and Maxwell's equations**

Thermodynamic potentials-Derivation of Maxwell's thermodynamic relations-Clausius-Clayperon's equation-Derivation for ratio of specific heats-Derivation for difference of two specific heats for perfect gas. Joule Kelvin effect-expression for Joule Kelvin coefficient for perfect and vander Waal's gas.

### **4. Low temperature Physics**

Introduction-Joule Kelvin effect-Porous plug experiment - Joule expansion-Distinction between adiabatic and Joule Thomson expansion-Expression for Joule Thomson cooling- Liquefaction of helium, Kapitza's method-Adiabatic demagnetization, Production of low temperatures - applications of substances at low temperature-effects of chloro and fluoro carbons on ozone layer.

### **5. Quantum theory of radiation**

Blackbody-Ferry's black body-distribution of energy in the spectrum of black body-Wein's displacement law, Wein's law, Rayleigh-Jean's law-Quantum theory of radiation-Planck's law-Measurement of radiation-Types of pyrometers-Disappearing filament optical pyrometer-experimental determination – Angstrompyrheliometer-determination of solar constant, Temperature of Sun.

## **Section V: Electricity, Magnetism& Electronics**

### **1. Electric field intensity and potential:**

Gauss's law statement and its proof- Electric field intensity due to (1) Uniformly charged sphere and (2) an infinite conducting sheet of charge. Electrical potential – equipotential surfaces-potential due to i) a point charge, ii) charged spherical shell and uniformly charged sphere.

## **2. Dielectrics:**

Electric dipole moment and molecular polarizability- Electric displacement D, electric polarization P – relation between D, E and P- Dielectric constant and susceptibility. Boundary conditions at the dielectric surface.

## **3. Electric and magnetic fields**

Biot-Savart's law, explanation and calculation of B due to long straight wire, a circular current loop and solenoid – Lorentz force – Hall effect – determination of Hall coefficient and applications.

## **4. Electromagnetic induction**

Faraday's law-Lenz's law- Self and mutual inductance, coefficient of coupling, calculation of self inductance of a long solenoid, energy stored in magnetic field. Transformer – energy losses - efficiency.

## **5. Alternating currents and electromagnetic waves**

Alternating current - Relation between current and voltage in LR and CR circuits, vector diagrams, LCR series and parallel resonant circuit, Q –factor, power in ac circuits.

## **6. Maxwell's equations**

Idea of displacement current - Maxwell's equations (integral and differential forms) (no derivation), Maxwell's wave equation (with derivation), Transverse nature of electromagnetic waves. Poynting theorem (statement and proof), production of electromagnetic waves (Hertz experiment).

## **7. Basic electronics:**

PN junction diode, Zener diode, Tunnel diode, I-V characteristics, PNP and NPN transistors, CB, CE and CC configurations – Relation between  $\beta$ ,  $\alpha$  and  $\beta$  - transistor (CE) characteristics - Determination of hybrid parameters, Transistor as an amplifier.

## **8. Digital electronics**

Number systems - Conversion of binary to decimal system and vice versa. Binary addition and subtraction (1's and 2's complement methods).Laws of Boolean algebra - De Morgan's laws-statement and proof, Basic logic gates, NAND and NOR as universal gates, exclusive- OR gate, Half adder and Full adder, Parallel adder circuits.

## **Section VI: Modern Physics**

### **1. Atomic and molecular physics**

Introduction –Drawbacks of Bohr's atomic model- Sommerfeld's elliptical orbits-relativistic correction (no derivation).Vector atom model and Stern-Gerlach experiment – quantum numbers associated with it. L-S and j- j coupling schemes. Zeeman effect and its experimental arrangement.

Raman effect, hypothesis, Stokes and Anti Stokes lines. Quantum theory of Raman effect. Experimental arrangement – Applications of Raman effect.

### **2. Matter waves & Uncertainty Principle**

Matter waves, de Broglie's hypothesis - wavelength of matter waves, Properties of matter waves - Davisson and Germer experiment – Phase and group velocities. Heisenberg's uncertainty principle for position and momentum (x and p), & energy and time (E and t). Experimental verification - Complementarity principle of Bohr.

### **3. Quantum (wave) mechanics**

Basic postulates of quantum mechanics-Schrodinger time independent and time dependent wave equations-derivations. Physical interpretation of wave function. Eigen functions, Eigen values. Application of Schrodinger wave equation to particle in one dimensional infinite box.

#### **4. General Properties of Nuclei**

Basic ideas of nucleus -size, mass, charge density (matter energy), binding energy, angular momentum, parity, magnetic moment, electric moments. Liquid drop model and Shell model (qualitative aspects only) - Magic numbers.

#### **5. Radioactivity decay:**

Alpha decay: basics of  $\alpha$ -decay processes. Theory of  $\alpha$ -decay, Gamow's theory, Geiger Nuttal law.  $\beta$ -decay, Energy kinematics for  $\beta$ -decay, positron emission, electron capture, neutrino hypothesis.

#### **6. Crystal Structure**

Amorphous and crystalline materials, unit cell, Miller indices, reciprocal lattice, types of lattices, diffraction of X-rays by crystals, Bragg's law, experimental techniques, Laue's method and powder diffraction method.

#### **7. Superconductivity:**

Introduction - experimental facts, critical temperature - critical field - Meissner effect – Isotope effect - Type I and type II superconductors - BCS theory (elementary ideas only) - applications of superconductors.

### **PART III: POLYMER SCIENCE**

#### **SECTION-I : FUNDAMENTALS OF POLYMERS**

##### **1. WORLD POLYMERS:**

Introduction – brief history of development of polymerization – concept of macromolecule – what are polymers – polymers in day today world – importance of polymers and scope of polymer science – examples of various polymers produced in India.

Introduction to Polymerization – Introduction – Repeat unit – Nomenclature – Functionality of polymers – Degree of Polymerization – Classification of polymers – definitions – various terms used in polymers – Thermoplastics – Thermosets – Elastomers, Fibers – Adhesives – Definition and examples under each category.

##### **2. CHEMICAL AND GEOMETRICAL STRUCTURES OF POLYMERS:**

Introduction – Micro structure – Organic Polymers – Inorganic Polymers – homopolymers and copolymers – Stereo regular polymers – Examples – Difference – inter molecular Forces - Texture and polymer structure.

##### **3. TYPES OF POLYMERIZATION:**

Definition of step growth and chain growth polymerization – differences – homogeneous polymerization – heterogeneous polymerization – bulk polymerization – Solution polymerization – suspension polymerization – Emulsion polymerization – Melt polycondensation – Comparison of different techniques.

##### **4. MECHANISM OF POLYMERIZATION :**

Free radical – Cationic – Anionic and coordination polymerization – Ziegler – Natta Catalysis – Ring opening polymerization – Differences and examples under each category – Elementary Treatment of the above mechanisms.

##### **5. MOLECULAR WEIGHT OF POLYMERS:**

Introduction – Importance of molecular weight – conceptual differences between Micro and Macromolecules – Weight average molecular weight – Number average molecular weight – Viscosity average molecular weight – polydispersity - Role of molecular weight in applications-

Elementary treatment – Determination of molecular weight – Osmometry – End group analysis – Light scattering measurements – Mark – Houwink equation – Ubbelohde viscometer etc.,

## **Section II: PROPERTIES OF POLYMERS**

### **1. TYPES OF POLYMERIZATION**

(a) **Step Polymerisation** – difference between step polymerisation and chain polymerization – synthesis of polyesters – polyamides and poly urethanes – Kinetics of step polymerization – Urea, Phenol formaldehyde resins.

(b) Chain polymerisation – introduction – Kinetics and mechanism of free radical addition polymerisation – Kinetic chain length – factors affecting chain polymerization.

### **2. PHYSICAL PROPERTIES OF POLYMERS**

Introduction – Molecular weight and mechanical properties secondary valency forces. Nature of chain packing-chain flexibility.

### **3. TRANSITION IN POLYMERS**

Glass transition temperature – Factors affecting glass transition temperature – Effect of crosslinking and crystallinity on glass transition temperature.

### **4. FLOW PROPERTIES OF POLYMERS**

Viscoelasticity – Spring model – Deformation of Polymeric material – Rubber elasticity.

### **5. NATURALLY OCCURRING POLYMERS**

Poly saccharides – Cellulose and starch – proteins – primary, secondary and tertiary structures with examples – Nucleic acids – Nucleosides and nucleotides elementary treatment.

### **6. POLYMER DEGRADATION**

Introduction – Thermal degradation – Photo degradation – Oxidative degradation – stabilizers – Antioxidants.

## **Section III: PLASTICS, RUBBERS AND ACRYLICS**

1. Preparation, properties and uses of (i) Polyethylene, Polypropylene, Polystyrene, PVC (ii) Polyesters, Polyamides (Nylon-6 & Nylon-6,6) (iii). Polyurethanes
2. Rubbers, Neoprene, Isoprene, Chloroprene, Butadiene rubbers (buna) Silicone, Rubbers, uses and Manufacture.
3. Resins-Phenol formaldehyde, urea formaldehyde and melamine – formaldehyde and epoxy –resins.
4. Acrylic polymers: Preparation properties and uses Poly(ethyl acrylate), Poly (Butylacrylate), Poly (methyl methacrylate)
5. Cellulose and its derivatives.

## **SECTION IV**

### **POLYMER PROCESSING**

#### **1. ELASTOMERIC FIBRE FORMING AND PLASTIC MATERIALS**

- a. Introduction
- b. Elastomeric Materials
- c. Fibre forming materials
- d. Plastic materials

#### **2. POLYMER PROCESSING**

Plastics, Fibre and elastomers – Compounding – Processing techniques – Calendering – die casting – rotational casting.

#### **3. INJECTION MOULDING – BLOW MOULDING – EXTRUSION**

Moulding – Elementary Treatment - Thermofoming and framing.

#### **4. REINFORCEMENT**

Fibre reinforcement – Hand –lay-up technique – filament winding technique.

#### **5. FIBRE SPINNING**

Dry Spinning – Wet Spinning.4. REINFORCEMENT

Fibre reinforcement – Hand –lay-up technique – filament winding technique.

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