

UNIVERSITY OF CALCUTTA

SYLLABI

FOR

THREE-YEAR B.Sc. HONOURS & GENERAL
COURSES OF STUDIES



Chemistry

2010

w.e.f. 2010-2011

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Chemistry Hons: Syllabus Scheme in modular form

Course names and distribution

PART – I (Year 1), total marks = 200 (Theory = 150, Practical = 50)

CHT	11a, 11b,	each 25 marks, Theory
CHT	12a, 12b,	each 25 marks, Theory
CHT	13a, 13b,	each 25 marks, Theory
CHP	14a+14b,	50 marks, Practical

PART – II (Year 2), total marks = 200 (Theory = 150, Practical = 50)

CHT	21a, 21b,	each 25 marks, Theory
CHT	22a, 22b,	each 25 marks, Theory
CHT	23a, 23b,	each 25 marks, Theory
CHP	24a+24b,	50 marks, Practical

PART – III (Year 3), total marks = 400 (Theory = 250, Practical = 150)

CHT	31a, 31b, 31c, 31d,	each 25 marks, Theory
CHT	32a, 32b, 32c,	each 25 marks, Theory
CHT	33a, 33b, 33c,	each 25 marks, Theory
CHP	34a, 34b,	25 and 50 marks, Practical
CHP	35a, 35b,	25 and 50 marks, Practical

Abbreviations:

CHP: Chem Hons Practical; CHT: Chem Hons Theory

First digit refers to year, second to paper.

Each CHT Exam = 1 hr for 25 marks, 2 hr for 50 marks, etc.

Each CHP Exam = 2-3 hr for 25 marks, 4 hr for 50 marks on each day

Notes:

1. Each Theory module of 25 marks contains units I (marks = 15) and II (marks = 10).
2. Number of class hours = 25-35 for a 25-mark Theory module, 70-80 for a 25-mark Practical module.

Chemistry Hons: Course Description

Year 1 PART – I

CHT 11a

Unit-I. Radioactivity and Atomic Structure

Nuclear stability and nuclear binding energy. Nuclear forces: meson exchange theory. Nuclear models (elementary idea): Concept of nuclear quantum number, magic numbers. Nuclear Reactions: Artificial radioactivity, transmutation of elements, fission, fusion and spallation. Nuclear energy and power generation. Separation and uses of isotopes. Radio chemical methods: principles of determination of age of rocks and minerals, radio carbon dating, hazards of radiation and safety measures.

Bohr's theory to hydrogen-like atoms and ions; spectrum of hydrogen atom. Quantum numbers. Introduction to the concept of atomic orbitals; shapes, radial and angular probability diagrams of s, p and d orbitals (qualitative idea). Many electron atoms and ions: Pauli's exclusion principle, Hund's rule, exchange energy, Aufbau principle and its limitation. Electronic energy level diagram and electronic configurations of hydrogen-like and polyelectronic atoms and ions. Term symbols of atoms and ions for atomic numbers < 30.

Unit-II. Chemical periodicity I

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. Position of hydrogen and noble gases in the periodic table.

Effective nuclear charges, screening effects, Slater's rules, atomic radii, ionic radii (Pauling's univalent), covalent radii. Ionization potential, electron affinity and electronegativity (Pauling's, Mulliken's and Allred-Rochow's scales) and factors influencing these properties. Inert pair effect. Group trends and periodic trends in these properties in respect of s-, p- and d-block elements.

CHT 11b

Unit-I. 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 (elementary idea).

Covalent bonding: Lewis structures, formal charge. Valence Bond Theory, directional character of covalent bonds, hybridizations, equivalent and non-equivalent hybrid orbitals, Bent's rule, VSEPR theory, shapes of molecules and ions containing lone pairs and bond pairs (examples from main groups chemistry), Partial ionic Character of covalent bonds, bond moment, dipole moment and electronegativity differences. Concept of resonance, resonance energy, resonance structures

Unit-II. Acid-Base reactions

Acid-Base concept: Arrhenius concept, theory of solvent system (in H₂O, NH₃, SO₂ and HF), Bronsted-Lowry's concept, relative strength of acids, Pauling rules. Amphoterism. Lux-Flood concept, Lewis concept. Superacids, HSAB principle. Acid-base equilibria in aqueous solution and p^H. Acid-base neutralisation curves; indicator, choice of indicators.

CHT 12a

Unit I. Acyclic stereochemistry

Representation of molecules in saw horse, Fischer, flying-wedge and Newman formulae and their inter translations, symmetry elements, molecular chirality.

Configuration: stereogenic units i) stereocentres: systems involving 1, 2, 3 centres, stereogenicity, chirotopicity. pseudoasymmetric (D/L and R/S descriptor, threo/erythro and syn/anti nomenclatures (for aldols) ii) stereoaxis: chiral axis in allenes & biphenyls, R/S descriptor; cis/trans, syn/anti, E/Z descriptors (for C=C, C=N).

Optical activity of chiral compounds: specific rotation, optical purity (enantiomeric excess), racemic compounds, racemisation (through cationic and anionic and radical intermediates), resolution of acids, bases and alcohols via diastereomeric salt formation.

Topicity of ligands and faces (elementary idea): Pro-R, Pro-S and Re /Si descriptors.

Conformation: Conformational nomenclature, eclipsed, staggered, gauche and anti; dihedral angle, torsion angle, energy barrier of rotation, relative stability of conformers on the basis of steric effect, dipole-dipole interaction, H-bonding; conformational analysis of ethane, propane, n-butane, haloethane, 1,2-haloethane, 1,2-glycol, 1,2-halohydrin; invertomerism of trialkylamines.

Unit II. 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-O 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 (C=C, conjugated diene and allyl systems) ii) cyclic p orbital system (neutral system: [4], [6] annulenes; charged system: 3,4,5-ring 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 (covalent & non covalent). Heat of hydrogenation and heat of combustion.

CHT 12b

Unit I. General treatment of reaction mechanism

Mechanistic classification: ionic, radical and pericyclic; heterolytic bond cleavage and heterogenic bond formation, homolytic bond cleavage and homogenic bond formation; representation of mechanistic steps using arrow formalism.

Reactive intermediates: carbocations (cabenium and carbonium ions), carbanions, carbon radicals, carbenes – structure using orbital picture, electrophilic/nucleophilic behaviour, stability, generation and fate (elementary idea)

Reaction thermodynamics: free energy and equilibrium, enthalpy and entropy factor, intermolecular & intramolecular reactions. Application of thermodynamic principles in tautomeric equilibria [keto-enol tautomerism, composition of the equilibrium in different systems (simple carbonyl, 1,3 and 1,2- dicarbonyl systems, phenols and related system), substituent and solvent effect].

Concept of acids and bases: effect of structure, substituent and solvent on acidity and basicity.

Reaction kinetics: transition state theory, rate const and free energy of activation, free energy profiles for one step and two step reactions, catalyzed reactions, kinetic control and thermodynamic control of reactions, isotope effect, primary kinetic isotopic effect (k_H/k_D), principle of microscopic reversibility, Hammond postulate.

Unit II. Nucleophilic substitution reactions

Substitution at sp^3 centre - Mechanism: S_N1 , S_N2 , S_N2' , S_Ni mechanisms, effect of solvent, substrate structure, leaving group, nucleophiles including ambident nucleophiles (cyanide & nitrite) substitution involving NGP; relative rate & stereochemical features [systems: alkyl halides, allyl halides, alcohols, ethers, epoxides].

Halogenation of alkanes and carbonyls.

Substitution at sp^2 carbon (carbonyl system) - Mechanism: $B_{AC}2$, $A_{AC}2$, $A_{AC}1$, $A_{AL}1$ (in connection to acid and ester). Systems: amides, anhydrides & acyl halides [formation and hydrolysis]

CHT 13a

Unit I. Kinetic theory and the gaseous state

Concept of pressure and temperature. Nature of distribution of velocities in one, two and three dimensions. Maxwell's distribution of speeds. Kinetic energy distribution in one, two and three dimensions, calculations of average, root mean square and most probable values in each case; calculation of number of molecules having energy $\geq \epsilon$, Principle of equipartition of energy and its application to calculate the classical limit of molar heat capacity of gases.

Collision of gas molecules; collision diameter; collision number and mean free path; frequency of binary collisions (similar and different molecules); wall collision and rate of effusion.

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 (Debye, Keesom and London interactions; Lennard-Jones potential, elementary idea).

Unit II. Thermodynamics – I

Importance and scope, definitions of system and surroundings; type of systems (isolated, closed and open). Extensive and intensive properties. Steady state and equilibrium state. Concept of thermal equilibrium and the zeroth-law of thermodynamics. Thermodynamic coordinates, state of a system, equation of state, state functions and path functions. Partial derivatives and cyclic rule. Concept of heat and work (IUPAC

convention). Graphical explanation of work done during expansion and compression of an ideal gas. Reversible and irreversible processes and work done.

First law of thermodynamics, internal energy (U) as a state function. Enthalpy as a state function. Heat changes at constant volume and constant pressure; relation between C_p and C_v using ideal gas and van der Waals equations. Joule's experiment and its consequence. Explanation of term $(\delta U/\delta V)_T$. Isothermal and adiabatic processes.

Thermochemistry: heat changes during physicochemical processes at constant pressure/volume. Kirchoff's relations. Bond dissociation energies. Changes of thermodynamic properties in different chemical changes.

CHT 13b

Unit I. Thermodynamics – II

Second law of thermodynamics – need for a Second law. Concept of heat reservoirs and heat engines. Kelvin – Planck and Clausius statements and equivalence of the two statements with entropic formulation. Carnot cycle and refrigerator. Carnot's theorem; thermodynamic scale of temperature.

Physical concept of entropy. Entropy as a measure of the microscopic but not macroscopic disorder. Values of $\int dQ/T$ and Clausius inequality. Entropy change of systems and surroundings for various processes and transformations. Entropy change during the isothermal mixing of ideal gases. Entropy and unavailable work. Auxiliary state functions (G and A) and their variation with T, P and V. Criteria for spontaneity and equilibrium.

Thermodynamic relations: Maxwell's relations, thermodynamic equation of state. Gibbs- Helmholtz equation, Joule-Thomson experiment and its consequences; inversion temperature. Joule-Thomson coefficient for a van der Waals gas. General heat capacity relations.

Unit II. Chemical kinetics

Introduction of reaction rate in terms of extent of reaction; rate constants, order and molecularity of reactions. Reactions of zero order, first order, second order and fractional order. Pseudo first order reactions (example using acid catalyzed hydrolysis of methyl acetate). Determination of order of a reaction by half-life and differential method. Rate-determining and steady-state approximation – explanation with suitable examples.

Opposing reactions, consecutive reactions and parallel reactions (with explanation of kinetic and thermodynamic control of products; all steps first order).

Temperature dependence of rate constant: Arrhenius equation, energy of activation. Homogeneous catalysis with reference to acid-base catalysis. Enzyme catalysis: Michaelis-Menten equation, turn-over number.

CHP 14a+14b

Qualitative inorganic analysis of mixtures containing not more than 4 radicals from the following:

Cation Radicals: Na^+ , K^+ , Ca^{+2} , Sr^{+2} , Ba^{+2} , Al^{+3} , Cr^{+3} , Mn^{+2} , Fe^{+3} , Co^{+3} , Ni^{+3} , Cu^{+2} , Zn^{+2} .

Anion Radicals: F^- , Cl^- , Br^- , BrO_3^- , I^- , SCN^- , S^{2-} , SO_4^{2-} , $\text{S}_2\text{O}_3^{2-}$, NO_3^- , NO_2^- , PO_4^{3-} , BO_3^{3-} , $\text{CrO}_4^{2-}/\text{Cr}_2\text{O}_7^{2-}$, $\text{Fe}(\text{CN})_6^{4-}$, $\text{Fe}(\text{CN})_6^{3-}$.

Insoluble Materials: Al_2O_3 , Fe_2O_3 , Cr_2O_3 , SnO_2 , SrSO_4 , BaSO_4 , CaF_2 .

Experiment A: Preliminary Tests for acid and basic radicals in given samples.

Experiment B: Wet tests for Acid and Basic radicals in given samples.

Experiment C: Confirmatory tests.

Notes:

At least 10 unknown samples are to be analyzed by each student during the laboratory session. Oxide, hydroxide, carbonate and bicarbonate should not be reported as radicals.

Chemistry Hons: Course Description

Year 2

PART – II

CHT 21a

Unit I. Chemical Periodicity II

General trends of variation of electronic configuration, elemental forms, metallic nature, magnetic properties (if any), catenation and catalytic properties (if any), oxidation states, inert pair effect (if any), aqueous and redox chemistry in common oxidation states, properties and reactions of important compounds such hydrides, halides, oxides, oxy-acids (if any), complex chemistry (if any) in respect of the following elements:

(i) s-block elements: Li-Na-K, Be-Mg-Ca-Sr-Ba.

(ii) p-block elements: B-Al-Ga-In-Tl, C-Si-Ge-Sn-Pb, N-P-As-Sb-Bi, O-S-Se-Te, F-Cl-Br-I, He-Ne-Ar-Kr-Xe

Unit II. Other Types of Bonding

Molecular orbital concept of bonding (elementary pictorial approach): sigma and pi-bonds, multiple bonding, MO diagrams of H_2 , F_2 , O_2 , C_2 , B_2 , CO, NO, CN^- , HF, and H_2O ; bond orders, bond lengths, Walsh Diagram. Coordinate bonding: Lewis acid-base adducts (examples), double salts and complex salts, Werner theory of coordination compounds. Ambidentate and polydentate ligands, chelate complexes. IUPAC nomenclature of coordination compounds (up to two metal centers). Coordination numbers, constitutional isomerism. Stereoisomerism in square planar and octahedral complexes.

Hydrogen bonding and its effects on the physical properties of compounds of the main group elements.

Metallic bonding: qualitative idea of band theory, conducting, semi conducting and insulating properties with examples from main group elements.

CHT 21b

Unit I. Chemistry of s- and p-block Elements

(i) Structure, bonding and reactivity of B_2H_6 ; $(SN)_x$ with $x = 2, 4$; phosphazines; interhalogens. (ii) Structure of borates, silicates, polyphosphates, borazole, boron nitride, silicones, thionic acids. (iii) Reactivity of polyhalides, pseudo halides, fluorocarbons, freons and NO_x with environmental effects. (iv) Chemistry of hydrazine, hydroxylamine, N_3^- , thio- and per-sulphates.

Noble gases from air; oxides, fluorides and oxofluorides of xenon; chemical and photochemical reactions of ozone.

Unit II. Precipitation and Redox Reactions

Solubility product principle, common ion effect and their applications to the precipitation and separation of common metallic ions as hydroxides, sulfides, phosphates, carbonates, sulfates and halides. Ion-electron method of balancing equation of redox reaction. Elementary idea on standard redox potentials with sign conventions, Nernst equation (without derivation). Influence of 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 (Latimer and Frost diagrams) of common elements and their applications. Disproportionation and comproportionation reactions (typical examples).

CHT 22a

Unit I. Addition reactions

Electrophilic addition to C=C: Mechanism, reactivity, regioselectivity and stereoselectivity. Reactions: halogenations, hydrohalogenation, hydration, hydrogenation, epoxidation, hydroxylation, ozonolysis, electrophilic addition to diene (conjugated dienes and allenes). Radical addition: HBr addition. Dissolving metal reduction of alkynes and benzenoid aromatics (Birch). Pericyclic addition: Diels-Alder reaction. Addition of singlet and triplet carbenes.

Nucleophilic addition to C=O: Mechanism, reactivity, equilibrium and kinetic control. Reactions with alcohols, amines, thiols, HCN, bisulfate, Wittig reaction. Carbonyl Reduction: hydride addition, Wolff-Kishner reduction, dissolving metal (Bouveault-Blanc reduction, Clemmensen Reduction), Cannizzaro reaction, Tischenko reaction, aldol condensation, benzoin condensation. Hydrolysis of nitriles and isonitriles. Nucleophilic addition to α,β -unsaturated carbonyl system (general principles).

Unit II. Elimination and aromatic substitution

Elimination - Mechanisms: E1, E2 and E1cB; reactivity, orientation (Saytzeff/Hofmann) and stereoselectivity; substitution vs elimination,

Electrophilic aromatic substitution: Mechanisms, orientation and reactivity. Reactions: nitration, nitrosation, sulfonation, halogenation, Friedel-Crafts reactions, one-carbon electrophiles (reactions: chloromethylation, Gatterman-Koch, Gatterman, Hoesch, Vilsmeier-Haack reaction, Reimer-Tiemann, Kolbe-Schmidt).

Nucleophilic aromatic substitution: Addition-elimination mechanism, S_N1 mechanism, benzyne mechanism.

CHT 22b

Unit I. Nitrogen compounds and Organometallics

Nitrogen compounds: amines (aliphatic & aromatic) [preparation, separation and identification of primary, secondary and tertiary amines], E. Clarke reaction, enamines, Mannich reaction, diazomethane, diazoacetic ester, aromatic nitro compounds, aromatic diazonium salts, nitrile and isonitrile.

Organometallics: preparation of Grignard reagent and organo lithium. Reactions: addition of Grignard and organo lithium to carbonyl compounds, substitution on -COX, conjugate addition by Gilman cuprates, Reformatsky reaction.

Unit II. Reactions: Rearrangements

1,2-shift: Rearrangement to electron-deficient carbon (Wagner-Meerwein rearrangement, pinacol rearrangement, dienone-phenol; Wolff rearrangement in Arndt-Eistert synthesis, benzil-benzilic acid rearrangement).

Electron-deficient nitrogen (Beckmann rearrangement, Schmidt rearrangement, Hofmann rearrangement, Lossen rearrangement, Curtius rearrangement).

Electron-deficient oxygen (Baeyer-Villiger oxidation, hydroperoxide rearrangement (cumene hydroperoxide-phenol rearrangement), Dakin reaction.

Aromatic rearrangements [migration from oxygen to ring carbon (Fries rearrangement, Claisen rearrangement); migration from nitrogen to ring carbon (Hofmann-Martius rearrangement, Fischer-Hepp rearrangement, N-azo to C-azo rearrangement, Bamberger rearrangement, Orton rearrangement, benzidine rearrangement.

CHT 23a

Unit I. Thermodynamics and Equilibrium

Open system, chemical potential and activity, partial molar quantities, 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 Hoff's reaction isotherm (deduction from chemical potential). Explanation of the free energy versus degree of advancement plot. Equilibrium constant and standard Gibbs free energy change. Definitions of K_p , K_C and K_x ; van't Hoff's reaction isobar and isochore from different standard states. Shifting of equilibrium due to change in external parameters e.g. temperature and pressure. Le Chatelier's principle and degree of advancement.

Activity and activity coefficients of electrolyte / ion in solution. Debye-Huckel limiting law (statement and applications only). Solubility equilibrium and influence of common ions and indifferent ions thereon. P^H , buffer solution, buffer capacity, salt hydrolysis (detailed treatment).

Unit II. Liquid State and Viscosity of Fluids

Nature of the liquid state, (short range order and long range disorder). Vapor pressure. Surface tension, surface energy, excess pressure, capillary rise and measurement of surface tension. Work of cohesion and adhesion, spreading of liquid over other surface. Vapour pressure over curved surface. Temperature dependence of surface tension.

General features of fluid flow (streamline flow and turbulent flow). Reynold number, nature of viscous drag for streamline motion, Newton' equation, viscosity coefficient. Poiseuille's equation (with derivation), temperature dependence of viscosity, principle of determination of viscosity coefficient of liquids by falling sphere method.

Viscosity of gases vs. liquids and kinetic theory of gas viscosity.

CHT 23b

Unit I. Quantum Chemistry I

Wave-particle duality, light as particles: photoelectric and Compton effects; electrons as waves and the de Broglie hypothesis.

Elementary concepts of operators, eigenfunctions and eigenvalues. Linear operators. Commutation of operators, fundamental commutator and uncertainty relation (without proof). 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.

Particle in a box: setting up of Schrodinger equation for one-dimensional box and its solution. Comparison with free particle eigenfunctions and eigenvalues. Properties of PB wave functions (normalisation, orthogonality, probability distribution). Expectation values of x , x^2 , p_x and p_x^2 and their significance in relation to the uncertainty principle. Extension of the problem to two and three dimensions and the concept of degenerate energy levels.

Unit II. Electrochemistry

Conductance and measurement of conductance, cell constant, specific conductance and molar conductance. Variation of specific and equivalent conductance with dilution for strong and weak electrolytes. Kohlrausch's law of independent migration of ions, ion conductance and ionic mobility. Equivalent and molar conductance at infinite dilution and their determination for strong and weak electrolytes. Ostwald's dilution law. Debye-Huckel model (physical idea only). Application of conductance measurement (determination of solubility product and ionic product of water). Conductometric titrations. Determination of transport number by moving boundary method.

Types of electrochemical cells and examples, cell reactions, emf and change in free energy, ΔH and ΔS of cell reactions from emf measurements. Thermodynamic derivation of Nernst equation. Standard cells. Half-cells / electrodes, different types of electrodes (with examples). Standard electrode potential (IUPAC convention) and principles of its determination. Types of concentration cells. Liquid junction potential and its minimisation.

Glass electrode and determination of pH of a solution. Potentiometric titrations: acid-base and redox.

CHP 24a

Analytical Estimations

1. Iodometry/iodimetry: Vitamin C.
2. Permanganometry: Fe^{III} and Mn^{II} in a mixture.
3. Dichromatometry: Fe^{III} and Cu^{II} in a mixture; Fe^{III} and Cr^{III} in a mixture.
4. Complexometry (EDTA): CaCO_3 and MgCO_3 in mixture; Mg^{II} and Zn^{II} in mixture.

CHP 24b

Instrumental Estimations

1. Spectrophotometry: Mn^{II} ; p^{K}_{in} .
2. Conductometry: HCl-AcOH mixture; dibasic acid.
3. Potentiometry: Halide ion.
4. p^{H} -metry: HCl-AcOH mixture; dibasic acid.
5. Ion-exchanger: Cation content of a sample by cation exchanger

Chemistry Hons: Course Description

Year 3 PART – III

CHT 31a

Unit I. 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 (example and applications). Stability constants of coordination compounds and their importance in inorganic analysis.

Structure and bonding: VB description and its limitations. Elementary Crystal Field Theory: splitting of d^n configurations in octahedral, square planar and tetrahedral fields, crystal field stabilization energy in weak and strong fields; pairing energy. Jahn-Teller distortion. Metal-ligand bonding (MO concept, elementary idea), sigma- and pi-bonding in octahedral complexes (qualitative pictorial approach) and their effects on the oxidation states of transitional metals (examples).

Magnetism and Colour: Orbital and spin magnetic moments, spin only moments of d^n ions and their correlation with effective magnetic moments, including orbital contribution; quenching of magnetic moment: super exchange and antiferromagnetic interactions (elementary idea with examples only); d-d transitions; L-S coupling; qualitative Orgel diagrams for $3d^1$ - $3d^9$ ions and their spectroscopic ground states; selection rules for electronic spectral transitions; spectrochemical series of ligands; charge transfer spectra (elementary idea).

Unit II. 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: $K_2Cr_2O_7$, $KMnO_4$, $K_4[Fe(CN)_6]$, $K_2[Ni(CN)_4]$, H_2PtCl_6 , $Na_2[Fe(CN)_5NO]$.

CHT 31b

Unit I. Organometallic Compounds

18-electron rule and its applications to carbonyls (including carbonyl hydrides and carbonylates), nitrosyls, cyanides, and nature of bonding involved therein. Simple examples of metal-metal bonded compounds and metal clusters. Metal-olefin complexes: zeises salt (preparation, structure and bonding), Ferrocene (preparation, structure and reactions). Hapticity(η) of organometallic ligands, examples of mono tri and penta-hapto cyclopentadienyl complexes. Simple examples of fluxional molecules. Coordinative unsaturation: oxidative addition and insertion reactions. Homogeneous catalysis by

organometallic compounds: hydrogenation, hydroformylation and polymerization of alkenes (Ziegler-Natta catalysis).

Unit II. Bioinorganic Chemistry

Elements of life: essential major, trace and ultratrace elements. Basic chemical reactions in the biological systems and the role of metal ions (specially Na⁺, K⁺, Mg²⁺, Ca²⁺, Fe^{3+/2+}, Cu^{2+/+}, and Zn²⁺). Metal ion transport across biological membrane Na⁺-ion pump, ionophores. Biological functions of hemoglobin and myoglobin, cytochromes and ferredoxins, carbonate bicarbonate buffering system and carbonic anhydrase. Biological nitrogen fixation, Photosynthesis: Photosystem-I and Photosystem-II. Toxic metal ions and their effects, chelation therapy (examples only), Pt and Au complexes as drugs (examples only), metal dependent diseases.

CHT 31c

Unit I. Electrochemical and spectral analysis, and analytical separation

Electrochemical methods: Conductometry, Potentiometry, pH-metry. Electrogravimetry, Coulometry. Spectrophotometry: Lambert-Beer law, Limits to Beer's law, Principle of spectrophotometric estimation of iron, manganese and phosphorous. Principles and instrumentations of atomic absorption and atomic emission spectrometry; estimation of sodium and potassium in water samples.

Ion exchange resins and their exchange capacities, principle and simple applications of ion exchange separation. Chromatographic separations: General description and classification of chromatographic methods, thin layer, paper and column chromatographic techniques and their simple applications, R_f-values and their significance, elution in column chromatography, migration rates of solutes, band broadening and column efficiency, column resolution.

Unit 2. Statistical methods in chemical analysis and environmental analysis

Errors in chemical analysis: Accuracy and precision of measurements, determinate indeterminate, systematic and random errors in chemical analysis with examples, absolute and relative errors; source, effect and detection of systematic errors; distribution of random errors, normal error curve, standard deviations, standard deviation of calculated results- sum or difference, product or quotient, significant figures, rounding and expressing results of chemical computations.

Principles for determination of BOD, COD, DO, TDS, in water samples. Detection and estimation of As, Hg, Cd, Pb, NH₄⁺, and F⁻, NO₃⁻, NO₂⁻ in water sample. Detection, collection and principles of estimation of CO, NO_x, SO₂, H₂S and SPM in air samples.

CHT 31d

Unit I: Gravimetric and titrimetric methods of analysis

Requirements of gravimetry: properties of precipitates and precipitating reagents, particle size and filterability of precipitates, colloidal and crystalline precipitates coprecipitation and post-precipitation drying and ignition of precipitates, principles of gravimetric estimation of chloride, phosphate, zinc, iron, aluminum and magnesium singly.

Primary and secondary standard substances in acid-base, redox, complexometric (EDTA) and argentometric titrations. Principle and application of redox titrimetric estimation based on the use of the following reagents: KMnO_4 , $\text{K}_2\text{Cr}_2\text{O}_7$, I_2 , $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$, $\text{KH}(\text{IO}_3)_2$ and KBrO_3 . Principle of argentometric estimation of chloride using adsorption indicators.

Principle of complexometric EDTA titration, metal ion indicators (examples), masking and demasking reactions, estimation of Cu-Zn, Fe-Al and Ca-Mg mixture by EDTA titration methods.

Dissolution, scheme of analysis and principles of estimation of the constituents of the following materials: dolomite, pyrolusite, chalcopyrites, Portland cement, basic slag, brass, steel and type metal.

Unit II. Thermodynamics of dissolution

Acidities of cations, factors influencing acidities (effects of charge and size); basicities of anions, factors influencing basicities (size and charge effects). Hydration energies of ions, Born-equation, enthalpy change associated with dissolution, solubility rules, thermodynamic interpretations of the rules; application of the rules for precipitation reactions, uses of the rules in quantitative and qualitative analysis, complexation reactions and their roles in dissolution processes.

CHT 32a

Unit I. Carbanion chemistry and cyclic stereochemistry

Carbanions: formation of enols and enolates (metal), alkylation of enolates, reactions of enolates with carbonyls (aldehydes, ketones and esters), conjugate addition of enolates.

Cyclic Stereochemistry: Baeyer strain theory.

Conformational analysis: cyclohexane, mono and disubstituted cyclohexane, symmetry properties and optical activity. Conformation & reactivity in cyclohexane system: elimination (E2), rearrangement, nucleophilic substitution ($\text{S}_{\text{N}}1$, $\text{S}_{\text{N}}2$, NGP), oxidation of cyclohexanol, esterification, saponification, lactonisation.

Unit II. Spectroscopy UV, IR, NMR (elementary)

UV Spectra: Electronic transition ($\sigma\text{-}\sigma^*$, $n\text{-}\sigma^*$, $\pi\text{-}\pi^*$ and $n\text{-}\pi^*$), relative positions of λ_{max} 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=O functions; factors effecting stretching frequencies (H-bonding, mass effect, electronic factors, bond multiplicity, ring size).

PMR Spectra: Nuclear spin, NMR active nuclei, principle of proton magnetic resonance, equivalent and non-equivalent protons, chemical shift δ , shielding / deshielding of protons, up-field and down-field shifts. NMR peak area (integration), diamagnetic anisotropy, relative peak positions of different kinds of protons (alkyl halides, olefins, alkynes, aldehyde H), substituted benzenes (toluene, anisole,

nitrobenzene, halobenzene, dinitrobenzenes, chloronitrobenzene), first order coupling (splitting of the signals: ordinary ethanol, bromoethane, dibromoethanes), coupling constants.

CHT 32b

Unit I. Synthetic strategies and Asymmetric synthesis

Retrosynthetic analysis: disconnections, synthons, donor and acceptor synthons, functional group interconversion, C-C disconnections and synthesis [one group and two-group (1,2 to 1,6-dioxygenated)], reconnection (1,6-di carbonyl), natural reactivity and umpolung, protection-deprotection strategy [alcohol, amine, carbonyl, acid]

Strategy of ring synthesis: thermodynamic factor, synthesis through enolate anion chemistry and carbonyl condensation reactions (including acetoacetic ester & malonic ester synthesis), synthesis through rearrangement (including pinacol, Favorski), synthesis of large rings, high dilution technique and acyloin reaction, Stobbe condensation.

Asymmetric synthesis: stereoselective and stereospecific reactions, diastereoselectivity and enantioselectivity (only definition), diastereoselectivity: addition of nucleophiles to C=O, adjacent to a stereogenic centre (Felkin-Anh model).

Unit II. Carbohydrate chemistry

Monosaccharides: Aldoses upto 6 carbons, structure of D-glucose & D-fructose (configuration & conformation), anomeric effect, mutarotation.

reactions: osazone formation, bromine – water oxidation, stepping-up (Kiliani method) and stepping-down (Ruff's & Wohl's method) of aldoses.

Disaccharides: glycosidic linkages, structure of sucrose.

CHT 32c

Unit I. Carbocycles and Heterocycles

Polynuclear hydrocarbons: syntheses and reactions of naphthalene, anthracene and phenanthrene.

Heterocyclic compounds: reactivity, orientation and important reactions of furan, pyrrole, pyridine, indole, synthesis (including retrosynthetic approach) pyrrole: Knorr pyrrole synthesis and Hantzsch synthesis. Hantzsch pyridine synthesis. Indole: Fischer, Madelung and Reissert synthesis, Skatrup quinoline and Bischler-Napieralski Synthesis of isoquinoline.

Unit II. Amino acids, peptides and nucleic acids

Amino acids: Synthesis: (Strecker, Gabriel, acetamido malonic ester, azlactone); isoelectric point, ninhydrin reaction.

Peptides: peptide linkage, syntheses of peptides using N-protection & C-protection, solid phase synthesis; peptide sequence: C-terminal and N-terminal unit determination (Edmann, Sanger & dansyl chloride).

Nucleic acids: pyrimidine & purine bases (only structure & nomenclature), nucleosides and nucleotides, DNA: Watson-Crick model, complimentary base –pairing in DNA.

CHT 33a

Unit I. Properties of solids, interfaces and dielectrics

Crystal, crystal planes, law of rational indices, Calculation of fraction occupied for simple cubic, bcc, and fcc. Miller indices. Bragg's law and its applications for the

determination of crystal structure for cubic system single crystal. Crystal structures of NaCl and KCl.

Special features of interfaces compared to bulk. Surface dynamics: Physical and chemical adsorption. Freundlich and Langmuir adsorption isotherms; multilayer adsorption and BET isotherm (no derivation required). Gibbs adsorption isotherm and surface excess. Heterogeneous catalysis (single reactant).

Colloids: lyophobic and lyophilic sols. Origin of charge and stability of lyophobic colloids. Coagulation and Schultz-Hardy rule. Zeta potential and Stern double layer (qualitative idea). Tyndall effect. Electrokinetic phenomenon (qualitative idea only).

Electrical properties of molecules: Polarizability of atoms and molecules, dielectric constant and polarisation, molar polarisation for polar and non-polar molecules. Clausius-Mosotti equation and Debye equation (both with derivation) and their application. Determination of dipole moments.

Unit II. Quantum Chemistry – II

Simple Harmonic Oscillator: setting up of the Schrodinger stationary equation, energy expression (without derivation), expression of wave function for $n = 0$ and $n = 1$ (without derivation) and their characteristic features.

Stationary Schrodinger equation for the H-atom in polar coordinates, separation of radial and angular (θ , ϕ) parts. Solution of ϕ -part and emergence of quantum number 'm'; energy expression (without derivation), degeneracy. Hydrogenic wave functions up to $n = 2$ (expression only); real wave function. Concept of orbitals and shapes of s and p orbitals.

CHT 33b

Unit I. Phase equilibrium and colligative properties

Definitions of phase, component and degrees of freedom. Phase rule and its derivations. Definition of phase diagram. Phase equilibria for one component system – water, CO_2 . First order phase transition and Clapeyron equation; Clausius-Clapeyron equation - derivation and use.

Liquid vapour equilibrium for two component systems. Ideal solution at fixed temperature and pressure. Principle of fractional distillation. Duhem-Margules equation. Henry's law. Konowaloff's rule. Positive and negative deviations from ideal behaviour. Azeotropic solution. Liquid-liquid phase diagram using phenol-water system. Solid-liquid phase diagram. Eutectic mixture. Nernst distribution law. Solvent extraction.

ΔG , ΔS , ΔH and ΔV of mixing for binary solutions. Vapour pressure of solution. Ideal solutions, ideally diluted solutions and colligative properties. Raoult's law. Thermodynamic derivation of colligative properties of solution (using chemical potentials) and their inter-relationships. Abnormal colligative properties.

Unit II. Statistical thermodynamics and the third law

Macrostates and microstates, thermodynamic probability, entropy and probability, Boltzmann distribution formula (with derivation). Applications to barometric distribution. Partition function and Einstein's theory of heat capacity of solids. Limitations of Einstein's theory and Debye's modification (qualitative).

Nernst heat theorem. Approach to zero kelvin, adiabatic demagnetisation. Planck's formulation of third law and absolute entropies.

CHT 33c

Unit I. Kinetics and photochemistry

Collision theory (detailed treatment); outline of Transition State theory. Primary kinetic salt effect. Lindemann theory of unimolecular reaction.

Potential energy curves (diatomic molecules), Frank-Condon principle and vibrational structure of electronic spectra. Bond dissociation and principle of determination of dissociation energy (ground state). Decay of excited states by radiative and non-radiative paths. Fluorescence and phosphorescence, Jablonsky diagram.

Laws of photochemistry: Grothaus-Draper law, Stark-Einstein law of photochemical equivalence and Lambert-Beer's 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.

Unit II. Spectroscopy

Rotational spectroscopy of diatomic molecules: rigid rotor model, selection rules, spectrum, characteristic features of spectral lines (spacing and intensity). Determination of bond length, effect of isotopic substitution.

Vibrational spectroscopy of diatomic molecules: SHO model, selection rules, spectra; anharmonicity and its consequences on energy levels, overtones, hot bands.

Raman Effect. Characteristic features and conditions of Raman activity with suitable illustrations. Rotational and vibrational Raman spectra. Rule of mutual exclusion with examples.

CHP 34a

Spectroscopic Analysis of Organic Compounds

A. Assignment of labelled peaks in the ¹H NMR spectrum of the known organic compounds explaining the relative δ values and splitting pattern.

B. Assignment of labeled peaks in the IR spectrum of the same compound.

(C-H, O-H, N-H, C=C, C=O, NO₂ stretching frequencies)

At least 10-15 compounds from among the list given below are to be chosen:

(i) p-Bromoacetanilide (ii) p-Methyl- α -bromoacetophenone (iii) Vanillin (iv) Cinnamic acid (v) p-Aminobenzoic acid (vi) Salicylamide (vii) o-Hydroxy acetophenone (viii) 4-keto pentanoic acid (ix) Benzylacetate (x) Diethylmaleate (xi) Diethylfumarate (xii) p-Nirtobenzaldehyde (xiv) Mesityl oxide (xv) o-Hydroxybenzaldehyde (xvi) p-Nitroaniline

A separate laboratory workbook should be maintained for these experiments.

CHP 34b

Experiment -1. Qualitative analysis of single solid organic compounds

A. Detection of special elements (N, Cl, S) by Lassaigne's test

B. Solubility and Classification (solvents: H₂O, 5% HCl, 5% NaHCO₃, 5% NaOH)

C. Detection of the following functional groups by systematic chemical tests:

Aromatic amino (-NH₂), aromatic nitro (-NO₂), Amide (-CONH₂, including imide), Phenolic -OH, Carboxylic acid (-COOH), Carbonyl (>C=O); only one test for each functional group is to be reported.

Each student, during laboratory session, is required to carry out qualitative chemical tests for all the special elements and the functional groups in known and unknown (at least 5) organic compounds.

Experiment - 2. Organic preparations

A. The following reactions are to be performed, noting the yield of the crude product:

1. Nitration of aromatic compounds
2. Condensation reactions
3. Hydrolysis of amides/ imides/ esters
4. Acetylation of phenols / aromatic amines
5. Benzoylation of phenols / aromatic amines
6. Side chain oxidation of aromatic compounds
7. Diazo coupling reactions of aromatic amines
8. Bromination of anilides
9. Redox reaction
10. Green 'multi-component -coupling' reaction

B. Purification of the crude product is to be made by crystallisation (water/alcohol, crystallisation after charcoal treatment, or sublimation, whichever is applicable).

C. MP of the purified product is to be noted.

Note: Each student is required to perform ALL the experiments cited above (in A, B and C) in classes.

CHP 35a

Experiments:

1. Determination of surface tension of a given solution by drop weight method using a stalagmometer, considering aqueous solutions of NaCl, acetic acid, ethanol etc, as systems.
2. Determination of viscosity coefficient of a given solution with Ostwald's viscometer considering aqueous solutions of cane-sugar, glycerol, ethanol, etc.
3. Determination of solubility of sparingly soluble salts in water and various Electrolyte medium by titrimetric method. KHTa as sparingly soluble salt in water, KCl, NaNO₃ may be used.

4. Determination of partition coefficient of Iodine or Acetic acid in water and an immiscible organic solvent.
5. Determination of the rate constant for the first order acid catalyzed hydrolysis of an ester (V_0 and V_∞ be supplied).
6. Determination of rate constant of decomposition of H_2O_2 by acidified KI solution using clock reactions.

A separate laboratory workbook should be maintained for these experiments.

CHP 35b

Experiments:

1. To study the kinetics of inversion of sucrose using polarimeter.
2. To study the phase diagram of a binary system (Phenol + water) and the effect of impurities (e.g. NaCl).
3. Determination of ionization constant of a weak acid by conductometric method.
4. To study the kinetics of saponification of ester by conductometric method.
5. Determination of the equilibrium constant of the reaction $KI + I_2 = KI_3$ by partition method (partition coefficient to be supplied).
6. Determination of E_0 of Fe^{+3}/Fe^{2-} couple in the hydrogen scale by potentiometric titration of ferrous ammonium sulfate solution using $KMnO_4$, or, $K_2Cr_2O_7$ as standard.
7. Determination of concentration of (i) $AgNO_3$ solution and (ii) solubility product of $AgCl$ by potentiometric titration of standard KCl solution against $AgNO_3$ solution.
8. Determination of pK values of weak monobasic, dibasic and polybasic acid by pH-metric method (e.g. using, acetic acid, succinic acid, oxalic acid, phosphoric acid, etc.).
9. Study of the kinetics of the reaction $I^- + S_2O_8^{2-}$ by colorimetric method.

Chemistry General: Syllabus Scheme in modular form

Course names and distribution

PART – I (Year 1), total marks = 100 (Theory = 100)

CGT 11a, 11b each 25 marks, Theory

CGT 12a, 12b each 25 marks, Theory

PART – II (Year 2), total marks = 200 (Theory = 100, Practical = 100)

CGT 21a, 21b each 25 marks, Theory

CGT 22a, 22b each 25 marks, Theory

CGP 23 50 marks, Practical

CGP 24 50 marks, Practical

PART – III (Year 3), total marks = 100 (Theory = 75, Practical = 25)

CGT 31a, 31b, 31c each 25 marks, Theory

CGP 32 25 marks, Practical

Abbreviations:

CGT: Chem General Theory; CGP: Chem General Practical

First digit refers to year, second to paper

Each CGT Exam = 1½ hr for 50 marks, or as stated later

Each CGP Exam = 3 hr for 25/50 marks on each day, or as stated later

Notes:

1. A Theory module of 25 marks would contain units I (marks = 15) and II (marks = 10).

2. Number of class hours = number of marks (Theory)

Number of class hours = 2-3 times the number of marks (Practical)

Chemistry Gen: Course Description

Year 1

PART - I

CGT 11a

Unit I. General Chemistry

Extra-nuclear Structure of atoms: Bohr's theory for hydrogen atom (simple mathematical treatment), atomic spectra of hydrogen and Bohr's model, Sommerfeld's model, quantum numbers and their significance, Pauli's exclusion principle, Hund's rule, electronic configuration of many-electron atoms, *Aufbau* principle and its limitations.

Radioactivity and Nuclear Structure of Atoms: Natural radioactivity; radioactive disintegration series, group displacement law, law of radioactive decay, half-life of radio elements. Atomic Nucleus: Stability of atomic nucleus, n/p ratio, nuclear binding energy, mass defect. Nuclear reactions: fission, fusion, transmutation of elements.

Chemical Periodicity: classification of elements on the basis of electronic configuration: general characteristics of s-, p-, d- and f-block elements. Positions of hydrogen and noble gases. Atomic and ionic radii, ionization potential, electron affinity, and electronegativity; periodic and group-wise variation of above properties in respect of s- and p- block elements.

Unit II. Principles of organic qualitative analysis

Reactions involving the detection of special elements N, S and Cl in an organic compound (only Lassaigne's test).

Reactions involving the detection of the following functional groups: Aromatic primary amino group (Diazo-coupling reaction); Nitro group (Mulliken Barker's test); Carboxylic acid group (reaction with NaHCO₃); Phenolic OH (FeCl₃ test); Carbonyl (aldehyde and ketone) group (DNP Test, etc.).

CGT 11b

Unit I. Basic organic chemistry I

Inductive effect, resonance and resonance energy. Homolytic and heterolytic bond breaking, electrophiles and nucleophiles; carbocations, carbanions and radicals (stability and reactivity)

Stereochemistry of carbon compounds: Different types of isomerism, geometrical and optical isomerism, optical activity, asymmetric carbon atom, elements of symmetry (plane and centre), chirality, enantiomers and diastereomers, R and S nomenclature, E and Z nomenclature, D and L nomenclature, Fischer projection formula of simple molecules containing one and two asymmetric carbon atoms.

Alkanes, alkenes and alkynes: Synthesis and chemical reactivity of alkanes, mechanism of free-radical halogenation of alkanes, general methods of synthesis of alkenes, electrophilic addition reaction, mechanism of bromination and hydrohalogenation, Markownikoff's addition, peroxide effect, hydroboration, ozonide formation, polymerization reaction of alkenes (definition and examples only), general methods of synthesis, acidity, hydration and substitution reactions of alkynes.

Aromatic Hydrocarbons: Structure of benzene, general mechanism of electrophilic substitution, reactions of benzene, synthesis of aromatic compounds using nitration, halogenation, Friedel-Craft's reactions.

Unit II. Basic organic chemistry II

Aldehydes and ketones: the nature of carbonyl group, methods of synthesis, physical properties, Cannizzaro reaction, relative reactivities and distinction of aldehydes and ketones, Aldol condensation (with mechanism), Perkin reaction, Benzoin condensation, Claisen condensation, Oxidation and reduction reactions.

Alkyl and Aryl halides: S_N1 , S_N2 , E1 and E2 reactions (elementary mechanistic aspects), Saytzeff and Hoffmann elimination reactions. Nucleophilic aromatic substitution.

CGT 12a

Unit I. Basic inorganic chemistry I

Ionic bonding: General characteristics of ionic compounds, sizes of ions, radius ratio rule and its limitation. Lattice energy, Born Haber cycle.

Covalent bonding: General characteristics of covalent compounds, valence-bond approach, directional character of covalent bond, hybridization involving s-, p-, d-orbitals, multiple bonding, Valence Shell Electron Pair Repulsion (VSEPR) concept, shapes of simple molecules and ions (examples from main group chemistry). Bond moment and dipole moment, partial ionic character of covalent bonds, Fajan's rules. Hydrogen bonding and its effect on physical and chemical properties.

Coordinate bonds and Coordination compounds: complex salts and double salts, Warner's theory of coordination, chelate complexes, stereochemistry of coordination numbers 4 and 6. IUPAC nomenclature of coordination complexes (mononuclear complexes only).

Unit II. Basic inorganic chemistry II

Comparative study of p-block elements: Group trends in electronic configuration, modification of pure elements, common oxidation states, inert pair effect, and their important compounds in respect of the following groups of elements:

- i) B-Al-Ga-In-Tl
- ii) C-Si-Ge-Sn-Pb
- iii) N-P-As-Sb-Bi
- iv) O-S-Se-Te
- v) F-Cl-Br-I

CGT 12b

Unit I. Basic organic chemistry III

Carboxylic acids and their derivatives: acidity of carboxylic acids and effects of substituents on acidity, chemical reactivity, mechanism of esterification of carboxylic acids and hydrolysis of esters (B_{AC2} and A_{AC2} only)

Phenols: synthesis, acidic character and chemical reactions of phenols, Kolbe reactions, Reimer-Tiemann reaction, Fries rearrangement, Claisen rearrangement.

Organometallic compounds: Grignard reagents – preparations and reactions, application of Grignard reagents in organic synthesis. [1^o-, 2^o- and 3^o-alcohols, aldehydes, ketones and carboxylic acids.]

Organic compounds containing nitrogen: aromatic nitro compounds – reduction under different conditions. [acidic, neutral and alkaline]. Methods of synthesis of aliphatic amines, Heinsberg's method of amine separation, Hofmann degradation, Gabriel's phthalimide synthesis, distinction of primary, secondary and tertiary amines; methods of synthesis of aromatic amines, basicity of aliphatic and aromatic amines. Diazotization and coupling reactions and their mechanisms; synthetic applications of benzene diazonium salts. [Sandmeyer's reaction, preparation of nitro compounds, phenols, carboxylic acids and hydrocarbons thereby]

Unit II. Basic organic chemistry IV

Carbohydrates: Introduction, occurrence and classification of carbohydrates, constitution of glucose, osazone formation, reactions of glucose and fructose, mutarotation, cyclic structures – pyranose and furanose forms (determination of ring-size excluded), epimerization, chain-lengthening (Kiliani –Fischer method) and chain-shortening (Ruff's method) in aldoses.

Amino acids, Proteins: methods of synthesis of α –amino acids (glycine and alanine using Gabriel's phthalimide synthesis and Strecker synthesis). Physical properties. Zwitterion structures, isoelectric point.

Chemistry Gen: Course Description

Year 2 PART - II

CGT 21a

Unit I. Basic physical chemistry I

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 law of molecular speeds (without derivation), most probable, average and root mean square speed of gas molecules, principle of equipartition of energy (without derivation). Mean free path and collision frequencies. Heat capacity of gases (molecular basis); viscosity of gases.

Real gases, compressibility factor, deviation from ideality, van der Waals equation of state, critical phenomena, continuity of states, critical constants.

Liquid state: physical properties of liquids and their measurements: surface tension and viscosity.

Unit II. Basic physical chemistry II

Chemical kinetics and catalysis: order and molecularity of reactions, rate laws and rate equations for first order and second order reactions (differential and integrated forms); zero order reactions. Determination of order of reactions. Temperature dependence of reaction rate, energy of activation. Catalytic reactions: homogeneous and heterogeneous catalytic reactions, autocatalytic reactions, catalyst poisons, catalyst promoters (typical examples).

CGT 21b

Unit I. Principles of qualitative inorganic analysis

Formation of sublimates; principle of flame test, borax-bead test, cobalt nitrate test, fusion test, chromyl chloride test; analytical reactions for the detection of nitrate, nitrite, halides, phosphate, arsenate, arsenite, sulphide, thiosulphate, sulphate, thiocyanate, borate, boric acid, carbonate. Analytical reactions for the detection of Cr^{3+} , Fe^{3+} , Ni^{2+} , Cu^{2+} , As^{3+} , Mn^{2+} . Importance of common-ion effect in the separation of Group II cations, and Group III cations.

Unit II. Basic inorganic chemistry III

Comparative study of s-block elements: Group trends in electronic configuration, modification of pure elements, common oxidation states, inert pair effect, chemical properties and reactions in respect of the following group elements:

- i) Li-Na-K
- ii) Be-Mg-Ca-Sr-Ba

Extraction and purification of elements from natural sources: Li, Cr, Ni, Ag, Au. Electroplating, galvanizing and anodizing.

CGT 22a

Unit I. Basic physical chemistry III

Thermodynamics: Definition of thermodynamic terms: Intensive and extensive variables, isolated, closed and open systems. Cyclic, reversible and irreversible processes. Thermodynamic functions and their differentials. Zeroth law of thermodynamics, concept of heat (q) and work (w).

First law of thermodynamics, internal energy (U) and enthalpy (H); relation between C_p and C_v , calculation of w , q , ΔU and ΔH 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: standard state, standard enthalpy changes of physical and chemical transformations: fusion, sublimation, vaporization, solution, dilution, neutralization, ionization, Hess's law of constant heat summation. Bond-dissociation energy, Born haber cycle for calculation of lattice energy. Kirchhoff's equation, relation between ΔH and ΔU of a reaction.

Spontaneous processes, heat engine, Carnot cycle and its efficiency, Second law of thermodynamics, Entropy (S) as a state function, molecular interpretation of entropy, entropy changes in simple transformations. Free energy: Gibbs function (G) and Helmholtz function (A), Gibbs-Helmholtz equation, criteria for thermodynamic equilibrium and spontaneity of a process.

Unit II. Basic physical chemistry IV

Chemical equilibrium: chemical equilibria of homogeneous and heterogeneous systems, derivation of expression of equilibrium constants; temperature, pressure and concentration dependence of equilibrium constants (K_p , K_c , K_x); Le Chatelier's principle of dynamic equilibrium.

Colloids: colloids and crystalloids, classification of colloids, preparation and purification of colloids: ferric hydroxide sol and gold sol. Properties of colloids: Brownian motion, peptization, dialysis, Tyndal effect and its applications. Protecting colloids, gold number, isoelectric points, coagulation of colloids by electrolytes, Schulze-Hardy rule.

CGT 22b

Unit 1. Basic physical chemistry V

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 (elementary idea). 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; hydrolysis of salts.

Solutions of electrolytes: Electrolytic conductance, specific conductance, equivalent conductance and molar conductance of electrolytic solutions. Influence of temperature and dilution on weak electrolytes.

Unit II. Basic physical chemistry VI

Electrode potential: Electrode potentials, Nernst Equation, reference electrodes: normal hydrogen electrode and calomel electrodes, Emf of electrochemical cells and its measurement, electrode potential series and its applications.

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.

CGP 23

Qualitative Analysis of Single Organic Compound(s)

Experiment A: Detection of special elements (N, Cl, and S) in organic compounds.

Experiment B: Solubility and Classification (solvents: H₂O, dil. HCl, dil. NaOH)

Experiment C: Detection of functional groups -NO₂, -NH₂, -COOH, carbonyl (-CHO, >C=O), -OH (phenolic) in solid organic compounds.

Experiments A - C with unknown (at least 6) solid samples containing not more than two of the above types of functional groups should be done.

CGP 24

Qualitative Analysis of Inorganic Mixtures:

Experiments A: Preliminary Tests for Acid and Basic radicals in given samples.

Experiments B: Wet tests for Acid and Basic radicals in given samples.

Experiments C: Confirmatory tests.

Acid Radicals: Cl⁻, Br⁻, I⁻, NO₂⁻¹, S²⁻, SO₄⁻², PO₄⁻³, BO₃³⁻, H₃BO₃.

Basic Radicals: Na⁺, K⁺, Ca⁺², Sr⁺², Ba⁺², Cr⁺³, Mn⁺², Fe⁺³, Ni⁺³, Cu⁺², NH₄⁺.

Note: At least 6 unknown samples are to be analyzed by each student during the laboratory session.

Chemistry Gen: Course Description

Year 3 PART - III

CGT 31a

Unit I. Chemical analysis

Gravimetric Analysis: Solubility product and common ion effect. Requirements of gravimetry. Gravimetric estimation of chloride, sulphate, lead, barium, nickel, copper and zinc.

Volumetric Analysis: Primary and secondary standard substances, principles of acid-base, oxidation-reduction, and complexometric titrations; acid-base, redox and metal-ion indicators. Principles of estimation of mixtures of NaHCO_3 and Na_2CO_3 (by acidimetry); iron, copper, manganese, chromium (by redox titration); zinc, aluminum, calcium, magnesium (by complexometric EDTA titration). Chromatographic methods of analysis: column chromatography and thin layer chromatography.

Unit II. Error analysis and computer applications

Accuracy and precision of quantitative analysis, determinate-, indeterminate-, systematic- and random-errors. Methods of least squares and standard deviations.

General introduction to computers, different components of a computer, hardware and software, input and output devices, binary numbers and arithmetic. Introduction to computer languages, programming and operating systems.

CGT 31b

Unit I. Industrial chemistry I

Fuels: Classification of fuel, heating values. Origin of coal, carbonization of coal, coal gas, producer gas, water gas, coal based chemicals. Origin and composition of petroleum, petroleum refining, cracking, knocking, octane number, anti-knock compounds, Kerosene, liquefied petroleum gas (LPG), liquefied natural gas (LNG), petrochemicals (C1 to C3 compounds and their uses).

Fertilizers: Manufacture of ammonia and ammonium salts, urea, superphosphate, biofertilizers.

Glass and Ceramics: Definition and manufacture of glasses, optical glass and coloured glass. Clay and feldspar, glazing and vitrification, glazed porcelain, enamel. Portland cement: composition and setting of cement, white cement.

Unit II. Industrial chemistry II

Polymers: Basic concept, structure and types of plastics, polythene, polystyrene, phenol-formaldehydes, PVC; manufacture, physical properties and uses of natural rubber, synthetic rubber, silicone rubber; synthetic fibres: Nylon-66, polyester, terylene, rayon; foaming agents, plasticizers and stabilizers.

Paints, Varnishes and Synthetic Dyes: Primary constituents of a paint, binders and solvents for paints. Oil based paints, latex paints, baked-on paints (alkyd resins). Constituents of varnishes. Formulation of paints and varnishes. Synthesis of Methyl orange, Congo red, Malachite green, Crystal violet.

Drugs and pharmaceuticals: Concept and necessity of drugs and pharmaceuticals. Preparation, and uses of Aspirin, Paracetamol, Sulphadiazine, Quinine, Chloroquine, Phenobarbital, Metronidazole. Fermentation Chemicals : Production, and purification of ethyl alcohol, citric acid, lactic acid, Vitamin B12, Penicillin.

CGT 31c

Unit I. Environmental chemistry

The Atmosphere: Composition and structure of the atmosphere: troposphere, stratosphere, mesosphere and thermosphere. Ozone layer and its role. Major air pollutants : CO, SO₂, NO and particulate matters –their origins and harmful effects, problems of ozone layer depletion, green house effect, acid rain and photochemical smog. Air pollution episodes. Air quality standard. Air pollution control measures: cyclone collector, electrostatic precipitator, catalytic converter.

The Hydrosphere : Environmental role of water, natural water sources, water treatment for industrial, domestic and laboratory uses. Water pollutants : action of soaps and detergents, phosphates, industrial effluents, agricultural run off, domestic wastes; thermal pollution radioactive pollution and their effects on animal and plant life, water pollution episodes. Water pollution control measures : waste water treatment: chemical treatment and microbial treatment; water quality standards : DO, BOD, COD, TDS and hardness parameters. Desalination of sea water : reverse osmosis, electro dialysis.

The Lithosphere: Water and air in soil, waste matters and pollutants in soil, waste classification, treatment and disposal. Soil pollution and control measures.

Unit II. Industrial chemistry III

Fats-Oils-Detergents : Fats and oils, natural fat, edible and inedible oil of vegetable origin. Common fatty acids, glycerides. Hydrogenation of unsaturated oil, production of vanaspati and margarine. Production of toilet and washing soaps, Enzyme-based detergents, detergent powder, liquid soaps.

Pesticides: Common pesticides : Production, applications and residual toxicity of gammaxane, aldrin, parathion, malathion, DDT, paraquat, decamethrin.

Food Additives: Food flavour, food colour, food preservatives, artificial sweeteners, acidulants, alkalies, edible emulsifiers and edible foaming agents, sequesterants – uses and abuses of these substances in food beverages.

CGP 32

Experiments:

1. Titration of $\text{Na}_2\text{CO}_3 + \text{NaHCO}_3$ mixture vs HCl using phenolphthalein and methyl orange indicators.
2. Titration of HCl + CH_3COOH mixture vs NaOH using two different indicators to find the composition.
3. To find the total hardness of water by EDTA titration.
4. To find the PH of an unknown solution by comparing color of a series of HCl solutions + 1 drop of methyl orange, and a similar series of NaOH solutions + 1 drop of phenolphthalein.
5. To determine the rate constant for the acid catalysed hydrolysis of an ester.
6. Determination of the strength of the H_2O_2 sample.
7. To determine the solubility of a sparingly soluble salt, e.g. KHTa (one bottle)

Appendix 1

Hons. Examination

Paper-wise distribution of modules CHT and CHP

Year 1

Paper IA (50 M):	CHT (12a+12b)	1day exam	2 hr	Theory
Paper IB (50 M):	CHT (13a+13b)	1day exam	2 hr	Do
Paper IIA (50 M):	CHT (11a+11b)	1day exam	2 hr	Do
Paper IIB (50 M):	CHP (14a+14b)	1day exam	4 hr	Practical

Year 2

Paper IIIA (50 M):	CHT (22a+22b)	1day exam	2 hr	Theory
Paper IIIB (50 M):	CHT (23a+23b)	1day exam	2 hr	Do
Paper IVA (50 M):	CHT (21a+21b)	1day exam	2 hr	Do
Paper IVB (50 M):	CHP (24a+24b)	1day exam	4 hr	Practical

Year 3

Paper V (100 M):	CHT (31a+31b+31c+31d)	1day exam	4 hr	Theory
Paper VIA (75 M):	CHT (32a+32b+32c)	1day exam	4 hr	Do
Paper VIIA (75 M):	CHT (33a+33b+33c)	1day exam	4 hr	Do
Paper VIIIA (50 M):	CHP 34b	1day exam	4 hr	Practical
Paper VIIIB (50 M):	CHP 35b	1day exam	4 hr	Do
Paper VIB (25 M) + Paper VIIIB (25 M):	CHP (34a+35a)	1day exam	4 hr	Do

Gen. Examination

Paper-wise distribution of modules CGT and CGP

Year 1

Paper I (100 M):	CGT (11a+11b+12a+12b)	1day exam	3 hr	Theory
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Year 2

Paper IIA (100 M):	CGT (21a+21b+22a+22b)	1day exam	3 hr	Theory
Paper IIIA (50 M):	CGP 23	1day exam	3 hr	Practical
Paper IIIB (50 M):	CGP 24	1day exam	3 hr	Practical

Year 3

Paper IVA (75 M):	CGT (31a+31b+31c)	1day exam	3 hr	Theory
Paper IVB (25 M):	CGP 32	1day exam	3 hr	Practical

Appendix 2

Instructions about Theoretical Examinations

Hons./Genl.

For a Theoretical Examination, any particular module of 25 marks is already subdivided into two units: Unit I (15 marks) and Unit II (10 marks). In any case [Hons./Gen. (yearly)] , the following scheme will be effective.

Unit – I: 5 questions of marks 5 each are to be set, out of which 3 are to be answered. Minimum marks for a part of a question will be 2.

Unit – II: 3 questions of marks 5 each are to be set, out of which 2 are to be answered. Minimum marks for a part of a question will be 2.

Appendix 3

General instructions about Practical Examinations Hons./Genl.

1. Candidates at the practical examinations are required to submit the *day to day record of all types of laboratory works* prescribed in the syllabus, performed by them, and duly signed by their teachers. Candidates failing to submit their laboratory work-books may be debarred from the examination.
2. One experiment/sample shall be assigned to a candidate through single draw lottery.
3. Outline of the procedure, wherever applicable, should be provided.
4. Use of *hazardous/toxic* chemicals should be avoided as far as practicable.
5. Weighing is to be done, wherever applicable, by *digital electronic balance* only.
6. Depending on the time and type of an experiment, *Primary standard solutions are to be provided at the time of examination*. The HE may decide the issue.
7. Drawing of linear least square plots, wherever applicable, is to be encouraged.
8. Theoretical classes, explaining the principles, should be taken.
9. Hons. practical examinations involving viva-voce of not less than 10 marks may be replaced by a *Lab. Quiz Test* (10 questions, 10 min for 10 marks; roughly one line answer for each question). This step will ensure better uniformity. Questions for different batches will be different. These are to be answered by students at the start of the first day of examination of a given batch. Questions will be prepared by the concerned HE for the specific practical examination during sample preparation. A viva-voce examination for 10 marks should not exceed 10 min.
10. In Appendix 5, different practical examinations are associated with specified “modalities of evaluation”. While the concerned HE may not strictly follow it under special circumstances (or, in case of specific experiments set by him), a general adherence to such a splitting pattern is expected to be beneficial to the students.

Appendix 4

Specific instructions about Practical Examinations

CHP (14a+14b), 50 M, 4 hr (Year 1)

Note for examination:

1. The sample must contain three, and only three, radicals.
2. Observation must be indicative of some changes in the sample under the experimental conditions. Vague observations such as “no characteristic change, inconclusive observation etc” are not to be entertained.
3. Presence as well as absence of radicals must be incorporated in the ‘Inference’ column according to observations.
4. Whenever a particular radical is detected in any experiment, its presence may mask the normal observations for the other radicals that are also responsive to the same test. Under the circumstances, the presence of the detected radicals should be shown in the ‘Inference’ column. It is needless to show the absence of the other radicals in the above experiment.
5. All the candidates must perform the “Preliminary orientational tests”. The proforma for the tests will be supplied to them.
6. The indicated radicals in the preliminary tests are to be confirmed by the student by appropriate test of his/her own choice.
7. In the preliminary ‘orientational test’ the following experiments are to be performed:
 - A. Dry heating of the sample
 - B. Flame test
 - C. Borax-bead test
 - D. Fusion test
 - E. Fluorescence test
 - F. Filtrate of the boiling mixture of the (sample + dil HCl + KNO₂ (a pinch)) + DMG + NH₄OH until ammoniacal
 - G. HCl extract + NaOH until alkaline, boiled and filtered: filtrate + H₂S
 - H. NaOH extract of the sample + NH₄Cl + H₂O – boiled and allowed to settle
 - I. Iodine-azide test
 - J. Heating of sample with dil H₂SO₄
 - K. Heating of sample with dil H₂SO₄ + Zn-dust
 - L. Heating of sample with conc. H₂SO₄
 - M. Heating of sample with conc. H₂SO₄ + Cu-turnings
 - N. Heating of sample with conc. H₂SO₄ + MeOH and ignition of the evolved gas

- O. HNO₃ extract + (NH₄)₂MoO₄ (excess)
 P. Na₂CO₃ extract + HNO₃ until acidic, boiled + Ba(NO₃)₂
 Q. Na₂CO₃ extract + HNO₃ until acidic, boiled + AgNO₃
 R. Na₂CO₃ extract + HCl until acidic, boiled + FeCl₃ + K₃[Fe(CN)₆]
 S. Na₂CO₃ extract + HCl until acidic, boiled + KI + starch
 T. Na₂CO₃ extract + HCl until acidic, boiled + FeCl₃

Marks:

- | | |
|-------------------------------|------------|
| 1. Orientational tests: | 20 M |
| 2. Confirmatory tests: | 12 M (4x3) |
| 3. Reporting of the radicals: | 3M |
| 4. Lab workbook: | 5 M |
| 5. Lab quiz/viva-voce: | 10 M |

CHP (24a+24b), 50 M, 4 hr (Year 2)

At least 4 experiments from 24a and 5 experiments from 24b are to be set in the examination. A student will take any one experiment.

Modalities of Evaluation:

- | | |
|--|------|
| 1) Principle and derivation of working formula = | 5 M |
| 2) Preparation of primary standard = | 5 M |
| 3) Tabular presentation of data = | 5 M |
| 4) Lab quiz/viva voce = | 10 M |
| 5) Lab. workbook = | 5 M |

Non-instrumental Expt.	Instrumental Expt.
Calculations based on working formula = 5 M	Plotting of data, etc. = 5 M Calculation = 5 M
Accuracy = 15 M	Accuracy = 10 M

CHP 34a, 25 M, total 4 hr with CHP 35a (Year 3)

At least 10 spectral analyses are to be set.

Modalities of Evaluation:

- | | |
|---------------|------|
| Expt. A (PMR) | 14 M |
| Expt. B (IR) | 8 M |
| Lab. workbook | 3 M |

CHP 34b 50 M, 4 hr (Year 3)

At the practical examination, two experiments, one each from 1 and 2, are to be assigned to a candidate. For qualitative analysis, one unknown solid organic compound containing not more than two of the functional groups included in the syllabus shall be assigned to a candidate. At least 6 different preparations are to be set in experiment 2.

Modalities of Evaluation:

Expt. 1A	3 M	Expt. 2A	12 M
Expt. 1B	3 M	Expt. 2B	5 M
Expt. 1C	6x1½= 9 M	Expt. 2C	3 M
Viva voce/Lab quiz	10 M	Lab workbook	5 M

CHP 35a, 25 M, total 4 hr with CHP 34a (Year 3)

At least 5 experiments out of 6 are to set in the practical examination.

Modalities of Evaluation:

1)	Working formula	= 2 M
2)	Presentation of data and graphs, if any	= 10 M
3)	Correct calculations and quality of results	= 5+5 M
4)	Lab. workbook	= 3 M
	Total Marks	= 25

Marks in 2) and 3) may be redistributed depending on the emphasis on graphs or numerical works, as appropriate to a particular experiment.

CHP 35b, 50 M, 4 hr (Year 3)

At least 6 experiments out of 9 are to set in the practical examination.

Modalities of Evaluation:

1)	Theory and working formula	= 5 M
2)	Presentation of data and graphs, if any	= 10+5 M
3)	Correct calculations and quality of results	= 10 +5 M
4)	Lab. workbook	= 5 M
5)	Viva-voce/lab quiz test	= 10 M
	Total Marks	= 50

Marks in 2) and 3) may be redistributed depending on the emphasis on graphs or numerical works, as appropriate to a particular experiment.

CGP 23, 50 M, 3 hr (Year 2)

In the practical examination one unknown solid organic compound containing not more than two of the functional groups mentioned shall be assigned to a candidate.

Marks distribution should be as follows:

Expt. A: Tests for special elements (positive/negative responses) –	9 M
Expt. B: Solubility tests and classification –	6 M
Expt. C: Tests for the 5 functional groups (positive/negative responses) [5 x 5] -	25 M
Lab record book –	10 M

CGP 24, 50 M, 3 hr (Year 2)

In the practical examination, one unknown sample shall be assigned to a candidate. The mixture may contain more than two radicals. But, *at least two radicals*, one acid and one basic, are to be reported. Radicals may be detected by systematic analysis or by semimicro tests, or both. Both positive and negative responses are to be recorded.

Marks distribution should be as follows:

(a) Dry tests for basic and acid radicals –	10 M
(b) Wet tests for acid and basic radicals –	15 M

- (c) Confirmatory tests for radicals found – 10 M (2x5)
(d) Correct reporting of two radicals – 5 M
(e) Lab record book – 10 M
[For wrong reporting of both the radicals, ½ mark may be awarded for each correct reporting of absence of a radical.]

CGP 32, 25 M, 3 hr (Year 3)

At least 3 experiments will be set in the practical examination. One experiment will be assigned to a candidate. To avoid accurate weighing by the students, standard solutions should be supplied.

Marks distribution:

Theory/Working formula	05 M
Presentation of data	05 M
Calculations and results	10 M
Lab. Record book	05 M

Appendix -5

Recommended list of books

1. Hons. Course

A. Textbooks

J. E Huheey, E. A. Keiter, R. L. Keiter: Inorganic Chemistry (Principle and structure and reactivity).

N. N. Greenwood, A. Earnshaw: Chemistry of the Elements

D. F. Shriver, P. W. Atkins, C. H. Langford: Inorganic Chemistry

A. G. Sharpe: Inorganic Chemistry

D. S. Skoog, D. M. West, F. G. Holler, S. R. Crouch: Fundamentals of Analytical Chemistry

D. Nasipuri: Stereochemistry of organic compounds: Principles and Applications

P. Sykes: A Guide to Mechanism in Organic Chemistry

J. March: Advanced Organic Chemistry

I. L. Finar: Organic Chemistry (Vol. I)

R. T. Morrison and R. N. Boyd: Organic Chemistry
W. Kemp: Organic spectroscopy
R. O. C. Norman and J. M. Coxon: Principle of organic synthesis
S. Warren: Organic synthesis: The disconnection approach

D. A. Mcquarrie and J. D. Simon: Physical Chemistry – A Molecular Approach
I. N. Levine: Physical Chemistry
G. W. Castellan: Physical Chemistry
P. W. Atkins: Physical Chemistry

B. Reference books

I. Kaplan: Nuclear Physics
S. N. Ghosal: Atomic and Nuclear Physics
F. A. Cotton, G. Wilkinson: Advanced Inorganic Chemistry
G. Wulfsberg: Inorganic Chemistry
D. M. P. Mingos: Essential Trends in Inorganic Chemistry
C. S. C. Phillips and R.J.P. Williams: Inorganic Chemistry

J. Clayden, N. Greeves, S. Warren and P. Wothers: Organic chemistry
J. A. Joule and K. Mills: Heterocyclic Chemistry (4 th Edition)
W. Carruthers: Modern methods of organic synthesis

K. Denbigh: The Principles of Chemical Equilibrium
C. N. Banwell and E.M. McCash: Fundamentals of Molecular Spectroscopy
R. S. Berry, S. A. Rice and J. Ross: Physical Chemistry
T. Engel and P. Reid: Physical Chemistry
W. J. Moore: Physical Chemistry
K. J. Laidler: Chemical Kinetics

C. Practical Chemistry books

G. Svehla: Vogel's Qualitative Inorganic Analysis.

J. Mendham, R. C. Denny, J. D. Barnes, M. J. K. Thomas: Vogel's Text Book of Quantitative Chemical Analysis.

G. N. Mukherjee: Semi-Micro Qualitative Inorganic Analysis (CU Publications)

Vogel's Text Book of Practical Organic Chemistry (5th Edition)

N. G. Mukherjee: Selected Experiments in Physical Chemistry

2. Gen. Course

A. Textbooks

P. K. Dutt: General and Inorganic Chemistry (Vol-I + Vol-II)

S. Sengupta: Organic Chemistry
S. R. Palit: Elementary Physical Chemistry

B. Practical Chemistry book

A. K. Nad, B. Mahapatra and A. Ghoshal: An Advanced Course in Practical Chemistry