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.

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.

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 landforms; Denudational processes : Weathering , erosion, transportation, weathering products and soils – profiles, types, duricrusts; 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

Principle of geological mapping and map reading, projection diagrams. Stress-strain relationships for elastic, plastic and viscous materials. Measurement of strain in deformed rocks. Behaviour of minerals and rocks under deformation conditions. Structural analysis of folds, cleavages, lineations, joints and faults. Superposed deformation. Mechanism of folding, faulting and progressive deformation. Shear

Zones: Brittle and ductile shear zones, geometry and products of shear zones; Mylonites and cataclasites, their origin and significance.Time relationship between crystallization and deformation. Unconformities and basement-cover relations. Structural behaviour of igneous plutons, diapirs and salt domes. Introduction to petrofabric analysis.

Section C: Geodynamics

Earth and its internal structure. Continental drift – geological and geophysical evidence and objections. An overview of plate tectonics including elementary concepts of plates, lithosphere, asthenosphere, types of plate boundaries and associated important geological features like oceanic trenches, volcanic arcs, accretionary wedges, topography of mid-ocean ridges, magnetic anomaly stripes and transform faults. Gravity anomalies at mid-ocean ridges, deep sea trenches, continental shield areas and mountain chains. Palaeomagnetism and its application for determining palaeoposition of continents. Isostasy, Orogeny and Epeirogeny. Seismic belts of the earth. Seismiciy at plate boundaries. Principles of Geodesy, Global Positioning System (GPS) and its application in crustal motion monitoring including neotectonics. Palaeoposition of India and Geodynamics of the Indian plate.

Section D: Stratigraphy

Principles of Statigraphy : History and Development of Statigraphy; Stratigraphic procedures (Surface and Subsurface); Concept of Lithofacies and Biofacies; Stratigraphic Correlation (Litho, Bio- and Chronostrarigraphic Correlation); Study of standard stratigraphic code (Lithostratigraphic, Biostratigraphic and Chronostratigraphic); Concepts of Magnetostratigraphy, Chemostratigraphy, Event stratigraphy, and Sequence stratigraphy; Nomenclature and the modern stratigraphic code. Radioisotopes and measuring geological time. Geological time-scale. Stratigraphic procedures of correlation of unfossiliferous rocks. Precambrian stratigraphy of India : Achaean stratigraphy -tectonic frame-work, geological history and evolution of Dharwar, and their equivalents; Easterghats mobile belt; Proterozoic stratigraphy -tectonic framework, geological history and evolution of Cuddapahs and their equivalents. Palaeozoic stratigraphy: Palaeozoic formations of India with special reference to type localities, history of sedimentation, fossil content. Mesozoic stratigraphy: Mesozoic formations of India with special reference to type localities, history of sedimentation, fossil content. Cenozoic stratigraphy: Cenozoic formations of India, Rise of the Himalayas and evolution of Siwalik basin. Stratigraphic boundaries: Stratigraphic boundary problems in Indian geology. Gondwana Supergroup and Gondwanaland. Deccan Volcanics. Quaternary stratigraphy. Rocks record, palaeoclimates and palaeogeography.

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

External symmetry of crystals: Symmetry Elements, methods of projection, derivation of 32 classes, Hermaun Muguin notation. Internal symmetry of crystals: Derivation of 230 space groups, diffraction of crystals by X-rays, Braggs' law. Principles of optical mineralogy : Optical mineralogy, polarized light, behaviour of isotropic and anisotropic minerals in polarized light, refractive index, double refraction, birefringence, sign of elongation, interference figures, 2V, dispersion in minerals. Optic sign, pleochroic scheme and determination of fast and slow vibrations and accessory plates. Introduction to mineralogy: Definition and classification of minerals. Structural and chemical principles of crystals / minerals, chemical bonds, ionic radii, coordination number (CN) and polyhedron. Structure, chemistry, physical and optical characters and paragenesis of mineral groups: Olivine, pyroxene, amphibole, mica and spinel groups; Feldspar, quartz, feldspathoid, aluminum silicate, epidote and garnet groups. Accessory minerals: Apatite, calcite,

corundum, scapolite, sphene and zircon. Earth mineralogy: Average mineralogical composition of crust and mantle, mineral transformations in the mantle with depth.

Earth in relation to the solar system and universe, cosmic abundance of elements. Composition of the planets and meteorites. Structure and composition of earth and distribution of elements. Trace elements and REE and their importance in fractional crystallization during magmatic / partial melting. Elementary crystal chemistry and thermodynamics. Introduction to isotope geochemistry. Geochronology and age of the Earth: Law of Radioactivity; Principles of isotopic dating, Decay schemes and Derivation of equation of age. Rb/Sr, U- Th –Pb methods of dating the rocks. Age of the Earth. Geochemistry and principles of evolution of hydrosphere, biosphere and atmosphere. Geochemical cycle and principles of geochemical prospecting.

Section B : Igneous Petrology

Origin of magmas: Mantle, onset of partial melting of mantle, processes of partial melting in mantle, mantle-magmas in relation to degree and depth-level of partial melting. Phase equilibrium in igneous systems: Binary and ternary systems. Bowen's reaction principle: Reaction series and its application to petrogenesis. Magmatic evolution and differentiation: Fractional crystallization, gravitational differentiation, gas streaming, liquid immiscibility and assimilation. Structures and textures: Definition, description, rock examples and genetic implications of common structures and textures of igneous rocks. Classification of igneous rocks: Mode, CIPW norm, IUGS and other standard classifications; Magmatism and tectonics: Inter-relationship between tectonic settings and igneous rock suites. Igneous rock suites: Form, structure, texture, modal mineralogy, petrogenesis and distribution of Ultramafic rocks: Dunite-peridotite-pyroxenite suite; kimberlites, lamprophyres, lamproites, komatiites; Basic rocks: Gabbro-norite-anorthosite-troctolite suite, Dolerites; Basalts and related rocks; Intermediate rocks: Diorite-monzonite-syenite suite; Andesites and related rocks; Acidic rocks: Granite-syenite-granodiorite-tonalite suite; Rhyolites and related rocks; Alkaline rocks: Shonkinite, ijolite, urtite, melteigite, malignite, alkali gabbros, alkali basalt, alkali granite, alkali syenite, nepheline syenite and phonolite; Carbonatites; Ophiolite suite.

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, Matasomatism; Deformation textures and textures related to recrystallization; Metamorphic reactions, elemental exchange and Pressure – Temperature conditions of 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, silicious 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

(1)) Provenance and diagenesis of sediments. Sedimentary textures. Framework, matrix and cement of terrigenous sediments. Definition, measurement and interpretation of grain size. Elements of hydraulics. Primary structures, palaeocurrent analysis. Biogenic and chemical sedimentary structures. Sedimentary environment and facies. Facies modeling for marine, non- marine and mixed sediments. Tectonics and sedimentation. Classification and definition of sedimentary basins. Sedimentary basins of India. Cyclic sediments. Seismic and sequence stratigraphy. Purpose and scope of basin analysis. Stratum contours and isopach maps.

Section E : Environmental Geology and Natural Hazards

Fundamental concepts of Environmental Geology - it's scope, objectives, and aims. Earth's thermal environment and Climates. Global warming. Green house effect. Ozone depletion –Ice sheets and fluctuation in sea levels. Concepts of ecosystem. Earth's major ecosystems terrestrial and aquatic.

Meteorology as environmental science. Air Pollution, sources of pollution, pollution due to dust and waste disposal. National and International standards. Environmental health hazards. Mining, opencast, underground, disposal of industrial and radio-active waste, dumping stacking, rehandling, management, mineral processing, tailing ponds, acid mine drainage, siltation, case studies. Mining below water table, mine water discharges, regional effects on water regime. Noise levels- national standards, mining machinery, ill effects. Air sampling techniques – respirable dust samplers, high volume air samplers, personal sampling pumps, weather monitoring equipments, automatic recorders. Elements of Environmental Impact Assessment – impacts, primary, secondary, prediction, assessment, base-line data generation, physical, biological, cultural, socioeconomic aspects. Carrying capacity based developmental planning – Assimilative capacity – supportive capacity – Resource based planning – Institutional strategies. Sustainable Developmental Planning - Applications of GIS in Environmental Management.Environmental Legislations in India.

Concepts and principles: Natural hazards – preventive/ precautionary measures – floods, landslides, earthquakes, river and coastal erosion. Distribution, magnitude and intensity of earthquakes. Neotectonics and seismic hazard assessment. preparation of seismic hazard maps. Impact of seismic hazards on long and short term environmental conditions. Mechanism of landslides, causes of major floods, cyclones and storms. Deforestation and land degradation. Coastal erosion, its causes and control of Geological hazards and crisis management.

GEOLOGY – PAPER III : 200 MARKS

Section A: Indian mineral deposits and mineral economics

Occurrence and distribution in India of metalliferous deposits - base metals, iron, manganese, aluminium, chromium, nickel, gold, silver, molybdenum. Indian deposits of non-metals – Diamond, mica, asbestos, barytes, gypsum, graphite, apatite and beryl. Gemstones, refractory minerals, abrasives and minerals used in glass, fertilizer, paint, ceramic and cement industries. Building stones. Phosphorite deposits. Placer deposits, rare earth minerals. Strategic, critical and essential minerals. India's status in mineral production vis a vis world scenario, Changing patterns of mineral consumption. UNFC classification, National Mineral Policy. Mineral Concession Rules. Marine mineral resources and Laws of Sea.

Section B: Ore genesis and Geophysics

Ore deposits and ore minerals. Magmatic processes of mineralization. Porphyry, skarn and hydrothermal mineralization. Fluid inclusion studies. Mineralisation associated with – (i) ultramafic, mafic and acidic rocks (ii) greenstone belts (iii) komatiites, anorthosites and kimberlites and (iv) submarine volcanism. Magma related mineralization through geological time. Stratiform and stratabound ores. Ores and metamorphism – cause and effect relations. Metallogeny and mineral belts.

Interrelationship between geology and geophysics - Role of geological and geophysical data in explaining geodynamical features of the earth. General and Exploration geophysics - Different types of geophysical methods; Gravity, magnetic, Electrical, Seismic - their principles and applications. Geophysical field operations - Different types of surveys, grid and route surveys, profiling and sounding techniques, scales of survey, presentation of geophysical data. Application of Geophysical methods - Regional geophysics, ore geophysics, engineering geophysics. Geophysical anomalies : correction to measured quantities, geophysical, anomaly, regional and residual (local) anomalies, factors controlling anomaly, depth of exploration. Integrated geophysical methods - Ambiguities in geophysical interpretation, Planning and execution of geophysical surveys.

Section C: Mineral exploration

Resource, reserve definitions; mineral resource in industries - historical perspective and present. A brief overview of classification of mineral deposits with respect to processes of formation in relation to exploration strategies. Principles of mineral prospecting and exploration - conceptualization, methodology and stages; sampling, subsurface sampling including pitting, trenching and drilling, core and non-core drilling, planning of bore holes and location of bore holes on ground. Core logging, geochemical exploration- nature of samples anomaly, strength of anomaly and controlling factors, coefficient of aqueous migration. Principles of reverse estimation, density and bulk density, factors affecting reliability of reserve estimation, reserve estimation based on geometrical models (square, rectangular, triangular and polygon blocks) regular and irregular grid patterns, statistics and error estimation. Application of Geophysical techniques, Geomorphological

and remote sensing techniques and Geobotanical and geochemical methods. Application of geostatistical techniques in Mineral Exploration.

Section D: Geology of fuels

Coal and its properties: Different varieties and ranks of coal. Origin of coal. Coalification process and its causes. Lithotypes, microlithotypes and macerals: their physical, chemical and optical properties. Maceral analysis of coal: Mineral and organic matter in coal. Petrographical methods and tools of examination. Fundamentals of coal petrology, concept of coal maturity, peat, lignite, bituminous and anthracite coal. Application of coal geology in hydrocarbon exploration. Applications of coal petrography. Proximate and ultimate analyses. Indian coal & lignite deposits. Industrial evaluation of coal characteristics with reference to coal classification. Geology and coal petrography of different coalfields of India. Uses of coal for various industries e.g. carbonization, liquefaction, power generation, gasification and coal-bed methane production.

Origin, migration and entrapment of natural hydrocarbons. Characters of source and reservoir rocks. Structural, stratigraphic and mixed traps. Techniques of exploration. Geographical and geological distributions of onshore and offshore petroliferous basins of India.

Mineralogy and geochemistry of radioactive minerals. Instrumental techniques of detection and measurement of radioactivity. Radioactive methods for prospecting and assaying of mineral deposits. Distribution of radioactive minerals in India. Radioactive methods in petroleum exploration – well logging techniques. Nuclear waste disposal – geological constraints.

Section E : Engineering Geology

Geological studies and evaluation in planning, design and construction of major civil structures. Elementary concepts of rock mechanics and soil mechanics. Site investigation, characterization and problems related to civil engineering projects: geological and geotechnical investigations for dams, reservoirs and spillways, tunnels, underground caverns, bridges, highways, shorelines. Problems of groundwater in engineering projects. Coastal geotechniques. Environmental considerations related to civil engineering projects. Resource evaluation of construction materials. Geological hazards (landslides and earthquakes), their significance, causes, preparedness and mitigation. Recent trends in geotechnical engineering. Geotechnical case studies of major projects in India.

GEOPHYSICS - PAPER I: 200 Marks
PART-A: 100 Marks

a. Solid Earth Geophysics:

Introduction to Geophysics its branches and relationship with other sciences. Solar system, its origin, characteristics of planetary members, Earth; its rotation and figure. Age of earth & various methods of determination. Tectonics and Geodynamics, Thermal history and its characteristics. Gravity field of earth and Isostasy. Geomagnetism, elements of earth's magnetism: Internal, External fields and their causes, Paleomagnetism, Polar wandering paths, Seafloor spreading, geophysical evidences. Elastic waves, internal structure of earth, variation of physical properties in the interior of earth.

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 spherically 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**:

Properties of scalars, vectors and tensors, Elements of vector analysis, Gradient, Divergence and Curl, Gauss's divergence theorem, Stokes theorem, Definition of fields, Gravitational field, Newton's Law of gravitation, Gravitation potential and fields due to bodies of different geometric shapes, Electrostatic field, Coulomb's law, Electrical permittivity and dielectric constant, Basic guiding equations, Magneto static field, Origin of Magnetic field, Ampere's law, Biot and Savart's law, Geomagnetic fields, Magnetic fields due to different type of structures, Solution of Laplace equation in Cartesian Coordinate, Cylindrical Polar Coordinate and Spherical Polar Coordinate, Complex Variables in Potential theory, Green's theorem in Potential Theory.

Concept of Image in Potential Theory, Analytical continuation in Potential fields, Numerical Methods in Potential Theory. Electrical fields in geophysics, point source, continuous distribution and double layers, equipotential and line of force. Current and potential in the earth, basic concept and equations of electromagnetic, Maxwell's equations, boundary conditions, elliptic polarization, electromagnetic potential and waves, radiation from dipoles, retarded potential, near and far fields, radiation resistance, EM field of a loops of wire on half space, multi-layered media, impedance and its application.

d. Geophysical Inversion:

Fundamental concepts of inverse theory, Basic definition of inversions with application to Geophysics. Probability, Inverses with discrete and continuous models. Forward problems versus Inverse problems. Formulation of inverse problems and their relation to a matrix problem, linear inverse problems, classification of inverse problems, least square solutions and minimum norm solution, concept of norms, concept of 'a priori' information, constrained linear least square inversion, review of matrix theory Introduction to finite difference method, forward, backward and central difference mthod. Application of finite difference method for solving Helmholtz equation. Introduction to finite element method, various steps, simple examples showing application of finite element method. Models and data spaces, householder transformation, data resolution matrix, model resolution matrix, Eigen values and Eigen vectors, singular value decomposition (SVD), generalized inverses, Non-linear inverse problems, Gauss Newton method, steepest descent (gradient) method, Marquardt-Levenberg method, Earthquake location problem, tomography problem. Probabilistic approach of inverse problems, maximum likelihood and stochastic inverse methods, Backus-Gilbert method, Global optimization techniques, genetic algorithm, simulated annealing methods, examples of inverting geophysical data.

PART-B: 100 Marks

a. Mathematical Methods of Physics:

Dimensional analysis, Vector algebra and vector calculus, Linear algebra, matrices, Cayley-Hamilton Theorem. Eigen values and eigenvectors. Linear ordinary differential equations of first & second order, Special functions (Hermite, Besse!, Laguerre and Legendre functions). Fourier series, Fourier and Laplace transforms. Elements of complex analysis, analytic functions; Taylor & Laurent series; poles, residues and evaluation of integrals. Elementary probability theory, random variables, binomial, Poisson and normal distributions. Central limit theorem. Green's function. Partial differential equations (Laplace, wave and heat equations in two and three dimensions). Elements of computational techniques: root of functions, interpolation, and extrapolation, integration by trapezoid and Simpson's rule, solution of first order differential equation using Runge-Kutta method. Finite difference methods. Tensors. Introductory group theory: SU (2), 0 (3). Complex Variables, Beta, Gamma functions and special functions, Laplace Transform & Fourier series, Fourier Transforms, Introductory methods of Numerical analysis. Operators and their properties.

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 non equilibrium processes; Diffusion equation.

b. Electrodynamics:

Gauss Theorem, Poison'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 potentials, uniqueness of electromagnetic potentials and concept of gauge, Lorentz gauge, Columb 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, Abrahama-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.

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 Poisons 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, Environmental studies...Data processing and interpretation of anomalies, modeling of 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 geo electric 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(disseminated 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 fields, Instrumentation, Field methods and interpretation of MT data and applications.

c. Seismic Prospecting:

Basic principles of seismic methods, Fermat's principle, Senell'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; Arhcie's and Humble's equations; principles, instrumentations, 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, sub-surface 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 & JJ coupling; Zeeman, Paschen Back & Stark effect; X-ray spectroscopy; Electron spin resonance, 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, hyperfine splitting, Nuclear Gamma Resonance: Principles of Mossbauer Spectroscopy, Line width, Resonance absorption, Mossbauer Spectrometer, Isomer Shift, Quadrupole splitting, magnetic field effects, applications.

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; lsospin; 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 invarianceandapplicationsofsymmetryargumentsto particle reactions, parity non-conservation 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..

GEOPHYSICS - PAPER III : 200 Marks

PART-A: 100 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:

Oceans and Seas, origin of continents and oceans, salinity, temperature and density of sea water. Introduction to Sea-floor features: Physiography, divisions of sea floor, continental shelves, slopes, aprons and abyssal planes, growth and decline of ocean basins, turbidity currents, submarine sedimentation and stratigraphy, occurrence of mineral deposits and hydrocarbons in offshore. Geophysical surveys and instrumentation, Gravity and Magnetic surveys, Instrumentation used in ship borne surveys, towing cable and fish, data collection and survey procedures, corrections and interpretation of data. Oceanic magnetic anomalies, sea floor spreading, Vine-Mathews hypothesis, geomagnetic time scale and dating sea floor, linear magnetic anomalies, Oceanic heat flow, ocean ridges, basins, marginal basins, rift valleys. Seismic surveys, energy sources, Finger, Boomer, Sparker, Exploder, Air gun, Vapour cook, Hydrophones, processing, data reduction and interpretation. Bathymetry, echo sounding, bathymetric charts, sea bed mapping, seabed sampling, dredging and coring, Navigation methods and Position location methods.

c. Geophysical Signal Processing:

Various types of signals, sampling theorem, aliasing effect, Fourier series and periodic waveforms, Fourier transform and its properties, Discrete Fourier transform and **FFT,** Auto and cross correlations, Power spectrum, Delta function, unit step function. Time domain windows, Z transform and properties, Inverse Z transform. Principles of digital filters, types of filters, moving average and recursive and non recursive filters Amplitude and phase response filters low pass, band pass and high pass filters, Processing of Random signals. Signal enhancement 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 photographic 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, pars and ferromagnetism; elements of superconductivity; Meissner effect, Josephson junctions and applications; elementary ideas about high temperature superconductivity.

b. Laser systems: Light amplification and relation between Einstein A and B coefficients. Rate equations for three level and four level systems. Ruby laser, Nd-YAG laser, CO2 laser, Dye laser, Excimer laser, Semiconductor laser.

c. Laser cavity modes: Line shape function and full width at half maximum (FWHM) for natural broadening, collision broadening, Doppler broadening, saturation behaviour of broadened transitioins, longitudinal and transverse modes. ABCD matrices and cavity stability criteria for confocal resonators. Quality factor, Q-switching, mode locking in lasers. Expression for intensity for modes oscillating at random and modes locke in phase. Methods of Q-switching and mode locking. Optical fiber waveguides, Fiber characteristics.

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 (registers, 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, satellite 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.

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 electro-negativity. 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, aqueous and redox chemistry in common oxidation states, properties and reactions of important compounds such hydrides, halides, oxides, oxy-acids, complex chemistry in respect of s-block and p-block elements.

Chemical Bonding and structure:

Ionic bonding: Size effects, radius ratio rules and their limitations. Packing of ions in crystals, lattice energy, Born-lande equation and its applications, Born-Haber cycle and its applications. Solvation energy, polarizing power and polarizability, ionic potential, Fazan's rules. Defects in solids. Covalent bonding: Lewis structures, formal charge. Valence Bond Theory, Molecular orbital Theory, hybridizations, VSEPR theory. Partial ionic Character of covalent bonds, bond moment, dipole moment and electro negativity differences. Concept of resonance, resonance energy, resonance structures. Schrodinger equation for the H-atom.

Coordinate bonding: Werner theory of coordination compounds, double salts and complex salts, Lewis acid-base. Ambidentate and polydentate ligands, chelate complexes. IUPAC nomenclature of coordination compounds. Coordination numbers, Geometrical isomerism. Stereoisomerism in square planar and octahedral complexes. Hydrogen bonding. Metallic bonding: qualitative idea of band theory, conducting, semi conducting and insulating properties.

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 do 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; spectro-chemical series of ligands; charge transfer spectra .

Acid-Base reactions

Acid-Base concept: Arrhenius concept, theory of solvent system, Bronsted-Lowry's concept, relative strength of acids, Pauling rules. Lewis concept. Acidbase equilibria in aqueous solution and pH. Acid-base neutralisation curves; indicator, choice of indicators.

Precipitation and Redox Reactions:

Solubility product principle, common ion effect. Ion-electron method of balancing equation of redox reaction. Standard redox potentials, Nernst equation. Influence on complex formation, precipitation and change of pH on redox potentials; formal potential. Feasibility of a redox titration, redox potential at the equivalence point, redox indicators. Redox potential diagram of common elements and their applications. Disproportionation and comproportionation reactions.

Organo metallic compounds:

18-electron rule and its applications to carbonyls, 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:

Radioactive decay - General characteristics, decay kinetics, parent -daughter decay growth relationships, determination of half-lives, Nuclear models -shell model, liquid drop model, Fermi gas model, Collective model and optical model. Nuclear stability. Decay theories. Nuclear reactions- fission, fusion and spallation reactions. Definition of curie and related calculations, preparation of artificial radionuclides by bombardment, radiochemical separation techniques. Experimental techniques in the assay of radioisotopes, gas filled detectors-ionization chamber, proportional and Geiger-Muller counters -G.M. Plateau, dead time, coincidence loss, determination of dead time, scintillation counters, solid state detectors.

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], H2PtC16, Na2[Fe(CN)5N0].

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 of energy 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 their 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, radius ratio and packing in crystals.

Thermodynamics:

Definition of thermodynamic terms. Thermodynamic functions and their differentials. Zeroth law, First law and Second law of thermodynamics. Cyclic, reversible and irreversible processes. Internal energy (U) and enthalpy

(H); relation between Cp and Cv, calculation of w, q, ?U and ?H for expansion of ideal gas under isothermal and adiabatic conditions for reversible and irreversible processes including free expansion. Joule-Thomson Coefficient and inversion temperature. Application of First law of 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 Gibb's 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 Hoffs reaction isotherm. Equilibrium constant and standard Gibbs free energy change. Definitions of KP, KC and Kx; van't Hoffs 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, buffer solutions and their pH values, buffer actions & buffer capacity; 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:

Conductance: cell constant, specific conductance and molar conductance. Kohlrausch's law of independent migration of ions, ion conductance and ionic mobility. Equivalent and molar conductance at infinite dilution. Ostwald's dilution law. Debye-Huckel theory. Application of conductance measurement. Conductometric titrations. Determination of transport number by moving boundary method. Types of electrochemical cells, cell reactions, emf and change in free energy, 6.H and AS of cell reactions. Nernst equation. Standard cells. Half-cells / electrodes, different types of electrodes. Standard electrode potential and principles of its determination. Types of concentration cells. Liquid junction potential. Glass electrode and determination of pH of a solution. Potentiometric titrations: acid-base and redox, electro chemical power sources; primary, secondary and fuel Cells, corrosion and inhibition of corrosion.

Photochemistry :

Frank-Condon principle and vibrational structure of electronic spectra. Bond dissociation and principle of determination of dissociation energy. Decay of excited states by radiative and non-radiative paths. Fluorescence and phosphorescence, Jablonsky diagram. Laws of photochemistry: Grotthus-Draper law, Stark-Einstein law of photochemical equivalence and Lambert-Beers law; quantum yield and its measurement for a photochemical process, actinometry. Photostationary state. Photosensitized reactions. Kinetics of HI decomposition, H2-Br2 reaction, dimerisation of anthracene.

Quantum Chemistry:

Wave-particle duality, Photoelectric and Compton effects, de Broglie hypothesis. Eigenfunctions and eigenvalues. Uncertainty relation, Expectation value. Hermitian operator. Schrodinger time-independent equation: nature of the equation, acceptability conditions imposed on the wave functions and probability interpretations of wave function. Schrodinger equation for one-dimensional box and its solution. Comparison with free particle eigenfunctions and eigenvalues.

Basic principles and application of spectroscopy:

Electromagnetic radiation, interaction with atoms and molecules and quantization of different forms of energies. Condition of resonance and energy of absorption for various types of spectra; origin of atomic spectra, spectra of hydrogen atoms, many electron atoms, spin and angular momentum. Rotational spectroscopy of diatomic molecules: rigid rotor model, selection rules, spectrum, characteristic features of spectral lines. Determination of bond length, effect of isotopic substitution. Vibrational spectroscopy of diatomic molecules: Simple Harmonic Oscillator model, selection rules, Raman Effect. Characteristic features and conditions of Raman activity with suitable illustrations. Rotational and vibrational Raman spectra.

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 Hooke's law, characteristic stretching frequencies of O-H, N-H, C-H, C-D, C=C, C=N, C=0 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.

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, aluminum as the oxinate and nickel as 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 Na2CO3, NaOH, Na202, K2S207; 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 lodometry, permaganometry, dichrometry, difference between iodometry and iodimetry.

Potentiometry: Fundamentals of potentiometry. indicator and ion-selective electrodes. Membrane electrodes. Glass electrode for pH measurement, glass electrodes for cations other than protons. Liquid membrane electrodes, solid state ion selective detectors and biochemical electrodes. Applications of potentiometry. Direct potentiometric measurements-determination of pH and fluoride. Redox and potentiometer titrations- Balancing redox reactions, calculation of the equilibrium constant of the reaction, titration curves, visual end point detection. Redox indicators-theory, working and choice. Potentiometric end point detection. Applications of redox titrations.

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 uni-dentate 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.

UV-Visible Spectroscopy:

Basic Principles of UV-Vis spectrophotometer. Lambert -Beer's Law and its limitations. Instrumentation consisting of source, monochromator, grating and detector. Spectrophotometric determination.

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 emission spectrometry.

X-ray methods of Analysis:

Introduction , theory of X-ray generation, X-ray spectroscopy, X-ray diffraction and X-ray fluorescence methods, Braggs 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 Minerals, Ores and Alloys:

Analysis of Minerals and Ores- estimation of (i) $CaCO_3$, $MgCO_3$ in dolomite (ii) Fe_2O_3, Al_2O_3, and TiO_2 in Bauxite.(iii) MnO and MnO_2 in Pyrolusite.

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 anlaysis 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:

Grignard reagents - preparations and reactions, application of Grignard reagents in organic synthesis. Organic compounds containing nitrogen: aromatic nitro compounds - reduction under different conditions. Methods of synthesis of aliphatic amines, Heinsberg's method of amine separation, Hofmann degradation, Gabriel's phthalimidesynthesis, distinction of primary, secondary and tertiary amines; methods of synthesis of aromatic amines, basicity of aliphatic and aromatic amines. Sandmeyer reactions; synthetic applications of benzene diazonium salts.

Bonding and physical properties:

Valence bond theory: concept of hybridisation, resonance (including hyperconjugation), orbital pictures of bonding sp3, sp2, sp: C-C, C-N & C-0 system). Inductive effect, bond polarization and bond polarizability, steric effect, steric inhibition of resonance. MO theory: sketch and energy levels of MOs of i) acyclic p orbital system ii) cyclic p orbital system, iii) neutral system. Frost diagram, Huckel's rules for aromaticity &

antiaromaticity; homoaromaticity. Physical properties: bond distance, bond angles, mp/bp & dipole moment in terms of structure and bonding. Heat of hydrogenation and heat of combustion.

Aldol and related reactions:

Keto-enol tautomerism, mechanism and synthetic applications of aldol condensations, Claisen reaction, Schmidt reaction, Perkin reaction, Knovenogal, benzoin, Cannizaro reaction, Michael addition. Aromatic substitution reactions - electrophilic, nucleophilic and through benzynes - 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. Stork enamine reactions, Michael addition, Mannich Reaction, Diels - Alder reaction.

Electrocyclic Reactions:

Molecular orbital symmetry, frontier orbitals of ethylene, 1,3 Butadiene, 1,3,5- Hexatriene, ally! system, classfication of pericyclic reactions FMO approach, Woodwrd- Hoffman correlation diagram method and perturbation of molecular (PMO) approach for the explanation of pericyclic reactions under thermal and photochemical conditions. Conrotatory and disotatory 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, addtion 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 wave length 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.

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- transrnissivity 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 'napping; 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 D: 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 hydroLteological studies.

Section E: Groundwater Management

Groundwater problems related to foundation work, mining, canals and tunnels; Over-exploitation of groundwater andgroundwater mining; Groundwater problems in urban areas; Ground water management in arid and semi arid areas; Climate change impact on graoundwater resources; Concept of sustainable development of groundwater resources; Groundwater management —supply side and demand side management; Rainwater harvesting and managed aquifer recharge; Conjunctive use of surface and groundwater; Groundwater legislation.