Entrance Test Syllabus
for
MSc Nanotechnology

Note: The Syllabus comprises of three sections, namely, Physics, Chemistry and Biology. Chemistry will be common and mandatory for all candidates. From sections Physics and Biology candidates will opt for either of the two.

Physics

Unit 1

Bravais lattice and seven crystal systems; Reciprocal Lattice. Elastic waves, density of states of continuous medium; Specific heat; Einstein and Debye models; Lattice waves; One-dimensional monoatomic lattice; Density of states of a lattice; The concept of Phonons, Quantum mechanical free electron gas; Electrical conductivity; Electrical resistivity versus temperature; Heat capacity of conduction electrons.

Molecular collisions; Mean free path and collision cross section; Transport Phenomenon: transport of momentum, mass and energy and their inter-relationship; Brownian motion; Einstein's theory. Deviation from perfect gas behaviour (Liquification of CO_2), van der Waals' equation of state, Nature of van der Waals forces, comparison with experimental results, Critical constants. Joule's expansion of ideal gas and of van der Waals gas; Joule coefficient, Estimates of J-T cooling.

Unit 2

The Fermi surface; Electrical conductivity (effects of the Fermi surface); Thermal conductivity in metals. Electrons in one dimensional periodic potential, Kronig-Penney model, concept of Brillouin zones, explanation of energy bands on the basis of Brillouin zones; Metals, insulators and semiconductors. Band structure, Intrinsic semiconductors, Temperature dependence of carrier concentration, Impurity states: donor and acceptor levels

Extrinsic semiconductors; The electron-hole concentration product; Electrical conductivity; Temperature dependence; The effect of magnetic field on a semiconductor; The Hall effect. p-n junction: working (on the basis of energy band diagram); Rectification property; Derivation of rectification equation; The junction transistor, Its working (on the basis of energy band diagram), Tunnel diode.

Unit 3

Black body radiation, Planck's radiation law, Photoelectric and Compton Effect. Pair Production. De-Broglie's matter wave; The concept of wave packets and group velocities; Heisenberg's uncertainty relation for p and x; Its extension to energy and time; Applications of uncertainty principle.

Schrödinger's wave equation (Time independent form), Particle in a box, Finite potential well and Tunnel Effect. Schrödinger's wave equation for Hydrogen atom, Quantum numbers (n, l, m), space quantization and electron probability density. Electron spin, Pauli's exclusion principle. Spin-orbit coupling.

Unit 4

Review of Interference of light; Interference in thin parallel films; Application to Non-reflecting films, Newton rings; Michelson interferometer and its application for precision determination of wavelength; Multiple beam interference; Fabry-Perot interferometer and etalon; Intensity distribution. Fraunhofer diffraction at a slit; the intensity distribution; Two slit diffraction pattern; The intensity distribution.

Diffraction at N parallel slits; intensity distribution at an N parallel slits. Resolution of images; Rayleigh criterion; Resolving power of a diffraction grating. Frensel half-period zones; The Zone-Plate; Diffraction at a circular aperture; Diffraction by a straight edge (analysis using half-period zones). Polarization by reflection, Malus's law; Double refraction; Refraction in Uniaxial crystals; Optical activity; Rotation of plane of polarization; Origin of optical rotation in liquids and in crystals.

Unit 5

Review of Biot-Savart and Ampere's laws; Magnetic vector potential; Magnetostatics boundary conditions and multipole expansion of the vector potential; Field of a magnetized object; Bound currents and physical interpretation; Ampere's law in magnetized materials; Magnetic susceptibility and permeability. Review of Faraday's law and induced electric field; Energy in magnetic fields

Electrodynamics before Maxwell; Maxwell's equations; Magnetic charge; Maxwell's equation in matter; Boundary conditions. Continuity Equation; Poynthing's Theorem; Electromagnetic waves in one dimension; Wave equation; Sinusoidal waves; Boundary conditions; Reflection and transmission; Polarization, Electromagnetic waves in vacuum; Wave equations for E and B, Monochromatic plane waves; Energy and momentum in electromagnetic waves.

Unit 6

Transistor load line; Transistor biasing techniques (Voltage divider); bias stability; Thermal runaway. h-parameters; h-parameter equivalent circuit for CE configuration; FET and its characteristics, MOSFET; types and characteristics, applications of MOSFET. Transistor amplifiers, Two-stage RC coupled amplifier; Equivalent circuit at mid-frequency, Gain at mid –frequency; Emitter follower.

General Theory of Image Formation: Cardinal Points of an optical system, general relationships, thick lens formula and lens combination, langrange equation of magnification. Abberations: Chromatic and monochromatic abberations and their reductions. Corrector plates.

Unit 7

Graphical representation of functions, Equation of straight-line, Graphs of non-linear functions, Logarithmic and exponential functions, trigonometric functions, Polar and spherical coordinates, Differential and integral calculus, Maxima and minima

Data Evaluation: Accuracy, Precision and significant figures in measurement, Types of errors; Mean and standard deviations. Characteristics of Computers, Computer and Its Components, Computer Software, Computer Language and Operating System.

Chemistry

Unit 1

Ionic Structures; Radius ratio effect, Coordination number and limitations of radius ratio rule. Lattice defects; Lattice energy and Born Haber Cycle. Solvation energy and solubility of ionic solids. Polarizing power and polarizability of ions; Fajan's rules.

Valence bond and molecular Orbital theories. VSEPR theory and shapes of molecules.

Atomic, Ionic, Metallic and Vander Waal radii. Ionization Potentials, successive ionization potentials; Electronegativity and Electron affinity. Hydrogen bonding and Vander-Waal forces.

s-block, p-block, d-block and f-block elements, their periodicity and general properties.

Werner's Coordination Theory, Effective atomic number, Valence bond and Crystal Field theories. Splitting of d orbitals in ligand fields and different symmetries. Structure, bonding, magnetic and spectral properties in transition metal complexes.

Unit 2

De-Broglie's wave equation and Heisenberg's uncertainty principle. Schrodinger's wave equation: significance of Ψ and Ψ^2. Radial and Angular wave functions and Probability distribution curves. Shapes of s, p, & d orbitals. Hund's multiplicity rule. Electron Configuration of Elements. Effective nuclear charge and its determination.

Electromagnetic radiation, regions of the spectrum and associated spectroscopies.

Rotational spectroscopy: Moment of inertia, classification of molecules on the basis of moment of inertia, classical treatment of rotation of rigid diatomic molecules, quantization of angular momentum, quantization of energy levels of rigid diatomic molecules, selection rules for transitions and associated spectrum, intensity of spectral lines, determination of bond length.

Vibrational Spectroscopy: Classical and quantum (qualitative) treatments of harmonic vibrations of diatomic molecules. Pure vibrational spectrum of diatomic molecules, selection rules, determination of force constant. vibrational degrees of freedom, idea of vibrational frequencies of different functional groups.

Unit 3

Hybridization, Inductive, Electrometric, Resonance and Hyperconjugative Effects. Hund's multiplicity rule. Electron Configuration of Elements. Effective nuclear charge and its determination Carbocations, Carbanions and Free radicals - structure and stability. Carbenes, Benzynes and Nitrenes. Methods for determination of reaction mechanism.

Concept of stereo isomerism: elements of symmetry, molecular chirality, enantiomers and diastereomers, Inversion, retention and racemisation. Sequence rules. R, S-System of nomenclature. Geometrical isomers, E, Z-system of nomenclature. Conformations of n-butane, ethylene glycol and 1 ,2-dibromoethane, cyclohexane and its monosubstituted derivative, Axial and equatorial bonds. Baeyer's strain theory and its limitations. Ring strain in smaller rings with respect to cyclopropane ring.

Unit 4

Electrophilic and free radical additions to carbon-carbon double bonds. Markownikov's and Anti Markownikov's addition. Nucleophilic substitution: Reactivity, structural, solvent effects and substitution in SN1, SN2 reactions. Elimination reactions: E1 and E2 mechanism, stereochemistry, orientation of double bonds. Aromatic Electrophilic substitutions: Halogenation, Sulphonation and Friedal Craft's reaction. Activating and deactivating substituents, orientation and ortho/para ratio. Birch Reduction.

Pinacole-Pinacolone, Fries and Claisen rearrangements. Gatterman, Huben-Hoesch and Reimer Tieman, Benzoin, Aldol, Perkin, Knoevenagal, Mannich and Cannizzaro's reactions. Meerwein-pondroff verley, Clemmenson and Wolf-Kishner reductions. Oppenaner and Baeyer-villiger oxidation. HVZ reaction.

Unit 5

Thermodynamic functions. First, Second and third law of thermodynamics. Heat capacity, Joule's Law, Joule-Thomson Coefficient and inversion temperature. Kirchhoff's Equation. Carnot cycle and its efficiency, Carnot theorem. Concept of entropy, entropy as a state function.

Chemical Kinetics and photochemistry: Rate order and molecularity of chemical reactions. Theories on reaction rates. Effect of temperature on rate of reaction, Arrhenius equation, concept of activation energy. Interaction of radiation with matter, Laws of photochemistry. Jablonski diagram - fluorescence, phosphorescence, non-radiative processes, quantum yield and photosensitized reactions.

Phase Equilibria: Phase, component and degree of freedom. Phase rule: application to one components system (water, sulphur and carbon dioxide) and two component systems. Equilibrium constant and free energy change. Clapeyron equation and Clausius-Clapeyron equation, applications.

Electrochemistry: Conductivity of electrolytes- Specific, molar and equivalent conductivity, Nernst equation for electrode potential, EMF series, hydrogen electrode, calomel electrode, glass electrode. Electrochemical series and its significance. Electrolytic and galvanic cells, cell EMF, its measurement and applications.

Unit 6

Gaseous State: Deviation of gases from ideal behaviour, PV isotherms of real gases, continuity of states, the isotherms of van der Waal's equation, relationship between critical constants and van der Waal's constants, the law of corresponding states, reduced equation of state. Root mean square, average and most probable velocities. Maxwell's distribution of molecular velocities, collision number, mean free path and collision diameter, Liquefaction of gases (based on Joule-Thomson effect).

Liquid State: Intermolecular forces, structure of liquids (a qualitative description). Dipole moment, induced dipole moment, Measurement of dipole moment (temperature method and refractivity method), Dipole moment and structure of molecules.

Solid State: Definition of space lattice, unit cell and its dimensions, crystal systems. Laws of crystallography: - (i) Law of constancy of interfacial angles (ii) Law of rational indices (iii) Law of symmetry. Symmetry elements in crystals, Lattice planes and Miller indices. X-ray diffraction by crystals.

Unit 7

Types of electronic excitations, chromophore and auxochrome. Bathochromic and hypsochromic shifts. UV spectra of conjugated enes and enones. Prediction of λ-max of enes and enones using Woodward rules.

Infrared spectroscopy: Infrared region, Molecular vibrations, Hooks law, selection rules, the infrared spectrum, Finger Print region. Effect of resonance, Inductive effect, H-bonding electronegativity on IR spectra. Characteristic absorption of the following functional groups- Alkanes, Alkenes, Alkynes, Alcohols, ethers, carbonyl compounds, amines and carboxylic acids. Interpretation of IR spectra of simple molecules such as ethyl bromide, ethanol, acetaldehyde, ethyl acetate and acetophenone.

Nuclear Magnetic resonance (NMR) spectroscopy: Basic principles, Proton magnetic resonance (^{1}H NMR). Shielding and deshielding of protons, chemical shift and equivalent and non-equivalent protons, spin-spin splitting and coupling constants. Areas of signals. Interpretation of NMR spectra of simple organic molecules.

Unit 8

Qualitative analysis: Underlying principles, Common-ion effect, Solubility product, Relation between Solubility and Solubility product. Macro, Semi micro; Micro; Ultra micro Analyses.

Quantitative analysis: Gravimetry: Introduction, Preparation of Solution and Precipitation methods. Physical properties of precipitates: Appearance, particle size and purity. Fractional precipitation. Colloidal State: Supersaturation; Precipitate formation, Co-precipitation and post -precipitation. Digestion, Washing, Ignition, and Gravimetric calculations.

Acid-Base titrations: Basic principles; preparation of standard solutions; primary and secondary standards, theory of Visual titration of acids and bases including polybasic acids. Indicators: Types, Selection, and Preparation of indicator solutions. Redox indicators: Types, selection and analysis of redox cycle. Redox titrations: Basic principles; Balancing of redox equations, Redox reagents and their Equivalent weights. Redox potentials and redox indicators.

Precipitation titrations: Basic principles; Detection of Equivalence points.

Biology

Unit 1

Biomolecules: Carbohydrates, Lipids, Proteins, Nucleic acids, and Vitamins. Types, Structure, and biological functions. Enzymes and their function. Cofactors and multimeric enzyme complexes. Enzyme inhibition.

Unit 2

Cell biology: Prokaryotic and Eukaryotic cells, cell membranes and its composition, cell Organelles-Nucleus, ER, Golgi complex, Lysosomes, Mitochondria, Peroxisomes. Extracellular matrix-basis for cell adhesion and communication. Phases of cell cycle with their function. General organization of bacterial cells. Gram +ve and –ve bacteria, bacterial cell culture, sterilization techniques. Structure of viruses.

Unit 3

Molecular Biology: Prokaryotic and Eukaryotic replication, transcription and translation. Mechanisms and cellular machinery involved. Regulation of gene expression, Operons concept (Lac and Trp), Oncogenes, Tumor suppresor genes, Genetic disorders.

Unit 4

Recombinant DNA technology: Cloning vectors, Restriction Endonucleases (types and specificity). Plasmids, Bacteriophages, Cosmids and phagemids. Basic concepts of PCR (polymerase chain reaction) and applications in modern biology. DNA modifying enzymes, Phosphatases, Ligases etc. DNA cloning (basic idea and steps).

Unit 5

Bio-techniques: Centrifugation, Electrophoresis (Agarose gel, Polyacrylamide and Starch), Blotting techniques, ELISA, RIA and cell visualization and imaging techniques. Introduction to mass spectrometry. Animal cell culture.

Unit 6

Animal Physiology and Metabolism: Physiology and development of circulatory, nervous system, respiratory, excretory and digestive systems. Endocrine and Exocrine: hormone diversity and action. Basic concepts in Metabolism: ATP as energy currency, glycolysis, TCA cycle, pentose phosopahate pathway, gluconeogenesis, oxidation and synthesis of fatty acids, general reactions of amino acid metabolism. Degradation and synthesis of purines and pyrimidines. Metabolic disorders.

Unit 7

Immunity, Cells of immune system. Antigen recognition and antibody formation. Antibody types and function, Mechanisms of distinguishing self from non self, Cellular receptors. Hypersensitivity and allergies.