SCHEDULE
STANDARD AND SYLLABUS

A paper in General English is compulsory and common for all the four categories and its standard will be such as may be expected of a science graduate. 3 compulsory papers each on Geology, Geophysics, Chemistry and Hydrogeology subjects will be approximately of the M.Sc. degree standard of an Indian University and questions will generally be set to test the candidate's grasp of the fundamentals in each subject.

There will be no practical examination in any of the subjects.

(1) GENERAL ENGLISH: 100 Marks
Candidate will be required to write a short Essay in English. Other questions will be designed to test their understanding of English and workmanlike use of words.

(2) GEOLOGY - PAPER I: 200 Marks

Section A: Geomorphology and Remote Sensing,
Introduction: Development, Scope, Geomorphic concepts, Types and Tools; Landforms: Role of Lithology, peneplaination, endogenous and exogenous forces responsible, climatic and Tectonic factors and rejuvenation of landform; Denudational processes: Weathering, erosion, transportation, weathering products and soils – profiles, types, processes; Hillslopes: Their characteristics and development, fluvial processes on hillslopes; River and drainage basin: Drainage pattern, network characteristics, Valleys and their development, processes of river erosion, transportation and deposition; Landforms produced by geomorphic agents: Fluvial, Coastal, Glacial and Aeolian landforms; Geomorphic indicators of neotectonic movements: Stream channel morphology changes, drainage modifications, fault reactivation, Uplift –subsidence pattern in coastal areas; Applied Geomorphology: Application in various fields of earth sciences viz. Mineral prospecting, Geohydrology, Civil Engineering and Environmental studies; Geomorphology of India: Geomorphical features and zones
Electromagnetic radiation – characteristics, remote sensing regions and bands; General orbital and sensor characteristics of remote sensing satellites; Spectra of common natural objects – soil, rock, water and vegetation. Aerial photos – types, scale, resolution, properties of aerial photos, stereoscopic parallax, relief displacement; Principles of photogrammetry; Digital image processing – characteristics of remote sensing data, preprocessing, enhancements, classification; Elements of photo and imagery pattern and interpretation, application in Geology; Remote sensing applications in interpreting structure and tectonics, Lithological mapping, mineral resources, natural hazards and disaster mitigation, groundwater potentials and environmental monitoring. Landsat, Skylab, Seasat and other foreign systems of satellites and their interpretation for geological and other studies; Space research in India – Bhaskara and IRS systems and their applications, Thermal IR remote sensing and its applications, Microwave remote sensing and its applications. Principles and components of Geographic Information System (GIS), remote sensing data integration with GIS, applications of GIS in various geological studies.

Section B: Structural Geology

Section C: Geodynamics

Section D: Stratigraphy


Section E: Palaeontology

Evolution of the fossil record and the geological time scale. Basic and functional morphology of major fossil groups. Species concept; Major evolutionary theories. Techniques in Palaeontology: mega fossils-microfossils – nannofossils, ichnofossils, collection, identification and illustration – binomial Nomenclature; Invertebrate Palaeontology – A brief study of morphology, classification, evolutionary trends and distribution of Bivalves, cephalopoda and Gastropods, Echinoids, Corals and Brachiopods. Vertebrate Palaeontology – Brief study of vertebrate life through ages. Evolution of reptiles and mammals; Siwalik vertebrate fauna; Biodiversity and mass extinction events; evidence of life in Precambrian times; Palaeontological perspective: Use of palaeontological data in a) Stratigraphy b) Palaeoecology and evolution; Introduction to Micropalaeontology; Types of Microfossils; Plant fossils: Gondwana flora and their significance. Different microfossil groups and their distribution in India; Application of palynology. Basic idea about statistical application in palaeontology. Fundamentals of isotopic studies of fossils.

GEOLOGY – PAPER II: 200 Marks

Section A: Mineralogy and Geochemistry & Isotope Geology


**Section B : Igneous Petrology**


Petrogenetic provinces : Continental areas: Volcanic-Flood basalts-Tholeiites (Deccan Trap, Columbia River basalts); Layered gabbroic intrusions: The Bushveld complex, Skaergaard intrusion, Still water complex. Plutonic: Carbonatites and alkaline rock complexes of India; Oceanic Rift valleys: MORB-Tholeiites-Ophiolites

**Section C : Metamorphic Petrology & Processes**

Concepts and Theory: Types of Metamorphism and their controlling factors; Common minerals of metamorphic rocks; Field observations, petrographic classification of common metamorphic rocks; Metamorphic facies and facies series. Effects of Metamorphism : Phase diagrams and graphic representation of mineral assemblages; Prograde and retrograde metamorphism, Metasomatism; Deformation textures and textures related to recrystallization; Metamorphic reactions, elemental exchange and Pressure – Temperature conditions; *Isograds*: Mineral assemblages equilibrium reaction textures and geo-thermo barometry. Experimental and thermodynamic appraisal of metamorphic reactions; Role of fluids in metamorphic reactions. Metamorphism types and products: Regional and thermal metamorphism of pelitic rocks. Regional and thermal metamorphism of basic and ultrabasic rocks; Regional and thermal metamorphism of impure, silicic carbonate rocks; Metamorphism of Granitoides, Charnockites and Migmatites. Metamorphism in space and time: Plate tectonics and metamorphic processes; Paired metamorphic belts, Archaean and Proterozoic terrains; Extraterrestrial Metamorphism (Impact and Shock Metamorphism); polymetamorphism

**Section D : Sedimentology**


**Section E : Environmental Geology and Natural Hazards**


**GEOLOGY – PAPER III : 200 MARKS**

**Section A: Indian mineral deposits and mineral economics**


**Section B: Ore genesis and Geophysics**


**Section C: Mineral exploration**


**Section D: Geology of fuels**


distributions of onshore and offshore petroliferous basins of India.

Section E: Engineering Geology
Geological studies and evaluation in planning, design and construction of major civil structures.

(2) GEOPHYSICS - PAPER I: 200 Marks
PART-A: 100 Marks

a. Solid Earth Geophysics:

b. Earthquake and Engineering Seismology:
Seismology, earthquakes, focal depth, epicenter, great Indian earthquakes, Intensity and Magnitude scales, Energy of earthquakes, foreshocks, aftershocks, Elastic rebound theory, Fault plane solutions, Seismicity and Seismotectonics of India, Frequency-Magnitude relation (b values), Velocity structure, VpNs studies. Elastic waves, their propagation characteristics. Seismic ray theory for sphere, vertically and horizontally stratified earth, basic principles of Seismic Tomography and receiver function analysis, seismic network and arrays, telemetry systems, Earthquake prediction; dilatancy theory, short-term, middle-term and long-term predictions, Seismic microzonation studies, application for engineering problems, Seismometry, Principle of electromagnetic seismograph, displacement meters, velocity meter, accelerometer, WWSSN stations, Strong motion seismograph, seismic arrays for detection of nuclear explosions, Broadband seismometry.

c. Mathematical methods in Geophysics:

d. Geophysical Inversion:

PART-B: 100 Marks

a. **Mathematical Methods of Physics:**

**Thermodynamics and Statistical Physics:**
Laws of thermodynamics and their consequences; Thermodynamic potentials, Maxwell relations; Chemical potential, phase equilibria; Phase space, micro- and macrostates; Micro canonical, canonical and grand-canonical ensembles and partition functions; Free Energy and connection with thermodynamic quantities; First- and second-order phase transitions; Classical and quantum statistics, ideal Fermi and Bose gases; Principle of detailed balance; Blackbody radiation and Planck's distribution law; Bose-Einstein condensation; Random walk and Brownian motion; Introduction to nonequilibrium processes; Diffusion equation.

b. **Electrodynamics:**
Gauss Theorem, Poisson's equation, Laplace's equation, solution to Laplace's equation in Cartesian coordinates, spherical, cylindrical coordinates, use of Laplace's equation in the solutions of electrostatic problems. Ampere's circuital law, magnetic vector potential, displacement current, Faraday's law of electromagnetic induction. Maxwell's equations, differential and integral forms, physical significance of Maxwell's equations. Wave equation, plane electromagnetic waves in free space, in non conducting isotropic medium, in conducting medium, electromagnetic vector an scalar uniqueness of electromagnetic potentials and concept of gauge, Lorentz gauge, Coulomb gauge, charged particles in electric and magnetic fields, charged particles in uniform electric field, charged particle in homogeneous magnetic fields, charged particles in simultaneous electric and magnetic fields, charged particles in non homogeneous magnetic fields. Lienard - Wiechert potentials, electromagnetic fields from Lienard - Wiechert potentials of a moving charge, electromagnetic fields of a uniformly moving charge, radiation due to non-relativistic charges, radiation damping, Abraham-Lorentz formula, Cherenkov radiation, radiation due to oscillatory electric dipole, radiation due to small current element. Condition for plasma existence, occurrence of plasma, magneto hydrodynamics, plasma waves. Transformation of electromagnetic potentials, Lorentz condition in covariant form, invariance or covariance of Maxwell field equations in terms of 4 vectors, electromagnetic field tensor, Lorentz transformation of electric and magnetic fields.

c. **Introductory Atmospheric and Space Physics:**
The Neutral atmosphere, atmospheric nomenclature, the Hydrostatic equation, geopotential height, expansion and contraction, fundamental forces in the atmosphere, apparent forces, atmospheric composition, solar radiation interaction with the neutral atmosphere, climate change. Electromagnetic radiation and propagation of Waves: EM Radiation, fundamentals of EM waves, effects of environment, Antennas-basic considerations, types of antennas. Propagation of Waves: ground wave, sky wave, and space wave propagation, troposcatter communication and extra terrestrial communication. The Ionosphere, morphology of ionosphere, the D, E and F-regions, chemistry of the ionosphere, ionospheric parameters, E and F region anomalies and irregularities in the ionosphere. Global Positioning Systems (GPS)-basic concepts, overview of GPS system, augmentation services, GPS system segment, GPS signal characteristics, GPS errors, multi path effects, GPS performance, satellite navigation system and applications.

(3) **GEOPHYSICS - PAPER II : 200 Marks**

PART-A: 100 Marks

a. **Geophysical Potential Fields (Gravity and Magnetic)***
Geophysical potential fields, Inverse square law of field, Principles of Gravity and Magnetic methods, Geoid, Spheroid, Nature of gravity and its variation, Properties of Newtonian potential, Laplace's and Poissons equations, Green's theorem, Gauss law, Concept of Bouguer gravity anomaly, Rock densities, factors controlling rock densities,
determination of density, theory of isostasy, Earth's main magnetic field, origin, temporal variations, Geomagnetic elements, Columb's law of magnetic force and fields, intensity of magnetization and induction, magnetic potential and its relation to field, units of measurement, origin of magnetic anomalies, interrelationship between different components of anomalies, Poison's relation, Magnetic susceptibility, factors controlling susceptibility (Bulk chemistry, cooling history, metamorphism...), magnetic minerals, rock classification, Natural and remnant magnetism, Asiatic and Spinner magnetometers, demagnetization effects. Principles of Gravity and Magnetic instruments, Plan of conducting GM surveys, reduction of gravity and magnetic data, Airborne magnetic surveys and magnetic gradient surveys, Shipborne surveys, Gravity and Magnetic data reduction, IGSN Gravity bases, International Gravity formula, IGRF corrections for magnetic field. Separation of regional and residual anomalies, ambiguity in interpretation, Application of GM surveys for Geodynamic studies, Mineral Exploration, Environmentalstudies...Data processingand interpretation of anomalies, modeling anomalies.

b. Electrical and Electromagnetic methods:
Electrical properties of rocks and their measurement, concepts and assumptions of horizontally stratified earth, anisotropy and its effects on electrical fields, the geologic section and geological section, D.0 Resistivity method, fundamental laws, concept on natural electric field, electrode configuration, choice of methods, Profiling, Vertical Electrical Sounding, SP Method, Origin of SP, application of SP surveys, Origin of Induced Polarization, Membrane and Electrode potential, time and frequency domains of measurement, IP, chargeability, percent frequency effect and metal factor, dipole theory of IP, Application of IP surveys for mineral exploration (dis emanated sulphides). Electromagnetic methods/ Telluric/Magneto Telluric methods, Passive and Active source methods, Maxwell's equations, electromagnetic potential and wave equations, boundary conditions, long wave length approximation, depth of penetration, amplitude and phase relations, real and imaginary components, Principles of EM prospecting, various EM methods, Dip angle method, Turam method, moving source-receiver methods - horizontal loop (Slingram) method, AFMAG, and VLF methods, Airborne EM systems - rotary field method, INPUT method, EM Profiling and sounding, Interpretation of EM anomalies, Principles of Ground Penetrating Radar (GPR), Origin and characteristics of MT methods, Instrumentation, Field methods and interpretation of MT data and applications.

c. Seismic Prospecting:
Basic principles of seismic methods, Fermat's principle, Snell's law, Reflection, refraction and diffraction from multilayered medium, Reflection and transmission coefficients, propagation model for exploration seismology, Seismic resolution, Seismic absorption and anisotropy, Seismic data acquisition, sources of energy, Geophones, geometry of arrays, Instrumentation, digital recording Seismic Surveys: Principle for multilayer refraction Travel time curves, corrections, Interpretation of data, Reflection principles, CDP, data processing, corrections, NMO correction, Interpretation of data, Fundamental of VSP method, Seismic Tomography. Principles of High Resolution Seismic (HRS) for coal exploration.

d. Borehole Geophysics (Principles of Well logging):
Objectives of well logging, fundamental concepts in borehole geophysics, borehole conditions, properties of reservoir rock formations, formation parameters and their relationships-formation factor, porosity, permeability, formation water resistivity, water saturation, irreducible water saturation, hydrocarbon saturation, residual hydrocarbon saturation; Archie's and Humble's equations; principles, instrumentation, operational procedures and interpretations of various geophysical logs, SP log, resistivity and micro resistivity logs, nuclear/radioactive logs, acoustic impedance and propagation logs, temperature log, caliper log and directional logs; production logging; clean sand and shaly sand interpretations; overlay and cross-plots of well-log data, determination of formation lithology, subsurface correlation and mapping, delineation of fractures; application of well-logging in hydrocarbon, groundwater, coal, metallic and non-metallic mineral exploration.

PART-B: 100 Marks

a. Atomic and Molecular Physics and Properties and Characterization of materials:
Quantum states of an electron in an atom; Electron spin; Stern-Gerlach experiment; Spectrum of Hydrogen, helium and alkali atoms; Relativistic corrections for energy levels of hydrogen; Hyperfine structure and isotopic shift; width of spectral lines; LS & J coupling Zeeman, Paschen Back & Stark effect; X-rayspectroscopy; Electronspresonance, Nuclear magnetic resonance, chemical shift; Rotational, vibrational, electronic, and Raman spectra of diatomic molecules; Frank - Condon principle and selection rules; Spontaneous and stimulated emission, Einstein A & B coefficients; Lasers, optical pumping, population inversion, rate equation; Modes of resonators and coherence length. Thermal properties, optical properties, fundamentals of transmission electron microscopy, study of crystal structure using TEM, study of microstructure using SEM. Resonance methods- Spin and an applied field- the nature of spinning particles, interaction between spin and a magnetic field, population on energy levels, the Larmor precession, relaxation times - spin-spin relation, spin-lattice relaxation, Electron spin resonance- Introduction, g factor, experimental methods, Nuclear Magnetic resonance- equations of motion, line width motional narrowing.
b. Nuclear and Particle Physics:
Basic nuclear properties: size, shape, charge distribution, spin and parity; Binding energy, semi-empirical mass formula; Liquid drop model; Fission and fusion; Nature of the nuclear force, form of nucleon-nucleon potential; Charge-independence and charge-symmetry of nuclear forces; Isospin; Deuteron problem; Evidence of shell structure, single-particle shell model, its validity and limitations; Rotational spectra; Elementary ideas of alpha, beta and gamma decays and their selection rules; Nuclear reactions, reaction mechanisms, compound nuclei and direct reactions; Classification of fundamental forces; Elementary particles (quarks, baryons, mesons, leptons); Spin and parity assignments, isospin, strangeness; Gell-Mann-Nishijima formula; C, P, and T invariance and applications of symmetry arguments to particle reactions, parity-nonconservation in weak interaction; Relativistic kinematics Crystalline and amorphous structure of matter; Different crystal systems; space groups; methods of determination of crystal structure; X-ray diffraction; scanning and transmission electron microscopes; Band theory of solids—conductors, insulators and semiconductors; Thermal properties of solids, specific heat; Debye theory; Magnetism: dia, para and ferromagnetism; elements of superconductivity; Meissner effect, Josephson junctions and applications; elementary ideas about high temperature superconductivity.

c. Electromagnetic Theory:
Electrostatics: Gauss' Law and its applications; Laplace and Poisson equations, boundary value problems; Magnetostatics: Biot-Savart law, Ampere's theorem, electromagnetic induction; Maxwell's equations in free space and linear isotropic media; boundary conditions on fields at interfaces; Scalar and vector potentials; Gauge invariance; Electromagnetic waves in free space, dielectrics, and conductors; Reflection and refraction, polarization, Fresnel's Law, interference, coherence, and diffraction; Dispersion relations in plasma; Lorentz invariance of Maxwell's equations; Transmission lines and wave guides; Dynamics of charged particles in static and uniform electromagnetic fields; Radiation from moving charges, dipoles and retarded potentials

d. Classical Mechanics:
Newton's laws; Phase space dynamics, stability analysis; Central-force motion; Two-body collisions, scattering in laboratory and centre-of-mass frames; Rigid body dynamics, moment of inertia tensor; non-inertial frames and pseudoforces; Variational principle, Lagrangian and Hamiltonian formalisms and equations of motion; Poisson brackets and canonical transformations; Symmetry, invariance and conservation laws, cyclic coordinates; Periodic motion, small oscillations and normal modes; Special theory of relativity, Lorentz transformations, relativistic kinematics and mass-energy equivalence.

(4) GEOPHYSICS - PAPER III : 200 Marks

a. Radiometric Exploration / Airborne Geophysical surveys for Geological Mapping:
Principles of radioactivity; radioactivity decay processes, units, radioactivity of rocks and minerals, Instruments, Ionisation chamber, G-M counter, Scintillation meter, Gamma ray spectrometer, Radiometric prospecting for mineral exploration (Direct/Indirect applications). Radiometric prospecting for beach placers; titanium, zirconium and rare-earths, portable gamma ray spectrometry and radon studies in seismology, environmental Applications, logging methods, radiometric dating techniques. Airborne geophysical surveys, planning of surveys, sensors, data corrections, flight path recovery methods, applications in geological mapping, interpretation of maps, identification of structural features, altered zones.

b. Marine Geophysics:

c. Geophysical Signal Processing:
for gravity and magnetic maps; regional residual separation, continuations, evaluation of derivatives, pseudo gravity transformations, reduction to poles and equator, Improvement of signal to noise ratio, source and geophone arrays as spatial filters. Earth as low pass filter.

d. Remote Sensing and GIS applications:
Fundamental concepts of remote sensing, electromagnetic radiation spectrum, energy-frequency-wavelength relationship, Boltzman Law, Wien Law, electromagnetic energy and its interactions in the atmosphere and with terrain features; elements of photograhic systems, reflectance and emittance, false color composites, remote sensing platforms, flight planning, geosynchronous and sun synchronous orbits, sensors, resolution, parallax and vertical exaggeration, relief displacement, mosaic, aerial photo interpretation and geological application. Fundamentals of photogrammetry, satellite remote sensing, multi-spectral scanners, thermal scanners, microwave remote sensing, fundamental of image processing and interpretation for geological applications. Introduction to Geographic Information Systems (GIS) spatial data structures, visualization and querying, spatial data analysis.

PART-B: 100 Marks

a. Solid State Physics:
Crystalline and amorphous structure of matter; Different crystal systems, space groups; methods of determination of crystal structure; X-ray diffraction, scanning and transmission electron microscopes; Band theory of solids-conductors, insulators and semiconductors; Thermal properties of solids, specific heat; Debye theory; Magnetism: dia, para and ferromagnetism; elements of superconductivity; Meissner effect, Josephson junctions and applications; elementary ideas about high temperature superconductivity.


d. Electronics and devices:
Semiconductor devices (diodes, junctions, transistors, field effect devices, homo and hetero junction devices) device structure, device characteristics, frequency dependence and applications. Opto-electronic devices (solar cells, photo detectors, LEDs) Operational amplifiers and their applications. Digital techniques and applications (reg-isters, counters, comparators and similar circuits). A/D and D/A converters. Microprocessor and microcontroller basics. Data interpretation and analysis. Precision and accuracy. Error analysis, propagation of errors. Least square fitting. Intrinsic extrinsic semiconductors, pn-p and n-p-n transistors; Amplifiers and oscillators; Op-amps; FET, JFET and MOSFET; Digital electronics-Boolean identities, De morgan’s laws, logic gates and truth tables; simple logic circuits; thermistors, solar cells, fundamentals of microprocessors and digital computers.

e. Digital electronics, Radar systems, Satellite communications:
Digital circuits, Number systems and codes, Combination logic circuits, sequential logic circuits, microprocessor architecture, functional diagram, Pin description, Timing diagram of read cycle, timing diagram of write cycle. Data transfer techniques-Serial transfer, parallel transfer etc. Radar systems, signal and data processing satellite communication-Fundamentals Designing a surveillance radar, tracking radar, signal and data processing, radar antenna parameters, satellites systems-communication satellite systems, communication satellites, orbiting satellites, satellite frequency bands, satellite orbit and inclinations. Multiple access techniques, earth station technology.

f. Quantum Mechanics:
Wave-particle duality; Wave functions in coordinate and momentum representations; Commutators and Heisenberg’s uncertainty principle; Matrix representation; Dirac’s bra and ket notation; Schroedinger equation (time-dependent and time-independent); Eigen value problems such as particle-in-a-box, harmonic oscillator, etc.; Tunneling through a barrier; Motion in a central potential; Orbital angular momentum, Angular momentum algebra, spin; Addition of angular momentum; Hydrogen atom, spin-orbit coupling, fine structure; Time-independent perturbation theory and applications; Variational method; WKB approximation; Time dependent perturbation theory and Fermi’s Golden Rule; Selection rules. Semi-classical theory of radiation; Elementary theory of scattering phase shifts, partial waves, Born approximation; Identical particles, Pauli’s exclusion principle, spin- statistics connection; Relativistic quantum mechanics: Klein Gordon and Dirac equations.

(2) CHEMISTRY PAPER-I (Inorganic Chemistry): 200 Marks

Chemical periodicity:
Periodic table, group trends and periodic trends in physical properties. Classification of elements on the basis of electronic configuration. Modern IUPAC Periodic table. General characteristic of s, p, d and f block elements. Effective nuclear charges, screening effects, atomic radii, ionic radii, covalent radii. Ionization potential, electron affinity and electronegativity. Group trends and periodic trends in these properties in respect of s-, p- and d-block elements. General trends of variation of electronic configuration, elemental forms, metallic nature, magnetic properties, catenation and catalytic properties, oxidation states, aequous and redox chemistry in common oxidation states, properties and reactions of important compounds such as hydrides, halides, oxides, oxo-acids, complex chemistry in order of s-block and p-block elements.

Chemical Bonding and structure:

Chemistry of coordination compounds:
Isomerism, reactivity and stability: Determination of configuration of cis- and trans- isomers by chemical methods. Labile and inert complexes, substitution reaction on square planer complexes, trans effect. Stability constants of coordination compounds and their importance in inorganic analysis. Structure and bonding: Elementary Crystal Field Theory: splitting of d configurations in octahedral, square planar and tetrahedral fields, crystal field stabilization energy; pairing energy; Jahn- Teller distortion. Metal-ligand bonding, sigma and pi bonding in octahedral complexes and their effects on the oxidation states of transitional metals. Orbital and spin magnetic moments, spin only moments of and their correlation with effective magnetic moments, d-d transitions; LS coupling, spectroscopic ground states, selection rules for electronic spectral transitions; spectrochemical series of ligands; charge transfer spectra.

Acid-Base reactions

Precipitation and Redox Reactions:

Organo metallic compounds:
18-electron rule and its applications to carbynls, nitrosyls, cyanides, and nature of bonding involved therein. Simple examples of metal-metal bonded compounds and metal clusters. Metal-olefin complexes: zeises salt, Ferrocene.

Nuclear chemistry:

s-Block Elements:
Hydride, hydration energies, solvation and complexation tendencies of alkali and alkaline-earth metals, principle of metallurgical extraction, Chemistry of Li and Be, their anomalous behaviour and diagonal relationships, alkyls and aryls.

p-Block Elements:
Comparative study of group 13 & 14 elements with respect to periodic properties. Compounds such as hydrides, halides, oxides and oxyacids; diagonal relationship; preparation, properties, bonding and structure of diborane,
borazine and alkalimetal borohydrides. Preparation, properties and technical applications of carbides and fluorocarbons. Silicones and structural principles of silicates.

**Chemistry of d- and f- block elements:**
General comparison of 3d, 4d and 5d elements in term of electronic configuration, elemental forms, metallic nature, atomization energy, oxidation states, redox properties, coordination chemistry, spectral and magnetic properties. f-block elements: electronic configuration, ionization energies, oxidation states, variation in atomic and ionic (3+) radii, magnetic and spectral properties of lanthanides, comparison between lanthanide and actinides, separation of lanthanides (by ion-exchange method). Chemistry of some representative compounds: K2Cr2O7, KMnO4, K4[Fe(CN)6], K2[Ni(CN)4], H2PtCl6, Na2[Fe(CN)5NO].

(3) CHEMISTRY PAPER-II (Physical Chemistry): 200

**Kinetic theory and the gaseous state:**
Gaseous state: Gas laws, kinetic theory of gas, collision and gas pressure, derivation of gas laws from kinetic theory, average kinetic energy of translation, Boltzmann constant and absolute scale of temperature. Maxwell’s distribution of speeds. Kinetic energy distribution, calculations of average, root mean square and most probable velocities. Principle of equipartition and its application to calculate the classical limit of molar heat capacity of gases.

**Collision of gas molecules, Real gases:**
Collision diameter; collision number and mean free path; frequency of binary collisions; wall-collision and rate of effusion. Real gases, Deviation of gases from ideal behaviour; compressibility factor; Andrew’s and Amagot’s plots; van der Waals equation and its characteristic features. Existence of critical state. Critical constants in terms of van der Waals constants. Law of corresponding state and significance of second virial coefficient. Boyle temperature. Intermolecular forces.

**Liquid state:** physical properties of liquids and the measurements: surface tension and viscosity

**Solids:** Nature of solid state, law of constancy of angles, concept of unit cell, different crystal system, Bravais lattices, law of rational indices, Miller indices, symmetry elements in crystals. X-ray diffraction, Bragg’s law, Laue’s method, powder method, radial ratio and packing in crystals.

**Thermodynamics:**

**Application of Second law of thermodynamics:**
Carnot cycle and its efficiency, Gibbs function (G) and Helmholtz function (A), Gibbs-Helmholtz equation, criteria for thermodynamic equilibrium and spontaneity of a process. Chemical equilibrium: chemical equilibria of homogeneous and heterogeneous systems; derivation of expression of equilibrium constants, Le Chatelier’s principle of dynamic equilibrium.

**Thermodynamics and Equilibrium:**
Chemical potential in terms of free energy and other thermodynamic state functions and its variation with temperature and pressure. Gibbs-Duhem equation; fugacity of gases and fugacity coefficient. Thermodynamic conditions for equilibrium, degree of advancement. Van’t Hoff’s reaction isotherm. Equilibrium constant and standard Gibbs free energy change. Definitions of KP, KC and Ks; van’t Hoff’s reaction isobar and isochore. Le Chatelier’s principle. Activity and activity coefficients of electrolyte/ion in solution. Debye-Huckel limiting law.

**Acids-bases and solvents:**
Modern aspects of acids and bases: Arrhenius theory, theory of solvent system, Bronsted and Lowry’s concept, Lewis concept with typical examples, applications and limitations. Strengths of acids and bases. Ionization of weak acids and bases in aqueous solutions. Application of Ostwald’s dilution law, ionization constants, ionic product of water, pH-scale, buffers and solutions and their pH values, buffer actions & buffer capacities; hydrolysis of salts.

**Solutions of non-electrolytes:** Colligative properties of solution, Raoult’s Law, relative lowering of vapor pressure, osmosis and osmotic pressure; elevation of boiling point and depression of freezing point of solvents.

**Chemical kinetics and catalysis:**
Order and molecularity of reactions, rate laws and rate equations for first order and second order reactions; zero order reactions. Parallel and consecutive reactions. Determination of order of reactions. Temperature dependence of reaction rate, energy of activation. Enthalpy of activation, entropy of activation, effect of dielectric constant and ionic strength of reaction rate, kinetic isotope effect; collision theory & transition State Theory of reaction rate, Catalytic reactions.

**Adsorption and Surface Chemistry:**
Physisorption & Chemisorption, adsorption isotherms, Freundlich and Langmuir adsorption isotherm, BET equation, surface area determination, heterogeneous catalysis; colloids, electrical double layer and colloid stability, electro-kinetic phenomenon; elementary ideas about soaps & detergents, micelles, emulsions.

**Electrochemistry:**

**Photochemistry:**

**Quantum Chemistry:**

**Basic principles and application of spectroscopy:**

**UV Spectra:** Electronic transition (a-a*, n-u*, IT-1T* and n-n*), relative positions of Amax considering conjugative effect, steric effect, solvent effect, red shift (bathochromic shift), blue shift (hypsochromic shift), hyperchromic effect, hypochromic effect (typical examples). IR Spectra: Modes of molecular vibrations; application of Hook's law, characteristic stretching frequencies of O-H, N-H, C=H, C-D, C≡C=C≡C=N, C=O functions; factors effecting stretching frequencies

**PMR Spectra:** Nuclear spin, NMR active nuclei, principle of proton magnetic resonance, equivalent and non-equivalent protons, chemical shift (?), shielding / deshielding of protons, up-field and down-field shifts NMR peak area, diamagnetic anisotropy, relative peak positions of different kinds of protons, substituted benzenes.

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(4) CHEMISTRY PAPER-III: 200 Marks

**PART-A (Analytical Chemistry): 100 Marks**

**Theoretical basis of Quantitative inorganic analysis:**
Law of mass action, chemical and ionic equilibrium, solubility, Solubility product and common ion effect, effect of temperature upon the solubility of precipitates, the ionic product of water, pH, effect of temperature on pH, Salt hydrolysis, hydrolysis constant, degree of hydrolysis, buffer solutions, different types of buffers and Henderson's equation.

**Gravimetric Analysis:**
General principles, stoichiometry, calculation of results from gravimetric data. Properties of precipitates. Nucleation and crystal growth, factors influencing completion of precipitation. Co-precipitation and post-precipitation, purification and washing of precipitates. Precipitation from homogeneous solution, a few common gravimetric determinations-chloride as silver chloride, sulphate as barium sulphate, aluminium as the oxinate and nickelas dimethyl glyoximate.

**Sampling and treatment of samples for chemical analysis:**
Techniques of collection of solids, liquids and gaseous samples, dissolution of solid samples, attack with water, acids, and alkalis, fusion with Na2O3, NaOH, Na2O2, K2S2O7; Microwave assisted digestion techniques (Only elementary idea)

**Volumetric Analysis:**
Equivalent weights, different types of solutions, Normal solutions, Molar solutions, and molal solutions and their inter relations. Primary and secondary standard substances: principles of different type of titrations - i) acid-base titration, ii) redox titration, iii) complexometric titrations. Types of indicators - i) acid-base, ii) redox iii) metal-ion indicators. Principles in estimation of mixtures of NaHCO3 and Na2CO3 (by acidimetry); Principles of estimation of iron, copper, manganese, chromium(by redox titration);

**Acid base titrations**: Principles of titrimetric analysis, titration curves for strong acid-strong base, weak acid-strong base and weak base-strong acid titrations, poly protic acids, poly equivalent bases, determining the equivalence point-theory of acid base indicators, colour change range of indicator, selection of proper indicator.

**Redox Titrations**: Principles behind the iodometry, permangemetry, dichrometry, difference between iodometry and iodimetry.


**Complexometric titrations**: Complex formation reactions, stability of complexes, stepwise formation constants, chelating agents, EDTA-acidic properties, complexes with metal ions, equilibrium calculations involving EDTA, conditional formation constants, derivation of EDTA titration curves, effect of other complexing agents, factors affecting the shape of titration curves-completeness of reaction, indicators for EDTA titrations-theory of common indicators, titration methods employing EDTA-direct, back and displacement titrations, indirect determinations, titration of mixtures, selectivity, masking and de-masking agents, typical applications of EDTA titrations-hardness of water, magnesium and aluminium in antacids, magnesium, manganese and zinc in a mixture, titrations involving undentate ligands-titration of chloride with Hg2+ and cyanide with Ag+.

**Chromatographic methods of analysis**: Basic principles and classification of chromatography. Importance of column chromatography and thin layer chromatography; Theory and principles of High Performance Liquid Chromatography (HPLC) and Gas Liquid Chromatography(GLC). Ion-exchange chromatography.


**Flame photometry and Atomic absorption spectrometry**: Emission spectra Vs absorption spectra. Basic Principles and theory of flame photometry. Applications of Flame photometers. Basic Principles and theory of AAS. Three different modes of AAS - Flame-MS, VGAAS, and GFAAS. Single beam and double beam AAS. Function of Halo Cathode Lamp (HCL) and Electrode Discharge Lamp (EDL). Different types of detectors used in MS. Different types of interferences-Matrix interferences, chemical interferences, Spectral interferences and background correction in AAS. Use of organic solvents. Quantitative techniques-calibration curve procedure and the standard addition technique. Typical commercial instruments for FP and MS. Applications. Qualitative and qualitative analysis. Relative detection abilities of atomic absorption and flame emissionspectrometry.

**X-ray methods of Analysis**: Introduction, theory of X-ray generation, X-ray spectroscopy, X-ray diffraction and X-ray fluorescence methods, Brags law, instrumentation, dispersion by crystals, applications. Preparation of pallets, glass beads, quantitative and qualitative measurement.

**Inductively coupled plasma spectroscopy**: Theory and Principles, plasma generation, utility of peristaltic pump, sampler - skimmer systems, ion lens, quadrupole mass analyzer, dynode / solid state Detector, different type of interferences- spectroscopic and non-spectroscopic interferences, isobaric and molecular interferences, applications.

Analysis of Metal and Alloys: (i) Cu and Zn in Brass (ii) Cu, Zn, Fe, Mn, Al and Ni in Bronze (iii) Cr, Mn, Ni, and P in Steel (iv) Pb, Sb, Sn in type metal.

**Analysis of petroleum and petroleum products**: Introduction, constituents and petroleum fractionation. Analysis of petroleum products-specific gravity, viscosity, Doctor test, aniline point, colour determination, cloud point, pour point Determination of water, neutralization value (acid and base numbers), ash content, Determination of lead in petroleum.
Analysis of coal and coke-Types, composition, preparation of sample, proximate and ultimate analysis calorific value by bomb Calorimetry.

**PART-B (Organic Chemistry): 100 Marks**

**Basic organic chemistry:**
Inductive effect, resonance and resonance energy. Homolytic and heterolytic bond breaking, electrophiles and nucleophiles; carbocations, carbanions and radicals (stability and reactivity). Alkanes, alkenes and alkynes: Synthesis and chemical reactivity of alkanes, mechanism of free-radical halogenation of alkanes. General methods of synthesis, electrophilic addition reactions and polymerization reaction (definition and examples only) of alkenes. General methods of synthesis, acidity, hydration and substitution reactions of alkynes.

**Organometallic compounds:**

**Bonding and physical properties:**

**Aldol and related reactions:**
Keto-enol tautomerism, mechanism and synthetic applications of aldol condensations, Claisen reaction, Schmidt reaction, Perkin reaction, Knovenagel, benzoin, Cannizaro reaction, Michael addition. Aromatic substitution reactions - electrophilic, nucleophilic and through benzenes - radical substitution of arenes - orientation of nucleophilic substitution at a saturated, carbon, SN1, SN2, SNi reactions - effect of structure, nucleophile, leaving group, solvent. Additions involving electrophiles, nucleophiles and free radicals.

**Mechanism of some name reactions:**
Aldol, Perkin, Benzoin, Cannizaro, Wittig, Grignard, Reformatsky, Hoffmann, Claisen and Favorsky rearrangements. Openauer oxidation, clemmensen reduction, Meerwein - Pondorf and Verley and Birch reductions. Storkenamine reactions, Michael addition, Mannich reaction, Diels - Alder reaction.

**Electrocyclic Reactions:**
Molecular orbital symmetry, frontier orbitals of ethylene, 1,3 Butadiene, 1,3,5- Hexatriene, allyl system, classification of pericyclic reactions FMO approach, Woodward- Hoffmann correlation diagram method and perturbation of molecular (PMO) approach for the explanation of pericyclic reactions under thermal and photochemical conditions. Conrotatory and disrotatory motions (4n) and (4n+2).

**Organic Reaction Mechanisms:**
Addition Elimination Mechanisms: (a) Addition to carbon multiple bonds- hydrogenation of double and triple bonds, hydroboration, birch reduction, Michael reaction, addition of oxygen and N, (b) Addition to carbon-hetero atom multiple bonds: Mannich reaction, Reductions of Carbonyl compounds, acids, esters, nitrites, addition of Grignard reagents, Reformatsky reaction, Tollen’s reaction, Wittig reaction: (c) Elimination reactions: Stereochemistry of eliminations in acyclic and cyclic systems, orientation in eliminations - Saytzeff and Hoffman elimination.

**Organic Spectroscopy:**
Infrared spectroscopy: Units of frequency wavelength and wave number, molecular vibrations, factors influencing vibrational frequencies, the IR spectrometer, characteristic frequencies of organic molecules and interpretation of spectra. Ultraviolet spectroscopy: Introduction, absorption laws, measurement of the spectrum, chromophores, definitions, applications of UV spectroscopy to Conjugated dines, trienes, unsaturated carbonyl compounds and aromatic compounds. Nuclear Magnetic Resonance Spectroscopy: (Proton and Carbon -13 NMR) The measurement of spectra, the chemical shift: the intensity of NMR signals and integration factors affecting the chemical shifts: spin-spin coupling to 13C IH-IH first order coupling: some simple IH-IH splitting patterns: the magnitude of IH-IH coupling constants.
Mass spectroscopy: Basic Principles: instrumentation; the mass spectrometer, isotope abundances; the molecular ion, meta stable ions.

(4) HYDROGEOLOGY 200 Marks

**Section A: Origin, occurrence and distribution of water.**
Water on earth; Types of water — meteoric, juvenile, magmatic and sea water; Hydrological Cycle and its components; Water balance; Water-bearing properties of rocks — porosity, permeability, specific yield and specific retention; Vertical distribution of water; Zone of aeration and zone of saturation; Classification of rocks according to their water-bearing properties; Aquifers; Classification of aquifers; Concepts of drainage basins and groundwater basins; Aquifer parameters - transmissivity and storage coefficient; Water table and piezometric surface; Fluctuations of water table and piezometric surface; Barometric and tidal efficiencies; Water table contour maps; Hydrographs; Springs; Geologic and geomorphic controls on groundwater; Hydrostratigraphic units; Groundwater provinces of India. Hydrogeology of arid zones of India; Hydrogeology of wet lands.

**Section B: Groundwater Hydraulics**

Theory of groundwater flow; Darcy's law and its applications; Determination of permeability in laboratory and in field; Flow through aquifers; steady, unsteady and radial flow conditions; Evaluation of aquifer parameters of confined, semi-confined and unconfined aquifers - Thiem, Thies, Jacob and Walton's methods; Groundwater modelling.

**Section C: Groundwater Exploration and Water Well Construction**

Geologic and hydrogeologic methods of exploration; Role of remote sensing in groundwater exploration; Hydrogeomorphic and lineament mapping; Surface geophysical methods — seismic, gravity, geo-electrical and magnetic methods; Types of water wells and methods of construction; Design, development, maintenance and revitalization of wells; Sub-surface geophysical methods; Yield characteristics of wells; Pumping tests methods, data analysis and interpretation;

**Section 1: Groundwater Quality**

Physical and chemical properties of water; Quality criteria for different uses; Graphical presentation of groundwater quality data; Groundwater quality in different provinces in India; Groundwater contamination; natural (geogenic) and anthropogenic contaminants; Saline water intrusion; Radio-isotopes in hydrogeological studies.