UNIVERSITY OF MUMBAI

Syllabus

for the

PET Examination

in

Nanoscience and Nanotechnology

(With effect from the Academic year 2020-21)

PREAMBLE

Coverage: The Chairperson and members of BoS may decide to include preamble. Preamble or Preface is optional and should be framed within one page. It should mention the salient features and essence of the curriculum/syllabus and highlight the need for revision. The constitution of India and most of the acts and laws of the Indian Penal Code have only one page preambles.

Dr. Anuradha Majumdar
(Dean, Science and Technology)

Prof. Shivram Garje
(Associate Dean, Science)

Name of Chairperson (BoS) : Prof. P. A. Mahanwar, ICT

Member(BoS) : Dr. Atul Chaskar

Member (BoS) : Dr. Suhas Jejurikar

Member (BoS) : Dr. Pravin Walke

Syllabus

Ph. D Entrance Test (PET)

For Admission in Ph. D course in Nanosciences and Nanotechnology

National Centre for Nanosciences and Nanotechnolgy, University of Mumbai

I. Nanophysics:

Solid State Physics: Fundamental of crystal structure, Translational vectors, Primitive unit cell, Different Bravais lattices, Miller indices, Crystal systems. Diamagnetism, Paramagnetism, ferromagnetism, ferromagnetic domains, Hysteresis, Curie temperature, Ferrites and its applications, anti-ferromagnetism, Neel temperature, Superconductivity, Critical magnetic field and Meissner effect, Free Electron and nearly free electron model, Energy levels and Density of orbital in 1D and 3D, Bloch theorem, Hall Effect, Origin of energy gap, Energy bands in Solids, Distinction between metal, semiconductor and insulator. Bragg's law and Diffraction conditions indirect and reciprocal lattice Ewald's construction, Laue method, Rotating Crystal method, Debye Scherer (Powder) method.

Classical and Quantum concepts: Lagrangian and Hamiltonian formulations, Concept of Entropy, Basics laws Thermodynamics, Thermodynamic processes, Ensembles,Photoelectric Effect, Black body radiations, De Broglie hypothesis, Heisenberg's uncertainty principle, Schrodinger equation, Compton Effect, Dual Nature of Electromagnetic Radiation,Wave-Particle Duality,Atomic Spectra, Bohr's Postulates, Bohr's Model, Atomic Energy States, Quantization Rules,Sommerfeld's Model, The Correspondence Principle.

Electronics: Fundamental of PN Junction, Diode and TransistorsCharacteristics, Transistor configurations, AC and DC circuits, Logic gates, Flip-flops, Boolean operations.

Fundamentals of Characterization Techniques: Optical Lens and Lens Aberrations, Polarizations, Optical Instrumentations, UV-visible spectroscopy, Raman spectroscopy, X-ray photoelectron spectroscopy, Scanning Electron microscopy (SEM), Transmission electron microscopy (TEM).

Stastical Physics: Probability, Theory of Gases, Boltzman distribution, Brownian motion, particles (Permions, Bosons , Plasomons) and their distribution.

Fundamentals of thin film deposition: Vacuum gauges, vacuum pumps and thin film deposition techniques (PVD: Pulsed laser deposition, Sputtering technique, Electron gun vapour deposition technique, Resistive heating evaporation technique; Chemical Vapour Deposition techniques)

References:

Kindly note that the references given below are purely suggestive and the syllabus coverage is not limited to the titles given below:

1. Introduction to Solid State Physics by Charles Kittle; Wiley-India.

2. Solid State Physics by Neil W. Ashcroft, N. David Mermin; Brooks/Cole Cengage Learning.
3. Solid State Physics by S.O. Pillai; New Age international Publishers.
4. Elementary Solid State Physics by M.A.Omar, Pearson Education.
5. Solid State Physics by Allen J.Dekker, MacMillan India Ltd.
6. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles by R. Eisberg; John Wiley and Sons
7. Fundamentals of Molecular Spectroscopy by W. S. Struve, John Wiley and Sons
8. Fundamentals of Molecular Spectroscopy by C. N. Banwell, McGraw-Hill
9. Electronic Principles by A. Malvino and D. Bates

II Nanochemistry:

Chemical Kinetics

Accounting for the rate laws: simple reactions, temperature dependence of reaction rates, consecutive reactions, (rate determining step approximation and steady-state approximation), pre-equilibria, unimolecular reactions – Lindeman-Hinshelwood mechanism. Kinetics of complex reactions - Chain reactions, polymerization reactions, explosions, photochemical reactions. Fast reactions: Study of kinetics by stop-flow technique, relaxation methods, flash photolysis, magnetic resonance method. Molecular reaction dynamics – collision theory, steric factor, diffusion-controlled reactions, activated complex theory, reaction coordinate and transition state, thermodynamic aspects, reaction between ions, salt effects, dynamics of molecular collisions, potential energy surfaces. Homogeneous catalysis – enzyme catalysis, Michael-Menten mechanism, acid base catalysis, autocatalysis, oscillating reactions. Heterogeneous catalysis – catalytic activity at surfaces. Examples: hydrogenation, oxidation, cracking and forming.

Chemical Bonding

Hybridisation: Derivation of wave functions for the following orbital hybridization types: sp (BeH2); sp2 (BF3); sp3 (CH4) considering only sigma bonding. *Molecular Orbital Theory* (LCAO-MO approach) for (a) Electron deficient species (B2H6), and (b) Electron rich species (tri-iodide ion, I3-). *Hydrogen bonding* – concept, types, properties, methods of detection and importance. Van der Waal's forces, ion-dipole, dipole-dipole, London forces. *Bent's Rule*. Reactivity of molecules: e.g. chloro-fluorides of phosphorous, fluoro-methane's, etc.

Organometallic Chemistry

Synthesis, structure and bonding in the following organometallic compounds: (a) Alkyl and Aryl derivatives, (b) Carbenes and Carbynes, (c) Alkene complexes, (d) Alkyne complexes, (e) Alkyl complexes, (f) Cyclopentadiene complexes and (g) Arenes complexes (sandwich and half sandwich complexes) (vi) Sixteen electron rule and electron counting with examples.

Surface Chemistry and Colloids

The colloidal state (Introduction, classification and the colloidal systems); structural characteristics; preparation and purification of the colloidal systems; Kinetic properties: The motion of the particle in liquid media; Brownian motion and translational diffusion; The ultracentrifuge; Osmotic pressure; Rotary Brownian motion; Optical properties: Optical and electron microscope; light scattering Liquid gas, liquid-liquid interfaces;

Surface and interfacial tensions; Adsorption and orientation at interfaces; association colloids-micelle formation; spreading; monomolecular films; The solid-gas interface; Adsorption of gases and vapors on solids; Composition and structure of solid surfaces; The solid liquid interface; contact angle and wetting; Ore flotation; Detergency; Adsorption from solution: Charged Interfaces: The electric double layer; Electro kinetic phenomena; Electro kinetic theory; Colloid Stability: Lyophobic sold; systems containing lyophilic material; stability control; Rheology; Introduction; Viscosity; Non-Newtonian flow; Viscoelasticity; Emulsion and foams: Oil in water; foams

Thermodynamics

State functions and exact differentials. Internal Energy, Enthalpy, Heat Capacity, Joule-Thomson coefficient. Clausius inequality, Entropy, Maximum Work, Thermodynamic equation of state, Maxwell relations, Helmholtz and Gibbs free energy, Temperature dependence of thermodynamic functions. Partial molar quantities, Chemical potential, Chemical potentials for ideal gases, gas mixtures and homogeneous solutions in multi component systems. Free energy, entropy and enthalpy of mixing for ideal gas mixtures and solutions, Fugacity and its relation to pressure, Equilibrium constant and its dependence on temperature and pressure. Vapor pressure – composition diagrams, Activity and activity coefficients, Excess functions, Gibbs-Duhem equation. Third law of thermodynamics, temperature dependence of entropy Phase rule and Phase Equilibria. Phase diagrams and their classification. Lambda transitions. Phase diagrams for partially miscible liquids for two components. Three Component Systems (Graphical representations of systems of three liquids, one pair of partially miscible liquid, bimodal curves, plait point, influence of temperature.) Experimental techniques for determination of thermodynamic quantities. Applications of Thermodynamics to Fractional Distillation, Zone Refining, Fuel Cells and Corrosion Processes. Thermodynamics of surfaces, Gibbs adsorption isotherm. Debye-Hückel theory, ionic atmosphere, activity coefficients of electrolyte solutions: Debye-Hückel limiting law, extension to higher concentrations. Electrolytic conductance and ion-ion interactions, Debye-Hückel-Onsager equation, Debye-Falkenhagen effect, Wien effect.

References:

Kindly note that the references given below are purely suggestive and the syllabus coverage is not limited to the titles given below:

1. A. W. Admson, Physical Chemistry of Surfaces, Wiley-Interscience (1990)
2. R. Aveyard and D. Haydon, An introduction to the principles of surface chemistry, Cambridge University Press (1973)
3. P. Hiemenz, Principle of colloid and surface chemistry, Dekker (1986)
4. E. Matijevic, Surface and colloid science, Wiley Inter science (1969)
5. M. Rosen, Surfactants and Interfacial phenomena, Wiley (1978)
6. T. Tadros, Surfactants, Academic Press (1984)
7. K. J. Laidter, Chemical Kinetics, Pearson Press
8. McQuarine and Simon, Physical Chemistry: A Molecular Approach
9. P. W. Atkinson, Physical Chemistry: ELBS with Oxford University Press
10. I. N. Levine, Physical Chemistry: McGraw-Hill
11. Fundamentals of Statistical and Thermal Physics by F. Reif; McGraw-Hill

III Nanobiology:

General Biology: The Cell and its three major parts – Cell Membrane, cytoplasm, nucleus; Cell theory and the cell as the basic unit of life - Structure of the Prokaryotic and eukaryotic cell, Viruses, eukaryotic, prokaryotic, organelles and their functions, Basics of Human Physiology, Biology of populations and communities

Basics of Biochemistry: Mole concept, normality and molarity calculations; Atoms, Molecules, isotopes and average atomic mass; biochemical reactions: synthesis & bio-composition; function of enzymes, substrate, active site and activation energy, enzyme reactions, inhibition and regulation; properties of water, elements, inorganic compounds, organic molecules and functional groups; structure and function of carbohydrates, lipids, steroids and proteins.

Molecular Biology: structure and functioning of DNA, RNA, Proteins, Enzymes, Micro and Macro biomolecules, Trace elements in biological systems, Enzymes and proteins, Synthesis of nucleic acids and proteins; Metabolism of Carbohydrate, lipid and nucleic acids; Structure of bio molecules and bio-molecular interactions; Thermodynamics and kinetics of biological systems; DNA repair, replication and recombination

Genetics & Evolution: Mendelian genetics, Heredity and variation, Chromosome structure and function, Nature of gene and its functions; Concept of Genomics, Online databases; Structure of DNA and RNA - DNA packaging - DNA replication - Central dogma - Transcription, genetic code, translation. - Gene expression and regulation. - Genome and human genome project. - DNA finger printing; Biological evolution and evidences for biological evolution; Darwin's contribution /Modern Synthetic theory of Evolution - Hardy – Weinberg's principle. Mechanism of evolution – Variation (Mutation & Recombination) and Natural Selection; Gene flow, adaptive radiation

Ecology and Environment: Meaning of ecology, environment, habitat and niche - Organisms and environment. Population and ecological adaptations - Population Interactions – mutualism, competition, predation, parasitism; Animal behaviour Ecology Evolution Diversity of organisms Evolutionary and population genetics Conservation biology; Carbon fixation, Pollination, Oxygen release Biodiversity and its conservation - Threats to and need for biodiversity conservation; Environmental Issues - Air Pollution and its control - Water pollution and its control - Agrochemicals and their effects - Solid waste management - Radioactive waste management - Greenhouse effect and global warming –
Ozone depletion, deforestation.

Microbiology and Cell Culture: Types of micro organisms and their characterization Pathogenic micro organisms; Bio-safety levels; anti-microbial properties; Genotoxicology and Environmental Mutagenesis, Cytogenetics, Cancer Biology, drug delivery; bio-imaging; Basics of – Microbial culture, Plant cell culture, Animal cell culture; biosynthesis of nanomaterials and characterization; nanotoxicity.

Reference books:

Kindly note that the references given below are purely suggestive and the syllabus coverage is not limited to the titles given below:

1. Cell Biology, Genetics, Molecular Biology, Evolution & Ecology, 2004 by Verma P.S., Agarwal V.K.; S. Chand Publishers
2. Microbiology; Michael Pelczar, Jr., E.C.S. Chan, Noel R Krieg; McGraw Hill Publications
3. iGenetics: A Molecular Approach, Third Edition 2009; Peter J Russel, Pearson Education
4. Lehninger Principles of Biochemistry; Seventh Edition, 2017; David L. Nelson; Michael M. Cox
5. The Cell – A Molecular Approch; Eighth edition, 2018; Geoffery M Cooper; Robert E. Hausman; Garland Science Publishing
6. Kuby Immunology; Eigth edition, 2018; Jenni Punt, Sharon Stranford, Patricia Jones, Judith A Owen; WH Freeman Publishers

IV Nanotechnology:

Introduction to miniaturization.Background, historical development of nanomaterials, units, Scaling laws: (in mechanics, electricity, electromagnetism, optics, heat transfer, fluids), organization of matter- atoms, molecules, clusters and supramolecules. Need based introduction to quantum effects.

Structure and Bonding: Chemical bonds (types and strength), Intermolecular forces, Molecular and crystalline structures- Bulk to surface transition, density of states, bandgap and dimensionality of nanomaterials, surface reconstruction, self-assembly.

Synthesis of Nanomaterials: Physical Methods: Mechanical, evaporation, chemical vapour deposition, ion beam techniques, molecular beam epitaxy, laser deposition.

Chemical methods: Colloids and colloids in solution, Langmuir-Blodgett (L-B) method, micro emulsion, sol gel methods, electrochemical methods etc.; uniformity of nanomaterials (size, properties distribution and yield)

Bio inspired methods: Microorganisms, plant based, using proteins and DNS templates, etc.

Examples of special nanomaterials: 2D materials, Carbon based materials, aerogels, zeolites, self-assembled nanomaterials, core shell particles, Nano Metals, Nano Ceramics, Nano Composites, other current interest nano structured / nano materials.

Scope of nanomaterials with respect to properties: Mechanical, magnetic, electrical, optical, biocompatibility, toxicity, chemical, emergent quantum properties.

Applications of Nanomaterials: Nano-electronics, Nano-optics, Nano magnetic-, chemical- and bio-sensing, energy applications, textiles, cosmetics, biotechnology, medical, construction, defence, and other contemporary applications.

Reference books:

Kindly note that the references given below are purely suggestive and the syllabus coverage is not limited to the titles given below:

1. Springer Handbook of Nanomaterials, -by Robert Vajtai
2. Nanotechnology: principles and practices, -by S. K. Kulkarni
3. Nanotechnology the whole story, -by B. Rogers, J Adams and S. Pennathur.

Note: The syllabus is based on core subjects, however research methodology and aptitude part is not included in this syllabus. It can be considered as common for all the disciplines.

Professor P. A. Mahanwar
Chairman- BOS

Dr. Atul Chaskar
Chairman- Syllabus Committee