Shivaji University, Kolhapur
School of Nanoscience and Technology

Entrance examination syllabus for **M.Sc. in Nanoscience and Technology**
(Weightage Physics - 30%, Chemistry - 30% and Nanoscience and Technology - 40%)

Physics

Mechanics

Vectors:
Vector algebra, Scalar and vector products, Derivatives of a vector with respect to a parameter (velocity and acceleration).

Ordinary Differential Equations: Differential equation; ordinary and partial differential equations, 1^{st} order homogeneous differential equations, 2^{nd} order homogeneous differential equations with constant coefficients.

Laws of Motion: Frames of reference, Newton's Laws of motion (with proof). Motion at nanoscale.

Momentum and Energy:
Conservation of linear and angular momentum, work and energy theorem, conservation of energy (Single particle), Dynamics of a system of particles (linear momentum, angular momentum and energy), Center of mass, Motion of rockets (qualitative treatment only).

Rotational Motion:
Angular velocity, angular momentum and Torque, Kinetic energy of rotation and moment of Inertia, Moment of inertia of a spherical shell, solid cylinder (only about axis of symmetry), Motionof spherical Shell and solid cylinder rolling down an inclined plane.

Gravitation:
Newton's Law of Gravitation, Motion of a particle in a central force field (motion in a plane, angular momentum is conserved, areal velocity is constant), Kepler's Laws (statement only), Satellite in circular orbit and applications, Geosynchronous orbits, Weightlessness, Basic idea of global positioning system (GPS).

Oscillations:
Simple harmonic motion, Differential equation of SHM and its solutions, Kinetic and Potential Energy, Total Energy and their time averages, Damped oscillations, Forced oscillations. Frequencyof nanoscale matters.

Elasticity:
Bending of beam, Bending moment, Cantilever (without considering weight of cantilever), Beam supported at both the ends (without considering weight of beam).

Torsional oscillation, Work done in twisting a wire, Twisting couple on a cylinder - Torsional pendulum-Determination of Rigidity modulus and moment of inertia, Determination of Y, η andσ by Searles method. Elasticity of nanoscale matters.

Surface Tension:
Surface tension (definition), Angle of contact and wettability, Relation between surface

tension, excess of pressure and radius of curvature, Experimental determination of surface tensionby Jaeger's method, Applications of surface tension. Hydrophobic and superhydrophobic nanostructured surface.

Electricity and Magnetism

Vector Analysis:
Scalar and Vector product, gradient, divergence, Curl and their significance, Vector Integration, Line, surface and volume integrals of Vector fields, Gauss-divergence theorem and Stoke's theorem of vectors (statement only).

Electrostatics:
Electrostatic Field, electric flux, Gauss's theorem of electrostatics, Electric potential as line integralof electric field, potential due to a point charge, electric dipole, uniformly charged spherical shelland solid sphere, Calculation of electric field from potential, Capacitance of an isolated spherical conductor, parallel plate, spherical and cylindrical condenser, Energy per unit volume in electrostatic field, Dielectric medium, Polarization, Displacement vector, Gauss's theorem in dielectrics, Parallel plate capacitor completely filled with dielectric. Electrostatic at nanoscale.

A.C. Circuits:
Complex numbers and their application in solving a. c. series LCR circuit, complex impedance, Reactance, Admittance, and Susceptance, Resonance in LCR series circuit, Sharpness of resonance (qualitative treatment only), Q-factor (definition only) A.C. Bridge - Owen's Bridge. Memristor circuits at nanoscale.

Magnetism:
Magnetostatics: Biot-Savart's law & its applications- straight conductor, circular coil, solenoid carrying current, Divergence and curl of magnetic field, Magnetic vector potential, Ampere's circuital law, Magnetic properties of materials: Magnetic intensity, magnetic induction, permeability, magnetic susceptibility, Brief introduction of dia-, para- and ferro-magnetic materials. Introduction to spintronics.

Electromagnetic Induction: Faraday's laws of electromagnetic induction, Lenz's law, self and mutual inductance, L of single coil, M of two coils, Energy stored in magnetic field.

Maxwell's equations and Electromagnetic wave propagation:
Equation of continuity of current, Displacement current, Maxwell's equations, Poynting vector, energy density in electromagnetic field, electromagnetic wave propagation through vacuum and isotropic dielectric medium, transverse nature of EM waves, polarization. Introduction to nanoelectrodynamics.

Thermal Physics and Statistical Mechanics

Laws of Thermodynamics:
Thermodynamic Description of system: Zeroth Law of thermodynamics and temperature. First law and internal energy, conversion of heat into work, Various Thermodynamical Processes, Applications of First Law: General Relation between CP & CV, Work Done during Isothermal and Adiabatic Processes, Compressibility & Expansion Coefficient, Reversible & irreversible processes, Second law & Entropy, Carnot's cycle & theorem, Entropy changes in reversible &

irreversible processes, Entropy-temperature diagrams, Third law of thermodynamics, Unattainability of absolute zero.

Thermodynamic Potentials: Enthalpy, Gibbs, Helmholtz and Internal Energy functions, Maxwell's relations & applications - Joule-Thompson Effect, Clausius-Clapeyron Equation, Expression for (CP – CV), CP/CV, TdS equations.

Kinetic Theory of Gases: Derivation of Maxwell's law of distribution of velocities and its experimental verification, Mean free path (Zeroth Order), Transport Phenomena: Viscosity, Conduction and Diffusion (for vertical case), Law of equipartition of energy (no derivation) and its applications to specific heat of gases; mono-atomic and diatomic gases.

Theory of Radiation: Blackbody radiation, Spectral distribution, Concept of Energy Density, Derivation of Planck's law, Deduction of Wien's distribution law, Rayleigh Jeans Law, Stefan Boltzmann Law and Wien's displacement law from Planck's law.

Statistical Mechanics: Phase space, Macrostate and Microstate, Entropy and Thermodynamic probability, Maxwell Boltzmann law - distribution of velocity - Quantum statistics - Fermi-Dirac distribution law - electron gas - Bose-Einstein distribution law - photon gas - comparison of three statistics.

Waves and Optics

Superposition of Two Collinear Harmonic oscillations: Linearity and Superposition Principle. (1) Oscillations having equal frequencies and (2) Oscillations having different frequencies (Beats). Superposition of Two Perpendicular Harmonic Oscillations: Graphical and Analytical Methods. Lissajous Figures with equal an unequal frequency and their uses.

Waves Motion- General: Transverse waves on a string. Travelling and standing waves on a string. Normal Modes of a string. Group velocity, Phase velocity. Plane waves. Spherical waves, Wave intensity.

Fluids: Surface Tension: Synclastic and anticlastic surface - Excess of pressure - Application to spherical and cylindrical drops and bubbles - variation of surface tension with temperature - Jaegar's method. Viscosity: Viscosity - Rate flow of liquid in a capillary tube - Poiseuille's formula - Determination of coefficient of viscosity of a liquid - Variations of viscosity of a liquid with temperature lubrication. Physics of low pressure - production and measurement of low pressure - Rotary pump - Diffusion pump - Molecular pump - Knudsen absolute gauge - penning and pirani gauge – Detection of leakage, Introduction to superfluidity

Sound: Simple harmonic motion - forced vibrations and resonance - Fourier's Theorem - Application to saw tooth wave and square wave - Intensity and loudness of sound - Decibels - Intensity levels - musical notes - musical scale. Acoustics of buildings: Reverberation and time of reverberation - Absorption coefficient - Sabine's formula - measurement of 20 reverberation time - Acoustic aspects of halls and auditoria.

Wave Optics: Electromagnetic nature of light. Definition and Properties of wave front. Huygens Principle.

Interference: Interference: Division of amplitude and division of wavefront. Young's Double Slit experiment. Lloyd's Mirror and Fresnel's Biprism. Phase change on reflection: Stokes' treatment. Interference in Thin Films: parallel and wedge-shaped films. Fringes of equal inclination (Haidinger Fringes); Fringes of equal thickness (Fizeau Fringes). Newton's Rings: measurement of wavelength and refractive index.

Michelson's Interferometer: Idea of form of fringes (no theory needed), Determination of wavelength, Wavelength difference, Refractive index and Visibility of fringes.

Diffraction: Fraunhofer diffraction: Single slit; Double Slit. Multiple slits & Diffraction grating. Fresnel Diffraction: Half-period zones. Zone plate. Fresnel Diffraction pattern of a straight edge, a slit and a wire using half-period zone analysis.
Polarization: Transverse nature of light waves. Plane polarized light – production and analysis. Circular and elliptical polarization.

Classical Mechanics, Classical Electrodynamics and Quantum Mechanics

Lagrangian Formulation:
Constraints, Degrees of freedom, generalized coordinates, Principle of virtual work, D'Alembert's principle, Lagrange's equation from D'Alembert's principle, Applications of Lagrange's equation to a particle in space, Atwood's machine and a bead sliding on uniformly rotating wire under force free condition.
Techniques of Calculus of Variation:
Hamilton's principle, Deduction of Hamilton's principle from D'Alembert's principle, Deduction of Lagrange's equation from Hamilton's principle, Applications-shortest distance between two points in a plane, Brachistochrone problem.
Charged Particles Dynamics:
Poisson's and Laplace's equations and their physical significance, Laplace's equation in one dimension and its solutions, Motion of charged particle - in uniform electric field E, magnetic field B, Crossed uniform electric field E and magnetic field B.
Matter Waves
Wave particle duality, De-Broglie hypothesis of matter waves, Derivation of wavelength of matter wave, Concept of wave packet, Relation between group velocity - phase velocity and group velocity-particle velocity, Davisson and Germer experiment, Uncertainty principle (statements only): position–momentum and energy- time, Application of uncertainty principle-non existence of free electrons in the nucleus.
Schrodinger's Wave Equation:
Wave function and its physical interpretation, Condition of physically acceptable wave function, Normalized and orthogonal wave function, Schrödinger time dependent and time independent (steady state) wave equations in 1D and 3D, Probability current density (continuity equation), Eigen values and Eigen functions, Expectation values of dynamic variables.

Operators in Quantum Mechanics:

Definition of an operator, Position operator (x), Linear momentum operator (p), Commutation relation in quantum mechanics, Commutation relation between x and p, Kinetic energy operator (T), Hamiltonian operator (H), Parity operator (π), Angular momentum operator (L) – components of angular momentum operator in Cartesian coordinate system, Ladder operators, Eigen values of Lz and L_2 (use equations for L_2 and Lz in spherical polar coordinates).

Applications of Schrodinger Equation:

Particle in a rigid box (infinite potential well) in one dimension and three dimension, Step potential- reflection and transmission coefficients, Potential barrier- tunneling effect (qualitative treatment), One dimensional simple harmonic oscillator (operator method)- energy levels, zero point energy, Schrodinger equation for Hydrogen atom in spherical polar coordinates, Separation of radial and angular parts, Solution of radial part of Schrodinger's equation - Energy Eigen values.

Solid State Physics and Nuclear and Particle Physics

Crystal Structure: Solids, amorphous, polycrystalline and crystalline materials; lattice, basis, unit cell- primitive, non-primitive unit cell, symmetry operations, symmetry elements of cube, Bravais lattice in two and three dimensions, Miller indices, Miller indices and inter-planer spacing, Simple crystal structures: SC, BCC, FCC and HCP (Co-ordination number, atomic radius, atoms per unit cell and packing fraction) 2. X-Ray Diffraction

Reciprocal lattice and its properties, Brillouin zone, Diffraction of X-rays by crystals, Ewald construction, Bragg's law in reciprocal lattice, Experimental methods in X-ray diffraction (Laue method, rotating crystal method, powder photograph method), Analysis of cubic crystal by powder method.

Magnetic Properties of Matter: Classical Langevin theory of diamagnetic and paramagnetic materials, Quantum mechanical treatment of paramagnetism, Curie's law, Weiss theory of ferromagnetism and ferromagnetic domains, Explanation of B-H curve, Hysteresis and energy loss.

Superconductivity: Idea of superconductivity, Critical temperature, Critical magnetic field, Meissner effect, Type-I and Type-II superconductors, London equation and penetration depth, Isotope effect, Application (magnetic levitation)

Elementary Band Theory of Solids Concept of density of states, Bloch theorem (statement only), Kroning– Penny model, Origin of energy gap, Velocity of electrons according to 8 band theory, Effective mass of an electron, Distinction between metals, semiconductors and insulators, Hall Effect - Hall voltage and Hall Coefficient.

General Properties of Nuclei and Nuclear Model: Constituents of nucleus and their intrinsic properties, Quantitative facts about size, mass, charge density (matter energy), binding energy, average binding energy and its variation with mass number, Liquid drop model approach, Semi empirical mass formula, Magic numbers. **Particle Accelerators**: Need of accelerators, Cyclotron- construction, working, theory and its limitations, Principle of phase stable orbit, Synchrocyclotron - construction and working, Synchrotrons- electron synchrotron and proton synchrotron, Betatron - principle, construction and working condition, expression of energy gain.

Chemistry

Atomic Structure, Bonding, GeneralOrganic Chemistry & Aliphatic Hydrocarbons

Atomic Structure:

Review of: Bohr's theory and its limitations, dual behaviour of matter and radiation, de Broglie's relation, Heisenberg Uncertainty principle. Hydrogen atom spectra. Need of a new approach to Atomic structure. Surface area of atoms and nanoscale materials.

What is Quantum mechanics? Time independent Schrodinger equation and meaning of various terms in it. Significance of ψ and ψ^2, Schrödinger equation for hydrogen atom. Radial and angular parts of the hydogenic wavefunctions (atomic orbitals) and their variations for 1s, 2s, 2p, 3s, 3p and 3d orbitals (Only graphical representation). Radial and angular nodes and their significance. Radial distribution functions and the concept of the most probable distance with special reference to 1sand 2s atomic orbitals. Significance of quantum numbers, orbital angular momentum and quantum numbers ml and ms. Shapes of s, p and d atomic orbitals, nodal planes. Discovery of spin, spin quantum number (s) and magnetic spin quantum number (ms).

Rules for filling electrons in various orbitals, Electronic configurations of the atoms. Stability of half-filled and completely filled orbitals, concept of exchange energy. Relative energies of atomic orbitals, Anomalous electronic configurations.

Chemical Bonding and Molecular Structure: Ionic Bonding: General characteristics of ionic bonding. Energy considerations in ionic bonding, lattice energy and solvation energy and their importance in the context of stability and solubility of ionic compounds. Statement of Born-Landé equation for calculation of lattice energy, Born-Haber cycle and its applications, polarizing power and polarizability. Fajan's rules, ionic character in covalent compounds, bond moment, dipole moment and percentage ionic character.

Covalent bonding: VB Approach: Shapes of some inorganic molecules and ions on the basis of VSEPR and hybridization with suitable examples of linear, trigonal planar, square planar, tetrahedral, trigonal bipyramidal and octahedral arrangements.

Concept of resonance and resonating structures in various inorganic and organic compounds. MO Approach: Rules for the LCAO method, bonding and antibonding. MOs and their characteristics for s-s, s-p and p-p combinations of atomic orbitals, nonbonding combination of orbitals, MO treatment of homonuclear diatomic molecules of 1st and 2nd periods (including idea of s-p mixing) and heteronuclear diatomic molecules such as CO, NO and NO^+. Comparison of VB and MO approaches. **Nano Perspective of bondings:** Bonding considerations at nanoscale.

Fundamentals of Organic Chemistry:

Physical Effects, Electronic Displacements: Inductive Effect, Electromeric Effect, Resonance and Hyperconjugation. Cleavage of Bonds: Homolysis and Heterolysis.

Structure, shape and reactivity of organic molecules: Nucleophiles and electrophiles. Reactive Intermediates: Carbocations, Carbanions and free radicals.

Strength of organic acids and bases: Comparative study with emphasis on factors affecting pK values. Aromaticity: Benzenoids and Hückel's rule.

Stereochemistry:

Conformations with respect to ethane, butane and cyclohexane. Interconversion of Wedge Formula, Newmann, Sawhorse and Fischer representations. Concept of chirality (upto two carbon atoms). Configuration: Geometrical and Optical isomerism; Enantiomerism, Diastereomerism and Meso compounds). Threo and erythro; D and L; cis - trans nomenclature; CIP Rules: R/S (for upto2 chiral carbon atoms) and E / Z Nomenclature (for upto two C=C systems).

Aliphatic Hydrocarbons:

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structure.

Alkanes: (Upto 5 Carbons). *Preparation:* Catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis, from Grignard reagent. *Reactions:* Free radical Substitution: Halogenation. Concept of Nanocatalysis.

Alkenes: (Upto 5 Carbons) *Preparation:* Elimination reactions: Dehydration of alkenes and dehydrohalogenation of alkyl halides (Saytzeff's rule); cis-alkenes (Partial catalytic hydrogenation) and trans alkenes (Birch reduction). *Reactions:* cis-addition (alk. $KMnO_4$) and trans-addition (bromine), Addition of HX (Markownikoff's and anti-Markownikoff's addition), Hydration, Ozonolysis, oxymecuratio n-demercuration, Hydroboration-oxidation.

Alkynes: (Upto 5 Carbons) *Preparation:* Acetylene from CaC_2 and conversion into higher alkynes; by dehalogenation of tetra halides and dehydrohalogenation of vicinal-dihalides.

Reactions: formation of metal acetylides, addition of bromine and alkaline $KMnO_4$, ozonolysis and oxidation with hot alk. $KMnO_4$.

Nanoscale carbon materials (carbonaceous materials-Bucky ball, graphene oxide, carbon nanotubes)

Chemical Energetics, Equilibria & Functional OrganicChemistry

Chemical Energetics:

Review of thermodynamics and the Laws of Thermodynamics.

Important principles and definitions of thermochemistry. Concept of standard state and standard enthalpies of formations, integral and differential enthalpies of solution and dilution. Calculation of bond energy, bond dissociation energy and resonance energy from thermochemical data. Variation of enthalpy of a reaction with temperature – Kirchhoff's equation.

Statement of Third Law of thermodynamics and calculation of absolute entropies of substances. Introduction to nanoscale thermodynamics.

Chemical Equilibrium:

Free energy change in a chemical reaction. Thermodynamic derivation of the law of chemical equilibrium. Distinction between ΔG and ΔG^o, Le Chatelier's principle. Relationships between Kp, Kc and Kx for reactions involving ideal gases.

Ionic Equilibria:

Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water. 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. Solubility and solubility product of sparingly soluble salts – applications of solubility product principle.

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structure.

Aromatic hydrocarbons:

Preparation (Case benzene): from phenol, by decarboxylation, from acetylene, from benzene sulphonic acid.

Reactions: (Case benzene): Electrophilic substitution: nitration, halogenation and sulphonation. Friedel-Craft's reaction (alkylation and acylation) (upto 4 carbons on benzene). Side chain oxidation of alkyl benzenes (upto 4 carbons on benzene).

Alkyl and Aryl Halides

Alkyl Halides (Upto 5 Carbons) Types of Nucleophilic Substitution (S_N1, S_N2 and S_Ni) reactions.

Preparation: from alkenes and alcohols.

Reactions: hydrolysis, nitrite & nitro formation, nitrile & isonitrile formation. Williamson's ether synthesis: Elimination vs substitution.

Aryl Halides

Preparation: (Chloro, bromo and iodo-benzene case): from phenol, Sandmeyer & Gattermann reactions.

Reactions (Chlorobenzene): Aromatic nucleophilic substitution (replacement by –OH group) and effect of nitro substituent. Benzyne Mechanism: KNH_2/NH_3(or $NaNH_2/NH_3$).

Reactivity and Relative strength of C-Halogen bond in alkyl, allyl, benzyl, vinyl and aryl halides.

Alcohols, Phenols and Ethers (Upto 5 Carbons**)**

Alcohols: *Preparation:* Preparation of 1°, 2° and 3° alcohols: using Grignard reagent, Ester hydrolysis, Reduction of aldehydes, ketones, carboxylic acid and esters.

Reactions: With sodium, HX (Lucas test), esterification, oxidation (with PCC, alk. $KMnO_4$, acidic dichromate, conc. HNO_3). Oppeneauer oxidation Diols: (Upto 6 Carbons) oxidation of diols. Pinacol-Pinacolone rearrangement.

Phenols: (Phenol case) *Preparation:* Cumene hydroperoxide method, from diazonium salts. *Reactions:* Electrophilic substitution: Nitration, halogenation and sulphonation. Reimer-Tiemann Reaction, Gattermann-Koch Reaction, Houben–Hoesch Condensation, Schotten – Baumann Reaction.

Ethers (aliphatic and aromatic): Cleavage of ethers with HI. Aldehydes and ketones (aliphatic and aromatic): (Formaldehye, acetaldehyde, acetone and benzaldehyde)

Preparation: from acid chlorides and from nitriles.

Reactions – Reaction with HCN, ROH, $NaHSO_3$, NH_2-G derivatives. Iodoform test. Aldol Condensation, Cannizzaro's reaction, Wittig reaction, Benzoin condensation. Clemensen reduction and Wolff Kishner reduction. Meerwein-Pondorff Verley reduction.

Introduction to functionalization of nanomaterial.

Solutions, Phase Equilibrium, Conductance, Electrochemistry & Functional Group Organic Chemistry-II

Solutions and Phase Equilibrium:

Solutions

Thermodynamics of ideal solutions: Ideal solutions and Raoult's law, deviations from Raoult's law – non-ideal solutions. Vapour pressure-composition and temperaturecomposition curves of ideal and non-ideal solutions. Distillation of solutions. Lever rule. Azeotropes. Partial miscibility of liquids: Critical solution temperature; effect of impurity on partial miscibility of liquids. Immiscibility of liquids- Principle of steam distillation. Nernst distribution law and its applications, solvent extraction.

Phase Equilibrium

Phases, components and degrees of freedom of a system, criteria of phase equilibrium. Gibbs Phase Rule and its thermodynamic derivation. Derivation of Clausius – Clapeyron equation and its importance in phase equilibria. Phase diagrams of one-component systems (water and sulphur) and two component systems involving eutectics, congruent and incongruent melting points (lead-silver, FeCl3-H2O and Na-K only, nanothermodynamics.

Conductance and Electrochemistry:

Conductance

Conductivity, equivalent and molar conductivity and their variation with dilution for weakand strong electrolytes. Kohlrausch law of independent migration of ions. Transference number and its experimental determination using Hittorf and Moving boundary methods. Ionic mobility. Applications of conductance measurements: determination of degree of ionization of weak electrolyte, solubility and solubility products of sparingly soluble salts, ionic product of water, hydrolysis constant of a salt. Conductometric titrations (only acidbase). Introduction to conductivity measurement of nanomaterials in solution, Zeta Potential

Electrochemistry

Reversible and irreversible cells. Concept of EMF of a cell. Measurement of EMF of a cell. Nernst equation and its importance. Types of electrodes. Standard electrode potential. Electrochemical series. Thermodynamics of a reversible cell, calculation of thermodynamic properties: ΔG, ΔH and ΔS from EMF data. Calculation of equilibrium constant from EMF data. Concentration cells with transference and without transference. Liquid junction potential and salt bridge. pH determination using hydrogen electrode and quinhydrone electrode. Potentiometric titrations - qualitative treatment (acid-base and oxidation-reduction only). Electrochemical synthesis, deposition of nanomaterials, examples only. Working principles of battries and supercapacitor and examples of nanomaterials.

Carboxylic acids and Amines:

Carboxylic acids (aliphatic and aromatic) Preparation: Acidic and Alkaline hydrolysis of esters. Reactions: Hell – Vohlard - Zelinsky Reaction. Carboxylic acid derivatives (aliphatic): (Upto 5 carbons) Preparation: Acid chlorides, Anhydrides, Esters and Amides from acids and their

interconversion. Reactions: Comparative study of nucleophilicity of acyl derivatives. Reformatsky Reaction, Perkin condensation. Amines and Diazonium Salts. Amines (Aliphatic and Aromatic): (Upto 5 carbons)

Preparation: from alkyl halides, Gabriel's Phthalimide synthesis, Hofmann Bromamide reaction. Reactions: Hofmann vs. Saytzeff elimination, Carbylamine test, Hinsberg test, with HNO2, Schotten – Baumann Reaction. Electrophilic substitution (case aniline): nitration, bromination, sulphonation. Diazonium salts: Preparation: from aromatic amines. Reactions: conversion to benzene, phenol, dyes.

Amino Acids, Peptides, Proteins and carbohydrates:

Preparation of Amino Acids: Strecker synthesis using Gabriel's phthalimide synthesis. Zwitterion, Isoelectric point and Electrophoresis. Reactions of Amino acids: ester of –COOH group, acetylation of –NH2 group, complexation with Cu2+ ions, ninhydrin test. Overview of Primary, Secondary, Tertiary and Quaternary Structure of proteins. Determination of Primary structure of Peptides by degradation Edmann degradation (Nterminal) and C–terminal (thiohydantoin and with carboxypeptidase enzyme). Synthesis of simple peptides (upto dipeptides) by N-protection (t-butyloxycarbonyl and phthaloyl) & Cactivating groups and Merrifield solid-phase synthesis. Carbohydrates: Classification, and General Properties, Glucose and Fructose (open chain and cyclic structure), Determination of configuration of monosaccharides, absolute configuration of Glucose and Fructose, Mutarotation, ascending and descending in monosaccharides. Structure of disacharrides (sucrose, cellobiose, maltose, lactose) and polysacharrides (starch and cellulose) excluding their structure elucidation. Concept of biomolecules as self-assembled nanomaterials. Introduction to biologically capped nanomaterials for used in SERS (Surface Enhanced Raman Spectroscopy), examples only.

Transition Metal & Coordination Chemistry, States Of Matter & Chemical Kinetics

Transition Elements, Coordination Chemistry and Crystal Field Theory:

Transition Elements (3d series)

General group trends with special reference to electronic configuration, variable valency, colour, magnetic and catalytic properties, and ability to form complexes and stability of various oxidation states (Latimer diagrams) for Mn, Fe and Cu.

Lanthanoids and actinoids: Electronic configurations, oxidation states, colour, magnetic properties, lanthanide contraction, separation of lanthanides (ion exchange method only)

Coordination Chemistry: Valence Bond Theory (VBT): Inner and outer orbital complexes of Cr, Fe, Co, Ni and Cu (coordination numbers 4 and 6). Structural and stereoisomerism in complexes with coordination numbers 4 and 6. Drawbacks of VBT. IUPAC system of nomenclature.

Crystal Field Theory: Crystal field effect, octahedral symmetry. Crystal field stabilization energy (CFSE), Crystal field effects for weak and strong fields. Tetrahedral symmetry. Factors affecting the magnitude of D. Spectrochemical series. Comparison of CFSE for Oh and Td complexes,

Tetragonal distortion of octahedral geometry. Jahn-Teller distortion, Square planar coordination. Important oxide nanomaterials of transition metal ions: Ti, Zn, V, Mn, Fe,

Kinetic Theory of Gases: Postulates of Kinetic Theory of Gases and derivation of the kinetic gas equation. Deviation of real gases from ideal behaviour, compressibility factor, causes of deviation. van der Waals equation of state for real gases. Boyle temperature (derivation not required). Critical phenomena, critical constants and their calculation from van der Waals equation.
Andrews isotherms of CO2. Maxwell Boltzmann distribution laws of molecular velocities and molecular energies (graphic representation – derivation not required) and their importance. Temperature dependence of these distributions. Most probable, average and root mean square velocities (no derivation). Collision cross section, collision number, collision frequency, collision diameter and mean free path of molecules. Viscosity of gases and effect of temperature and pressure on coefficient of viscosity (qualitative treatment only).

Liquids and Solids: Liquids
Surface tension and its determination using stalagmometer. Viscosity of a liquid and determination of coefficient of viscosity using Ostwald viscometer. Effect of temperature on surface tension and coefficient of viscosity of a liquid (qualitative treatment only). Definition of Ostwald ripening, Relationship between surface tension and spherical nature of liquids.
Solids: Forms of solids. Symmetry elements, unit cells, crystal systems, Bravais lattice types and identification of lattice planes. Laws of Crystallography - Law of constancy of interfacial angles, Law of rational indices. Miller indices. X–Ray diffraction by crystals, Bragg's law. Structures of NaCl, KCl and CsCl (qualitative treatment only). Defects in crystals. Glasses and liquid crystals.

Aromatic hydrocarbons:

Preparation (Case benzene): from phenol, by decarboxylation, from acetylene, from benzenesulphonic acid.
Reactions: (Case benzene): Electrophilic substitution: nitration, halogenation and sulphonation. Friedel-Craft's reaction (alkylation and acylation) (upto 4 carbons on benzene).Side chain oxidation of alkyl benzenes (upto 4 carbons on benzene).

Alkyl and Aryl Halides
Alkyl Halides (Upto 5 Carbons) Types of Nucleophilic Substitution (SN1, SN2 and SNi) reactions.
Preparation: from alkenes and alcohols.
Reactions: hydrolysis, nitrite & nitro formation, nitrile & isonitrile formation. Williamson'sether synthesis: Elimination vs substitution. Aryl Halides
Preparation: (Chloro, bromo and iodo-benzene case): from phenol, Sandmeyer& Gattermann reactions.
Reactions (Chlorobenzene): Aromatic nucleophilic substitution (replacement by –OH group)and effect of nitro substituent. Benzyne Mechanism: KNH2/NH3(or NaNH2/NH3). Reactivity and Relative strength of C-Halogen bond in alkyl, allyl, benzyl, vinyl and aryl halides.

Chemical Kinetics:

The concept of reaction rates. Effect of temperature, pressure, catalyst and other factors on reaction rates. Order and molecularity of a reaction. Derivation of integrated rate equations for zero, first and second order reactions (both for equal and unequal concentrations of reactants). Half–life of a reaction. General methods for determination of order of a reaction.

Concept of activation energy and its calculation from Arrhenius equation. Theories of Reaction Rates: Collision theory and Activated Complex theory of bimolecular reactions. Comparison of the two theories (qualitative treatment only).

Inorganic and Organic Chemistry

Theories of Acids, Bases, Chemistry of f-Block Elements, Metal Bondings in Transition Metal Complex and Co-ordination Chemistry, Organic Reagents, and Reactions

Acids, Bases and Non-aqueous Solvents and Chemistry of f- Block Elements

Introduction to theories of Acids and Bases-Arrhenius concept, Bronsted-Lowry concept, Lewis Concept, Lux-Flood Concept (definition and examples), Hard and Soft Acids and Bases. (HSAB Concept), Classification of acids and bases as hard, soft and borderline. Pearson's HSAB concept. Acid–Base strength and hardness-softness. Applications and limitations of HSAB principle. Chemistry of Non aqueous Solvents. Introduction, definition and characteristics of solvents. Classification of solvents. Physical properties and Acid-Base reactions in Liquid Ammonia (NH_3) and Liquid Sulphur Dioxide (SO_2).

Lanthanides: Introduction and Occurrence. Electronic Configuration. Oxidation State. Lanthanide contraction. Separation of Lanthanides by Ion exchange method.

Actinides: Position in periodic table. Electronic configuration. General methods of preparation of transuranic elements. Neutron capture – followed by β decay. Accelerated projectile bombardment. Heavy ion bombardment. IUPAC nomenclature of the super heavy elements with atomic number (Z) greater than 100.

Metal Ligand bonding in Transition Metal Complexes and Co-ordination Chemistry

Crystal field theory (CFT): Introduction: Shapes of d-orbitals, Basic assumptions of CFT. Crystal field splitting of d-orbitals of metal ion in octahedral, tetrahedral, square planar complexes and John-Teller distortion. Factors affecting the Crystal field splitting. High spin and low spin octahedral complexes w.r.t. Co (II). Crystal Field stabilization energy (CFSE), Calculation with respect to octahedral complexes only. Limitations of CFT.

Molecular orbital theory (MOT): Introduction, MOT of octahedral complexes with sigma bonding. Merits and demerits of MOT.

Coordination Chemistry: Inorganic Reaction mechanism Introduction,

Classification of Mechanism: Association, dissociation, interchange and the rate determining steps. $S_N{}^1$ and $S_N{}^2$ reactions for inert and labile complexes. Mechanism of substitution in cobalt (III) octahedral complexes. Trans effect and its theories. Applications of trans effect in synthesis

of Pt (II) complexes.

Reagents and Reactions in Organic Synthesis and Retrosynthesis

Reagents: Preparation and Applications of following reagents. Lithium aluminium hydride LiAlH4. Raney Nickel. Osmium tetraoxide. Selenium dioxide (SeO_2). Dicyclohexyl Carbodiimide (DCC). Diazomethane.

Reactions : Statement, General Reaction, Mechanism and Synthetic applications: Diels -Alder reaction. Meerwein –Pondorff-Verley reduction. Hofmann rearrangement. Wittig reaction. Wagner-Meerwein rearrangement. Baeyer Villiger oxidation. Problem based on above reactions.

Retrosynthesis: Introduction. Recapitulation of basics of reaction mechanism and reagents. Terms used- Target molecule (TM), Disconnection, Synthons, Synthetic equivalence, Functional group interconversion (FGI), one group disconnection (w. r. t. suitable examples). Retrosynthetic analysis and synthesis of target molecules: Cinnamaldehyde, Cyclohexene, para methoxy acetophenone, Methyl-3-phenyl propionate, α,α-dimethyl benzyl alcohol, Paracetamol.

Electrophilic addition to >C=C< and −C≡C− bonds and Natural products

Addition to Carbon-Carbon double (>C=C<): Introduction. Examples of addition reactions. Mechanism of electrophilic addition to >C=C< bond,C=C< bond, orientation & reactivity, Hydrohalogenation. Anti-Markovnik off's addition (peroxide effect). Rearrangements (support for formation of carbocation). Addition of halogens. Addition of water. Addition of hypohalous acids (HO-X). Hydroxylation (formation of 1,2-diols). Hydroboration-oxidation (formation of alcohol). Hydrogenation (formation of alkane). Ozonolysis (formation of aldehydes & ketones). **Addition to Carbon-Carbon triple (−C≡C−) bond**: Introduction. Examples of addition reactions. Mechanism of electrophilic addition to−C≡C−bond. Addition of halogens. Addition of halogen acids.Addition of hydrogen. Addition of water. Formation of metal acetylides. Named Reactions [4] Diels -Alder reaction. Meerwein –Pondorff-Verley reduction. Hofmann rearrangement. Wittig reaction. Wagner- Meerwein rearrangement. Baeyer Villiger oxidation.

Physical Chemistry

(Elements of Quantum Mechanics, Chemical Kinetics, Thermodynamics, Chemistry of Solutions, Solid State Chemistry, Electrochemistry, Spectroscopy and Photochemistry)

Elementary quantum mechanics, Thermodynamics and Chemical Kinetics

Elementary quantum mechanics: Introduction, Drawbacks of classical mechanics, Black body radiation, Photoelectric effect, Compton effect, Duel nature of matter and energy: De Broglie hypothesis. The Heisenberg's uncertainty principle. Concept of energy operators (Hamiltonian). Derivation of Schrodinger wave equation, well behaved function. Physical interpretation of the ψ and ψ2 . Particle in a one dimensional box. Numerical problems.

Thermodynamics: Introduction. Free energy: Gibbs function (G) and Helmholtz function (A), Criteria for thermodynamic equilibrium and spontaneity. Relation between ΔG and ΔH : Gibbs-Helmholtz equation. Phase equilibria: Clapeyron – Clausius equation and its applications. Thermodynamics derivation of law of mass action, Van't – Hoff isotherm and isochore. Fugacity and activity concepts. Partial molar quantities, Partial molar volume, Concept of chemical

potential, Gibbs-Duhem equation. Numerical problems.

Chemical Kinetics and Catalysis: Introduction. Simultaneous reactions such as: Opposing reaction: (Derivation of rate equation for first order opposed by first order expected).Side reaction. Consecutive reactions. Chain reaction. Explosive reaction (Derivation of rate equation and Numerical problems are not expected). **Catalysis:** Introduction. Classification of catalytic reaction- Homogenous and Heterogeneous. Types of Catalysis. Characteristics of catalytic reactions. Mechanism of catalysis. Intermediate compound formation theory. Adsorption theory. Industrial applications of catalysis.

Solid State Chemistry, Solutions, Phase Equilibria and Distribution Law: **The Solid State** Introduction: Space lattice, lattice sites, lattice planes, unit cell. Laws of crystallography: Law of constancy of interfacial angles, Law of rational indices, Law of crystal symmetry. Weiss indices and Miller indices. Cubic lattice and types of cubic lattice, planes or faces of a simple cubic system, spacing of lattice planes. Diffraction of X-rays, Derivation of Bragg's equation. Determination of crystal structure by Bragg's method. Determination of crystal structure of NaCl and KCl on the basis of Bragg's equation. Numerical problems. **Solutions** Introduction. Ideal solutions, Raoult's law, Vapour pressure of ideal and non ideal solutions of miscible liquids. Composition of liquid and vapour, vapour pressure and boiling point diagrams of miscible liquids. Distillation of miscible liquid pairs. Type I : Systems with intermediate total vapour pressure (i.e. System in which b.p. increases regularly – Zeotropic). Type II : Systems with a maximum in the total vapour pressure (i.e. System with a b.p. minimum – Azeotropic). Type III : Systems with a minimum in the total vapour pressure (i.e. System with a b.p. Maximum – Azeotropic). Solubility of partially miscible liquids. Maximum solution temperature type: Phenol – water system.Minimum solution temperature type: Triethyl amine – water system.Maximum and minimum solution temperature type: Nicotine – water system.Distillation of partially miscible liquid pairs.Vapour pressure and distillation of immiscible liquids, steam distillation. **Phase Equilibria**: Introduction. Gibbs phase rule : Phase rule equation and explanation of terms involved in the equation. Phase diagram, true and metastable equilibria. One component systems: Water system. Sulphur system with explanation for polymorphism. Two component systems: Eutectic system: (Ag – Pb system); Desilverisation of lead. Freezing mixture: (KI –H2O system). Formation of compound with congruent melting point (FeCl3 – H2O). Three component solid-liquid system: Development of triangular phase diagram: (Acetic acid – Chloroform –water system). **Distribution law**: Introduction, solute, solvent and solution, miscible and immiscible liquids. Nernst distribution law and its limitations. Modification of distribution law with respect to change in molecular state of solute (association and dissociation of solute in one of the solvent). Applications of the distribution law: Process of extraction (derivation expected). Determination of solubility of solute in particular solvent. distribution indicators. determination of molecular weight of solute in different solvents. Numerical problems.

Electromotive force: Convention: Reduction potentials to be used) Introduction. Thermodynamics of electrode potentials, Nernst equation for electrode and cell potentials in terms of activities. E.M.F. series. Types of electrodes: Description in terms of construction, representation, half cell reaction and emf equation for: Metal – metal ion electrode. Amalgam electrode. Metal – insoluble salt electrode. Gas – electrode. Oxidation – Reduction electrode.

Reversible and Irreversible cells. Chemical cells without transference. Concentration cells with and without transference. Liquid – Liquid junction potential: Origin, elimination and determination. Equilibrium constant from cell emf, Determination of the thermodynamic parameters such as ΔG, ΔH and ΔS. Applications of emf measurements: Determination of pH of solution using Hydrogen electrode. Solubility and solubility product of sparingly soluble salts (based on concentration cells). Numerical problems.

Spectroscopy and Photochemistry-

Spectroscopy: Introduction. Electromagnetic radiation. Interaction of radiation with matter, Electromagnetic spectrum, Energy level diagram. Electronic Spectra (UV-Vis), Modes of electronic transitions. Rotational spectra of diatomic molecules: Rigid rotor model, moment of inertia, energy levels of rigid rotor, selection rules, Intensity of spectral lines, determination of bond length, isotope effect, Microwave oven. Vibrational spectra of diatomic molecules: Simple Harmonic oscillator model, Vibrational energies of diatomic molecules, Determination of force constant, Hook's Law for Calculation of vibrational frequency, overtones. Raman spectra: Concept of polarizability, pure rotational and pure Vibrational Raman spectra of diatomic molecules, selection rules. Comparative study of IR and Raman spectra, rule of mutual exclusion-CO2 molecule. Magnetic Resonance (NMR and ESR). Magnetic and nonmagnetic nuclei, Chemical shift: definition, measurement, calculation, Factors affecting Chemical shift, Shielding & deshielding. Numerical problems.

Photochemistry: Introduction, Difference between thermal and photochemical processes. Laws of photochemistry: i) Grotthus - Draper law ii) Lambert law iii) Lambert – Beer's law (with derivation) iv) Stark-Einstein law. Quantum yield, Reasons for high and low quantum yield. Factors affecting Quantum yield. Photosensitized reactions – Dissociation of H_2, Photosynthesis. Photodimerisation of anthracene. Jablonski diagram depicting various processes occurring in the excited state: Qualitative description of fluorescence and phosphorescence. Chemiluminescence, Electroluminescence and Bioluminescence. Numerical problems.

Nanoscience and Technology

Phy &Chem. at Nanoscale: Physics and Chemistry at Nanoscale

Introduction to Nanoscience: Introduction to Nanoscale, Nanomaterials, Nanoscienceand Nanotechnology. Nanoscience effects: Quantum size effects, Quantum confinement effect, Bhorexciton radius, surface area to volume ratio etc. The development of nanoscale science: scaling up approach, scaling down approach, Generations of nanotechnology/ Nanotechnology Timeline: Pre-18th Century, 19th Century, 20th Century, 21st Century. Classification of nanomaterials:0D, 1D, 2D and 3D and types of nanomaterials (QDs, QW, CNT's, Bucky Balls, etc.) Nanocomposites: Types of nanocomposites and applications. **Nano and Nature:** Lycurgus Cup, stained glass windows, Damascus saber blades, Nanoscopiccolours (Butterfly wings), Bioluminescence (fireflies), Tribology, Nano tribology (Gecko's Sticky Feet, Nasturtium Leaf-Lotus effect etc.) in nature. Brief applications of nanomaterials / Consumer products: Television, Energy, Automobile, Textile, Space, Defense and Engineering etc.

Making of nanostructures: Top down: Overview of top down nanofabrication processes. Mechanical methods: Mechanical grinding (ball milling), Lithographic methods: Types of lithography techniques i.e. photolithography, electron beam lithography, X-ray lithography, Nano-imprint lithography. Thin film technologies: Thermal methods: Thermal evaporation, e-beam evaporation. Plasma methods: DC and RF Magnetron Sputtering, High-energy methods: Pulsed Laser Deposition etc. Advantages and disadvantages of Top down approaches.

Making of nanostructures: Bottom up: Overview of bottom up nanofabrication processes. Growth mechanism: nucleation and growth of nanomaterials: Ostwald Ripening, sintering. Vapor – phase synthesis: Chemical vapor deposition (CVD): Types of CVD process, Atomic Layer Deposition, Molecular beam epitaxy (MBE), Inert gas condensation, Spray Pyrolysis, Flame pyrolysis.Liquid-phase synthesis: Colloidal methods: Metal and semiconducting nanoparticles, Solution precipitation, Electrodeposition, Sol-gel technique: Introduction. Sol-gel process: synthesis of Aerogel, Xerogel, sol-gel coating processes.Hydrothermal synthesis, Dip coating, spin coating, flow coating etc.Template synthesis of nano pattering.Advantages and Disadvantages of Top down approaches.

Visualization and manipulation tools Microscopy: Basics, Working principle and applications. Optical microscopy, Scanning electron microscopy (SEM), Transmission electron microscopy (TEM). Difference between SEM and TEM. Scanning Probe Microscope (SPM) techniques: Scanning Tunneling Microscopy (STM) and Atomic force microscopy. Optical Tweezers: Basics, Working principles and applications.

Phy. & Chem. Prop. of Nanamat.: Physical and Chemical Propertiesof Nanomaterials

Physical Properties of Nanomaterials Mechanical Characterization – Plastic deformation, Toughness, Stiffness, Ductility, modulus and load carrying capability, fatigue – abrasion and wear resistance etc. Stress-Strain Curve. Hardness of nanomaterials: Nanoindentation, Nanomachines, Mechanical properties of CNT. Micro Electromechanical Systems (MEMS), Nano Electromechanical Systems (NEMS). Thermodynamics of Nanomaterials: Melting point and phase transition processes at nanoscale materials. Classical thermodynamics Vs Nano thermodynamics.

Electronic Properties of Nanomaterials Density of states of 3D, 2D, 1D and 0D dimensional nanostructures. Clusters of metals and semiconductors, nanowires. Size-induced metal insulator-transition (SIMIT). Electronic transport in 1,2 and 3 dimensions. Effective mass, Drude conduction of metals - mean free path in 3D-diffusive transport and ballistic conduction. Coulomb blockade. Single electron transistors (SET), Tunnel diodes: Esaki tunneling diode (ETD), Resonant tunneling diode (RTD). Fundamentals of electrical conductivity in carbon nanotubes. CNT based 15 transistor, electrical conductivity of nanocomposites.

Optical properties of Nanomaterials Interaction of light with matter: Absorption-Emission. Direct and indirect band gap transitions, radiative - nonradiative process, photoluminescence. Surface Plasmon: Interaction of light with metal, scattering, extinction. Difference between Surface Plasmon Resonance (SPR) and Localized Surface Plasmon Resonance (LSPR). Origin of color generation from metal nanoparticles, Size and Shape dependent optical properties of metal nanoparticles. Applications of nano plasmonics. Quantum dots (QDs): optical properties of QD nanomaterials. Size dependent band gap tuning: optical absorption and optical emission. Optical properties of core-shell nanomaterials. Optoelectronic applications of nanomaterials: detection, PV solar cells, photoelectrochemical cells, light emitting diodes etc.

Magnetic properties of nanomaterials: Origin of magnetism in materials, Classification into Dia-, Para- and Ferro- magnetic materials, Hysteresis in ferromagnetic materials, domains, soft and hard magnetic materials, Coercivity vs particle size, Single domain particles, superparamagnetism, Exchange coupling in magnetic multilayers (RKKY Coupling), Giant Magnetoresistance (GMR), Origin of GMR, Oscillatory exchange coupling, spin valve, Magnetic Tunnel Junction (MTJ),Spin Field Effect Transistor (SFET).

Nanomedicine

Introduction to Nanobiology and Nanomedicine Nanobiology – Introduction. Biological Nanostructures and natural biological assemblies at nanoscale: Bacterial S layers, phospholipid membranes, viruses, Nucleic acids, Oligosaccharides, polysaccharides, biological polymers, Proteins. Biological nanomotors, protein assemblies: Kinesin and dynein, cilia. Bacterial flagella: structure and function; nanomotor. Ion channels: nanopores of high specificity. Bioinspired nanomaterials: DNA and peptide based. Interaction between biomolecules and nanoparticle surfaces.

Synthesis of Nanomaterials and nanoformulations Characterization techniques for nanomaterials.Nanobioassemblies: Different types of inorganic materials used for thesynthesis of hybrid nano-bio Assemblies. Concept of drug andformulation/dosage form. Physicochemical and biological properties ofdrugs. Routes of dosage form administration. Formulation ofnanocrystals, nanoemulsions, polymeric micelles. Introduction toliposome and solid lipid nanoparticles (SLN). Fate of nanoformulationsin body.

Nanomedicine: Applications of nano in biology. Concept of disease, Cause and molecular/cellular progression of key diseases including infectious, 10 inherited diseases, immunological diseases and cancer. Approach to developing nanomedicines. Various kinds of nanosystems in use. Nanodrug administration nano-devices for drug delivery and theranostics. Introduction to the potentials, applications and challenges of nanomedicine. Nanomedicine and tissue engineering, nanobiomachines and nanorobots.

Environmental Nanotechnology

Water and Soil pollution: Environmental pollutants in water & soil, hazardous and toxic wastes, waste water characteristics and parameters. Traditional water Treatment, nanomaterial Contamination in Aqueous Environmental, Ground water pollution, sources, effects, control, Current Nanotechnology for water treatment: Activated Carbon-A Simple Traditional Nanotechnology, Membranes and separation Technology. The Environment (Protection) Act, 1986, The Water (Preventi on and Control of Pollution) Act, 1974

Air pollution & Nano-toxicology: Toxicity due to airborne Nanomaterials, Engineered nanomaterial's in the environment and Health Effects of Nanoparticles through Air, Absorption and pulmonary deposition of Nanoparticles, Elimination of dusts deposited in the lungs, Nanoparticles absorption mechanisms from air, Effects of ultrafine dusts. Gas Separation: Advanced Membrane Technology, Chemical Sensing and Detection. The Air (Prevention and Control of Pollution) Act, 1981

The Environmental and Applied Nano-Technology: Traditional Methods of Detecting, Environmental Contaminants, Type of Environmental Sensors, Sensing of chemical pollutants (Gas sensors: Introduction),basic sensing mechanism, application of TiO_2, Solar Energy and Nanotechnology, Important characteristics and environmental applications of Mesoporous materials

Green Nanotechnology: Definition and principles of Green Chemistry and it's significance, Biosynthesis of nanoparticles from plants, fungi & microorganisms and their application. Energy efficient resources and materials in Nanotechnology, Biological Sensors and Detectors and their applications Future aspects and importance of Nanotechnology in environmental conservation

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