Syllabus for

THREE-YEAR B.Sc. (MAJOR) PROGRAMME

(CHEMISTRY)

(Six Semester Course)

(Effective from the Academic Year 2019-20)

Rajiv Gandhi University
Rono Hills, Doimukh 791 112
Arunachal Pradesh
2019

Contents

PREFACE

Keeping in view the need to impart value based education; a student friendly syllabus incorporating new ideas and theories in chemistry has been prepared. This course will enable the students to comprehend the theory, concepts, and applications of inorganic, organic and physical chemistry. Focus has been given to inculcate interdisciplinary skills that would allow the students both vertical and horizontal mobility in their progression.

The faculties from the different branches of chemistry – Inorganic, Organic and Physical Chemistry had separate and joint sessions and arrived at a proposed revised Syllabus in Chemistry for 3-year (6 Semester) B.Sc. (Major) course. The revised syllabus is approved by the Board of Under-Graduate Studies (BUGS), which constitutes of faculty members, professors from other state and central universities and cognate subject expert in a meeting held from May 17-18, 2019 and finally placed before the Academic Council for approval.

18th May 2019
Rono Hills, Doimukh

Dr. Rajesh Chakrabarty
Chairman
Board of Under Graduate Studies (BUGS)
Department of Chemistry, RGU

SALIENT FEATURES OF THE COURSE STRUCTURE

(a) B.Sc. B.Ed. with major in Chemistry course will consist of 8 semesters of 4-year duration.

(b) In each paper; course code, course title, set of topics and the list of recommended books were listed.

(c) Keeping in view the professional nature of the course, there will be 14 (fourteen) Major courses (MC), 1 (one) Skill Enhancement Course (SCE), 2 (two) Department Specific Electives (DSE) and 1 (one) Choice Based Course (CBC).

(d) The nomenclature of the papers are mentioned in the course content.

(e) In Department Specific Electives-II (DSE-II), each student of Semester VII shall have to opt for project work. For project work, the area of the work would be to be decided by the advisor. On completion of the project work, students will have to submit the work in the form of a report followed by oral presentation in the presence of faculty members and external expert(s).

(f) Each paper will have a theory and a practical component (except for CBC).

(g) In terms of marks, theoretical component of each MC paper is of 75 marks; 15 marks for sessional and 60 marks for terminal examination. Each theoretical paper consists of 5 (five) modules/units carries 15 marks each. Practical component of each MC paper is of 25 marks.

COURSE STRUCTURE

Semester	Course Code	Course Title	Maximum Marks		
			Sessional	Terminal Exam	Total
Semester I	CHEM-(T) 111	Inorganic, Organic & Physical Chemistry-I	15	60	75
	CHEM-(P) 111	Chemistry Laboratory Course I	5	20	25
Semester II	CHEM-(T) 121	Inorganic, Organic & Physical Chemistry-II	15	60	75
	CHEM-(P) 121	Chemistry Laboratory Course II	5	20	25
Semester III	CHEM-(T) 231	Inorganic, Organic & Physical Chemistry-III	15	60	75
	CHEM-(P) 231	Chemistry Laboratory Course III	5	20	25
	CHEM-SB 232	Water Treatment and Analysis	20	80	100
Semester IV	CHEM-(T) 241	Inorganic, Organic & Physical Chemistry-IV	15	60	75
	CHEM-(P) 241	Chemistry Laboratory Course IV	5	20	25
	CHEM-SB 242	Soil and Agricultural Chemistry	20	80	100
Semester V	CHEM 351	Inorganic Chemistry I	20	80	100
	CHEM 352	Organic Chemistry I	20	80	100
	CHEM 353	Physical Chemistry I	20	80	100
	CHEM 354	Chemistry Laboratory Course V	20	80	100
Semester VI	CHEM 361	Inorganic Chemistry II	20	80	100
	CHEM 362	Organic Chemistry II	20	80	100
	CHEM 363	Physical Chemistry II	20	80	100
	CHEM 364	Chemistry Laboratory Course VI	20	80	100
				TOTAL	**1400**

GENERAL OBJECTIVES OF THE COURSE

The objective of the syllabus is to enable the students to

- Understand structure of atom, concept of orbitals, explain different types of chemical bonds and predict/explain the geometry of molecules.
- Understand the synthesis, structure/bonding, reactions and mechanism for different classes of organic compounds.
- Know Chemistry of the elements belonging to different blocks in periodic table.
- Understand Chemical and ionic equilibria.
- Understand metallurgy and processes involved in extraction of metals from their ores.
- Understand the laws of thermodynamics and thermochemistry.
- Describe Properties of solution and colligative properties.
- Know Coordination chemistry, magnetic and electronic spectrum of transition metal complexes.
- Illustrate Principles and applications of UV-VIS, rotational and IR spectroscopy and elucidate the explain structure of organic compounds based on these data.
- Understand Nuclear chemistry and various internuclear processes.
- Explain Bioinorganic chemistry and role of metals in biological processes and the role of enzymes in biochemistry.
- Describe Electrochemical processes.
- Explain Different states of matter, phases and their equilibria, different surface phenomena.
- Understand Laws of photochemistry and application.
- Understand the chemistry of inorganic and organic polymer.
- Identify the cation and anions present in a salt mixture.
- Calibrate different apparatus in laboratory and prepare different standard solutions.
- Prepare, Identify, analyze and estimate different inorganic and organic compounds.
- Perform estimations of different chemical entities in solution.
- Measure different physical parameter of a system like surface tension, viscosity, pH etc.
- Study kinetics of different chemical reactions.
- Develop skills in conductometry, potentiometry, polarimetry and colorimetry.

FIRST SEMESTER
CHEM-(T) 111
(Inorganic, Organic and Physical Chemistry-I)

Maximum Marks: **75** (Terminal – 60, Sessional – 15)
Terminal Examination Duration: 2½ Hours

UNIT I: Atomic Structure 12 Marks

Bohr's theory, its limitations and atomic spectrum of hydrogen atom. Wave mechanics: de Broglie equation, Heisenberg's Uncertainty Principle and its significance, Schrödinger's wave equation, significance of ψ and ψ^2. Quantum numbers and their significance. Normalized and orthogonal wave functions. Sign of wave functions. Radial and angular wave functions for hydrogen atom. Radial and angular distribution curves. Shapes of *s*, *p*, *d* and *f* orbitals.

Pauli's Exclusion Principle, Hund's rule of maximum multiplicity, Aufbau's principle and its limitations, Variation of orbital energy with atomic number.

UNIT II: Periodicity of Elements 12 Marks

s, p, d, f block elements, the long form of periodic table. Detailed discussion of the following properties of the elements, with reference to *s* and *p*-block.

(a) Effective nuclear charge, shielding or screening effect, Slater rules, variation of effective nuclear charge in periodic table.
(b) Atomic radii (van der Waals)
(c) Ionic and crystal radii.
(d) Covalent radii (octahedral and tetrahedral)
(e) Ionization enthalpy, Successive ionization enthalpies and factors affecting ionization energy. Applications of ionization enthalpy.
(f) Electron gain enthalpy, trends of electron gain enthalpy.
(g) Electronegativity, Pauling's/ Mulliken's/ Allred Rachow's/ and Mulliken-Jaffé's electronegativity scales. Variation of electronegativity with bond order, partial charge, hybridization, group electronegativity. Sanderson's electron density ratio.

UNIT III: Basics of Organic Chemistry 12 Marks

Organic Compounds: Classification, and Nomenclature, Hybridization, Shapes of molecules, Influence of hybridization on bond properties.

Electronic Displacements: Inductive, electromeric, resonance and mesomeric effects, hyperconjugation and their applications; Dipole moment; Organic acids and bases; their relative strength.

Homolytic and Heterolytic fission with suitable examples. Electrophiles and Nucleophiles; Nucleophlicity and basicity; Types, shape and their relative stability of Carbocations, Carbanions, Free radicals and Carbenes. Introduction to types of organic reactions and their mechanism: Addition, Elimination and Substitution reactions.

UNIT IV. Chemistry of Aliphatic Hydrocarbons 12 Marks

A. Carbon-Carbon sigma bonds

Chemistry of alkanes: Formation of alkanes, Wurtz Reaction, Wurtz-Fittig Reactions, Free radical substitutions: Halogenation - relative reactivity and selectivity.

B. Carbon-Carbon pi bonds

Formation of alkenes and alkynes by elimination reactions, Mechanism of E1, E2, E1cb reactions. Saytzeff and Hofmann eliminations.

Reactions of alkenes: Electrophilic additions their mechanisms (Markownikoff/ Anti Markownikoff addition), mechanism of oxymercuration-demercuration, hydroboration-oxidation, ozonolysis, reduction (catalytic and chemical), *syn* and *anti*-hydroxylation (oxidation). 1,2- and 1,4- addition reactions in conjugated dienes and, Diels-Alder reaction; Allylic and benzylic bromination and mechanism, e.g. propene, 1-butene, toluene, ethyl benzene.

Reactions of alkynes: Acidity, Electrophilic and Nucleophilic additions. Hydration to form carbonyl compounds, Alkylation of terminal alkynes.

UNIT V: States of Matter I 12 Marks

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.

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, virial equation of state; van der Waals equation expressed in virial form and calculation of Boyle temperature. 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.

Recommended Books

Inorganic Chemistry:

1. Lee, J. D., *Concise Inorganic Chemistry*, 5th Ed., Wiley India (2008).
2. Housecroft, C. E.; Constable, E. C. *Chemistry-An Introduction to Organic, Inorganic and Physical Chemistry*, 4th Ed., Pearson Education (2010).
3. Atkins, P.; Overton, T.; Rouke, J.; Weller, M.; Armstrong, F.; Hagerman, M., *Shriver Atkins's Inorganic Chemistry*, 6th Ed., Oxford University Press India (2015).
4. Miessler, G.; Tarr, D. A., *Inorganic Chemistry*, 3rd Ed., Pearson Education India (2008).
5. Cotton, F. A.; Wilkinson, G.; Gaus, P. L., *Basic Inorganic Chemistry*, 3rd Ed., Wiley India (2007).
6. Puri, B. R.; Sharma, L. R.; Kalia, K. C., *Principles of Inorganic Chemistry*, 33rd Ed., Vishal Publishing (2017).

Organic Chemistry:

1. Greeves, N.; Clayden, J.; Warren, S., *Organic Chemistry*, 2nd Ed., Oxford University Press India (2014).
2. Smith, M. B.; March, J., *March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure*, 7th Ed., Wiley India (2015).
3. Solomons, T. W. G.; Fryhle, C. B., *Organic Chemistry*, 11th Ed., Wiley India (2015).
4. Bruice, P. Y., *Organic Chemistry*, 7rd Ed., Pearson Education India (2013).
5. Ghosh, S. K., *Advanced General Organic Chemistry, Part-I & Part-II*, 3rd Ed., New Central Book Agency (2010).
6. Bhal, B. S.; Bhal, A., *A Textbook of Organic Chemistry*, 22nd Ed., S. Chand and Company (2016).

Physical Chemistry

1. Atkins, P. W.; de Paula, J.; Keeler, J., *Physical Chemistry,* 11th Ed., Oxford University Press India (2018).
2. Bahl, A.; Bahl, B. S.; Tuli, G. D., *Essentials of Physical Chemistry*, S. Chand and Company (2010).
3. Negi, A. S.; Anand, S. C., *Physical Chemistry*, New Age International Publishers (2007).
4. Puri, B. R.; Sharma, L. R.; Pathania, M. S., *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing (2017).
5. Silbey, R. J.; Alberty, R. A.; Bawendi, M. G., *Physical Chemistry*, 4th Ed., Wiley India (2006).
6. Kapoor, K. L., *A Textbook of Physical Chemistry: States of Matter and Ions in Solution*, Vol. I, 6th Ed., McGraw Hill Education India (2019).

FIRST SEMESTER
CHEM-(P) 111
(Chemistry Laboratory Course I)

Maximum Marks: **25** (Terminal – 20, Sessional –5)
Terminal Examination Duration: 3 Hours

1. Titrimetric Analysis
   (a) Determination of alkali content of antacid tablets using HCl.
   (b) Estimation of calcium content in chalk as calcium oxalate.
   (c) Estimation of free alkali present in different soaps/detergents.

   10 Marks

2. Purification of organic compounds by crystallization using Water /Alcohol /Alcohol-Water and determination of their melting points.

   5 Marks

3. Viva voce

   5 Marks

Recommended Books

1. Mendham, J.; Denney, R. C., Barnes, J. D.; Thomas, M.; Sivasankar, B., *Vogel's Quantitative Chemical Analysis*, 6th Ed., Pearson Education India (2009).

SECOND SEMESTER
CHEM-(T) 121
(Inorganic, Organic and Physical Chemistry-II)

Maximum Marks: **75** (Terminal – 60, Sessional – 15)
Terminal Examination Duration: 2½ Hours

UNIT I: Chemical Bonding-I 12 marks

Covalent bond: Ionic and covalent bonding (characteristics and properties), Valence Bond theory. Application of Hybridisation (*sp, sp^2, sp^3, dsp^3* and *d^2sp^3*) to explain structure of simple molecules. Bent's rule, Resonance and resonance energy. Polarity in covalent molecules, dipole moment, percentage ionic character and electro negativity difference. Valence shell electron pair repulsion theory (VSEPR), shapes of simple molecules and ions containing lone pairs and bond pairs of electrons, multiple bonding (σ and π bond approach) and bond lengths.

UNIT II: Chemistry of Halogenated Hydrocarbons 12 Marks

Alkyl halides: Methods of preparation, nucleophilic substitution reactions – S_N1, S_N2 and S_Ni mechanisms with stereochemical aspects and effect of solvent etc.; nucleophilic substitution vs. elimination.
Aryl halides: Preparation, including preparation from diazonium salts. Nucleophilic aromatic substitution; Benzyne mechanism. Relative reactivity of alkyl, allyl/benzyl, vinyl and aryl halides towards nucleophilic substitution reactions.

Organometallic compounds of Mg and Li – Use in synthesis of organic compounds.

UNIT III: Alcohols, Phenols, Ethers and Epoxides 12 Marks

Alcohols: Properties and relative reactivity of 1°, 2°, 3° alcohols, general methods of preparation of monohydric alcohols.Bouvaelt-Blanc Reduction; Preparation and properties of glycols: Oxidation by periodic acid and lead tetraacetate, Pinacol-Pinacolone rearrangement;

Phenols: Preparation and properties; Acidity and factors effecting it, Ring substitution reactions, Reimer–Tiemann and Kolbe's–Schmidt Reactions, Fries and Claisen rearrangements with mechanism. Formation of phenolphthalein and reduction of phenol (no mechanism).

Ethers and Epoxides: Preparation and reactions with acids. Reactions of epoxides with alcohols, ammonia derivatives and $LiAlH_4$.

UNIT IV: States of Matter II 12 Marks

Gaseous State: Maxwell distribution and its use in evaluating molecular velocities (average, root mean square and most probable velocity) and average kinetic energy, law of equipartition of energy, degrees of freedom and molecular basis of heat capacities.

Liquid State: Physical properties of liquids; vapour pressure, surface tension and coefficient of viscosity, and their determination. Effect of addition of various solutes on surface tension and viscosity. Explanation of cleansing action of detergents. Temperature variation of viscosity of liquids and comparison with that of gases.

Solid State: Nature of the solid state, law of constancy of interfacial angles, law of rational indices, Miller indices, crystal systems and Bravais lattices; X-ray diffraction, Bragg's law. Defects in solids – point defects, Stoichiometric and non-stoichiometric defects.

UNIT V: Chemical and Ionic Equilibrium 12 Marks

Thermodynamics criteria for equilibrium in chemical reactions. Characteristics of chemical equilibrium. Limitations of the equation for chemical equilibrium. Law of mass action as applied to homogenous and heterogeneous equilibrium reactions. Derivation of the expression of equilibrium constant. Relationship between K_p and K_c. Le Chatelier's principle.

Strong and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water. Ionization of weak acids and weak bases. pH and its determination, pH scale, common ion effect. Dissociation constants of mono-, di-and triprotic acids.

Salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts. Buffer solutions; derivation of Henderson equation and its applications; buffer capacity, buffer range, buffer action and applications of buffers in analytical chemistry. Solubility and solubility product of sparingly soluble salts- applications of solubility product. Qualitative treatment of acid – base titration curves (calculation of pH at various stages). Theory of acid–base indicators; selection of indicators and their limitations.

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7. Kapoor, K. L., *A Textbook of Physical Chemistry: Thermodynamics and Chemical Equilibrium*, Vol. II, 6th Ed., McGraw Hill Education India (2019).

SECOND SEMESTER
CHEM-(P) 121
(Chemistry Laboratory Course II)

Maximum Marks: **25** (Terminal – 20, Sessional –5)
Terminal Examination Duration: 3 Hours

1. Physical Chemistry experiments:
   (a) Determine the viscosity of a liquid by Ostwald's viscometer (Density of the liquid to be provided. Suggested liquids: ethanol, acetone, chloroform and carbon tetrachloride).
   (b) Determine the surface tension of a liquid by drop number method (Density of the liquid to be provided. Suggested liquids: as in exp. 1(a).
   (c) Determine the solubility of a given salt (KNO_3) at different temperatures and determine the enthalpy of dissolution.
   (d) Determine the heat of neutralisation of HCl and NaOH using water calorimeter.

8 Marks

2. Volumetric Analysis:
   (a) Estimation of Fe(II) and oxalic acid using standardized $KMnO_4$ solution.
   (b) Estimation of Fe(II) with $K_2Cr_2O_7$ using internal (diphenylamine, anthranilic acid) and external indicator.
   (c) Estimation of Cu^{2+} ions by titrating against thiosulphate.

7 Marks

3. Viva voce

5 marks

Recommended Books

1. Raj, G., *Advanced Practical Inorganic Chemistry*, Krishna Prakashan (2013).
2. Svehla, G.; Sivsankar, B., *Vogel's Qualitative Inorganic Analysis*, 7th Ed., Pearson Education India (2012).

THIRD SEMESTER
CHEM-(T) 231
(Inorganic, Organic and Physical Chemistry-III)

Maximum Marks: **75** (Terminal – 60, Sessional – 15)
Terminal Examination Duration: 2½ Hours

UNIT I: Compounds of *s*- and *p*-block Elements 12 Marks

Study of the following compounds with emphasis on structure, bonding, preparation, properties and uses.

(i) Boron: Boric acid and borates, boron nitrides, borohydrides (diborane).
(ii) Carbon: Types of carbide, CaC_2, SiC, Al_4C_3- preparation, properties and uses
(iii) Silicon: Silane, silicon halides, silicones and siloxanes.
(iv) Nitrogen & Phosphorus: ammonia-manufacture (Haber's process), Oxides and oxoacids of nitrogen and phosphorus.
(v) Sulphur: Sulphuric acid and its properties as dehydrating agent, oxidizing property and action on metals and non-metals. Peroxo acids of sulphur.
(vi) Halogen: interhalogen compounds, polyhalide ions, pseudohalogens and basic properties of halogens.

UNIT II: Transition Elements 12 Marks

General group trends with special reference to electronic configuration, colour, variable valency, magnetic and catalytic properties, and ability to form complexes. Stability of various oxidation states and emf. (Latimer & Bsworth diagrams). Difference between the first, second and third transition series.

Introduction to coordination chemistry, classification of ligands, Werner's theory, nomenclature of coordination compounds. Isomerism in coordination complexes. Valence bond theory (VBT) and its application to octahedral and tetrahedral complexes, limitations of VBT. Crystal Field Theory (CFT), splitting pattern of *d*-orbital in tetrahedral and octahedral complexes, Crystal Field Stabilization Energy (CFSE), factors affecting CFSE, spectrochemical series, limitations of CFT.

UNIT III: Nitrogen Containing Functional Groups 12 Marks

Preparation and reactions of nitroalkanes, nitroarenes, nitriles and isonitriless.

Amines: Nomenclature of amines, types and its physical properties, structural features affecting basicity of amines, separation of a mixture of primary, secondary and tertiary amines (Hoffman method and Hinsberg method). Preparation of alkyl and aryl amines (reduction of nitrocompounds, nitriles, reductive amination of aldehyde and ketonic compounds), Gabriel Phthalimide reaction, Hoffmann exhaustive methylation, Hoffmann Bromamide reaction, Mannich rection and nitrous acid test for distinction of primary, secondary and tertiary amines.
Diazonium salts: Preparation and their synthetic applications.

UNIT IV: Chemical Thermodynamics-I 12 Marks

Thermodynamic terms and basic concepts; thermodynamic systems (open, closed and isolated system); state and path functions; state variables, extensive and intensive properties, thermodynamic processes (isothermal, adiabatic, isochoric and isobaric process). Zeroth law of thermodynamics.

First law of thermodynamics: Concept of heat, *q*, work, *w*, internal energy, *U*, and statement of first law; enthalpy, *H*, relation between heat capacities, calculations of *q*, *w*, *U* and *H* for reversible and irreversible processes under isothermal and adiabatic conditions. The limitations of the first law of thermodynamics.

UNIT V: Solutions and Colligative Properties 12 Marks

Thermodynamics of ideal solutions: Ideal solutions and Raoult's law, deviations from Raoult's law – non-ideal solutions. Vapour pressure-composition and temperature-composition curves of ideal and non-ideal solutions.

Colligative properties: Relation between four colligative properties (i) relative lowering of vapour pressure, (ii) elevation of boiling point, (iii) depression of freezing point and (iv) osmotic pressure with amount of solute. Applications of colligative properties in calculating molar masses of normal, dissociated and associated solutes in solution.

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1. Lee, J. D., *Concise Inorganic Chemistry*, 5th Ed., Wiley India (2008).
2. Housecroft, C. E.; Constable, E. C. *Chemistry-An Introduction to Organic, Inorganic and Physical Chemistry*, 4th Ed., Pearson Education (2010).
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5. Silbey, R. J.; Alberty, R. A.; Bawendi, M. G., *Physical Chemistry*, 4th Ed., Wiley India (2006).
6. Kapoor, K. L., *A Textbook of Physical Chemistry: States of Matter and Ions in Solution*, Vol. I, 6th Ed., McGraw Hill Education India (2019).
7. Kapoor, K. L., *A Textbook of Physical Chemistry: Thermodynamics and Chemical Equilibrium*, Vol. II, 6th Ed., McGraw Hill Education India (2019).

THIRD SEMESTER
CHEM-(P) 231
(Chemistry Laboratory Course III)

Maximum Marks: **25** (Terminal – 20, Sessional –5)
Terminal Examination Duration: 3 Hours

1. Systematic qualitative analysis of organic compounds (solid): To detect the elements (nitrogen, sulphur and halogens) and functional group present.

   10 Marks

2. Preparation of pure and dry sample of the following:
   Acetanilide, *p*-nitroacetanilide, aspirin, iodoform, picric acid.

   5 Marks

3. Viva voce

   5 marks

Recommended Books

1. Furniss, B. S.; Hannafold, A. J.; Smith, P. W. G.; Tatchell, A. R., *Vogel's Textbook of Practical Organic Chemistry*, 5th Ed., Pearson Education India (2003).
2. Clarke, H. T., *A Handbook of Organic Analysis: Qualitative and Quantitative*, 4th Ed., CBS Publishers India (2007).
3. Agarwal, O. P., *Advanced Practical Organic Chemistry*, Krishna Prakashan (2014).

THIRD SEMESTER
CHEM-SB 232
(Water Treatment and Analysis)

Maximum Marks: **100** (Terminal – 80, Sessional – 20)
Terminal Examination Duration: 3 Hours

UNIT I 16 Marks

Introduction: characteristics of water, alkalinity. Hardness: unit of hardness, total solids, oxidation, transparency, silica content.

Purification of water for drinking purpose: portability of water, clarification, coagulation, contact and electro chemical coagulation, sterilization and disinfection of water, precipitation, aeration, ozonisation, chlorination.

UNIT II 16 Marks

Water softening methods: Clark's process, lime soda process, modified lime soda process, permutit or zeolite process, ion exchange process, demineralization of water.

Determination of hardness of water: titration method, complexometric method using EDTA. Expressing hardness: equivalents of calcium carbonate. Problems to determine temporary and permanent hardness.

UNIT III 16 Marks

Hard water and industries, industrial water treatment, boiler feed water method of softening, prevention of plumbo solvency, scales in boilers and consequences, internal conditioning methods.

Desalination of brackish water: elecrodialysis, reverse osmosis, removal of Fe, Mn and silicic acid, effluent treatment of water from paper industry, petrochemical, fertilizer industry and power station.

UNIT IV 16 Marks

Water analysis: sampling of water for analysis, chemical substances affecting portability, colour, turbidity, odour, taste, temperature, pH and electrical conductivity.

Analysis of solids present in water: suspended solids, dissolved solids, total acidity, alkalinity, free CO_2, free chlorine, Ca, Mg, Fe, Mn, Ag and Zn.

UNIT V 16 Marks

Analysis of chemical substances affecting health: NH_3, nitrate, nitrite, cyanide, sulphate, sulphide, chloride, fluoride. Measurement of toxic chemical substances, analysis of chemical substances indicative of pollution, dissolved oxygen, bio chemical oxygen demand (BOD), chemical oxygen demand (COD).

Bacteriological examination of water: total count test, E-coli test, E-coli index, most probable number method, biological examination of water, physical examination of water. Radioactivity of water: methods of removing radioactivity from water.

Recommended Books

1. Sharma, B. K. *Industrial Chemistry*, Krishna Prakashan (2011).
2. Mahajan, S. P., *Pollution Control in Process Industries*, Tata McGraw Hill Publishing India (2017).
3. Varashney, C. K., *Water Pollution and Management*, 2nd Ed., New Age International Publishers (2018).
4. Clesceri, L. S.; Greenberg, A. E.; Eaton, A. D., *Standard Methods for the Examination of Water and Waste Water*, 20th Ed., American Public Health Association (APHA) & American Water Works Association (1999).

FOURTH SEMESTER
CHEM-(T) 241
(Inorganic, Organic and Physical Chemistry-IV)

Maximum Marks: **75** (Terminal – 60, Sessional – 15)
Terminal Examination Duration: 2½ Hours

UNIT I: Chemistry of Lanthanides, Actinides and Noble Gas 12 Marks

Chemistry of Lanthanides and Actinides: Electronic configuration, oxidation states, colour, spectral and magnetic properties, lanthanide contraction, separation of lanthanides (ion-exchange method only).

Noble gases: Occurrence and uses, rationalization of inertness of noble gases, Clathrates; preparation and properties of XeF_2, XeF_4 and XeF_6; Nature of bonding in noble gas compounds (Valence bond treatment and MO treatment for XeF_2). Molecular shapes of noble gas compounds (VSEPR theory).

UNIT II: Chemical Kinetics-I 12 Marks

Order and molecularity of a reaction; rate laws in terms of the advancement of a reaction; differential and integrated form of rate equation up to second order reactions; experimental methods of the determination of rate laws. Factors affecting rate of reaction. Half-life period and order of a reaction. Temperature dependence of reaction rate and activation energy.

Steady state approximation and kinetics of simple reactions (e.g. decomposition of ozone, reaction between NO and O_2, iodination of acetone, decomposition of gaseous N_2O_5).

UNIT III: Electrochemistry 12 Marks

Quantitative aspects of Faraday's laws of electrolysis, rules of oxidation/reduction of ions based on half-cell potentials, applications of electrolysis in metallurgy and industry.

Chemical cells, reversible and irreversible cells with examples. Electromotive force of a cell and its measurement, Nernst equation; Standard electrode (reduction) potential and its application to different kinds of half-cells. Application of EMF measurements in determining (i) free energy, enthalpy and entropy of a cell reaction, (ii) equilibrium constants, and (iii) pH values, using standard hydrogen electrode (SHE), calomel electrode. Concentration cells with and without transference, liquid junction potential; determination of activity coefficients and transference numbers. Qualitative discussion of potentiometric titrations (acid-base, redox, precipitation).

UNIT IV: Carbonyl Compounds 12 Marks

Structure, reactivity and preparation; Nucleophilic additions, Nucleophilic addition-elimination reactions with ammonia derivatives with mechanism; Mechanisms of Aldol and Benzoin condensation, Knoevenagel condensation, Claisen-Schmidt, Perkin, Cannizzaro and Wittig reaction, Beckmann and Benzil-Benzilic acid rearrangements, haloform reaction and Baeyer Villiger oxidation, α-substitution reactions, oxidations and reductions (Clemmensen,

Wolff-Kishner, $LiAlH_4$, $NaBH_4$, MPV, PDC and PGC). Addition reactions of unsaturated carbonyl compounds: Michael addition.

Active methylene compounds: Keto-enol tautomerism. Preparation and properties of diethyl malonate and ethyl acetoacetate.

UNIT V: Carboxylic Acids and their Derivatives 12 Marks

Preparation, physical properties and reactions of monocarboxylic acids: Typical reactions of dicarboxylic acids, hydroxy acids and unsaturated acids: succinic/phthalic, lactic, malic, tartaric, citric, maleic and fumaric acids.

Preparation and reactions of acid chlorides, anhydrides, esters and amides; Comparative study of nucleophilic substitution at acyl group -Mechanism of acidic and alkaline hydrolysis of esters, Claisen condensation, Dieckmann and Reformatsky reactions, Hofmann bromamide degradation and Curtius rearrangement.

Recommended Books

Inorganic Chemistry:

1. Lee, J. D., *Concise Inorganic Chemistry*, 5th Ed., Wiley India (2008).
2. Housecroft, C. E.; Constable, E. C. *Chemistry-An Introduction to Organic, Inorganic and Physical Chemistry*, 4th Ed., Pearson Education (2010).
3. Atkins, P.; Overton, T.; Rouke, J.; Weller, M.; Armstrong, F.; Hagerman, M., *Shriver Atkins' Inorganic Chemistry*, 6th Ed., Oxford University Press India (2015).
4. Miessler, G.; Tarr, D. A., *Inorganic Chemistry*, 3rd Ed., Pearson Education India (2008).
5. Huheey, J. E.; Keiter, E. A.; Keiter, R. L.; Medhi, O. K., *Inorganic Chemistry: Principles of Structures and Reactivity*, 4th Ed., Pearson Education India (2006).
6. Cotton, F. A.; Wilkinson, G.; Gaus, P. L., *Basic Inorganic Chemistry*, 3rd Ed., Wiley India (2007).
7. Puri, B. R.; Sharma, L. R.; Kalia, K. C., *Principles of Inorganic Chemistry*, 33rd Ed., Vishal Publishing (2017).

Organic Chemistry:

1. Greeves, N.; Clayden, J.; Warren, S., *Organic Chemistry*, 2nd Ed., Oxford University Press India (2014).
2. Smith, M. B.; March, J., *March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure*, 7th Ed., Wiley India (2015).
3. Solomons, T. W. G.; Fryhle, C. B., *Organic Chemistry*, 11th Ed., Wiley India (2015).
4. Bruice, P. Y., *Organic Chemistry*, 7rd Ed., Pearson Education India (2013).
5. Ghosh, S. K., *Advanced General Organic Chemistry, Part-I & Part-II*, 3rd Ed., New Central Book Agency (2010).
6. Bhal, B. S.; Bhal, A., *A Textbook of Organic Chemistry*, 22nd Ed., S. Chand and Company (2016).

Physical Chemistry:

1. Atkins, P. W.; de Paula, J.; Keeler, J., *Physical Chemistry*, 11th Ed., Oxford University Press India (2018).
2. Bahl, A.; Bahl, B. S.; Tuli, G. D., *Essentials of Physical Chemistry*, S. Chand and Company (2010).
3. Negi, A. S.; Anand, S. C., *Physical Chemistry*, New Age International Publishers (2007).
4. Puri, B. R.; Sharma, L. R.; Pathania, M. S., *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing (2017).
4. Silbey, R. J.; Alberty, R. A.; Bawendi, M. G., *Physical Chemistry*, 4th Ed., Wiley India (2006).

FOURTH SEMESTER
CHEM-(P) 241
(Chemistry Laboratory Course IV)

Maximum Marks: **25** (Terminal – 20, Sessional –5)
Terminal Examination Duration: 3 Hours

1. Systematic qualitative analysis of inorganic salt mixture containing four radicals (two acid and two basic radicals) in absence of interfering radicals.

15 marks

4. Viva voce

5 marks

Recommended Books

1. Viswanathan, B.; Raghavan, P. S., *Practical Physical Chemistry*, Viva Books India (2014).
2. Yadav, J. B., *Advanced Practical Physical Chemistry*, Krishna Prakashan (2015).

FOURTH SEMESTER
CHEM-SB 242
(Soli and Agricultural Chemistry)

Maximum Marks: **100** (Terminal – 80, Sessional – 20)
Terminal Examination Duration: 3 Hours

UNIT I: Introduction to Soil Science 16 Marks

Formation of soil. Classification of soil and properties of soil. Soil Texture, Textural classes. Adsorption of ions, ion exchange, CEC & AEC, factors influencing ion exchange and its significance. Soil organic matter, composition, decomposability, Humus, fractionations of organic matter

UNIT II: Soil fertility and Nutrient Management 16 Marks

Soil as a source of plant nutrients, essential and beneficial elements, criteria of essentiality, problem soils-Acid, salt affected and calcareous soils, characteristics, nutrient availabilities, reclamation–mechanical, chemical and biological methods. Methods of soil testing– chemical methods, critical levels of different nutrients in soil.

UNIT II: Soil Fertility and Productivity I 16 Marks

Fertilizers: effect of nitrogen, potassium and phosphorous on plant growth, classification of fertilizers, requisites of a good fertilizers, nitrogenous fertilizers, phosphatic fertilizers, super phosphate of lime, triple super phosphate, NPK fertilizers, ill effects of fertilizers, effect of mixed fertilizers on soil pH.

UNIT III: Soil Fertility and Productivity II 16 Marks

Commercial method of preparation of urea and triple superphosphate.
Manures: Organic manures, farmyard manure, handling and storage of – oil cakes, bone meal, meat meal, fish meal, blood meal and green manures.

UNIT IV: Pesticides 16 Marks

Classification of insecticides, stomach poisons, contact poisons and fumigants and insecticides. Organic insecticides: DDT, gammexane, malathion, parathion. General methods of application and toxicity of – fungicides, herbicides, rodenticides, pesticides. Adverse environmental effects of pesticides and safety measures when using pesticides.

Recommended Books

1. Biswas, T. D.; Mukherjee, S. K. *Text Book of Soil Science*, Tata McGraw Hill India (2017).
2. Brady, N. C.; Well, R. R. *The Nature and Properties of Soil*, 14th Ed. Pearson, Education India (2013).
3. Troeh, F. R.; Thompson, L. M., *Soils and Soil Fertility*, 6th Ed., Wiley India (2018).

4. Havlin, J. L.; Tisdale, S. L.; Nelson, W. L.; Beaton, J. D., Soil Fertility and Fertilizers, 8th Ed., Pearson Education India (2016).
5. Sharma, B. K., *Industrial Chemistry*, Krishna Prakashan (2011).

FIFTH SEMESTER
CHEM 351
(Inorganic Chemistry-I)

Maximum Marks: **100** (Terminal – 80, Sessional – 20)
Terminal Examination Duration: 3 Hours

UNIT I: Chemical Bonding -II 16 marks

Molecular orbital theory. Molecular orbital diagrams of diatomic and simple polyatomic molecules N_2, O_2, C_2, B_2, F_2, CO, NO, and their ions; HCl, BeF_2, CO_2, (idea of s-p mixing and orbital interaction to be given).

Metallic Bond: Qualitative idea of band theory. Semiconductors and insulators.

Weak Chemical Forces: van der Waals forces, ion-dipole forces, dipole-dipole interactions, induced dipole interactions, Instantaneous dipole-induced dipole interactions. Repulsive forces, Hydrogen bonding (theories of hydrogen bonding, valence bond treatment). Effects of chemical force, melting and boiling points, solubility energetics of dissolution process.

UNIT II: General principles of Metallurgy and chemistry of *s*- and *p*-Block Elements 16 Marks

General principles of Metallurgy: Chief modes of occurrence of metals based on standard electrode potentials. Ellingham diagrams for reduction of metal oxides using carbon as reducing agent. Hydrometallurgy, Methods of purification of metals (Al, Pb, Ti, Fe, Cu, Ni, Zn): electrolytic, oxidative refining, Kroll process, Parting process, van Arkel-de Boer process and Mond's process.

Chemistry of s- and p-Block Elements: Inert pair effect, Relative stability of different oxidation states, diagonal relationship and anomalous behaviour of first member of each group. Allotropy and catenation. Complex formation tendency of *s* and *p* block elements.

UNIT III: Acids and Bases 16 Marks

Arrhenius, Bronsted-Lowry, and Lewis concepts of acids and bases, Proton transfer equilibria in water, solvent levelling, Classification of acids and bases as hard and soft. Pearson's HSAB concept, acid-base strength and hardness and softness. Theoretical basis of hardness and softness, electronegativity and hardness and softness. Applications of acid base chemistry in qualitative analysis and catalysis, superacids and superbases.

UNIT IV: Analytical Chemistry 16 Marks

Principles of separation and identification of a mixture of cations and anions (qualitative analysis). Principles of estimation of metals quantitatively by complexometric methods, Principle of acid-base titration, Theory of indicators.
Introduction to methods of gravimetric analysis, purity of precipitate, coprecipitation, post precipitation, optimum conditions of precipitation, role of DMG, α-nitroso-β-naphthol and *p* -hydroxy quinoline in gravimetric analysis.

Basic principles of chromatography, classification, principles of chromatographic separation, nature of adsorbent, solvent system; R_f values. Column, thin layer, HPLC and paper chromatography.

UNIT V: Bioinorganic Chemistry 16 Marks

Metal ions present in biological systems, classification of elements according to their action in biological system. Geochemical effect on the distribution of metals. Na^+/K^+ pump. Ca^{2+} transport. Role of calcium in muscle contraction, blood-clotting. Excess and deficiency of some trace metals.

Toxicity of metal ions (Hg, Pb, Cd and As), reasons for toxicity, Use of chelating agents in medicine.

Iron and its application in bio-systems, Haemoglobin; Storage and transfer of iron.

Recommended Books

1. Lee, J. D., *Concise Inorganic Chemistry*, 5th Ed., Wiley India (2008).
2. Housecroft, C. E; Sharpe, A. G., *Inorganic Chemistry*, 5th Ed., Pearson Education (2018).
3. Atkins, P.; Overton, T.; Rouke, J.; Weller, M.; Armstrong, F.; Hagerman, M., *Shriver Atkins's Inorganic Chemistry*, 6th Ed., Oxford University Press India (2015).
4. Miessler, G.; Tarr, D. A., *Inorganic Chemistry*, 3rd Ed., Pearson Education India (2008).
5. Huheey, J. E.; Keiter, E. A.; Keiter, R. L.; Medhi, O. K., *Inorganic Chemistry: Principles of Structures and Reactivity*, 4th Ed., Pearson Education India (2006).
6. Cotton, F. A.; Wilkinson, G.; Gaus, P. L., *Basic Inorganic Chemistry*, 3rd Ed., Wiley India (2007).
7. Puri, B. R.; Sharma, L. R.; Kalia, K. C., *Principles of Inorganic Chemistry*, 33rd Ed., Vishal Publishing (2017).
8. Mendham, J.; Denney, R. C., Barnes, J. D.; Thomas, M.; Sivasankar, B., *Vogel's Quantitative Chemical Analysis*, 6th Ed., Pearson Education India (2009).
9. Lippard, S. J.; Berg, J. M., *Bioinorganic Chemistry*, Viva Books India (2007).

FIFTH SEMESTER
CHEM 352
(Organic Chemistry-I)

Maximum Marks: **100** (Terminal – 80, Sessional – 20)
Terminal Examination Duration: 3 Hours

UNIT I: Stereoisomerism 16 Marks

Concept of isomerism, Types of isomerism.
Geometrical Isomerism- determination of configuration of geometric isomers, cis-trans, sequence rules and *E* & *Z* system of nomenclature, geometric isomerism in oximes and alicyclic compounds.

Optical isomerism-elements of symmetry, molecular chirality, writing the Fischer projection and flying wedge formulae. Illustration of inter-conversion of one type of structural representation into another type of formulae. Enantiomers, diastereomers, stereogenic centre, optical activity, properties of enantiomers, optical purity, chiral and achiral molecules with two stereogenic centres, threo and erythro designation, meso compounds, inversion, retention and racemization, Resolution of enantiomers by salt forming method.

Conformational isomerism: conformational analysis of alkanes: conformations of cyclohexane, axial and equatorial bonds. Energy diagrams of cyclohexane: Chair, Boat and Twist boat forms; Relative stability with energy diagrams. Newman Projection and Sawhorse projection. Difference between configuration and conformation.

UNIT II: Aromatic hydrocarbons and reactions of benzene derivatives 16 Marks

Aromaticity: Hückel rule, Aromatic ions, antiaromaticity and non-aromaticity. Aromatic electrophilic substitution, mechanism, role of sigma and pi complexes, energy profile diagram, mechanism of nitration, halogenations, sulphonation, mercuration and Friedel craft's reaction. Substitution of mono substituted benzenes, activating and deactivating substituents, directive effects of the groups and its theory, ortho-para ratio, substitution of disubstituted benzene.

UNIT III: Polynuclear Hydrocarbons 16 Marks

Properties and Reactions of naphthalene phenanthrene and anthracene Structure, Preparation and structure elucidation of important derivatives of naphthalene and anthracene.

UNIT IV: Heterocyclic Compounds 16 Marks

Classification and nomenclature, Structure, aromaticity in 5-numbered and 6-membered rings containing one heteroatom (pyrrole, furan, thiophene and pyridine). Synthesis, reactions and mechanism of substitution reactions of: Furan, Pyrrole (Paal-Knorr synthesis, Knorr pyrrole synthesis, Hantzsch synthesis), Thiophene, Pyridine (Hantzsch synthesis), Pyrimidine, Structure elucidation of indole, Fischer indole synthesis and Madelung synthesis), Structure elucidation of quinoline and isoquinoline, Skraup synthesis, Friedlander's synthesis, Knorr

quinoline synthesis, Doebner- Miller synthesis, Bischler-Napieralski reaction, Pictet-Spengler reaction, Pomeranz-Fritsch reaction.

UNIT V: Colours, Dyes and Pigments 16 Marks

Classification, Colour and constitution; Mordant and Vat Dyes; Chemistry of dyeing. Synthesis and applications of: Azo dyes – Methyl Orange and Congo Red (mechanism of Diazo Coupling); Triphenyl Methane Dyes -Malachite Green, Rosaniline and Crystal Violet; Phthalein Dyes – Phenolphthalein and Fluorescein; Natural dyes –structure elucidation and synthesis of Alizarin and Indigo; Edible Dyes with examples.

Recommended Books

1. Greeves, N.; Clayden, J.; Warren, S., *Organic Chemistry*, 2nd Ed., Oxford University Press India (2014).
2. Smith, M. B.; March, J., *March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure*, 7th Ed., Wiley India (2015).
3. Solomons, T. W. G.; Fryhle, C. B., *Organic Chemistry*, 11th Ed., Wiley India (2015).
4. Bruice, P. Y., *Organic Chemistry*, 7rd Ed., Pearson Education India (2013).
5. Ghosh, S. K., *Advanced General Organic Chemistry*, *Part-I & Part-II*, 3rd Ed., New Central Book Agency (2010).
6. Bhal, B. S.; Bhal, A., *A Textbook of Organic Chemistry*, 22nd Ed., S. Chand and Company (2016).
7. Nasipuri D., *Stereochemistry of Organic Compounds: Principles and Applications*, 3rd Ed., New Age International Publishers (2018).
8. Sengupta, S., *Basic Stereochemistry of Organic Molecules*, 2nd Ed., Oxford University Press India (2018).

FIFTH SEMESTER
CHEM 353
(Physical Chemistry – I)

Maximum Marks: **100** (Terminal – 80, Sessional – 20)
Terminal Examination Duration: 3 Hours

UNIT I: Chemical Thermodynamics-II 16 Marks

Thermochemistry: Heats of reactions: standard states; enthalpy of formation and enthalpy of combustion and its applications; calculation of bond energy, bond dissociation energy and resonance energy from thermochemical data, effect of temperature (Kirchhoff's equations) and pressure on enthalpy of reactions. Hess's law of constant heat summation

Second law of thermodynamics: Spontaneous process; criteria of spontaneity; concept of entropy; statement of second law; cyclic processes and Carnot cycle and its efficiency. Calculation of entropy change of ideal gas with change in P, V and T. Physical significance of entropy. Clausius inequality, calculation of entropy changes during various processes. Helmholtz function and Gibbs function and the direction of spontaneous change. Maxwell relations and derivation of thermodynamic equation of state; Gibbs-Helmholtz equation.

Standard state free energy change. Clapeyron and Clausius-Clapeyron equation and their applications. van't Hoff isotherm. Third law of thermodynamics – Nernst heat theorem.

UNIT II: Chemical Kinetics II and Catalysis 16 Marks

Kinetics of complex reactions (integrated rate expressions up to first order only): (i) Opposing reactions (ii) parallel reactions and (iii) consecutive reactions and their differential rate equations.

Theories of reaction rates: Collision theory - Mathematical treatment and its limitations. Simple treatment of transition state or absolute reaction rate theory. Theory of unimolecular reaction-Lindemann mechanism.

Homogeneous and heterogeneous catalysis and their theories. Types of catalysis: Enzyme catalysis (points of difference with general heterogeneous catalysis, characteristics, factors affecting and kinetics of enzyme catalyst). Michaelis-Menten equation. Acid Base catalysis (type and mechanism), effect of pH and temperature.

UNIT III: Phase Equilibria 16 Marks

Phase, components and degrees of freedom of a system; criteria of phase equilibrium. Gibbs phase rule and its thermodynamic derivation. Derivation of Clausius – Clapeyron equation and its importance in phase equilibria. Phase diagram of one component systems (water and sulphur) and two component system (silver-lead and KI-H_2O).

Nernst distribution law and its limitations, thermodynamic derivation. Modification of distribution law to cases of association and dissociation of solute and complex formation. Application of the law in the process of extraction.

UNIT IV: Conductance 16 marks

Arrhenius theory of electrolytic dissociation. Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Molar conductivity at infinite dilution. Kohlrausch law of independent migration of ions. Debye-Hückel-Onsager equation.

Ionic velocities, mobilities and their determinations, transference numbers and their relation to ionic mobilities, determination of transference numbers using Hittorf and Moving Boundary methods. Applications of conductance measurement: (i) degree of dissociation of weak electrolytes, (ii) ionic product of water (iii) solubility and solubility product of sparingly soluble salts, (iv) conductometric titrations, and (v) hydrolysis constants of salts.

UNIT V: Photochemistry 16 Marks

Thermal and photochemical reactions. Lambert and Beer's law and its limitation; physical significance of absorption coefficient. Laws of photochemistry; quantum yield; actinometry. Primary and secondary processes. Examples of high and low quantum yields, photochemical equilibrium and the differential rate of photochemical reactions (decomposition of HI, reaction between hydrogen and bromine); photosensitized reactions, quenching. Role of photochemical reactions in biochemical processes, photo stationary states. Simple ideas of fluorescence, phosphorescence, and chemiluminiscence.

Recommended Books

1. Atkins, P. W.; de Paula, J.; Keeler, J., *Physical Chemistry*, 11th Ed., Oxford University Press India (2018).
2. Bahl, A.; Bahl, B. S.; Tuli, G. D., *Essentials of Physical Chemistry*, S. Chand and Company (2010).
3. Negi, A. S.; Anand, S. C., *Physical Chemistry*, New Age International Publishers (2007).
4. Puri, B. R.; Sharma, L. R.; Pathania, M. S., *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing (2017).
5. Silbey, R. J.; Alberty, R. A.; Bawendi, M. G., *Physical Chemistry*, 4th Ed., Wiley India (2006).
6. Rakshit, P. C., *Physical Chemistry*, Revised Ed. Sarat Book House (2014).
7. Kapoor, K. L., *A Textbook of Physical Chemistry: States of Matter and Ions in Solution*, Vol. I, 6th Ed., McGraw Hill Education India (2019).
8. Kapoor, K. L., *A Textbook of Physical Chemistry: Thermodynamics and Chemical Equilibrium*, Vol. II, 6th Ed., McGraw Hill Education India (2019).

FIFTH SEMESTER
CHEM 354
(Chemistry Laboratory Course V)

Maximum Marks: **100** (Terminal – 80, Sessional – 20)
Terminal Examination Duration: 8 Hours

1. Systematic qualitative analysis of inorganic mixtures containing not more than six radicals including interfering radicals:

   Basic radicals: Mercurous, mercuric, silver, lead, copper, cadmium, bismuth, stannous, stannic, antimony, arsenic, ferrous, ferric, aluminium, chromium, manganese, cobalt, nickel, zinc, calcium, strontium, barium, magnesium, sodium, potassium and ammonium radicals.

   Acid radicals: Phosphate, arsenate, borate, acetate, nitrite, nitrate, sulphite, sulphide, sulphate, thiosulphate, chloride, bromide, iodide, fluoride, carbonate, chromate and arsenite. (Insoluble salts are to be avoided).

   30 Marks

2. Physical Chemistry Experiments
   (a) Study the variation of surface tension of detergent solutions with concentration.
   (b) Study the variation of viscosity of sucrose solution with the concentration of solute.
   (c) Determination of critical solution temperature and composition of the phenol-water system
   (d) Study the absorbance spectra (300-800 nm) of $KMnO_4$ (in 0.1 M H_2SO_4 solution) and determine the λ_{max} values.
   (e) Conductometric titration involving strong acid and strong base.
   (f) Kinetics of acid hydrolysis of methyl acetate/ ethyl acetate.

   30 Marks

3. Viva voce 20 Marks

Recommended Books

1. Raj, G., *Advanced Practical Inorganic Chemistry*, Krishna Prakashan (2013).
2. Svehla, G.; Sivsankar, B., *Vogel's Qualitative Inorganic Analysis*, 7th Ed., Pearson Education India (2012).
3. Viswanathan, B.; Raghavan, P. S., *Practical Physical Chemistry*, Viva Books India (2014).
4. Yadav, J. B., *Advanced Practical Physical Chemistry*, Krishna Prakashan (2015).

SIXTH SEMESTER
CHEM 361
(Inorganic Chemistry – II)

Maximum Marks: **100** (Terminal – 80, Sessional – 20)
Terminal Examination Duration: 3 Hours

UNIT I: Structure and Energetics in Metallic and Ionic solids 16 Marks

Packing of spheres: Hexagonal and cubic closed packing, packing efficiency, Tetrahedral and octahedral holes in close packed structure; radius ratios in determining structure type among ionic solids. Characteristic structure types of ionic solids: CsCl, NaCl, Spalerite and Wurtzite types of ZnS, fluorite and anti-fluorite. Lattice energy, Statement of Born-Landé equation for calculation of lattice energy, Born-Haber cycle and its applications.

UNIT II: Inorganic Rings, cages and Polymers 16 Marks

Types of inorganic polymers. Comparison with organic polymer, synthesis, structural aspects and applications of Borazine or borazole, boron nitrides, silicates, silicones, siloxanes. Phosphazenes.

UNIT III: Nuclear Chemistry 16 Marks

Theory of radioactive disintegration, Alpha, beta and gamma rays. Rate of disintegration, half-life and average life period. Radioactive equilibrium, transmutation of elements, Soddy-Fajan's group displacement law, application of radioactivity. Isotopes and isobars. Separation of isotopes. Positive ray analysis. Nuclear forces, packing fraction, mass defect, binding energy. Nuclear fission and fusion. Atom bomb and hydrogen bomb. Linear accelerators. E values of nuclear reactions. Artificial radioactivity.

UNIT IV: Organometallic Compounds-I 16 Marks

Definition and classification of organometallic compounds on the basis of bond type. Concept of hapticity of organic ligands.

Metal carbonyls: 18 electron rule, electron count of mononuclear, polynuclear and substituted metal carbonyls of 3*d* series. General methods of preparation (direct combination, reductive carbonylation, thermal and photochemical decomposition) of mono and binuclear carbonyls of 3*d* series. Structures of mononuclear and binuclear carbonyls of Cr, Mn, Fe, Co and Ni.

UNIT V: Organometallic Compounds-II 16 Marks

Synthesis, structure and bonding of compounds with alkene and alkyne and allyl ligands.

Ferrocene: Preparation and reactions (acetylation, alkylation, metallation, Mannich Condensation). Structure and aromaticity. Comparison of aromaticity and reactivity with that of benzene.

Homogeneous catalysis by organometallic compounds: Hydrogenation (Wilkinson's Catalyst), hydroformylation (Co salts) and Ziegler-Natta Polymerization.

Synthesis and structure of organometallic compounds of Sn and Pb, Organometallic compounds of Zn, Cd and Hg.

Recommended Books

1. Lee, J. D., *Concise Inorganic Chemistry*, 5th Ed., Wiley India (2008).
2. Housecroft, C. E; Sharpe, A. G., *Inorganic Chemistry*, 5th Ed., Pearson Education (2018).
3. Atkins, P.; Overton, T.; Rouke, J.; Weller, M.; Armstrong, F.; Hagerman, M., *Shriver Atkins' Inorganic Chemistry*, 6th Ed., Oxford University Press India (2015).
4. Miessler, G.; Tarr, D. A., *Inorganic Chemistry*, 3rd Ed., Pearson Education India (2008).
5. Huheey, J. E.; Keiter, E. A.; Keiter, R. L.; Medhi, O. K., *Inorganic Chemistry: Principles of Structures and Reactivity*, 4th Ed., Pearson Education India (2006).
6. Cotton, F. A.; Wilkinson, G.; Gaus, P. L., *Basic Inorganic Chemistry*, 3rd Ed., Wiley India (2007).
7. Puri, B. R.; Sharma, L. R.; Kalia, K. C., *Principles of Inorganic Chemistry*, 33rd Ed., Vishal Publishing (2017).
8. Elias, A.; Gupta, B. D., *Basic Organometallic Chemistry: Concepts, Syntheses and Applications*, 2nd Ed., Universities Press India (2013).
9. Meherotra, R. C., *Organometallic Chemistry: A Unified Approach*, 2nd Ed., New Age International Publishers (1991).

SIXTH SEMESTER
CHEM 362
(Organic Chemistry – II)

Maximum Marks: **100** (Terminal – 80, Sessional – 20)
Terminal Examination Duration: 3 Hours

UNIT I: Pericyclic Reactions 16 Marks

Introduction, FMOs: HOMO and LUMOs (only upto conjugated triene system). Types of pericyclic reactions: electrocyclic, cycloaddition (2+2, 2+4 Diels-Alder reactions), sigmatropic *H*-shift (1,3; 1,5 and 1,7). Cope and Claisen rearrangement.

UNIT II: Organic Photochemistry 16 Marks

Theory of photochemistry; photophysical processes, electronic excitation, excited states, Jablonski diagram, Franck-Condon principle. Fluorescence and phosphorescence, Photosensitizers, Einstein's law of photochemical equivalence, quantum yield.
Typical photoreactions: Photoreaction of benzophenone, photolytic reactions of ketones. Norrish type-I and Norrish type-II reactions.

UNIT III: Carbohydrates 16 Marks

Classification and their biological importance.

Monosaccharides: Configuration of monosaccharides, structure elucidation and derivation of configurations of glucose and fructose, epimers, evidences for cyclic structure, mechanism of mutarotation, Cyclic structure of glucose, fructose, anomers, Haworth projections and conformation of D-glucose, determination of ring size of glucose, Interconversions of aldoses and ketoses; Killiani-Fischer synthesis and Ruff degradation; mechanism of osazone formation. Formation of glycosides.
Disaccharides – Structure elucidation of sucrose, lactose and maltose.

Polysaccharides – Elementary treatment of starch, cellulose and glycogen.

UNIT IV: Lipids and Nucleic Acids 16 Marks

Lipids, Oils and fats: Introduction to lipids, classification. Common fatty acids present in oils and fats, Omega fatty acids, Trans fats, Hydrogenation, Saponification value, Iodine number. Biological importance of triglycerides, phospholipids, glycolipids, and steroids (cholesterol).

Nucleic acids
Components of nucleic acids, Nucleosides and nucleotides; Structure, synthesis and reactions of: Adenine, Guanine, Cytosine, Uracil and Thymine; Structure of polynucleotide.

UNIT V: Amino Acids, Peptides and Proteins 16 Marks

Structure of amino acids, dipolar structure, isoelectric point, synthesis of α-amino acids - glycine, alanine, phenyl alanine by HVZ, reductive amination method and Strecker synthesis.

Bonding in peptides, peptide synthesis – synthesis of H- Leu-Ala-OH only from alanine and leucine.
Classification of proteins. Protein structure – primary, secondary tertiary and quaternary structure, protein denaturation.

Recommended Books

1. Greeves, N.; Clayden, J.; Warren, S., *Organic Chemistry*, 2nd Ed., Oxford University Press India (2014).
2. Smith, M. B.; March, J., *March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure*, 7th Ed., Wiley India (2015).
3. Solomons, T. W. G.; Fryhle, C. B., *Organic Chemistry*, 11th Ed., Wiley India (2015).
4. Bruice, P. Y., *Organic Chemistry*, 7rd Ed., Pearson Education India (2013).
5. Ghosh, S. K., *Advanced General Organic Chemistry, Part-I & Part-II*, 3rd Ed., New Central Book Agency (2010).
6. Bhal, B. S.; Bhal, A., *A Textbook of Organic Chemistry*, 22nd Ed., S. Chand and Company (2016).
7. Singh, J.; Singh, J. *Photochemistry and Pericyclic Reactions*, 4th Ed., New Age International Publishers (2019).
8. Berg, J. M.; Tymoczko, J. L.; Stryer, L., *Biochemistry*, 9th Ed., W. H. Freeman (2019).
9. Voet, D.; Voet, J. G., Pratt, C. W., *Biochemistry*, 4th Ed., John Wiley and Sons (2012).
10. Campbell, M. K.; Farrell, S. O.: McDougal, O. M., *Biochemistry*, 8th Ed., Cengage Learning (2013).

SIXTH SEMESTER
CHEM 363
(Physical Chemistry – II)

Maximum Marks: **100** (Terminal – 80, Sessional – 20)
Terminal Examination Duration: 3 Hours

UNIT I: Surface Chemistry and Colloids 16 Marks

Adsorption: Physical and chemical adsorption. Adsorption isotherms (Freundlich and Langmuir). Applications of adsorption.

Colloidal State: Classification of colloids, Preparation and purification of colloidal solution, Properties of colloids: Tyndal effect, Brownian movement, electrophoresis, electroosmosis, origin of charge, coagulation of colloids, Hardy-Schultz rule, protective action of colloids, Gold number. Emulsions, types and preparation of emulsion.

UNIT II: Introduction of polymeric materials 16 Marks

Different schemes of classification of polymers, polymer nomenclature, criteria for polymer solubility, solubility parameter, Thermodynamics of polymer solutions, entropy, enthalpy, and free energy change of mixing of polymers solutions, Flory- Huggins theory, lower and upper critical solution temperatures.

Number average and weight average molecular weights, determination of molecular weights of polymers by viscosity and osmotic pressure method.

UNIT III: Quantum Chemistry 16 Marks

Inadequacy of classical mechanics, Black body radiation, Planck's hypothesis, photoelectric effect, Compton effect, de Broglie equation and Heisenberg's uncertainty principle. Postulates of quantum mechanics, quantum mechanical operators. Eigen values and Eigen functions. Normalization and orthogonality of wave functions-Schrodinger wave equation. Solution of Schrodinger wave equation for free particles and particles in a one dimensional box; concept of quantization.

UNIT IV: Molecular Spectroscopy-I 16 Marks

Regions of the electromagnetic spectrum, Interaction of electromagnetic radiation with molecules and various types of spectra; Born-Oppenheimer approximation. Basic elements of spectroscopy; width and intensity of spectral transition.

Rotation spectroscopy: Selection rules, intensities of spectral lines, determination of bond lengths of diatomic and linear triatomic molecules, isotopic substitution.

Vibrational spectroscopy: Classical equation of vibration, computation of force constant, amplitude of diatomic molecular vibrations, anharmonicity, Morse potential, dissociation energies, fundamental frequencies, overtones, hot bands, degrees of freedom for polyatomic molecules, modes of vibration, concept of group frequencies.

UNIT V: Molecular Spectroscopy-II 16 Marks

Raman spectroscopy: Qualitative treatment of Rotational Raman effect; Effect of nuclear spin, Vibrational Raman spectra, Stokes and anti-Stokes lines; their intensity difference, rule of mutual exclusion.

Electronic spectroscopy: Franck-Condon principle, electronic transitions, singlet and triplet states, fluorescence and phosphorescence, dissociation and predissociation, calculation of electronic transitions of polyenes using free electron model.

Recommended Books

1. Atkins, P. W.; de Paula, J.; Keeler, J., *Physical Chemistry*, 11th Ed., Oxford University Press India (2018).
2. Bahl, A.; Bahl, B. S.; Tuli, G. D., *Essentials of Physical Chemistry*, S. Chand and Company (2010).
3. Negi, A. S.; Anand, S. C., *Physical Chemistry*, New Age International Publishers (2007).
4. Puri, B. R.; Sharma, L. R.; Pathania, M. S., *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing (2017).
5. Silbey, R. J.; Alberty, R. A.; Bawendi, M. G., *Physical Chemistry*, 4th Ed., Wiley India (2006).
6. Kapoor, K. L., *A Textbook of Physical Chemistry: States of Matter and Ions in Solution*, Vol. I, 6th Ed., McGraw Hill Education India (2019).
7. Kapoor, K. L., *A Textbook of Physical Chemistry: Thermodynamics and Chemical Equilibrium*, Vol. II, 6th Ed., McGraw Hill Education India (2019).
8. Billmeyer, F. W., *Textbook of Polymer Science*, 3rd Ed. Wiley India (2007).
9. Levine, I. N., *Quantum Chemistry*, 7th Ed., Pearson Education India (2016).
10. Prasad, R. K., *Quantum Chemistry*, 4th Ed., New Age International Publications (2010).
11. McQuarrie, D. A., *Quantum Chemistry*, Viva Books (2016).
12. Banwell C. N.; McCash, E. M., *Fundamentals of Molecular Spectroscopy*, 4th Ed., McGraw Hill Education (2017).
13. Pavia, D. L.; Lampman, G. M.; Kriz, G. S.; Vyvyan, J. A., *Introduction to Spectroscopy*, 5nd Ed., Cenegage Learning India (2015).

SIXTH SEMESTER
CHEM 364
(Chemistry Laboratory Course VI)

Maximum Marks: **100** (Terminal – 80, Sessional – 20)
Terminal Examination Duration: 8 Hours

1. Students have to do the analysis of the following mixtures (anyone mixture in the examination), preferably one volumetrically and the other gravimetrically or both gravimetrically:

   Cu and Ni; Cu and Zn; Pb and Zn; Fe and Ni.

   40 Marks

2. Organic estimation of
   a) Aniline
   b) Glucose
   c) Glycine

   20 Marks

3. Viva voce 20 Marks

Recommended Books

1. Mendham, J.; Denney, R. C., Barnes, J. D.; Thomas, M.; Sivasankar, B., *Vogel's Quantitative Chemical Analysis*, 6th Ed., Pearson Education India (2009).
2. Furniss, B. S.; Hannafold, A. J.; Smith, P. W. G.; Tatchell, A. R., *Vogel's Textbook of Practical Organic Chemistry*, 5th Ed., Pearson Education India (2003).
3. Clarke, H. T., *A Handbook of Organic Analysis: Qualitative and Quantitative*, 4th Ed., CBS Publishers India (2007).
4. Agarwal, O. P., *Advanced Practical Organic Chemistry*, Krishna Prakashan (2014).