7. CHEMESTRY

Preface

The FYUG syllabus for Chemistry has been framed as per NEP-2020 guidelines. This undergraduate course in Chemistry has been addressed to the students enrolled for 3-year UG Major and Multidisciplinary program, 4-year UG Honours, and Honours with the Research program of the University at the beginning of their careers. This course aims to disseminate knowledge in the field of academic, research, and professional development of students. The course in Chemistry has been divided into three sections, one each in Inorganic, Organic, and Physical Chemistry. The course on Inorganic Chemistry covers the basic understanding of atomic models, periodic properties of elements, and chemical bonding. A unit has been devoted to elementary knowledge of the nucleus and nuclear reactions. The course also covers theoretical and practical aspects of qualitative and quantitative analysis. A large part of Organic Chemistry is concerned with reactions leading to the formation and breaking of carbon-carbon bonds and the synthesis of various organic compounds including natural products. It also aims to impart knowledge to the students on the various oxidation and reduction methods for the modification of functional groups. Emphasis has been given to learning the scope and limitations of the reactions and the effect of structure on reactivity and selectivity. The course on Physical Chemistry includes the determination of structure and the geometrical arrangement of atoms in solids, the liquefaction of gases, and a quantitative relation between the heat capacities of a substance at constant pressure and constant volume. It aims to introduce the students to thermodynamic parameters and state functions and develop the basic concepts of thermodynamics and the direction of spontaneous change. The course also covers some elementary ideas on the kinetics of the reaction and the feasibility of a given reaction.

Programme Outcomes

At the end of the programme, the students are expected to have sound knowledge of fundamental concepts of inorganic, organic, and physical chemistry. The acquired hands-on training will enable the students to analyze and identify various ions and functional groups.

CHE-100: INTRODUCTORY CHEMISTRY – I

(Contact Hours: 75, Credits: 4)

***Objective**: The main objective of this course is to demonstrate scientific understanding of the structure of matter and its physical and chemical transformations so that students will be able to apply appropriate theories to predict chemical structure, reactivity, and physical properties. It would also provide students with hands-on training in qualitative analysis of various inorganic ions.*

***Learning outcomes**: The contents assignments and assessments of this course are aligned to understand the fundamental concepts of chemistry in all three branches viz. inorganic, organic, and physical chemistry. Also, they will learn inorganic qualitative analysis to identify the acidic and basic radicals present in inorganic salts.*

PART-A (Theory)

Unit I: Inorganic Chemistry-I Marks: 7 (Internal); 18 (End Sem.) 15 hours

(a) Structure of Atom: Bohr's Atomic model and its limitations, De- Broglie's matter waves, Heisenberg's Uncertainty principle, Schrodinger's wave equation and its importance, Physical concepts of Ψ and Ψ^2, Quantum numbers, Shapes of s, p and d orbitals, Principles of electronic configuration: Hund's Rule, Pauli's exclusion Principle, and Aufbau principle, Screening effect and effective nuclear charge.

(6 marks, 5 hours)

(b) Chemical periodicity: Long form of periodic table, Modern periodic law, Types of elements on the basis of electronic configuration, Periodic variation in properties: atomic and ionic radii, ionization enthalpy, electron gain enthalpy and electronegativity, Diagonal relationships.

(5 marks, 4 hours)

(c) Chemical Bonding : Valence shell electron pair repulsion (VSEPR) theory and shapes of molecules and ions:- BeF_2, CO_2, BF_3, BO_3^{3-}, O_3, H_3O^+, NH_3, H_2O, PCl_3, PCl_5, SF_4, SF_6, Basic idea of valence bond theory and its limitations, Concept of hybridization of orbitals and its implications on bond length, bond energy, bond angles and shapes of molecules with following examples: BeF_2, BF_3, $AlCl_3$, H_3O^+, NH_3, H_2O, PCl_3, PCl_5, SF_4, SF_6, ClF_3, I_3^-, LCAO-MO theory and its application to homonuclear diatomic molecules (H_2, Be_2, N_2, N_2^+, N_2^{2+}, N_2^- N_2^{2-}, O_2, O_2^-, O_2^{2-}, O_2^+ O_2^{2+}), Polarity of covalent bonds and dipole moment, Polarizing power, Polarizability

of ions and Fajan's rule, Concept of lattice energy and Born-Haber cycle (NaCl).

(8 marks, 6 hours)

Unit II: Organic Chemistry-I Marks: 6 (Internal); 19 (End Sem.) 15 hours

(a) Nomenclature, Structure, Bonding, and Properties: Nomenclature of organic molecules (hydrocarbons, halogen compounds, aldehydes, ketones, alcohols, ethers, amines, carboxylic acids, esters, amides and nitro compounds). Hybridisation and its implications on the bond length, bond energy, bond angles, shape of the molecules with following examples: (i) CH_4, CH_3^-, RNH_2 (ii) C_2H_4, CH_3^+, carbonyl compounds (C=O) and (iii) C_2H_2, R-C≡N, ketene. Nature of covalent bond and its orbital representation in molecules listed above, Electronegativity, Inductive effect, Effect of H-bonding on boiling point and solubility of organic compounds, Conjugation, Resonance, Hyperconjugation (propene and toluene), Heterolytic and homolytic bond cleavage, Electrophiles and nucleophiles, Reactive intermediates: carbocations, carbanions and free radicals.

(8 marks, 6 hours)

(b) Alkanes and Cycloalkanes: Methods of preparation of alkanes (with special reference to mechanism of Kolbe, Würtz, Würtz-Fittig and Corey-House reactions), Chemical reactivity (oxidation and cracking). Mechanism of chlorination, Relative reactivity of halogens towards different types of alkanes. General methods of preparation of cycloalkanes (up to cyclohexane) and their reactions with halogens and HX, Baeyer's strain theory – modifications and its limitations.

(5 marks, 4 hours)

(c) Alkenes and Alkynes: Synthesis and reactivity of alkenes, Markownikoff's rule and anti-Markownikoff's rule, Mechanism of hydrogenation, bromination, hydration, halohydration, hydroboration, oxidation, epoxidation, ozonolysis, hydroxylation and polymerization, Comparative acidity of ethane, ethane and ethyne, Synthesis and reactivity of alkynes: electrophilic addition reactions (halogenation, hydration, HX and HOX), ozonolysis; alkynides (Na, Cu and Ag) and polymerization.

(6 marks, 5 hours)

Unit III: Physical Chemistry-I Marks: 6 (Internal); 19 (End Sem.) 15 hours

(a) States of Matter

***(i) Gaseous State-I*:** Postulates of kinetic theory of gases, Collisions and gas pressure, Average kinetic energy, Root mean square velocity and absolute temperature of gas, Boltzmann constant, Gas laws and kinetic theory, Liquification of CO_2 gas, Real gases - deviation from ideality,

Compressibility factor and its variation with pressure and temperature for different gases, and van der Waals equation of state.

(7 marks, 6 hours)

***(ii) Liquid State-I*:** Qualitative description of the structure of liquids, Physical properties of liquids: vapour pressure, Surface tension, Viscosity, Refractive index (definitions and descriptions). Effect of additive (sodium chloride and ethanol) on surface tension and viscosity of liquid.

(4 marks, 3 hours)

(iii) Solid State-1: Elementary discussion on the types of unit cells, Crystal systems, Crystal defects, Bragg's law.

(3 marks, 2 hours)

(b) *Chemical Kinetics-I*: Rate of reaction and rate constant, Molecularity and order of a reaction, Zero order reaction, Differential and integrated forms of rate equations of first and second order reactions, Pseudo-first order reactions, Determination of order of reactions, Effect of temperature on reaction rates and energy of activation, Effect of catalyst.

(5 marks, 4 hours)

PART-B (Practical)

Unit IV: Inorganic Laboratory-I Marks: 6 (Internal); 19 (End Sem.) 30 hours

Experiment: *Qualitative analysis of inorganic mixtures containing at least five radicals/ions (from the list given below) to be completed - one of the radicals/ions must be interfering (borate, chromate or phosphate).*

List of ions/radicals:

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

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

Interfering radicals/ions: borate, chromate, phosphate.

End-semester External Evaluation Distribution (Duration: 6 hours)		
1	Qualitative Analysis	12 Marks
2	Viva voce	5 Marks
3	Laboratory record	2 Marks
In-semester Internal Evaluation Distribution		
1	Laboratory attendance and performance	2 Marks
2	Test and Viva voce	4 Marks

Suggested books:

1. Concise Inorganic Chemistry, J. D. Lee, 5th Ed., Wiley India, New Delhi (2014).
2. General and Inorganic Chemistry (Part-I), R. Sarkar, 3rd Revised Ed., New Central Book Agency, India (2011).
3. Vogel's Qualitative Inorganic Analysis, G. Svehla, 6th Revised Ed., Orient Longman, London (1987).
4. Modern Organic Chemistry, M. K. Jain and S. P. Sharma, Vishal Publishing Co., Jalandhar (2020).
5. Organic Chemistry, J. Clayden, N. Greeves, S. Warren and P. Wothers, Oxford University Press, London (2012).
6. Principles of Physical Chemistry, B. R. Puri, L. R. Sharma and M. S. Pathania, Vishal Publication Co., Jalandhar (2020).
7. Physical Chemistry, P. W. Atkins and De-Paula Atkins, 7th Ed, Oxford University Press, London (2006).
8. University Chemistry Practical, P. C. Kamboj, Vishal Publishing Co., Jalandhar (2009-2010).

Notes:

(i) A candidate must obtain minimum pass marks (which will include both the internal and end-semester marks) stipulated by the University **separately** both in the theory (Part A) and practical components (Part B) to clear the course.

(ii) The marks allotted to each component of different units should be strictly adhered to in making the question paper.

CHE-150: INTRODUCTORY CHEMISTRY – II

(Contact Hours: 75, Credits: 4)

Objective*: The primary objective of this course is to provide a broad foundation in chemistry that stresses scientific understanding and reasoning along with problem solving aptitude. It would also provide the students with the skills required to analyze and comprehend the chemical composition of organic compounds.*

Learning outcomes*: Upon successful completion of this course, the students will have an understanding in the principles and applications of various theories in inorganic, organic, and physical chemistries. Also, they will learn the techniques to identify the functional groups and analyze the organic samples to know their properties.*

PART-A (Theory)

Unit I: Inorganic Chemistry-II Marks: 6 (Internal); 19 (End Sem.) 15 hours

(a) Nucleus and Radioactivity-I: Nuclear particles (neutrons and protons) and concept of mesons and pions, Mass defect and nuclear binding energy (including numerical), Packing fraction, Natural and artificial radioactivity, Radioactive disintegration series, First order rate equation of radioactive disintegration, Half-life and average life period, Group displacement law, Neutron-proton ratio and its implications, Elementary concepts of fusion and fission.

(5 marks, 4 hours)

(b) Redox reactions: Electronic concepts of oxidation and reduction, Oxidation number, Common oxidants and reductants, Calculation of equivalent weights of oxidants and reductants, Balancing of redox reactions by ion electron method. *(4 marks, 3 hours)*

(c) Principles of qualitative and quantitative analysis: Solubility product and its application in group separation of cations, Standard solutions: primary and secondary solutions, Concentrations of standard solutions: molarity, molality and normality, Volumetric analysis: redox titrations

(permanganometry, dichromometry and sodium thiosulphate with iodide), iodometric and iodimetric titrations. *(5 marks, 4 hours)*

(d) Acid-base Concept: Arrhenius and Bronsted-Lowry concept, Lewis concept, Solvent system (Franklin) concept and its limitation, Effect of solvent in relative strengths of acids and bases, Levelling and differentiating effect, Relative strengths of acids and bases (pKa and pH concept), HSAB principle.

(5 marks, 4 hours)

Unit II: Organic Chemistry-II Marks: 7 (Internal); 18 (End Sem.) 15 hours

(a) Organic Stereochemistry–I: Concept of isomerism, Types of isomerism, Configurational and conformational isomerism (ethane and butane), Fischer, Newman and Sawhorse projections with suitable examples, Geometrical isomerism, Configuration of geometrical isomers, E and Z nomenclature (including oximes), Optical isomerism: optical activity, chiral carbon atom, enantiomers, diastereomers, R/S nomenclature (with one chiral carbon atom only)

(6 marks, 5 hours)

(b) Aromatic Hydrocarbons and Aromaticity: Molecular orbital picture of benzene, Resonance energy, Aromaticity, Hückel's (4n+2) rule and its application to simple molecules and ions, Electrophilic substitution reactions in aromatic hydrocarbons and general pattern of the mechanism, Effect of substituent groups (activating and deactivating groups, directive influence): mechanism of nitration, sulphonation, halogenation (nuclear and side-chain), formylation (Gattermann and Gattermann – Koch), Friedel – Craft's alkylation and acylation.

(5 marks, 4 hours)

(c) Nucleophilic Substitution Reactions: Nucleophile, Ambident nucleophile (KCN, AgCN, KNO_2, $AgNO_2$), Difference between nucleophiles and bases, S_N^1, S_N^2, NGP, S_N^i, Factors affecting substitution reactions (structure of substrate, nature of nucleophile, solvent and role of leaving group), Mechanism and stereochemistry of substitution reactions.

(5 marks, 4 hours)

(d) Elimination reactions: E^1, E^2, E^1cB mechanism, Orientation in elimination reactions (Saytzeff's and Hoffmann rules). *(3 marks, 2 hours)*

Unit III: Physical Chemistry-II Marks: 6 (Internal); 19 (End Sem.) 15 hours

***(a) Thermodynamics-I*:** Concept of system and surrounding, types of systems, Intensive and extensive properties, Types of processes: isothermal, adiabatic, isobaric, reversible, irreversible and cyclic processes; Thermodynamic functions: state variables and exact differentials, Path functions and inexact differentials, Zeroth law of thermodynamics, Reversibility and maximum work in ideal gas expansion. First law of thermodynamics: Statement, internal energy, enthalpy,

Heat capacity at constant pressure (Cp) and volume (Cv), Concept of heat, Relation between Cp and Cv, Spontaneous processes, Entropy, Second law of thermodynamics, Joule-Thomson coefficient and inversion temperature. (*10 marks, 8 hours)*

***(b) Thermochemistry*:** Exothermic and endothermic reactions, Hess's law of constant heat summation, Enthalpy of formation, Standard state, Enthalpy of combustion, Enthalpy of neutralization, Enthalpy of solution, Enthalpy of dilution, Kirchhoff's equations: influence of temperature on ΔH and ΔU of a reaction. *(5 marks, 4 hours)*

(c) Adsorption and Surface Phenomena: Physisorption and chemisorption, Adsorption isotherms: derivation and application of Gibbs and Langmuir adsorption isotherm. *(4 marks, 3 hours)*

PART-B (Practical)

Unit IV: Organic Laboratory-I Marks: 6 (Internal); 19 (End Sem.) 30 hours

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

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

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

-COOH, -OH (phenolic), -CHO, >C=O, $-NH_2$ and $-NO_2$

(c) Preparation of the derivative.

End-semester External Evaluation Distribution (Duration: 6 hours)		
1	Qualitative Analysis	12 Marks
2	Viva voce	5 Marks
3	Laboratory record	2 Marks
In-semester Internal Evaluation Distribution		
1	Laboratory attendance and performance	2 Marks
2	Test and Viva voce	4 Marks

Suggested Books:

1. Inorganic Chemistry, R. L. Dutta, 3rd Ed., The New Book Stall, India (1973).

2. Principles of Inorganic Chemistry, B. R. Puri, L.R. Sharma and K.C. Kalia, 33rd Ed., Vishal Publishing Co. (2019-20).
3. Organic Chemistry, S. N. Mukherjee, S. P. Singh and R. P. Kapoor, Vol I (2017), II (2018) & III (2018), New Age Publishers, India.
4. Basic Stereochemistry of organic molecules, S. Sengupta, 2nd Ed., Oxford University Press, London (2018).
5. Physical Chemistry, P. C. Rakshit (revised by S. C. Rakshit), 6th Ed., Sarat Book House, Kolkata (2014).
6. A Textbook of Physical Chemistry, Vol 1 & 2, K. L Kapoor, 4th Ed. Macmillan Publishers India Ltd. (2011).
7. Vogels Textbook of Practical Organic Chemistry, B. S. Furniss, A. J. Hanaford, P. W. G. Smith and A. R. Tatchell, 5th Ed., John Wiely, New York (1989).

Notes:

(i) A candidate must obtain minimum pass marks (which will include both the internal and end-semester marks) stipulated by the University **separately** both in the theory (Part A) and practical components (Part B) to clear the course.

(ii) The marks allotted to each component of different units should be strictly adhered to in making the question paper.