



GU/Acad –PG/BoS - GU-ART /2025-26/579

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CIRCULAR

The syllabus for the Goa University–Admission Ranking Test (GU-ART) of **Master of Science in Chemistry** and **B.Ed. in Chemistry** Programmes, approved by the Academic Council in its meeting held on 7th November 2025 is attached.

The Dean/Vice-Dean (Academic) of the School of Chemical Sciences and the Principals of all the affiliated Colleges are requested to take note of the above and bring the contents of this Circular to the notice of all concerned, including students aspiring to pursue the Master's and B.Ed. Programmes.

(Ashwin V. Lawande)
Deputy Registrar – Academic

To,

1. The Dean, School of Chemical Sciences, Goa University.
2. The Vice-Dean (Academic), School of Chemical Sciences, Goa University.
3. Principals of all the affiliated Colleges.

Copy to:

1. Controller of Examinations, Goa University.
2. Assistant Registrar (Admissions), Goa University.
3. Assistant Registrar Examinations (UG/PG), Goa University.
4. Director, Directorate of Internal Quality Assurance, Goa University for uploading the Syllabus on the University website.



GOA UNIVERSITY

SYLLABUS FOR GOA UNIVERSITY-ADMISSIONS RANKING TEST (GU-ART)
FOR MASTER'S & B.Ed. IN CHEMISTRY PROGRAMMES
(ORGANIC/INORGANIC/PHYSICAL/ANALYTICAL/PHARMACEUTICAL)

Effective from AY: 2026-27

Modules	Content
Module 1:	Organic Chemistry
	Fundamentals of Organic Chemistry Basic Organic Chemistry: Electronic Displacements: Inductive Effect, Mesomeric effect, Resonance and Hyperconjugation. Cleavage of Bonds. Structure, shape and reactivity of organic molecules: Nucleophiles and electrophiles. Reactive Intermediates: Carbocations, Carbanions and free radicals. Strength of organic acids and bases. Factors affecting pKa values. Aliphatic Hydrocarbons: Functional group approach for the following reactions: Alkanes: Wurtz reaction, Kolbe's synthesis, Reactions: Free radical Substitution: Halogenation. Alkenes: Preparation: Dehydration of alcohols and dehydrohalogenation of alkyl halides, Markownikoff's and anti-Markownikoff's addition. Alkynes: Acetylene from CaC_2 and conversion into higher alkynes; by dehalogenation of tetra halides and dehydrohalogenation of vicinal-dihalides. formation of metal acetylides, addition of HX and bromine. Aromaticity: Concept of aromaticity, Huckel's Rule, nomenclature of benzenoids, naphthalene and anthracene compounds. Types of organic reactions and structure, properties and uses of selected organic compounds: Addition, elimination, substitution, oxidation, reduction and rearrangement. Structure, properties and uses of Ethanol, acetone, ethyl acetate, formaldehyde, acetylene, benzoic acid, n-butane, chloroform, diethyl ether, cresol, benzaldehyde, aniline, urea, glucose, lauric acid. Preparation of ethanol, benzoic acid, acetone, acetylene, ethyl acetate, diethyl ether. Aromatic hydrocarbons: Preparation (benzene): from phenol, from acetylene. Reactions: (benzene): nitration, halogenation and sulphonation. Friedel-Craft's reaction. Preparation of toluene, ethylbenzene, isopropylbenzene, acetophenone, propiophenone, butyrophenone, <i>n</i>-

propylbenzene, *n*-butylbenzene, *t*-butylbenzene, isobutylbenzene. Side chain oxidation of alkyl benzenes to benzoic acid.

Alkyl and Aryl Halides: Alkyl Halides: IUPAC Nomenclature (examples upto 5 Carbons), Preparation: from alkenes and alcohols. Reactions: hydrolysis, nitrite & nitro formation. Types of Nucleophilic Substitution (SN1 & SN2) reactions (mechanism without stereochemistry). Aryl Halides: Preparation: Sandmeyer reaction. Replacement by –OH group to give phenol and effect of nitro substituent). Benzyne Mechanism.

Alcohols, Phenols, Ethers and Carbonyl Compounds: Alcohols: IUPAC Nomenclature (examples upto 5 Carbons), Preparation of 1°, 2° and 3° alcohols: using Grignard reagent, Ester hydrolysis, Reduction of aldehydes, ketones, Reactions: With sodium, HX, esterification, oxidation.

Phenols: Preparation: Cumene hydroperoxide method, from diazonium salts. Reactions: nitration, halogenation and sulphonation. Ethers (aliphatic and aromatic): Williamson's synthesis. Cleavage of ethers with HI. Aldehydes and ketones. Preparation: from alcohols and acid chlorides. Reactions—with HCN, ROH, NH₃, 2,4-DNP, NH₂OH, Iodoform test. preparation of chalcone.

Carboxylic acids and its derivatives: Carboxylic acids. IUPAC nomenclature, Preparation: Acidic and Alkaline hydrolysis of esters, Oxidation of Toluene to benzoic acid. Hydrolysis of cyanides, Grignard synthesis of carboxylic acids. Reactions: Hell - Volhard - Zelinsky Reaction. Carboxylic acid derivatives (aliphatic): (up to 5 carbons) Preparation: Acid chlorides, Anhydrides, Esters and Amides from acids and their interconversions, Reactions: Comparative study of the nucleophilicity towards acyl derivatives. Hydrolysis of acid chlorides, acid amide to carboxylic acids.

Amines and Diazonium Salts: Amines. IUPAC nomenclature, Preparation: from alkyl halides, Gabriel's phthalimide synthesis, Hofmann bromamide reaction. Reduction of cyanides, reduction of nitroarenes. Reactions: Elimination reactions Hofmann vs. Saytzeff elimination, Carbylamine test, Hinsberg test, with HNO₂, Schotten – Baumann reaction. Electrophilic substitution of aniline: nitration, bromination, sulphonation. Diazonium salts: Preparation from aromatic amines, conversion to benzene, phenol, chlorobenzene, bromobenzene. Preparation of azo dye of aniline with β -naphthol.

Introduction to Stereochemistry: Types of isomerism. Stereoisomerism, conformational isomerism. Conformations with respect to ethane. Interconversion of Wedge Formula, Newmann, Sawhorse and Fischer representations. Configuration: Geometrical and Optical isomerism; Enantiomerism, Diastereomerism and Meso compounds. Threo and erythro; D and L; cis – trans nomenclature; Cahn Ingold Prelog Rules: R/ S and E / Z Nomenclature.

Module 2:	Inorganic Chemistry
	Fundamentals of Inorganic Chemistry Atomic Structure: Bohr's theory, dual behaviour of matter and radiation, de Broglie's relation, Heisenberg Uncertainty principle. Hydrogen atom spectra. Need of a new approach to atomic structure. Schrodinger equation and wave function. Radial and angular nodes and their significance. Quantum numbers and their significance, Discovery of spin, spin quantum number (s) and magnetic spin quantum number (ms). Shapes of s, p and d atomic orbitals, nodal planes. Rules for filling electrons in various orbitals, electronic configurations of the atoms. Relative energies of atomic orbitals, Anomalous electronic configurations. Introduction to the periodic table: Classification of the elements into s,p,d and f -block elements on the basis of electronic configuration, Trends in the periodic table (atomic and ionic size). Periodicity of Elements: Periodicity, and magic numbers. Valence Electronic configurations. Periodic properties of the elements and their trends: Atomic radii, van der Waal's radii, Ionic radii and Covalent radii, shielding or screening effect, Effective nuclear charge, Slater rules. Ionization Energy, Successive ionization energies and factors affecting ionization energy. Electron Affinity. Electronegativity: Pauling's and Allred Rochow's scale. Factors affecting electronegativity. Acid- Base Theories: Arrhenius Concept, Bronsted Theory, Lewis Concept of Acids and Bases. Chemical Bonding and Molecular Structure: Concept of electron density, Covalent bonding, Lewis theory, octet rule. Valence bond theory: Rules for Resonance or Canonical Structures. Bonding in Polyatomic Species: Promotion, Hybridization, sp^3 hybridisation in CH_4, NH_3 and H_2O) Types of hybrid orbitals-sp, sp^2, sp^3, sp^3d, sp^3d^2 and sp^3d^3. b) Co-ordinate covalent bond: VSEPR Theory, Application of the theory to explain the geometry of molecules like H_2O, NH_3, $TiCl_4$, ClF_3, OF_2, NH_4^+ and ICl_2^-. Molecular Orbital Theory (MO) approach: Comparing Atomic Orbitals and Molecular Orbitals. Bonding and Antibonding MOs. LCAO-MO diagrams for O_2, N_2). Heteronuclear diatomic molecules: CO, NO and NO^+ and bond orders. Prediction of stability/reactivity and magnetic nature O_2, O_2^+, O_2^-, O_2^{2-}. Ionic bonding: Energy considerations in ionic bonding; Types of Ionic Crystals, Radius Ratio Rules. Lattice energy, 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. Solids: Symmetry elements, unit cells, crystal systems, Bravais lattice. Miller indices, X-Ray diffraction by crystals, Bragg's law. Determination of lattice parameters using powder method. Structures of NaCl, KCl and CsCl (qualitative treatment only). (Numerical are expected)

	Theoretical Basis for the Qualitative Inorganic Analysis: Common ion effect, solubility product, complex ion formation, buffers, applications in inorganic qualitative analysis. s - block Elements: Electronic configuration, Periodic trends in Properties viz. size of atom, ion, ionization potential, flame colouration, and reactivity. Diagonal relationship between Li-Mg and Be-Al, Solubility and hydration, Biological roles. Selected topics on p-block elements: Chemistry of Group 13 elements: Comparative study w.r.t. oxides, halides & hydrides. Electron deficient compounds – BH_3, BF_3, BCl_3. Boranes and types of Boranes, Wade's formula. Preparations, structure and bonding in diborane and tetraborane. Introduction to carboranes. Borates. Chemistry of Group 14 elements: Comparative study w.r.t. oxides, halides & hydrides. Preparation of extra pure Silicon and Germanium. Silicates: classification and structure. Chemistry of Group 15 elements: Comparative study w.r.t. oxides & oxyacids, halides & hydrides. Structures of NO, NO_2, N_2O, N_2O_4. Synthesis of ammonia by Haber-Bosch process, synthesis of HNO_3 by Ostwald's process (Physico-chemical principles not expected). Chemistry of Noble Gases: Chemical properties and uses. Clathrates. Preparation, structure and bonding in xenon compounds (XeF_2, XeF_4, XeO_6, XeO_4, XeO_2F_2, $[\text{XeO}_6]^{4-}$, XeOF_4). Comparative Chemistry of the Transition Metals: Electronic configuration, significance and special stability of empty, half-filled and completely filled d orbitals. Complex formation, variable oxidation states, unusual oxidation states and their stabilities in aqueous solutions (w.r.t. vanadium and chromium), colour, magnetic and catalytic properties of transition metals and their compounds. Chemistry of titanium and vanadium w.r.t. properties of their oxides and chlorides. Qualitative tests for the ions of the first transition series. Coordination Compounds: Molecular compounds: double salts and complex salts. Werner's theory of coordination compounds. Nomenclature of coordination compounds. Coordination numbers and geometries, Effective atomic number Rule. Structural isomerism. Stereoisomerism w.r.t. C.N. = 4 and 6 only. Role of coordination compounds in biology and medicine w.r.t. Chlorophyll, Haemoglobin and cisplatin.
Module 3:	Physical Chemistry
	Fundamentals of Physical Chemistry Gaseous state: Critical phenomenon; PV isotherms of real gases, continuity of states, the isotherms of van der Waal's equation relation between critical constants and van der Waal's constants. Law of corresponding states, reduced equation of state. Molecular velocities: root mean square, average and most probable velocities, Qualitative discussion of Maxwell's

distribution of molecular velocities, collision number, mean free path and collision diameter. Numerical problems.

Liquid State: Determination of Surface Tension by Capillary Rise Method and stalagmometer method. Viscosity, Poiseuille equation, Ostwald Method, Effect of Temperature on Viscosity of a Liquid. Numerical problems.

Solutions: Raoult's law and deviation from Raoult's Law (Ways of expressing concentration: Molarity, Normality, Molality Mole fraction, parts per million). Factors influencing the solubility of gases. Henry's law. Numerical problems.

Chemical Equilibrium: Free energy change in a chemical reaction. law of chemical equilibrium. Definition of ΔG and ΔG° , Le Chatelier's principle. Relationships between K_p , K_c and K_x .

Phase equilibria & Colligative properties: Criteria of phase equilibrium. Phase diagrams of water, sulphur and CO_2 , Zn-Mg, AgPb, NaCl- H_2O . Raoult's law. Colligative properties. Osmosis and osmotic pressure. Experimental methods and determination of molecular weight. (Numerical are expected).

Distribution Law: Nernst Distribution Law –modification of distribution law Application of distribution law - solvent extraction, determination of association, dissociation in one solvent or both the solvent. (Numericals are expected)

Thermodynamics: Intensive and extensive properties.

First law of thermodynamics: Heat capacities at constant volume and at constant pressure and their relationship, calculation of w , q , dU & dH for the expansion of ideal gases under isothermal and reversible conditions. Second law of thermodynamics: Carnot cycle and its efficiency. Entropy as a function of V & T , P & T , entropy change in physical and chemical processes, reversible, irreversible and equilibrium conditions. Gibbs free energy and Helmholtz work function. Third law of thermodynamics: Calculation of absolute entropies of substance (numericals to be solved).

Chemical Kinetics: Law of Mass action, effect of temperature, pressure and catalyst on reaction rates. Rate equations for zero, first and second order reactions. Half-life of a reaction. General methods for determination of order of a reaction. Concept of activation energy and its calculation from Arrhenius equation. (numericals are expected).

Nuclear Chemistry: Composition of the nucleus, Mass defect and binding energy, Q – value of nuclear reactions, nuclear binding force; shell model and liquid drop model, radioactive disintegration, decay constant, half-life and average life, Group displacement law, artificial radioactivity, detection and measurement of radioactivity, ionization chamber, GM counter and proportional counter, Scintillation counter. Essential parts of the nuclear

	reactor, Breeder reactor, chain reaction and its control, reprocessing of spent fuel, application of radio isotopes- in the field of medicine, agriculture, industry, as traces and in carbon dating. (numerical to be solved) Photochemistry: Grothus-Draper law, Stark-Einstein law. Quantum yield or efficiency, factors affecting quantum efficiency. Primary and secondary photophysical processes and Jablonski diagram. Kinetics of photochemical reactions of H₂ & Br₂. Distinction between luminescence, fluorescence, phosphorescence and chemiluminescence. Introduction to LASER. (numericals to be solved).
Module 4:	Analytical Chemistry
	Introduction to analytical techniques: Classification of instrumental methods, analytical process (steps involved in chemical analysis). Evaluation of analytical data: Determinate and indeterminate error, constant and proportionate errors, absolute and relative error, correction and minimization of errors. Determination of accuracy in terms of relative error. Relative average deviation, Standard deviation, Variance and Coefficient of variance. (Numericals to be solved) Classical methods of analysis: Principles of gravimetric analysis: Principles of titrimetric analysis: Theories of acid-base, redox (including iodometric/iodimetric), complexometric, and precipitation titrations - choice of indicators for Acid base titrations. Solvent Extraction: Percentage extraction, role of complexing agents, separation factor, types, (Numerical problems are to be solved) UV-Visible Spectroscopy: Beer's and Lambert's law, , Quantitative calculations. Sources, monochromators, cells. Photoelectric colorimeters and Spectrophotometers: Single & Double beam; comparison between colorimeter and spectrophotometer; applications: qualitative & quantitative analysis. (Numericals to be solved) Types of electronic transitions, Chromophores and Auxochromes with examples, λ_{max}, Bathochromic and Hypsochromic shifts, hypochromic and hyperchromic effects. Application of Woodward - Fieser rules for calculation of λ_{max} for the following systems: α, β unsaturated aldehydes, ketones. Conjugated dienes: alicyclic, homoannular and heteroannular, extended conjugated systems (aldehydes, ketones and dienes) (problems to be solved).
Module 5:	Pharmaceutical Chemistry
	Pharmaceutical Chemistry: Classifications of drugs based on their uses, definition, giving one example with structure: Antibacterial- (Sulphacetamide), Antifungal- (Clotrimazole), Antiviral (Amantadine HCl), Anthelmintics (Mebendazole), Antiamoebic (Metronidazole), Antimalarial

	(Chloroquine), Antitubercular (Isoniazid), Antihypertensive (Methyl Dopa), Anticoagulant (Warfarin). IUPAC names, Synthesis and uses of following drugs: Aspirin, paracetamol, Ibuprofen, Sulphacetamide, Clotrimazole, Phenobarbital, Dapsone. Mechanism of Action of representative drugs: Analgesic and Anti-inflammatory drugs (Ibuprofen), Sulphonamides, Central nervous depressant (Phenobarbital). Structure Activity Relationship of representative drugs: Effect of functional groups on physiological activity of drugs: hydroxy, acidic, alkyl, aldehyde, ketone, cyano, halogens.
Module 6:	Industrial Chemistry
	Understanding Key Industries: Raw materials and basic requirements of following industries: petroleum industry, glass industry, cement industry, fertilizers, chlor - alkali industry, polymer industry, paper industry, -iron & steel industry, Pharmaceutical industry. Temperature and pressure measurement: Temperature glass thermometers, bimetallic thermometer, vapor filled Thermometer, resistance thermometer, radiation pyrometers, Manometers, barometers, Bourdon pressure gauge: bellow type, diaphragm type pressure gauges, Macleod gauges, Pirani gauges. Industrial waste and treatment processes: Types of industrial wastes, treatment and disposal of industrial waste, effluents of industrial units.
Module 7:	Basics of Chemical Laboratory Management
	General Safety measures and precaution: Personal protection. Explosion and fire Hazards- General aspects, Explosive compounds, potentially dangerous mixture, some specific dangers of explosion, Fire hazards, Dangerous operation in Laboratory, Conduct of explosive or violent reaction. Reactive inorganic reagents- Strong Acids, Strong Bases, Halogens, Reactive halides, Chromium trioxide, chromate and dichromates. Hazards due to toxic chemical- ingestion, inhalation, direct absorption, highly toxic solids, toxic gases, other harmful substance, carcinogenic substance. Chemical management: Use safer solvent, materials, and design. Experimental products for degradation after use, include real-Time Control to prevent pollution, minimize potential for accidents. Safety datasheet (SDS), Globally Harmonized System (GHS) for hazard communication, Labeling commercially packaged chemicals, chemical container, Experimental materials. Storage of chemicals in stock room and laboratories- storage according to compatibility, Containers and equipment,

	cold storage, flammable and combustible liquids, gas cylinders, highly reactive substances, highly toxic substance. Common Apparatus and glassware: Balances: Care and uses of analytical balances, errors in weighing, Graduated glassware: Graduated apparatus, Temperature standards, graduated flask, pipettes, Burettes, weight burettes, Graduated (measuring) cylinders. General apparatus: glassware, ceramics, plastic ware, heating apparatus, Desiccators and dry boxes, Stirring apparatus, filtration apparatus, weighing bottles. Types of joints. Use of cocks and rubber stopper. Reagents and standard solution: Preparation of standard solution. Molarity, Molality, Normality, ppm, ppb, mole fraction, percentage (calculation expected with examples), Strength and dilutions of acids and bases, buffer solutions. Construction, working and maintenance of cells and electrodes: Conductivity cell, Reference electrode, Saturated Calomel electrode, hydrogen electrode, silver electrode, working electrode- platinum electrode, copper electrode, zinc electrode.
Textbooks:	1. A. Bahl, B.S. Bahl and G.D. Tuli, Essentials of Physical Chemistry, S. Chand Publications, 26th Edn., New Delhi, 2019. 2. R. Puri, L. R. Sharma and M. S. Pathania, Principles of Physical Chemistry, Vishal Publishing Co., Jalandhar, 47th Edn., 2021. 3. G. W. Castellan, Physical Chemistry, 4th Edn., Addison-Wesley (Narosa reprint), 2004. 4. Samuel Glasstone, Textbook of Physical Chemistry, 2nd Edn., Macmillan, 1953. 5. U. N. Dash, Nuclear Chemistry, S. Chand & Sons, New Delhi, 2010. 6. K. K. Rohatgi-Mukherji, Fundamentals of Photochemistry, 3rd Edn., New Age International Publishers, New Delhi, 2017. 7. J. D. Lee, Concise Inorganic Chemistry, 5th Edn., Wiley India, 2003. 8. P. W. Atkins, T. L. Overton, J. P. Rourke, M. T. Weller & F. A. Armstrong, Shriver & Atkins' Inorganic Chemistry, 5th Edn., Oxford University Press, 2010. 9. R. Puri, L. R. Sharma and K. C. Kalia, Principles of Inorganic Chemistry, 33rd Edn., Vishal Publishing Co., 2020. 10. S. Prakash, G. D. Tuli, S. K. Basu and R. D. Madan, Advanced Inorganic Chemistry Vol. I, S. Chand & Co., New Delhi, 2013. 11. S. Prakash, G. D. Tuli, S. K. Basu and R. D. Madan, Advanced Inorganic Chemistry Vol. I, 19th Edn., S. Chand Publishers, 2016. 12. M. C. Day and J. Selbin, Theoretical Inorganic Chemistry, ACS Publications, 1962.

13. F. A. Cotton, G. Wilkinson and P. L. Gaus, Basic Inorganic Chemistry, 3rd Edn., Wiley India, 2007.
14. F. A. Cotton and G. Wilkinson, Advanced Inorganic Chemistry, 3rd Edn., Wiley, 1972.
15. J. E. Huheey, E. A. Keiter, R. L. Keiter and U. K. Medhi, Inorganic Chemistry: Principles of Structure and Reactivity, Pearson Education, 2006.
16. I. L. Finar, Organic Chemistry Vol. I, 6th Edn., Pearson Education, India, 1973.
17. I. L. Finar, Organic Chemistry Vol. II, 3rd Edn., Longmans, London, 1964.
18. R. T. Morrison, R. N. Boyd and S. K. Bhattacharjee, Organic Chemistry, 7th Edn., Pearson, Bangalore, 2010.
19. Francis A. Carey, Organic Chemistry, 4th Edn., Tata McGraw Hill, India, 2000.
20. Paula Yurkanis Bruice, Organic Chemistry, 3rd Edn., Pearson Education Asia, 2014.
21. B. K. Sharma, Instrumental Methods of Chemical Analysis, 5th Edn., Goel Publishing House, Meerut, 2004.
22. G. Chatwal and S. Anand, Instrumental Methods of Chemical Analysis, 5th Edn., Himalaya Publishing, 2003.
23. H. Willard, L. Merritt and J. A. Dean, Instrumental Methods of Analysis, 7th Edn., CBS Publishers, 2004.
24. A. Skoog and J. J. Leary, Principles of Instrumental Analysis, 4th Edn., Saunders College, 1992.
25. G. D. Christian, Analytical Chemistry, 6th Edn., Wiley, New York, 2004.
26. G. H. Jeffery, J. Bassett, J. Mendham and R. C. Denney, Vogel's Textbook of Quantitative Chemical Analysis, 5th Edn., Longman, UK, 1989.
27. B. S. Furniss, A. J. Hannaford, P. W. G. Smith and A. R. Tatchell, Vogel's Textbook of Practical Organic Chemistry, 5th Edn., Pearson Education, 2011.
28. K. Raghuraman, D. V. Prabhu, C. S. Prabhu and P. A. Sathe, Basic Principles in Analytical Chemistry, 5th Edn., Shet Publications, 2010.
29. L. Pavia, G. M. Lampman and G. S. Kriz, Introduction to Spectroscopy, 3rd Edn., Thomson Learning, 2001.
30. R. M. Silverstein and F. Webster, Spectrometric Identification of Organic Compounds, 5th Edn., John Wiley & Sons, 1991.
31. D. Nasipuri, Stereochemistry of Organic Compounds – Principles and Applications, 4th Edn., New Academic Science, UK, 2013.
32. B. K. Sharma, Industrial Chemistry Vol. I & II, 7th Edn., Krishna Prakashan, Meerut, 2014.

	33. L. Patrick, Introduction to Medicinal Chemistry, 7th Edn., Oxford University Press, UK, 2023. 34. D. Sriram and P. Yogeshwari, Medicinal Chemistry, 2nd Edn., Pearson Education, London, 2010.
References/ Readings:	1. J. N. Gurtu, Physical Chemistry Vol. I, 10th Edn., Pragati Prakashan, Meerut, 2016. 2. Gurtu and Gurtu, Advanced Physical Chemistry, Pragati Prakashan, Meerut, 2019. 3. Gurdeep Raj, Advanced Physical Chemistry, 36th Edn., Goel Publishing House, Meerut, 2010. 4. R. L. Madan, Chemistry for Degree Students, 1st Edn., S. Chand & Co., New Delhi, 2017. 5. C. N. R. Rao, University General Chemistry, Macmillan Publishers, 1973 (Reprint 2009). 6. H. J. Arnikaar, Essentials of Nuclear Chemistry, 4th Edn., New Age International Publishers, New Delhi, Reprint 2018. 7. P. L. Soni and Mohan Katyal, Textbook of Inorganic Chemistry, 20th Edn., Sultan Chand & Sons, 1997. 8. B. E. Douglas and D. H. McDaniel, Concepts and Models of Inorganic Chemistry, Oxford University Press, 1970. 9. N. N. Greenwood and A. Earnshaw, Chemistry of the Elements, 2nd Edn., Pergamon Press, 1984. 10. Catherine E. Housecroft and Alan G. Sharpe, Inorganic Chemistry, 4th Edn., Pearson, 2012. 11. Geoff Rayner-Canham and Tina Overton, Descriptive Inorganic Chemistry, 4th Edn., Brooks/Cole, 2010. 12. Glen E. Rodgers, Inorganic Chemistry, 3rd Edn., Brooks/Cole, 2012. 13. L. Pauling, The Nature of the Chemical Bond, 3rd Edn., Cornell University Press, 1960. 14. Neil G. Connelly, T. Damhus, R. M. Hartshorn, A. T. Hutton, Nomenclature of Inorganic Chemistry (IUPAC Recommendations 2005), RSC Publishing, 2005. 15. Graham Solomons, T. W., Fryhle, C. B. & Snyder, S. A., Organic Chemistry, 12th Edn., John Wiley & Sons, UK, 2016. 16. McMurry, J. E., Fundamentals of Organic Chemistry, 7th Edn., Cengage Learning India, 2013. 17. P. Sykes, A Guidebook to Mechanism in Organic Chemistry, 6th Edn., Longman Scientific & Technical, UK, 1985. 18. A. Bahl and B. S. Bahl, Advanced Organic Chemistry, S. Chand, New Delhi, 2012. 19. Jerry March, Advanced Organic Chemistry, 4th Edn., John Wiley, New Jersey, 2007.

20. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas and B. Sivasankar, Vogel's Textbook of Quantitative Chemical Analysis, 6th Edn., Pearson, 2009.
21. John Kenkel, Analytical Chemistry for Technicians, 4th Edn., CRC Press, 2013.
22. W. Kemp, Organic Spectroscopy, 3rd Edn., Palgrave Macmillan, New York, 1991.
23. P. S. Kalsi, Spectroscopy of Organic Compounds, 6th Edn., New Age International, New Delhi, 2004.
24. E. L. Eliel, Stereochemistry of Carbon Compounds, Tata McGraw Hill, New York, 1962.
25. V. M. Potapov, Stereochemistry, Mir Publishers, Moscow, 1979.
26. Jain & Jain, Engineering Chemistry, 17th Edn., Dhanpat Rai Publishing, New Delhi, 2015.
27. Pol, Date, Adhav & Shinde, A Textbook of Industrial Chemistry, Manali Prakashan, Pune, 2021.
28. H. N. Njenga, Industrial Chemistry, African Virtual University, 2019.
29. J. A. Kent, Riegel's Handbook of Industrial Chemistry, 10th Edn., Springer, New York, 2012.
30. R. Norris Shreve, The Chemical Process Industries, 4th Edn., McGraw-Hill, 1984.
31. H. Singh and V. K. Kapoor, Medicinal and Pharmaceutical Chemistry, 3rd Edn., Vallabh Prakashan, New Delhi, 2012.
32. W. O. Foye, T. L. Lemke and D. A. Williams, Principles of Medicinal Chemistry, 7th Edn., Wolters Kluwer/Bi Waverly, New Delhi, 2012.
33. J. H. Beale and J. H. Block, Wilson and Gisvold's Textbook of Organic, Medicinal and Pharmaceutical Chemistry, 12th Edn., Lippincott Williams & Wilkins, USA, 2011.
34. D. Lednicher and L. A. Meischer, Organic Chemistry of Drug Synthesis Vols. I–III, John Wiley & Sons, New Jersey, 2005.
35. M. E. Wolff, Burger's Medicinal Chemistry and Drug Discovery, 5th Edn., John Wiley & Sons, New Jersey, 1997.
36. National Research Council, Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards, National Academies Press, Washington DC, 2001.
37. John O'M. Bockris and A. K. Reddy, Modern Electrochemistry Vol. I: Ionics, 2nd Edn., Springer, UK, 1989.