SYLLABUS STRUCTURE & MARKS DISTRIBUTION FOR THE NEW B.Sc. PROGRAMME IN CHEMISTRY (NEHU)
(ONLY CHEMISTRY PAPERS MENTIONED)

First Semester	*Total: 100 Marks*
Chem EH 101: Inorganic, Organic & Physical Theory	– 75 marks
Chem E 102: Practical (Organic - Elective)	– 25 marks
Chem H 103: Practical (Organic – Honours)	– 25 marks

Second Semester	*Total: 100 Marks*
Chem EH 201: Inorganic, Organic & Physical Theory	– 75 marks
Chem EH 202: Practical (Physical)	– 25 marks

Third Semester	*Total: 100 Marks*
Chem EH 301: Inorganic, Organic & Physical Theory	– 75 marks
Chem EH 302: Practical (Inorganic-I)	– 25 marks

Fourth Semester	*Total: 100 Marks*
Chem EH 401: Inorganic, Organic & Physical Theory	– 75 marks
Chem EH 402: Practical (Inorganic-II)	– 25 marks

Fifth Semester	*Total: 200 Marks*
Chem H 501: Inorganic Theory	– 50 marks
Chem H 502: Organic Theory	– 50 marks
Chem H 503: Physical Theory	– 50 marks
Chem H 504: Practical (Organic)	– 25 marks
Chem H 505: Practical (Physical)	– 25 marks

Sixth Semester	*Total: 200 Marks*
Chem H 601: Inorganic Theory	– 50 marks
Chem H 602: Organic Theory	– 50 marks
Chem H 603: Physical Theory	– 50 marks
Chem H 604: Practical (Inorganic)	– 35 marks
Chem H 605: Seminar	– 15 marks

Note. EH stands for Elective & Honours together; **H** stands for Honours alone; **E** stands for Elective alone. The above assignments of Course Numbers (e.g. **Chem EH 101**) is only tentative

First Semester **Total: 100 Marks**

Chem EH 101: ***Inorganic, Organic & Physical Theory*** ***75 marks***

PART A (Inorganic) **25 Marks**

Unit I *12½ marks*

(a) Structure of Atom: Limitations of Bohr's atomic model; idea of the de Broglie matter waves, Heisenberg's uncertainty principle; Schrodinger's wave equation and its importance; quantum numbers; concept of wave function; physical concepts of Ψ and Ψ^2; radial and angular wave functions; shapes of s, p and d-orbitals, Aufbau principle, Pauli's Exclusion Principle, Hund's rule, electronic configurations of atoms, screening effect and effective nuclear charge, extra stability of half-filled and completely filled orbitals.

(b) Nucleus and Radioactivity-I: Nuclear particles; nuclear binding energy; mass defect and packing fraction; natural and artificial radioactivity; radioactive disintegration series; first order rate equation of radioactive disintegration; half life and average life period, group displacement law , unit of radioactivity; neutron-proton ratio and its implications, importance of radioactive isotopes, elementary concepts of fusion and fission.

(c) Chemical Periodicity: Long form of periodic table, modern periodic law, types of elements on the basis of electronic configuration; periodic variation in properties – atomic and ionic radii, ionization enthalpy, electro gain enthalpy, and electro negativity; diagonal relationship.

Unit II *12½ marks*

(a) Covalent Bonding: Basic idea of valence bond theory and its limitations; Concept of hybridization of orbitals; valence shell electron pair repulsion (VSEPR) theory and shapes of molecules and ions: BeF_2, BF_3, H_3O^+, NH_3, H_2O, H_2S, O_3, CO_2, BO_3^{3-}, PCl_3, PCl_5, SF_4, SF_6; polarity of covalent bonds and dipole moment. LCAO-MO theory and its application to homonuclear diatomic molecules (H_2, N_2, O_2, O_2^{-2}, O_2^-, O_2^+, Ne).

(b) Ionic Bonding: Ionic structures; radius ratio effect; limitation of radius ratio rule; concept of lattice energy and Born-Haber cycle; polarizing power; polarizability of ions and Fajan's rule.

*(c) **Bonding in Metals, Semiconductors and Hydrogen Bond**:* Qualitative idea of free electron theory and band theory in solids; elementary ideas on semiconductors (n and p types); hydrogen bonding – concept and types of H-bonding – application to inorganic molecules.

PART B (Organic) **25 Marks**

Unit III *12½ marks*

*(a) **Structure, Bonding & Properties**:* Hybridisation of orbitals, implications of hybridisation on the concept of bond length, bond energy, bond angles, shape of the molecules with following examples: (i) CH_4, H_3O^+, $^-CH_3$, RNH_2 ; (ii) C_2H_4, $^+CH_3$, BF_3, $AlCl_3$, carbonyl compounds, and (iii) C_2H_2, R-CN, allene, ketene.

Nature of covalent bond and its orbital representation in molecules listed above.

Bronsted-Lowry and Lewis concepts of acids and bases, electronegativity, polarity of bonds and dipole moment, inductive effect and its role in substituted aliphatic carboxylic acids, effect of H-bonding on boiling point and solubility of organic compounds.

Conjugation, resonance, hyper-conjugation (propene and toluene), homolytic and heterolytic bond cleavage. Types of reagents – electrophiles and nucleophiles. Reactive intermediates: carbocatons, carbonions, free radicals, carbenes - stability and examples.

*(b) **Organic Stereochemistry-I**:* Concept of isomerism, types of isomerism - configuratonal and conformational isomerism. Fischer, Newman and sawhorse projections with suitable examples, geometrical isomerism, configuration of geometrical isomers, E and Z nomenclature, geometric isomers of oximes; optical isomerism – optical activity, chiral carbon atom, enantiomers, diastereomers, meso compounds, racemic mixture, resolution of racemic mixtures.

Unit IV *12½ marks*

*(a) **Alkanes and Cycloalkanes:*** Nomenclature, methods of formation (with special reference to mechanism of Kolbe, Corey-House and Wurtz reactions), chemical reactivity (oxidation, cracking, aromatization). Reaction profile, activation energy, transition state and intermediate mechanism of chlorination, relative reactivity of halogens towards different types of alkanes, nitration, sulphonation.

General method of preparation of cycloalkanes (upto cyclohexane) and their rection with halogens and HX. Baeyer's strain theory- its limitations and modifications.

*(b) **Alkenes and Alkynes***: Nomenclature of alkenes, methods of formation, chemical reactivity, mechanisms of hydrogenation, bromination, hydration, halohydration, hydroboration and Markownikoff's rule, mechanism of radical addition, peroxide effect, oxidation reactions, epoxidation, ozonolysis, hydroxylation. Polymerization.

Nomenclature, structure and bonding in alkynes, methods of formation, chemical reactivity, electrophilic addition reactions (halogenation,hydration, HX, HOX), ozonolysis, alkynides (Na, Cu and Ag) and polymerization; compare acidity of ethane, ethene and ethyne.

*(c) **Aromatic Hydrocarbons and Aromaticity***: Structure of benzene, molecular orbital picture of benzene, stability of benzene ring, resonance energy, aromaticity, Huckel's (4n+2) rule and its application to simple molecules and ions, electrophilic, substitution reactions in aromatic hydrocarbons and general pattern of the mechanism, effect of substituent groups (activating and deactivating groups, directive influence) – mechanism of nitration, sulphonation, halogenation nuclear and side chain, formylation (Gattermann and Gattermann-Kotch), Friedel-Craft's alkylation and acylation.

PART C (Physical) **25 Marks**

Unit V *12.5 Marks*

*(a) **Gaseous State-I***: Kinetic theory of gases - postulates of kinetic theory, collisions and gas pressure, average kinetic energy, root mean square speed and absolute temperature of gas, Boltzmann constant, gas laws and kinetic theory. Real gases - deviation from ideality, compressibility factor, van der Waals equation of state, virial equation of state.

*(b) **Liquid State-I***: Qualitative description of the structure of liquids, Physical properties of liquids - vapour pressure, surface tension, viscosity, refractive index (definitions and descriptions), Liquid crystals- elementary discussion on structure and types of liquid crystals.

Unit VI *12.5 marks*

*(a) **Crystalline State-I***: Law of constancy of interfacial angles, crystal planes, law of rational indices, Miller indices, space lattice and unit cell, packing in crystals, crystal defects.

*(b) **Colloids***: Classification of colloids, preparation of colloids – peptisation, Bredig's method and condensation methods, purification of colloids, properties of colloids – Tyndall effect, Brownian movement, electrophoresis and electro-osmosis, protective colloids and gold number.

Chem H 102: Practical (*Organic – Honours Only*) 25 Marks

Laboratory Course (Organic Chemistry)

Total Time Practical Exams: ***6 hours***

1. Qualitative Analysis *20 marks*

Systematic qualitative analysis of organic compounds containing **two** functional groups:

(a) Detection of elements (N, Cl, Br, I and S)

(b) Determination of any two of the following functional groups present in a single organic compound (with systematic reporting)

-COOH, -OH (phenolic), -CHO, -CO-, $-NH_2$, $-NO_2$, $-CONH_2$, $-SO_3H$

(c) Determination of the melting point/boiling point of the compound

(d) Identification of the compound with help of a reference book

(e) Preparation of the derivative and determination of its melting point

2. Viva Voce *3 marks*

3. Laboratory Record (Internal Assessment) *2 marks*

Chem E 103: Practical (*Organic – Elective Only*) 25 Marks

Laboratory Course (Organic Chemistry)

Total Time Practical Exams: ***6 hours***

1. Qualitative Analysis *15 marks*

Systematic qualitative analysis of organic compounds containing **one** functional group:

(a) Detection of elements (N, Cl, Br, I)

(b) Determination of one of the following functional groups (with systematic reporting)
-COOH, $-NH_2$, $-NO_2$, -OH (phenolic), -CHO and –CO-

(c) Preparation of the derivative

2. Viva Voce *5 marks*

3. Laboratory Record (Internal Assessment) *5 marks*

Note: Courses **Chem H 102** and **Chem E 103** are different courses with separate papers.

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Second Semester **Total: 100 Marks**

Chem EH 201: *Inorganic, Organic & Physical Theory* — *75 marks*

Part A (Inorganic) — 25 marks

Unit I — *12 ½ marks*

(a) ***Principles of Qualitative and Quantitative Analysis***: Solubility product and its applications in the Group separations of cations, Volumetric analysis – standard solutions, primary standards, expressing concentrations of standard solutions, redox titrations (potassium permanganate, potassium dichromate, sodium thiosulphate and iodine), iodometric and iodimetric titrations, acid-base indicators and its theory.

(b) ***Acid-Base Concept***: Arrehenius and Bronsted-Lowry concept, the solvent-system (Franklin) concept and its limitations; Lewis concept; effect of solvent on relative strengths of acids and bases – leveling effect; Relative strengths of acids and bases (pK_a and pH concept).

Unit II — *12 ½ marks*

(a) ***Redox Reactions***: Electronic concepts of oxidation and reduction, oxidation number, common oxidants and reductants, balancing of redox reactions by ion electron method, calculation of equivalent weights of oxidants and reductants, standard electrode potential, electrochemical series and its application.

(b) ***Some Concepts of Metallurgy***: Minerals and ores, principles and methods of extraction – concentration, oxidation, reduction, electrolytic method and refining, occurrence and principles of extraction of aluminium, copper and iron.

(c) ***Industrial Chemistry***

(i) Fertilizers – Nitrogen fertilizer, manufacture of ammonia, and urea. Phosphatic fertilizers – calcium superphosphate, and NPK fertilizers.

(ii) Cement – constituents, manufacture and setting process, role of gypsum.

(iii) Paints and Pigments: constituents of paints; classification of pigments on the basis of their colour with examples.

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Part B (Organic) **25 Marks**

Unit III *12½ marks*

(a) ***Nucleophilic Substitution Reactions***: Nucleophile, ambident nucleophile, SN^1, SN^2, SN^i, factors affecting substitution reactions (structure of substrate, nature of nucleophile, solvent, role of leaving group), mechanism and stereochemistry of substitution reactions difference between nucleophile and bases.

(b) ***Elimination reactions:*** E^1, E^2, E^1cB mechanisms, orientation in elimination reactions (Saytzeff's and Hoffmann's rules).

(c) ***Alkyl Halides***: Preparation and reactions (hydrogenolysis, aqueous and alcoholic KOH, NH_3, carbon nucleophiles, sulphur nucleophiles, KCN, AgCN, KNO_2, $AgNO_2$, RCOOAg, RONa, Mg, Li, Na).

(d) ***Aromatic Halogen Compounds***: Introduction preparation and chemical reactivity, nuclear and side chain halogenation, electrophilic and nucleophilic substitution in aromatic halogen compounds. Role of ring substituents in nucleophilic substitutions.

Unit IV *12½ marks*

(a) ***Alcohols***: Classification and nomenclature, method of preparation including hydration, hydroboration-oxidation and oxymercuration-reduction, industrial prepration of ethyl alcohol (from molasses and starch), reaction of alcohols, distinction between primary, secondary and tertiary alcohols (Victor Meyer's test, Lucas test), preparation and chemical reactions of glycol (HNO_3, HCl, PX_3, terephthalic acid, Oxidation) and glycerol (HNO_3, HI, oxalic acid, $KHSO_4$)

(b) ***Phenols***: Nomenclature, structure and bonding. Preparation, industrial preparation from Cumene, physical properties and acidic character, chemical reactions, nitration, halogenation, sulphonation, Kolbe's reaction, Reimer-Tiemann reaction, phenol-formaldehyde resin.

(c) ***Aldehydes and Ketones***: Nomenclature and structure of the carbonyl group, method of preparation of aldehydes and ketones (both aliphatic and aromatic), chemical reactivity of carbonyl group, mechanism of nucleophilic additions and addition-elimination reactions with HCN, $NaHSO_3$, NH_2OH, NH_2-NH_2, $C_6H_5NHNH_2$, $NH_2CONHNH_2$) and Cannizzaro reaction; acidity of α-hydrogen in carbonyl compounds and formation of enolates, aldol condensation,

Perkin reaction and reactions with Grignard reagents, benzoin condensation, reduction and oxidation reactions (Clemmensen and Wolff-Kishner reductions).

Part C (Physical) **25 Marks**

Unit V *12.5 marks*

a) ***Thermodynamics-I*:** Definition of thermodynamic terms- system and surrounding, types of systems, intensive and extensive variables, types of processes- isothermal, adiabatic, isobaric, reversible, irreversible and cyclic processes; Thermodynamic functions- state variables and exact differentials, concept of heat and work, path functions and inexact differentials, zeroth law of thermodynamics, work done during reversible volume change of ideal gas.

First law of thermodynamics: Statement, internal energy, enthalpy, heat capacity at constant pressure (C_p) and volume (C_v), relation between C_p and C_v. Limitations of first law, spontaneous processes, statements of second law. Joule-Thomson coefficient and inversion temperature.

b) ***Macromolecules:*** Characteristics of macromolecules; degree of polymerization; concepts of number and weight average molecular mass; determination of molecular mass by osmometry and viscometry.

Unit VI *12.5 marks*

a) ***Thermochemistry*:** Exothermic and endothermic reactions, Hess's law of constant heat summation, enthalpy of formation, standard state, enthalpy of combustion, enthalpy of neutralization, enthalpy of solution, enthalpy of dilution, Kirchoff's equations- influence of temperature on ΔH and ΔU of a reaction

b) ***Adsorption and Surface Phenomena:*** Physisorption and chemisorption, adsorption isotherms, derivation and application of Langmuir adsorption isotherm, Freundlich adsorption isotherm.

Chem EH 202: *Practical* (Physical) *25 Marks*

Laboratory Course (Physical)

The following experiments are to be carried out in the class. In the examination, each student should be asked to do any **one** experiment from this list given below.

List of **Experiments**

1) Determination of the heat of neutralization of a strong acid by a strong base.
2) Determination of molecular weight by Rast's method
3) Study of the heat of dilution of H_2SO_4 and then to determine the strength of an umknown acid.
4) Determination of the velocity constant of the decomposition of hydrogen peroxide in presence of ferric chloride as catalyst by titrating against $KMnO_4$.
5) Determination of the solubility of $BaCl_2$/NaCl at two different temperatures and to determine the heat of solution.
6) Determination of the velocity constant of the hydrolysis of methyl acetate catalysed by an acid.

Assignment of Marks

Viva Voce	: 05 Marks
Laboratory Record	: 05 Marks
Experiment	: 15 Marks

Third Semester **Total: 100 Marks**

Chem **EH 301**: ***Inorganic, Organic & Physical Theory*** ***75 marks***

Part A **(Inorganic)** **25 marks**

Unit I: **s- and p-Block Elements and Their Compounds** *8 marks*

Group discussion of the elements with respect to position in the periodic table, electronic configuration, atomic and ionic radii, ionization enthalpy, electron gain enthalpy, electronegativity, oxidation states, variation of acidic and basic properties of their oxides and oxy-acids, inert pair effect and catenation.

Preparation, important reactions, structure and use of the following compounds: sodium thiosulphate. potassium iodide, boric acid, aluminium chloride, lithium aluminium hydride, hydrazine, and lead tetraacetate.

Unit II: d- and f-Block Elements 8 *marks*

Electronic configuration of d-block elements. Transition metals-defination andcharacterstic features of transition metals, relative stability of oxidation states. variation of properties in first, second and third row transition metals.

Electronic configurations of lanthanides and actinides, comparison of their oxidations states, synthetic elements, variation in their atomic and ionic radii – lanthanide contraction ,difficulty in the separation of lanthanides – and ion exchange method of separation.

Preparation, important reactions, structures and uses of nickel tetracarbonyl, potassium ferrocyanide, potassium ferricyanide, potassium dichromate, potassium permanganate, and uranium hexafluoride.

Unit III: Coordination Compounds 9 *marks*

Werner's Coordination theory, coordination number, ligands and their classification, chelation, applications of chelate formation; nomenclature of coordination compounds, effective atomic number rule, isomerism in coordination compounds, geometrical and optical isomerism in 4- and 6-coordinate complexes; Sidgwick's effective atomic number rule, stereochemistry of complexes with coordination numbers 4 and 6, bonding in transition metal complexes: valence bond theory and elementary idea of crystal field theory for octahedral and tetrahedral complexes.

Part B **(Organic)** **25 Marks**

Unit IV *12½ marks*

(a) ***Carboxylic Acids and their Derivatives*:** Nomenclure, structure and bonding, effect of substituents on the acidity of carboxylic groups, methods of preparation, chemical reactivity, reactions of oxalic acid, succinic acid and citric acid. Preparation and properties of acid chlorides, amides, esters and anhydrides.

(b) ***Organometallic Compounds-I:*** Grignard reagents: Synthesis of alkanes, alcohols, acids, aldehydes, ketones, amines with mechanism. Organolithium compounds: preparation and reactions with H_2O, CO_2 & epoxide.

(c) ***Active Methylene Compounds*:** Active methylene group, examples of active methylene compounds, tautomerism, difference between tautomerism and resonance (keto-enol tautomerism). Synthetic use of ethyl acetoacetate and diethyl malonate.

Unit V *12½ marks*

(a) ***Nitro Compounds (Aliphatic and Aromatic)*:** Preparation, properties (aliphatic)– α–hydrogen acidity, halogenation, reaction with NaOH, HNO_2, hydrolysis, carbonyl compounds. Reduction of aromatic nitro compounds (aliphatic and aromatic)

(b) ***Amines (Aliphatic and Aromatic):*** Nomenclature and structure of amines, preparation of amines, basicity and effect of substituents on basicity, chemical reactivity- acylation, action of nitrous acid, action of CS_2, carbyl amine reaction, condensation with carbonyl groups and ring substitution. Distinction between primary, secondary and tertiary amines and their separation.

(c) ***Diazo Compounds*:** Preparation and stability of diazo compounds (aliphatic and aromatic). Reactions of benzene diazonium chloride. Preparation and reactions of diazomethane.

Part C **(Physical)** **25 Marks**

Unit VI *12½ marks*

(a) ***Thermodynamics-II*:** Carnot cycle and its efficiency, Carnot's theorem, Entropy (S) as a state function, entropy changes of ideal gases in different processes. Gibbs function (G) and Helmholtz function (A), criteria for thermodynamic equilibrium and spontaneity, variation ΔG

and A with pressure, volume and temperature. Gibbs-Helmholtz equation, Clausius-Clapeyron equation, Trouton's rule.

3. ***Chemical Equilibrium:*** Law of mass action, equilibrium constant (K) from thermo-dynamic considerations, temperature and pressure dependence of equilibrium constants (K_p and K_c) – van't Hoff equation, relation of K_p and K_c, equilibria in homogeneous and heterogeneous systems, Le Chatelier's principle.

Unit VII *12½ marks*

1. ***Chemical Kinetics-I*:** Rate of reaction and rate constant, molecularity and order of a reaction, zero order reaction, differential and integrated forms of rate equations of first and second order reactions, pseudo-unimolecular reactions, determination of order of reactions, effect of temperature on reaction rates and energy of activation, effect of catalyst.

2. ***Dilute Solutions*:** Colligative properties, Raoult's law and Henry's law, relative lowering of vapour pressure, elevation in boiling point, depression in freezing point, osmosis, osmotic pressure and its determination, relation between colligative properties and molecular mass, determination of molecular mass, van't Hoff factor, abnormal molar mass, Reverse osmosis and its applications.

CHEM EH 302: Practical *(Inorganic-I)* **25 marks**

Laboratory Course (Inorganic)

Practical Examination Time: **6** hours

Part I: Qualitative Analysis *20 marks*

Inorganic Mixtures containing five radicals/ions to be analyzed – one of the radicals /ions must be interfering (borate, chromate or phosphate). Following ions/radicals to be included:

Pb^{2+}, Hg_2^{2+}, Hg^{2+}, Cu^{2+}, Cd^{2+}, Bi^{3+}, As^{3+}, Sb^{3+}, Sn^{2+}, Sn^{4+}, Fe^{2+}, Fe^{3+}, Al^{3+}, Ba^{2+}, Cr^{3+}, Zn^{2+}, Co^{2+}, Ni^{2+}, Ca^{2+}, Sr^{2+}, Mg^{2+}, K^+, NH_4^+.

Br^-, I^-, SO_4^{2-}, NO_3^-, BO_3^{3-}, PO_4^{3-}, CrO_4^{2-}.

Part II: *5 marks*

Sessional Work : 2 marks

Viva Voce : 3 marks

Fourth Semester — *Total: 100 Marks*

Chem EH 401: *Inorganic, Organic & Physical Theory* — *75 marks*

PART A (Inorganic) — **25 Marks**

Unit I — *15 marks*

a) ***Organometallic Chemistry-I:*** Definition and classification; synthesis, properties, nature of bonds, structure and application of one organometallic compound each of lithium, magnesium, and iron.

b) ***Inorganic Polymers:*** General properties of Inorganic polymers and distinction from the organic polymers; synthesis, structural aspects and uses of silicones, phosphonitrilic halides, phosphazenes, and tetrasulphurtetranitride.

c) ***Interhalogens, Polyhalides and Pseudohalides*** – types of interhalogens and their reactivity, polyhalides of iodine, definition of pseudohalides – study of CN^-, SCN^-, structure of ClF_3, BrF_3, BrF_5 and IF_7.

Unit II — *10 marks*

a) ***Earth's Atmosphere***: Acid rain, smog, ozone layer (formation, decomposition, ozone hole).

b) ***Waste-water treatment***: General criteria and guidelines; primary treatment, secondary treatment (activated sludge process and use of coagulants), and tertiary treatments processes disinfection, sand bed filtration, electrodialysis, reverse osmosis).

c) ***Solid waste disposal***: Composting; anaerobic digestion of biological wastes; incineration and landfills; e-pollution.

d) ***Radioactive waste***: Types, sources and methods of disposal.

Part B (Organic) — **25 Marks**

Unit III — *12½ marks*

(a) ***Carbohydrates-I***: Classification and nomenclature, interrelationship among monosachharides. Reaction of glucose and fructose with Br_2, HCN, Tollen's reagent, Fehling's solution, hydroxylamine, phenylhydrazine, HNO_3 and osazone formation. Elucidation of pyranose and

furanose structures. Determination of ring size. Haworth projection formula, configuration of glucose and fructose. Epimerization, inter-conversion of aldoses and ketoses. Ascending and descending series.

***(b) Amino Acids*:** Classification, synthesis of α-haloacids and Gabriel syntheses of glycine, alanine, phenyl alanine; glutamic and aspartic acids. Physical properties, isoelectric points and zwitterionic structure. Elementary ideas of proteins and peptides.

***(c) Urea*:** Preparation of urea, reactions of urea with HNO_3, H_2O, HNO_2, NaOBr, CH_3COCl, C_2H_5OH, NH_2NH_2 and diethyl malonate, formation of biuret.

***(d) Drugs*:** Classification of drugs as antipyretic, analgesic, antibacterial, antiviral, antibiotic, sulpha drugs and tranquilizer with one example each. Synthesis and use of aspirin, paracetamol, sulphaguanidine, barbituric acid.

Unit IV *12½ marks*

(a) Heterocyclic Compounds-I: Introduction; molecular orbital picture, aromatic charact-eristics and resonance, preparation and electrophilic substitution reactions of pyrrole, furan and thiophene. Structure, synthesis and reactions of pyridine, comparative basicity of pyrrole/ pyridine, pyrrole/ pyrrolidine and pyridine/ piperidine.

(b) Fats, Oils, Soaps and Detergents: Animal and vegetable oils, drying and non-drying oils, hydrogenation, iodine value, RM value and saponification value, soaps and detergents, mechanism of cleansing action of soap and detergents.

***(c) Dyes*:** Relationship between colour and constitution, chromophore and auxochrome, classification of dyes (based on structure and application), syntheses of methyl orange, Bismarck brown, Malachite green and phenolphthalein.

Part C (Physical) **25 Marks**

Unit V *12½ marks*

(a) Ionic Equilibrium: Ostwald's dilution law and its uses, dissociation equilibria of weak electrolytes, dissociation constant of weak acids (K_a), ionic product of water (K_w), hydrogen ion concentration and pH scale, buffer solutions and buffer activity, hydrolysis constant (K_b), relation between K_a, K_w and K_b, derivation of hydrolysis constant for salts of (i) strong acid and

weak base, (ii) weak acid and strong base and (iii) weak acid and weak base, solubility product, common ion effect.

(b) ***Electrochemistry-I*****:** Electrical transport –conduction in metals and in electrolyte solutions, specific conductance, equivalent and molar conductances and their determination, variation of equivalent and specific conductance with concentration of strong and weak electrolytes. Migration of ions and Kohlrausch law, transport numbers and their determination using Hittorf's and moving boundary methods. Arrhenius theory of electrolyte dissociation.

Unit VI *12½ marks*

(a) Electrochemistry-II: Electrochemical cells. Half cells: types and examples; types of reversible electrodes; Electrode reactions; Nernst equation and standard electrode potentials; different types of electrodes, reference electrodes; sign conventions; electrochemical series.

(b) Phase Equilibria**:** Phase rule and meaning of the terms phase, components and degrees of freedom, equilibrium between phases, phase diagram for one component systems (water and sulphur systems), Typical phase diagrams of two component systems involving eutectic (KI-H_2O), congruent (phenol-aniline) and incongruent (NaCl-H_2O) melting points.

Liquid-liquid mixtures, fractional distillation of binary miscible liquids, azeotropes (ethanol-water system), partial miscibility of liquids, lower and upper critical solution temperatures (triethylamine-water, phenol-water and nicotine-water systems), steam distillation, Nernst distribution law – derivation and its application.

Chem EH 402: *Practical (Inorganic-II)* **25 marks**

Laboratory Course (Inorganic)

Total Practical Examination Time: **6** hours

Part I : Quantitative Analysis ***20 marks***

Volumetric Estimation: Redox titration involving potassium permanganate, and potassium dichromate for the estimation of Fe^{2+}, Fe^{3+} and Ca^{2+} and iodometric estimation of Cu^{2+}.

Part II: ***5 marks***

a) Sessional Work: 2 Marks

b) Viva Voce: 3 Marks

Fifth Semester — *Total: 200 Marks*

Chem H 501: Inorganic Theory — 50 marks

Unit I *10 marks*

(a) Molecular Symmetry: Symmetry elements and symmetry operations: symmetry planes and reflections, inversion center, proper axis and proper rotations, improper axis and improper rotations; molecular point groups; systematic classification of molecules into point groups with examples{(i) linear molecules, ($C_{\infty v}$, D_{∞}h), (ii) molecules with no C_n or S_n,(C_s and C_1 only) , (iii) molecules with cubic point group, (T_d and O_h) , (iv) H_2O, NH_3, $XeOF_4$, XeF_4, PF_5, B_2H_6, Cyclohexane (chair and boat forms)}.

(b) Error Analysis: Significant figures; errors, types of error; accuracy and precision; normal distribution of indeterminate errors; propagation of errors – mean and standard deviations; rejection of data – the F-test, t-test and Q-test.

Unit II *10 marks*

(a) Complexometric titration (using EDTA), metal ion indicators, masking and demasking reagents; principles of argentometric titrations, estimation of chloride using adsorption indicators; principles of gravimetric estimation of chloride, theory of precipitation, co-precipitation, post-precipitation and digestion of the precipitate.

(b) Organic Reagents in Inorganic Analysis: Basic qualities of the reagents and conditions; advantages of organic precipitants and their limitations; study of Oxine, α-nitroso β-naphthol, cupferron, cupron, and dimethylglyoxime .

Unit III *10 marks*

Nucleus and Radioactivity-II: Types of radioactive decay; radioactive equilibrium; spontaneous fission, nuclear reactions, Q value, principles of separation of isotopes – gaseous diffusion, electrolysis and electromagnetic separation methods; application of radioisotopes as tracers; detection and measurement of radioactivity.

Stability of nucleus and nuclear forces, magic number concept, nuclear binding energy; Basic principles and types of nuclear reactors; India's Nuclear Energy Programme.

Unit IV *10 marks*

Crystal Field Theory (CFT): (i) d-orbital splitting by electrostatic field (octahedral, tetrahedral and square planar geometry), and (ii) magnetic properties (high spin and low spin complexes); factors affecting crystal field splitting energy (10Dq value) and spectrochemical series; Structural and thermodynamic effects of d-orbital splitting, variation of ionic radii, Jahn-Teller effect, hydration and lattice energies of first row transition metal ions; octahedral vs. tetrahedral coordination; adjusted CFT and molecular orbital theory for octahedral complexes.

Unit V *10 marks*

***Magnetochemistry*:** Explanations of diamagnetism, paramagnetism, ferromagnetism and anti-ferromagnetism, origin of paramagnetic moment: electron spin moment and orbital angular moment, magnetic susceptibility, Curie law, Curie-Weiss law, Bohr magneton, magnetic susceptibility measurement by Gouy and Faraday methods; explanation of magnetic behaviour of $K_4[Fe(CN)_6]$, $K_3[Fe(CN)_6]$, $[Co(NH_3)_6]Cl_6$, $K_2[Ni(CN)_4]$, $K_3[CoF_6]$, $K_3[MnF_6]$, $Ni(CO)_4$.

Chem H 502: Organic Theory — 50 Marks

Unit I — *12½ marks*

***(a) Organic Acids and Bases*:** Bronsted-Lowry and Lewis concepts of acids and bases, electro-negativity, polarity of bonds and dipole moment, inductive effect and its role in substituted aliphatic carboxylic acids. Relative strengths of acids and bases [alcohols, phenols, carboxylic acid, dicarboxylic acids, amines, heterocyclic compounds, carbon acids and bases]; pKa concept; effect of resonance, induction, hybridisation, H-bonding and steric effect on acidity and basicity of molecules.

***(b) Polynuclear Aromatic Hydrocarbons*:** Introduction; molecular orbital structure of naphthalene; resonance; Preparations, reactions, mechanism and orientation of electrophilic substitution. Preparations and reactions of α- and β-naphthols (azo-coupling, reactions with HNO_2 and $FeCl_3$. Preparation and reactions of anthracene.

Unit II — *12½ marks*

***(a) Organic Stereochemistry-II*:** Nomenclature of enantiomers (R and S); relative and absolute configuration; inversion, retention, conformation and conformational isomerism in ethane and *n*-butane; conformation of cyclic compounds – cyclohexane, mono-substituted and disubstituted cyclohexanes with reference to their relative stability; stereochemical aspects of addition of bromine to alkenes.

***(b) Introduction to Dienes*:** Conjugated, isolated and cumulated dienes (allenes); preparations and reactions of conjugated dienes (1,3-butadiene and isoprene). Addition reaction of 1,3–dienes (1,2 and 1,4).

***(c) Polymers*:** Types of polymers and polymerization processes. Addition (chain-growth) polymerization; free radical vinyl polymerization; ionic vinyl polymerization [Ziegler–Natta polymerisation]. Condensation (step-growth) polymerization, polyesters, polyamides, urea-formaldehyde resins, polyurethanes. Natural and synthetic rubbers.

Unit III — *12½ marks*

***(a) Introduction to Organic Synthesis*:** Formation of carbon-carbon bond, electrophilic and nucleophilic carbon species, acid-assisted reaction (Friedel Crafts alkylation and acylation,

Gatterman-Koch formylation), base assisted condensations (Knoevenagel, Michael, Wittig reaction, Claisen reaction, Claisen-Schmidt reaction, Mannich reaction).

Formation and acid-assisted cleavage of acetals and ketals, mechanisms of formation and hydrolysis of esters and amides (acyclic and cyclic).

***(b) Rearrangements*:** Carbocation rearrangements – pinacole-pinacolone, Wagner-Meerwein, dienone-phenol. Beckmann, Wolff, Hofmann, Curtius, Lossen, Schmidt, benzil-benzilic acid, benzidine-semidene, Favorskii, Fries and Claisen rearrangements.

***(c) Inorganic Reagents in Organic Synthesis*:** $NaBH_4$, $LiAlH_4$, B_2H_6, Na/liq.NH_3, aluminium isopropoxide, $KMnO_4$, $K_2Cr_2O_7$, HIO_4, Lead tetraacetate, peracids.

Unit IV *12½ marks*

***(a) Heterocyclic Compounds-II*:** Introduction to condensed five- and six-membered heterocycles, preparation and reactions of indole, quinoline and isoquinoline with special reference to Fischer-Indole synthesis, Skraup and Bischler-Napieralski syntheses.

***(b) Green Chemistry*:** Definition, goals, principles and techniques (brief discussions); Applications to common reactions. Solvent free reactions, Ultrasound reactions, Microwave assisted reactions, Reactions in aqueous and ionic media.

***(c) Interconversions*:** Interconversion involving following functional groups (mechanism not required): -OH. –CHO, -CO, -COOH, -COOR,-$CONH_2$, -NH_2, NHR, -NO_2, -CN, SO_3H, X(Cl, Br, I). (Aliphatic to aliphatic and aromatic to aromatic)

Chem H 503: Physical Theory 50 Marks

Unit I: Gaseous State-II *12 marks*

Maxwell's distribution law of molecular speeds, molecular speeds and energy distribution as a function of temperature, calculation of the most probable, average and root mean square speeds of molecules, Maxwell-Boltzmann distribution, degrees of freedom of motion, principle of equipartition of energy, collision diameter, collision cross-section, collision frequency and mean free path, viscosity of gases, Boyle temperature, critical phenomena-critical constants, p-v isotherm of carbon dioxide, continuity of state, law of corresponding states and reduced equation of state, vapour density and limiting density.

Unit II: Liquid State-II *8 marks*

Determination of surface tension, viscosity and refractive index of liquids. Physical properties and chemical constitution- additive and constitutive properties, molar volume, parachor, specific and molar refraction. Polar and non-polar liquids, dielectric constant, dipole moment, structure of molecules, polarization, Clausius-Mossotti equation.Dipole induced dipole and vander Waals interactions in molecules.

Unit III: Crystalline State-II *8 marks*

Symmetry elements in crystals-plane of symmetry, axis of symmetry, centre of symmetry, seven crystal systems, Law of symmetry, Bravais lattices, X-ray diffraction of crystals, Bragg's law, crystal structure determination-Laue's method and powder method, Frenkel and Schottky defects.

Unit IV: Thermodynamics-III *10 marks*

Thermodynamic scale of temperature, , Maxwell's relations, definition of chemical potential., concept of chemical potential, equilibrium between different phases, derivation of phase rule from the concept of chemical potential, partial molal quantities, variation of chemical potential with temperature and pressure, chemical potential of a component in an ideal mixture, Gibbs-Duhem equation.

Nernst heat theorem, third law of thermodynamics and its application to the determination of entropy, concept of residual entropy.

Unit V: Chemical Kinetics-II *12 marks*

Catalyzed reactions – homogeneous catalysis, acid-base catalysis, enzyme catalysis - Michaelis-Menten equation; Theory of Reaction rates – collision theory, transition state theory of unimolecular and bimolecular reactions.

Complex reactions – opposite, parallel, consecutive and chain reactions, rate determining step, steady state approximation and derivation of rate laws of complex reactions.

Chem H 504 (Practical – Organic) 25 Marks

Laboratory Course (Organic)

Total Time for Practical Exams: ***6 hours***

1. Separation of Mixtures *8 marks*

(a) Separation of binary organic mixtures based on acid-base concept

(b) Determination of melting points

2. Organic Preparation *12 marks*

(a) Preparation of the following compounds

(i) Phthalimide (from phthalic anhydride)

(ii) m-Dinitrobenzene (from benzene)

(iii) Picric acid (from phenol)

(iv) p-Bromoacetanilide (from acetanilide)

(v) Benzilic acid (from benzil)

(vi) Methyl Orange (from sulphanilic acid)

3. Viva Voce *3 marks*

4. Laboratory Record (Internal Assessment) *2 marks*

Chem H 505 (Practical – Physical) 25 Marks

Laboratory Course (Physical)

Total Practical Examination Time: **6 hours**

The following experiments are to be carried out in the class. In the examination, each student should be asked to do any **one** experiment

List of Experiments

1. Conductometric titrations of an acid by a base.
2. Acid-base titration using potentiometer.
3. Verification of Beer-Lambert's law using copper sulfate or $K_2Cr_2O_7$ solution colorimetrically and determination of the concentration of the supplied solution
4. Determination of velocity constant for the decomposition of hydrogen peroxide using ferric chloride as catalyst; and to determine the activation energy.
5. Determination of the heat of solution of solid calcium chloride and to determine lattice with the help of Born-Haber cycle.
6. Determination of the critical solution temperature of the phenol-water system.
7. Study on the kinetics of the reaction between potassium persulfate and potassium iodide at two temperatures with determination of activation energy
8. Study of the adsorption of oxalic acid on charcoal and verification of Freundlich's adsorption isotherm.
9. Determination of surface tension of a liquid/solution by drop-weight method.
10. To obtain the viscosity–composition (v/v) curve of ethanol-water/ glycerol-water/ methanol-water system and to determine the composition (v/v) of a given unknown mixture.
11. Determination of partition coefficient of a solute between two immiscible solvents (e.g. iodine in water/organic solvent; benzoic acid in water/benzene).
12. Determination of pKa value of different sets of buffer by pH-metric titration using glass electrode

(*cont'd* .....

Distribution of marks:

Viva Voce	:	05 Marks
Laboratory Record:		05 Marks
Experiment:		15 Marks

Sixth Semester — *Total: 200 Marks*

Chem H 601: Inorganic Theory — 50 marks

Unit I: Organometallic Chemistry-II *12 marks*

Synthesis, properties, nature of bonds, structure and application of organometallic compounds of lithium (alkyl and aryl), magnesium (RMgX and MgR_2), iron (ferrocene) and tin (R_3SnX, R_2SnX_2 types); metal-ethylenic complexes and homogeneous hydrogenation;

Π-acid ligands, mononuclear and dinuclear carbonyls and nitrosyls and the nature of bonding in them – their uses in metallurgy; Important applications of organometallic compounds in heterogeneous catalysis – hydrogenation of alkenes using Wilkinson's catalyst and synthesis of acetic acid using rhodium carbonyl iodide catalyst.

Unit II: Bioinorganic Chemistry *12 marks*

Essential and trace elements in biological processes, criteria of essential elements, pH of biological fluid, metalloporphyrins, structure, and functions of haemoglobin, myoglobin and chlorophyll; role of Fe and Mg in haemoglobin and chlorophyll, role of Co in vitamin B_{12}, Carbonic anhydrase, its characteristics and functions,. Non-complexing cations in biochemical processes, Na^+-K^+ pump; Toxic effects of metal ions with reference to mercury, lead, beryllium and aluminum; deficiency of Fe, Ca, Mg and iodine; Platinum complexes as anti-cancer drugs.

Unit III: Spectroscopic Methods in Inorganic Chemistry *10 marks*

Application of the following techniques for Inorganic and Coordination compounds:

(a) UV-Visible Spectroscopy: Free ion terms and their splitting in octahedral symmetry, Selection rules, Orgel diagrams for octahedral and tetrahedral complexes (d^1, d^2, d^8,and d^9 systems).

(b) IR Spectroscopy: Basic principles, spectral studies of coordination compounds containing following molecules or ions as ligands: H_2O, CN, CO, SO_4^{2-}, and halides (F, Cl, Br, I)

Unit IV *8 marks*

Reactivity of Coordination Compounds: Thermodynamic stability; Stepwise formation constant, Kinetic lability and inertness, Mechanisms of Ligand displacement reactions in octahedral and

square planar complexes, the *trans* effect, Determination of composition of complexes by spectrophotometric method.

Unit V *8 marks*

Nanomaterials: General introduction to nanomaterials and emergence of nanotechnology, Types of nano materials, Synthesis of nanoparticles of gold, platinum and silver; properties of nanoparticles; important applications of nanoparticles.

Chem H 602: Organic Theory — 50 Marks

Unit I — *12½ marks*

(a) ***Carbohydrates-II***: Disaccharides: Maltose and sucrose – their reactions and structure, structure of cellulose and starch (detailed study not required), preparation of cellulose nitrate, cellulose acetate and cellophane.

(b) Natural Products: (i) Terpenoids: Introduction, isoprene rule, classification, isolation, structural elucidation and syntheses of citral and geraniol. (ii) Alkaloids: Introduction, classification, physiological action, extraction and syntheses of nicotine and cocaine.

Unit II — *12½ marks*

(a) Peptides, Proteins and Vitamins: *(i) Peptides* – definition and preparation of di- and tripeptides from α-amino acids. *(ii) Proteins* - introduction, classification, primary, secondary, tertiary and quart-ernary structures of proteins, α- and β-proteins, helical and sheet structures. *(iii) Vitamins* – definition, classification and biological importance of vitamins. Carotenoids – occurrence, isolation and synthesis, β-carotene as a source of vitamin A_1, synthesis of vitamin A_1 and ascorbic acid.

(b) Topics in Biological Chemistry: *(i) Enzymes* – Introduction, nomenclature and characteristics. Mechanism of enzyme action (a general picture); mechanism of action of the enzyme chymotripsin as a peptidase.; co-enzyme, co-enzymes derived from niacin and thiamine, lipoic acid, co-enzyme A, energy production in biological system (role of ATP and ATP-ADP cycle), glycolysis and tricarboxylic acid cycle. *(ii) Nucleic acids*: Structure of purine and pyrimidine bases in nucleic acid (adenine, guanine, cytosine, uracil and thiamine) [no synthesis]. Structure of nucleosides, nucleotides and DNA, replication of DNA.

Unit III — *12½ marks*

(a) Organic Photochemistry: Molecular energy and photochemical energy, excitation of molecules, Franck-Condon principle, dissipation of energy, Jablonski diagram, singlet-triplet states, fluorescence and phosphorescence, photosensitization and quenching, quantum yield. Introduction to photochemical reactions of carbonyl compounds, photoreduction. Norrish Type I and Type II cleavages. Paterno-Buchi reaction.

***(b) Pericyclic Reactions*:** Definition and scope of pericyclic reactions. *(i) Electrocyclic reactions* – stereochemistry, conrotatory and disrotatory ring closures and ring opening (simple examples like 1,4 disubstituted 1,3-buta-diene, 1,6-disubstituted-1,3.5-hexatriene, 1,8-disubstituted-1,3,5,7-octatetraene). Woodward-Hoffmann rules for electrocyclic reactions, frontier molecular orbital theory (correlation diagram not required). *(ii) Cycloaddition reactions* - Definition of dienes and dienophiles, *supra-supra* and *antara-antara* modes of cycloadditions ($\pi_s^4 + \pi_s^2$, $\pi_s^4 + \pi_a^2$, $\pi_s^2 + \pi_s^2$, $\pi_s^2 + \pi_a^2$) by taking examples of simple dienes and dienophiles.

Unit IV Spectroscopy for Structural Analysis *12½ marks*

(a) Mass Spectrometry – Basic principles, types of ions produced in mass spectrometer, molecular ion peak, base peak and metastable ion, determination of molecular mass of organic compounds.

(b) Ultraviolet and Visible Spectroscopy – Basic principles of UV and visible spectroscopy, application to conjugated polyenes, carbonyl compounds and α,β-unsaturated carbonyl compounds, Woodward rules.

(c) Infrared Spectroscopy - Basic principles, characteristic vibrational frequencies of carbonyl compounds, hydroxyl and amino compounds.

(d) Nuclear Magnetic Resonance Spectroscopy - Basic principles, chemical shifts, shielding and deshielding of protons, chemically equivalent protons, PMR- peak area and proton counting. Characteristics protons - chemical shifts and coupling constants for ethyl bromide, toluene, p-xylene, o-and p-nitrotoluene, anisole, ethyl alcohol, ethyl acetate, acetaldehyde and acetic acid.

Chem H 603: Physical Theory — 50 Marks

Unit I: Boltzmann Distribution — **8 marks**

Idea of mathematical and thermodynamic probability; entropy and probability; Boltzmann distribution (without derivation) for non-degenerate and degenerate cases; application to barometric distribution formula. Idea of partition functions.

Unit II: Elementary Quantum Mechanics — **12 marks**

Failure of classical mechanics: Black-body radiation, Planck's radiation law, photoelectric effect, Compton effect, heat capacity of solids; Postulates of quantum mechanis; Model systems (with complete derivation of wavefunction & energy expression): Particle-in-a-box, rigid rotor, harmonic oscillator; quantum numbers and their importance.

Unit III: Molecular Spectroscopy — **12 marks**

Introduction: electromagnetic radiation, regions of the spectrum, basic features of different spectrometers, statement of the Born-Oppenheimer approximation, degrees of freedom.

Rotational and Vibrational spectra of diatomic molecules: frequency expressions, selection rules and applications to estimate molecular parameters; isotope effect in vibrational spectrum.

Unit IV: Photochemistry — **8 marks**

Beer-Lambert's law, Einstein's law; Concept of potential energy curves; Frank-Condon principle; primary photophysical processes; Jablonski diagram; Fluorescence and phosphor-escence; photochemical reactions and quantum yield, photosensitized reactions.

Unit V: Electrochemistry-III — **10 marks**

Activity and ionic activity coefficient; mean ionic activity. Ion atmosphere; electrophoretic and relaxation effects; Onsager equation (qualitative); Wien and Debye-Falkenhagen effects; Debye-Huckel theory (qualitative) and the limiting law. Solubility of sparingly soluble salts and ionic strength of medium. Standard cells, concentration cells (with and without transport), liquid junction potentials.EMF of a cell and its measurements. Calculation of thermodynamic parameters (ΔH, ΔG, ΔS and K) from cell EMF, polarization and over potential. Applications of Ag/AgCl, quinhydrone and glass electrodes. potentiometric titrations with examples.

Chem H 604: Practical (Inorganic) — 35 Marks

Laboratory Course (Inorganic Quantitative Analysis) — *25 marks*

Total Practical Examination Time: **12 hours**

Estimation (volumetric or gravimetric) of metal constituents from mixtures of Iron-Calcium, Iron-Copper, Copper-Zinc, Calcium-Barium, Copper-Nickel (separation of one metal constituent must be carried out).

Sessional Work and Viva Voce — *10 marks*

(a) *Sessional Work*: 3 marks

(b) *Viva Voce:* 7 marks

Chem H 605: Seminar — 15 Marks

The Seminar shall be conducted internally by the Department of Chemistry of the respective colleges. There shall be no external examiner, but the Seminar shall be conducted formally latest by the end of October each year. A Report of the same along with the marks awarded shall be sent to the Examinations Department on or before 30th November each year.

The Topic of the Seminar shall be decided by the Department and informed to the student at least 30 (thirty) days ahead of the exact date of the Seminar. Each student shall choose a topic in consultation with the Department. The topics must be from any of the subjects of contemporary interest in Chemistry. Students must submit a Write-up of the Seminar.

Marks distribution shall be as follows:

1. Write-up and content : 4 marks
2. Presentation : 7 marks
3. Questions/Answers : 4 marks

Recommended Text Books for B.Sc. (Chemistry)

A. Inorganic Chemistry

1. B.R. Puri, L.R. Sharma and K.C. Kalia, Principles of Inorganic Chemistry, S.L.N. Chand & Co., Jalandhar (2000).
2. G. Wulfsberg, Inorganic Chemistry, Viva Book Pvt. Ltd., New Delhi (2002).
3. F.A. Cotton and G. Wilkinson, Basic Advanced Inorganic Chemistry. Wiley Eastern Ltd., New Delhi (1990).
4. B.L. Agarwal and S.K. Agarwal, A Test Book of Inorganic Chemistry, Ratan Prakashan Mandir, Agra (1988).
5. G. Raj, Advanced Inorganic Chemistry, Vol. I & II, Geol Publishing House, Meerut (2001).
6. H.J. Arnikar, Essentials of Nuclear Chemistry, Wiley Eastern Ltd., New Delhi (1999).
7. A.K. De, Environmental Chemistry, New Age International, New Delhi (2002).
8. G.S. Dhaliwal, G.S. Sangha and P.K. Ralhan, Fundamentals of Environmental Science, Kalyani Publishers, Ludhiana (1998).
9. N. Dutt and P.K. Dutt, The Environment and its Problems, Sarat Book, Kolkata (2002).
10. A.I. Vogel (revised by G. Svehla), Qualitative Inorganic Analysis, 7th Ed., Pearson Edu. Asia Ltd., Delhi (2002).
11. A.I. Vogel (revised by G.H. Jeffery, J. Bassett, J. Mendham and R.C. Denney, Textbook of Quantitative Chemical Analysis, 5th ed., Addison Wesley Longman, Singapore (1999).
12. J.N. Gurtu and R. Kapoor, Advanced Experimental Chemistry, Vol. II, S. Chand & Co., New Delhi (1987).
13. D. Banerjee, Co-ordination Chemistry, Tata MeGraw-Hill, New Delhi (1999).
14. W.U. Malik, G.D. Tuli, S.K. Bose and R.D. Madan, Selected Topics in Inorganic Chemistry, 6th ed., S. Chand & Co., New Delhi (1995).
15. J.D. Lee, Concise Inorganic Chemistry, 4th ed., ELBS (1994).
16. R.K. Das, Industrial Chemistry Part I & II, Kalyani Publ., Ludhiana (1989).
17. S. Usha Rani, Analytical Chemistry, Macmillan, Delhi (2000).

B. Organic Chemistry

I. L. Finar, Organic Chemistry, Vol. I & II, 5th ed., Pearson Edu. Ltd., Delhi (2001).

2. G. Marc Loudon, Organic Chemistry, Oxford Univ. Press (2002).

3. J. Clayden, N. Greeves, S. Warren and P. Wothers, Organic Chemistry, Oxford Univ. Press (2000).

4. P.S. Kalsi, Stereochemistry, 4th ed., New Age International, New Delhi (2000).

5. P.S. Kalsi, Spectroscopy of Organic Compounds, 4th ed., New Age International, New Delhi (2000)

6. P.S. Kalsi, Organic Reactions and their Mechanism, 4th ed., New Age International, New Delhi (2000).

7. D. Nasipuri, Stereochemistry, 2nd ed., New Age International, New Delhi (1996).

8. T.W.G. Solomons, Organic Chemistry, 6th ed., John Wiley & Sons (1996).

9. B.S. Bahl and A. Bahl, Advanced Organic Chemistry, S. Chand & Co., New Delhi (1977).

10. R.T. Morrison and R.N. Boyd, Organic Chemistry, 5th edn., Prentice-Hall of India, New Delhi (1989).

11. J. March, Advanced Organic Chemistry, 3rd ed., McGraw Hill, New York (1985).

12. S.M. Mukherjee, S.P. Singh and R.P. Kappor, Organic Chemistry, Vol I, II & III, Wiley Eastern Ltd., New Delhi (1991).

13. S.M. Mukherjee and S.P. Singh, Reactions Mechanism in Organic Chemsitry, MacmIllan (1998).

14. Y.R. Sharma, Organic Absorption Spectroscopy, S. Chand & Co., Delhi (1992).

15. A.I. Vogel, A Text Book of Practical Organic Chemistry, Longmans (1999).

C. Physical Chemistry

1. P. Atkins and de Paula, Atkins' Physical Chemistry, 7th ed., Oxford Univ. Press (2002).
2. P.C. Rakshit (revised by S.C. Rakshit), Physical Chemistry, 6th ed., Sarat Book, Kolkata (2001).
3. B.R. Puri, L.R. Sharma and M.S. Pathania, Principles of Physical Chemsitry, S.L. N. Chand & Co., Jalandhar (1991).
4. G. Raj, Advanced Physical Chemistry, Goel Pub. House, Meerut (2002).
5. R.S. Berry, S.A. Rice and J. Ross, Physical Chemistry, Oxford Univ. Press (2000).
6. D.A. McQuarries and J.D. Simon, Physical Chemistry, Viva Books Pvt. Ltd., New Delhi (199[illegible]
7. G.M. Castellan, Physical Chemistry, Narosa Pub. House,Delhi (1986).
8. S. Glasstone, Textbook of Physical Chemistry, Macmillan India Ltd., Madras (1981).
9. W.J. Moore, Basic Physical Chemistry, Prentice Hall of India, New Delhi (1986).
10. G.M. Barrow, Physical Chemistry, McGraw Hill, New York (1983).
11. R.A. Alberty, Physical Chemistry 6th ed., Wiley Eastern Ltd., New Delhi (1991)
12. A.S. Negi and S.C. Annad, A Textbook of Physical Chemistry, Wiley Eastern Ltd., New Delhi (1991).
13. S. Glasstone, An Introduction of Electrochemistry, (Reprint), Affiliated East- West Press, New Delhi (2002).
14. J.B. Yadav, Advanced Practical Physical Chemistry, 20th ed., Goel Publ. House, Meerut (200[illegible]
15. V.D. Athawale and P.Mathur, Experimental Physical Chemistry, New Age International Publ., New Delhi (2001).
16. J.N. Gurtu and R.Kapoor, Advanced Experimental Chemistry, Vol.I,S. Chand & Co., New Delhi (1984).