National Education Policy
Proposed Syllabus- Chemistry
Cooch Behar Panchanan Barma University

Semester I

Major I- Fundamentals of Chemistry -1 (Credit 6, Theory 4 and Practical 2)

Number of Classes required – 4 h theory and 4 h practical per week basis

(Objective: this course would benefit the students in understanding the basics and fundamental periodic parameters of elements through periodic table, brief and comprehensive knowledge of acid base theories, basics of organic reaction mechanism and stereochemistry, property of gases, gas law and ionic equilibrium)

Inorganic Chemistry

A. **Periodic Table & Periodic Properties** The long form of periodic table. Classification of elements in to s, p, d and f-block elements. Slater's rule, Periodic properties & trends in the periodic properties with reference to s and p-block elements: (a) Atomic radii (van der Waals) (b) Ionic and crystal radii. (c) Covalent radii (d) Ionization enthalpy, successive ionization enthalpies and factors affecting ionization energy. Applications of ionization enthalpy. (e) Electron gain enthalpy, trends of electron gain enthalpy. (f) Electronegativity, Pauling's/ Mulliken's. Variation of electronegativity with bond order, partial charge, hybridization, group electronegativity. Trends in the periodic properties.

14 Lectures

B. **Acid base:** Brönsted-Lowry concept of acid-base reactions, solvated proton, relative strength of acids, types of acid-base reactions, leveling & differentiating solvents, Lewis acid-base concept, Classification of Lewis acids, Hard and Soft Acids and Bases (HSAB) Application of HSAB principle. **6 Lectures**

Suggested Textbooks:

- **Concise Inorganic Chemistry by J D Lee (5th Edition)**
- **Inorganic Chemistry by R. L. Dutta & G.S. De**
- **General and Inorganic Chemistry by Ramaprasad Sarkar- Volume 1**

Organic Chemistry

A. Fundamental of Organic Chemistry:

- Organic Compounds; Concept of Hybridization, Shapes of molecules, Nature of bonding in Organic molecules, Influence of hybridization on bond properties. Calculation of formal charges double bond equivalent (DBE).
- Electronic Displacements: Inductive, electromeric, resonance and mesomeric effects, hyperconjugation and their applications; resonance energy; bond polarization and bond polarizability; steric effect, steric inhibition of resonance. Dipole moment; Organic acids and bases; their relative strength
- Reaction thermodynamics: Free energy and equilibrium, enthalpy and entropy factor,intermolecular & intramolecular reactions. Thermodynamically and kinetically controlled reactions.
- Organic reaction mechanism (elementary idea): Definition and classification of organic reactions: substitution, addition, elimination, rearrangement, oxidation, and reduction reactions with suitable examples. Homolytic and Heterolytic fission with suitable examples. Curly arrow rules; Electrophiles and Nucleophiles; Nucleophilicity, nucleofugacity, and basicity.
- Reactive intermediates: Carbocations, carbanions, free radicals, carbenes: structure, formation, and their relative stability.
- Tautomerism: Prototropy (keto-enol, nitro - aci-nitro, nitroso-oximino, diazo-amino and enamine-imine systems); composition of the equilibrium in different systems (simple carbonyl; 1,2- and 1,3-dicarbonyl systems, phenols and related systems), factors affecting keto-enol tautomerism; application of thermodynamic principles in tautomeric equilibria.
- Classification and nomenclature of organic compounds (carbocyclic, aromatic, heterocyclic and heteroaromatic compounds), aromaticity, Huckel rule, anti-aromaticity explanation with examples. 12 Lectures

B. Stereochemistry -I

- Fischer Projection, Newmann and Sawhorse Projection formulae and their interconversions;
- Geometrical isomerism: cis–trans and, syn-anti isomerism E/Z notations with C.I.P rules.
- Optical Isomerism: Optical Activity, Specific Rotation, Chirality/Asymmetry, Enantiomers, Molecules with two or more chiral centers, Distereoisomers, meso-compounds, Racemic mixture, and resolution. Relative and absolute configuration: D/L and R/S designations. (8 Lectures)

Suggested Textbooks:

- A guidebook to mechanism in organic chemistry; Peter Sykes
- Organic Chemistry, Vol. 1, 6e: FINAR
- Basic Stereochemistry of Organic Molecules, Subrata .Sengupta.
- Organic chemistry: Solomon's Global edition

Physical Chemistry

A. Gaseous State: Behaviour of real gases: Deviations from ideal gas behaviour, compressibility factor, Z, and its variation with pressure for different gases. Causes of deviation from ideal

behaviour. van der Waals' equation of state, its derivation and application in explaining real gas behaviour, mention of other equations of state (Berthelot, Dietrici); virial equation of state; van der Waals equation expressed in virial form and calculation of Boyle temperature. Experimental isotherms of real gases and their comparison with van der Waals isotherms, continuity of states, critical state, relation between critical constants and van der Waals constants, law of corresponding states. ,

(12 lectures)

B. Ionic equilibrium: Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water. Ionization of weak acids and bases, Salt hydrolysis, pH scale, Buffer solutions; derivation of Henderson equation and its applications; buffer capacity, buffer range, buffer action. Qualitative treatment of acid – base titration curves (calculation of pH at various stages). Theory of acid–base indicators; selection of indicators and their limitations. (8 lectures)

Suggested Textbooks:

- Physical Chemistry, 7thEdition, P. C. Rakshit
- Kapoor, K.L., Textbook of Physical Chemistry (Volume 1 and Volume-2), McGraw Hill Education
- Comprehensive Physical Chemistry, Part 1, Hrishikesh Chatterjee

Practical

- **Detection of special elements (N, S, Cl, Br, I) by Lassaigne's test**
- **Melting point of the given compound**
- Understand and practice the calibration of glassware (burette, pipette, volumetric flask). Preparation of solutions of different Molarity/Normality of titrants
- Preparation of buffer solutions and determination of pH
- (i) Estimation of carbonate and hydroxide present together in mixture. (ii) Estimation of carbonate and bicarbonate present together in a mixture. (iii) Estimation of free alkali present in different soaps/detergents

Minor-1

General Chemistr-1

(Objective: In this course, basics of three branches of chemistry like atomic structure, bonding theories, fundamentals of reaction mechanism, stereochemistry, basic thermodynamics and chemical equilibrium is introduced to have a solid base on chemistry)

(Credits: Theory-04, Practicals-02) Theory: 60 Lectures

Section A: Inorganic Chemistry-1 (20 lectures)

Atomic Structure: Review of Bohr's theory and its limitations, dual behaviour of matter and radiation, de Broglie's relation, Heisenberg Uncertainty principle. Hydrogen atom spectra. Need of a new approach to Atomic structure. What is Quantum mechanics? Time independent Schrodinger equation and meaning of various terms in it. Significance of ψ and ψ^2 , Schrödinger equation for hydrogen atom. Radial and angular parts of the hydogenic wavefunctions (atomic orbitals) and their variations for 1s, 2s, 2p, 3s, 3p and 3d orbitals (Only graphical representation). Radial and angular nodes and their significance. Radial distribution functions and the concept of the most probable distance with special reference to 1s and 2s atomic orbitals. Significance of quantum numbers, orbital angular momentum and quantum numbers ml and ms. Shapes of s, p and d atomic orbitals, nodal planes. Discovery of spin, spin quantum number (s) and magnetic spin quantum number (ms). Rules for filling electrons in various orbitals, Electronic configurations of the atoms. Stability of half-filled and completely filled orbitals, concept of exchange energy. Relative energies of atomic orbitals, Anomalous electronic configurations. (12 Lectures)

Chemical Bonding and Molecular Structure

Ionic Bonding: General characteristics of ionic bonding. Energy considerations in ionic bonding, lattice energy and solvation energy and their importance in the context of stability and solubility of ionic compounds. Statement of Born-Landé equation for calculation of lattice energy, Born-Haber cycle and its applications, polarizing power and polarizability. Fajan's rules, ionic character in covalent compounds, bond moment, dipole moment and percentage ionic character. Covalent bonding: VB Approach: Shapes of some inorganic molecules and ions on the basis of VSEPR and hybridization with suitable examples of linear, trigonal planar, square planar, tetrahedral, trigonal bipyramidal and octahedral arrangements. Concept of resonance and resonating structures in various inorganic and organic compounds. (10 Lectures)

Section B: Organic Chemistry-1 (20 Periods)

Fundamentals of Organic Chemistry :

Physical Effects, Electronic Displacements: Inductive Effect, Electromeric Effect, Resonance and Hyperconjugation. Cleavage of Bonds: Homolysis and Heterolysis. Structure, shape and reactivity of organic molecules: Nucleophiles and electrophiles. Reactive Intermediates: Carbocations, Carbanions and free radicals. Strength of organic acids and bases: Comparative study with emphasis on factors affecting pK values. Aromaticity: Benzenoids and Hückel's rule. (10 Lectures)

Stereochemistry Conformations with respect to ethane, butane and cyclohexane. Interconversion of Wedge Formula, Newmann, Sawhorse and Fischer representations. Concept of chirality (up to two carbon atoms). Configuration: Geometrical and Optical isomerism; Enantiomerism, Diastereomerism and Meso compounds). Threo and erythro; D and L; cis – trans nomenclature; CIP Rules: R/ S (for upto 2 chiral carbon atoms) and E / Z Nomenclature (for up to two C=C systems). (10 Lectures)

Part-C

Physical Chemistry

Basic Thermodynamics: Introduction, thermodynamic terms, work, heat energy, 0^{th} law, 1^{st} law enthalpy, heat capacity Jule-Thompson effect, 2^{nd} law of thermodynamics, entropy, entropy of mixing, Carnot

cycle, irreversible process, Cp, Cv, entropy & probability, entropy change in chemical reactions and their application. 3rd law of thermodynamics. (10 Lectures)

Chemical Equilibrium: Free energy change in a chemical reaction. Thermodynamic derivation of the law of chemical equilibrium. Distinction between ΔG and ΔG^{O}, Le Chatelier's principle. Relationships between K_p, K_c and K_x for reactions involving ideal gases. (10 Lectures)

Practical

1. Detection of extra elements (N, S, Cl, Br, I) in organic compounds (containing up to two extra elements)
2. Estimation of sodium carbonate and sodium hydrogen carbonate present in a mixture.
3. Estimation of oxalic acid by titrating it with $KMnO_4$.
4. Estimation of water of crystallization in Mohr's salt by titrating with $KMnO_4$.
5. Estimation of Fe (II) ions by titrating it with $K_2Cr_2O_7$ using internal indicator.

Semester-II

Major II - Fundamentals of Chemistry -2 (Credit 6, Theory 4 and Practical 2)
Number of Classes required – 4 h theory and 4 h practical per week basis

INORGANIC CHEMISTRY

A. Atomic Structure: Bohr's theory, its limitations and atomic spectrum of hydrogen atom. Wave mechanics: de Broglie equation, Numerical Problems on calculation of wavelength of an electron Heisenberg's Uncertainty Principle and its significance. Schrödinger's wave equation, significance of ψ and ψ^2 . Hamiltonian operator. Eigen values and function. Concept of orbitals, Radial and angular parts of the hydrogenic wave function (atomic orbitals) and their variations for 1s, 2s, 2p, 3s, 3p and 3d orbitals (graphical representation only). Quantum numbers and their significance. Contour boundary and probability diagrams. The four types of quantum numbers, shapes, s, p and d atomic orbitals, discovery of spin, spin quantum numbers (s) and magnetic spin quantum number (m_s). Electronic configuration of elements. Principles (Aufbau, Pauli's exclusion principle and Hund's rule). Stability of half-filled and completely filled orbitals. Relative energies of atomic orbitals, Anomalous electronic configurations **12 Lectures**

B. Bonding: lonic bond: General characteristics, types of ions, size effects, radius ratio rule and its limitations. Packing of ions in crystals. Born-Landé equation with derivation and importance of Kapustinskii expression for lattice energy. Madelung constant, Born-Haber cycle and its application, Solvation energy.

(ii) Covalent bond: Lewis structure, Valence Bond theory (Heitler-London approach). Energetics of hybridization, equivalent and non-equivalent hybrid orbitals. Resonance and resonance energy,

Formal charge, Covalent character in ionic compounds, polarizing power and polarizability. Fajan's rules and consequences of polarization. 8 lectures

Suggested Textbooks:

- **Concise Inorganic Chemistry by J D Lee (5th Edition)**
- **Inorganic Chemistry by R. L. Dutta & G.S. De**
- **General and Inorganic Chemistry by Ramaprasad Sarkar- Volume 1**

ORGANIC CHEMISTRY

A. **Chemistry of aliphatic hydrocarbons with reaction mechanisms**: Notations used to represent electron movements and directions of reactions- curly arrows, formal charges. Types of bonds breaking- homolytic and heterolytic. Types of reagents- Electrophiles, nucleophiles, nucleophilicity and basicity. Types of organic reactions- nucleophilic substitution addition, elimination, rearrangement and pericyclic reactions, explanation with examples. **Chemistry of Aliphatic hydrocarbons**, Carbon-Carbon Sigma bonds Chemistry of alkanes: Formation of alkanes, Wurtz reaction, Free radical substitution, Halogenation- relative reactivity and selectivity Carbon-carbon pi bonds **Chemistry of alkenes**: Formation of alkenes and alkynes by elimination reaction. Mechanism of E1, E2, E1cB reaction, syn/anti elimination. Saytzeff and Hofmann eliminations. syn and anti-addition; addition of H_2, X_2 Addition of HBr to propene, Free radical addition of HBr to propene. Addition of halogens to alkenes-carbocation and halonium ion mechanism. Stereospecificity of halogen addition. Ozonolysis reaction and mechanism. Addition of hydrogen halides to alkenes, mechanism, regioselectivity and relative rates of addition. Hydrogenation, hydration, hydroxylation and epoxidation of alkenes, explanation with examples, 1,2 and 1,4- addition reactions in conjugated dienes. Diels-Alder reaction, Allylic and benzylic bromination and mechanism in propene, 1-butene, 1-toluene and ethylbenzene. **Chemistry of alkynes:** oxymercuration-demercuration, hydroboration-oxidation, ozonolysis, hydroxylation, reaction with NBS, Reactions of alkynes; acidity, Alkylation of terminal alkynes, electrophilic addition: hydration to form carbonyl compounds, Relative reactivity of alkenes and alkynes, 1,2-and 1,4-addition reactions in conjugated dienes, Diels Alder reaction **Chemistry of alkyl halides**: Methods of preparation and properties, nucleophilic substitution reactions – S_N1, S_N2 and S_Ni mechanisms with stereochemical aspects and effect of solvent; nucleophilic substitution v/s elimination. Organometallic compounds of Mg (Grignard reagent) – Use in synthesis of organic compounds. 12 Lectures

B. **Advanced Stereochemistry:** Chirality, elements of Symmetry, simple axis, plane of symmetry, centre of symmetry, alternating axis of symmetry. Asymmetry & disymmetry, optical activity, specific rotation, molar rotation. Enantiomerism & Diastereoisomerism, Stereogenic centres, systems with chiral centres, Stereogenic centres involving C=C, C=N; D/L, R/S, E/Z, syn/ anti,

cis/trans, meso/dl, threo/erythro nomenclature. Isomerism involving two like/unlike stereogenic centres (AA, AB, ABA and ABC types), pseudo-asymmetric centres, stereogenicity.

8 **Lectures**

Suggested Textbooks:

- A guidebook to mechanism in organic chemistry; Peter Sykes
- Organic Chemistry, Vol. 1, 6e: FINAR
- Basic Stereochemistry of Organic Molecules, Subrata .Sengupta.
- Organic chemistry: Solomon's Global edition

Physical Chemistry

A. Gaseous State: Kinetic molecular model of a gas: postulates and derivation of the kinetic gas equation; collision frequency; collision diameter; mean free path and viscosity of gases, including their temperature and pressure dependence, relation between mean free path and coefficient of viscosity, calculation of σ from η; variation of viscosity with temperature and pressure. Maxwell distribution and its use in evaluating molecular velocities (average, root mean square and most probable) and average kinetic energy, law of equipartition of energy, degrees of freedom and molecular basis of heat capacities. Barometric distribution law. **10 Lectures**

B. Liquids: Nature of liquid state, qualitative treatment of the structure of the liquid state. Physical properties of liquids-vapor pressure, its origin and definition, Vapor pressure of liquids and intermolecular forces, and boiling point. Surface tension, its origin and definition, Capillary action in relation to cohesive and adhesive forces, determination of surface tension by (i) using stalagmometer (drop number and drop mass method both) and (ii) capillary rise method, Effects of addition of sodium chloride, ethanol and detergent on the surface tension of water and its interpretation in terms of molecular interactions, Role of surface tension in the cleansing action of detergents Coefficient of viscosity and its origin in liquids, Interpretation of viscosity data of pure liquids (water, ethanol, ether and glycerol) in the light of molecular interactions, Effects of addition of sodium chloride, ethanol and polymer on the viscosity of water, relative viscosity, specific viscosity and reduced viscosity of a solution, comparison of the origin of viscosity of liquids and gases, effect of temperature on the viscosity of a liquid and its comparison with that of a gas. **10 Lectures**

(These topics are well elaborated in the following references

- Physical Chemistry, 7thEdition, P. C. Rakshit
- Kapoor, K.L., Textbook of Physical Chemistry (Volume 1 and Volume-2), McGraw Hill Education

- Comprehensive Physical Chemistry, Part 1, Hrishikesh Chatterjee

Practical

1. **preparation of some selected organic/inorganic compounds:**

    a. **Potash alum**
    b. **Royal blue complex of copper(II)**
    c. **p-Bromo acetanilide**
    d. **Benzoylation of aniline**

2. Surface tension of ethanol/methanol/iso-propanol-water mixture
3. Viscosity of glycerol-water and PEG-water mixture

Minor-II

General Chemistr-1

(Credits: Theory-04, Practicals-02) Theory: 60 Lectures

Inorganic Chemistry

General group trends with special reference to electronic configuration, variable valency, colour, magnetic and catalytic properties, ability to form complexes and stability of various oxidation states (Latimer diagrams) for Mn, Fe and Cu. Lanthanoids and actinoids: Electronic configurations, oxidation states, colour, magnetic properties, lanthanide contraction, separation of lanthanides (ion exchange method only). (12 Lectures)

MO Approach: Rules for the LCAO method, bonding and antibonding MOs and their characteristics for s-s, s-p and p-p combinations of atomic orbitals, nonbonding combination of orbitals, MO treatment of homonuclear diatomic molecules of 1st and 2nd periods (including idea of s-p mixing) and heteronuclear diatomic molecules such as CO, NO and NO^+ . Comparison of VB and MO approaches. (8 lectures)

Organic Chemistry

Aliphatic Hydrocarbons Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structure. Alkanes: (Up to 5 Carbons). Preparation: Catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis, from Grignard reagent. Reactions: Free radical Substitution: Halogenation. Alkenes: (Up to 5 Carbons) Preparation: Elimination reactions: Dehydration of alkenes and dehydrohalogenation of alkyl halides (Saytzeff's rule); cis alkenes (Partial catalytic hydrogenation) and trans alkenes (Birch reduction). Reactions: cis-addition (alk. KMnO4) and trans-addition (bromine), Addition of HX (Markownikoff's and antiMarkownikoff's addition), Hydration, Ozonolysis, oxymecuration-demercuration, Hydroboration-oxidation. Alkynes: (Up to 5 Carbons) Preparation: Acetylene from CaC2 and conversion into higher alkynes; by dehalogenation of tetra halides and dehydrohalogenation of vicinal-dihalides. Reactions: formation of metal acetylides, addition of bromine and alkaline KMnO4, ozonolysis and oxidation with hot alk. KMnO4. (12 Lectures)

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

(8 Lectures)

Physical Chemistry

Chemical Energetics: Review of thermodynamics and the Laws of Thermodynamics. Important principles and definitions of thermochemistry. Concept of standard state and standard enthalpies of formations, integral and differential enthalpies of solution and dilution. Calculation of bond energy, bond dissociation energy and resonance energy from thermochemical data. Variation of enthalpy of a reaction with temperature – Kirchhoff's equation. Statement of Third Law of thermodynamics and calculation of absolute entropies of substances. (10 Lectures)

Ionic Equilibrium: Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water. Ionization of weak acids and bases, pH scale, common ion effect. Salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts. Buffer solutions. Solubility and solubility product of sparingly soluble salts – applications of solubility product principle. (12 Lectures)

Laboratory

(Credits: Practicals-02) practical: 60 hours of practical classes

pH measurements Measurement of pH of different solutions like aerated drinks, fruit juices, shampoos and soaps (use dilute solutions of soaps and shampoos to prevent damage to the glass electrode) using pH-meter. a) Preparation of buffer solutions: (i) Sodium acetate-acetic acid (ii) Ammonium chloride-ammonium hydroxide Measurement of the pH of buffer solutions and comparison of the values with theoretical values.

Preparations: Mechanism of various reactions involved to be discussed. Recrystallisation, determination of melting point and calculation of quantitative yields to be done.

(a) Bromination of Phenol/Aniline (b) Benzoylation of amines/phenols (c) Oxime and 2,4-dinitrophenylhydrazone of aldehyde/ketone.

MULTIDISCIPLINARY COURSE:

WATER MANAGEMENT (WATER RESOURCE - ECONOMICS, GOVERNANCE AND POLICY) (CREDITS - 03)

Paper outcome: It is expected to give an exposure to students of social and natural sciences and humanities for better understanding of water resources, water economics, water governance and policy.

A. Water resources and sustainable development Water as a resource, Dublin-Rio Principles on Water and Sustainable Development, Brief account of concept of water stress, scarcity, water footprint and virtual water trade, Right to Water (SDG-6); Entitlements and criteria, Concept and overview of Water, Sanitation and Hygiene (WASH), Swach Bharat Mission and National Water Mission
B. Water economics Valuing of water: The use and non-use values of water, Introduction to water valuation methods: Non-revenue waters (NRW) and unaccounted for water (UFW); Metering water uses; Water management through economic instruments. Water Pricing - Approach and Models: Significance of water pricing Water pricing models - flat rate and uniform rate, Brief account of water pricing practices in India and abroad.
C. Water governance, conflicts and policy Water Governance: Elements and dimensions of water governance; Effective water governance schemes; Indicators of good governance. Water Governance in India: Salient features of National water policy 2012 and Jammu and Kashmir Water Resource (Regulation and Management) act 2010, Conflicts in Water Pricing: Conflicts on subsidy verses sustainability, overview of global water conflicts and interstate water conflicts in India.

Suggested readings:

- Handbook of Water Economics: Principles and Practice (2003) by Colin H. Green; Publisher - Willy
- Handbook of Water Economics (2015)by Ariel Dinar and Kurt Schwabe (editors); Publisher - Edward Elgar
- Water and the Laws in India (2009) by Ramaswamy R. Iyer; Publisher - SAGE Publications
- Water Law Poverty and Development, Water Sector Reforms in India by Philippe Cullet; Publisher - Oxford (2009)
- Water Resource Economics: Towards a Sustainable Use of Water for Irrigation in India (2015) by M.G. Chandrakanth; Publisher - Springer
- Water Governance: An Evaluation of Alternative Architectures (2013), by A. Gunawansa and L. Bhullar (editors) Publisher - Edward Elgar (2013

Further Reading

- **Inorganic Chemistry by Sharpe (3rd Edition)**
- **Advanced Inorganic Chemistry by G H Bailey and William Briggs**
- Fundamental Concepts of Inorganic Chemistry by A K Das (volume 1, 2 and 3)
- Morrison, R. N.; Boyd, R. N. (2010) Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), 7th Edition
- Stereochemistry Nashipuri
- Physical Chemistry by Castellan
- Physical Chemistry by Atkins, 9th Edition
- Purcell, K.F & Kotz, J.C. Inorganic Chemistry W.B. Saunders Co, 1977.
- Huheey, J.E., Inorganic Chemistry, Prentice Hall, 1993.
- Cotton, F.A. & Wilkinson, G, Advanced Inorganic Chemistry. Wiley-VCH, 1999
- Basolo, F, and Pearson, R.C., Mechanisms of Inorganic Chemistry, John Wiley & Sons, NY, 1967.
- Greenwood, N.N. & Earnshaw A., Chemistry of the Elements, Butterworth- Heinemann,1997.
- Atkins, P.W & Paula, J.D. Physical Chemistry, 10th Ed., Oxford University Press (2014).
- Castellan, G. W. Physical Chemistry 4th Ed., Narosa (2004).
- Mortimer, R. G. Physical Chemistry 3rd Ed., Elsevier: NOIDA, UP (2009).
- Barrow, G. M., Physical Chemistry 5th Ed., Tata McGraw Hill: New Delhi (2006). Engel, T. & Reid, P. Physical Chemistry 3rd Ed., Prentice-Hall (2012).
- Rogers, D. W. Concise Physical Chemistry Wiley (2010).
- Silbey, R. J.; Alberty, R. A. & Bawendi, M. G. Physical Chemistry 4th Ed., John Wiley & Sons, Inc. (2005).
- Banwell, C. N. & McCash, E. M. Fundamentals of Molecular Spectroscopy 4th Ed. Tata McGraw-Hill: New Delhi (2006).
- Chandra, A. K. Introductory Quantum Chemistry Tata McGraw-Hill (2001).
- House, J. E. Fundamentals of Quantum Chemistry 2 nd Ed. Elsevier: USA (2004). Kakkar, R. Atomic & Molecular Spectroscopy: Concepts & Applications, Cambridge University Press (2015).
- Lowe, J. P. & Peterson, K. Quantum Chemistry, Academic Press (2005).