Syllabus for Nanoscience (PGQP50)

This Question paper has two Sections. Section I for M.Tech. Nanoscience and Section II for M.Sc. Nanoscience. Candidate has to choose the relevant section.

SECTION 1 for M.Tech

CHEMICAL SCIENCES:

Periodic Table and periodicity in properties: Chemical bonding and shapes of compounds, VSEPR theory, lattice energy. Main group elements (s and p blocks). Transition metals and inner transition metals (d and f block). Allotropes. Coordination compounds. Organometallic compounds. Stoichiometry. Acids and bases. Oxidation reduction and precipitation reactions. Radioactivity. Nuclear reactions: fission and fusion.

Quantum mechanics: Chemical bonding. Chemical thermodynamics. Kinetic theory of gases. Electrochemistry & Chemical kinetics: Conductance, EMF, Free energy, Nernst equation, redox systems, electrochemical cells, Reactions of various order, Arrhenius equation, Enzyme kinetics, Catalysis. Solutions. Ionic equilibria in solutions, pH and buffer solutions, Hydrolysis, Solubility product, Phase equilibria–Phase rule. Vapour pressure and Osmotic pressure. Molecular weight determination.

IUPAC nomenclature. Stereochemistry. Organic reactive intermediates: Generation, stability and reactivity of carbocations, carbanions, free radicals, carbenes, benzynes and nitrenes. Organic reaction mechanisms involving addition, elimination and substitution reactions with electrophilic, nucleophilic or radical species. Common named reactions and rearrangements – applications in organic synthesis. Polymers.

PHYSICAL SCIENCES:

Interference. Diffraction. Polarization. Quantum mechanics: Postulates; Wave-particle duality. Commutators and Heisenberg uncertainty principle. Schrödinger equation (time-dependent and time-independent). Exactly- solvable systems: particle-in-a-box, harmonic oscillator and the hydrogen atom. Tunneling through a barrier. Electrostatics: Gauss's law and its applications, Laplace and Poisson equations, boundary value problems. Magneto statics: Biot-Savart law, Ampere's theorem. Electromagnetic induction. Scalar and Vector potentials, Maxwell equations. First and second laws of thermodynamics, Thermodynamic functions, Heat capacity,

enthalpy, entropy. Bonding in solids, Crystal structures. Bravais lattices. Miller indices. Reciprocal lattice. Bragg's law and applications; Diffraction and the structure factor. Elastic properties, phonons, lattice specific heat. Free electron theory and electronic specific heat. Drude model of electrical and thermal conductivity. Hall Effect and thermoelectric power. Electron motion in a periodic potential, Band theory of solids: metals, insulators and semiconductors. Dielectrics. Ferroelectrics. Magnetic materials. Superconductivity: type-I and type-II superconductors.

BIOLOGICAL SCIENCES:

Biomolecules: Biomolecules (carbohydrates, lipids, proteins, nucleic acids and vitamins). Stabilizing interactions (Van der Waals, electrostatic, hydrogen bonding, hydrophobic interaction, etc.). Biophysical chemistry (pH, buffer, reaction kinetics, thermodynamics, colligative properties). Bioenergetics, glycolysis, oxidative phosphorylation. Catalysis, enzymes and enzyme kinetics.

Cell Biology: Membrane structure and function; Cell organelles; Cell division and cell cycle. Microbes, infectious disease biology, cancer and microbial diseases.

Fundamental Processes: DNA replication, repair and recombination, RNA synthesis and processing and Protein synthesis

Immunology: Innate and adaptive immunity, antigens, antibody, antigen-antibody interactions, immune responses, congenital and acquired immune deficiencies, vaccines.

Genetics: Mendelian principles, Gene: Allele, multiple alleles, mutation types and cause.

Human Physiology: Blood, coagulation, blood groups, Heart, Endocrine glands, Hormones and diseases.

SECTION II for M.Sc.

INORGANIC CHEMISTRY

Quantum numbers and their significance. s, p, d, f block elements, the long form of periodic table. Detailed discussion of the following properties of the elements, with reference to s & p-block. Effective nuclear charge, shielding or screening effect, Slater rules, variation of effective nuclear charge in periodic table. General characteristics, types of ions, size effects, radius ratio rule and its limitations. Packing of ions in crystals. Born-Landé equation with derivation and lattice energy. Madelung constant, Born-Haber cycle and its application, solvation energy. Lewis structure, Valence Bond theory, Molecular orbital theory. Formal charge, Valence shell electron

pair repulsion theory (VSEPR), Redox equations, Standard Electrode Potential and its application to inorganic reactions. Bronsted-Lowry concept of acid-base reactions, solvated proton, relative strength of acids, types of acid-base reactions, levelling solvents, Lewis acid-base concept, Classification of Lewis acids, Hard and Soft Acids and Bases (HSAB) Application of HSAB principle. Inert pair effect, diagonal relationship Allotropy and catenation. Complex formation tendency of s and p block elements. Study of the compounds with emphasis on structure, bonding, preparation, properties and uses. Boric acid and borates, boron nitrides, borohydrides (diborane) carboranes and graphitic compounds, silanes, Oxides and oxoacids of nitrogen, Phosphorus and chlorine. Peroxo acids of sulphur, interhalogen compounds, polyhalide ions, pseudo halogens and basic properties of halogens. Werner's theory, valence bond theory (inner and outer orbital complexes), electro neutrality principle and back bonding. Crystal field theory, measurement of

10 Dq (Δo), CFSE in weak and strong fields, pairing energies, factors affecting the magnitude of

10 Dq (Δo, Δt). Octahedral vs. tetrahedral coordination, tetragonal distortions from octahedral geometry Jahn-Teller theorem, square planar geometry. Qualitative aspect of Ligand field and MO Theory.

PHYSICAL CHEMISTRY

Intensive and extensive variables; state and path functions; isolated, closed and open systems; zeroth law of thermodynamics. First law: Concept of heat, q, work, w, internal energy, U, and statement of first law; enthalpy, H, relation between heat capacities, calculations of q, w, U and H for reversible, irreversible and free expansion of gases (ideal and van der Waals) under isothermal and adiabatic conditions. Heats of reactions: standard states; enthalpy of formation of molecules and ions and enthalpy of combustion and its applications; calculation of bond energy. Second Law: Concept of entropy; thermodynamic scale of temperature, statement of the second law of thermodynamics; molecular and statistical interpretation of entropy. Calculation of entropy change for reversible and irreversible processes. Third Law: Statement of third law, concept of residual entropy, calculation of absolute entropy of molecules. Free Energy Functions: Gibbs and Helmholtz energy; variation of S, G, A with T, V, P; Free energy change and spontaneity. Relation between Joule-Thomson coefficient and other thermodynamic parameters; inversion temperature. Miller indices, elementary ideas of symmetry, symmetry elements and symmetry operations, qualitative idea of point and space groups, seven crystal systems and fourteen Bravais lattices.

Ionization of weak acids and bases, pH scale, common ion effect, Salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts. Buffer solutions; derivation of Henderson equation and its applications; buffer capacity, buffer range. Kinetic molecular model of a gas: postulates and derivation of the kinetic gas equation; collision frequency. Maxwell distribution and its use in evaluating molecular velocities (average, root mean square

and most probable) and average kinetic energy. Order and molecularity of a reaction, rate laws in terms of the advancement of a reaction, differential and integrated form of rate expressions up to second order reactions, experimental methods of the determination of rate laws, kinetics of complex reactions.

ORGANIC CHEMISTRY

Homolytic and Heterolytic fission with suitable examples. Curly arrow rules, formal charges; Electrophiles and Nucleophiles; Nucleophlicity and basicity; Types, shape and their relative stability of Carbocations, Carbanions, Free radicals and Carbenes. Introduction to types of organic reactions and their mechanism: Addition, Elimination and Substitution reactions. Fischer Projection, Newmann and Sawhorse Projection formulae and their interconversions; Geometrical isomerism: cis–trans and, syn-anti isomerism E/Z notations with C.I.P rules. Optical Isomerism: Optical Activity, Specific Rotation, Chirality/Asymmetry, Enantiomers, Molecules with two or more chiral-centres, Distereoisomers, meso structures, Racemic mixture and resolution. Relative and absolute configuration: D/L and R/S designations

PHYSICS

Basics of classical mechanics; Laws of motion; Planck's theory, de Broglies's hypothesis, The Harmonic Oscillator: Schrodinger approach; Hydrogenic Atoms: Orbitals. Free electron gas in one and three dimensions. Thermionic emission, work function, electrical conductivity of the free electron gas Energy Bands: Fermi-Dirac Statistics; Holes; Effective Mass; Density of States: 3D,

2D, 1D; Conduction & Valence Bands; Electrons in periodic potential, Origin of energy bands in solids, classification of solids as metals, insulators and semiconductors on the basis of the band picture, Origin of the energy gap (qualitative discussions). Temperature dependence of Fermi energy. Crystal structure, Packing fraction, specific surface energy and surface stress, effect on the lattice parameter, Bragg's law of diffraction, Size and shape dependent optical, emission, electronic transport, refractive index, dielectric, mechanical, magnetic; quantum confinement in semiconductors; Mechanical properties – Stress and Strain concept, Elastic properties, General Optics and Optical properties - refraction, reflection, Absorption, Transmission, luminescence, Magnetic properties - paramagnetism - ferromagnetism - domain theory - magnetic hysteresis, – antiferromagnetism. Basics of Themodynamics, Laws of thermodynamics and related applications, Concepts of free energy and entropy. Semiconductor Physics; Energy Band Diagram: Electron Energy Bands, Dopant Atoms and Energy Levels, Position of Fermi Energy Level, Solid state phase transformations, excitons, band-gap variations-quantum confinement, Charge Carriers in Semiconductors: Intrinsic and Extrinsic Semiconductors, Carrier Transport Phenomena: Carrier Drift, Carrier Diffusion, Hall Effect. Semiconductor Electronic

devices: p-n Junction, p-n Junction Diode, Metal-Semiconductor and Semiconductor Heterojunctions, Bipolar Transistor, Concept of direct and indirect band gap in semiconductors.

BIOLOGICAL SCIENCES

Evolution and origin of life, biological classification systems Plant anatomy and physiology: plant tissues, hormones, mineral nutrition, biofertilizers and pesticides Animal anatomy and physiology: animal tissues, blood, digestive system, respiratory system, excretion system, nervous system, endocrine system, reproduction system, skeleton system. Cytology and molecular biology: Cell and cell organelles, cell cycle, cell division-Mitosis and meiosis, DNA, RNA, DNA replication, translation, transcription, DNA repair mechanism. Biochemistry: Basic structures and functions of amino acids, carbohydrates, lipids, proteins. Enzymes. Kidney and liver function tests. Ecology: Ecosystem, ecological pyramids, environment pollution and green house effects. Immunology: Basics of immunology, antigens, antibody, antigen-antibody interactions, types of immunity, immunological disorders, hypersensitivity reactions, monoclonal antibodies, and immunization. Microbiology: Classification of pathogens, Gram staining, diseases and treatments. Genetics: Mendelian genetics, genetic disorders, and gene therapy. Biotechnology: Molecular biology techniques including DNA transformation techniques, types of vectors, cloning and expression. Restriction enzymes, types of polymeric chain reactions (PCR), and gel electrophoresis.