FOUR YEAR UNDERGRADUATE (FYUG) PROGRAMME UNDER NEW EDUCATION POLICY, 2020

CHEMISTRY

Date of Approval in Academic Council -30th May and 21st June 2024

Preface

The FYUG syllabus for Chemistry has been framed as per NEP-2020 guidelines. This under graduate 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 Research program of the University. The course in Chemistry consists of three major branches, i.e. Inorganic, Organic and Physical Chemistry. Inorganic Chemistry covers atomic model, periodic properties of elements, chemical bonding, nuclear reactions, and symmetry of molecules. Emphasis has been given to various other topics such as main group elements, transition metals, organometallic and coordination compounds. The course also covers analytical, industrial, environmental, bioinorganic chemistry as well as 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 and reactions of various organic compounds including carbonyl and nitrogen containing compounds, polymers, heterocyclic compounds, drugs, dyes, and natural products. Emphasis has been given to learn the scope and limitations of the reactions and effect of structure on reactivity and selectivity. Topics on green chemistry, spectroscopy and practical on identification of organic compounds, and green method of synthesis have also been covered. The course on Physical Chemistry emphasizes to build the basic concepts and foundation skills to explain the properties of different systems (gaseous, liquid and solid) in molecular level. It also aims to introduce the students to thermodynamic parameters including state functions and develop the basic concepts of thermodynamics as well as the direction of spontaneous change. The course also covers elaborate discussion on the kinetics of the reaction and the feasibility of a given reaction. The students will also get to learn the structural effect and molecular properties in controlling the macroscopic behavior of the systems by quantum mechanical principles, spectroscopic studies and statistical thermodynamic analysis from first principles. A series of laboratory experiments covered in this course will help the students to understand and utilize the theoretical knowledge in "real world" situation.

Programme Outcome

At the end of the programme, the students are expected to have sound knowledge on fundamental concepts of inorganic, organic and physical chemistry. The acquired hands-on training through several laboratory experiments will enable the students to utilize the theoretical foundation in solving the real problems to make them face the challenges in higher studies/future endeavors. The knowledge gathered at the end of this course will help the students for self-employability and make them ready to face the corporate and/or academic world.

Structure of the syllabus (Chemistry)

SEMESTER 1

Course Code	Title of the Course	Credit			Total Contact Hours
		Theory	Practical	Total	
CHE 100	Introductory Chemistry-I	3	1	4	75
CHE 100	Introductory Chemistry-I (Minor)	3	1	4	75
MDC 100--119	Any one of the available courses as notified by the University from time to time	3	-	3	45
AEC 120--129	Any one of the available courses as notified by the University from time to time	3	-	3	45
SEC 130--139	Any one of the available courses as notified by the University from time to time			3	45-90
VAC-140	Mention the name of the paper	3	-	3	45
	Total			**20**	

SEMESTER 2

Course Code	Title of the Course	Credit			Total Contact Hours
		Theory	Practical	Total	
CHE 150	Introductory Chemistry-II	3	1	4	75
CHE 150	Introductory Chemistry-II (Minor)	3	1	4	75
MDC 160--169	Any one of the available courses as notified by the University from time to time	3	-	3	45
AEC 170--179	Any one of the available courses as notified by the University from time to time	3	-	3	45
SEC 180--199	Any one of the available courses as notified by the University from time to time			3	45-90
VAC-190--199	Any one of the available courses as notified by the University from time to time	3	-	3	45
	Total			**20**	

SEMESTER 3

Course Code	Title of the Course	Credit			Total Contact Hours
		Theory	Practical	Total	
CHE 200	Chemistry–III	4	-	4	60
CHE 201	Organic Chemistry Laboratory	-	4	4	120
MDC 210--219	Any one of the available courses as notified by the University from time to time	3	-	3	45
AEC 220--229	Any one of the available courses as notified by the University from time to time	3	-	3	45
SEC 230--239	Any one of the available courses as notified by the University from time to time			3	45-90
VTC-240--249	Any one of the available courses as notified by the University from time to time	1	3	4	105
	Total			**20**	

SEMESTER 4

Course Code	Title of the Course	Credit			Total Contact Hours
		Theory	Practical	Total	
CHE 250	Inorganic Chemistry-I	4	-	4	60
CHE 251	Organic Chemistry-I	4	-	4	60
CHE 252	Physical Chemistry-I	4	-	4	60
CHE 253	Inorganic Chemistry Laboratory	-	4	4	120
VTC 260--269	Any one of the available courses as notified by the University from time to time	1	3	4	105
	Total			**20**	

SEMESTER 5

Course Code	Title of the Course	Credit			Total Contact Hours
		Theory	Practical	Total	
CHE 300	Chemistry-IV	4	-	4	60
CHE 301	Organic Chemistry-II	4	-	4	60
CHE 302	Chemistry-V	4	-	4	60
CHE 302	General Chemistry – III (Minor)	3	1	4	75
CHE-303	Internship/Apprenticeship/Community engagement and service/Field based learning or minor project	-	4	4	120
	Total			**20**	

SEMESTER 6

Course Code	Title of the Course	Credit			Total Contact Hours
		Theory	Practical	Total	
CHE 350	Inorganic Chemistry-II	4	-	4	60
CHE 351	Organic Chemistry-III	4	-	4	60
CHE 352	Physical Chemistry-II	4	-	4	60
CHE 353	Physical Chemistry Laboratory	-	4	4	60
VTC 360--369	Any one of the available courses as notified by the University from time to time	1	3	4	105
	Total			**20**	

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.

SEMESTER 3

Instructions for Semester 3
For a 100 mark paper (4 credits), 25 marks will be assigned for sessional and 75 marks for end semester examination. The end semester practical examination with 100 marks will be of six hours duration. The internal assessment will be based on sessional examination and/or assignments.

Course Code: CHE-200
Course Title: CHEMISTRY-III
Total Contact Hours: 60 (T)

Course Objectives
To provide students with a comprehensive understanding of inorganic chemistry principles, including main group elements, transition metals, and related compounds. Additionally, it equips students with a foundational understanding of mathematical concepts relevant to chemistry. The course delves into the intricacies of chemical equilibrium, including both chemical and ionic equilibria.

Learning Outcomes
Learner of this course will possess a comprehensive understanding of inorganic chemistry principles, encompassing main group elements, transition metals, and related compounds. The students will also be equipped to apply mathematical tools to interpret chemical data, predict equilibrium behaviors, and make informed decisions in scientific contexts.

PART-A (Inorganic) Marks: 12 (In-Sem.): 38 (End Sem.) (30 hours)

Unit I: Main group elements

(a) s- and p-block elements and their Compounds: Group discussion of the elements with respect to their position in the periodic table, electronic configuration, Atomic and ionic radii, Ionization enthalpy, Electron gain enthalpy, Electronegativity, Oxidation states, Variation of acidic and basic properties of their oxides and oxy-acids, Inert -pair effect and catenation.
Preparation, important reactions, structure and use of the following compounds: sodium thiosulphate, potassium iodide, quick lime, bleaching powder, diborane, boric acid, aluminum chloride, lithium aluminum hydride, hydrazine, hydroxylamine, hydrazoic acid and lead tetra-acetate.

(12 marks, 10 hours)

(b) Interhalogens, Polyhalides and Pseudohalides: Definition of interhalogen, polyhalide and pseudohalide compounds, Different types of interhalogens and their reactivity, polyhalides of iodine; preparation and reactivity of pseudohalides: cyanogen, and thiocynogen, structure of ClF_3, BrF_3, BrF_5, and IF_7.

(7 marks, 5 hours)

Unit II: Transition metals

(a) d- and f-block elements and their Compounds: Transition metals - Definition and characteristic features of transition metals, electronic configuration of d-block elements, General characteristics of transition metals: Atomic and ionic radii, Melting and boiling point, Ionization energies, oxidation states, colour, reducing and catalytic properties, and magnetic properties. Variation of properties in first, second and third row transition metals.
Lanthanides and Actinides: Electronic configuration of lanthanides and actinides, oxidation states of lanthanides and actinides, variation in their atomic and ionic radii – lanthanide contraction, separation of lanthanides: solvent method and ion exchange method of separation only, synthetic elements, synthesis of Np and Pu only

Preparation, important reactions, structures and uses of nickel tetra-carbonyl, potassium ferricyanide, potassium dichromate, potassium permanganate, sodium nitroprusside, sodium cobaltinitrite, Nessler's reagent and uranium hexafluoride

(12 marks, 10 hours)

(b) Chemical Bonding-II: Molecular orbital Theory (MOT): Salient features of molecular orbital theory, Formation of molecular orbitals: Linear combination of atomic orbitals, Conditions for the combination of atomic orbitals, Shapes of molecular orbitals, Applications of MOT to homo and heteronuclear diatomic molecules : H_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-}, Cl_2, CO and NO). Electronic configuration of molecules and molecular behavior viz. bond order, bond length, nature of the bond, and magnetic nature.

(7 marks, 5 hours)

PART-B (Physical) Marks: 13 (In-Sem.): 37 (End Sem.) (30 hours)

Unit III: Fundamental Mathematics

(a) Mathematics for Chemistry-I: Mathematical functions, polynomial expressions, logarithms, the exponential function, units of a measurement, interconversion of units, constants and variables, equation of a straight line, plotting graphs; Basic Trigonometric functions; differentiation: Functions, limits, derivative, physical significance, basic rules of differentiation, maxima and minima, partial differentiation, cyclic rule; Integration: rules of integration, definite and indefinite integrals.

(9 marks, 7 hours)

(b) Mathematics for chemistry-II: Fundamentals of Permutations and combinations; Probability meaning and definition, Quadratic equation and their solutions; Mathematical series: Power series, Taylor, and Maclaurin series; Mathematical relations: vectors (Vectors, dot, cross and triple products), matrices (3x3), determinants (3x3), Stirling approximation.

(9 marks, 8 hours)

Unit IV: Equilibria

(a) Chemical Equilibrium: Law of mass action, equilibrium constant (K) from thermodynamic considerations, temperature and pressure dependence of equilibrium constants (K_p and K_c - van't Hoff equation, relation of K_p and K_c, equilibria in homogeneous and heterogeneous systems, Le Chatelier's principle, effect of addition inert gases on equilibrium constant.

(9 marks, 7 hours)

(b) Ionic Equilibrium: Dissociation constant of weak acids (K_a) and weak bases (K_b), ionic product of water (K_w), pH scale of solution, common ion effect; buffer solutions and buffer activity, types of buffers, Henderson-Hasselbalch equation; Hydrolysis of salts: hydrolysis constant (K_h), relation between K_a, K_w and K_b, derivation of hydrolysis constant of salts of acids and bases; Solubility product.

(10 marks, 8 hours)

Notes: A candidate must obtain minimum pass marks (as per NEHU rule) to clear the course.

Suggested Readings

1. Advanced Inorganic Chemistry, Satya Prakash, G.D. Tuli, S.K. Basu, R.D. Madan, Vol-I, 19th Ed., S. Chand & Co (2005).
2. Inorganic Chemistry, A.G. Sharpe, 3rd Ed., ELBS, Longman (1994)
4. Mathematics for Physical Chemistry, D.A. McQuarrie, University Science Book, Sausalito, CA (2008)
5. Atkin's Physical Chemistry, P.W. Atkins and J. De-Paula, 8th Ed., Oxford University Press, London (2006)

Course Code: CHE-201
Course Title: ORGANIC CHEMISTRY LABORATORY
Total Contact Hours: 120 (P)

Course Objectives

Hands-on experience in the separation of the organic binary mixture based on the acid-base concept and compound synthesis.

Learning Outcomes

Upon successful completion of this course, students will learn separation techniques, functional group detection, derivative preparation, and melting point measurement. Moreover, they will learn the preparation of organic compounds following green chemistry principles.

Laboratory Course (Organic)

1. *Separation of Mixtures*
   (a) Separation of binary organic mixtures based on acid-base concept.
   (b) Analysis and preparation of derivatives, determination of melting points of compounds and derivatives, identification of compounds
2. *Organic Preparation*
   Preparation of the following compounds:
   (a) Phthalimide (from phthalic anhydride)
   (b) *m*-Dinitrobenzene (from nitrobenzene)
   (c) Picric acid (from phenol)
   (d) *p*-Bromoacetanilide (from acetanilide)
   (e) Benzilic acid (from benzil)
3. *Green method of synthesis of the following compounds*
   (a) benzilic acid
   (b) *p*-bromoacetanilide
   (c) acetanilide (acetylation of primary amines)
   (d) α,β-unsaturated ester/nitrile (Knoevenagel condensation)

Marks Distribution	***In-semester***	***End-semester***	***Exam duration***
1. Separation of mixtures	15	40	
2. Organic Preparation	5	10	
3. Green method of synthesis	-	10	18 hours
4. Viva voce	3	10	
5. Laboratory records	2	5	

Notes: A candidate must obtain minimum pass marks (as per NEHU rule) to clear the course.

Suggested Readings

1. Vogels Textbook of Practical Organic Chemistry, B.S. Furniss, A.J. Hanaford, P.W.G. Smith and A.R. Tatchell, 5th Ed., John Wiley, New York (1989)

SEMESTER 4

Instructions for Semester 4
For a 100 mark paper (4 credits), 25 marks will be assigned for sessional and 75 marks for end semester examination. The end semester practical examination with 100 marks will be of six hours duration. The internal assessment will be based on sessional examination and/or assignments.

Course Code: CHE-250
Course Title: INORGANIC CHEMISTRY-I
Contact Hours: 60

Course Objectives
The main objective about this course will be to make the students aware about different basic concepts of the bonding principles responsible for the energetics and structure of the coordination and organometallic chemistry. In this course they will also learn about the theories of analytical chemistry used in different analytical techniques and to interpret the experimental data by using statistical methods.

Learning Outcomes
The students of this semester will be benefited from this course by knowing more about the compounds formed by the metals in a complex form. The critical analytical thinking of the learner will also improve in respect of the analytical and statistical procedures during the analysis of various compounds after completion of this course.

Unit I: Analytical Chemistry-I

Standard solutions : Primary and secondary, Concentrations of standard solutions, Applications of chemical equilibrium to analytical separations and estimations : equilibrium constants, activity coefficients, acid-base equilibrium, solubility equilibrium, distribution equilibria, complex ion equilibria and stability constants, Basic theories of systematic qualitative analysis : solubility product, common ion effect, pH and buffer actions, complex formation, Volumetric analysis : permanganatometry, dichromatometry, iodometric and iodimetric analysis, Complexometrictitrations with special emphasis on EDTA titrations, Theory of indicators, Gravimetric analysis: theory of precipitation, fractional precipitation, co-precipitation and post precipitation.

(19 marks, 15 hours)

Unit II: Coordination Chemistry-I

Double salts an complex salts, Werner's Coordination theory, Coordination number, Ligands and their classification , Chelation and its applications of chelate formation, Nomenclature of coordination compounds(mono and poly-nuclear), Determination of composition of complexes by spectrophotometric method, Effective atomic number rule, Factors influencing complex formation, Isomerism in coordination compounds : structural isomerism: Ionization, hydrate, linkage, coordination, coordination position, ligand, conformational and polymerization isomerism and stereoisomerism: geometrical and optical isomerism in 4-and 6- coordinate complexes only

(19 marks, 15 hours)

Unit III: Organometallic Chemistry-I, Applications of Organic reagents & non-aqueous solvents

(a) Organometallics-I: Definition and classification of organometallic compounds, Nomenclature of organometallic compounds, General characteristics of organometallic compounds: Ionic bonded,

Sigma bonded and electron deficient bridged compounds, Synthesis, properties, nature of bonds, structure and application of one organometallic compound each of lithium (LiR; R= alkyl or aryl), Methyl Lithium), magnesium (RMgX and MgR_2).

*(b) Organic reagents in Inorganic analysis***:** Oxine, 1-Niroso-2-napthol, Cupferron, Cupron, Dithizone, Acetylacetone, Dimethylglyoxime, Salicyladoxime, Alizarin –S, Rhodamine-B.

(c) Non aqueous solutions: Characteristic properties of a solvent, Classification of solvents, Reactions in liquid ammonia and liquid sulphur dioxide (neutralization, redox, precipitation, complex formation and solvolysis reactions), Action of metals in liquid ammonia.

(19 marks, 15 hours)

Unit IV: Data Analysis

Significant figures, Accuracy and precision, Errors (determinate and indeterminate), Ways of expressing errors, Normal distribution of indeterminate errors, Propagation of errors-addition and subtraction, multiplication and division, Minimization of errors, Significant figures and propagation of error, Average mean deviation, Standard deviations, Coefficient of correlation and variance, Method of least squares, Rejection of data: Q-test, Test for significance: the F-test and t-test.

(18 marks, 15 hours)

Notes: A candidate must obtain minimum pass marks (as per NEHU rule) to clear the course.

Suggested Readings

1. Principles of Inorganic Chemistry, B.R. Puri, L.R. Sharma & K.C. Kalia, Vishal publishing Co. (2019)
2. Analytical Chemistry, Gary D. Christian, 6th Ed., John Wiley & Sons (Asia), Pte. Lts. (2011)
3. Basic Organometallic Chemistry: Concepts, Syntheses and Applications, A. J. Elias and B.D. Gupta, Universities Press (India) Pvt Ltd (2010)

Course Code: CHE-251
Course Title: ORGANIC CHEMISTRY-I
Contact Hours: 60

Course Objectives
To provide a solid foundation on various aromatic, aliphatic compounds and organometallic reagents.

Learning Outcomes
On successful competition of this course, students will be able to know more about the properties and applications of different organic compounds including functional group inter-conversions.

Unit I: Functional Groups in Organic Chemistry

(a) Aromatic Halogen Compounds: Introduction, preparation and chemical reactivity, nuclear and side chain halogenation, electrophilic and nucleophilic substitution in aromatic halogen compounds (bimolecular displacement, benzyne mechanism). Role of ring substituents in nucleophilic substitutions. Relative reactivity of alkyl, allyl, aryl, benzyl and vinyl halides towards nucleophilic substitution.
(b) Alcohols: Classification, method of preparation (hydration, hydroboration-oxidation and oxymercuration-reduction, reaction of alcohols, distinction between primary, secondary and tertiary alcohols (Victor Meyer's test, Lucas's test, Oxidation by $K_2Cr_2O_7$ and metallic Cu), preparation and chemical reactions of glycol (HNO_3, HCl, PX_3, terephthalic acid, oxidation) and glycerol (HNO_3, HI, oxalic acid, $KHSO_4$).
(c) Epoxides: Properties of epoxides and reactions with alcohols, HCN, NH_3, amines & $LiAlH_4$.
(d) Phenols: Nomenclature, Preparation (from benzene diazonium salts, benzene sulphonic acids and cumene), physical properties and acidic character, comparison of acid strength of phenols with alcohols, effect of substituents on acidity of phenols, chemical reactions: nitration, halogenation, sulphonation, Kolbe's reaction, Reimer-Tiemann reaction, phenol-formaldehyde resin.

(19 marks, 15 hours)

Unit II: Carbonyl Compounds and their Derivatives

(a) Aldehydes and Ketones: Method of preparation of aldehydes and ketones (from alcohols, Rosenmund reduction, Gattermann-Koch), Structure and reactivity of carbonyl group, mechanism of nucleophilic additions and addition-elimination reactions with HCN, $NaHSO_3$, NH_2OH, NH_2-NH_2, $C_6H_5NHNH_2$, 2,4-DNPH, $NH_2CONHNH_2$); Formation and acid-assisted cleavage of acetals and ketals; acidity of α-hydrogen in carbonyl compounds and formation of enolates, aldol condensation, Perkin reaction, Cannizzaro reaction, reactions with Grignard reagents, benzoin condensation, oxidation reactions (haloform reaction, Tollen's reagent, Fehling's solution, bromine water) and reduction reactions (Clemmensen and Wolff-Kishner reductions),.
(b) Carboxylic Acids and their Derivatives: Structure and bonding, effect of substituents on the acidity of aliphatic and aromatic carboxylic acids, methods of preparation (oxidation of alcohols and aldehydes, acid hydrolysis of nitriles), chemical reactions (reduction using $LiAlH_4$, Hell Volhard Zelinsky reaction), Preparation and reactions of succinic acid, citric acid, tartaric acid, maleic acid and fumaric acid. Preparation and reactions of esters, acid chlorides, acid anhydrides, and amides, comparison of the chemical reactivity of these derivatives.

(18 marks, 15 hours)

Unit III: Nitrogen-containing Compounds

(a) Nitro Compounds (Aliphatic and Aromatic): Preparation, properties (aliphatic) α–hydrogen

acidity, reaction with HNO_2, carbonyl compounds in the presence of NaOH, Nef reaction and halogenations of nitro-aromatics.
(b) Amines (Aliphatic and Aromatic): Preparation of amines (reduction of nitro compounds and Gabriel phthalimide synthesis), basicity and effect of substituents on basicity, reaction with acetyl chloride, benzoyl chloride, nitrous acid, CS_2, $CHCl_3$/KOH (carbylamine reaction), carbonyl groups and ring substitution. Distinction between primary, secondary, and tertiary amines (Hinsberg and Hoffmann).
(c) Diazo Compounds: Preparation and stability of diazo compounds (aliphatic and aromatic). Reactions of benzene diazonium chloride (Sandmeyer, diazo coupling, and arylation). Preparation and reactions of diazomethane.
(d) Urea: Preparation of urea, reactions of urea with HNO_3, H_2O, HNO_2, NaOBr, CH_3COCl, C_2H_5OH, NH_2NH_2 and diethyl malonate, formation of biuret.

(19 marks, 15 hours)

Unit IV: Specialized Organic Compounds

(a) Organometallic Compounds: Grignard reagent and its application in the synthesis of alkanes, alcohols, acids, aldehydes, ketones, and amines with mechanism. Organolithium compounds: preparation and reactions with H_2O, CO_2 & epoxide.
(b) Active Methylene Compounds: Active methylene group, keto-enol tautomerism. Preparation of ethyl acetoacetate and diethyl malonate, application of ethyl acetoacetate and diethyl malonate in the synthesis of butanoic acid, succinic acid, cinnamic acid, crotonic acid, ethyl methyl ketone and barbituric acid;
(c) Interconversions: Interconversion involving the following functional groups (mechanism not required): -OH. –CHO, -CO, -COOH, -COOR, $-CONH_2$, $-NH_2$, NHR, $-NO_2$, -CN, SO_3H, X (Cl, Br, I), (aliphatic to aliphatic and aromatic to aromatic).

(19 marks, 15 hours)

Notes: A candidate must obtain minimum pass marks (as per NEHU rule) to clear the course.

Suggested Readings

1. Modern Organic Chemistry, M.K. Jain and S.P. Sharma, Vishal Publishing Co., Jalandhar (2020)
2. Advanced Organic Chemistry, B.S. Bahl and A. Bahl, 6th Ed., S. Chand & Co., New Delhi (2022)
3. Organic Chemistry, R.T. Morrison and R.N. Boyd, 6th Ed., Prentice-Hall of India, New Delhi (2002)

Course Code: CHE-252
Course Title: PHYSICAL CHEMISTRY-I
Contact Hours: 60

Course Objectives

This course aims to impart a deep understanding in physical chemistry, covering the Gaseous State, Thermodynamics, and Electrochemistry. Students will explore Maxwell's distribution law, thermodynamic principles including entropy and Gibbs function, and electrochemical concepts such as cell reactions and electrode potentials.

Learning Outcomes

Upon completion, students will demonstrate a strong grasp of molecular speed distributions, thermodynamic laws, and electrochemical principles, enhancing their overall understanding and application of physical chemistry concepts.

Unit I: Gaseous State-II

Maxwell's distribution law of molecular speeds, molecular speeds and energy distribution as a function of temperature, calculation of the most probable, average and root mean square speeds of molecules, degrees of freedom of motion, principle of equipartition of energy, collision diameter, collision cross-section, collision frequency and mean free path, viscosity of gases, Boyle temperature, critical phenomena-critical constants, P-V isotherm of carbon dioxide, continuity of state, law of corresponding states and reduced equation of state. (19 marks, 15 hours)

Unit II: Thermodynamics-II

Limitations of the first law, statements of second law, spontaneous processes. Carnot cycle and its efficiency, Carnot's theorem, Entropy (S) as a state function, entropy changes of ideal gases in different processes. Gibbs function (G) and Helmholtz function (A), criteria for thermodynamic equilibrium and spontaneity, variation of G and A with pressure, volume and temperature, Gibbs-Helmholtz equation, Clausius-Clapeyron equation, Trouton's rule. (19 marks, 15 hours)

Unit III: Electrochemistry-I

Conduction in metals and in electrolyte solutions, specific conductance, equivalent and molar conductance and their determination, variation of equivalent and specific conductance with concentration of strong and weak electrolytes, determination of cell constant. Migration of ions, Hittorf's theoretical device, transport number and its determination; Kohlrausch law and its application; Conductometric titrations (acids – bases); Ostwald Dilution law, Debye-Huckel theory; activity and ionic activity coefficient, ionic strength; Debye- Huckel theory (qualitative) and the limiting law. (18 marks, 15 hours)

Unit IV: Electrochemistry-II

Electrochemical cells; Half cells: types and examples; types of reversible electrodes; Electrode reactions; Nernst equation and standard electrode potentials; reference electrodes (Hydrogen and calomel electrodes); sign conventions; determination of (i) free energy, enthalpy and entropy of a cell reaction, (ii) equilibrium constants; Electrochemical series; Concentration cells (with and without transport), liquid junction potentials. polarization and over potential. Applications of Hydrogen electrode, quinhydrone and glass electrodes in the determination of pH; potentiometric titrations (acid-base, redox). (19 marks, 15 hours)

Notes: A candidate must obtain minimum pass marks (as per NEHU rule) to clear the course.

Suggested Readings

1. Principles of Physical Chemistry, B.R. Puri, L.R. Sharma and M.S. Pathania, Vishal Publication Co., Jalandhar (2020)
2. Atkin's Physical Chemistry, P.W. Atkins and J. De-Paula, 8th Ed., Oxford University Press, London (2006)
3. Physical Chemistry: a molecular approach, D.A. McQuarrie and J.D. Simon, Viva Books Pvt. Ltd., New Delhi (2010)

Course Code: CHE-253
Course Title: INORGANIC CHEMISTRY LABORATORY
Contact Hours: 120

Course Objectives
Learning quantitative estimation of elements in inorganic salts and synthesis of coordination compounds.

Learning Outcomes
On completion of the course the students will learn principles of analysis of compounds and practical methods of analysis through various titrimetric techniques and gravimetric methods. In this practical they will learn synthesis of inorganic complexes.

Laboratory Course (Inorganic)

1. Volumetric Analysis
(a) Redox titrations involving potassium permanganate, oxalic acid and potassium dichromate for estimation of iron and calcium, iodometric estimation of Cu^{2+}.
(b) Estimation of the following constituents from the mixtures: Iron-Calcium; Copper-Iron; Calcium-Barium; Copper-Zinc.

2. Complexometric Titration
Titration using EDTA: Ca^{2+}, Mg^{2+} and Zn^{2+}

3. Gravimetric methods
Estimation of Zn^{2+}, Ba^{2+} Mg^{2+} and Pb^{2+}

4. Preparation of the following inorganic complexes
Tris(thiourea) copper(I) sulphate; Hexammine cobalt(III) chloride; Potassium trioxalato chromate and Potassium chlorochromate.

Marks Distribution	***In-semester***	***End-semester***	***Exam duration***
1. Estimation of mixture	15	40	
2. Preparation of coordination compound	5	15	18 hours
3. Viva voce	3	15	
3. Laboratory records	2	5	

Notes: A candidate must obtain minimum pass marks (as per NEHU rule) to clear the course.

Suggested Readings

1. Vogel's Textbook of Qualitative Inorganic Analysis, J. Bassett, R.C. Denney, G.H. Jeffery and J. Mendham, 4th Ed., ELBS, Longman Group Ltd., (1985)
2. A Manual of Practical Chemistry, R. C. Bhattacharjee, 10th Ed., Book Sellers and Publishers, Calcutta (1980)
3. Comprehensive Experimental Chemistry, 1st Ed., New Age International(P) Ltd., (reprint,2009)

SEMESTER 5

Instructions for Semester 5
For a 100 mark paper (4 credits), 25 marks will be assigned for sessional and 75 marks for end semester examination. The end semester practical examination with 25 marks will be of four hours duration. The internal assessment will be based on sessional examination and/or assignments.

Course Code: CHE-300
Course Title: CHEMISTRY-IV
Contact Hours: 60

Course Objectives
This course aims to provide students with a deep understanding of molecular symmetry analysis and its application in simplifying complex problems related to molecular structure. Students will also learn metallurgical techniques for extracting metals, focusing on iron, copper, and aluminum, along with an exploration of non-aqueous solvents and inorganic polymers, including synthesis, characterization, and properties.

Learning Outcomes
By the end of this course, students will be proficient in detecting molecular symmetry using various symmetric operations, enhancing their understanding of molecular structure and properties. They will gain knowledge of metallurgical techniques, specifically in the extraction of metals like iron, copper, and aluminum, leading to a deeper insight into metals and their applications. Additionally, students will appreciate the importance of non-aqueous solvents and inorganic polymers in daily life, understanding their applications and usefulness in various contexts.

PART-A (Inorganic) Marks: 13 (In-Sem.): 37 (End Sem.) (30 hours)

Unit I: Symmetry of molecules

Molecular Symmetry: Definition of symmetry elements, inversion centre, proper axis and proper rotations, improper axis and improper rotations, symmetry planes and its classification Definition of symmetry operations, Successive symmetry operations of σ, *i*, C_n, S_n. Molecular point group and systematic classification of molecules into point groups with examples *viz*. H_2, O_2, CO, CO_2, HCN, H_2O, H_2O_2, BF_3, NH_3, $XeOF_4$, XeF_4, PF_5, SbF_5, B_2H_6, $B(OH)_3$, C_2H_2, ferrocene (eclipsed and staggered form), $PtCl_4^{2-}$, *cis*-$[PtCl_2(NH_3)_2]$, *trans*-$[PtCl_2(NH_3)_2]$, cis-N_2F_2, trans-N_2F_2, cyclohexane, benzene, borazole, $[Fe(py)_6]^{2+}$, MnO_4^-, C_6H_6, $C_5H_5^-$, $H_2C{=}C{=}CH_2$, SOF_2, SOClF, SOF_4, SF_6, geometrical isomers of: $[MA_2B_4]$, $[MA_3B_3]$, $[MA_2B_2C_2]$ (where A, B and C are unidentate ligands). Molecular symmetry for compounds having co-ordination numbers 2 to 9.

(19 marks, 15 hours)

Unit II: Metallurgy and Polymers

(a) Metals and Metallurgy: Minerals and ores, Types of ores, Metallurgy: pulverization of ore, concentration of ores : electromagnetic separation, hydraulic washing, leaching, froth-floatation, calcination and roasting of ores, Various methods of reductions : Gold Schmidt's aluminothermic process, thermite welding process, reduction by coke or coal, electrolytic reductions, smelting, flux and slag, Refining and purifications methods : liquation, process, zone refining process, fractional distillation process, Parke's process, electrolytic process, amalgamation process, Extraction of copper from copper pyrites , Iron from hematite and Aluminum from bauxite.

(12 marks, 10 hours)

(b) Inorganic Polymers: General characteristics of inorganic polymers and comparison with organic polymers, Synthesis, structural aspects and applications of the following inorganic polymers: silicones, polyphosphazenes, tetrasulphurtetranitride.

(6 marks, 5 hours)

PART-B (Physical) Marks: 12 (In-Sem.): 38 (End Sem.) (30 hours)

Unit III: Molecular Spectroscopy and Liquid Properties

(a) Molecular Spectroscopy-I: Introduction: electromagnetic radiation and interaction with molecules (Absorption and emission), regions of the spectrum, Born-Oppenheimer approximation (statement only), degrees of freedom. Rotational (rigid rotor) and Vibrational (S.H.O.) spectra of diatomic molecules: frequency expressions, selection rules and applications to estimate molecular properties; isotope effect in vibrational spectrum. Anharmonicity and Morse Potential.

(12 marks, 10 hours)

(b) Liquid State-II: Determination of surface tension, viscosity and refractive index of liquids. Physical properties and chemical constitution- additive and constitutive properties, molar volume, parachor, specific and molar refraction. Polar and non-polar liquids, dielectric constant, dipole moment, structure of molecules, polarization, Clausius-Mossotti equation.

(7 marks, 5 hours)

Unit IV: Photochemical Reactions

(a) Photochemistry: Difference between thermal and photochemical reactions, Grotthus-Draper law, Beer-Lambert's law, Stark-Einstein law of photochemical equivalence and quantum yield, Jablonski diagram; Fluorescence and phosphorescence. photochemical reactions – decomposition of ammonia, hydrogen iodide and acetaldehyde, photochemical equilibrium – photodimerization of anthracene, photosensitized reactions, actinometry, chemiluminescence.

(7 marks, 6 hours)

(b) Chemical Kinetics-II: Complex reactions – opposite, parallel, consecutive and chain reactions (formation of HBr, decomposition of acetaldehyde), Theory of Reaction rates – collision theory, transition state theory. Catalyzed reactions – rate determining step, steady state approximation, enzyme catalysis - Michaelis-Menten mechanism (including LB plot, MM constant).

(12 marks, 9 hours)

Notes: A candidate must obtain minimum pass marks (as per NEHU rule) to clear the course.

Suggested Readings

1. Symmetry and Spectroscopy of Molecules, K Veera Reddy, New Age International(P) Ltd., (2002)
2. Chemical Applications of Group Theory, F.A. Cotton 2nd Ed., Wiley Eastern Ltd., (1992).
3. Advanced Inorganic Chemistry, Satya Prakash, G.D. Tuli, S.K. Basu, R.D. Madan, Vol-I, 19th Ed., S. Chand & Co. (2005)
4. Physical Chemistry, P.C. Rakshit (revised by S.C. Rakshit), 7th Ed., Sarat Book Distributors, Kolkata (2014)
5. Physical Chemistry: a molecular approach, D.A. McQuarrie and J.D. Simon, Viva Books Pvt. Ltd., New Delhi (2010)

Course code: CHE-301
Course Title: ORGANIC CHEMISTRY-II
Contact Hours: 60

Course Objectives
Introduction to carbohydrates, proteins, vitamins, polynuclear hydrocarbons, and polymers. The stereochemistry of cyclic compounds and polymer chemistry will also be covered.

Learning Outcomes
Upon successful completion of the course, students will have a clear understanding of the properties, reactivity, application, and stereochemical aspects of carbohydrates, proteins, vitamins, cyclic compounds, and polynuclear hydrocarbons. Students will also learn about the synthesis, applications, and properties of polymers.

Unit I: Carbohydrates and Polysaccharides

Carbohydrates: Classification, D/L nomenclature, reducing/non-reducing sugars, aldoses and ketoses, monosaccharides - Glucose and fructose, Fischer Projection formula, Reaction of glucose and fructose with Br_2-water, HCN, Tollen's reagent, Fehling's solution, hydroxylamine, phenylhydrazine, HNO_3 and osazone formation. Determination of ring size by HIO_4 method. Haworth projection formula, conformational structures of glucose and fructose. Epimerization, inter-conversion of glucose and fructose. Ascending (Kiliani) and descending series (Wohl).
Disaccharides: Sucrose and maltose; elucidation of structure, hydrolysis.
Polysaccharides: structure of cellulose, starch (details not required), preparation of cellulose nitrate, cellulose acetate, cellophane and rayon.

(18 marks, 15 hours)

Unit II: Amino acids, Peptides, Proteins and Vitamins

(a) Amino Acids, Peptides and Proteins: Amino acids - Classification, D/L nomenclature, physical properties, isoelectric points and zwitterionic structure, synthesis of α-haloacids and Gabriel syntheses of glycine, alanine, phenyl alanine; glutamic and aspartic acids.
Peptides - Definition and preparation of di- and tripeptides from α-amino acids.
Proteins - Introduction, classification, structure of proteins - primary, secondary (α- and β-proteins, helical and sheet structures), tertiary and quaternary; denaturation of proteins.
(b) Vitamins: Definition and biological importance of vitamins. Carotenoids – occurrence, isolation and synthesis of β-carotene, synthesis of vitamin A_1 and ascorbic acid.

(19 marks, 15 hours)

Unit III: Organic synthesis and Rearrangements

(a) Organic Synthesis: Formation of carbon-carbon bond, electrophilic and nucleophilic carbon species, acid-assisted reaction (Friedel Crafts alkylation and acylation, Gattermann-Koch formylation), base assisted condensations (Knoevenagel, Michael, Wittig reaction, Claisen reaction, Claisen-Schmidt reaction, Mannich reaction, Dieckmann), Reformatsky reaction.
(b) Rearrangements: Carbocation rearrangements – pinacole-pinacolone, Wagner-Meerwein, dienone-phenol. Beckmann, Wolff, Hofmann, Curtius, Lossen, Schmidt, benzil-benzilic acid, benzidine-semidene, Favorskii, Fries and Claisen rearrangements.
(c) Inorganic Reagents in Organic Synthesis: $NaBH_4$, $LiAlH_4$, B_2H_6, Na/liq.NH_3, aluminium isopropoxide (MPV reduction and Oppenauer oxidation), $KMnO_4$, $K_2Cr_2O_7$, HIO_4, Lead tetraacetate, peracids.

(19 marks, 15 hours)

Unit IV: Aromatic hydrocarbons, Stereochemistry and Polymers

(a) Polynuclear Aromatic Hydrocarbons: Introduction; molecular orbital structure of naphthalene; resonance; Preparations, reactions, mechanism and orientation of electrophilic substitution. Preparations and reactions of α- and β-naphthols (azo-coupling, reactions with HNO_2 and $FeCl_3$. Preparation and reactions of anthracene.
(b) Organic Stereochemistry-II: Relative and absolute configuration, nomenclature of enantiomers (R and S); inversion, retention, conformation and conformational isomerism in ethane and *n*-butane; conformation of cyclic compounds – cyclohexane, mono-substituted and disubstituted cyclohexanes (1,2-, 1,3-, 1,4-) with reference to their relative stability; stereochemical aspects of addition of bromine to alkenes.
(c) Polymers: Types of polymers and polymerization processes. Addition (chain-growth) polymerization; free radical vinyl polymerization; ionic vinyl polymerization, Ziegler–Natta polymerization. Condensation (step-growth) polymerization, polyesters (Dacron), polyamides (Nylon-6, Nylon-6,6), urea-formaldehyde resins (Bakelite), polyurethanes. Natural and synthetic rubbers (Neoprene, Buna-S, Butyl rubber), vulcanization process.

(19 marks, 15 hours)

Notes: A candidate must obtain minimum pass marks (as per NEHU rule) to clear the course.

Suggested Readings

1. Modern Organic Chemistry, M.K. Jain and S.C. Sharma, Vishal Publishing Co., Jalandhar (2009)
2. Reaction mechanism and Reagents in Organic Chemistry, G.R. Chatwal, Himalaya Publishing House, New Delhi (2015)
3. Reactions Rearrangements and Reagents, S.N. Sanyal, 4th Ed., Bharati Bhawan Publishers (2019)

Course Code: CHE-302
Course Title: CHEMISTRY-V
Contact Hours: 75

Course Objectives

This course aims to cover a wide range of chemistry topics, including industrial and environmental chemistry, pharmaceuticals, and phase equilibria. Students will explore industrial processes, environmental pollutants, drug classifications, properties of fats and oils and phase diagrams of common systems. In the practical component, they will conduct experiments to reinforce theoretical concepts.

Learning Outcomes

Upon completion, students will possess a comprehensive understanding of inorganic, organic, and physical chemistry concepts. They will be able to analyze industrial processes, identify environmental pollutants, synthesize pharmaceuticals, interpret phase diagrams, and conduct laboratory experiments effectively, enhancing their practical skills in chemistry.

PART-A (Theory)

Unit I: Inorganic Chemistry-III Marks: 6 (In-Sem.): 19 (End Sem.) (15 hours)

(a) Industrial Chemistry: (i) Fertilizers: Nitrogenous fertilizer-manufacture of ammonia and urea, Phosphatic fertilizers- calcium superphosphate, phosphatic slag and nitrophosphate, Mixed fertilizer: NPK fertilizers; (ii) Cement: constituents, manufacture and setting process, role of Gypsum; (iii) Paints and pigments: different parts of paints, classification of pigments.

(8marks, 7 hours)

(b) Environmental Chemistry: (i) Chemistry of air environment: Classification of air pollutants, Air pollutants and their effects, Particle size and chemical nature of air pollutants, Oxides of carbon, sulphur, nitrogen and hydrocarbon- their health hazards and environmental effects, Photochemical smog and its constituents, Environmental effects of ozone and fluorocarbons, greenhouse effect, Acid rains; (ii) Chemistry of water environment: Classification of water pollutants, Characterization of waste waters, Problems caused by pollutants like soaps, detergents, phosphates and waste chemicals related to mercury and lead compounds; (iii) Chemistry of soil environment: Sources of soil pollution, Effect of pesticides, synthetic fertilizers, industrial effluents and urban waste on environment.

(11 marks, 8 hours)

Unit II: Organic Chemistry-III Marks: 6 (In-Sem.): 19 (End Sem.) (15 hours)

(a) Drugs: Antipyretic, analgesic, antibacterial, antiviral, antibiotic, sulpha drugs and tranquilizer with examples. Synthesis and use of aspirin, paracetamol, sulphaguanidine, barbituric acid.

(6 marks, 5 hours)

(b) Fats, Oils, Soaps and Detergents: Animal and vegetable oils, drying and non-drying oils, hydrogenation, iodine value, RM value and saponification value, soaps and detergents, mechanism of cleansing action of soap and detergents.

(6 marks, 5 hours)

(c) Dyes: Relationship between colour and constitution, chromophore and auxochrome, classification of dyes (based on structure and application), syntheses of methyl orange, Bismarck brown, Malachite green and phenolphthalein.

(7 marks, 5 hours)

Unit III: Physical Chemistry-III **Marks: 7 (In-Sem.): 18 (End Sem.)** **(15 hours)**

(a) Phase Equilibria-I: Phase rule and meaning of the terms phase, components and degrees of freedom, equilibrium between phases, phase diagram for one component systems (water and sulphur systems), Typical phase diagrams of two component systems involving eutectic (KI-H_2O), congruent (phenol-aniline) and incongruent (NaCl-H_2O) melting points.

(8 marks, 6 hours)

(b) Phase Equilibria-II: Liquid-liquid mixtures, fractional distillation of binary miscible liquids, azeotropes (ethanol-water system), partial miscibility of liquids, lower and upper critical solution temperatures (triethylamine-water, phenol-water and nicotine-water systems), steam distillation, Nernst distribution law-derivation and its application. Three component system: Phase diagram of CO_2 system.

(10 marks, 9 hours)

PART-B (Practical)

Unit V: Laboratory work (Physical) **Marks: 6 (In-Sem.): 19 (End Sem.)** **(30 hours)**

Experiments

(1) Determination of the heat of neutralization of a strong acid by a strong base.
(2) Determination of molecular weight by Rast's method
(3) Study of the heat of dilution of H_2SO_4 and then to determine the strength of an unknown acid.
(4) Determination of the velocity constant of the decomposition of hydrogen peroxide in presence of ferric chloride as catalyst by titrating against $KMnO_4$.
(5) Determination of the solubility of $BaCl_2$/NaCl at two different temperatures and to determine the heat of solution.
(6) Determination of the velocity constant of the hydrolysis of methyl acetate catalyzed by an acid.

Marks Distribution	***In-semester***	***End-semester***	***Exam duration***
1. Experiment	2	12	6 hours
2. Viva voce	2	5	
3. Laboratory records	2	2	

Suggested Readings

1. A Text Book of Environmental Chemistry and Pollution Control, S.S. Dara & D.D. Mishra, 1st Ed., S. Chand & Co. Ltd. (2012)
2. Industrial Chemistry: Part-II, R.K. Das, 1st Ed., Kalyani Publishers (1994)
3. Reaction mechanism and Reagents in Organic Chemistry, G.R. Chatwal, Himalaya Publishing House, New Delhi (2015)
4. Reactions Rearrangements and Reagents, S.N. Sanyal, 4th Ed., Bharati Bhawan Publishers (2019)
5. Principles of Physical Chemistry, B.R. Puri, L.R. Sharma and M.S. Pathania, Vishal Publication Co., Jalandhar (2020)
6. Senior Practical Physical Chemistry, B.D. Khosla, V.C. Garg, A. Gulati, S. Chand & Co. (2015)

Course Code: CHE-302 (Minor)
Course Title: GENERAL CHEMISTRY-III
Contact Hours: 75

Course Objectives
This course aims to cover a wide range of chemistry topics, including industrial and environmental chemistry, pharmaceuticals, phase equilibria, and physical chemistry principles. Students will explore industrial processes, environmental pollutants, drug classifications, properties of fats and oils, phase diagrams, and macromolecules. In the practical component, they will conduct experiments to reinforce theoretical concepts.

Learning Outcomes
Upon completion, students will possess a comprehensive understanding of inorganic, organic, and physical chemistry concepts. They will be able to analyze industrial processes, identify environmental pollutants, synthesize pharmaceuticals, interpret phase diagrams, and conduct laboratory experiments effectively, enhancing their practical skills in chemistry.

PART-A (Theory)

Unit I: Inorganic Chemistry-III Marks: 6 (In-Sem.): 19 (End Sem.) (15 hours)

(a) Industrial Chemistry: (i) Fertilizers: Nitrogenous fertilizer-manufacture of ammonia and urea, Phosphatic fertilizers- calcium superphosphate, phosphatic slag and nitrophosphate, Mixed fertilizer: NPK fertilizers; (ii) Cement: constituents, manufacture and setting process, role of Gypsum; (iii) Paints and pigments: different parts of paints, classification of pigments.

(8marks, 7 hours)

(b) Environmental Chemistry: (i) Chemistry of air environment: Classification of air pollutants, Air pollutants and their effects, Particle size and chemical nature of air pollutants, Oxides of carbon, sulphur, nitrogen and hydrocarbon- their health hazards and environmental effects, Photochemical smog and its constituents, Environmental effects of ozone and fluorocarbons, greenhouse effect, Acid rains.

(ii) Chemistry of water environment: Classification of water pollutants, Characterization of waste waters, Problems caused by pollutants like soaps, detergents, phosphates and waste chemicals related to mercury and lead compounds.

(iii) Chemistry of soil environment: Sources of soil pollution, Effect of pesticides, synthetic fertilizers, industrial effluents and urban waste on environment.

(11 marks, 8 hours)

Unit II: Organic Chemistry-III Marks: 6 (In-Sem.): 19 (End Sem.) (15 hours)

(a) Drugs: Antipyretic, analgesic, antibacterial, antiviral, antibiotic, sulpha drugs and tranquilizer with examples. Synthesis and use of aspirin, paracetamol, sulphaguanidine, barbituric acid.

(6 marks, 5 hours)

(b) Fats, Oils, Soaps and Detergents: Animal and vegetable oils, drying and non-drying oils, hydrogenation, iodine value, RM value and saponification value, soaps and detergents, mechanism of cleansing action of soap and detergents.

(6 marks, 5 hours)

(c) Dyes: Relationship between colour and constitution, chromophore and auxochrome, classification of dyes (based on structure and application), syntheses of methyl orange, Bismarck brown, Malachite green and phenolphthalein.

(7 marks, 5 hours)

Unit III: Physical Chemistry-III **Marks: 7 (In-Sem.): 18 (End Sem.)** **(15 hours)**

(a) Phase Equilibria-I: Phase rule and meaning of the terms phase, components and degrees of freedom, equilibrium between phases, phase diagram for one component systems (water and sulphur systems), Typical phase diagrams of two component systems involving eutectic (KI-H_2O), congruent (phenol-aniline) and incongruent (NaCl-H_2O) melting points.

(8 marks, 6 hours)

(b) Phase Equilibria-II: Liquid-liquid mixtures, fractional distillation of binary miscible liquids, azeotropes (ethanol-water system), partial miscibility of liquids, lower and upper critical solution temperatures (triethylamine-water, phenol-water and nicotine-water systems), steam distillation, Nernst distribution law-derivation and its application. Three component system: Phase diagram of CO_2 system.

(10 marks, 9 hours)

PART-B (Practical)

Unit V: Laboratory work (Physical) **Marks: 6 (In-Sem.): 19 (End Sem.)** **(30 hours)**

Experiments

(1) Determination of the heat of neutralization of a strong acid by a strong base.
(2) Determination of molecular weight by Rast's method
(3) Study of the heat of dilution of H_2SO_4 and then to determine the strength of an unknown acid.
(4) Determination of the velocity constant of the decomposition of hydrogen peroxide in presence of ferric chloride as catalyst by titrating against $KMnO_4$.
(5) Determination of the solubility of $BaCl_2$/NaCl at two different temperatures and to determine the heat of solution.
(6) Determination of the velocity constant of the hydrolysis of methyl acetate catalyzed by an acid.

Marks Distribution	***In-semester***	***End-semester***	***Exam duration***
1. Experiment	2	12	6 hours
2. Viva voce	2	5	
3. Laboratory records	2	2	

Suggested Readings

1. A Text Book of Environmental Chemistry and Pollution Control, S.S. Dara & D.D. Mishra, 1st Ed., S. Chand & Co. Ltd. (2012)
2. Industrial Chemistry: Part-II, R.K. Das, 1st Ed., Kalyani Publishers (1994)
3. Reaction mechanism and Reagents in Organic Chemistry, G.R. Chatwal, Himalaya Publishing House, New Delhi (2015)
4. Reactions Rearrangements and Reagents, S.N. Sanyal, 4th Ed., Bharati Bhawan Publishers (2019)
5. Principles of Physical Chemistry, B.R. Puri, L.R. Sharma and M.S. Pathania, Vishal Publication Co., Jalandhar (2020)
6. Senior Practical Physical Chemistry, B.D. Khosla, V.C. Garg, A. Gulati, S. Chand & Co. (2015)

SEMESTER 6

Instructions for Semester 6
For a 100 mark paper (4 credits), 25 marks will be assigned for sessional and 75 marks for end semester examination. The end semester practical examination with 100 marks will be of six hours duration. The internal assessment will be based on sessional examination and/or assignments.

Course Code: CHE-350
Course Title: INORGANIC CHEMISTRY-II
Contact Hours: 60

Course Objectives
The main objective of this semester course are to make the students familiarize with the higher-level chemistry such as coordination, organometallic, bioinorganic chemistry. Students will also learn about the reactivity of coordination compounds with emphasis on mechanism and their rate laws.

Learning Outcomes
The learners will have the knowledge to learn more about the coordination compounds and their reactivity with special emphasis on metals containing organic group. Special topic of bioinorganic have been included to create greater interest among the students.

Unit I: Coordination Chemistry-II

Valence bond theory and its limitations, Basic principle of crystal field theory, d-Orbital splitting in electrostatic field(octahedral, tetrahedral and square planar), Crystal field stabilizing energy(10 Dq values), Factors affecting the magnitude of crystal field splitting energy, Spectrochemical series, Structural and thermodynamic effects of d-orbital splitting- variation of ionic radii, hydration and lattice energies of the first row transition metal ions, Jahn - Teller effect , Adjusted CFT and molecular orbital theory for octahedral complexes.

(19 marks, 15 hours)

Unit II: Organometallic Chemistry-II

General method of preparation of organometallic compounds, Reaction mechanism of organometallic reactions: oxidative addition and reductive elimination, nucleophilic and electrophilic addition, insertion and abstraction, Umplong effect, Synthesis, nature of bonds, structure, properties and application of organometallic compounds of iron (ferrocene) and tin (R_3SnX, R_2SnX_2 types), π-acid ligands, Mononuclear and dinuclear carbonyls and nitrosyls and the nature of bonding in them - their uses in metallurgy, Effective atomic number rule in metal carbonyls and metal nitosyls compounds, Important applications of organometallic compounds in heterogeneous catalysis – alkene polymerization, hydrogenation of alkenes using Wilkinson's catalyst and synthesis of acetic acid using rhodium carbonyl iodide catalyst.

(19 marks, 15 hours)

Unit III: Bioinorganic Chemistry-I

Essential and trace elements in biological processes, Criteria of essential elements, Metalloporphyrin, Structure and functions and physiological behavior of haemoglobin and myoglobin, Cooperatively of dioxygen binding, Chlorophyll and its functions, Vitamin B_{12} and role of Co in vitamin B_{12}, Metalloenzymes, Carbonic anhydrase and carboxypeptidase their characteristics and functions, pH of biological fluids, Non-complexing cations in biochemical processes: Na^+-K^+ pump; Toxic effectsof metal ions with reference to mercury, lead, beryllium and aluminium; Deficiency of Fe, Ca, Mg and iodine; Platinum complexes as anticancer drugs.

(19 marks, 15 hours)

Unit IV: Coordination Chemistry-III

Reactivity of Coordination Compounds, Stability of complex ions, Thermodynamic stability and kinetic stability, Lability and inertness of complexes, Factors affecting the stability of a complexes, Chelate effect and macrocyclic effect: thermodynamic point of view. Stepwise and overall formation constants and their relationship. Trends in the stepwise formation constants. Anomalies in the values of stepwise formation constants of: (i) halogeno complexes of Hg(II), (ii) ethylenediamine complexes of Zn(II), (iii) phenanthroline complexes of Fe(II), (iv) ethylenediamine complexes of Cu(II). Mechanism of ligand substitution reactions in octahedral and square planar complexes, Isomerization and racemization of tris-chelate complexes, Stereochemical non-rigidity and fluxional molecules,The trans effect.

(18 marks, 15 hours)

Notes: A candidate must obtain minimum pass marks (as per NEHU rule) to clear the course.

Suggested Readings

1. Advanced Inorganic Chemistry, F.A. Cotton, G. Wilkinson, C.A. Murillo and M. Bochmann, 6th Ed., John Wiley & Sons (Asia) Pt. Ltd. (2009)
2. Bioinorganic Chemistry, K. Hussain Reddy, New Age International Publishers, 1st Ed. (2007)
3. Organometallic Chemistry - A Unified Approach, R.C. Mehrotra & A. Singh, 2nd Ed., New Age International (P) Ltd. (2009)
4. Inorganic Chemistry - Principles of Structure and Reactivity, J.E. Huheey, E.A. Keiter, R.A. Keiter & O.K. Medhi, 4th Ed, Pearson Education. (2009)

Course Code: CHE-351
Course Title: ORGANIC CHEMISTRY-III
Contact Hours: 60

Course Objectives
To give an idea on heterocyclic molecules, biomolecules, natural products, spectroscopy, green chemistry, and the influence of heat and light on organic reactions.

Learning Outcomes
Students will learn about nomenclature, synthesis, properties, and reactivities of various heterocycles, natural products, and biomolecules, selectivity and reactivity of various organic molecules under the influence of heat and light energy. They will have ideas on green chemistry principles, various greener techniques for synthesis, etc. This paper will also provide a clear knowledge of the principle and application of various spectroscopic techniques.

Unit I: Heterocyclic Compounds

Structure and reactivity, Paal-Knorr synthesis of pyrrole, furan and thiophene, Knorr pyrrole synthesis, synthesis of furan from pentose and pyrrole from furan, comparative reactivity in Diels Alder and diazo coupling reaction, electrophilic substitution reactions (nitration, sulphonation, Friedel-Crafts) of pyrrole, furan and thiophene. Structure, synthesis (Hantzsch synthesis) and reactions of pyridine (electrophilic, and nucleophilic substitutions). Condensed five- and six-membered heterocycles, preparation and reactions of indole (with special reference to Fischer-Indole synthesis, Madelung synthesis). Preparation and reactions of quinoline and isoquinoline (with special reference to Knorr, Skraup and Bischler-Napieralski syntheses). Comparative basicity of pyrrole/pyridine, pyrrole/pyrrolidine and pyridine/piperidine.

(18 marks, 15 hours)

Unit II: Natural Products, Bioorganic chemistry and Green Chemistry

(a) Natural Products: (i) Terpenoids: Introduction, isoprene rule, classification, structural elucidation of citral and geraniol; synthesis of citral, geraniol and *a*-Terpeniol. (ii) Alkaloids: Introduction, classification, physiological action and syntheses of nicotine and cocaine.
(b) Topics in Bioorganic Chemistry: (i) Enzymes: Introduction, nomenclature and characteristics. Mechanism of enzyme action (a general picture); mechanism of action of the enzyme chymotripsin as a peptidase.; co-enzyme, co-enzymes derived from niacin and thiamine, lipoic acid, co-enzyme A, energy production in biological system (role of ATP and ATP-ADP cycle), glycolysis and tricarboxylic acid cycle. *(ii) Nucleic acids*: Structure of purine and pyrimidine bases in nucleic acid (adenine, guanine, cytosine, uracil and thiamine) [no synthesis]. Structure of nucleosides, nucleotides, RNA and DNA.
(c) Green Chemistry: Definition, goals, principles and techniques (brief discussions); Solvent free reactions (Reformatsky, Dieckmann condensation), Ultrasound reactions (Heck reaction, Cannizaro reaction), Microwave assisted reactions (Biginelli reaction, Hoffmann elimination), reactions in aqueous media (Diels-Alder, Claisen rearrangement) and ionic liquid (Oxidation of benzyl alcohol using $KMnO_4$ in [bmim][BF_4], Diels-Alder reaction) – their advantages over conventional method (mechanism not required).

(19 marks, 15 hours)

Unit III: Pericyclic Reactions and Photochemistry

(a) Pericyclic Reactions: Definition and types of pericyclic reactions. (i) Electrocyclic **r**eactions; conrotatory and disrotatory ring closures and ring opening (simple examples like 1,4-disubstituted-1,3-buta-diene; 1,6-disubstituted-1,3,5-hexatriene), stereochemistry, Woodward-Hoffmann rules for

electrocyclic reactions, frontier molecular orbital theory (correlation diagram not required). (ii) Cycloaddition reactions; Definition of dienes and dienophiles, *supra-supra* and *antara-antara* modes of cycloadditions ($\pi_s^4 + \pi_s^2$, $\pi_s^4 + \pi_a^2$, $\pi_s^2 + \pi_s^2$, $\pi_s^2 + \pi_a^2$) by taking examples of simple dienes and dienophiles. Woodward-Hoffmann rules for cycloaddition reactions, frontier molecular orbital theory (correlation diagram not required).

(b) Organic Photochemistry: Molecular energy and photochemical energy, excitation of molecules, Franck-Condon principle, dissipation of energy, Jablonski diagram, singlet-triplet states, fluorescence and phosphorescence, photosensitization and quenching, quantum yield. Introduction to photochemical reactions of carbonyl compounds: Norrish Type I and Type II cleavages, photoreduction, Paterno-Buchi reaction, *supra-supra* and *antara-antara* modes of cycloadditions ($\pi_s^4 + \pi_s^2$, $\pi_s^4 + \pi_a^2$, $\pi_s^2 + \pi_s^2$, $\pi_s^2 + \pi_a^2$) by taking examples of simple dienes and dienophiles. Woodward-Hoffmann rules for cycloaddition reactions, frontier molecular orbital theory (correlation diagram not required).

(19 marks, 15 hours)

Unit IV: Spectroscopy in Organic Chemistry

(a) Ultraviolet and Visible Spectroscopy: Basic principles of UV and visible spectroscopy, application to conjugated polyenes, carbonyl compounds and α, β-unsaturated carbonyl compounds, Woodward-Fieser rules.

(b) Infrared Spectroscopy: Basic principles, characteristic vibrational frequencies of simple organic compounds such as alcohols, phenols, carbonyl compounds and acid derivatives, amines, nitriles, alkynes and alkenes.

(c) Nuclear Magnetic Resonance Spectroscopy: Basic principles, chemical shifts, shielding and deshielding of protons, chemically equivalent protons, peak area and proton counting, Characteristics protons - chemical shifts and coupling constants of vicinal (ethyl alcohol, ethyl acetate, acetaldehyde), geminal (styrene), cis- & trans- (cinnamic acid), ortho-, meta-, para- protons (toluene, p- xylene, *o*- and *p*-nitrotoluene, anisole).

(d) Mass Spectrometry: Basic principles, molecular ion peak, base peak and metastable ion, fragmentation pattern, N-Rule, Simple applications in structure elucidation (butane, iso-pentane, ethanol, 2- butanol, ethyl propylamine, acetone, ethyl methyl ketone, ethyl benzene), McLafferty rearrangement (butanal, methyl pentanoate and hexanoic acid).

Application of UV, IR, NMR Spectroscopy and Mass Spectrometry in structure elucidation of simple organic molecules

(19 marks, 15 hours)

Notes: A candidate must obtain minimum pass marks (as per NEHU rule) to clear the course.

Suggested Readings

1. Modern Organic Chemistry, M.K. Jain and S.C. Sharma, Vishal Publishing Co., Jalandhar (2009)
2. Organic Chemistry, S.M. Mukherjee, S.P. Singh and R.P. Kapoor, Vol I/II/III, Wiley Eastern Ltd. (New Age International)
3. Elementary Organic Spectroscopy: Principles and Chemical Applications, Y.R. Sharma, S. Chand & Co. (2013)

Course Code: CHE-352
Course Title: PHYSICAL CHEMISTRY-II
Contact Hours: 60

Course Objectives

This course aims to delve into advanced topics in quantum mechanics and statistical thermodynamics. Students will explore the failures of classical mechanics, wave-particle duality, quantum postulates, and thermodynamic ensembles. They will learn about phenomena like black-body radiation, the photoelectric effect, and the Boltzmann distribution, gaining insights into quantum behavior and thermodynamic principles.

Learning Outcomes

Students will grasp quantum mechanics concepts like wave-particle duality and statistical thermodynamics principles, enabling them to analyze atomic spectra and thermodynamic systems effectively. They will also develop skills in analyzing non-equilibrium processes and applying phenomenological equations to study entropy production and electrokinetic phenomena.

Unit I: Thermodynamics-III

Thermodynamic scale of temperature, Maxwell's relations, definition of chemical potential, concept of chemical potential, equilibrium between different phases, derivation of phase rule from the concept of chemical potential, partial molal quantities, variation of chemical potential with temperature and pressure, chemical potential of a component in an ideal mixture, Gibbs-Duhem equation. Nernst heat theorem, third law of thermodynamics and its application to the determination of entropy, concept of residual entropy.

(18 marks, 15 hours)

Unit II: Quantum Mechanics-I

Failure of classical mechanics: Black-body radiation, Planck's radiation law, photoelectric effect, Compton effect, heat capacity of solids, atomic and molecular spectra; Wave Particle Duality: de Broglie relation & Heisenberg's Uncertainty principle; Postulates of quantum mechanics; Schrodinger wave equation, Wave function and its significance, Normalization and Orthogonality, Eigen value equation.

(20 marks, 16 hours)

Unit III: Statistical Thermodynamics-I

Limitations of classical thermodynamics; concept of ensemble and its different types; concept of distribution; Thermodynamic probability, relationship between entropy and probability; Boltzmann distribution for non-degenerate and degenerate cases (with derivation); Partition function: definition, molecular partition functions, relation between molecular and molar partition functions. Thermodynamic parameters in term of partition function (without derivation).

(20 marks, 16 hours)

Unit IV: Non-equilibrium Thermodynamics

Entropy of irreversible processes – Clausius inequality; entropy production (heat flow, chemical reactions, electrochemical reactions) and entropy flow; Entropy production in open systems; Rate of entropy production – generalized forces and fluxes; Phenomenological equations, Onsager reciprocity relation; Electrokinetic phenomena; Stationary non-equilibrium states -states of minimum entropy production.

(17 marks, 13 hours)

Notes: A candidate must obtain minimum pass marks (as per NEHU rule) to clear the course.

Suggested Readings

1. Principles of Physical Chemistry, B.R. Puri, L.R. Sharma and M.S. Pathania, Vishal Publication Co., Jalandhar (2020)
2. Physical Chemistry, P.C. Rakshit (revised by S.C. Rakshit), 7th Ed., Sarat Book Distributors, Kolkata (2014)
3. Physical Chemistry: a molecular approach, D.A. McQuarrie and J.D. Simon, Viva Books Pvt. Ltd., New Delhi (2010)

Course Code: CHE-353
Course Title: PHYSICAL CHEMISTRY LABORATORY
Contact Hours: 120

Course Objectives
Conduct experiments to reinforce physical chemistry principles, including titrations, colorimetry, conductometry, kinetics, thermodynamics, and adsorption studies.

Learning Outcomes
Students will gain practical proficiency in experimental techniques, data analysis, and interpretation, enhancing their understanding of physical chemistry concepts.

Laboratory Course (Physical)

Part A (Instrumental Experiments) Marks: 12 (In-Sem.): 38 (End Sem.) (60 hours)

Experiments
(a) Conductometric titrations of an acid by a base (strong acid vs. strong base; weak acid vs strong base).
(b) Acid-base titration using potentiometer (strong acid vs. strong base; weak acid vs strong base).
(c) Verification of Beer-Lambert's law using $CuSO_4$ or $K_2Cr_2O_7$ solution colorimetrically and determination of the concentration of the supplied solution.
(d) Determination of pK_a value of different sets of buffers by pH-metric titration using glass electrode.
(e) Determination of cell constant and hence the specific conductance of an electrolyte by conductometry.
(f) pH-metric titration of (i) strong acid with strong base, (ii) weak acid with strong base and determination of dissociation constant of a weak acid.
(g) Estimation of ferrous ammonium sulphate using standard potassium dichromate solution potentiometrically.

Part B (Non-instrumental Experiments) Marks: 13 (In-Sem.): 37 (End Sem.) (60 hours)

Experiments
(a) Determination of velocity constant for the decomposition of hydrogen peroxide using ferric chloride as catalyst; and to determine the activation energy.
(b) Determination of the heat of solution of solid calcium chloride and to determine lattice with the help of Born-Haber cycle.
(c) Determination of the critical solution temperature of the phenol-water system.
(d) Study on the kinetics of the reaction between potassium persulfate and potassium iodide at two temperatures with determination of activation energy.
(e) Study of the adsorption of oxalic acid on charcoal and verification of Freundlich's adsorption isotherm.
(f) Determination of surface tension of a liquid/solution by drop-weight method.
(g) To obtain the viscosity–composition (v/v) curve of ethanol-water/ glycerol- water/ methanol water system and to determine the composition (v/v) of a given unknown mixture.
(h) Determination of partition coefficient of a solute between two immiscible solvents (e.g., iodine in water/organic solvent; benzoic acid in water/benzene).
(i) To study the kinetics of iodine clock reaction.

Type	*Marks Distribution*	*In-semester*	*End-semester*	*Exam duration*
Instrumental experiment	1. Experiment 2. Viva voce 3. Laboratory records	7 3 2	25 8 5	6 hours
Non-instrumental experiment	1. Experiment 2. Viva voce 3. Laboratory records	8 3 2	24 8 5	6 hours

Notes: A candidate must obtain minimum pass marks (as per NEHU rule) to clear the course.

Suggested Readings

1. Senior Practical Physical Chemistry, B.D. Khosla, V.C. Garg, A. Gulati, S. Chand & Co. (2015)
2. Experiments in Physical Chemistry, W.C. Garland, J.W. Nibler, D.P. Shoemaker, 8th Ed., McGraw Hill, New York (2008)

REFERENCE BOOKS

A. Inorganic Chemistry

1. General and Inorganic Chemistry, Vol. I and II, Dr P. K. Dutt and Prof. P. K. Dutt, 10th Ed, Sarat Book House, (1990).
2. Advanced Inorganic Chemistry, Vol. II, Satya Prakash, G. D. Tuli, S. K. Basu and R. D. Madan, S. Chand and Company Ltd., revised (2005).
3. Inorganic Chemistry, R. L. Dutta (Vol-II), 2rd Ed, The New Book Stall, (1987).
4. Inorganic Chemistry, 3rd Ed., Cengage Learning, Indian reprint (2016).
5. Principles of Inorganic Chemistry, B. R. Puri, L. R. Sharma & K. C. Kalia, Vishal Publishing Co., (2019-2020).
6. Basic Concepts of Analytical Chemistry, S. M. Khopkar, 2nd Ed., New Age International (P) Ltd., (1998).
7. University Practical Chemistry, P. C. Khamboj, Vishal Publishing Co., (2009-2010).
8. Quantitative Analysis, R. A. Day & A.L. Underwood, 5th Ed., Prentice Hall of India Private Ltd., (1988).
9. Analytical Chemistry, Gary D. Christian, 6th Ed., John Wiley & Sons (Asia), Pvt. Ltd., reprint (2011)
10. Symmetry and Spectroscopy of Molecules, K. Verra Reddy, New Age International(P) Ltd., (2002).
11. Chemical Applications of Group Theory, F. A. Cotton, 2nd Edn., Wiley Eastern Ltd., (1992)
12. A Text Book of Inorganic Polymers, A. K. Bhagi, G. R. Chatwal, 1st Edn., Himalaya Publishing House, (2001).
13. Industrial Chemistry, Part-I, R. K. Das, Kalyani Publishers, 1st Edn., 1994
14. Principles of Nanotechnology, N. Phani Kumar, Scitech Publications (India)Pvt. Ltd.
15. Organometallic Chemistry- A Unified Approach, R. C. Mehrotra & A. Singh, New Age International(P) Ltd., 2nd Edn., 2009.
16. Bioinorganic Chemistry, K. Hussian Reddy, New Age International Publishers, 1st Edn., 2007.
17. Introduction to Ligand Fields., B. N. Figgis, Interscience Publishers, 1966
18. A Text book of Environmental Chemistry and Pollution Control, S. S. Dara & D. D. Mishra, S. Chand & Co. Ltd., 1st Edn., 2012
19. Industrial Chemistry, Part-II, R. K. Das, Kalyani Publishers, 1st Edn., 1994,
20. Environmental Chemistry, Anil K. De and Arnab K. De, New Age International (P) Ltd., (2001)

B. Organic Chemistry

1. A. I. Vogel, *A Text Book of Practical Organic Chemistry*, Longmans.
2. J. Singh & J. Singh, *Photochemistry and Pericyclic Reactions*, New Age international publishers.
3. O. P. Agarwal, *Organic Natural Products - Vol 1&2*, Krishna's
4. O. P. Agarwal, *Chemistry of Organic Natural products Vol. I*, Goel Publishing House Meerut.
5. P. S. Kalsi, *Organic Reactions and their Mechanisms*, New Academic Science Limited (2010)
6. P. S. Kalsi, *Spectroscopy of Organic Compounds*, 4th ed., New Age International, New Delhi.
7. P. S. Kalsi, *Stereochemistry*, 4th ed., New Age International, New Delhi.
8. P. T. Anastas and J. K. Warner, *Oxford Green Chemistry – Theory and Practical*, Oxford University Press.
9. R. K. Bansal, *Heterocyclic chemistry*, 7th ed., New Age Int.(P)Ltd, New Delhi.
10. R. T. Morrison and R. N. Boyd, *Organic Chemistry*, 5th ed., Prentice-Hall of India, New Delhi.
11. S. M. Mukherjee and S. P. Singh, *Reactions Mechanism in Organic Chemistry*, Macmillan.
12. S. N. Sanyal, *Reactions Rearrangements and Reagents*, Bharati Bhawan Publishers
13. V. K. Ahluwalia & M. R. Kidwai, *New Trends in Green Chemistry*, Anamalaya Publishers.
14. V. K. Ahluwalia, R. K. Parashar, *Organic Reaction Mechanisms*, Alpha Science International (2006)
15. V. Kumar, *An Introduction to Green Chemistry*, Vishal Publishing Co. Jalandhar.

16. Y. R. Sharma, *Organic Absorption Spectroscopy*, S. Chand & Company Pvt. Ltd., Delhi.
17. Subrata Sen Gupta, *Basic Stereochemistry of Organic Molecules*, Oxford University Press.
18. A, K, Nad, B, Mahapatra, A, Ghoshal, *An Advanced Course In Practical Chemistry*, New Central Book Agency P Ltd.
19. Ratan Kumar Kar, Frontier Orbital and Symmetry Controlled Pericyclic Reactions, Book & Allied Ltd.

C. Physical Chemistry

1. A. S. Negi, S. C. Anand, A Text book of Physical Chemistry, New Age International Publishers, N. Delhi.
2. N. B. Singh, S. S. Das, & Ram Ji Singh, Physical Chemistry, New Age International Publishers, N. Delhi.
3. Arun Bhal, B. S. Bhal & G. D. Tuli, Essential of Physical Chemistry, S. Chand & Co.
4. V. D. Athawale & P. Mathur, Experimental Physical Chemistry, New Age International Publ., New Delhi
5. J. N. Gurtu & R. Kapoor, Advanced Experimental Chemistry, Vol. I, S. Chand & Co., New Delhi.
6. G. Raj, Advanced Physical Chemistry, Goel Pub. House, Meerut.
7. R. S. Barry, S. A. Rice and J. Ross, Physical Chemistry, Oxford Univ. Press.
8. S. Glasstone, Textbook of Physical Chemistry, Macmillan India Ltd., Madras.
9. W. J. Moore, Basic Physical Chemistry, Prentice Hall of India, New Delhi.
10. G. M. Barrow, Physical Chemistry, McGraw Hill, New York.
11. R. A. Alberty, Physical Chemistry 6th ed., Wiley Eastern Ltd., New Delhi
12. S. Glasstone, An Introduction of Electrochemistry, (Reprint), Affiliated East- West Press, New Delhi.
13. J. B. Yadav, Advanced Practical Physical Chemistry, 20th ed., Goel Publ. House, Meerut.
14. P. Atkins and R. Friedman, Molecular Quantum Chemistry P. Atkins Oxford University Press, 2011.
15. Mortimer, R. Mathematics for Physical Chemistry. 3rd ed. Elsevier, 2005.
16. Yates, P. Chemical Calculations. 2nd ed. CRC Press, 2007.

MARKING & EVALUATION SCHEME

1st Semester				
Course code	***Total marks***	***Sections***	***In-semester***	***End-semester***
CHE-100 (Major)	100	**Introductory Chemistry-I**		
	100	***Part A: Theory***		
CHE-101 (Minor)		**Unit I: Inorganic Chemistry-I**		
		(a) Structure of atom		5
		(b) Chemical Periodicity	7	5
		(c) Chemical bonding-I		8
		Unit II: Organic Chemistry-I		
		(a) Nomenclature, Structure, bonding and Properties		8
		(b) Alkanes and Cycloalkanes	6	5
		(c) Alkenes and Alkynes		6
		Unit III: Physical Chemistry-I		
		(a) States of Matter		
		(i) Gaseous State-I		7
		(ii) Liquid State-I	6	4
		(iii) Solid State-I		3
		(b) Chemical Kinetics-I		5
		Part B: Practical ***(Duration: 6 hours)***		
		Unit IV: Laboratory Work (Inorganic)		
		1. Experiment	2	12
		2. Viva voce	2	5
		3. Lab records	2	2
			25	75

2nd Semester				
Course code	***Total marks***	***Sections***	***In-semester***	***End-semester***
CHE-150 (Major)	100	**Introductory Chemistry-II**		
	100	***Part A: Theory***		
CHE-150 (Minor)		**Unit I: Inorganic Chemistry-II**		
		(a) Nucleus and Radioactivity		10
		(b) Redox reactions	6	4
		(c) Acid-base Concept		5
		Unit II: Organic Chemistry-II		
		(a) Organic Stereochemistry-I		5
		(b) Aromatic Hydrocarbons and Aromaticity	7	5
		(c) Nucleophilic Substitution reactions		5
		(d) Elimination reactions		3
		Unit III: Physical Chemistry-II		
		(a) Thermodynamics-I		10
		(b) Thermochemistry	6	5
		(c) Adsorption and Surface Phenomena		4
		Part B: Practical ***(Duration: 6 hours)***		
		Unit IV: Laboratory Work (Organic)		
		1. Experiment	2	12
		2. Viva voce	2	5
		3. Lab records	2	2
			25	75

3rd Semester				
Course code	***Total marks***	***Sections***	***In-semester***	***End-semester***
CHE-200 (Major)	100	**Chemistry-III**		
		Part A: Inorganic chemistry		
		Unit I: Main group elements		
		(a) *s*- and *p*-block elements and their compounds		12
		(b) Interhalogens, Polyhalides & Pseudohalides	12	7
		Unit II: Transition Metals		
		(a) *d*- and *f*-block elements and their compounds		12
		(b) Chemical Bonding-II		7
		Part B: Physical Chemistry		
		Unit III: Fundamental Mathematics		
		(a) Mathematics for Chemistry-I		9
		(b) Mathematics for Chemistry-II		9
		Unit IV: Equilibrium	13	
		(a) Chemical Equilibria		10
		(b) Ionic Equilibrium		9
			25	75
CHE-201 (Major)	100	**Organic Chemistry Laboratory (Duration: 18 hours)**		
		1. Separation of mixtures	15	40
		2. Organic Preparation	5	10
		3. Green method of synthesis		10
		4. Viva voce	3	10
		5. Laboratory records	2	5
			25	75
4th Semester				
Course code	***Total marks***	***Sections***	***In-semester***	***End-semester***
CHE-250 (Major)	100	**Inorganic Chemistry-I**		
		Unit I: Analytical Chemistry-I		19
		Unit II: Coordination Chemistry-I		19
		Unit III: Organometallic Chemistry-I	25	19
		Unit IV: Data Analysis		18
			25	75
CHE-251 (Major)	100	**Organic Chemistry-I**		
		Unit I: Functional group in Organic Chemistry		19
		(a) Aromatic halogen Compounds		
		(b) Alcohols		
		(c) Epoxides		
		(d) Phenols		
		Unit II: Carbonyl Compounds and their derivatives		18
		(a) Aldehydes and Ketones		
		(b) Carboxylic Acids and their Derivatives		
		Unit III: Nitrogen-containing compounds		19
		(a) Nitro Compounds		
		(b) Amines	25	

		(c) Diazo Compounds (d) Urea		
		Unit IV: Specialized Organic compounds (a) Organometallic Compounds (b) Active Methylene Compounds (c) Interconversions		19
			25	75
CHE-252 (Major)	100	**Physical Chemistry-I**		
		Unit I: Gaseous State-II		19
		Unit II: Thermodynamics-II		18
		Unit III: Electrochemistry-I	25	19
		Unit IV: Electrochemistry-II		19
			25	75
CHE-253 (Major)	100	**Inorganic Chemistry Laboratory (Duration: 18 hours)**		
		1. Estimation of mixture	15	40
		2. Preparation of coordination compound	5	15
		3. Viva voce	3	15
		4. Laboratory records	2	5
			25	75
5th Semester				
Course code	***Total marks***	***Sections***	***In-semester***	***End-semester***
CHE-300 (Major)	100	**Chemistry-IV** ***Part A: Inorganic chemistry***		
		Unit I: Symmetry of molecule Molecular Symmetry		19
		Unit II: Metallurgy and Polymers	13	
		(a) Metals and Metallurgy		12
		(b) Inorganic Polymers		6
		Part B: Physical chemistry		
		Unit III: Molecular Spectroscopy and Liquid Properties (a) Molecular Spectroscopy-I		12
		(b) Liquid State-II	12	7
		Unit IV: Photochemical Reactions (a) Photochemistry		7
		(b) Chemical Kinetics-II		12
			25	75
CHE-301 (Major)	100	**Organic Chemistry-II**		
		Unit I: Carbohydrates and Polysaccharides		18
		Unit II: Amino acids, Peptides, Proteins and Vitamins (a) Amino Acids, Peptides and Proteins (b) Vitamins		19
		Unit III: Organic synthesis and Rearrangements (a) Organic synthesis (b) Rearrangements (c) Inorganic Reagents in Organic Synthesis	25	19
		Unit IV: Aromatic hydrocarbons, Stereochemistry and Polymers (a) Polynuclear Aromatic Hydrocarbons		19

		(b) Organic Stereochemistry-II (c) Polymers		
			25	75
CHE-302 (Major) 100 CHE-302 (Minor)	100	**Chemistry-V/General Chemistry-III** ***Part A: Theory*** **Unit I: Inorganic Chemistry-III** (a) Industrial Chemistry (b) Environmental Chemistry **Unit II: Organic Chemistry-III** (a) Drugs (b) Fats, Oils, Soaps and Detergents (c) Dyes **Unit III: Physical Chemistry-III** (a) Phase Equilibria-I (b) Phase Equilibria-II ***Part B: Practical*** **(Duration: 6 hours)** **Unit IV: Laboratory Work (Physical)** 1. Experiment 2. Viva voce 3. Lab records	 6 6 7 2 2 2	 8 11 6 6 7 8 10 12 5 2
			25	75
CHE-303 (Major)	100	**Internship**		

6th Semester				
Course code	***Total marks***	***Sections***	***In-semester***	***End-semester***
CHE-350 (Major)	100	**Inorganic Chemistry-II**		
		Unit I: Coordination Chemistry-II	25	19
		Unit II: Organometallic Chemistry-II		19
		Unit III: Bioinorganic Chemistry-I		19
		Unit IV: Coordination Chemistry-III		18
			25	75
CHE-351 (Major)	100	**Organic Chemistry-III**		
		Unit I: Heterocyclic Compounds	25	18
		Unit II: Natural products, Bioorganic chemistry and Green Chemistry (a) Natural Products (b) Topics in Bioorganic Chemistry (c) Green Chemistry		19
		Unit III: Pericyclic reactions and Photochemistry (a) Pericyclic Reactions (b) Organic Photochemistry		19
		Unit IV: Spectroscopy in Organic chemistry (a) Ultraviolet and Visible Spectroscopy (b) Infrared Spectroscopy (c) Nuclear Magnetic Resonance Spectroscopy (d) Mass Spectrometry		19
			25	75

CHE-352 (Major)	100	**Physical Chemistry-II**		
		Unit I: Thermodynamics-III	25	18
		Unit II: Quantum Mechanics-I		20
		Unit III: Statistical Thermodynamics-I		20
		Unit IV: Non-equilibrium Thermodynamics		17
			25	75
CHE-353 (Major)	100	**Physical Chemistry Laboratory**		
		Part A–Instrumental Experiments **(Duration: 6 hours)**		
		Experiment	7	25
		Viva voce	3	8
		Laboratory records	2	5
		Part B–Non-instrumental Experiments **(Duration: 6 hours)**		
		Experiment	8	24
		Viva voce	3	8
		Laboratory records	2	5
			25	75