RABINDRANATH TAGORE UNIVERSITY

Department of Chemistry

PROPOSED STRUCTURE OF SYLLABUS OF THE FOUR YEARS UNDERGRADUATE PRORAMME (FYUGP) IN CHEMISTRY AS PER NEP 2020.

COURSE STRUCTURE

RABINDRANATH TAGORE UNIVERSITY, HOJAI, ASSAM

AS PER NEP-2020

BACHELOR OF CHEMISTRY

COURSE STRUCTURE

Semester	Category of Course	Course Code	Course Title	Total Credit
I	DSC-1(Major)	MAJ-CHM-1.1	Foundation Course Chemistry-I	4 3(T)+1(P)
	Minor-1	MIN-CHM-1.1	Introductory Chemistry-I	4 3(T)+1(P)
	MD/GE-1	MD-CHM-1.1	Importance of Chemistry in Society	3
	SEC-1	SEC-CHM-1.1	Intellectual Property Right	3
	AECC-1			2
	VAC-1			2
	VAC-2			2
	Total Credit			**20**
II	DSC-2 (Major)	MAJ-CHM-2.1	Foundation Course Chemistry-II	4 3(T)+1(P)
	Minor-2	MIN-CHM-2.1	Introductory Chemistry-II	4 3(T)+1(P)
	MD/GE-2	MD-CHM-2.1	Molecules of Life	3

	SEC-2	SEC-CHM-2.1	Fuel Chemistry	3 2(T)+1(P)
	AECC-2			2
	VAC-3			2
	VAC-4			2
	Total Credit			**20**
III	DSC-3 (Major)	MAJ-CHM-3.1	Foundation Course Chemistry-III	4 3(T)+1(P)
	DSC-4 (Major)	MAJ-CHM-3.2	Foundation Course Chemistry-IV	4 3(T)+1(P)
	Minor-3	MIN-CHM-3.1	Introductory Chemistry-III	4 3(T)+1(P)
	GE/MD – III	MD-CHM-3.1	Pesticide Chemistry	3
	SEC - III	SEC-CHM-3.1	Industrial Chemistry	3 2(T)+1(P)
	AECC – III			2
	Total Credit			**20**
IV	DSC-5 (Major)	MAJ-CHM-4.1	Inorganic Chemistry-I	4 3(T)+1(P)
	DSC-6 (Major)	MAJ-CHM-4.2	Organic Chemistry-I	4 3(T)+1(P)
	DSC-7 (Major)	MAJ-CHM-4.3	Physical Chemistry-I	4 3(T)+1(P)
	Minor-4	MIN-CHM-4.1	Introductory Chemistry-IV	4 3(T)+1(P)
	AECC – IV			2
	Summer Internship			2
	Total Credit			**20**
V	DSC-8 (Major)	MAJ-CHM-5.1	Inorganic Chemistry-II	4 3(T)+1(P)
	DSC-9 (Major)	MAJ-CHM-5.2	Organic Chemistry-II	4 3(T)+1(P)
	DSC-10 (Major)	MAJ-CHM-5.3	Physical Chemistry-II	4 3(T)+1(P)
	DSC-11 (Major)	MAJ-CHM-5.4	Quantum Chemistry & Molecular Spectroscopy-I	4 3(T)+1(P)
	Minor-5	MIN-CHM-5.1	General Chemistry-I	4 3(T)+1(P)
	Total Credit			**20**
VI	DSC-12 (Major)	MAJ-CHM-6.1	Inorganic Chemistry-III	4 3(T)+1(P)

	DSC-13 (Major)	MAJ-CHM-6.2	Organic Chemistry-III	4 3(T)+1(P)
	DSC-14 (Major)	MAJ-CHM-6.3	Physical Chemistry-III	4 3(T)+1(P)
	DSC-15 (Major)	MAJ-CHM-6.4	Quantum Chemistry & Molecular Spectroscopy-II	4 3(T)+1(P)
	Minor-6	MIN-CHM-6.1	General Chemistry-II	4 3(T)+1(P)
	Total Credit			**20**
VII	DSC-16 (Major)	MAJ-CHM-7.1	Inorganic Chemistry-IV	4 3(T)+1(P)
	DSC-17 (Major)	MAJ-CHM-7.2	Organic Chemistry-IV	4 3(T)+1(P)
	DSC-18 (Major)	MAJ-CHM-7.3	Physical Chemistry-IV	4 3(T)+1(P)
	DSC-21 (Major) (Additional paper only for non-research)	MAJ-CHM-7.4	Analytical Methods in Chemistry	4 3(T)+1(P)
	Minor-7	MIN-CHM-7.1	General Chemistry-III	4 3(T)+1(P)
	Total Credit			**20**
VIII	DSC-19 (Major)	MAJ-CHM-8.1	Advanced topics in Chemistry-I	4 3(T)+1(P)
	DSC-20 (Major)	MAJ-CHM-8.2	Advanced topics in Chemistry-II	4 3(T)+1(P)
	DSC-22 (Major)(Additional paper only for non-research)	MAJ-CHM-8.3	Chemistry of Nano-materials	4 3(T)+1(P)
	DSC-23 (Major) (Additional paper only for non-research)	MAJ-CHM-8.4	Supramolecular Chemistry	4 3(T)+1(P)
	Minor-8	MIN-CHM-8.1	General Chemistry-IV	4 3(T)+1(P)
	Total Credit			**20**

B. SC. IN CHEMISTRY

DETAILED SYLLABUS OF FYUGP SEMESTER-I

Title of the Course: Foundation Course Chemistry - 1 (DSC - 1)

Course Code: MAJ-CHM-1.1

Total Credit: 4 (3 Credits theory +1 Credit Practical)

Distribution of Marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course Objective: Teaching of basic knowledge of chemistry in the disciplines of inorganic, organic and physical chemistry.

Theory: 3 Credits Total course hour: 45 hr Duration of Examination: 2 hr.

Unit - 1: Atomic Structure & Periodic Table: (15 L, 20 Marks)

Introduction to Quantum mechanics, Time independent Schrödinger Wave Equation and its derivation. Significance of ψ and ψ^2. Application of Schrödinger equation to hydrogen atom (in terms of spherical polar coordinates), Radial and Angular parts of the hydrogenic wave functions (atomic orbitals) and their variations for 1s, 2s, 2p, 3s, 3p and 3d orbitals (Only graphical representation). Radial and Angular nodes and their significance. Probability distribution curves and radial probability distribution curves, Quantum numbers and their significance, Shapes of s, p and d atomic orbitals. Pauli's Exclusion Principle, Hund's rule of maximum multiplicity, Aufbau's principle and its limitations- Electronic configurations of the elements (Z=1 to 30), effective nuclear charge, shielding/screening effect, Slater's rules. Variation of effective nuclear charge in Periodic Table.

Periodic Law (Mendeleev and Mosley), Classification of elements into s, p, d, and f - blocks, Nuclear Charge, Effective Nuclear Charge, Shielding and Slater's Rule.

Concept, Variations and factors affecting various periodic properties (atomic/ionic radii, ionization energy, electron affinity and electronegativity), Inert pair effect, Anomalous behaviour of first element in respective groups of representative elements, Diagonal relationship of Li and Mg; Be and Al.

Unit - 2: States of Matter (Gases & Liquids): (15 L, 20 Marks)

Gaseous State: Elementary aspects of kinetic theory of gases, Ideal and real gases. Boyle temperature (derivation not required), Molecular velocity, collision frequency, collision diameter, Collision cross section, collision number and mean free path and coefficient of viscosity, calculation of and n, variation of viscosity with temperature and pressure.

Maxwell's Boltzmann distribution law of molecular velocities (Most probable, average and root mean square velocities). Relation between RMS, average and most probable velocity and average kinetic energies. (Mathematical derivation not required), law of equipartition of energy. Behaviour of real gases: Deviation from ideal gas behaviour, Compressibility factor (Z) and its variation with pressure for different gases. Causes of deviation from ideal behaviour, van der Waals equation of state (Mathematical derivation not required) and application in explaining real gas behaviour. Critical phenomena-Andrews isotherms of CO, critical constants and their calculation from van der Waals equation, Continuity of states, Law of corresponding states. Numerical problems.

Liquid State: Qualitative treatment of structure of liquids, physical properties of liquids, vapour pressure, surface tension- Explanation of cleansing action of detergents, parachor-determination and application, viscosity, Newtonian and non-Newtonian liquid, liquid crystals.

Unit - 3: Fundamentals of Organic Chemistry and Stereochemistry: (15 L, 20 Marks)

Review of hybridization, sigma and pi bonds, IUPAC Nomenclature of poly functional organic compounds, comparative study of bond lengths, bond angles, bond energies and dihedral angles, bond polarity, dipole moment and illustration with examples of organic compounds, delocalization, electron displacement effects and their applications: inductive effect, electrometric effect, resonance effect, hyperconjugation, and steric effect.

Organic Reaction Mechanism: Definition, classification of organic reactions: substitution, addition, elimination, rearrangement, oxidation and reduction reactions with suitable examples. Use of curved arrows, types of bond fission, electrophiles, nucleophiles, nucleophilicity, nucleofugacity and basicity. Reactive intermediates: Energy profile diagrams, structure, formation and stability and reactions of carbocations, carbanions, free radicals and carbenes.

Stereochemistry:

Stereoisomerism: Definition of stereoisomerism, conformational isomers and configurational isomers (distinction between conformation and configuration). Newman, Sawhorse and Fischer projection formulae and their interconversions.

Geometrical isomerism: Definition, reason for geometrical isomerism, E and Z, notation - CIP rules and examples, syn and anti isomers in compounds containing C=N.

Optical isomerism: Chirality/asymmetry, enantiomerism, diastereomerism and meso compounds. R and S notations (compounds with two asymmetric centers), D and L configurations and threo and erythro nomenclature, racemic mixture and racemization, Resolution: Definition, Resolution of racemic mixture by: i) Mechanical separation ii) Formation of diastereomers iii) Biochemical methods. Biological significance of chirality, Problems are to be solved wherever applicable.

Practical: 1 Credit   Total course hour: 30 hr   Duration of Examination: 3 hr.

List of Experiments:

1. Preparations of solutions of different concentrations and standardization of solutions.
2. Volumetric estimation of oxalic acid with $KMnO_4$.
3. Determine the surface tension of various liquids by drop number method.
4. Determination of viscosity of aqueous solutions at room temperature.
5. Purification of organic compounds by crystallization using the following solvents:
a. Water b, Alcohol c. Alcohol-water
6. Determination of the melting points of above compounds (Kjeldahl method andelectrically heated melting point apparatus).
7. Separation of a mixture of o - and p - nitrophenol or o- and p-aminophenol by thin layer chromatography (TLC).

Learning Outcome:
After successfully completing the course, students will have a firm grasp of the ideas of atomic and molecular structure, chemical bonding, periodic characteristics, gaseous and liquid states of matter, basic organic reaction mechanisms, and stereochemistry. Practical works on volumetric estimation, determination of viscosity & surface tension and chromatographic separation techniques will enhance student's theoretical knowledge on these topics.

Suggested reading:

1. Inorganic Chemistry by Puri, Sharma and Kalia
2. Inorganic Chemistry by J.E.Huheey
3. Basic Inorganic chemistry by Cotton and Wilkinson
4. A Text Book of Physical Chemistry by Negi & S.C. Anand
5. Physical Chemistry by Atkins, P. W. & Paula, J.
6. Principles of Physical Chemistry by Puri, Sharma, Pathania, ShobanLal
7. Organic Chemistry by R.I. Morrison & R.N. Boyd, S.K. Bhattacharjee
8. Organic Chemistry by Janice Gorzynski Smith " Editon)
9. Organic Chemistry —a mechanistic approach by T. Okuyama and H. Maskill
10. Comprehensive Practical Organic Chemistry: Qualitative Analysis by V. K. Ahluwalia andSunita Dhingra.
11. Advanced Practical Physical Chemistry by J. B. Yadav.
12. Vogel's Quantitative Inorganic Analysis.

Title of the Course: Introductory Chemistry - I (DSE -1, Minor)
Course Code: MIN-CHM-1.1

Total Credit: 4 (3 Credits theory + 1 Credit Practical)

Distribution of Marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course Objective:

To develop a fundamental understanding of chemistry with regard to atomic structure and chemical bonding to place an emphasis on behaviours of gas molecules and liquids; to build a foundational understanding of fundamental organic chemistry and stereochemistry.

Theory: 3 Credits Total course hour: 45 hr Duration of Examination: 2 hr

Unit -1: Inorganic Chemistry: (15 L, 20 Marks)

Atomic Structure:

(Recapitulation of Bohr's Theory, de Broglie, Theory, Heisenberg Uncertainty Principle)

Schrödinger's time independent wave equation, Significance of ψ and ψ^2, Schrödinger equation for Hydrogen atom (qualitative treatment only). Quantum numbers, Electronic configuration of elements, periodic properties — effective nuclear charge, ionization energy, electron affinity, electronegativity (Pauling, Mulliken's and Allred-Rochow scales). Redox potential.

Chemical Bonding and Molecular Structure -1:

Ionic Bonding, Lattice Energy and Solvation Energy and their importance in the context of Stability and Solubility of ionic compounds. Ion polarization. Fajan's rules and its application, dipole moment and percentage ionic character.

Unit -2: Physical Chemistry: (15 L, 20 Marks)

Kinetic Theory of gases:

Derivation of the expression of pressure on the basis of Kinetic Theory of Gases, Types of molecular velocities, definition and simple problems based on root mean square speed, most probable speed, collision frequency, collision diameter, mean free path, heat capacity of gases, Deviation from ideal behaviour, van der Waals equation, van der Waals constants, critical constants, law of corresponding states, degree of freedom, law of equipartition of energy (derivation not required), viscosity of gases and effect of temperature and pressure on coefficient of viscosity).

Liquid state:
Qualitative treatment of the structure of liquids, Physical properties of liquids, vapour pressure. Surface tension and its determination using stalagmometer. Viscosity of a liquid and determination of coefficient of viscosity using Ostwald Viscometer. Effect of temperature on surface tension and coefficient of viscosity of a liquid (qualitative treatment) Parachor-determination and application.

Unit -3: Organic Chemistry: (15 L, 20 Marks)
Development of Organic Chemistry, IUPAC nomenclature of organic molecules, Electron Displacement Effects - Inductive Effect, Electromeric effect, mesomeric effect, resonance and hyperconjugation.

Mechanism of organic reactions:
Homolytic and heterolytic breaking of covalent bond, basicity and nucleophilicity, comparative acid-base strength of organic molecules, reaction intermediates –Carbenium ion, carbanion and carbon free radical, their preparation and stability.

Stereochemistry:
Sterioisomerism-Enantiomerism and Diastereoisomerism, Absolute and relative configuration of stereoisomers, E/Z, R/S and D/L nomenclature, Chirality and Optical isomerism, necessary conditions, Optical purity, Conformation of n-butane and cyclohexane, Relative stability of conformers.

Practical: 1 Credit Total course hour: 30 hr Duration of Examination: 3 hr.

List of Experiments:
1. Preparations of solutions of different concentrations and standardization of solutions.
2. Volumetric estimation of oxalic acid with $KMnO_4$.
3. Determine the surface tension of various liquids by drop number method.
4. Determination of viscosity of aqueous solutions at room temperature.
5. Purification of organic compounds by crystallization using the following solvents:
a. Water b. Alcohol c. Alcohol-water
6. Detection of elements present in the supplied organic sample.

Learning outcome:

At the end of this course student's will knowledge on the basic concepts of the structure of atoms, ionic bonding, properties of moving gas molecules, physical properties of liquids, basics of organic reaction mechanism and stereochemistry. The experiments included in practical section will enhance the knowledge of students in the respective theory topics.

Suggested reading:

1. Inorganic Chemistry by Puri, Sharma and Kalia
2. Inorganic Chemistry by J.E.Huheey
3. Basic Inorganic chemistry by Cotton and Wilkinson
4. A Text Book of Physical Chemistry by Negi & S.C. Anand
5. Physical Chemistry by Atkins, P. W. & Paula, J.
6. Principles of Physical Chemistry by Puri, Sharma, Pathania and Shoban Lal
7. Organic Chemistry by R.I. Morrison & R.N. Boyd, S.K. Bhattacharjee
8. Organic Chemistry by Janice Gorzynski Smith (2™ Editon)
9. Organic Chemistry - a mechanistic approach by T. Okuyama and H. Maskill
10. Comprehensive Practical Organic Chemistry: Qualitative Analysis by V. K. Ahluwalia and Sunita Dhingra.

11. Advanced Practical Physical Chemistry by J. B. Yadav.
12. Vogel's Quantitative Inorganic Analysis.

Title of the Course: Importance of Chemistry in Society (GR/MD -I)

Course Code: MD-CHM-1.1

Total Credit: 3

Distribution of Marks: 45 (End Semester) (45T) + 15 (In-Semester) + 15(HA/S/GD)

Course objective: This course aims to create a connection between chemical concepts and social, political, economic, and ethical concerns. This basic chemistry course will show how chemistry intersects with daily living.

Theory: 3 Credits **Total course hour:** 45 hr **Duration of Examination:** 3 hr.

Unit - 1: History and Relevance of Chemistry (10 L, 20 Marks)

Life without Chemistry

Chemistry of Life: Introduction, Chemical basis of life, Periodic table, Elements in human body, Essential and Non-Essential elements, Metal deficiency diseases.

Food Chemistry: Food processing - colouring and flavouring agents, Food preservation-Viscosity builders, bulking agents and artificial sweeteners. Permitted and non-permitted food additives and food colours.

Unit - 2: Chemistry in Everyday Life: (25 L, 40 Marks)

(Applications, Uses and Impact of Chemistry)

Pharmaceuticals: Introduction, Contribution of chemistry to human health and historical developments in medicine. Classification of drugs and some common drugs used in our daily life. (8 marks)

Plastics and Polymers: Introduction to polymers, types of polymers. Plastic in daily use, Environmental Hazards of plastics, Recycling of plastics. Biodegradable plastics. (8 marks)

Cosmetics: Basic concepts-composition and classification of creams-sun screen and suntan lotions- deodorants, talcum powder-dentifiers, lipsticks, oils, face creams, toilet powder, skin products, dental cosmetics, hair dyes, shaving cream, shampoo. (14 marks)

Soaps: Basic chemical composition of soaps, Surface active agents, toilet soap, bathing bars, washing soaps. Bio-degradability. (5 marks)

Detergents: Introduction, mode of action of detergents, common detergents, environmental hazards. (5 marks)

Unit - 3: Impact of Chemistry in Other Fields: (10 L, 20 Marks)

The Chemistry and Art Connection: Electromagnetic spectrum, Relationship between light and colour, cause of colour in objects, the earliest use of colour, use of colour to decorate the body and surroundings.

Colourants: Pigments and dyes, Chemistry of art conservation and restoration.

The chemistry and sports connection: Chemistry of sports materials, use of performance enhancing drugs in sports and their side effects.

Learning outcomes: At the end of this course, students will be able to -

1. Know the importance of the role of chemistry in everyday life.
2. Think critically and logically.
3. Aware of the chemicals found in all aspects of daily life.
4. Connect chemistry with pollution, health care, energy, nutrition and life, and visual arts.

Suggested reading:

1. Chemistry in Daily Life by Kripal Singh
2. The Chemistry of Food and Nutrition by A. W. Duncan
3. Organic Chemistry by I L Finar, Vol -2
4. Polymer Science by V R Gowariker

Title of the Course: Intellectual Property Right (SEC -1)

Course Code: SEC-CHM-1.1

Total Credit: 3

Distribution of Marks: 45 (End Semester) (45T) + 15 (In-Semester) + 15(HA/S/GD)

Course objectives: The public's image of science and its methods has significantly changed in this period of liberalisation and globalisation. At all levels - legislative, administrative, and judicial - the significance of preserving scientific discoveries with economic potential or the intellectual property rights is being addressed. Following a minimally acceptable level for the protection and enforcement of intellectual property rights has become mandatory for India as a result of its ratification of the WTO agreement. The goal of this course is to inform the participants of the complexity of this problem.

Theory: 3 Credits **Total course hour: 45 hr** **Duration of Examination: 2 hr**

Unit - 1: Introduction to Intellectual Property: (5L, 10 marks)

Historical Perspective, Different Types of Intellectual Properties, Importance of protecting Intellectual Property,

Unit-2: Copyrights: (3 L, 5 marks)

Introduction, How to obtain, Differences from Patents.

Unit - 3: Trade Marks: (5L, 10 marks)

Introduction, How to obtain, Different types of marks - Collective marks, certification marks, service marks, Trade names, etc. Differences from Designs.

Unit - 4: Patents: (10 L, 15 marks)

Historical Perspective, Basic and associated right, WIPO, PCT system, Traditional Knowledge,

Patents and Healthcare - balancing promoting innovation with public health, Software patents and their importance for India.

Unit - 5: Geographical Indications: (5 L, 10 marks)

Definition, rules for registration, prevention of illegal exploitation, importance to India.

Unit - 6: Industrial Designs: (3 L, 5 marks)

Definition, How to obtain, features, International design registration.

Unit - 7: Trade Secrets: (5 L, 10 marks)

Introduction and Historical Perspectives, Scope of Protection, Risks involved and legal aspects of Trade Secret Protection.

Unit - 8: Different International agreements: (10 L, 15 marks)

(i) General Agreement on Tariffs & Trade (GATT), Trade Related Intellectual Property Rights (TRIPS) agreement
(ii) General Agreement on Trade related Services (GATS)
(iii) Madrid Protocol
(iv) Berne Convention
(v) Budapest Treaty

Learning outcomes:
Students will have a thorough knowledge of the significance and varieties of IPR after finishing this course. The legal and financial components of the IP system will also be made clear in this course.

Suggested reading:

1. Textbook on intellectual property rights by N K Acharya
2. Intellectual Property Rights: Unleashing the Knowledge Economy by P Ganguli
4. Intellectual Property and Copyright in a Nutshell: Patents, Trademarks by Arthur Raphael Miller, Micheal H. Davis.
5. Intellectual property rights in the WTO and developing countries by Jayashree Watal.

B. SC. IN CHEMISTRY

DETAILED SYLLABUS OF FYUGP SEMESTER-II

Title of the Course: Foundation Course Chemistry - 2 (DSC - 2)

Course Code: MAJ-CHM-2.1

Total Credit: 4 (3 Credits theory + 1 Credit Practical)

Distribution of Marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course Objective: Teaching of basic knowledge of chemical bonding in inorganic and organic molecules including week intermolecular forces, chemical thermodynamics and aliphatic hydrocarbons.

Theory: 3 Credits Total course hour: 45 hr Duration of Examination: 2 hr

Unit - 1: Bonding and Structure: (16 L, 20 marks)

Ionic Bonding: Energy consideration in ionic bonding, lattice Energy. Born - Haber cycle and its application, polarizing power and polarizability. Fajan's rule, Bond moment, dipole moment and percentage ionic character. Hydrogen Bonding.

Covalent Bonding: VB Approach-Concept of hybridization (sp, sp^2, sp^3, sp^3d, sp^3d^2 and dsp^2), VSEPR Theory. Resonance and Resonance energy: Study of some inorganic and organic compounds (O_3, NO_3^- , CO_3^{2-}, SO_4^{2-}, $RCOO^-$, C_6H_6), Bonding and antibonding MOs and their characteristics for s-s, s-p and p-p combination of atomic orbitals non-bonding combination of orbitals, MO treatment of homonuclear diatomic molecules and heteronucear diatomic molecules such as CO, NO and NO^+.

Metallic Bond: Qualitative idea of valence bond and band theories. Semiconductors and insulators, defects in solids.

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

Unit - 2: Chemical Thermodynamics: (16 L, 20 marks)

Intensive and extensive variables; state and path functions; isolated, closed and open systems; zeroth law of thermodynamics.

First law of thermodynamics: Concept of heat, g, work, w, internal energy, U, and statement of first law; enthalpy, H, relation between heat capacities, calculations of q, w, U and H for reversible, irreversible and free expansion of gases (ideal and van der Waals) under isothermal and adiabatic conditions. Law of equipartition of energy, degrees of freedom and molecular basis of heat capacities.

Thermochemistry: Heats of reactions: standard states; enthalpy of formation of molecules and ions and enthalpy of combustion and its applications; calculation of bond energy, bond dissociation energy and resonance energy from thermochemical data, effect of temperature (Kirchhoff's equations) and pressure on enthalpy of reactions. Adiabatic flame temperature, explosion temperature.

Second Law of thermodynamics: Concept of entropy; thermodynamic scale of temperature, statement of the second law of thermodynamics; molecular and statistical interpretation of entropy. Calculation of entropy change for reversible and irreversible processes.

Third Law of thermodynamics: Statement of third law, concept of residual entropy, calculation of absolute entropy of molecules.

Free Energy Functions: Gibbs and Helmholtz energy; variation of S, G, A with T, V, P; spontaneous process-enthalpy change, entropy change and free energy change considerations. Relation between Joule-Thomson coefficient and other thermodynamic parameters; inversion temperature; Gibbs-Helmholtz equation; Maxwell relations; thermodynamic equation of state.

Unit - 3: Chemistry of Aliphatic Hydrocarbons: (12 L, 20 marks)

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

Alkenes and Alkynes: Formation of alkenes and alkynes by elimination reactions, Mechanism of El, E2, E1cb reactions. Saytzeff and Hoffmann eliminations. Reactions of alkenes: Electrophilic additions and their mechanisms (Markownikoff / Anti Markownikoff addition), mechanism of oxymercuration-demercuration,hydroboration-oxidation, ozonolysis, reduction (catalytic and chemical), syn and anti hydroxylation(oxidation). 1, 2-and 1, 4-addition reactions in conjugated dienes and, Diels-Alderreaction; Allylic and benzylic bromination and mechanism, e.g. propene, 1-butene, toluene, ethylbenzene.

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

Practical: 1 Credit Total course hour: 30 hr Duration of Examination: 3 hr.

List of Experiments:

1. Estimation of Fe (II) by standardized oxalic acid.
2. Estimation of Fe (II) by potassium dichromate solution using diphenylamine indicator.
3. Systematic qualitative analysis of organic samples having one functional group.
4. Determination of partition / distribution coefficient of (i) iodine in water-carbon tetrachloride mixture and (ii) benzoic acid in water -toluene mixture.

Learning outcomes:

The fundamentals of chemical bonding, all the laws of thermodynamics and how they apply, and the production and characteristics of aliphatic hydrocarbons are among the things that students will study after finishing the theory course. At the end of Practical classes students will know about quantitative analysis of solutions containing Fe (II) ion, qualitative analysis of organic compounds and how to determine the partition / distribution coefficient.

Suggested reading:

1. Inorganic Chemistry by Puri, Sharma and Kalia
2. Inorganic Chemistry by J.E.Huheey
3. Basic Inorganic chemistry by Cotton and Wilkinson
4. G.W. Castellan: Physical Chemistry
5. A Text Book of Physical Chemistry by Negi & S.C. Anand
6. Physical Chemistry by Atkins, P. W. & Paula, J.
7. Principles of Physical Chemistry by Puri, Sharma, Pathania and Shoban Lal
8. Organic Chemistry by R.I. Morrison & R.N. Boyd, S.K. Bhattacharjee
9. Organic Chemistry by I L Finar, Vol -1
10. Comprehensive Practical Organic Chemistry: Qualitative Analysis by V. K. Ahluwalia and Sunita Dhingra.
11. Advanced Practical Physical Chemistry by J. B. Yadav
12. Vogel's Quantitative Inorganic Analysis

Title of the Course: Introductory Chemistry -2 (DSE - 2, Minor)

Course Code: MIN-CHM-2.1

Total Credit: 4 (3 Credits theory + 1 Credit Practical)

Distribution of Marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course Objective: To give students a fundamental understanding of chemical bonding and how molecular structure is connected to it. To educate students about the nature of salt solution. To make students aware of the production process and characteristics of aliphatic hydrocarbons.

Theory: 3 Credits Total course hour: 45 hr Duration of Examination: 2 hr.

Unit - 1: Inorganic Chemistry: (16 L, 20 marks)

Chemical Bonding and Molecular Structure-2

Covalent Bonding: VB Approach-Concept of hybridization, sp, sp^2, sp^3, sp^3d, sp^3d^2 and dsp^2 VSEPR Theory. Resonance and Resonance energy: Study of some inorganic and organic compounds (O_3, NO_3^-, CO_3^{2-}, SO_4^{2-}, $RCOO^-$, C_6H_6). Molecular Orbital Approach: LCAO method, bonding and anti bonding MOs and their characteristics for s-s, s-p and p-p combination of atomic orbitals, nonbonding combination of orbitals, MO treatment of homonuclear diatomic molecules and heteronuclear diatomic molecules such as CO, NO and NO^+

Hydrogen Bonding, types of hydrogen bonding and its application in explaining molecular properties.

Coordination Chemistry:

Werner's theory. Different types of ligands, IUPAC Nomenclature of Co-ordination compounds. Isomerism of 4-and 6- coordinate compounds. Introduction to Valence Bond Theory (VBT) and Crystal Field Theory (CFT) and their applications.

Unit - 2: Physical Chemistry: (15 L, 20 marks)

Solids:

Forms of solids, unit cells, crystal systems, Bravais lattice, types and identification of lattice planes. Miller and Weiss indices. Laws of crystallography- Law of constancy of interfacial angles. Law of rational indices. X-Ray diffraction by crystals. Bragg's law. Structure of NaCl, KCl and CsCl (qualitative treatment only). Defects in crystals. Liquid crystals.

Ionic Equilibria:

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

Unit - 3: Organic Chemistry: (14 L, 20 marks)

Chemistry of Aliphatic Hydrocarbons

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

Alkenes and Alkynes: Formation of alkenes and alkynes by elimination reactions, Mechanism of E1, E2, E1cb reactions. Saytzeff and Hofmann eliminations. Reactions of alkenes: Electrophilic additions and their mechanisms (Markownikoff/ Anti Markownikoff addition), mechanism of oxymercuration-demercuration,hydroboration-oxidation, ozonolysis, reduction (catalytic and chemical), syn and anti hydroxylation(oxidation). 1,2-and 1,4-addition reactions in conjugated dienes and, Diels-Alderreaction; Allylic and benzylic bromination and mechanism, e.g. propene, 1-butene, toluene, ethylbenzene.

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

Practical: 1 Credit Total course hour: 30 hr Duration of Examination: 3 hr.

List of Experiments:

1. Estimation of Fe (II) by standardized oxalic acid.
2. Systematic qualitative analysis of organic samples having one functional group.
3. Determination of partition / distribution coefficient of (i) iodine in water-carbon tetrachloride mixture.

Learning outcomes:

At the end of this course, students will be able know

1. about the different theories of covalent bonding and how each of these theories explain the structure and properties of inorganic molecules.
2. about the crystal structure of ionic solids
3. about the behaviour of ionic solids in solution state.
4. about the pH of salt solution and buffer action.
5. about the preparation and chemistry of aliphatic hydrocarbons.

Suggested reading:

1. Inorganic Chemistry by Puri, Sharma and Kalia
2. Inorganic Chemistry by J.E.Huheey
3. Basic Inorganic chemistry by Cotton and Wilkinson
4. A Text Book of Physical Chemistry by Negi & S.C. Anand
5. Physical Chemistry by Atkins, P. W. & Paula, J.
6. Principles of Physical Chemistry by Puri, Sharma, Pathania and Shoban Lal
7. Organic Chemistry by R.I. Morrison & R.N. Boyd, S.K. Bhattacharjee
8. Organic Chemistry by I L Finar, Vol - 1
9. Comprehensive Practical Organic Chemistry: Qualitative Analysis by V. K. Ahluwalia and Sunita Dhingra.
10. Advanced Practical Physical Chemistry by J. B. Yadav.
11. Vogel's Quantitative Inorganic Analysis.

Title of the Course: Molecules of Life (GR/MD - II)

Course Code: MD-CHM-2.1

Total Credit: 3

Distribution of Marks: 45 (End Semester) (45T) + 15 (In-Semester) + 15(HA/S/GD)

Course objective: To make students aware of molecules present in the bio system and their structure and importance.

Theory: 3 Credits   Total course hour: 45 hr   Duration of Examination: 2 hr

Unit -1: Proteins: (12 L, 20 Marks)

Sources, Composition and Biological values of protein, Elementary ideas of proteins and amino acids, Essential and Non-essential amino acids. Peptide bonds, Polypeptides, Qualitative ideas of structure of proteins (Primary, secondary, Tertiary and Quaternary structure), Denaturation and coagulation of proteins; Factors contributing to denaturation and coagulation of proteins.

Unit - 2: Vitamins: (12 L, 20 Marks)

Classification and Nomenclature. Sources, deficiency diseases, and structures of Vitamin A, Vitamin B, Vitamin C, Vitamin D, Vitamin E & Vitamin K.

Unit - 3: Nucleic Acids: (11 L, 20 Marks)

Nucleic acids and their Chemical composition. Classifications, functions and structure of nucleic acids. Concept of DNA finger printing and its applications.

Unit-4: Oils and fats: (10 L, 20 Marks)

Composition of edible oils, detection of purity, rancidity of fats and oil. Tests for adulterants like argemone oil and mineral oils. Soaps & Detergents: Definition, classification, manufacturing of soaps and detergents, composition and uses.

Suggested reading:

1. Organic Chemistry by I L Finar, Vol -2
2. Principles of Biochemistry by A. L. Lehninger, M M Cox and D L Nelson
3. A Text Book of Organic Chemistry by B S Bahl and Arun Bahl.

Learning outcomes:
By the end of the course, students will be able to comprehend and illustrate how the structure of biomolecules affects their reactivity and biological capabilities. The course also will describe different varieties of vitamins and their function.

Title of the Course: Fuel Chemistry (SEC - 2)

Course Code: SEC-CHM-2.1

Total Credit: 3 (2 credits theory + 1 credit practical)

Distribution of Marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course Objectives:

The course aims to give students a fundamental knowledge of the science and technology behind the manufacture, behaviour, and management of lubricants, petrochemicals, and hydrocarbon fuels. As a result, they will be equipped to successfully contribute to the field of petroleum chemistry and technology.

Theory: 2 Credits   Total course hour: 30 hr   Duration of Examination: 2 hr

Unit-1: Review of energy sources (renewable and non-renewable): (9 L, 18 mark)

Classification of fuels and their calorific value.

Coal: Uses of coal (fuel and nonfuel) in various industries, its composition, carbonization of coal. Coal gas, producer gas and water gas- composition and uses. Fractionation of coal tar, uses of coaltar bases chemicals.

Unit-2: Petroleum and Petrochemical Industry: (15 L, 25 marks)

Composition of crude petroleum; Different types of petroleum products and their applications. Principle and process of fractional distillation, Cracking - Thermal and catalytic cracking; Qualitative treatment of non-petroleum fuels -LPG, CNG, LNG, bio-gas, fuels derived from biomass, fuel from waste; synthetic fuels -gaseous and liquids.

Petrochemicals: Vinyl acetate, Propylene oxide, Isoprene, Butadiene, Toluene and its derivatives Xylene.

Unit-3: Lubricants: (6 L, 17 marks)

Classification of lubricants, lubricating oils (conducting and non-conducting), Solid and semi solid lubricants, synthetic lubricants. Properties of lubricants- viscosity index, cloud point, pore point.

Practical: 1 Credit   Total course hour: 30 hr   Duration of Examination: 3 hr.

List of Experiments:

1. To determine the aniline point of a given lubricating oil
2. To determine the acid value of a given oil.
3. To determine the enthalpy of combustion of liquid fuels using spirit alcohol burner.
4. To perform the proximate analysis of coal
5. To perform the ultimate analysis of the coal sample

Learning Outcome:

Students will learn about the many categories of renewable and non-renewable energy sources at the end of this course. Students will gain knowledge of the characteristics of coal and crude oil, as well as their classification, separation into individual products, and application in a variety of sectors. They will also learn how to calculate physically relevant industrial parameters for fuels and lubricants.

Suggested reading:

1. Engineering Chemistry by P C Jain and M Jain.
2. Industrial Chemistry by B K Sharma.

B. SC. IN CHEMISTRY

DETAILED SYLLABUS OF FYUGP SEMESTER-III

Course Title: Foundation Course Chemistry- III (DSC - 3)

Course Code: MAJ-CHM-3.1

Total Credit: 4 (3 Credit Theory + 1 Credit Practical)

Distribution of marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course objective:

The course aims to equip students with foundational chemistry knowledge, focusing on acids, bases, metallurgical principles, stereochemistry, and organic synthesis, phase equilibria, solid-state chemistry, fostering analytical and practical chemical skills.

Theory: 3 credits **Total course hour: 45 hr** **Duration of examination: 2 hr**

Unit-1: Acids and bases **(8L, 10 marks)**

Bronsted-Lowry concept of acid-base reaction, solvated proton, relative strength of acids, types of acids-base reactions, leveling solvents, Lewis acid-base concept, classification of Lewis acids, Hard& soft acids and bases (HSAB), Pearson's concept, bonding in hard-hard and soft-soft combinations, application of (HSAB) principle, Symbiosis, theoretical basis of hardness and softness, electro negativity and hardness and softness.

Unit-2: Oxidation-Reduction and general principle of metallurgy (7L, 10 marks)

Redox equation, standard electrode potential and its application to inorganic reactions, principles involved in volumetric analysis to be carried out in class. Principles and applications of Ellingham diagram, General methods of isolation and purification of Electrolytic process and Mond's process, Zone refining.

Unit-3: Prostereoisomerism (8L, 10 marks)

Prostereogenic centre, Topicity of ligands and faces, Enantiotopic and Diastereotopic atoms, groups and faces, Pro-*R* and Pro-*S* designation of enantiotopic groups and atoms, *Re* and *Si* designation of enantiotopic and diastereotopic faces.

Stability of cycloalkanes, Baeyer strain theory. Conformational analysis of cyclic systems: mono- and di-substituted cyclohexanes. Stereochemistry of fused ring systems (Decalin).

Unit-4: Chemistry of alkyl and aryl halides **(7L, 10 marks)**

Alkyl Halides: Preparation from alkenes and alcohols. Nucleophilic substitution reaction and its types (SN^1, SN^2 and SN^i reactions), solvolysis, halide displacement reactions. Williamson's ether synthesis and elimination vs substitution. Aryl Halides: Preparation: from phenol, Sandmeyer & Gattermann reactions. Reactions: aromatic nucleophilic substitutions. Benzyne formation and reactions.

Unit-5: Phase Equilibrium **(9 L, 12 marks)**

Concept of phases, components and degree of freedom, derivation of Gibbs Phase Rule for nonreactive and reactive system; Clausius-Claperyon equation and its application to solid-liquid, liquid-vapour and solid-vapour equilibria, phase diagram for one component system with applications. Phase diagram for system of solid-liquid equilibria involving eutectic, congruent and incongruent melting points, solid solutions.

Binary solutions: Gibbs-Duhem-Margules equation, its derivation and applications to fractional distillation of binary miscible liquids (ideal and non-ideal), azeotropes, lever rule, partial miscibility of liquids, CST, miscible pairs, steam distillation.

Nernst distribution law: its derivation and applications.

Unit-6: Basic Crystallography **(6 L+ 8 marks)**

Basic law of crystallography, crystal system, crystal lattice, Miller indices and simple face centered and body centered cubic lattice, number of points in a unit cell. X-Ray diffraction study of crystals, Bragg's law, determination of crystal structure- introduction to powder and single crystal methods of structure analysis, crystal structure of NaCl and KCl, packing of crystals, closed packed structure, radius ratio.

Practical: 1 Credit **Total course hour: 30 hr** **Duration of Examination: 3 hr**

List of experiments:

1. Volumetric estimation of water of crystallization in Mohr's salt by titrating with $KMnO_4$.
2. Volumetric estimation of Na_2CO_3 and $NaHCO_3$ present together in a mixture.
3. Detection of functional groups in organic compounds.
4. Preparation of organic compounds using classical organic reactions like nitration, bromination, acetylation, and condensation.
5. Determination of critical solution temperature and composition of the phenol-water system and to study the effect of impurities on it.
6. Construction of the phase diagram using cooling curves or ignition tube method:
   i. simple eutectic method,
   ii. congruently melting point
7. Distribution of acetic/benzoic acid between water and cyclohexane.
8. Study the equilibrium of at least one of the following reactions by the distribution method
   i. $I_2\,(aq) + I \rightarrow I_2\,(aq)$
   ii. $Cu^{2+}\,(aq) + nNH_3 \rightarrow Cu(NH_3)_n$

 # Expt no 1-4 are compulsory and any two from expt no 5-8

Learning outcome:

Upon completing this foundation course in Chemistry, students will be able to understand and apply key chemical concepts such as redox chemistry in metallurgical processes and strengths of acids and bases. phase equilibria, solid-state chemistry, prostereoisomerism, and the chemistry of alkyl and aryl halides. Students will gain proficiency in interpreting redox reactions in metallurgical processes, stereochemistry, phase diagrams and, crystallography. Additionally, students will develop practical skills in analysing X-ray diffraction data and synthesizing chemical compounds, preparing them for advanced studies and research in chemical sciences.

Suggested reading:

1. Physical Chemistry by Atkins & Paula
2. Principles of Physical Chemistry by Puri, Sharma & Pathania
3. A text book of Physical Chemistry by Negi & Anand
4. Inorganic Chemistry by Puri, Sharma &Kalia
5. Inorganic Chemistry by J E Huheey
6. Basic Inorganic Chemistry by Cotton and Wilkinson
7. Stereochemistry of Organic Compounds: Principles and Applications by D. Nasipuri, 4^{th} Ed., New Age International Publishers.
8. Organic Chemistry by Janice Gorzynski Smith, 2^{nd} Ed., The McGraw Hill Com.
9. Comprehensive Practical Organic Chemistry: Qualitative Analysis by V. K. Ahluwalia and Sunita Dhingra

Course title: Foundation Course Chemistry – IV (DSC - 4)

Course Code: MAJ-CHM-3.2

Total Credit: 4 (3 credit Theory + 1 Credit Practical)

Distribution of marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course objective:

This course aims to deepen understanding of chemistry of s, p- block elements, noble gases, chemical reactions involved in alcohols, phenols and ethers as well as chemical equilibrium, and ionic behaviour.

Theory: 3 credits **Total course hour: 45 hr** **Duration of examination: 2 hr**

Unit -1: Main group elements, Chemistry of s and p block elements (10 L, 10 marks)

Diagonal relationship and anomalous behavior of first member of each group. Inert pair effect, Relative stability of different oxidation states. Reaction of alkali and alkaline earth metals with oxygen, hydrogen and water. Catenation and allotropy. Allotropes of carbon, phosphorous. Oxides of nitrogen, phosphorous sulphur and chlorine. Borohydrides (diborane) and carboranes, Wades rule, Interhalogen compounds, polyhalide ions and pseudohalogens. Hydrides and their classification: ionic, covalent and interstitial. Basic properties of halogens.

Unit-2: Noble gages: (5 L, 10 marks)

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

Unit-3: Alcohols, Phenols and Ethers (15 L + 20 marks)

Alcohols: Preparation of 1°, 2° & 3° alcohols and 1,2-diols: using Grignard reagent, ester hydrolysis, reduction of aldehydes, ketones, carboxylic acid and esters. Reactions with alkali metals, HX (Lucas test), esterification, oxidation (with PCC, alkaline $KMnO_4$, acidic dichromate, conc. HNO_3). Oppeneauer oxidation. Diols: oxidation of diols. Pinacol-Pinacolone rearrangement.

Phenols: Preparation - Cumene hydroperoxide method, from diazonium salts. Reactions - Electrophilic substitution and name reactions (Kolbe-Schmidt reaction, Riemer Tieman reaction, Lederer- Manasse reaction)

Ethers: (aliphatic and aromatic): Important methods of preparation, important reactions.

Unit-4: Chemical Equilibrium: (6 L, 8 marks)

Criteria of thermodynamics equilibrium, degree of advancement of reaction, chemical equilibria in ideal gases, concept of fugacity. Thermodynamics derivation of relation between Gibbs free energy of reaction and reaction quotient. Equilibrium constants and their quantitative dependence on temperature, pressure and concentration. Free energy of mixing and spontaneity; thermodynamic derivation of relations between the various equilibrium constants K_p, K_c and K_x. Le Chatelier principle (quantitative treatment).

Unit-5: Ionic equilibria (9 L, 12 marks)

Strong, moderate and weak electrolyte, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water. Ionization of weak acids and bases, pH scale, common ion effect; dissociation constant of mono, di and triprotic acids (exact treatment).

Salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts. Buffer solutions; derivation of Henderson equation and its applications; buffer capacity, buffer range, buffer action and applications of buffers in analytical chemistry and biochemical processes in the human body.

Practical: 1 Credit Total course hour: 30 hr Duration of Examination: 3 hr

List of experiments:

1. **Inorganic Preparation (A minimum of two experiments are to be performed):**
   a) Tetramminecopper (II) sulphate, $[Cu(NH_3)_4]SO_4.H_2O$
   b) Cis and trans $K[Cr(C_2O_4)_2.(H_2O)_2]$ Potassium dioxalatodiaquachromate (III)

c) Tetramminecarbonatocobalt (III) ion
d) Potassium tris (oxalate) ferrate (III)

2. Chromatography of metal ions:

Principles involved in chromatographic separation. Paper chromatographic separation of following metal ions:

a) Ni(II) and Co (II)
b) Fe(III) and Al(III)

3. Systematic qualitative analysis of organic compounds.

a. Identification of functional groups in a given organic sample: Simple functional groups such as alcohols, phenols, amines, nitro, carbonyl and carboxylic acid groups.
b. Prepare derivatives of a given organic sample containing single functional group (alcohols, phenols, amines, nitro, carbonyl and carboxylic acid groups)

4. pH metric titration (Any one)

a) strong acid vs. strong base
b) weak acid vs. strong base

5. Preparation of buffer solutions of different pH (Any one)

a) Sodium acetate-acetic acid
b) Ammonium chloride- ammonium hydroxide

Learning outcome:

Upon completing this foundation course in Chemistry, students will be adept at understanding and applying

1. inorganic compounds with emphasis on their structure, bonding, preparation and properties
2. principles of chemical and ionic equilibria, thermodynamics, and the preparation and reactions of alcohols, phenols, and ethers.
3. students will be proficient at calculating equilibrium constants, pH values, and buffer capacities, and develop clear understanding of preparation and chemical reactivity of alcohols, phenols and ethers. This knowledge will enable them to tackle advanced topics in chemistry and apply their skills in various scientific and industrial settings.

Suggested reading:

1. Physical Chemistry by Atkins & Paula
2. Principles of Physical Chemistry by Puri, Sharma & Pathania
3. A text book of Physical Chemistry by Negi & Anand
4. Inorganic Chemistry by Puri, Sharma & Kalia
5. Inorganic Chemistry by J E Huheey
6. Basic Inorganic Chemistry by Cotton and Wilkinson
7. Organic Chemistry, Vol – I, by I L Finar, PEARSON.

Title of the course: Industrial Chemistry (SEC-3, Major)

Course Code: SEC-CHM-3.1

Total Credit: 3 (2 credit Theory + 1 Credit Practical)

Distribution of marks: 75 (End Semester) (50T+25P)

Course objective: To provide understanding of materials in industrial applications, fertilizers, drugs and energy devices.

Theory: 2 credits **Total course hours: 30** **Duration of examination: 2 hr.**

Unit – 1: Industrial applications **(5L, 8 marks)**

Water purification methods - zeolites, ion-exchange resins and reverse osmosis; Protective coatings for corrosion control: cathodic and anodic protection - PVD technique.

Unit – 2: Functional materials **(10L, 15 marks)**

Oxides of AB, AB_2, ABO_3 type (specific examples); Composites - types and properties; Polymers - thermosetting and thermoplastic polymers – synthesis and application (TEFLON, BAKELITE); Conducting polymers- polyacetylene and effect of doping – chemistry of display devices specific to OLEDs; Nano materials – introduction, bulk *vs* nano (quantum dots), top-down and bottom-up approaches for synthesis, and properties of nano Au.

Unit – 3: Fertilizers **(5L, 7 marks)**

Chemical fertilizers and organic manures-types of chemical fertilizers, nitrogenous fertilizers-methods of production of ammonia and urea, phosphatic fertilizers, potassic fertilizers and their applications.

Unit – 4: Energy Devices **(7L, 15 marks)**

Electrochemical and electrolytic cells – electrode materials with examples (semi-conductors), electrode-electrolyte interface- chemistry of Li ion secondary batteries, supercapacitors; Fuel cells: H_2-O_2 and solid oxide fuel cell (SOFC); Solar cells - photovoltaic cell (silicon based), photoelectrochemical cells and dye-sensitized cells.

Unit – 5: Drugs **(3L, 5 marks)**

Synthetic drug, synthesis of aspirin and paracetamol. Importance of chiral drugs.

Practical: 1 Credit **Total course hour: 30 hr** **Duration of Examination: 3 hr**

List of Experiments (Minimum three)

1. Determination of hardness of water sample by complexometric titration before and after ion-exchange process
2. Preparation of tin oxide by sol- gel method and its characterization
3. Laboratory scale preparation of important drug intermediate - para aminophenol for the synthesis for acetaminophen

4. Determination of Chemical Oxygen Demand (COD) of waste water
5. Colorimetric estimation of Ni^{2+} using conventional and smart phone digital-imaging methods.

Learning outcome: Following this course, students will have an understanding of both the most recent and historical advancements in industrial chemistry.

Suggested reading:

1. Theodore E. Brown, H Eugene, LeMay Bruce E. Bursten, Catherine Murphy, Patrick Woodward, Matthew E. Stoltzfus, Chemistry: The Central Science, 2017, 14th edition, Pearson Publishers, 2017. UK
2. Solid State Chemistry and its Applications, Anthony R. West. 2014, 2nd edition, Wiley, UK.
3. AngÃ¨le Reinders , Pierre Verlinden, Wilfried van Sark, Alexandre Freundlich, Photovoltaic solar energy: From fundamentals to Applications, 2017, Wiley publishers, UK.
4. Lawrence S. Brown and Thomas Holme, Chemistry for engineering students, 2018, 4th edition – Open access version.

Course Title: Introductory Chemistry – III (DSE - 3)

Course Code: MIN-CHM-3.1

Total Credit: 4 (3 credit Theory + 1 Credit Practical)

Distribution of marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course objective: The objective of this course to provide introductory ideas on s and p-block elements, transition Series elements, chemistry of alkyl and aryl halides, alcohol, phenol and ether, First and Second law of thermodynamics.

Theory: 3 credits **Total course hour: 45 hr** **Duration of examination: 2 hr**

Unit-1: s and p-block elements **(10 L, 12 marks)**

Inert pair effect, Relative stability of different oxidation states. Diagonal relationship. Allotropes of carbon, Sulphur and Phosphorous. Anomalous behavior of first member of each group. Complex formation tendency of s- and p-block elements. Hydrides and their classifications. Boron hydrides (Diborane). Boron nitride. Oxides and oxyacids of nitrogen, phosphorous and chlorine. Interhalogen compounds and pseudohalogens.

Unit-2: Transition Series (3d Series) **(5 L, 8 marks)**

General group trends with special reference to electronic configuration, variable valency, colour, magnetic and catalytic properties, ability to form complexes and stability of various oxidation states (Latimer diagrams) for Mn and Cu. Frost Ebsworth diagram.

Unit-3: Chemistry of alkyl and aryl halides (7L, 10 marks)

Alkyl Halides: Preparation from alkenes and alcohols. Nucleophilic substitution reaction and its types (SN^1, SN^2 reactions), solvolysis. Elimination vs substitution.

Aryl Halides: Preparation: from phenol, Sandmeyer & Gattermann reactions. Reactions: aromatic nucleophilic substitutions. Benzyne formation and reactions.

Unit-4: Alcohol, Phenol and Ether (8 L, 10 marks)

Alcohols: General methods of preparation alcohols. Reactions with HX (Lucas test), esterification, oxidation (with PCC, alkaline $KMnO_4$, acidic dichromate, conc. HNO_3). Diols: Pinacol-Pinacolone rearrangement.

Phenols: Preparation - Cumene hydroperoxide method, from diazonium salts. Reactions - Electrophilic substitution and important named reactions.

Ethers: Williamson's synthesis of ethers, important reactions of ether.

Unit-5: First Law of Thermodynamics (8 L, 10 marks)

Thermal equilibrium and zeroth law of thermodynamics- concept of temperature, Mechanical work, SI sign convention. 1^{st} law of thermodynamics, internal energy, enthalpy, reversible and irreversible processes, calculation of W, Q, ΔU, ΔH for expansion of ideal gas, isothermal work and enthalpy, relation between enthalpy change, and entropy change, molar heat capacities, relation between C_p and C_v, adiabatic processes- relation between P, V and T, Joule-Thomson effect, liquefication of gases, Enthalpy of reaction, enthalpy of different processes. Hess law calculations based on Hess law.

Unit-6: Second Law of Thermodynamics (7L, 10 marks)

Second law of thermodynamics, Spontaneous and Non-Spontaneous processes cyclic process- Carnot cycle, Entropy, Entropy change in reversible and irreversible processes and for ideal gas, concept of work function and free energy.

Practical: 1 Credit Total course hour: 30 hr Duration of Examination: 3 hr

List of experiments:

1. Semi-micro qualitative analysis using H_2S of mixture-not more than four ionic species (two anions and two cations and excluding insoluble salts) out of the following:

CO_3^{2-},NO_2^-,S^{2-},SO_3^{2-},$S_2O_3^-$,CH_3COO^-,F^-,Cl^-,Br^-,I^-,NO_3^-,BO_3^-,$C_2O_4^{2-}$,PO_4^{3-},NH_4^+,K^+,Pb^{2+},Cu^{2+},Cd^{2+},Bi^{3+},Sn^{2+},Sb^{3+},Fe^{3+},Al^{3+},Cr^{3+},Zn^{2+},Mn^{2+},Co^{2+},Ni^{2+},Ba^{2+},Sr^{2+},Ca^{2+}, Mg^{2+}.

(*Spot tests to be carried out wherever feasible*)

2. Acid-base Titrations: (Any one)

a) Estimation of Carbonate and hydroxide present together in a mixture.

b) Estimation of Carbonate and bicarbonate present together in a mixture.

3. Detection of functional groups in organic compounds.

4. Determination of heat capacity and enthalpy of reactions (Minimum three):

a) Determination of heat capacity of a calorimeter for different volumes using change of enthalpy data of a known system (method of back calculation of heat capacity of calorimeter from known enthalpy of solution or enthalpy of neutralization).
b) Determination of heat capacity of the calorimeter and enthalpy of neutralization of hydrochloric acid with sodium hydroxide.
c) Calculation of the enthalpy of ionization of ethanoic acid.
d) Determination of heat capacity of the calorimeter and integral enthalpy (endothermic and exothermic) solution of salts.
e) Determination of basicity/proticity of a polyprotic acid by the thermochemical method in terms of the changes of temperatures observed in the graph of temperature versus time for different additions of a base. Also calculate the enthalpy of neutralization of the first step.
f) Determination of enthalpy of hydration of copper sulphate.
g) Study of the solubility of benzoic acid in water and determination of ΔH.

Learning outcome: After completion of this course, students will be able to understand and apply concepts of s and p-block elements, Transition Series, Alcohol, Phenol and Ethers and thermodynamics in real life applications.

Suggested reading:

1. Physical Chemistry by Atkins & Paula
2. Principles of Physical Chemistry by Puri, Sharma & Pathania
3. A text book of Physical Chemistry by Negi & Anand
4. Inorganic Chemistry by Puri, Sharma & Kalia
5. Inorganic Chemistry: Principles of Structure and Reactivity by J E Huheey,E A Keiter, R L Keiter &O K Medhi.
6. Basic Inorganic Chemistry by Cotton and Wilkinson
7. A Text Book of Organic Chemistry by Arun Bahl and B. S. Bhal, S CHAND.
8. Comprehensive Practical Organic Chemistry: Qualitative Analysis by V. K. Ahluwalia and Sunita Dhingra

Course Title: Pesticide Chemistry (GE/MD-III)

Course Code: MD-CHM-3.1

Total Credit: 3

Distribution of marks: 45 (End Semester) (45T) + 15 (In-Semester) + 15(HA/S/GD)

Course objective: This course is aimed at providing students with the basic understanding of pesticides, types, benefits and environmental hazards as well as knowledge of pesticides formulation and packaging.

Theory: 3 credits **Total course hour: 30 hr** **Duration of examination: 3 hr**

Unit-1: **(8 L, 10 marks)**

General introduction to pesticides (natural and synthetic), benefits and adverse effects, changing concepts of pesticides, structure activity relationship. Chemical and Botanical pesticides, Classification of pesticides based on chemicals, nature, types of targets, Systemic and non-systemic Pesticides

Unit-2: **(10 L, 20 marks)**

Synthesis and technical manufacture and uses of representative pesticides in the following classes: Organochlorines (DDT, Gammexene); Organophosphates (Malathion, Parathion); Carbamates (Carbofuran and carbaryl); Quinones (Chloranil), Anilides (Alachlor and Butachlor). Ecofriendly pesticides. Degradation, mode of actions and toxicity.

Safety measures: Environmental aspects and degradability

Unit-3: **(12 L, 30 marks)**

Introduction of pesticide formulations: Definition, History, Purpose. Brief account of main types. Study of conventional formulations: Dusting, Powders/ Dust Formulations (DP), Granules (GR), Water Dispersible Powders/Wettable powders (WDP/WP), Soluble Concentrates (SC), Emulsifiable concentrates (EC), Ultra Low volume (ULV) with respect to their ingredients, advantages and disadvantages.

Current trends in single trip containers, Liquid Formulations: Rigid plastics, High Density Polyethylene, (HDPE), Polyethylene Terephathalate (PET), Ethylene Vinyl Alcohol (EVOH), and Polyamide (PA). Solid Formulations: Polyethylene, Laminates–Low Density Polyethylene (LDPE), Aluminum foil, LDPE plus ether, Polypropylene (PP), Polyester (PET), Polyamide (PA) Paper, Water soluble Films Paper on packaging material used to pack pesticides (technical and formulation) like Dust, EC, SC, WP, WDG).

Recent insect attractants, Chemosterilants and Repellents, Applications of Neem in plant protection: Introduction, Chemical constituents and Mode of action, Bio-efficacy of neem preparations.

Learning Outcome:

Upon completion of the course the students will

1. Understand the types of pesticides, mode of actions, degradability and associated toxicity with the use of pesticides
2. Know about the pesticide formulations and packaging styles.
3. be able to correlate the classroom knowledge with the real-life applications.

Suggested reading:

1. R. Cremlyn: Pesticides, Preparation and Mode of Action, John Wiley & Sons, New York, 1978.
2. R P Bateman, Pesticide Applications, AAB Press, 2004.
3. Principles of Pesticide chemistry: S K Handa, Ed. by Agrobios (India), 2008.
4. Pesticide Science & Biotechnology: R Greenhalgh and T R Robers, IUPAC, Blackwell Scientific Publications, 1987.
5. The Chemical Process Industries: D N Shreve
6. Pesticide Chemistry: G Matolesy, M. Nadasy, V. Andriska, Elsevier Sc. Publisher, USA, 1988.

B.SC. IN CHEMISTRY

DETAILED SYLLABUS OF FYUGP SEMESTER-IV

Title of the course: Inorganic Chemistry – I (DSC-5)

Course Code: MAJ-CHM-4.1

Total Credit: 4 (3 credit Theory + 1 Credit Practical)

Distribution of marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course objective:

To give the students a fundamental understanding of Inorganic Polymers, structure and applications connected to it. To educate students about the nature of Transition elements, Lanthanides and Actinides, Coordination Chemistry and give some knowledge about Bioinorganic Chemistry. To make students aware of the Principles of Qualitative and Quantitative analysis

Prerequisite: Basic inorganic chemistry.

Theory: 3 credits **Total course hour: 45 hr** **Duration of examination: 2 hr**

Unit 1: Inorganic Polymers (5L+10 Marks)

Types of Inorganic polymers, Comparison with organic polymers, synthesis, structural aspects and applications of silicones and siloxanes, Borazines, Silicates and Phosphazenes and polysulphates.

Unit 2: Transition Elements (8L+10 Marks)

Characteristics of d-block elements, Oxides, hydroxides and salts of first row metals; General group trends with spectral reference to electronic configuration, Colour, variable valency, magnetic and catalytic properties, ability to form complexes, stability of various oxidation states and e.m.f. (latimer and Frost ebsworth diagrams). Difference between the first, second and third transition series.

Unit 3: Lanthanoids and Actinoids (8L+8 Marks)

Electronic configuration, Oxidation states, colour, spectral and magnetic properties, Lanthanide contraction, Causes and consequences. Separation of Lanthanides (Ion –exchange method only).

General features of Actinoids: Formation of complexes. Comparison with lanthanoids.

Unit 4: Coordination Chemistry (9L+12 Marks)

Coordination compounds, types of ligands, Werner's theory. IUPAC nomenclature and isomerism in coordination compounds. Stereochemistry of complexes with 4 and 6 coordination numbers. Valence bond theory (inner and outer orbital complexes), electroneutrality principle and back bonding, Crystal field theory, measurement of 10 Dq (Δ_o), CFSE in weak and strong fields, pairing energies, factors affecting the magnitude of 10 Dq (Δ_0, Δ_t). Octahedral versus tetrahedral coordination, trigonal distortions from octahedral geometry. Jahn-Teller theorem, square planar geometry. Qualitative aspects of ligand field and Molecular orbital theory. Chelate effect. Lability and inertness.

Unit 5: Bioinorganic Chemistry (8L+10 Marks)

Metal ions present in biological systems, classification of elements according to their action in biological system. Sodium-Potassium pump, Carbonic anhydrase and carboxypeptidase. Excess and deficiency of some trace metals Toxicity of metal ions (Hg, Pb, Cd, As), reasons for toxicity, Use of metals in medicine: Use of chelating agents in medicine.

Iron and its application in bio-systems. Myoglobin and hemoglobin. Role of hemoglobin and myoglobin in biological systems. Cooperativity effect and Bohr effect.

Unit 6: Analytical Chemistry (7L+10 Marks)

Principles of qualitative and quantitative analysis. Acid-base, oxidation-reduction and complexometric titrations using EDTA; Precipitation reactions; use and types of indicators; use of organic reagents in inorganic analysis. Radioactivity. Nuclear reactions, applications of isotopes.

Practical: 1 Credit Total course hour: 30 hr Duration of Examination: 3 hr

List of experiments:

1. **Iodo/Iodimetric titration:**
   i. Estimation of Cu(II) and $K_2Cr_2O_7$ using sodium thiosulphate solution iodimetrically
   ii. Estimation of available Chlorine in bleaching powder iodometrically.
2. **Inorganic Preparatios (minimum 2):**
   i. Preparation of Cuprous chloride, CuCl
   ii. Preparation of Aluminium potassium sulphate $KAl(SO_4)_2.12H_2O$ (Potash alum) or Chrome alum.
   iii. Preparation of Manganese (III) phosphate, $MnPO_4{\cdot}H_2O$

Learning outcome:

Upon completion of this course the students will gain an understanding of

1. Structural aspects and applications of Inorganic polymer.
2. Predict the characteristics of d-block elements
3. Knowledge of Lanthanoids and Actinoids
4. Introduction to Coordination Chemistry, Valence bond theory, Crystal field theory, Molecular orbital theory.
5. Metal ions in Bioinorganic Chemistry and their applications.
6. Analytical Chemistry.

Suggested reading:

1. Inorganic Chemistry: Principles of Structure and Reactivity by J E Huheey, E A Keiter, R L Keiter & O K Medhi.
2. Basic Inorganic Chemistry by Cotton and Wilkinson
3. Advanced Inorganic Chemistry by Cotton and Wilkinson
4. Inorganic Chemistry by Puri, Sharma & Kalia.
5. A Text Book of Practical Chemistry by Sudarshan Barua

Title of the course: Organic Chemistry - I (DSC-6)

Course Code: MAJ-CHM-4.2

Total Credit: 4 (3 credit Theory + 1 Credit Practical)

Distribution of marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course objective:

This course aims at introducing some important topics of organic chemistry, namely carbonyl compounds, carboxylic acids, amines and aromatic hydrocarbons.

Prerequisite: Basic organic chemistry reaction mechanism.

Theory: 3 credits **Total course hour: 45 hr** **Duration of examination: 2 hr**

Unit 1: Carbonyl Compounds **(15L+20 Marks)**

Preparation of carbonyl compounds from other functional groups. Reactions – with HCN, ROH, $NaHSO_3$, amine derivatives. Cannizzaro's reaction, Benzoin condensation. Chemistry of -carbon of carbonyls - pKa of C-H, keto-enol tautomerism. Halogenation, haloform reaction, aldol reaction. Reformatsky reaction, Michael reaction, Robinson annulation, Knoevenagel condensation, Claisen ester condensation, Perkin reaction, Stobbe condensation, Darzens reaction, acyloin condensation, McMurry coupling Wittig reaction and other named reactions. Malonic and acetoacetic esters: Characteristic reactions of active methylene group, synthetic uses of malonic, acetoacetic and cyanoacetic ester.

Unit 2: Carboxylic acids **(10L+15 Marks)**

Preparation carboxylic acids by acid and base mediated hydrolysis of esters. Reactions: Hell–Vohlard-Zelinsky reaction and reactions involving carboxylic functionality. Carboxylic acid derivatives: acid chlorides, anhydrides, esters and amides from acids and their interconversion.

Unit 3: Amines **(10L+15 Marks)**

Preparation of amines from alkyl halides, Gabriel's Phthalimide synthesis, Hofmann bromamide reaction and by reduction reactions. Reactions - Hofmann degradation, qualitative tests for amines, Schotten – Baumann Reaction. Electrophilic substitution: nitration, bromination, sulfonation. Diazonium compounds – preparation and reactions.

Unit 4: Aromatic hydrocarbons: **(10L+10 Marks)**

Preparation of benzene from phenol, by decarboxylation and from acetylene. Reactions of benzene: electrophilic substitution: nitration, halogenation and sulfonation. Friedel-Craft's reaction - alkylation and acylation. Side chain oxidation of alkyl benzenes.

Practical: 1 Credit **Total course hour: 30 hr** **Duration of Examination: 3 hr**

List of experiments (Minimum four):

1. Estimation of Glycine
2. Estimation of hydroxyl group
3. Estimation of Carboxylic acid
4. Estimation of Glucose
5. Determination of saponification value of fats and oils.

Learning outcome:

After completing this course students will know how to synthesize carbonyl compounds, carboxylic acids, amines, and aromatic hydrocarbons, in addition to learning about their reactivity.

Suggested reading:

1. Organic Chemistry, Vol – I, by I L Finar, PEARSON.
2. Organic Chemistry by Janice Gorzynski Smith, 2nd Ed., The McGraw Hill Com.
3. Vogel's Text Book of Practical Organic Chemistry, 5^{th} Ed., PEARSON.
4. Comprehensive Practical Organic Chemistry: Qualitative Analysis by V. K. Ahluwalia and Sunita Dhingra

Title of the course: Physical Chemistry – I (DSC-7)

Course Code: MAJ-CHM-4.3

Total Credit: 4 (3 credit Theory + 1 Credit Practical)

Distribution of marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course objective: The course aims to provide a comprehensive understanding of electrochemistry and solution chemistry, emphasizing theoretical foundations, analytical techniques, and practical applications in both laboratory and industrial settings.

Prerequisite: Basic foundational knowledge in general chemistry, including chemical bonding, reaction kinetics, and thermodynamics.

Theory: 3 credits **Total course hour: 45 hr** **Duration of examination: 2 hr**

Unit 1: Electrochemistry I **(15L+20 Marks)**

Arrhenius theory of electrolytic dissociation, conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Molar conductivity at infinite dilution. Kohlrausch law of independent migration of ions. Debye-Huckel-Onsager equation, Wien effect, Debye-Falkenhagen effect, Walden's rules. Ionic velocities, mobilities and their determinations, transference number and their relation to ionic mobilities, determination of transference number using Hittorf and Moving Boundary methods. Applications of conductance measurement: (i) degree of dissociation of weak electrolytes, (ii) ionic product of water (iii) solubility and solubility product of sparingly soluble salts, (iv) conductometric titrations, and (v) hydrolysis constants of salts.

Unit 2: Electrochemistry II **(20L+25 Marks)**

Quantitative aspects of Faraday's law of electrolysis, rules of oxidation/reduction of ions based on half-cell potentials, Chemical cells, reversible and irreversible cells with examples. Electromotive force of a cell and its measurement, Nernst equation; Standard electrode (reduction) potential and its application to different kinds of half-cells. Application of EMF measurements in determining (i) free energy, enthalpy and entropy of a cell reaction, (ii) equilibrium constant, and (iii) pH values, using hydrogen, quinine-hydroquinone, glass and SbO/Sb_2O_3 electrodes. Concentration cells with and without transference, liquid junction potential; determination of activity coefficients and transference numbers. Qualitative discussion of potentiometric titrations (acid-base, redox, precipitation). Applications of electrolysis in metallurgy and industry.

Unit 3: Solution **(10L+15 Marks)**

Dilute solutions, lowering of vapour pressure, Raoult's and Henry laws and their applications. Excess thermodynamic functions. Osmosis and osmotic pressure. Determination of molar mass for osmotic pressure measurement. Relation between osmotic pressure and vapour pressure lowering of an ideal solution, Theory of semi permeability, reverse osmosis, van't hoff law, van't hoff factor. Thermodynamic derivation using chemical potential to derive relations between the four colligative properties (i) relative lowering of vapour pressure, (ii) elevation of boiling point, (iii) Depression of freezing point, (iv) osmotic pressure and amount of solute. Application in calculating molar masses of normal, dissociated and associated solutes in solution.

Practical: 1 Credit **Total course hour: 30 hr** **Duration of Examination: 3 hr**

List of experiments (Minimum four):

1. Determination of cell constant and hence the specific conductance of an electrolyte.
2. Conductometric titrations of i. strong acid vs strong base, ii. Weak acid vs strong base.

3. Determination of equivalent conductance of a strong electrolyte at various dilutions and verification of Onsager equation.
4. Determination of equivalent conductance, degree of dissociation and dissociation constant of a weak acid.
5. Potentiometric titration of a mixture of strong and weak acids vs strong base.
6. Potentiometric titration of ferrous ammonium sulphate against standard $K_2Cr_2O_7$, $KMnO_4$ and determination of redox potential of Fe(II)-Fe(III) system.

Learning outcome:

Upon completing this course, students will be able to

1. Understand key electrochemical concepts, including electrolytic dissociation, conductivity, and electrochemical cell dynamics.
2. Apply principles such as Kohlrausch's Law and the Nernst equation to solve electrochemical problems.
3. Conduct experiments to determine ionic mobilities, dissociation degrees, and thermodynamic properties.
4. Analyze solution behavior using colligative properties and osmotic pressure.
5. Integrate theoretical knowledge with practical applications in industry and laboratory settings.

Suggested reading:

1. Physical Chemistry by Atkins & Paula
2. Principles of Physical Chemistry by Puri, Sharma & Pathania
3. A text book of Physical Chemistry by Negi & Anand
4. Practical Chemistry by Yadav.

Course Title: Introductory Chemistry – IV (DSE-4)

Course Code: MIN-CHM-4.1

Total Credit: 4 (3 credit Theory + 1 Credit Practical)

Distribution of marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course objective: To provide knowledge and hands on experience of acids-bases, metallurgical processes, chemical reactions involving carbonyl compounds, carboxylic acids and amines, electrochemistry principles and applications.

Theory: 3 credits **Total course hour: 45 hr** **Duration of examination: 2 hr**

Unit-1: Acids and Bases, Oxidation-Reduction and general principles of metallurgy.

(15 L + 20 marks)

Bronsted-Lowry concept of acids base reaction, Solvated proton, relative strength of acids, types of acids-base reactions, leveling solvents, Lewis acid-base concept, classification of

Lewis acids, Hard & soft acids and bases (HSAB), Pearson's concept, Bonding in hard-hard and soft-soft combinations, Application of (HSAB) principle, Symbiosis.

Redox equation, standard electrode potential and its application to Inorganic reactions, principles involved in volumetric analysis, principles and applications of Ellingham diagram, General methods of isolation and purification of Electrolytic process and Mond's process, Zone refining.

Unit-2: Carbonyl compounds, Carboxylic acids and Amines (15 L + 20 marks)

Carbonyl Compounds: General methods of preparation of carbonyl compounds. Reactions – with HCN, ROH, $NaHSO_3$, amine derivatives. Important name reactions involving carbonyl compounds. Haloform reaction, aldol reaction, Cannizzaro reaction, Reformatsky reaction, Michael addition, Knoevenagel condensation, Perkin reaction, and Wittig reaction.

Carboxylic acids: Preparation carboxylic acids by acid and base mediated hydrolysis of esters. Hell-Vohlard-Zelinsky reaction. Carboxylic acid derivatives: acid chlorides, anhydrides, esters and amides from acids and their interconversion.

Amines: Preparation of amines from alkyl halides, Gabriel's Phthalimide synthesis, Hofmann bromamide reaction. Reactions - Hofmann degradation, qualitative tests for amines, Schotten – Baumann Reaction. Electrophilic substitution: nitration. Diazonium compounds – preparation and Sandmeyer reaction.

Unit-3: Electrochemistry (10 L + 20 marks)

Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Kohlrausch law of independent migration of ions. Transference number and its experimental determination using moving boundary methods. Ionic mobility. Conductometric titrations.

Reversible and irreversible cells. Concept of EMF of a cell. Measurement of EMF of a cell. Nernst equation and its importance. Types of electrodes. Standard electrode potential. Electrochemical series. Thermodynamics of a reversible cell, calculation of thermodynamic properties: ΔG, ΔH and ΔS from EMF data.

Unit-4: Solutions (5 L + 20 marks)

Thermodynamics of ideal solution: Ideal solutions and Raoult'slaw, deviations from Raoult's law, non-ideal solutions, vapour pressure-composition, temperature-composition curves for ideal and non-ideal solutions, distillation of solution and Lever rule.

Practical: 1 Credit Total course hour: 30 hr Duration of Examination: 3 hr

List of experiments:

1. Volumetric estimation of
   a) water of crystallization in Mohr's salt by titrating with $KMnO_4$.
      or
   b) Na_2CO_3 and $NaHCO_3$ present together in a mixture

2. Detection of functional groups in organic compounds.
3. Determination of cell constant and hence the specific conductance of an electrolyte.
4. Conductometric titrations
    a) strong acid vs strong base,
        or
    b) Weak acid vs strong base.

Learning outcome: After completion of this course students will be able to understand and apply the concepts of acids-bases, redox reactions involved in metallurgical processes, reactions involving carboxylic acids, amines and electrochemistry in real life applications.

Suggested reading:

1. A Text Book of Organic Chemistry by Arun Bahl and B. S. Bhal, S CHAND.
2. Comprehensive Practical Organic Chemistry: Qualitative Analysis by V. K. Ahluwalia and Sunita Dhingra.
3. Physical Chemistry by Atkins & Paula
4. Principles of Physical Chemistry by Puri, Sharma & Pathania
5. A text book of Physical Chemistry by Negi & Anand
6. Practical Chemistry by Yadav.

B.SC. IN CHEMISTRY

DETAILED SYLLABUS OF FYUGP SEMESTER-V

Course Title: Inorganic Chemistry-II (DSC-8)

Course Code: MAJ-CHM-5.1

Total Credit: 4 (3 Credit Theory + 1 Credit Practical)

Distribution of marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Theory: 3 Credits Total course hour: 45 hr Duration of Examination: 2 hr

Course objective: The course aims to equip students with knowledge, focusing on nuclear chemistry & radio-activity and bonding and application aspects of coordination chemistry. The unit on reaction mechanism is included for the students to get acquainted with the kinetic and thermodynamic factors governing the reaction path and stability of inorganic compounds. This course introduces students to organometallic chemistry. Various aspects like classifications, structure, bonding, variety and reactivity of some organometallic complexes are included for the students to appreciate.

Unit-1: Nuclear Chemistry & Radio-activity (10 Lectures)

Classification of nuclides based on the number of nucleons- Isotopes, Isobars, Isotones; Nuclear Isomer; Nuclear Spin; Shape of Nucleus; The Neutron to Proton Ratio and Different Modes of Decay; Fajans & Soddy's Group Displacement Law; Artificial Radioactivity; Nuclear Reactions- transmutation of elements, fission, fusion and spallation; Nuclear Reaction Cross-Section; The Disintegration Series; Packing Fraction, Nuclear Binding Energy and Nuclear Stability; magic numbers; Radioactive Decay Kinetics; Application of Radioactivity in Age Determination; Separation and uses of radioactive isotopes; Nuclear Forces; Nuclear Model- Nuclear and Shell Model.

Unit-2: Coordination Chemistry-II (12 Lectures)

Factors affecting the magnitude of 10 Dq (Δ_o, Δ_t): role of coordination geometry; Crystal field splitting of d orbitals in different types of coordination geometry; Spectrochemical series of ligands and metals; Uses and limitations of CFT; Evidences in favour of CFT: variation of hydration energies, lattice energy, octahedral crystal ionic radii, spinel, OSSE; Experimental evidences in favour of metal-ligand overlap; Nephelauxetic series; Structural distortion and lowering of symmetry, electronic, steric and Jahn-Teller effects on energy levels; Molecular Orbital approach of bonding in coordination compounds; Stability of metal complexes: Thermodynamic and kinetic stability; Stabilization of unusual oxidation states (higher oxidation states and lower oxidation states) of metals.

Unit-3: Inorganic Reaction Mechanism-I (12 Lectures)

Introduction to inorganic reaction mechanisms. Thermodynamic and Kinetic stability, Inert and Labile Complexes, Classification of ligand substitution reaction mechanism, associative, dissociative, interchange. Ligand field effects and reaction rates, Mechanism of substitution in octahedral complexes: Acid and Base Hydrolysis, Kinetics of octahedral substitution reaction, Substitution reactions in square planar complexes, Trans- effect, theories of trans effect, Mechanism of nucleophilic substitution in square planar complexes.

Unit-4: Organometallic Chemistry-I (11 Lectures)

Definition and classification of organometallic compounds; Concept of hapticity of organic ligands; Effective Atomic Number (EAN) Rule; Eighteen Electron (18e) Rule; Metal Carbonyls- 18 electron rule, electron count of mononuclear, polynuclear and substituted metal carbonyls of 3d series. General methods of preparation (direct combination, reductive carbonylation, thermal and photochemical decomposition) of mono and binuclear carbonyls of 3d series. Structures of mononuclear and binuclear carbonyls of Cr, Mn, Fe, Co and Niusing VBT. π-acceptor behaviour of CO, synergic effect and use of IR data to explain extent of back bonding; Metal Nitrosyls.

Practical: 1 Credit Total course hour: 30 hr Duration of Examination: 3 hr

List of experiments:

1. Qualitative semimicro analysis of mixtures containing 3 anions and 3 cations:
Emphasis should be given to the understanding of the chemistry of different reactions. The following radicals are suggested:
CO_3^{2-}, NO_2^-, S^{2-}, SO_3^{2-}, $S_2O_3^{2-}$, CH_3COO^-, F^-, Cl^-, Br^-, I^-, NO_3^-, BO_3^{3-}, $C_2O_4^{2-}$, PO_4^{3-}, NH_4^+, K^+, Pb^{2+}, Cu^{2+}, Cd^{2+}, Bi^{3+}, Sn^{2+}, Sb^{3+}, Fe^{3+}, Al^{3+}, Cr^{3+}, Zn^{2+}, Mn^{2+}, Co^{2+}, Ni^{2+}, Ba^{2+}, Sr^{2+}, Ca^{2+}, Mg^{2+}
Mixtures should preferably contain one interfering anion, or insoluble component ($BaSO_4$, $SrSO_4$, $PbSO_4$, CaF_2 or Al_2O_3) or combination of anions e.g., CO_3^{2-} and SO_3^{2-}, NO_2^- and NO_3^-, Cl^- and Br^-, Cl^- and I^-, Br^- and I^-, NO_3^- and Br^-, NO_3^- and I^-.
Spot tests should be done whenever possible.
2. Inorganic preparations:
(i) Potassium Trioxalato Chromate(III), $K_3 [Cr (C_2O_4)_3] \cdot 3H_2O$
(ii) Prussian Blue $Fe_4[Fe(CN)_6]_3$
(iii) Synthesis of ammine complexes of Ni(II)
(iv) Preparation of acetylacetanato complexes of Cu^{2+}/Fe^{3+}
(v) Hexammino Cobaltic Chloride, $[Co (NH_3)_6]Cl_3$

Learning outcome:

(i) On completion of this course the students will be able to understand fundamental aspects of nuclear chemistry and radio-activity.

(ii) Students will be expected to enrich themselves by the detail discussion on coordinate bonding through crystal field theory and molecular orbital theory and application part of coordination chemistry.

(iii) By studying this course the students will be expected to learn about how ligand substitution and redox reactions take place in coordination complexes. Students should understand the relationship between thermodynamics and kinetics in inorganic reactions.

(iv) Students will also learn about organometallic compounds like metal carbonyl and metal nitrosyl, comprehend their bonding, stability, reactivity and uses.

(v) Through practical courses, students will grasp the theoretical foundation of qualitative inorganic analysis, including the principles of separation and identification of ions in a mixture. They will understand and apply concepts like the common ion effect, solubility product, ionic product and other relevant equilibrium principles.

(vi) Preparation of simple inorganic compounds is introduced to give hands-on experience of inorganic synthesis. Experiments in this course will boost their quantitative estimation skills and introduce the students to preparative methods in inorganic chemistry.

Suggested reading:

(1) Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson, 2006.
(2) Cotton, F.A. & Wilkinson, G, Advanced Inorganic Chemistry Wiley-VCH, 1999.
(3) Atkin, P. Shriver & Atkins' Inorganic Chemistry 5th Ed. Oxford University Press (2010).
(4) Elias, B. D. Gupta, Basic Organometallic Chemistry, Universities Press (ed. 2), 2013.
(5) Crabtree, R. H. The Organometallic Chemistry of the Transition Metals. New York, NY: John Wiley, 2000.
(6) R. P. Sarkar, General and Inorganic Chemistry (Vol. 1), New Central Book Agency, ed. 3, 2011
(7) Asim K. Das Fundamental Concepts of Inorganic Chemistry, Vol-1, Vol-4, Vol-5 & Vol-6, CBS Publishers & Distributors
(8) H J Arnikar, Essentials of Nuclear Chemistry, New Age International Publishers.
(9) Vogel's Qualitative Inorganic Analysis, Revised by G. Svehla. Pearson Education, 2012.
(10) Marr, G. and Rockett, R.W. Practical Inorganic Chemistry, Van Nostrand Reinhold. 1972.
(11) An Advanced Course in Practical Chemistry by Nad, Mahapatra & Ghosal. Publisher, New Central Book Agency (P) Limited, 2014.

Title of the Course: Organic Chemistry-II (DSC-9)

Course Code: MAJ-CHM-5.2

Total Credit: 4 (3 Credit Theory + 1 Credit Practical)

Marks Distribution: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15 (HA/S/GD)

Course Objective: To equip students with a comprehensive understanding of spectroscopic methods, reaction mechanisms, and structural principles in organic chemistry, enabling them to analyze, interpret, and synthesize organic compounds effectively through both theoretical and practical approaches.

Prerequisite: A foundational understanding of organic chemistry, including knowledge of functional groups, basic reaction mechanisms, and introductory spectroscopy (UV, IR, NMR), as well as general principles of chemical bonding and molecular structure.

Theory: 3 Credits **Total course hour: 45 hr** **Duration of Examination: 2 hr**

Unit 1: Spectroscopic Methods of Structure Determination (20 Lectures)

UV-Visible Spectroscopy: Basic principle of electronic transitions, effect of conjugation on λ_{max}, Woodward-Fieser rules for conjugated dienes and α, β-unsaturated carbonyl compounds,
IR Spectroscopy: Basic principle of molecular vibrations, characteristic frequencies of carbonyl, hydroxyl, amino, acids and hydrocarbons, identification of functional groups using IR,
NMR Spectroscopy: Principles of NMR spectroscopy, chemical shift (^{1}H NMR), shielding and deshielding effects, chemical and magnetic equivalence, spin-spin coupling, splitting patterns, coupling constants, Karplus equation, basics of ^{13}C NMR, proton decoupling, and applications of spin decoupling and DEPT techniques. Application to simple organic molecules.
Mass spectrometry: Principle, types of ion produced in mass spectrometer, molecular ion peak, base peak and metastable ion, determination molecular weight of organic compounds, MS analysis with fragmentation pattern of simple organic molecules.

Unit 2: Rearrangement Reactions (10 Lectures)

General concept, electrophilic, nucleophilic and radical rearrangement; Migratory aptitudes of groups, Stereoelectronic effects in rearrangement reactions.
Carbenes: Generation, Structure and stability. Carbene-Based Rearrangement Reactions: Wolff Rearrangement, Simmons-Smith, Carbylamine Reaction,
Nitrenes: Generation and Structure. Nitrene-Based Rearrangement Reactions: Curtius, Hofmann, Schmidt and Lossen Rearrangement.
Free Radical Rearrangements: Hunsdiecker, Barton and Hofmann–Löffler–Freytag Reaction.

Unit 3: Pericyclic Reactions (5 Lectures)

Types of pericyclic reactions (Electrocyclic, Cycloaddition and Sigmatropic Rearrangements), Symmetry in σ and π molecular orbitals, Frontier Molecular Orbitals. Electrocyclic Reactions: Conrotatory and Disrotatory motion in ring opening and ring closing reactions in (4n) and (4n+2) π electron systems, FMO method, Woodward Hoffmann rule. Cycloaddition Reactions: [2+2] and [4+2] π cycloaddition reactions, Diels Alder reaction (electron rich and electron poor dienes and dienophiles, Stereochemistry, Alder rule of endo addition).

Sigmatropic Reactions: [1, 3], [1, 5] and [3, 3] sigmatropic rearrangements, Cope rearrangement, Claisen Rearrangements

Unit 4: Organic Photochemistry (5 Lectures)

Principles, light absorption, Jablonski diagram, singlet and triplet states; laws of photochemistry: Grotthuss-Draper law, Stark-Einstein law; types of photochemical reactions: photodissociation, photoisomerization, photoreduction, and photooxidation; excited state properties: energy transfer, fluorescence, phosphorescence, quenching; photoreactions of carbonyl compounds: Norrish Type I and Type II reactions, Paternò-Büchi reaction; photochemistry of alkenes: cis-trans isomerization.

Unit 5: Heterocyclic Compounds (5 Lectures)

Classification, nomenclature and structure; Aromaticity in 5-numbered and 6-membered rings; Synthesis and reactivities of: Furan, Pyrrole and Thiophene, Pyridine, Indole, Quinoline, Isoquinoline; Synthesis and aromaticity in pyrimidine and purine.

Practical: 1 Credit **Total course hour: 30 hr** **Duration of Examination: 3 hr**

List of Experiments:

1. Green synthesis of acetanilide
2. Preparation of methyl orange
3. Preparation of benzilic acid from benzyl
4. Diels-Alder reaction between furan and maleic acid
5. Preparation of benzanilide from benzophenone
6. Differentiation between of *o*-/*p*-hydroxybenzaldehyde by IR spectroscopy (Spectra to be provided).
7. Differentiation between of benzoic acid and cinnamic acid by UV spectroscopy (Spectra to be provided)
8. Synthesis of 3,5-dimethyl pyrazole by condensation of acetylacetone and hydrazine.

Learning Outcomes:

By the end of the course, students will be able to:

- Understand and apply key spectroscopic techniques (UV-Vis, IR, NMR, MS) for structure determination of organic compounds.
- Analyze major organic reaction mechanisms, including rearrangements, pericyclic, and photochemical processes.
- Interpret molecular behavior using theoretical principles like FMO theory, Woodward–Hoffmann rules, and stereoelectronic effects.
- Explore the structure, aromaticity, and reactivity of important heterocyclic compounds.
- Develop essential laboratory skills through hands-on synthesis, with an emphasis on green and sustainable chemistry practices.

Suggested reading:

1. Silverstein R.M. (2005), Spectrometric Identification of organic compounds, 7th edition, John Wiley and Sons.
2. Kemp W. (2019), Organic Spectroscopy, Third Edition, MacMillan.
3. Pavia, D. (2015), Introduction to Spectroscopy, Fifth Edition, Cengage Learning India Pvt. Learning.
4. Scheinmann, F., Introduction to spectroscopic methods for identification of organic compounds, Volume 2, Pergamon Press.
5. McMurry, J.E. Fundamentals of Organic Chemistry, 7th Ed. Cengage Learning India Edition, 2013.
6. Clayden, J., Greeves N., Warren, S., Organic Chemistry, Oxford University Press 2nd Ed., 2012.
7. M. B. Smith, J. March, March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure, 2007 John Wiley & Sons, Inc.
8. Norman, R.O.C. and Coxon, C. M. Principles of Organic Synthesis, CRC Press, New York, 2009.
9. Sankararaman, S. Pericyclic Reactions – A textbook. Wiley-VCH, 2005.
10. Fleming, I. Pericyclic Reactions, Oxford University Press, 1999.
11. Davies, D. T., Aromatic Heterocyclic Chemistry (Oxford Chemistry Primers) 1st Edition

Course Title: Physical Chemistry II (DSC-10)

Course Code: MAJ-CHM-5.3

Total Credit: 4 (3 Credit Theory + 1 Credit Practical)

Distribution of marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course objective: This course aims to provide undergraduate students with a fundamental understanding of reaction rates, mechanisms, and factors influencing chemical kinetics. It also covers the principles of surface chemistry and catalysis, enabling students to relate molecular behavior to macroscopic phenomena and apply concepts in both academic and industrial chemical contexts.

Theory: 3 Credits **Total course hour: 45 hr** **Duration of Examination: 2 hr**

Unit-1: Chemical Kinetics (20 Lectures)

Order and molecularity of a reaction, experimental determination of order of reactions, rate laws in terms of the advancement of a reaction, differential and integrated form of rate expressions up to second order reactions, experimental methods of the determination of rate laws, Steady state approximation, kinetics of complex reactions: (i) Opposing reactions (ii) parallel reactions and (iii) consecutive reactions and their differential rate equations (iv) chain reactions, Enzyme catalysis: Derivation of Michaelis-Menten equation and interpretation of Lineweaver-Burk Plots. Eadie- Hofstee plot. Unimolecular reactions: Lindemann mechanism, Hinshelwood correction.

Temperature dependence of reaction rates; Arrhenius equation; activation energy. Collision theory of reaction rates, Activated complex theory, thermodyamic formulation and derivation of Eyring equation. Evaluation of Arrhenius pre-exponential factor from transition state theory.

Unit-2: Surface Chemistry (10 Lectures)

Absorption, Adsorption, Types of adsorption: Physical adsorption, dissociative and molecular chemisorption, adsorption isotherms, Frieundlich, Langmuir and BET adsorption isotherms.

Unit-3: Catalysis (15 Lectures)

Catalyst and catalysis, Types of catalyst, activity, selectivity and stability of catalysts, turn over frequency, turn over number, homogeneous and heterogeneous catalysts, homogeneously and heterogeneously catalyzed reactions, acid-base catalysis, theory of heterogeneous catalysis, Langmuir-Hinshelwood and Eley-Rideal mechanisms of heterogeneously catalyzed reactions, autocatalysis, poisoning of catalyst, deactivation and reactivation of catalysts, effect of particle size and efficiency of nanoparticles as catalysts.

Practical: 1 Credit **Total course hour: 30 hr** **Duration of Examination: 3 hr**

List of Experiments:

1. Determination of rate constants of hydrolysis of an ester in presence of an acid.

2. Determination of rate constants of hydrolysis of an ester in presence of a base (saponification)
3. Determination of activation energy of a chemical reaction
4. Surface Tension Measurement Using Drop Number Method
5. Adsorption of Acetic Acid on Activated Charcoal
6. Catalytic Decomposition

Learning outcome:

Upon completion, students will be able to analyze reaction kinetics, interpret mechanisms, and understand catalysis, and adsorption phenomena. They will gain practical experience on these topics which will enable them to develop a strong conceptual base for advanced studies or careers in chemistry-related fields.

Suggested reading:

(1) Atkin's Physical Chemistry, P. Atkins, J. de Paula, J. Keeler.

(2) Chemical Kinetics, K. J. Laidler

(3) Physical Chemistry, Puri, sharma, Pathania.

(4) Physical Chemistry, P. C. Rakshit.

(5) Jadav, J. B. Advanced Practical Physical Chemistry, (Krishna Prakashan, 2015)

(6) Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).

(7) Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. Experiments in Physical Chemistry 8^{th} Ed.; McGraw-Hill: New York (2003).

(8) Halpern, A. M. & McBane, G. C. Experimental Physical Chemistry 3rd Ed.; W.H. Freeman & Co.: New York (2003).

Title of the Course: Quantum Chemistry & Molecular Spectroscopy-I (DSC - 11)

Course Code: MAJ-CHM-5.4

Total Credit: 4 (3 Credits theory +1 Credit Practical)

Distribution of Marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Theory: 3 Credits Total course hour: 45 hr Duration of Examination: 2 hr.

Course Objective: The objective of this course is to introduce the basic principles of Quantum mechanics and to solve few model problems using those principles. A student will have knowledge of postulates of quantum mechanics, operator algebra, commutation relations, and uncertainty principles. Students will also learn the techniques how to solve Schrodinger equation for simple model systems. To provide students the idea of how rotational motion of microscopic particles can be treated quantum mechanically giving rise to important concepts of space quantization, quantization of angular momentum and various selection rules associated with rotational motion. They will also learn the use of transformation of coordinate from Cartesian to spherical polar and use of Relative and COM coordinates. By the end of this course the student should get prepared for taking more advanced course on quantum chemistry in the coming semesters.

The primary objective of a Molecular Spectroscopy course is to equip students with a strong understanding of how molecules interact with light, enabling them to analyze and interpret spectroscopic data. This includes learning fundamental concepts, mastering various spectroscopic techniques like Rotational, IR, UV-visible and applying this knowledge to determine molecular structure and properties.

Quantum Chemistry and Molecular Spectra-I

Unit-1: Quantum Mechanics I: (15 Lectures)

Failures of Classical Physics, Black Body Radiation, Photo-electric effect, Wave-particle duality, Wave Equation, Postulates of quantum mechanics, quantum mechanical operators, eigenfunction & eigenvalue, linear and Hermitian operator, commutation, probabilistic interpretation, well-behaved function, normalization of the wave function, Heisenberg Uncertainty principle, Schrödinger equation and its application to free particle and "particle-in-a-box" (rigorous treatment): quantization of energy levels, zero-point energy, eigenfunctions, nodal properties, extension to two- and three-dimensional boxes, separation of variables, degeneracy, selection rule and application of the present model.

Unit 2: Quantum Mechanics II: (15 Lectures)
Quantum mechanical treatment of simple harmonic oscillator: setting up of Schrödinger equation and its solution by operator method and usual technique, discussion of solution and wave functions, vibrational energy of diatomic molecules, uncertainty principle, zero-point energy, selection rule, and application of the model. Orbital angular momentum: operators in polar coordinates, operator algebra for rotational motion, commutation rules, quantization of square of total angular momentum and z-component, determination of eigenvalues and eigenfunctions of ***L2*** and ***Lz*** operators by usual technique ,space quantization, central force problem, setting up of Schrödinger equation in polar coordinates.

Unit 3: Molecular Spectroscopy-I (15 Lectures)

Characterization of electromagnetic radiation, regions of spectra, quantization of energy in molecules; representation of spectra, basic elements of spectroscopy, signal-to-noise ratio, intensity and width of spectral transition.

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

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

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

Practical: 1 Credit **Total course hour: 30 hr** **Duration of Examination: 3 hr**

List of experiments:

1. Study the 200-500 nm absorbance spectra of $KMnO_4$ and $K_2Cr_2O_7$ (in 0.1 M H_2SO_4) and determine the λ_{max} values. Calculate the energies of the two transitions in different units (J molecule^{-1}, kJ mol^{-1}, cm^{-1}, eV).
2. Study the pH-dependence of the UV-Vis spectrum (200-500 nm) of $K_2Cr_2O_7$.
3. To determine the dissociation constant of an indicator by spectrophotometry (phenolphthalein).
4. To study the kinetics of alkaline hydrolysis of crystal violet by spectrophotometry.

Learning outcome: After the completion of this course, students will be able to learn

1. The principles of quantum mechanics, including the Schrödinger equation, and apply it to understand the behaviour of electrons in atoms and molecules.
2. The quantum mechanical treatment of the simple harmonic oscillator and how quantum mechanics modifies our understanding of classical harmonic motion, particularly at the atomic and subatomic levels.
3. The principles of molecular spectroscopy and how it can be used to gain information about molecules.
4. The importance of rotational, vibrational and electronic spectroscopy for the molecular characterizations.
5. The analysis of UV-Vis spectra of some common molecules.

Suggested reading:

(1) Atkins' Physical Chemistry, P. Atkins, J. de Paula, J. Keeler,

(2) A Textbook of Physical Chemistry, Volume- 3, K. L. Kapoor,

(3) Quantum Chemistry, Ira N. Levine, Pearson Education India,

(4) Quantum Chemistry, R. K. Prasad, New Age International.

(5) Fundamentals of Molecular Spectroscopy, C. N. Banwell.

(6) Quantum Chemistry Including Molecular Spectroscopy, B. K. Sen.

(7) Jadav, J. B. Advanced Practical Physical Chemistry, (Krishna Prakashan, 2015)

(8) Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).

(9) Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. Experiments in Physical Chemistry 8th Ed.; McGraw-Hill: New York (2003).

(10) Halpern, A. M. & McBane, G. C. Experimental Physical Chemistry 3rd Ed.; W.H. Freeman & Co.: New York (2003).

Course Title: General Chemistry-I (DSE-5)
Course Code: MIN-CHM-5.1

Total Credit: 4 (3 Credit Theory + 1 Credit Practical)

Distribution of marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course objective: The objective of this course is to provide students with a comprehensive understanding of coordination chemistry, lanthanides and actinides, heterocyclic compounds, chemical kinetics, and chemical equilibrium. It aims to develop both theoretical knowledge and practical skills through the study of structure, bonding, reactivity, and properties of various chemical systems, while reinforcing concepts through hands-on laboratory experiments and analytical techniques.

Prerequisite: Knowledge of general and inorganic chemistry, basic organic chemistry, physical chemistry (thermodynamics, kinetics, equilibrium), laboratory techniques (spectroscopy, chromatography), and basic math skills.

Theory: 3 Credits Total course hour: 45 hr Duration of Examination: 2 hr.

Unit-1: Coordination Chemistry-II (15 Lectures)

CFSE in weak and strong fields, pairing energies, factors affecting the magnitude of 10 Dq (Δ_o, Δ_t).Octahedral vs. tetrahedral coordination, Electronic structure and spectra of transition metal complexes, Elementary idea of magnetic properties of transition metal complexes.

Unit-2: Lanthanides and Actinides (8 Lectures)

Electronic configuration, oxidation states, colour, spectral and magnetic properties, lanthanide contraction.

Unit-3: Chemistry of heterocyclic compounds (15 Lectures)

Heterocycles (monocyclic and bicyclic) with one heteroatom: Heterocyclic compounds: furan, pyrrole, thiophene, pyridine, indole, quinoline and isoquinoline synthesis, structure and bonding, properties.

Unit-4: Chemical Kinetics (15 Lectures)

Order and molecularity of a reaction, rate laws in terms of the advancement of a reaction, differential and integrated rate laws for the first, second order reactions, determination of order, temperature dependence of reaction rates, Arrhenius equation.

Unit-5: Chemical equilibrium (7 Lectures)

The law of mass action, free energy and equilibrium constant, factors influencing equilibrium constant, relationship between Kp and Kc. Le-Chatelier’s principle, Numerical problems.

Practical: 1 Credit Total course hour: 30 hr Duration of Examination: 3 hr

List of experiments:

1. Inorganic Preparation:

a) Tetramminecopper (II) sulphate, $[Cu(NH_3)_4]SO_4.H_2O$

b) Cis and trans $K[Cr(C_2O_4)_2.(H_2O)_2]$ Potassium dioxalatodiaquachromate (III)

2. **Chromatography of metal ions:**

Principles involved in chromatographic separation. Paper chromatographic separation of Ni(II) and Co (II) metal ions.

3. Chromatography: Separation of a mixture of organic compounds by thin layer chromatography (TLC):

(a) 2, 4- Dinitrophenyl hydrazones of acetone and butanone from their mixture. Determination of R_f values.

(b) 2, 4- Dinitrophenyl hydrozones of benzophenone and benzil from their mixture. Determination of R_f values.

4. Acid hydrolysis of methyl acetate with hydrochloric acid.

Learning outcome:

Students will be able to:

- Explain CFSE, pairing energies, and factors influencing crystal field splitting in octahedral and tetrahedral complexes.
- Describe the electronic structure, spectral, and magnetic properties of transition metal, lanthanide, and actinide complexes, including lanthanide contraction.
- Analyze the structure, bonding, synthesis, and reactivity of key heterocycles: furan, pyrrole, thiophene, pyridine, indole, quinoline, and isoquinoline.
- Apply chemical kinetics principles, derive rate laws, and assess temperature effects using the Arrhenius equation.
- Interpret the law of mass action, calculate equilibrium constants, and predict shifts using Le Chatelier’s principle.
- Perform inorganic synthesis, chromatography, and kinetic experiments to reinforce theoretical concepts.

Suggested reading:

(1) Inorganic Chemistry, Puri, Sharma & Kalia

(2) Principles of Physical Chemistry by Puri, Sharma & Pathania.

(3) Ahluwalia, V.K. & Dhingra, S. Comprehensive Practical Organic Chemistry: Qualitativ Analysis, University Press (2000).

(4) An Advanced Course in Practical Chemistry by Nad, Mahapatra & Ghosal. Publisher, New Central Book Agency (P) Limited, 2014.

B. SC. IN CHEMISTRY

DETAILED SYLLABUS OF FYUGP SEMESTER-VI

Course Title: Inorganic Chemistry-III (DSC-12)

Course Code: MAJ-CHM-6.1

Total Credit: 4 (3 Credit Theory + 1 Credit Practical)

Distribution of marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course objective: The course aims to equip students with knowledge, focusing on diverse organometallic complexes using different kind of organic ligands including carbene, carbyne, alkene, alkyne, allyl, alkyl, and cyclic polyenes. This course also includes different kinds of reaction in organometallic chemistry such as oxidative addition, reductive elimination and migratory insertion. This introductory course intends to make learners familiar with structure and emerging properties of inorganic solids. Bioinorganic chemistry is included in this course to acquaint students on the aspects of metal containing proteins and enzymes with their functions in biological systems. This course aims to provide a comprehensive understanding of cage, metal cluster, and ring compounds, including their synthesis, structures, bonding, and applications, focusing on both main group and transition metal systems.

Theory: 3 Credits **Total course hour: 45 hr** **Duration of Examination: 2 hr.**

Unit-1: Organometallic Chemistry-II (15 Lectures)

Metal-Carbene complexes (Fischer Carbene & Schrock Carbene); Metal-Carbyne complexes; Metal-Alkene complexes- Zeise's salt: Preparation and structure, evidences of synergic effect; Metal-Alkyne complexes; Metal-Allyl complexes and special focus on their fluxional behaviour; Complexes of Cyclic Polyenes (cyclobutadiene complexes, cyclopentadienyl complexes, arene complexes, cycloheptatrienyl complexes, cyclooctatetraene (cot) complexes); Ferrocene: Preparation and reactions (acetylation, alkylation, metallation, Mannich condensation), Structure and aromaticity, Comparison of aromaticity and reactivity with that of benzene, Metal Alkyls: Important structural features of methyl lithium (tetramer) and trialkyl aluminium (dimer), Reaction in organometallic Chemistry: Oxidative addition, reductive elimination and migratory insertion, fluxional organometallic compounds.

Unit-2: Structure and properties of Solids (10 Lectures)

Description of Crystal Structures, Simple Cubic (sc), Body Centred Cubic (bcc), Face Centred Cubic (fcc) unit cell, Packing Fraction and Density of crystal system, Close Packed Structures (hcp, ccp), Zinc Sulphide (ZnS) structure: Wurtzite and Zinc Blende, Diamond Cubic (dc) unit cell, Graphite Layer Lattice, AB, AB_2 and A_2B_3 types common structures, Factors affecting the properties of Solid, Structure of mixed oxides-spinel, inverse spinel, ilmenite, perovskite, Layer lattices (2D Lattices), Chain Lattices (1D Lattices), Structure of Silicates and Isopoly and Heteropoly Acids: Representative examples of complex ionic crystals.

Unit-3: Bio-inorganic Chemistry-II (10 Lectures)

Some important metal containing proteins and enzymes with their biological functions; Myoglobin, hemoglobin, hemocyanin, hemerythrin, cytochromes, cytochrome c oxidase, superoxide dismutase, cytochrome P-450, catalase, peroxidase, rubredoxin, ferredoxins; Biological fixation of nitrogen; chlorophyll and photosynthesis; Vitamin B12; Important metal complexes in medicine (examples only), chelation therapy, antimicrobial activity, antiarthritic gold complexes, anticancer compounds (Pt-complexes and metallocenes), MRI contrast agents, X-Ray contrast agents, lithium therapy in psychiatric mind disorder.

Unit-4: Cage, Metal Clusters and Ring Compounds (10 Lectures)

Cage compounds- higher boron hydrides- structure and reactivity, equation of balance-styx numbers, Lipscomb topological diagrams, Wades rules, Jemmis' unifying electron counting rule, carboranes, metallocarborane, metalloborranes and heteroboranes, phosphorous cage compounds, metal clusters- cluster classification, skeletal electron counting, bonding in metal clusters, polyhedral skeleton electron pair theory (PSEPT), low nuclearity (M_3, M_4) and high nuclearity (M_5-M_{10}) carbonyl clusters: application of isolobal and isoelectronic relationships, capping rules, Zintl ions.

Practical: 1 Credit   Total course hour: 30 hr   Duration of Examination: 3 hr

List of experiments:

1. Oxidation-Reduction Titrimetry:
Estimation of Fe^{2+} and Fe^{3+} with $K_2Cr_2O_7$ solution.
2. Complexometric Titration:
(i) Estimation of Zn^{2+} using EBT / Xylenol orange as indicator
(ii) Estimation of Mg^{2+}
(iii) Estimation of Ca^{2+}
(iv) Estimation of Hardness of water: Total, Permanent and Temporary hardness
(v) To estimate the concentration of Ca in commercially available medicines.
(vi) To estimate the Mg present in multivitamins.

Learning outcome:

On completion of this course the students will be able to understand:

(i) The field of organometallic chemistry with a special emphasis on different kind of organometallic reactions and how diverse organic ligands make metal-carbon bond.

(ii) The structure and properties of solids, and correlate structure with material properties like thermal, electrical, and magnetic behaviour.

(iii) The importance of the inorganic elements besides the carbon, hydrogen, oxygen and nitrogen in the biological system. The students will also be able to understand the role of metal ions in the basic biological processes like photosynthesis, respiration, nitrogen fixation, etc.

(iv) The structure and bonding of inorganic cage, metal cluster and ring compounds & able to correlate the structure and property of inorganic cage, cluster and ring compounds.

(v) The principles of redox reactions, perform redox titrations, interpret the experimental results, and apply this knowledge to determine the concentration of unknown solutions or analyze samples.

(vi) The principles behind complexometric titration, including the use of indicators to detect the endpoint, they should be able to recognize the applications of complexometric titration, such as determining the concentration of metal ions in solutions, analyzing water hardness, and analyzing various samples in analytical chemistry and pharmaceutical industries.

Suggested reading:

(1) Miessler, G. L. & Donald, A. Tarr. Inorganic Chemistry 4th Ed., Pearson, 2010.
(2) Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.
(3) Atkin, P. Shriver & Atkins' Inorganic Chemistry 5th Ed. Oxford University Press (2010).
(4) Elias, B. D. Gupta, Basic Organometallic Chemistry, Universities Press (ed. 2), 2013.
(5) Crabtree, R. H. The Organometallic Chemistry of the Transition Metals. New York, NY: John Wiley, 2000.
(6) Asim K. Das Fundamental Concepts of Inorganic Chemistry, Vol. 3, 6 & Asim K Das, Bioinorganic Chemistry. CBS Publications & Distributors
(7) Solid State Chemistry and its Applications 2nd Edition by Anthony R. West, Wiley, 2022.
(8) Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.
(9) Lippard, S.J. & Berg, J.M. Principles of Bioinorganic Chemistry Panima Publishing Company 1994.
(10) Marr, G. and Rockett, R.W. Practical Inorganic Chemistry, Van Nostrand Reinhold. 1972.
(11) Mendham, J. Vogel's Quantitative Chemical Analysis, Pearson, 2009.
(12) An Advanced Course in Practical Chemistry by Nad, Mahapatra & Ghosal. Publisher, New Central Book Agency (P) Limited, 2014.

Title of the Course: Organic Chemistry-III (DSC-13)

Course Code: MAJ-CHM-6.2

Total Credit: 4 (3 Credit Theory + 1 Credit Practical)

Marks Distribution: 70 (End Semester) (45T+25P) +15 (In-Semester) + 15 (HA/S/GD)

Course Objective: To impart a comprehensive understanding of natural products and biomolecules, including their classification, structural elucidation, synthesis, and biological significance. The course also emphasizes practical skills in isolation, identification, and analysis of key compounds through laboratory experiments.

Prerequisite: Students should have a basic understanding of organic chemistry, including reaction mechanisms and stereochemistry, along with fundamental laboratory skills such as extraction, distillation, and titration. Familiarity with basic concepts of biochemistry is also recommended.

Theory: 3 Credits Total course hour: 45 hr Duration of Examination: 2 hr.

Unit 1: Alkaloids and Terpenes (9L)

Alkaloids: General idea and classification of natural products, distinction between primary and secondary metabolites, occurrence, general structural features, isolation methods, and biological functions of alkaloids, Hoffmann's exhaustive methylation and Emde's modification as structural elucidation techniques; Structure elucidation, synthesis and physiological action of Nicotine.

Terpenes: Occurrence and classification of terpenes, isoprene rule, structure elucidation and synthesis of citral, limonene, and pinene.

Unit 2: Carbohydrate Chemistry (9 Lectures)

Classification of carbohydrates (monosaccharides, disaccharides, polysaccharides) and their general properties;detailed structural study of glucose and fructose including both open-chain and cyclic forms; Configuration systems: D/L and R/S notations applied to glucose and fructose; Concepts of mutarotation and its mechanistic explanation; Oxidation reactions of monosaccharides using Br_2 water and con HNO_3; Structural elucidation of common disaccharides (sucrose and lactose) and polysaccharides (starch and cellulose), highlighting their glycosidic linkages and biological relevance.

Unit 3: Biomolecules-I (9 Lectures)

Amino acids, Peptides and their classification. α-Amino Acids - Synthesis, ionic properties, pKa values, isoelectric point and electrophoresis; Study of peptides: Determination of their primary structures through end group analysis; Synthesis of dipeptides using N-protecting, C-protecting and C-activating groups (solution phase and solid-phase synthesis) Primary, secondary, tertiary and quaternary structure of proteins.

Nucleobases, Nucleosides and nucleotides, Structure of polynucleotides; Double-helix structure of DNA, Types and structures of RNAs; Elementary ideas of DNA replication, Transcription and Translation.

Unit 4: Biomolecules-II (9 Lectures)

Definition of lipids, Introduction to oils and fats; common fatty acids present in oils and fats, Hydrogenation of fats and oils, Saponification value, iodine number, Reversion and rancidity Phospholilpids and cell membrane.

Steroids: Introduction, occurrence, structure, Diel's hydrocarbon, nomenclature of steroid hydrocarbons, structure and biological functions of the following steroids- Cholesterol, Sex Hormones (Estrogen, androgen and progesterone), Adrenocortical hormones (Cortisone and cortisol) and Ergosterol (antirachitic effect)

Unit 5: Enzymes (9 Lectures)

Introduction, classification and characteristics of enzymes; Salient features of active site of Enzymes; Mechanism of enzyme action (taking trypsin as example), factors affecting enzyme action, coenzymes and cofactors and their role in biological reactions, specificity of enzyme action (including stereospecificity), enzyme inhibitors and their importance, phenomenon of inhibition (competitive, uncompetitive and non-competitive inhibition including allosteric inhibition).

Practical: 1 Credit **Total course hour: 30 hr** **Duration of Examination: 3 hr**

Experiments:

1. Qualitative analysis of carbohydrates: aldoses and ketoses, reducing and non-reducing sugars.
2. Determination of Iodine number of vegetable oil or a fat.
3. Extraction of Essential Oils by Steam Distillation.
4. Extraction of Curcumin from Turmeric.
5. Extraction and Estimation of Lycopene from Tomato.
6. Isolation of Piperine from Black Pepper.
7. Synthesis of 4-methyl-7-hydroxycoumarin by condensation of resorcinol with ethyl acetoacetate.
8. Qualitative test for identification of alkaloids (Dragendorff Reagent and Mayer's reagent test) and terpenoids (Salkowski test).

Learning Outcomes:

By the end of the course, students will be able to:

- Understand the classification, structure, and functions of major classes of natural products and biomolecules.

- Apply basic techniques for structural elucidation and synthesis of bioactive compounds.
- Explain fundamental biochemical processes and molecular interactions in living systems.
- Perform standard laboratory procedures for the extraction, identification, and analysis of natural substances.
- Interpret experimental results and relate them to theoretical concepts in natural product and biomolecular chemistry.

Suggested reading:

1. Finar, I.L. Fifth Edition Organic Chemistry, Volume 2, Pearson Education, 2008
2. Morrison, R. N.; Boyd, R. N. & Bhattacharjee, S. K. Organic Chemistry, (Pearson Education)
3. Bruice, P.Y. (2020), Organic Chemistry, Egighth Edition, Pearson Education
4. Lehninger, A. L., Nelson, D. L., Cox, M. M., & Cox, M. M. (2005). Lehninger principlesof biochemistry. Macmillan India.
5. Berg, J.M., Tymoczko, J.L. and Stryer, L. (2006) Biochemistry. 6th Edition. W.H. Freeman and Co
6. Voet, D., Pratt, C. W. and Voet, J. G. (2012) Principles of Biochemistry. 4th Edition. Wiley
7. A.I. Vogel: Textbook of Practical Organic Chemistry, 5th edition, Prentice-Hall
8. F. G. Mann & B. C. Saunders, Practical Organic Chemistry, Orient Longman (1960)

Course Title: Physical Chemistry III (DSC-14)

Course Code: MAJ-CHM-6.3

Total Credit: 4 (3 Credit Theory + 1 Credit Practical)

Distribution of marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course Objective:
This course aims to develop a foundational understanding of surface chemistry, macromolecular science, and solid-state chemistry. It covers the principles, properties, and applications of colloidal systems, polymers, and crystalline solids. Emphasis is placed on the behaviour of matter at the microscopic and macroscopic levels, mechanisms of polymerization, and the electronic properties of materials. The course prepares students for advanced study and research by integrating theoretical knowledge with practical and industrial relevance.

Theory: 3 Credits   Total course hour: 45 hr   Duration of Examination: 2 hr.

Unit 1: Colloids (15 Lectures)

Definition of colloids, Classification of colloids, Solids & liquids (sols), Liquids in liquids (emulsions): types of emulsions, Preparation of emulsifier liquids in solids Gels: elastic and non-elastic gels, imbibition, synergesis.
Purification of colloidal solutions–dialysis and ultra-filtration. Kinetic, electrical and optical properties of colloidal systems-Ultra microscope, Coagulation of colloids, Hardy-Schulz rule and gold number, Electrical double layer and zeta potential, Stability of colloids in solution. Surface charge of colloidal particles.
Surfactants-micelles, critical micelle concentration, sedimentation and streaming potential.
Application of colloids-Cottrell precipitator-sewage disposal-formation of deltas.

Unit 2: Macromolecules (20 Lectures)

Monomers, polymers, repeating units, functionality. Nomenclature of polymers. Importance and applications of polymers. Classification of polymers. Number average molecular weight, Weight average molecular weight, Degree of polymerization, Polydispersity Index.

Polymerisation reactions -Addition and condensation -Mechanism of cationic, anionic and free radical addition polymerization; Metallocene-based Ziegler-Natta polymerisation of alkenes; Preparation and applications of plastics – thermosetting (phenol-formaldehyde, Polyurethanes) and thermosoftening (PVC, polythene);

Fabrics – natural and synthetic (acrylic, polyamido, polyester); Rubbers – natural and synthetic: Buna-S, Chloroprene and Neoprene; Vulcanization; Polymer additives; Introduction to liquid crystal polymers; Biodegradable and conducting polymers with examples.

Unit 3: Solids (10 Lectures)
Defects in solids: Crystal defects and non-stoichiometric defects, Band theory of solids, Semiconductors, Insulators, Superconductivity: Type I and II superconductors, Meissner effect, BCS theory, Dielectric and ferroelectric materials, Magnetic properties of solids.

Practical: 1 Credit Total course hour: 45 hr Duration of Examination: 3 hr.

List of Experiments:

1. Preparation and Purification of a Colloidal Solution (Starch or Ferric Hydroxide)
2. Study of Coagulation of Colloids (Hardy-Schulze Rule)
3. Viscosity Measurement of Polymer Solutions
4. Molecular weight determination of a polymer
5. Free Radical Polymerization of Styrene
6. Preparation of Bakelite
7. Measurement of Band Gap in Semiconductors (e.g., ZnO)

Learning outcome: Upon successful completion of the course, students will be able to classify and analyze colloidal systems, understand polymer types and polymerization mechanisms, and interpret the structure and electronic properties of solids. They will gain proficiency in surface chemistry concepts like emulsions, micelles, and zeta potential, as well as in polymer characterization and the application of band theory. Students will be able to correlate the concepts to practical applications.

Suggested reading:

(1) Physical Chemistry, Atkins and Paola
(2) Physical Chemistry, Puri, Sharma, Pathani
(3) Principles of Colloid and Surface Chemistry, P C Hiemenz and R Rajagopalan,
(4) Elements of Physical Chemistry, Macmillan,
(5) Principles of Polymer Chemistry, P. J. Flory
(6) Jadav, J. B. Advanced Practical Physical Chemistry, (Krishna Prakashan, 2015)
(7) Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).
(8) Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. Experiments in Physical Chemistry 8th Ed.; McGraw-Hill: New York (2003).
(9) Halpern, A. M. & McBane, G. C. Experimental Physical Chemistry 3rd Ed.; W.H. Freeman & Co.: New York (2003).

Title of the Course: Quantum Chemistry & Molecular Spectroscopy-II (DSC - 15)

Course Code: MAJ-CHM-6.4

Total Credit: 4 (3 Credits theory +1 Credit Practical)

Distribution of Marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Theory: 3 Credits Total course hour: 45 hr Duration of Examination: 2 hr.

Course Objective:

The aim of this course is to enrich the students more with quantum chemistry, and molecular spectroscopy. In quantum chemistry unit the students will be taught the Particle on a ring and rigid rotator model for diatomic molecule, treatment of H-like atoms, Approximation methods for many-electron systems, statement of Variation theorem and Perturbation theorem along with the quantum mechanical approaches of chemical bonding. In spectroscopy unit Raman, electronic, spin resonance, and electronic spectroscopy will be introduced.

Unit 1: Quantum Mechanics III (25 Lectures)

Particle on a ring and rigid rotator model for diatomic molecule: Schrödinger equation, transformation to spherical polar coordinates, separation of variables, spherical harmonics, solution of Schrödinger equation, discussion of solution, selection rules and application.

Treatment of H-like atoms: setting up of Schrodinger equation in spherical polar coordinates, separation of radial & angular part, quantization of energy (only final energy expression), quantum numbers, *n*, *l* and *m*, nature of wave function up to $n = 3$ (only expression), real wave function, radial distribution function, average and most probable distances of electron from nucleus, concept of orbitals & shapes of *s*, *p*, *d* orbitals.

Solution of Schrödinger equation for *H*-like atoms. Approximation methods for many-electron systems, statement of variation theorem and its application to simple systems (particle- in-a-box and hydrogen atom). Perturbation theorem and its applications.

Chemical bonding: Covalent bonding, valence bond and molecular orbital approaches, LCAO-MO treatment of H_2+. Bonding and antibonding orbitals. Qualitative extension to H_2. Comparison of LCAO-MO and VB treatments of H_2 (only wavefunctions, detailed solution not required) and their limitations. Refinements of the two approaches (Configuration Interaction for MO, ionic terms in VB). Qualitative description of LCAO-MO treatment of homonuclear and heteronuclear diatomic molecules (HF, LiH). Localised and non-localised molecular orbitals treatment of triatomic (BeH_2, H_2O) molecules. Qualitative MO theory and its application to AH_2 type molecules. valence bond and molecular orbital approaches, VBT and MOT for H_2+ molecular ion, LCAO-MO treatment, bonding and antibonding orbitals.

Unit 2: Molecular Spectroscopy II (20 Lectures)

Raman spectroscopy: Qualitative treatment of Rotational Raman effect; Vibrational Raman spectra, Stokes, and anti-Stokes lines; their intensity difference, rule of mutual exclusion. **Nuclear Magnetic Resonance (NMR) spectroscopy**: Principles of NMR spectroscopy, Larmor precession, chemical shift and low-resolution spectra, different scales, spin-spin coupling and high-resolution spectra, Relaxation time, Interpretation of PMR spectra of organic molecules.
Electron Spin Resonance (ESR) spectroscopy: Its principle, hyperfine structure, ESR of simple radicals.

Practical: 1 Credit **Total course hour: 30 hr** **Duration of Examination: 3 hr**

List of experiments:

1. IR spectroscopic analysis of some simple molecules.
2. ^{1}H-NMR spectroscopic analysis of some simple molecules.

Learning outcome: After the completion of this course, students will be able to learn

1. How to apply quantum mechanics to rotational motion, specifically in molecules. This includes calculating rotational energy levels, understanding wave functions, and analyzing the properties of angular momentum.

2. The solving of Schrödinger equation for hydrogen-like atoms leads to understanding the energy levels, shapes, and orientations of atomic orbitals.
3. A more fundamental explanation for chemical bonding than classical models.
4. The principles and applications of Raman, ESR and NMR Spectroscopy.
5. The analysis of IR and NMR spectra of some common molecules.

Suggested reading:

(1) Atkins' Physical Chemistry, P. Atkins, J. de Paula, J. Keeler
(2) A Textbook of Physical Chemistry, Volume- 3, K. L. Kapoor
(3) Quantum Chemistry, Ira N. Levine, Pearson Education India
(4) Quantum Chemistry, R. K. Prasad, New Age International
(5) Fundamentals of Molecular Spectroscopy, C. N. Banwell
(6) Jadav, J. B. Advanced Practical Physical Chemistry, (Krishna Prakashan, 2015)
(7) Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).
(8) Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. Experiments in Physical Chemistry 8th Ed.; McGraw-Hill: New York (2003).
(9) Halpern, A. M. & McBane, G. C. Experimental Physical Chemistry 3rd Ed.; W.H. Freeman & Co.: New York (2003).

Course Title: General Chemistry-II (DSE-6)

Course Code: MIN-CHM-6.1

Total Credit: 4 (3 Credit Theory + 1 Credit Practical)

Distribution of marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course objective: The objective of this course is to provide students with a comprehensive understanding of qualitative inorganic analysis, separation techniques, and the chemistry of biological compounds. It aims to equip students with knowledge of thermodynamics, reaction mechanisms, and practical laboratory skills. The course emphasizes the integration of theoretical principles and hands-on experiments, enabling students to apply their understanding to solve complex chemical problems.
Prerequisite: The prerequisites for this course include basic knowledge of general, organic, and inorganic chemistry, thermodynamics, and laboratory techniques, along with an understanding of chemical reactions and stoichiometry.

Theory: 3 Credits   Total course hour: 45 hr   Duration of Examination: 2 hr.

Unit-1: Theoretical Principles of Qualitative Inorganic Analysis (10 Lectures)

Basic principles involved in analysis of cations and anions and solubility products, common ion effect. Principles involved in separation of cations into groups and choice of group reagents. Interfering anions (fluoride, borate, oxalate and phosphate) and need to remove them after Group II.

Unit-2: Separation Techniques (5 Lectures)

Principle, distribution ratio and partition coefficient, successive extraction and separation; different methods of extraction systems including Column Chromatography and Thin Layer chromatography.Unit-3: Chemistry of heterocylic compounds

Unit 3: Amino acids, nucleic acids, lipids, carbohydrates (15 Lectures)

Nucleic acids: Components of nucleic acids, Nucleosides and nucleotides; Structure of polynucleotides, complimentary base, genetic codes and degeneracy of genetic codes; RNA and protein biosynthesis: transcription and translation.
Lipids: Introduction to oils and fats; common fatty acids present in oils and fats, Hydrogenation of fats and oils, Saponification value, acid value, iodine number; Reversion and rancidity.

Carbohydrates: Classification, and General Properties, Glucose and Fructose (open chain and cyclic structure), D,L and R,S configuration of Glucose and Fructose, Mutarotation, oxidation withBr_2 water and concentrated HNO_3 and stereochemical outcome of the oxidation reactions, Structure of disacharrides (sucrose and lactose) and polysacharrides (starch and cellulose).
Unit 4: Third Law of thermodynamics & Free Energy (15 Lectures)

Third Law of thermodynamics, residual entropy, calculation of absolute entropy of molecules, Gibbs and Helmholtz energy, variation of S, G, A with T, V, P, Free energy change and spontaneity.

Practical: 1 Credit Total course hour: 30 hr Duration of Examination: 3 hr

List of experiments:

1. Iodo/Iodimetric titration:
i. Estimation of Cu(II) and $K_2Cr_2O_7$ using sodium thiosulphate solution iodimetrically
ii. Estimation of available Chlorine in bleaching powder iodometrically.
2. Preparations (mechanism of reactions involved to be discussed) of the following (any two)
(a) Oxime and 2,4 dinitrophenylhydrazone of aldehyde/ketone
(b) Bromination of Phenol/Aniline/Acetanilide
(c) Benzoylation of amines/phenols
Recrystallisation, determination of melting point and calculation of quantitative yields be done.
3. Determination of enthalpy of hydration of copper sulphate
4. Study of the solubility of benzoic acid in water and determination of ΔH.

Learning outcome:
Students will:

- Understand separation techniques including distribution ratio, partition coefficient, and chromatography (TLC, column).
- Learn the structure and function of nucleic acids, amino acids, lipids, and carbohydrates, and related biochemical processes.
- Apply thermodynamic principles: third law, entropy, Gibbs free energy, and factors affecting spontaneity.
- Perform titrations, organic syntheses (oximes, hydrazones, bromination, benzoylation), and physical chemistry experiments.
- Analyze experimental data to determine thermodynamic properties and reaction mechanisms.
- Integrate theoretical knowledge with lab techniques to solve complex chemical problems.

Suggested reading:

1. Vogel's Qualitative Inorganic Analysis, Revised by G. Svehla. Pearson Education, 2012.
2. Mendham, J. Vogel's Quantitative Chemical Analysis, Pearson, 2009.
3. B. Y. Paula. Organic Chemistry, 8th edition, Pearson Education India.
4. Morrison, R. N. and Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
5. McMurry, J. E. Fundamentals of Organic Chemistry, 7th Ed. Cengage Learning India Edition, 2013
6. Nelson, D.L., Cox, M.M. and Lehninger, A.L. (2009) Principles of Biochemistry. 4th Edition. W.H. Freeman and Co.
7. Vogel's Textbook of Practical Organic Chemistry
8. P.W. Atkins: Physical Chemistry.
9. G.W. Castellan: Physical Chemistry.

B. SC. IN CHEMISTRY

DETAILED SYLLABUS OF FYUGP SEMESTER-VII

Course Title: Inorganic Chemistry-IV (DSC-16)

Course Code: MAJ-CHM-7.1

Total Credit: 4 (3 Credit Theory + 1 Credit Practical)

Distribution of marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course objective: The aim of this course is to introduce the students with the fundamental concepts of group theory like matrix representation, symmetry elements and operations, reducible and irreducible representation, application of group theory in predicting the IR and Raman active vibrational modes, orbital symmetry and chemical reactions. This course will establish the basic foundation of electronic structure, spectra and magnetic properties of transition and inner-transition metal complexes. Students will also learn the characterization of inorganic compounds by NMR Spectroscopy.

Theory: 3 Credits   Total course hour: 45 hr   Duration of Examination: 2 hr.

Unit-1: Group Theory (10 Lectures)

Symmetry elements and symmetry operations, symmetry groups, molecular dissymmetry and optical activity, symmetry point groups for compounds having co-ordination number 2 to 9, matrix representation of groups, reducible and irreducible representation, the great orthogonality theorem, Direct product representation. Projection operator, symmetry adapted linear combination, vibrational modes as bases for group representation, symmetry selection rules for IR and Raman spectra.

Unit-2: Electronic structure and spectra of transition and inner-transition metal complexes (12 Lectures)

Spectroscopic states, Crystal Field Theory, Russel-Saunders Coupling (L-S Coupling) and Term Symbols, Orgel and Tanabe-Sugano diagrams, selection rules, band intensities and band width, Adjusted Crystal Field Theory, Spectrochemical and Nephelauxetic series, molecular orbital theory of complexes (including complexes with and without π bonding), MO diagrams for octahedral and tetrahedral complexes, Jahn-Teller effect, Charge-transfer spectra (LMCT, MLCT), optical properties of lanthanides and actinides.

Unit-3: Magnetic properties of transition and inner transition metal complexes (15 Lectures)

Types of magnetic behaviour: dia-, para-, ferro- and anti-ferromagnetic compounds, Curie and Curie-Weiss laws, Orbital and spin magnetic moments, spin-orbit coupling, spin only moments of d^n ions and their correlation with effective magnetic moments including orbital contribution; quenching of magnetic moment: super exchange and anti-ferromagnetic interactions, temperature independent paramagnetism, application of Crystal Field Theory to explain magnetic properties, spin-crossover. Thermodynamic effects-hydration, ligation, lattice energy, magnetic properties of lanthanides and actinides.

Unit 4: Physical Characterization of Inorganic Compounds by NMR Spectroscopy (10 Lectures)

Basic principle and spectral display, Application NMR spectroscopy-fundamentals, the contact and pseudo-contact shifts, factors affecting nuclear relaxation, application of H-1, C-13, P-31 and F-19 NMR towards the structural elucidation of metal-organic complexes, an overview of metal nuclides with emphasis on Pt-195 and Sn-119 NMR.).

Practical: 1 Credit **Total course hour: 30 hr** **Duration of Examination: 3 hr**

List of experiments:

1. Gravimetric Analysis:
i. Estimation of nickel (II) using Dimethylglyoxime (DMG).
ii. Estimation of copper as CuSCN
iii. Estimation of iron as Fe_2O_3 by precipitating iron as $Fe(OH)_3$.
iv. Estimation of Al (III) by precipitating with oxine and weighing as $Al(oxine)_3$ (aluminium oxinate).
2. Estimation of Iron(III) and Copper(II) in a mixture.

Learning outcome:
On completion of this course the students will be able to learn:

(i) The point group a molecule belongs, symmetry species of the normal modes of vibration and their spectroscopic activities. The student will learn how to generate molecular orbitals by symmetry adapted linear combination of atomic orbitals (SALC) which will help one doing quantum chemistry calculation with more ease.

(ii) To interpret electronic spectra of transition metal complexes, understanding the nature of d-d transitions and other charge transfer transitions and their relationship to color.

(iii) The magnetic properties of transition and inner transition metal complexes.

(iv) The physical characterization of some inorganic compounds by NMR Spectroscopy.

(v) The principles of gravimetric analysis, perform accurate quantitative analysis, and apply the method to determine the concentration of analytes in various samples.

(vi) How quantitatively analyze the mixture using techniques like redox titrations and gravimetric methods, understanding the principles of analytical chemistry and achieving accurate results.

Suggested reading:

(1) Bioinorganic photochemistry by G. Stochel. Wiley.
(2) Principles and Applications of Photochemistry by Brian Wardle. Wiley.
(3) Fundamental of Photochemistry by K K Rohatgi-Mukherjee, New Age International Publishers.
(4) Chemical Applications of Group Theory by F. A. Cotton.
(5) Symmetry and Spectroscopy of Molecules by K Veera Reddy.
(6) Asim K. Das Fundamental Concepts of Inorganic Chemistry, Vol. 5, 6, 7.
(7) O. Kahn, Molecular Magnetism.
(8) R. P. Sarkar, General and Inorganic Chemistry (Vol. 2), New Central Book Agency, ed. 3, 2011,
(9) Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.
(10) Housecroft, C.E. and Sharpe, A.G. (2012) Inorganic Chemistry. 4th Edition, Pearson, Harlow.
(11) Marr, G. and Rockett, R.W. Practical Inorganic Chemistry, Van Nostrand Reinhold. 1972.
(12) Mendham, J. Vogel's Quantitative Chemical Analysis, Pearson, 2009.
(13) An Advanced Course in Practical Chemistry by Nad, Mahapatra & Ghosal. Publisher, New Central Book Agency (P) Limited, 2014.

Course Title: Organic Chemistry-IV (DSC-17)

Course Code: MAJ-CHM-7.2

Total Credit: 4 (3 Credit Theory + 1 Credit Practical)

Marks Distribution: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15 (HA/S/GD)

Course Objective: To introduce advanced concepts in organic chemistry, focusing on key reagents, reaction mechanisms, and their applications in synthesis, medicinal chemistry, and polymer science through integrated theory and practical work.

Prerequisite: A basic foundation in organic chemistry, including knowledge of: Functional groups and their reactivity, Fundamental reaction mechanisms and Basic principles of chemical bonding.

Theory: 3 Credits **Total course hour: 45 hr** **Duration of Examination: 2 hr.**

Unit 1: Organometallic reagents and Organosulphur compounds (9 Lectures)

Introduction to organometallic Reagents: Fundamental concepts, structure and bonding; Grignard reagents, organolithium compounds, organozinc and organocopper reagents.

Preparation and reactions of thiols, Acidity and nucleophilicity of thiols, Disulfide formation and biological relevance of it, Umpolung of carbonyl compounds using dithiane and synthetic utility
Desulfurization reaction.

Unit 2: Selected Oxidizing and reducing agents used in organic transformations (9 Lectures)

Common oxidizing agents: PCC, PDC (Pyridinium dichromate), $KMnO_4$, OsO_4, m-CPBA, Swern oxidation (DMSO/oxalyl chloride), Dess–Martin periodinane, Ozone (O_3), Woodward and Prevost reactions.

Common reducing agents: $LiAlH_4$, $NaBH_4$, H_2/Pd, Zn/Hg in HCl (Clemmensen reduction), hydrazine/KOH (Wolff–Kishner reduction), Na/NH_3 (Birch reduction), DIBAL-H (Diisobutylaluminium hydride), Lindlar catalyst (Pd/$BaSO_4$ with quinoline), Raney nickel.

Unit 3: C-C and C=C bond formations reactions (9 Lectures)

C–C Bond Forming Reactions: Alkylation of enamines and enolates (kinetic vs thermodynamic); Transition metal-catalyzed C–C bond formation: general mechanisms and key reactions- Heck, Suzuki, Stille, Sonogashira.

C=C Bond Forming Reactions: Pyrolytic syn elimination: thermal elimination mechanisms, ester pyrolysis, xanthate ester pyrolysis (Chugaev reaction), and amine oxide pyrolysis (Cope elimination), stereospecificity and mechanism; Stereoselectivity of Wittig reaction, comparison with Horner-Wadsworth-Emmons reaction; Peterson olefination and Shapiro reaction.

Unit 4: Introduction to Medicinal Chemistry (9 Lectures)

Definition and classification of drugs, prodrugs, History of drug development: Aspirin, paracetamol, sulpha drugs, Receptors, drug-receptor interaction, agonist, antagonist; Chemotherapeutic index & therapeutic index, IC_{50}, EC_{50}, LD_{50} values; Lead compound, structure activity relationship Quantitative structure activity relationships (QSAR).
Drugs of the different pharmacological classes: Antibiotics, Antifungal, Antiviral and anti HIV-AIDS, Antimalarials, Analgesics and antipyretics, Anticancer.

Unit 5: Introduction to Organic Polymers (9 Lectures)

Macromolecules: Characteristics of macromolecules, classification of polymers, polymerisation reaction (addition and condensation), and degree of polymerization. Types of polymers and polymerization process: Addition polymers, stereo controlled dipolymers, condensation polymers, Zeigler-Natta catalyst. Manufacture and application of the following polymers: Natural rubber and synthetic rubber; Synthetic fibres: Polyesters, polyamides; Plastics: Polythenes and polyurethanes; Foaming agents: Plasticisers and stabilizers.

Practical: 1 Credit **Total course hour: 30 hr** **Duration of Examination: 3 hr**

Experiments:

1. Preparation of paracetamol.
2. Separation of a mixture of dyes by Thin Layer Chromatography (TLC).
3. Preparation of Starch-PVA Film
4. Separation and Qualitative Analysis of Two-Component Organic Mixtures
   (a) Preliminary examination: physical properties, ignition test, solubility.
   (b) Detection of extra elements (N, S, halogens) using Lassaigne's test.
   (c) Separation of components based on differential solubility in acid, base, or organic solvents.
   (d) Systematic qualitative analysis of functional groups (carboxylic acids, phenols, amines, alcohols, aldehydes, ketones, esters, etc.).
   (e) Confirmatory tests and derivative preparation.
   (f) Melting/boiling point determination and report writing.

Learning Outcome:

By the end of the course, students will be able to:

- Gain foundational knowledge of organometallic and organosulfur chemistry, including their structures, properties, and synthetic applications.
- Understand the role and mechanism of commonly used oxidizing and reducing agents in organic transformations.
- Acquire conceptual and practical understanding of key carbon-carbon and carbon-carbon double bond forming reactions.
- Develop a basic understanding of medicinal chemistry, including drug classification, design, and drug-receptor interactions.
- Learn the principles of polymer chemistry, types of polymers, polymerization methods, and industrial applications.
- Build practical skills in organic synthesis, compound analysis, and separation techniques through hands-on laboratory work.

Suggested reading:

1. Norman, R.O.C. and Coxon, C. M. Principles of Organic Synthesis, CRC Press, New York, 2009.
2. Carruthers, W. and Coldham, I (2004), Moder Methods of Organic Synthesis, 4th Edition, Cambridge University Press.

3. Clayden, J., Greeves N., Warren, S., Organic Chemistry, Oxford University Press 2nd Ed., 2012.
4. M. B. Smith, J. March, March's Advanced Organic Chemistry: Reactions, Mechanisms,
   and Structure, 2007 John Wiley & Sons, Inc
5. B. Y. Paula, Organic Chemistry, 8th edition, Pearson Education India.
6. F. W. Billmeyer, *Textbook of Polymer Science*, John Wiley & Sons, Inc.
7. V. R.Gowariker, N. V. Viswanathan, &J. Sreedhar, *Polymer Science*, New Age International (P) Ltd. Pub
8. A.I. Vogel: Textbook of Practical Organic Chemistry, 5th edition, Prentice-Hall
9. F. G. Mann & B. C. Saunders, Practical Organic Chemistry, Orient Longman (1960)

Course Title: Physical Chemistry IV (DSC-18)

Course Code: MAJ-CHM-7.3

Total Credit: 4 (3 Credit Theory + 1 Credit Practical)

Distribution of marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course objective: This course aims to deepen the understanding of classical and statistical thermodynamics, focusing on the thermodynamic behavior of mixtures, phase equilibria, and nonideal systems. It integrates statistical mechanics to relate microscopic behavior to macroscopic thermodynamic properties, including entropy, energy distributions, and partition functions. The course also introduces non-equilibrium thermodynamics, emphasizing entropy production, Onsager relations, and real-world applications such as diffusion, electrokinetics, and biological systems.

Theory: 3 Credits Total course hour: 45 hr Duration of Examination: 2 hr.

Course Content:

Unit 1: Chemical Thermodynamics (15 Lectures)

Brief review of thermodynamic functions and laws of thermodynamics: Temperature dependence of thermodynamic functions, Experimental determination of thermodynamic functions, Thermodynamic description of mixtures, Gibbs-Duhem equation, Chemical equilibrium, Thermodynamic description of phase transitions, Clapeyron-Claussius equation, Phase diagrams, Thermodynamics of nonideal systems – fugacity and activity concepts, excess properties.

Unit 2: Statistical thermodynamics (15 Lectures)

Concepts of statistical thermodynamics, entropy and probability, ensembles, distribution laws of MB, FD and BE, partition functions and statistical formulation of macroscopic variables.

Use of statistical thermodynamics including calculation of electrical and magnetic properties, and heat capacity of solids, application of BE statistics to helium.

Unit 3: Non-equilibrium thermodynamics (15 Lectures)
Non-equilibrium thermodynamics, thermodynamic criteria for non-equilibrium states, Assumptions of non-equilibrium thermodynamics, uncompensated heat, entropy production and entropy flow, entropy balance, Onsager formalism, relation between forces and fluxes, transformations of generalized fluxes and forces, microscopic reversibility and Onsager's reciprocity relations.
Electrokinetic phenomena, diffusion, electric conduction, irreversible thermodynamics for biological systems, coupled reactions.

Practical: 1 Credit **Total course hour: 30 hr** **Duration of Examination: 3 hr**

List of Experiments:

1. Determination of Enthalpy and Entropy of Dissolution (e.g., Benzoic Acid)
2. Phase Diagram Construction for Binary Systems (e.g., Naphthalene–Biphenyl)
3. Diffusion Coefficient Determination (e.g., $KMnO_4$ in Water)

Learning outcome: After completion of the course, the learner shall be able to apply classical thermodynamic principles to mixtures, phase transitions, and chemical equilibria, including nonideal systems. They will interpret and calculate thermodynamic functions, fugacity, activity and excess functions. Students will use statistical thermodynamics to derive macroscopic properties from molecular behaviour, employing MB, FD, and BE statistics. They will analyze non-equilibrium processes, entropy production, and Onsager reciprocity in real systems, including electrokinetic and biological phenomena, enabling advanced analysis and research in physical chemistry.

Suggested reading:

1. Engel, T. and Reid, P. Thermodynamics, Statistical Thermodynamics and Kinetics, 2nd Edn., (Pearson, New Delhi, 2011).
2. Atkins, P. and Paula, J. de. Atkins' Physical Chemistry, 10th Edn., (Oxford University Press, New Delhi, 2014).
3. Kalidas, C. and Sangaranarayanan, M.V. Non-equilibrium Thermodynamics, Principles and applications, (Mcmillan, New Delhi, 2002).
4. Berry, R. Rice S. A. and Ross, J. Physical Chemistry, 2nd Edn., (Oxford, London, 2010).
5. Physical Chemistry. I. N. Levine, McGraw Hill.
6. Physical Chemistry. R. G. Mortimer, Academic Press.
7. Statistical Mechanics. D. A. McQuarrie, University Science Books.

8. Jadav, J. B. Advanced Practical Physical Chemistry, (Krishna Prakashan, 2015)
9. Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).
10. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. Experiments in Physical Chemistry 8th Ed.; McGraw-Hill: New York (2003).

Course Title: Analytical Methods in Chemistry (DSC-21)

Course Code: MAJ-CHM-7.4

Total Credit: 4 (3 Credit Theory + 1 Credit Practical)

Distribution of marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course Objective: This is a foundation course designed to complement the needs of students to learn more about the qualitative/quantitative characterization and separation techniques. The content of this course aims to cover some of the widely used instrumental techniques for characterization of samples. Experiments included aim at giving students hands on experience using different instrumental techniques and chemical analysis. Through this course the students will introduce into the working principles of modern instruments (which recognize the status of a scientific department) applying the knowledge on basic science.

Theory: 3 Credits Total course hour: 45 hr Duration of Examination: 2 hr.

Unit-1

Qualitative and quantitative aspects of analysis (5 Lectures)

Sampling, evaluation of analytical data, errors, accuracy and precision, methods of their expression, normal law of distribution if indeterminate errors, statistical test of data; F, Q and t test, rejection of data, and confidence intervals.

Unit-2

Optical methods of analysis (15 Lectures)

Origin of spectra, interaction of radiation with matter, fundamental laws of spectroscopy and selection rules, validity of Beer-Lambert's law.

UV-Visible Spectrometry: Basic principles of instrumentation (choice of source, monochromator and detector) for single and double beam instrument;

Basic principles of quantitative analysis: estimation of metal ions from aqueous solution, geometrical isomers, keto-enol tautomers. Determination of metal complex composition using Job's method of continuous variation and mole ratio method.

Infrared Spectroscopy: Basic principles of instrumentation (choice of source, monochromator & detector) for continuous wave and Fourier transform spectrometers; sampling techniques.

Structure elucidation through interpretation of data. Effect and importance of isotope substitution.

Flame Atomic Absorption and Emission Spectrometry: Basic principles of instrumentation (choice of source, monochromator, and detector, choice of flame and Burner designs. Techniques of atomization and sample introduction. Method of background correction, sources of chemical interferences and their method of removal. Techniques for the quantitative estimation of trace level of metal ions from water samples.

Unit-3

Thermal methods of analysis (5 Lectures)

Theory of thermogravimetry (TG), basic principle of instrumentation.
Techniques for quantitative estimation of Ca and Mg from their mixture.

Unit-4

Electroanalytical methods (5 Lectures)

Classification of electroanalytical methods, basic principle of pH metric, potentiometric and conductometric titrations. Techniques used for the determination of equivalence points. Techniques used for the determination of pKa values.

Unit-5

Advanced Experimental Instruments: Basic principles and applications (15 Lectures)

Electron Microscopy: transmission electron microscopy (TEM), scanning electron microscopy (SEM), atomic force microscopy (AFM), fluorescence confocal microscopy, fluorescence correlation spectroscopy, UV-VIS absorption spectrometry, fluorimetry, FTIR spectrometry, atomic absorption spectrometry, excited state lifetime measurement techniques: TCSPC, transient absorption, up-conversion etc.

Practical: 1 Credit   Total course hour: 30 hr   Duration of Examination: 3 hr

List of experiments:

1. Separation Techniques

Chromatography:
(a) Separation of mixtures
(i) Paper chromatographic separation of Fe^{3+}, Al^{3+}, and Cr^{3+}.
(ii) Separation and identification of the monosaccharides present in the given mixture (glucose & fructose) by paper chromatography. Reporting the R_f values.
(b) Separate a mixture of Sudan yellow and Sudan Red by TLC technique and identify them on the basis of their R_f values.
(c) Chromatographic separation of the active ingredients of plants, flowers and juices by TLC

2. Solvent Extractions

(i) To separate a mixture of Ni^{2+} & Fe^{2+} by complexation with DMG and extracting the Ni^{2+}-DMG complex in chloroform, and determine its concentration by spectrophotometry.

(ii) Solvent extraction of zirconium with amberliti LA-1, separation from a mixture of irons and gallium.
3. Determine the pH of the given aerated drinks fruit juices, shampoos and soaps.
4. Determination of Na, Ca, Li in cola drinks and fruit juices using fame photometric techniques.
5. Analysis of soil:
(i) Determination of pH of soil.
(ii) Total soluble salt
(iii) Estimation of calcium, magnesium, phosphate, nitrate
6. Ion exchange:
(i) Determination of exchange capacity of cation exchange resins and anion exchange resins.
(ii) Separation of metal ions from their binary mixture.
(iii) Separation of amino acids from organic acids by ion exchange chromatography.
7. Spectrophotometry:
(i) Determination of pKa values of indicator using spectrophotometry.
(ii) Structural characterization of compounds by infrared spectroscopy.
(iii) Determination of dissolved oxygen in water.
(iv) Determination of chemical oxygen demand (COD).
(v) Determination of Biological oxygen demand (BOD).
(vi) Determine the composition of the Ferric-salicylate/ ferric-thiocyanate complex by Job's method.

Learning outcome: On successful completion students will be have theoretical understanding about choice of various analytical techniques used for qualitative and quantitative characterization of samples. At the same time through the experiments students will gain hands on experience of the discussed techniques. This will enable students to take judicious decisions while analyzing different samples. Here the students may have the necessary background for the working at any experimental laboratory.

Suggested reading:
1. Mendham, J. et al.: Vogel's Text Book of Quantitative Chemical Analysis ; 6th Ed. Pearson Education, 2009.
2. Willard, Hobert H. et al.: Instrumental Methods of Analysis, 7th Ed. CBS Publishers & Distributors, 2004.
3. Christian, Gary D: Analytical Chemistry, 6th Ed. Wiley India (P) Ltd., 2004.
4. Harris, Daniel C: Exploring Chemical Analysis, 4th Ed. W. H. Freeman, 2008.
5. Khopkar, S.M.: Basic Concepts of Analytical Chemistry, 3rd Ed. New Age, International Publisher, 2009.
6. Skoog, D.A. Holler F.J. and Nieman, T.A. Principles of Instrumental Analysis, 6th Ed. Thomson Asia Pvt. Ltd. Singapore.
7. Mikes, O. and Chalmes, R.A. Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Ltd. London.1979
8. Ditts, R.V. Analytical Chemistry: Methods of separation.Van Nostrand, New York, 1974.

Course Title: General Chemistry-III (DSE-7)
Course Code: MIN-CHM-7.1
Total Credit: 4 (3 Credit Theory + 1 Credit Practical)
Distribution of marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course objective: The course aims to provide an understanding of nuclear chemistry, quantitative inorganic analysis, and the chemistry of amino acids, peptides, and proteins. Students will also learn quantum chemistry fundamentals and gain hands-on experience with laboratory techniques like titrimetric analyses, synthesis, chromatography, and spectroscopy.
Prerequisite: A basic understanding of general and organic chemistry, algebra, calculus, and introductory physics is required.

Theory: 3 Credits Total course hour: 45 hr Duration of Examination: 2 hr.

Unit-1: Nuclear Chemistry & Radio-activity (10 Lectures)

Classification of nuclides based on the number of nucleons- Isotopes, Isobars, Isotones, The Neutron to Proton Ratio and Different Modes of Decay; Fajans & Soddy's Group Displacement Law, Nuclear Reactions- fission, fusion, Radio-active disintegration series, Application of Radioactivity in Age Determination; Uses of radioactive isotopes.

Unit-2: Theoretical Principles of Quantitative Inorganic Analysis (5 Lectures)

Basic Principles of Quantitative Inorganic Analysis, Acidimetry and alkalimetry, Oxidimetry and Reductimetry, Iodometry and Iodimetry, Complexometry.

Unit 3: Amino Acids, Peptides and Proteins (15 Lectures)

Preparation of Amino Acids: Strecker synthesis and Gabriel's phthalimide synthesis; Zwitterion, Isoelectric point and Electrophoresis; Reactions of Amino acids: ester of –COOH group, acetylation of $–NH_2$group, complexationwith Cu^{2+} ions, ninhydrin test; Overview of Primary, Secondary, Tertiary and Quaternary Structure of proteins; Determination of Primary structure of Peptides by degradation Edmann degradation (Nterminal) and C–terminal (thiohydantoin and with carboxypeptidase enzyme); Synthesis ofsimple peptides (upto dipeptides) by N-protection (t-butyloxycarbonyl and phthaloyl) and Cactivating groups and Merrifield solid-phase synthesis.

Unit-4: Introduction to Quantum Chemistry (15 Lectures)

Black-body radiation, Plank's radiation law, photoelectric effect, Bohr's model of hydrogen atom (no derivation) and its defects, Compton effect, de Broglie hypothesis, Heisenberg's uncertainty principle, operator concept, Hamiltonian operator, Schrödinger wave equation and its importance, physical interpretation of the wave function, Numerical problems.

Practical: 1 Credit   Total course hour: 30 hr   Duration of Examination: 3 hr

List of experiments:

1. Inorganic Preparatios:
i. Preparation of Cuprous chloride, CuCl
ii. Preparation of Aluminium potassium sulphate $KAl(SO_4)_2.12H_2O$ (Potash alum) or Chrome alum.
2. Oxidation –Reduction Titrimetry:
Estimation of Oxalic acid and sodium oxalate in a given mixture.
3. Determination of saponification value of an oil/fat.
4. Determination of iodine value of an oil/fat.
5. Determination of concentration of Glycine solution by formylation method.
6. Paper chromatographic separation of mixture of any three amino acids from their mixture (alanine, glycine and leucine or any other set). Spray reagent : Ninhydrin
7. Study the 200-500 nm absorbance spectra of $KMnO_4$ and $K_2Cr_2O_7$ (in 0.1 M H_2SO_4)

Learning outcome:
Students will be able to understand

- Classification of nuclides and understanding of nuclear decay, fission, and fusion.
- Application of acid-base, redox, iodometric, and complexometric titrations.
- Synthesis, reactions, and structure of amino acids and peptides.
- Core quantum chemistry concepts: black-body radiation, photoelectric effect, Bohr's model, de Broglie hypothesis, Schrödinger equation.
- Execution of inorganic syntheses and titrimetric analyses; determination of solution concentrations and fat/oil properties.
- Use of paper chromatography and spectroscopy for biochemical analysis.

Suggested reading:
1. R. P. Sarkar, General and Inorganic Chemistry (Vol. 1), New Central Book Agency, ed. 3, 2011.
2. Asim K. Das Fundamental Concepts of Inorganic Chemistry, Vol-1, CBS Publishers & Distributors.
3. Mendham, J. Vogel's Quantitative Chemical Analysis, Pearson, 2009.
4. B. Y. Paula. Organic Chemistry, 8th edition, Pearson Education India.
5. A.I. Vogel: Textbook of Practical Organic Chemistry, 5th edition, Prentice-Hall
6. Atkins' Physical Chemistry, P. Atkins, J. de Paula, J. Keeler,
7. A Textbook of Physical Chemistry, Volume- 4, K. L. Kapoor,
8. Quantum Chemistry, Ira N. Levine, Pearson Education India,
9. Quantum Chemistry, R. K. Prasad, New Age International.
10. An Advanced Course in Practical Chemistry by Nad, Mahapatra & Ghosal. Publisher, New Central Book Agency (P) Limited, 2014.

B. SC. IN CHEMISTRY

DETAILED SYLLABUS OF FYUGP SEMESTER-VIII

Course Title: Advanced topics in Chemistry-I (DSC-19)

Course Code: MAJ-CHM-8.1

Total Credit: 4 (3 Credit Theory + 1 Credit Practical)

Distribution of marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course objective: The unit on reaction mechanism is included for the students to get acquainted with the oxidation reduction reaction, Outer-sphere and inner-sphere electron transfer reaction-characteristics and controlling factors, racemization in octahedral complexes etc. A course on transition metals in catalysis aims to equip students with a comprehensive understanding of how transition metals, with their unique properties, facilitate chemical reactions as catalysts, covering mechanisms, applications, and their role in both industrial and biological processes. The unit of Asymmetric synthesis is included to provide students with essential knowledge and practical skills in asymmetric synthesis. Further, students will be provided with advanced understanding to explore photochemical and fast reaction mechanisms, including energy transfer, quenching, reaction dynamics, and femtochemistry, with emphasis on theoretical models, molecular techniques, and their kinetic applications.

Theory: 3 Credits **Total course hour: 45 hr** **Duration of Examination: 2 hr.**

Unit 1: Inorganic Reaction Mechanism-II (10 Lectures)

Oxidation Reduction Reaction / Redox Reaction, Outer-sphere and inner-sphere electron transfer reaction-characteristics and controlling factors, ligand transfer, role of bridging ligand, chemical mechanism of electron transfer, complementary and non-complimentary redox reactions. racemization in octahedral complexes.

Unit 2: Transition metals in catalysis (10 Lectures)

Study of the following industrial processes and their mechanism:

1. Alkene hydrogenation (Wilkinson's Catalyst)
2. Hydroformylation (Co catalysts)
3. Wacker Process
4. Synthetic gasoline (Fischer Tropsch reaction)
5. Synthesis gas by metal carbonyl complexes

Unit 3: Introduction to Asymmetric synthesis (10 Lectures)

Stereoselective and racemization reactions, Explanation of stereoselectivity using energy profile diagrams, Cram's Rule and Felkin-Anh model for predicting stereochemical outcomes, Use of chiral auxiliaries, chiral reagents, and chiral catalysts in asymmetric synthesis, Merits and demerits of chiral inducing agents, Evans oxazolidinones for enantioselective alkylation, Sharpless asymmetric epoxidation, CBS catalyst and its role in asymmetric reduction, Resolution of racemic mixtures via diastereomeric recrystallization and kinetic resolution, Asymmetric synthesis using the chiral pool approach, Mechanistic insights and efficiency of stereoselective transformations in organic synthesis.

Unit 4: Chemical Dynamics (15 Lectures)

Energy transfer in photochemical reactions: photosensitization and quenching, Stern-Volmer equation (quenching of fluoroscence), Role of photochemical reactions in biochemical processes, photostationary states, chemiluminescence, Oscillatory reactions.
Reaction in solutions, Bronsted-Bjerrum Equation, Unimolecular reactions, RRK, RRKM theory, molecular beam techniques, reaction dynamics, potential energy surface, Study of fast reactions, Femtochemistry.

Practical: 1 Credit **Total course hour: 30 hr** **Duration of Examination: 3 hr**

List of experiments:

(i) Quantitative estimation involving volumetric (redox and complexometry), gravimetric and spectrophotometric methods of analysis of constituents in three component mixtures, alloys and minerals.
(ii) Synthesis and characterization of inorganic compounds, including those involving green synthetic methodology: Characterization includes elemental analysis, studies by IR, electronic spectra, magnetic susceptibility, conductance measurements, cyclic voltammetry. TG, DSC.
(iii) Determine the rate constant of the acid catalyzed hydrolysis of methyl acetate.

(iv) Determine the rate constant of saponification of ethyl acetate.

(v) Determine the activation energy of the hydrolysis of methyl acetate catalyzed by hydrochloric acid.

Learning outcome:

On completion of this course the students will be able to understand:

(i) The students will be able to realise the role of crystal field theory and molecular orbital theory in controlling the reactivity of inorganic meal complexes.
(ii) The structures of industrially important different organometallic catalysts and details about their catalytic activities.
(iii) Students will grasp key concepts of asymmetric synthesis and stereoselective transformations.

(iv) Students will understand energy transfer in photochemical and biochemical systems, analyze reaction dynamics using RRKM theory, explore fast reactions via femtochemistry, and interpret potential energy surfaces and molecular interactions.
(v) Upon completing this practical course, students will be able to quantitatively analyze constituents in three-component mixtures, alloys, and minerals using volumetric (redox and complexometry), gravimetric, and spectrophotometric methods, demonstrating proficiency in chemical analysis techniques.
(vi) Upon completion of a course on the synthesis and characterization of inorganic compounds, including those involving green synthetic methodologies, students will be able to understand and apply principles of inorganic chemistry, design and execute syntheses, and characterize synthesized compounds using various analytical techniques, with a focus on environmentally friendly methods.

Suggested reading:

(1) Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.
(2) Elias, B. D. Gupta, Basic Organometallic Chemistry, Universities Press (ed. 2), 2013.
(3) Asim K. Das Fundamental Concepts of Inorganic Chemistry, Vol. 5, 6.
(4) Clayden, J.; Greeves, N. and Warren S. (2012), Organic Chemistry, 2nd Edition, Oxford Publishers.
(5) Physical Chemistry: A Molecular Approach. D. A. McQuarrie and J. D. Simon, University.
(6) Physical Chemistry. P. W. Atkins and J. de Paula, Oxford University Press.
(7) Physical Chemistry. I. N. Levine, McGraw Hill.
(8) Chemical Kinetics. K.J. Laidler, Pearson.
(9) Chemical Kinetics and Reaction Dynamics, P.L. Houston, Dover Publications, 2006
(10) Mendham, J. Vogel's Quantitative Chemical Analysis, Pearson, 2009.
(11) An Advanced Course in Practical Chemistry by Nad, Mahapatra & Ghosal. Publisher, New Central Book Agency (P) Limited, 2014.
(12) Jadav, J. B. Advanced Practical Physical Chemistry, (Krishna Prakashan, 2015)
(13) Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).
(14) Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. Experiments in Physical Chemistry 8^{th} Ed.; McGraw-Hill: New York (2003).

Course Title: Advanced topics in Chemistry-II (DSC-20)

Course Code: MAJ-CHM-8.2

Total Credit: 4 (3 Credit Theory + 1 Credit Practical)

Distribution of marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course objective: This course aims to equip students with a comprehensive understanding of physical characterization techniques, specifically Electron Paramagnetic Resonance (EPR) and Mössbauer Spectroscopy, and their applications in the study of inorganic compounds, enabling them to interpret spectra and understand the properties of these materials. This is a course designed to complement the needs of students to learn more about the various methods for separating mixtures based on their physical properties. This course also aims to prepare students with a comprehensive understanding of retrosynthetic analysis, green chemistry, and click chemistry for sustainable and efficient organic synthesis. Further, students will be provided with in-depth knowledge to develop an understanding of the interaction of electromagnetic radiation with matter, radiative and non-radiative processes, quantum yield, and the principles and kinetics of photochemical reactions including fluorescence, phosphorescence, and quenching. Electrochemical interfaces, electrical double layer models, electrochemical kinetics, and the application of these concepts in overpotential behavior and battery technology, basic principles of polarography will be discussed.

Theory: 3 Credits Total course hour: 45 hr Duration of Examination: 2 hr.

Unit 1: Physical characterization of Inorganic compounds by EPR and Mossbauer Spectroscopy (12 Lectures)

Basic principle of EPR, Standard material for ESR spectroscopy (dpph), detailed understanding of hyperfine coupling constant, significance of g-tensors, application to detect free radicals (H, CH_3, C_6H_5, NH_2, CD_3, PH_4, F_2^-, $[BH_3]^-$, etc.) and various transition metal complexes having one unpaired electron, charge transfer spectra and its application.

Mössbauer spectroscopy: Mossbauer effect, nuclear recoil, Doppler effect, instrumentation, chemical shift-examples, quadruple effect, effect of magnetic field, effect of simultaneous electric and magnetic fields, typical spectra of iron and tin compounds, application of Mössbauer spectroscopy-nature of metal-ligand bond, coordination number, structure, oxidation state; NQR.

Unit-2: Separation Techniques (5 Lectures)

Mechanism of extraction: extraction by solvation and chelation.
Principle of solvent extraction: Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from aqueous solution, extraction of organic species from the aqueous and nonaqueous media.
Chromatography: Classification, principle and efficiency of the technique including Column Chromatography and Thin Layer chromatography.
Mechanism of separation: adsorption, partition & ion exchange.
Development of chromatograms: frontal, elution and displacement methods.

Unit 3: Retrosynthetic Analysis (8 Lectures)

Retrosynthesis-disconnection approach, synthons and synthetic equivalents; umpolung; Functional Group Interconversions (FGI); One group C-C disconnections, One group C-X disconnections, retrosynthesis of some simple organic compounds.

Unit 4: Green Chemistry (5 Lectures)

The essentials of green chemistry: definitions, adverse effects of chemicals on health and the environment, Accidents with Chemicals Wastes and Minimization, history of the development of Green Chemistry, sustainability as it relates to GC, and ethical awareness; Goals of Green Chemistry; Limitations/ Obstacles in the pursuit of the goals of Green Chemistry.

Unit-5: Photochemistry (8 Lectures)

Characteristics of electromagnetic radiation, Radiative and non-radiative transitions, fluorescence and phosphorescence, Lambert-Beer's law and its limitations, physical significance of absorption coefficients. Laws of photochemistry, quantum yield, examples of low and high quantum yields, photochemical reactions and kinetics of photochemical reactions, quenching.

Unit 6: Advanced Electrochemistry (7 Lectures)

Reaction at the electric interface, Electrical double layer, Helmholtz, Guoy-Chapman, Stern model, Overpotential, Butler-Volmer equation, Charge transfer kinetics, Tafel equation and exchange current density, Electro Analytical Techniques, Solid State Batteries.

Practical: 1 Credit **Total course hour: 30 hr** **Duration of Examination: 3 hr**

Experiments:

1. Synthesis of coumarin by Pechmann condensation and study of the absorption and fluorescence spectra of the synthesized coumarine
2. Synthesis of dibenzalpropanone
3. Synthesis of benzoin (thiamine catalyzed synthesis)
4. Synthesis of dihydropyrimidinone
5. Solvent free aldol condensation between acetophenone and 3,4-dimethoxybenzaldehyde\
6. Any other synthesis may be given time to time

Learning Outcome:

By the end of the course, students will be able to:

(i) Apply ESR in characterizing inorganic compounds,
(ii) Understand the basic principle of nuclear quadruple resonance spectroscopy (NQR) and apply it in analyzing various metal complexes,
(iii) Get the idea to unveil the structure and properties relationship through the spectroscopic investigations.
(iv) Understand and explain the principles of various separation methods, apply them to solve problems, and choose the appropriate technique for specific applications, including designing and optimizing separation processes.
(v) Apply retrosynthetic analysis for designing organic synthesis routes.
(vi) Understand principles and applications of green chemistry.
(vii) Explore click chemistry and its relevance in modern synthesis.
(viii) Perform and analyze organic reactions through practical lab work.
(ix) Explain the characteristics of electromagnetic radiation, apply Lambert-Beer's law, differentiate between fluorescence and phosphorescence, evaluate quantum yields, and analyze photochemical reaction mechanisms and kinetics including quenching phenomena.
(x) Understand the structure of the electrical double layer, compare Helmholtz, Guoy-Chapman, and Stern models, interpret electrochemical kinetics via the Butler-Volmer equation, and apply these principles to technologies like batteries and electrochemical devices.
(xi) Understand the basic principle of Polarography.

Suggested reading:

1. Clayden, J.; Greeves, N. and Warren S. (2012), Organic Chemistry, 2nd Edition, Oxford Publishers.
2. Smith, M. B. (2016), Organic Synthesis, 4th Edition, Academic Press, Inc.
3. Kalsi, P.S. (2022), Organic Synthesis through Disconnection Approach, 3rd Edition, MedTech Science Press
4. Coxon, J. M. and Norman, R.O.C. (1993), Principles of Organic Synthesis, 3rd Edition, CRC Press.
5. Carruthers, W. and Coldham, I (2004), Moder Methods of Organic Synthesis, 4th Edition, Cambridge University Press.
6. Shirame, S. P. and Bhosale, R. B. (2018), Green Approach in Click Chemistry. Book Chapter in Green Chemistry. Editors: Saleh, H. M. and Koller, M.
7. Click Chemistry and Bioorthogonal Chemistry. Nobel Prize in Chemistry 2022.
8. Caron, S. (2011). Editor of Practical Synthetic Organic Chemistry: Reactions, Principles and Techniques. Wiley.
9. Monograph on Green Chemistry Laboratory Experiments.

10. Palleros, D. R. (2004). Solvent-Free Synthesis of Chalcones. Journal of Chemical Education, 81, 1345-1347.
11. Asim K. Das Fundamental Concepts of Inorganic Chemistry, Vol. 7.
12. R.S. Drago, Physical Methods, 1972, New York. Edn.
13. N. N. Greenwood - Mossbauer Spectroscopy (1971, Springer)
14. P. Gütlich, E. Bill, A. X. Trautwein – Mossbauer Spectroscopy and Transition Metal Chemistry_ Fundamentals and Applications.
15. Mendham, J. et al.: Vogel's Text Book of Quantitative Chemical Analysis ; 6th Ed. Pearson Education, 2009.
16. Christian, Gary D: Analytical Chemistry, 6th Ed. Wiley India (P) Ltd., 2004.
17. Mikes, O. and Chalmes, R.A. Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Ltd. London.1979.
18. Ditts, R.V. Analytical Chemistry: Methods of separation.Van Nostrand, New York, 1974.
19. Atkins Physical Chemistry, Atkins and Paola
20. E. Gileadi, Physical Electrochemistry, Fundamental Techniques and Applications, Wiley Publication, 2011.
21. Fundamentals of Photochemistry, K.K. Rohatagi-Mukherjee.

Course Title: Chemistry of Nano-materials (DSC-22)

Course Code: MAJ-CHM-8.3

Total Credit: 4 (3 Credit Theory + 1 Credit Practical)

Distribution of marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course objective: The primary objective of a "Chemistry of Nanomaterials" course is to provide students with a comprehensive understanding of the chemistry involved in synthesizing, characterizing, and utilizing nanomaterials. This includes knowledge of different synthesis methods, how properties change at the nanoscale, and the applications of these materials in various fields.

Theory: 3 Credits Total course hour: 45 hr Duration of Examination: 2 hr.

Unit: Chemistry of Nano-materials (45 Lectures)

Introduction of Nanomaterials and Nanosciences, Different types of Nanomaterials: 0D, 1D, 2D Nanomaterials, 3D-Nanomaterials or Bulk Nanomaterials, Properties of Nanomaterials- special references to surface properties and mechanical properties, Stabilization of Nanoparticles: Electrostatic and Steric Stabilization, Quantum Dots (QDs), Surface Plasmon Resonance (SPR) and optical properties of metallic nanoparticles (Plasmonic Nanoparticles), The Carbon Nanoworld: Fullerenes, Graphenes and Nanotubes, Synthesis of Nanomaterials: Top-Down and Bottom-Up Approach, Characterisation techniques of Nanomaterials, Applications of Nanomaterials and Nanotechnology.

Practical: 1 Credit Total course hour: 30 hr Duration of Examination: 3 hr

Experiments:

1. Synthesis of NiO, AgO, and ZnO nanoparticles.

2. Synthesis of green Silver nanoparticle.

3. Preparation of GO/$ZnFe_2O_4$ nano composites.

Learning Outcome: After the completion of this course, Students will

1. Gain a fundamental understanding of what nanomaterials are, how they are classified, and the basic principles behind their unique properties compared to their bulk counterparts.
2. Learn about different synthesis techniques for creating nanomaterials, such as top-down and bottom-up approaches. Become familiar with various characterization techniques to analyze the morphology, structure, and properties of these materials.
3. Understand the effects of quantum confinement on electronic and optical properties, and how these properties can be tailored for specific applications.
4. Explore the various applications of nanomaterials in fields like medicine, materials science, electronics, and energy.
5. Recognize the interdisciplinary nature of nanoscience and nanotechnology, connecting concepts from chemistry, physics, and engineering.
6. Develop critical thinking skills to evaluate and select appropriate synthesis methods and characterization techniques for specific applications.

Suggested reading:

(1) Nanostructures & Nanomaterials: Synthesis, Properties and Applications by Guozhong Cao, Imperial College Press.
(2) Fundamentals and Applications of Nanomaterials by Zhen Guo & Li Tan, Artech House.
(3) Nanoparticles - Nanocomposites Nanomaterials: An Introduction for Beginners by Dieter Vollath, Wiley-VCH
(4) Introduction to Nanoscience by S.M. Lindsay, Oxford.
(5) Introduction to Nanomaterials and Nanoscience by Asim K Das and Mahua Das, CBS Publications & Distributor.
(6) Nanomaterials – Synthesis, Properties and Applications, Nitin K. Puri.
(7) Handbook of Research on Nanomaterials, Nanochemistry ond Smart Materials, A. K. Haghi and G. E. Zaikov.

Course Title: Supramolecular Chemistry (DSC-23)

Course Code: MAJ-CHM-8.4

Total Credit: 4 (3 Credit Theory + 1 Credit Practical)

Marks Distribution: 70 (End Semester) (45T+25P) +15 (In-Semester) + 15 (HA/S/GD)

Course Objective: To introduce the principles of supramolecular chemistry and develop skills in designing, understanding, and applying non-covalent interactions in molecular recognition, materials, and biological systems.

Prerequisite: Foundational understanding of organic, inorganic, and physical chemistry, including reaction mechanisms, coordination compounds, thermodynamics, and kinetics.

Theory: 3 Credits **Total course hour: 45 hr** **Duration of Examination: 2 hr.**

Unit 1: Fundamentals of Supramolecular Chemistry (15 Lectures)

Introduction and Historical Background; Types of Non-Covalent Interactions; Molecular Recognition and Self-Assembly; Host–guest chemistry, Molecular self-assembly and Cooperative interactions; Thermodynamics and Kinetics of Binding: Binding constants: association/dissociation, Thermodynamic vs kinetic control, Factors affecting supramolecular interactions

Unit 2: Host Molecules and Supramolecular Architectures (5 Lectures)

Various host Systems and their applications in molecular recognition: Crown ethers, cryptands, spherands, Cyclodextrins and calixarenes.
Mechanically Interlocked Molecules: Catenanes, rotaxanes; Helicates, and knots; molecular machines; Molecular devices and electronics.
Supramolecular Materials: Supramolecular polymers, gels, and fibers, Stimuli-responsive materials.

Unit 3: Crystal Engineering and Coordination Frameworks (10 Lectures)

Fundamentals of Crystal Engineering: Crystal nucleation and growth; Crystal structure analysis.
Supramolecular Synthons and Interactions: Hydrogen bonding, halogen bonding, Role in crystal packing and design.
Polymorphism and Co-Crystals: Types, importance, and applications; Pharmaceutical and material implications.
Coordination Polymers and MOFs: 1D, 2D, and 3D frameworks; Porous structures and cavity design; Applications: catalysis, gas storage, separation.

Unit 4: Supramolecular Chemistry in Biology (15 Lectures)

Enzyme-substrate complexes, DNA base pairing, Protein-ligand interactions, Membrane transport systems, Self-assembly in biological systems, Molecular machines in biology, Synthetic receptors, Drug-DNA interactions, Biomimetic systems, Supramolecular therapeutics, Biosensors, Nanocarriers for drug delivery.

Practical: 1 Credit **Total course hour: 30 hr** **Duration of Examination: 3 hr**

Experiments:

1. Preparation of oxacalix[3]arenes: (a) 4-t-Butyloxacalix[3]arene, (b) 4-Phenyloxacalix[3]arene
2. Preparation of tetraphenylporphyrin, Copper Phthalocyanin, cyclic tetralactam.
3. Preparation of a Preparation of cyclotriveratrylene
4. Preparation of a liquid clathrate($(H_3O[18]crown\text{-}6)^+ HCl_2^-$. n(toluene)
5. Preparation of a C_{60}-macrocyclic complex: C_{60}-4-Methyl(N-benzyl)azacalix[3]arene.
6. Determination of binding constant of various host-guest complex using Job's Plot.

Learning Outcome:

By the end of the course, students will be able to:

- **Understand the core principles of supramolecular chemistry**, including non-covalent interactions, molecular recognition, and self-assembly processes.
- **Learn about host-guest chemistry** and the application of various host molecules (e.g., crown ethers, cyclodextrins) in molecular recognition and self-assembly.
- **Explore crystal engineering** and coordination frameworks, including polymorphism, co-crystals, and applications in catalysis and gas storage.
- **Apply supramolecular chemistry in biological systems**, such as enzyme-substrate interactions, drug delivery, and biomimetic systems.
- **Develop practical lab skills** by synthesizing various supramolecular compounds and understanding their design and characterization for real-world applications.

Suggested reading:

1. Supramolecular Chemistry: Concepts and Perspectives by J-M. Lehn (Wiley-VCHVerlag GmbH; 1st edition, 6 June 1995)
2. Supramolecular Chemistry from Biological Inspiration to Biomedical Applications by Peter J. Cragg. (Spinger)
3. Core Concepts in Supramolecular Chemistry and Nanochemistry by J. W. Steed, D. R. Turner, K. J. Wallace. (John Wiley and Sons, Ltd)
4. Encyclopedia of Supramolecular Chemistry, vol 1 edited by J. L. Atwood, J. Steed. (Taylor & Francis)
5. Supramolecular Chemistry Second Edition by J. L. Atwood, J. Steed. (John Wiley and Sons, Ltd)
6. Supramolecular Chemistry– Fundamentals and Applications. Advanced Textbook by T. Kunitake, K Ariga, Berlin: Springer-Verlag Heidelberg, 2006. 208 p. ISBN 978-3- 540- 01298-6.
7. Introduction to Supramolecular Chemistry by H. Dodziuk, Kluwer Academic Publishers, The Netherlands (2002).

8. A Practical Guide to Supramolecular Chemistry by Peter J. Cragg. (John Wiley and Sons, Ltd)

Course Title: General Chemistry-IV (DSE-8)

Course Code: MIN-CHM-8.1

Total Credit: 4 (3 Credit Theory + 1 Credit Practical)

Distribution of marks: 70 (End Semester) (45T+25P) + 15 (In-Semester) + 15(HA/S/GD)

Course objective: To develop a clear understanding of solid-state structure, photochemistry, spectroscopy, and phase behavior, along with practical skills in analytical techniques. The course prepares students for advanced studies and research in physical and inorganic chemistry.
Prerequisite: Students are expected to have a basic background in general chemistry, including atomic structure, chemical bonding, and fundamental principles of thermodynamics and kinetics. Prior exposure to organic and inorganic chemistry at the undergraduate level will be beneficial.

Theory: 3 Credits Total course hour: 45 hr Duration of Examination: 2 hr.

Unit 1: Structure and properties of Solids (5 Lectures)

Description of Crystal Structures, crystal defects-intrinsic and extrinsic, thermodynamics of crystal defects, Schottky and Frenkel defects, color centers, electronic properties of solids: conductors, semiconductors, insulators, superconductors.

Unit 2: Inorganic Photochemistry (5 Lectures)

Basics of photochemistry- absorption, excitation, photochemical laws, Franck-Condon principles, Jablonski diagram-concept of Fluorescence and Phosphorescence.

Unit 3: Photochemistry and Pericyclic reactions (10 Lectures)

Theory of photochemistry, Jablonski diagram, Frank-Condon principle, Photosensitisers, Einstein's law of photochemical equivalence, typical photoreactions such as photoreaction of benzophenone, photolytic reactions of ketones.
Pericyclic reactions**:** Basic concepts of pericyclic reaction and examples of electrocyclic, cycloaddition and sigmatropic rearrangements reactions, FMO analysis and Woodward Hoffmann selection rules for [2+2] cycloaddition reaction.

Unit 4: Application of Spectroscopy (10 Lectures)

UV-Visible: Review of basic principles, application of UV to conjugated polyenes, carbonyl compounds and unsaturated compounds, Woodward's rules. *Infrared:* Review of basic principles, characterization of vibrational frequency of carbonyl, hydroxyl and amine compounds. *NMR*: Review of basic principles, chemical shift, shielding and deshielding of protons and their application in structural elucidation of simple organic compounds: methane, ethane, ethylene, acetylene, benzene, acetone, ethanol and acetic acid.

Unit 5: Phase Equilibrium (7 Lectures)

Statement and meaning of the terms: phase, component and degree of freedom, Gibbs phase rule, phase equilibria of one component systems-water, carbon dioxide and sulphur.

Unit 6: Colloids (8 Lectures)

Definition of colloids, Classification of colloids, Solids &liquids(sols), Liquids in liquids(emulsions): types of emulsions, Surfactants-micelles, critical micelle concentration, Coagulation of colloids, Hardy-Schulz rule and gold number.

Practical: 1 Credit   Total course hour: 30 hr   Duration of Examination: 3 hr

List of experiments:

1. Gravimetric Analysis:
Estimation of nickel(II) using dimethylglyoxime (DMG)
2. Complexometric Titration:
Estimation of Zn^{2+} using EBT / Xylenol orange as indicator
3. Estimation of glucose/cholesterol/ urea/uric acid by colorimeter.
4. Determination of concentration of Glycine solution by formylation method.
5. Partition Coefficient of I_2 between Organic solvent and Water.

Learning outcome:

- Understand crystal structures, defects, and their thermodynamic aspects.
- Grasp basic photochemical principles and excited state processes.
- Analyze photochemical and pericyclic reactions with mechanistic insight.
- Apply UV, IR, and NMR spectroscopy for structural elucidation.
- Interpret phase equilibria using Gibbs phase rule in one-component systems.
- Perform quantitative analyses through gravimetric, titrimetric, and instrumental methods.

Suggested reading:

1. Solid State Chemistry and its Applications 2nd Edition by Anthony R. West, Wiley, 2022.
2. Introduction to solid state physics by Charles Kittel, Chapman & Hall, Ltd.

3. Principles and Applications of Photochemistry by Brian Wardle. Wiley.
4. Fundamental of Photochemistry by K K Rohatgi-Mukherjee, New Age International Publishers.
5. Norman, R.O.C. and Coxon, C. M. Principles of Organic Synthesis, CRC Press, New York, 2009.
6. Sankararaman, S. Pericyclic Reactions – A textbook. Wiley-VCH, 2005.
7. Fleming, I. Pericyclic Reactions, Oxford University Press, 1999.
8. Organic spectroscopy by W. Kemp (Mcmillan).
9. Spectrometric identification of organic compounds by R. Silverstein (Willey).
10. Spectroscopy of organic compounds by P.S. Kalsi (New Age Publishers).
11. Mann, F.G. & Saunders, B.C. Practical Organic Chemistry, Pearson Education (2009).
12. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. Practical Organic Chemistry, 5th Ed., Pearson (2012).
13. Principles of Physical Chemistry by Puri, Sharma & Pathania
14. A text book of Physical Chemistry by Negi & Anand
15. An Advanced Course in Practical Chemistry by Nad, Mahapatra & Ghosal. Publisher, New Central Book Agency (P) Limited, 2014.

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