‘

# FOUR YEAR UNDERGRADUATE PROGRAMME (FYUP)

## (B.Sc. with Chemistry)
## Undergraduate Program
## 2025

**MANIPUR UNIVERSITY**

**CANCHIPUR-795003**

**MANIPUR UNIVERSITY**
**Bachelor of Science in Chemistry with Honors**
**(Effective from Academic Year 2025-26)**

| Semester | Course | | Title of the paper | Credit | Total Credit |
|---|---|---|---|---|---|
| I (First) | Category | Code | | | |
| | Major-1 | **MJC45CHM101(T)25** | CHEMISTRY MAJOR-I | 3 | 4 |
| | | **MJC45CHM101(P)25** | CHEMISTRY MAJOR-I(P) | 1 | |
| | Minor-1 | **MNC45CHM101(T)25** | CHEMISTRY MINOR-I | 3 | 4 |
| | | **MNC45CHM101(P)25** | CHEMISTRY MINOR-I(P) | 1 | |
| | MDC-1 | **MDC45CHM101(T)25** | INTRODUCTORY CHEMISTRY | 3 | 3 |
| | AEC-1 | **AEC Pool** | (LANGUAGE & COMMUNICATION SKILLS) | 4 | 4 |
| | SEC-1 | **SEC45CHM101(T)25** | WATER REMEDIATION AND CONSERVATION STUDIES | 3 | 3 |
| | VAC-1 | **VAC45CHM101(T)25** | VAC-1 | 2 | 2 |
| | | | | **Total credits** | **20** |
| II (Second) | Major-2 | **MJC45CHM102(T)25** | CHEMISTRY MAJOR-II | 3 | 4 |
| | | **MJC45CHM102(P)25** | CHEMISTRY MAJOR-II(P) | 1 | |
| | Minor-2 | **MNC45CHM102(T)25** | CHEMISTRY MINOR-II | 3 | 4 |
| | | **MNC45CHM102(P)25** | CHEMISTRY MINOR-II(P) | 1 | |
| | MDC-2 | **MDC45CHM102(T)25** | CHEMISTRY IN EVERYDAY LIFE | 3 | 3 |
| | AEC-2 | **AEC Pool** | ACADEMIC WRITING | 4 | 4 |
| | SEC-2 | **SEC45CHM102(T)25** | SEC-2 BIOFERTILIZER | 3 | 3 |
| | VAC-2 | **VAC45CHM102(T)25** | VAC-2 | 2 | 2 |
| | | | | **Total credits** | **20** |
| | Major-3 | MJC50CHM203(T)25 | CHEMISTRY MAJOR-III | 3 | 4 |

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|---|---|---|---|---|---|
| III (Third) | | MJC50CHM203(P)25 | CHEMISTRY MAJOR-III(P) | 1 | |
| | Major-4 | MJC50CHM204(T)25 | CHEMISTRY MAJOR-IV | 3 | 4 |
| | | MJC50CHM204(P)25 | CHEMISTRY MAJOR-IV(P) | 1 | |
| | Minor-3 | MNC50CHM203(T)25 | CHEMISTRY MINOR-III | 3 | 4 |
| | | MNC50CHM203(P)25 | CHEMISTRY MINOR-III(P) | 1 | |
| | MDC-3 | MDC50CHM203(T)25 | MDC-III: ENVIRONMENTAL SCIENCE | 3 | 3 |
| | SEC-3 | SEC50CHM203(T)25 | SEC-III: RENEWABLE ENERGIES (SOLAR AND BIOMAS) | 3 | 3 |
| | VAC-3 | VAC Pool | | 2 | 2 |
| | | | | **Total Credit** | **20** |
| IV (Four) | Major-5 | MJC50CHM205(T)25 | CHEMISTRY MAJOR-V | 3 | 4 |
| | | MJC50CHM205(P)25 | CHEMISTRY MAJOR-V(P) | 1 | |
| | Major-6 | MJC50CHM206(T)25 | CHEMISTRY MAJOR-VI | 3 | 4 |
| | | MJC50CHM206(P)25 | CHEMISTRY MAJOR-VI(P) | 1 | |
| | Major-7 | MJC50CHM207(T)25 | CHEMISTRY MAJOR-VII | 3 | 4 |
| | | MJC50CHM207(P)25 | CHEMISTRY MAJOR-VII(P) | 1 | |
| | Major-8 | MJC50CHM208(T)25 | CHEMISTRY MAJOR-VIII | 3 | 4 |
| | | MJC50CHM208(P)25 | CHEMISTRY MAJOR-VIII(P) | 1 | |
| | Minor-4 | MNC50CHM204(T)25 | CHEMISTRY MINOR-IV | 3 | 4 |
| | | MNC50CHM204(P)25 | CHEMISTRY MINOR-IV(P) | 1 | |
| | | | | **Total Credit** | **20** |

**MANIPURUNIVERSITY**
**Bachelor of Science (Hons) Chemistry**
**(Effective from Academic Year 2025-26)**

**SEMESTER-I**

**CHEMISTRY MAJOR -1**

**COURSE CODE: MJC45CHM101(T)25** **(45 classes of 1 hour each)**

| L | T | P | Credit |
|---|---|---|---|
| 3 | 0 | 1 | 4 |

**1.1 Major Courses**
**1.1 CHEMISTRY - A. INORGANIC CHEMISTRY - I**
**1.2 CHEMISTRY - B. ORGANIC CHEMISTRY – I**
**1.3 CHEMISTRY- C. PHYSICAL CHEMISTRY-I**

**On completion of this course, the students will be able to understand:**
**Learning objective:**

- Atomic theory and its evolution.
- Learning scientific theory of atoms, concept of wave function.
- Elements in periodic table; physical and chemical characteristics, periodicity.
- Atomic structure, chemical bonding, and molecular geometry based on accepted models.
- Understand atomic theory of matter, composition of atom.
- Identity of given element, relative size, charges of proton, neutron and electrons, and their assembly to form different atoms.
- Physical and chemical characteristics of elements in various groups and periods according to ionic size, charge, etc. and position in periodic table.
- Characterize bonding between atoms, molecules, interaction and energetic, hybridization and shapes of atomic, molecular orbitals, bond parameters, bond distances and energies.
- Valence bond theory incorporating concepts of hybridization predicting geometry of molecules.
- Importance of hydrogen bonding, metallic bonding.
- Basic of organic molecules, structure, bonding, reactivity and reaction mechanisms. molecules and nomenclature.
- Reactivity, stability of organic molecules, structure, reaction stereochemistry
- Electrophile, nucleophiles, free radicals, electronegativity, resonance, and intermediates
  along the reaction pathways.
- Mechanism of organic reactions (effect of nucleophile / leaving group, solvent), substitution *vs*. elimination

- ❖ Physical properties of each state of matter and laws related to describe the states.
- ❖ Calculation of lattice parameters.

## SECTION A: INORGANIC CHEMISTRY

**UNIT-1 Atomic Structure: (5 Classes of 60 minutes each)**

Brief revision of Bohr model and its limitations, atomic spectra of Hydrogen and Hydrogen-like atoms, Quantization of angular momentum, dual nature of electrons, de Broglie equation, wave functions, Quantum numbers and their significance, concept of orbit and orbitals. Radial probability diagrams andshapes of s, p and dorbitals. Pauli's Exclusion Principle, Hund's rule of maximum multiplicity, Aufbau's principle and its limitations, Electronic configuration of atoms, Variation of orbital energy with atomic number.

**UNIT-2: Periodicity of Elements**: **(5 Classes of 60 minutes each)**

Details on modern Periodic Table with reference to the periodic changes of atomic, ionic andcovalent radii. Ionisation energies, successive ionization energies, factors affecting ionization energy and application of ionization energy. Electron affinity and electron negativity, Pauling, Mullikan, Alfred Rachow scales of electronegativity. Bond order, partial charge, hybridization, group electronegativity, Effective nuclear charge, shielding or screening effect, Slater's rule, variation of effective nuclear charge in periodic table.

**UNIT-3: Chemical Bonding: (8 Classes of 60 minutes each)**

Type of chemical bonding and its characteristics:

*Ionic bond*: General characteristics, type of ions, size effect, radius ratio rule and its limitation, packing of ions in crystals, Madelung constant, Born-Haber cycle and its application, Solvation energy.

*Covalent bond*: Lewis structure, Shapes of simple molecules containing lone/bond-pairs of electrons, multiple bonding, sigma and pi-bond approach, Valence Shell Electron Pair Repulsion Theory (VSEPR), Valence Bond theory (Heitler-London approach). Molecular orbital theory. Molecular orbital diagrams of simple homonuclear/heteronuclear diatomic molecules, $N_2$, $O_2$,$B_2$, $F_2$, CO, NO and their ions.(ideas of s-p mixing and orbital interaction to be given.)Hybridization of atomic orbitals (s,p and d only), shapes of s, p and d hybrid orbitals, $BeF_2$, $BF_3$, $NH_3$, $H_3O^+$, $SF_4$, $ClF_3$, $ICl_2^-$.

Covalent character in ionic compounds and Ionic character in covalent compounds. Bond moment and Dipole moment. Ionic character from dipole moment and electronegativity difference.

## Section B. ORGANIC CHEMISTRY – I

**UNIT-4: Basic Concepts of Organic Chemistry: (8 classes of 60 minutes each)**

Organic Compounds: Classifications and nomenclature, hybridization, shapes of molecules, influence of hybridization on bond properties. Electronic displacements: Inductive, electromeric, resonance and mesomeric effects, hyperconjugation and their applications.

Organic acids and bases and their relative strengths. Homolytic and heterolytic fission with suitable examples. Curly arrow rules, formal charges, Electrophiles and Nucleophiles, Nucleophilicity and basicity, Types, shape and relative stabilities of reaction intermediates (Carbocations, Carbanions, Free radicals, Carbenes and Nitrenes). Organicreactions and their mechanism: Addition, Elimination and Substitution reactions.

**UNIT-5: Chemistry of Aliphatic Hydrocarbons: (12 classes of 60 minutes each)**

Preparation, properties and reactions of alkanes: Wurtz reaction, Wurtz-Fittig reaction, Free radical substitutions: Halogenation -relative reactivity and selectivity.

Preparation, properties and reactions of alkenes and alkynes: Elimination reactions, Mechanism of E1, E2, E1cB reactions. Saytzeff's and Hofmann's eliminations. Electrophilic additions, their mechanisms (Markownikoff /Anti-Markownikoff addition), mechanism of oxymercuration-demercuration, hydroboration- oxidation, ozonolysis, reduction (catalytic and chemical), *syn*- and *anti*-hydroxylation (oxidation). 1, 2- and 1,4-addition reactions in conjugated dienes and Diels-Alder reaction; Allylic and benzylic bromination and mechanism, e.g. propene, 1-butene, toluene, ethylbenzene, acidity of alkynes

Cycloalkanes and Conformational Analysis, Cycloalkanes and stability, Baeyer strain theory, Conformation analysis, Energy diagrams of cyclohexane: Chair, Boat and Twist boat forms.

## Section C. PHYSICAL CHEMISTRY-I

**UNIT-6: Introduction to Classical Thermodynamics (7 class of 60 minutes each)**

Intensive and extensive variables; state and path functions; isolated, closed and open systems; Laws of thermodynamics, zeroth law of thermodynamics. First law: Concept of heat (q), work (w), internal energy (U), 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.

Thermochemistry: Heat 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), pressure on enthalpy of reactions.

**Total Number of Hours = 45**

**Recommended Books/References:**


1. Lee,J.D. *Concise Inorganic Chemistry,* Wiley, 5thEdn.
2. Douglas, B.E., McDaniel, D.H., AlexanderJ.J., *Concepts & Models of Inorganic Chemistry, (Third Edition)* John Wiley & Sons, 1999.
3. Atkins, P.W. and DePaula, J. *Physical Chemistry*, Tenth Edition, Oxford University Press,2014.
4. Rodger, G.E. *Inorganic and Solid state Chemistry*, Cengage Learning, 2002
5. Morrison, R.N. and Boyd, R.N. Organic Chemistry, 6thEdn., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
6. Pine S.H. Organic Chemistry, Fifth Edition, McGraw Hill, (2007)
7. F.A. Carey, Organic Chemistry, Seventh Edition, Tata McGraw Hill (2008).
8. J. Clayden, N. Greeves, S. Warren, Organic Chemistry, 2ndEd., (2012), Oxford University Press.
9. F.A. Carey, R.J. Sundberg, Advanced Organic Chemistry, Part A: Structure and mechanism, Kluwer Academic Publisher, (2000).


**Semester I Practical**
**(1 Credit)**

**MJC45CHM101(P)25: Inorganic Chemistry Laboratory (Major)**

**Titrimetric Analysis**

(i) Calibration and use of apparatus.
(ii) Preparation of solutions of different Molarity/Normality of titrants.
(iii) Use of primary and secondary standard solutions.

**Acid-Base Titrations (any one of the following)**

(i) Estimation of carbonate and hydroxide present together in mixture.
(ii) Estimation of carbonate and bicarbonate present together in a mixture.
(iii) Estimation of free alkali present in different soaps/detergents

**Field Study Tour:** Collection of water and soil samples and their Analysis and Submission of their Report

**CHM 101 (P): Organic Chemistry Laboratory I (Major)**

1. Purification of organic compounds by crystallization using the following solvents:
   a. Water b. Alcohol c. Alcohol-Water
2. Determination of the melting points of given organic compounds and unknown organic compounds (using Kjeldahl method and electrically heated melting point apparatus).
3. Effect of impurities on the melting point–mixed melting point of two unknown organic compounds.
4. Determination of boiling point of liquid compounds. (boiling point lower than and more than100°C by distillation and capillary method)
5. Chromatography : Separation of a mixture of two amino acids by ascending and horizontal paper chromatography

**Mark distribution in practical**:(1 credit)

| Inorganic Chemistry | Organic Chemistry | Lab. Note Book | Viva voce | Total |
|---|---|---|---|---|
| 6 Marks | 12 Marks | 3 Marks | 4Marks | 25 Marks |

**Recommended Books/References:**


1. Mendham, J., *A.I. Vogel's Quantitative Chemical Analysis,* Sixth Edition, Pearson, 2009.
2. Svehala G. and Sivasankar I.B, *Vogel's Qualitative Inorganic Analysis*, Pearson, India, 2012.
3. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry,* Pearson Education (2009)
4. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5thEd.,* Pearson (2012)


(List of experiments and references are suggestive. However, more experiments can be added/list of experiments can be revised as per available facilities).

**SEMESTER-I**

**CHEMISTRY MINOR-1**

**CHEMISTRY MINOR -1**
**MNC45CHM101(T)25**

**Course Code:**

**(45 classes of 1 hour each)**

| L | T | P | Credit |
|---|---|---|---|
| 3 | 0 | 1 | 4 |

**1.1 MINOR COURSES**

**1.1 CHEMISTRY - A. INORGANIC CHEMISTRY - I**

**1.2 CHEMISTRY - B. ORGANIC CHEMISTRY – I**

**1.3 CHEMISTRY- C. PHYSICAL CHEMISTRY-I**

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- Valence bond theory incorporating concepts of hybridization predicting geometry of molecules.
- Importance of hydrogen bonding, metallic bonding.
- Basic of organic molecules, structure, bonding, reactivity and reaction mechanisms. molecules and nomenclature.
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- Electrophile, nucleophiles, free radicals, electronegativity, resonance, and intermediates
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- Calculation of lattice parameters.

## SECTION A: INORGANIC CHEMISTRY

**UNIT-1 Atomic Structure:** (5 Classes of 60 minutes each)

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**UNIT-2: Periodicity of Elements**: (5 Classes of 60 minutes each)

Details on modern Periodic Table with reference to the periodic changes of atomic, ionic and covalent radii. Ionisation energies, successive ionization energies, factors affecting ionization energy and application of ionization energy. Electron affinity and electron negativity, Pauling, Mullikan, Alfred Rachow scales of electronegativity. Bond order, partial charge, hybridization, group electronegativity, Effective nuclear charge, shielding or screening effect, Slater's rule, variation of effective nuclear charge in periodic table.

**UNIT-3: Chemical Bonding:** (8 Classes of 60 minutes each)

Type of chemical bonding and its characteristics:

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## Section B. ORGANIC CHEMISTRY – I

**UNIT-4: Basic Concepts of Organic Chemistry:**(8 classes of 60 minutes each)

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Organic acids and bases and their relative strengths. Homolytic and heterolytic fission with suitable examples. Curly arrow rules, formal charges, Electrophiles and Nucleophiles, Nucleophilicity and basicity, Types, shape and relative stabilities of reaction intermediates (Carbocations, Carbanions, Free radicals, Carbenes and Nitrenes). Organicreactions and their mechanism: Addition, Elimination and Substitution reactions.

**UNIT-5: Chemistry of Aliphatic Hydrocarbons:** (12 classes of 60 minutes each)

Preparation, properties and reactions of alkanes: Wurtz reaction, Wurtz-Fittigreaction, Free radical substitutions: Halogenation -relative reactivity and selectivity.

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Cycloalkanes and Conformational Analysis, Cycloalkanes and stability, Baeyer strain theory, Conformation analysis, Energy diagrams of cyclohexane: Chair, Boat and Twist boat forms.

## Section C. PHYSICAL CHEMISTRY-I

**UNIT-6: Introduction to Classical Thermodynamics** (7 class of60 minutes each)

Intensive and extensive variables; state and path functions; isolated, closed and open systems; Laws of thermodynamics, zeroth law of thermodynamics. First law: Concept of heat (q), work (w), internal energy (U), 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.

Thermochemistry: Heat 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), pressure on enthalpy of reactions.

Total Number of Hours = 45

**Recommended Books/References:**


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3. Atkins, P.W. and DePaula, J. *Physical Chemistry*, Tenth Edition, Oxford University Press,2014.
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6. Pine S.H. Organic Chemistry, Fifth Edition, McGraw Hill, (2007)
7. F.A.Carey,Organic Chemistry, Seventh Edition,Tata McGraw Hill (2008).
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9. F.A. Carey, R.J. Sundberg, Advanced Organic Chemistry, Part A: Structure and mechanism, Kluwer Academic Publisher, (2000).


## Semester I Practical
## (1 Credit)

**Inorganic Chemistry Laboratory (Major)**

**Titrimetric Analysis**

(i) Calibration and use of apparatus.
(ii) Preparation of solutions of different Molarity/Normality of titrants.
(iii) Use of primary and secondary standard solutions.

**Acid-Base Titrations(any one of the following)**

(i) Estimation of carbonate and hydroxide present together in mixture.
(ii) Estimation of carbonate and bicarbonate present together in a mixture.
(iii) Estimation of free alkali present in different soaps/detergents

**CHN501: Organic Chemistry Laboratory I (Major)**

1. Purification of organic compounds by crystallization using the following solvents:
   a. Water b. Alcohol c. Alcohol-Water
2. Determination of the melting points of given organic compounds and unknown organic compounds (using Kjeldahl method and electrically heated melting point apparatus).
3. Effect of impurities on the melting point–mixed melting point of two unknown organic compounds.
4. Determination of boiling point of liquid compounds. (boiling point lower than and more than100°C by distillation and capillary method)
5. Chromatography : Separation of a mixture of two amino acids by ascending and horizontal paper chromatography

**Mark distribution in practical**:(1 credit)

| Inorganic Chemistry | Organic Chemistry | Lab. Note Book | Viva voce | Total |
|---|---|---|---|---|
| 6 Marks | 12 Marks | 3 Marks | 4Marks | 25 Marks |

**Recommended Books/References:**


1. Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis,* Sixth Edition, Pearson, 2009.
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4. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5thEd.,* Pearson (2012)


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## MDC-I: Introductory Chemistry

Semester: I

**Paper: Introductory Chemistry** **Course Code: MDC45CHM101(T)25**

| L | T | P | Credit |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

Course Objectives: (30 Hrs)

By studying this course, the students will be able to understand

1. Atomic theory and its evolution.
2. Learning the scientific theory of atoms.
3. Elements in the periodic table, physical and chemical characteristics, and periodicity.
4. To predict the atomic structure, chemical bonding, and molecular geometry based on accepted models.
5. To understand the atomic theory of matter, consider the composition of an atom.
6. Identity of given element, relative size, charges of proton, neutron, and electrons, and their assembly to form different atoms.
7. Defining isotopes, isobars, and isotones.
8. Physical and chemical characteristics of elements in various groups and periods.
9. Nature of bonding various molecules/ions.
10. Behaviour of gases.
11. Solutions, their strength, and colligative properties.
12. Fundamentals of organic chemistry.

## 1. Atomic structure: (5 Hrs)

Bohr's atomic theory, Calculation of radius of atom and calculation of energy of electron in hydrogen-like atoms, Electromagnetic radiation and electromagnetic spectrum, hydrogen spectrum and its origin, Limitations of Bohr's atomic theory, de-Broglie theory, Heisenberg's uncertainty principle, quantum numbers, Aufbau principle, Hund's rule, Pauli's exclusion principle, electronic configuration of atoms and ions.

## 2. Periodicity: (4 Hrs)

Modern periodic law and modern periodic table, Classification of elements into blocks, atomic radius, Ionisation energy, Electron affinity, Electronegativity and their variation in the periodic table, Diagonal relationship, Inert pair effect.

## 3. Chemical bonding: (4 Hrs)

General idea about chemical bonds and their types- ionic bond, covalent bond and coordinate bond, Valence bond theory of covalent bond, Explanation of shapes of molecules/ions VSPER theory and hybridisation, Covalent character in ionic bond, Ionic character in covalent bond, Intermolecular forces.

## 4. Gaseous state: (4 Hrs)

Ideal gas and ideal gas equation, Kinetic theory of gases, Real gases and their deviation from ideal gas behaviour, van der Waals equation and its derivation, Significance and units of terms involved in van der Waals equation.

## 5. Solutions: (4 Hrs)

Solutions and their classifications, Concentration of solution and various terms used to express the strength of solution, Calculations related to strength of solution, Colligative properties of solution and related numerical problems.

## 6. Introduction to organic chemistry: (9 Hrs)

Organic compounds and their classification, Functional group, Homologous series, Types of carbon chains, carbon atoms & hydrogen atoms, IUPAC nomenclature of organic compounds, Hybridisation and shapes of organic molecules, General idea about structural isomerism and stereoisomerism in organic compounds, Aromaticity and its implications.

Fission of covalent bonds, Electrophiles and nucleophiles, Electronic displacements in organic molecules, Resonance, Organic reaction intermediates- carbocation, carbanion & free radicals, Types of organic reactions.

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

1. Atomic theory and its evolution.
2. Learning the scientific theory of atoms.
3. Elements in the periodic table: physical and chemical characteristics, periodicity.
4. To predict the atomic structure, chemical bonding, and molecular geometry based on accepted models.
5. To understand the atomic theory of matter, consider the composition of an atom.
6. Identity of given element, relative size, charges of proton, neutron, and electrons, and their assembly to form different atoms.
7. Defining isotopes, isobars, and isotones.
8. Physical and chemical characteristics of elements in various groups and periods.
9. Nature of bonding various molecules/ions.
10. Behaviour of gases.
11. Solutions, their strength, and colligative properties.
12. Fundamentals of organic chemistry

Suggested Readings:

1. Kumar Indrajit, Undergraduate Introductory Chemistry, Pragati Prakashan Meerut, 2023.
2. Lee, J. D. Concise Inorganic Chemistry, Wiley, 5th Edn.
3. Atkins, P. W. and De Paula, J. Physical Chemistry, Tenth Edition, Oxford University Press, 2014.
4. R. N. Morrison & R. N. Boyd, Organic Chemistry, 6th Edn., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
5. S. H. Pine, Organic Chemistry, Fifth Edition, McGraw Hill, (2007)
6. F. A. Carey, Organic Chemistry, Seventh Edition, Tata McGraw Hill (2008).
7. J. Clayden, N. Greeves, S. Warren, Organic Chemistry, 2nd Ed., (2012), Oxford University Press.

**SEC-1: COURSE CODE** **SEC45CHM101(T) 25**

## Water remediation & Conservation studies

(30 lectures of 60 minutes each)

| L | T | P | Cr |
|---|---|---|---|
| 3 | 0 | 0 | 3 |

**Learning outcomes:**

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

1. Learn about the sources of water pollutants and the mechanisms of detoxification, bio-remediation and need of green chemistry.
2. Understand the importance of water conservation and erosion of soil and how to control the erosion.

**UNIT-1: Water pollutants (15 Hrs)**

Sources of water pollutants, pollutants, Industrial and human contribution, WHO recommendation about potable water, current scenario of drinking water quality, chemistry of toxicants like arsenic, fluoride, chromium, lead and mercury, cause and effects of water pollution, remediation, techniques involved such as adsorption, coagulation-filtration, Nalgonada techniques, reverse osmosis, activated charcoal detoxification, applications of non-toxic oxides and mixed oxides, regeneration and recycling, mechanisms of detoxification, bio-remediation, need of green chemistry, future scope.

**UNIT-2: Water conservation and erosion of soil ( 15 Hrs)**

Introduction to water conservation and erosion of soil, forms of water erosion, factors affecting water erosion, types of water erosion, mechanics of water erosion control, agronomical measures of water erosion control, Terraces for water erosion control, modelling of water-shed processes, Case study of water-shed modelling for water conservation and water quality.

**Recommended Books/references:**


1. Cittenden J.C., TrussellJ.R., HandD.W., HoweK.J.,Tchobanoglous G.,*Water Treatment: Principles and Design*, MWH publication.
2. De, A.K. *Environmental Chemistry*, Wiley Eastern
3. Clarson D., Dara S.S., *A textbook of Environmental Chemistry and Pollution Control,* S Chand & Co.
4. Edzwald J., *Water Quality & Treatment: A Handbook on Drinking Water,* Water Resources and Environmental Engineering Series)

**SEMESTER-II**

**CHEMISTRY MAJOR- 2** **COURSE CODE: MJC45CHM102(T)25**

**(45 classes of 1 hour each)**

| L | T | P | Credit |
|---|---|---|---|
| 3 | 0 | 1 | 4 |

**2.1 CHEMISTRY: A. MAJ II: INORGANIC CHEMISTRY-II**
**2.2 CHEMISTRY –B MAJ II: ORGANIC CHEMISTRY – II**
**2.3 CHEMISTRY –C MAJ II: PHYSICAL CHEMISTRY – II**

**Paper II (CHM 502C)**
**(Theory)**
**3 Credits**

**SECTION A: INORGANIC CHEMISTRY**

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

**Learning objective:**

- Familiarization with various states of matter.
- Physical properties of each state of matter and laws related to describe the states.
- Calculation of lattice parameters.
- Importance of hydrogen bonding, metallic bonding.
- Define oxidation and reduction.
- Identify oxidizing and reducing agents.
- Understand redox reaction.
- Define and identify aromatic compounds base on Huckel's rule.
- Describe the planer ring shaped structure and stability of the aromatic compounds.
- Explain the unique reactivity of aromatic compounds including electrophilic substitution reaction.

**Section A. INORGANIC CHEMISTRY - II**

**UNIT-1: Metallic bonding and Weak chemical forces: (7 classes of 60 minutes each)**

(i) Metallic Bond: Qualitative idea of valence bond and band theories, Semiconductors, Insulators, defects in solids. (ii) Weak Chemical Forces: van der Waals, ion-dipole, dipole-dipole, induced dipole dipole induced dipole interactions, Lenard-Jones 6-12 formula, hydrogen bond, effects of hydrogen bonding on melting and boiling points, solubility, dissolution.

**Unit 2: Oxidation and Reduction Reaction**: (6 classes of 60 minutes each)

Electronic concept of oxidation number, concept of oxidation-reduction, redox equations, standard electrode potential and its applications to inorganic reactions, principles involved in volumetric analysis to be carried out in the class.

## Section B. ORGANIC CHEMISTRY – II

**UNIT-3: Aromatic Hydrocarbons (9 classes of 60 minutes each)**

Aromaticity: Huckel's rule, aromatic character of arenes, cyclic carbocations / carbanions and heterocyclic compounds with suitable examples; Electrophilic aromatic substitution: halogenation, nitration, sulphonation and Friedel-Craft's alkylation / acylation with their mechanism; Directing effects of substituent groups.

## Section C. PHYSICAL CHEMISTRY – II

**UNIT-4: Gaseous State** (8 classes of 60 minutes each)

Deviations from ideal gas behavior, compressibility factor and its variation with pressure for different gases. Causes of deviation from ideal behavior. Van der Waals equation of state, its derivation and application in explaining real gas behaviour; Berthelot and Dieterici equation; virial equation of state; van der Waals equation expressed in virial form, Boyle temperature. Isotherms of real gases and their comparison with van der Waals isotherms, continuity of states, critical state, critical and van der Waals constants, law of corresponding states. Kinetic molecular model of a gas: postulates and derivation of the kinetic gas equation; collision frequency; collision diameter; mean free path and viscosity of gases, including their temperature and pressure dependence, relation between mean free path and coefficient of viscosity, calculation of σ from η; variation of viscosity with temperature and pressure. Maxwell distribution and its use in evaluating molecular velocities (average, root mean square and most probable) and average kinetic energy, law of equipartition of energy, degrees of freedom and molecular basis of heat capacities.

**UNIT-5: Liquid State** (7 classes of 60 minutes each)

Structure and physical properties of liquids; vapour pressure, surface tension, viscosity, and their dependence on temperature, Effect of addition of various solutes on surface tension and viscosity; temperature variation of surface tension and viscosity of liquids; cleansing action of detergents; structure of water

**UNIT- 6 : Solid State** (8 classes of 60 minutes each)

Nature of the solid state; law of constancy of interfacial angles; law of rational indices; Miller Page 21 of 102 indices; elementary ideas of symmetry, symmetry elements and symmetry operations; qualitative idea of point and space groups; seven crystal systems

and fourteen Bravais lattices; X-ray diffraction, Bragg's law; a simple account of rotating crystal method and powder pattern method.

**Recommended Books/References:**


1. Atkins, P. W. & Paula, J. de Atkin's Physical Chemistry 8th Ed., Oxford University Press (2006).
2. Ball, D. W. Physical Chemistry Thomson Press, India (2007).
3. Castellan, G. W. Physical Chemistry 4th Ed. Narosa (2004).
4. Mortimer, R. G. Physical Chemistry 3rd Ed. Elsevier: NOIDA, UP (2009).
5. Barrow, G. M. Physical Chemistry 5th Ed. Tata McGraw Hill (2007).
6. Lee,J.D. Concise Inorganic Chemistry, Wiley, 5thEdn.
7. Douglas, B.E., McDaniel, D.H., AlexanderJ.J., Concepts & Models of Inorganic Chemistry, (Third Edition) John Wiley & Sons, 1999.
8. Atkins, P.W. and DePaula, J. Physical Chemistry, Tenth Edition, Oxford UniversityPress,2014.
9. Rodger, G. E. Inorganic and Solid State Chemistry, Cengage Learning, 2002.


## Semester II (Major 2) Practical

**(1 Credit)**

| L | T | P | Credit |
|---|---|---|---|
| 0 | 0 | 1 | 1 |

**COURSE CODE: MJC45CHM102(P)25**

**CHM-102(P): Physical Chemistry Laboratory –**

(List of experiments and references are suggestive. However, more experiments can be added/list
of experiments can be revised as per available facilities).

**1. Surface tension measurements**

a) Determine the surface tension by (i) drop number, and (ii) drop weight method.
b) Study the variation of surface tension of detergent solutions with concentration.

**2. Viscosity measurements using Ostwald's viscometer**

a) Determination of viscosity of aqueous solutions of (i) polymer, (ii) ethanol, and (iii) sugar at room temperature.
b) Viscosity of sucrose solution with the concentration of solute.

**3. pH metry**

a) Effect on pH of addition of HCl/NaOH to solutions of acetic acid, sodium acetate and their mixtures.
b) Preparation of buffer solutions of different pH (i) Sodium acetate-acetic acid, (ii) Ammonium
chloride-ammonium hydroxide
c) pH metric titration of (i) strong acid vs. strong base, (ii) weak acid vs. strong base.

d) Determination of dissociation constant of a weak acid.

**CHM 102(P) Inorganic Chemistry Laboratory**

*Oxidation-Reduction Titrimetric Analysis*

(i) Estimation of Cu(II) by using standardized Sodium Thiosulphate solution.

(ii) Estimation of Fe(II) by using standard $K_2Cr_2O_7$ solution

**Field Study Tour:** Collection of salt samples and their Analysis and submission of their Report

**Recommended Books/References:**


1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis, Sixth Edition, Pearson, 2009.
2. Svehala G. and Sivasankar I.B, Vogel's Qualitative Inorganic Analysis, Pearson, India, 2012.


(List of experiments and references are suggestive. However, more experiments can be added/list of experiments can be revised as per available facilities).

**Mark distribution in practical**: (1 credit)

| Physical Chemistry | Inorganic Chemistry | Lab. Note Book | Viva voce | Total |
|---|---|---|---|---|
| 12 | 6 | 3 | 4 | 25 |

**SEMESTER-II**

**CHEMISTRY MINOR- 2** **COURSE CODE: MNC45CHM102(T)25**

**(45 classes of 1 hour each)**

| L | T | P | Credit |
|---|---|---|---|
| 3 | 0 | 1 | 4 |

**2 MINOR COURSES**

**2.1 CHEMISTRY A: INORGANIC CHEMISTRY-II**
**2.2 CHEMISTRY B: ORGANIC CHEMISTRY – II**
**2.3 CHEMISTRY C: PHYSICAL CHEMISTRY – II**

**Paper II** **3 credits**

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

**Learning objective:**

- Familiarization with various states of matter.
- Physical properties of each state of matter and laws related to describe the states.
- Calculation of lattice parameters.
- Importance of hydrogen bonding, metallic bonding.
- Define oxidation and reduction.
- Identify oxidizing and reducing agents.
- Understand redox reaction.
- Define and identify aromatic compounds base on Huckel's rule.
- Describe the planer ring shaped structure and stability of the aromatic compounds.
- Explain the unique reactivity of aromatic compounds including electrophilic substitution reaction.

## Section A. INORGANIC CHEMISTRY - II

**UNIT-1: Metallic bonding and Weak chemical forces: (7 classes of 60 minutes each)**

(i) Metallic Bond: Qualitative idea of valence bond and band theories, Semiconductors, Insulators, defects in solids. (ii) Weak Chemical Forces: van der Waals, ion-dipole, dipole-dipole, induced dipole dipole induced dipole interactions, Lenard-Jones 6-12 formula, hydrogen bond, effects of hydrogen bonding on melting and boiling points, solubility, dissolution.

**Unit 2: Oxidation and Reduction Reaction**: **(6 classes of 60 minutes each)**

Electronic concept of oxidation number, concept of oxidation-reduction, redox equations, standard electrode potential and its applications to inorganic reactions, principles involved in volumetric analysis to be carried out in the class.

## Section B. ORGANIC CHEMISTRY – II

**UNIT-3: Aromatic Hydrocarbons (9 classes of 60 minutes each)**

Aromaticity: Huckel's rule, aromatic character of arenes, cyclic carbocations / carbanions and heterocyclic compounds with suitable examples; Electrophilic aromatic substitution: halogenation, nitration, sulphonation and Friedel-Craft's alkylation / acylation with their mechanism; Directing effects of substituent groups.

## Section C. PHYSICAL CHEMISTRY – II

**UNIT-4: Gaseous State (8 classes of 60 minutes each)**

Deviations from ideal gas behavior, compressibility factor and its variation with pressure for different gases. Causes of deviation from ideal behavior. Van der Waals equation of

state, its derivation and application in explaining real gas behaviour; Berthelot and Dieterici equation; virial equation of state; van der Waals equation expressed in virial form, Boyle temperature. Isotherms of real gases and their comparison with van der Waals isotherms, continuity of states, critical state, critical and van der Waals constants, law of corresponding states. Kinetic molecular model of a gas: postulates and derivation of the kinetic gas equation; collision frequency; collision diameter; mean free path and viscosity of gases, including their temperature and pressure dependence, relation between mean free path and coefficient of viscosity, calculation of σ from η; variation of viscosity with temperature and pressure. Maxwell distribution and its use in evaluating molecular velocities (average, root mean square and most probable) and average kinetic energy, law of equipartition of energy, degrees of freedom and molecular basis of heat capacities.

**UNIT-5: Liquid State (7 classes of 60 minutes each)**

Structure and physical properties of liquids; vapour pressure, surface tension, viscosity, and their dependence on temperature, Effect of addition of various solutes on surface tension and viscosity; temperature variation of surface tension and viscosity of liquids; cleansing action of detergents; structure of water

**UNIT- 6 : Solid State (8 classes of 60 minutes each)**

Nature of the solid state; law of constancy of interfacial angles; law of rational indices; Miller Page 21 of 102 indices; elementary ideas of symmetry, symmetry elements and symmetry operations; qualitative idea of point and space groups; seven crystal systems and fourteen Bravais lattices; X-ray diffraction, Bragg's law; a simple account of rotating crystal method and powder pattern method. Analysis of powder diffraction patterns of NaCl, CsCl and KCl. Defects in crystals. Glasses and liquid crystals

**Recommended Books/References:**


1. Atkins, P. W. & Paula, J. de Atkin's Physical Chemistry 8th Ed., Oxford University Press (2006).
2. Ball, D. W. Physical Chemistry Thomson Press, India (2007).
3. Castellan, G. W. Physical Chemistry 4th Ed. Narosa (2004).
4. Mortimer, R. G. Physical Chemistry 3rd Ed. Elsevier: NOIDA, UP (2009).
5. Barrow, G. M. Physical Chemistry 5th Ed. Tata McGraw Hill (2007).
6. Lee,J.D. Concise Inorganic Chemistry, Wiley, 5thEdn.
7. Douglas, B.E., McDaniel, D.H., AlexanderJ.J., Concepts & Models of Inorganic Chemistry, (Third Edition) John Wiley & Sons, 1999.
8. Atkins, P.W. and DePaula, J. Physical Chemistry, Tenth Edition, Oxford UniversityPress,2014.
9. Rodger, G. E. Inorganic and Solid State Chemistry, Cengage Learning, 2002.

**Semester II (Minor 2) Practical (1 Credit)**

| L | T | P | Credit |
|---|---|---|---|
| 0 | 0 | 1 | 1 |

**COURSE CODE:MNC45CHM102(P)25**

**Physical Chemistry Laboratory –**

(List of experiments and references are suggestive. However, more experiments can be added/list
of experiments can be revised as per available facilities).

**1. Surface tension measurements**

a) Determine the surface tension by (i) drop number, and (ii) drop weight method.
b) Study the variation of surface tension of detergent solutions with concentration.

**2. Viscosity measurements using Ostwald's viscometer**

a) Determination of viscosity of aqueous solutions of (i) polymer, (ii) ethanol, and (iii) sugar at room temperature.
b) Viscosity of sucrose solution with the concentration of solute.

**3. pH metry**

a) Effect on pH of addition of HCl/NaOH to solutions of acetic acid, sodium acetate and their mixtures.
b) Preparation of buffer solutions of different pH (i) Sodium acetate-acetic acid, (ii) Ammonium
chloride-ammonium hydroxide
c) pH metric titration of (i) strong acid vs. strong base, (ii) weak acid vs. strong base.
d) Determination of dissociation constant of a weak acid.

(List of experiments and references are suggestive. However, more experiments can be added/list of experiments can be revised as per available facilities).

**Mark distribution in practical**: (1 credit)

| Physical Chemistry | Inorganic Chemistry | Lab. Note Book | Viva voce | Total |
|---|---|---|---|---|
| 12 | 6 | 3 | 4 | 25 |

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**MULTIDISCIPLINARY COURSE (MDC)- 2**

**CHEMISTRY IN EVERYDAY LIFE**

**MDC-2: COURSE CODE** **MDC 45CHM102(T)25**

**(30 classes of 1 hour each)**

| L | T | P | Credit |
|---|---|---|---|
| 2 | 1 | 0 | 3 |

**I. Learning Objectives**

On completion of this course, the student will be able

LO-1. To understand the use and applications 12 principles of Green Chemistry, identify greener solvents and use of renewable energy sources of sustainable chemistry. To define the importance of inorganic elements in vital systems. To understand the importance of minerals and essentially trace elements and beneficial elements of living system.

LO-2. Understanding water's unique properties helps explain a lot about water's behavior. Student's working knowledge of water quality and characteristics of water sources. Students understand the terms: micelle, hard water, soft water, temporary hardness, and permanent hardness. Students acquire knowledge of the cleaning capacity of soap in hard and soft water. Based on the acquired skill, students will be able to classify the given water as hard water or soft water. Students acquire skills to perform the experiment in the real lab.

LO-3. To get basic understanding of Food additives sugar substitutes, sweeteners, food colors, antioxidants, stabilizers, Biomaterial etc. used in food industry.

LO-4. To get knowledge of classes of adhesives, their preparation and bonding mechanisms.

**II. Course Outcomes**

On Completion of this course, the student has been able to

CO-1 To understand environmental impact and sustainability of chemical processes and products, through the use of green chemistry principle. To define the importance of inorganic elements in vital systems. Explain the importance of minerals and essentially trace elements and beneficial elements of living system.

CO-2 To understand the general properties of water and develop awareness about water quality criteria and standards, Knowledge of basic concepts and techniques of soap and detergent industry and their relation to public health and environment.

CO-3 It will help to Remember and identify the additives in food and their functions.

CO-4 To understand and remembers the classes of adhesives, their preparation and

bonding mechanisms.

## III. Course Content

**UNIT – 1: Green and Sustainable Chemistry** **(10 Hrs)**

1. **Green and Sustainable Chemistry**

Twelve principle of green chemistry with their explanation and examples, Use and examples of sustainable chemistry based on the principles, Green solvents –Super critical fluid, SC $CO_2$ and water as solvent, Energy requirement for reactions-renewable sources of energy, Use of microwave and Ultrasonic energy.

2. **Bio inorganic Chemistry**

Essential and trace elements and bioinorganic chemistry, periodic survey of essential and trace elements: biological importance and relative abundance of the elements, the cell and distribution of the elements in the cell, The role of metal ions in the life process with special reference metal-protein systems and metalloenzymes, Communication and Sensing Roles of Metal ions, The role of metal ions in the basic biological reactions, Biological functions of bio-metals.

**UNIT – 2:** **(10 HRS)**

1. **Water chemistry**

Physical and chemical properties of water, temporary and permanent hardness of water and its removal process, Drawbacks of Acidity, alkalinity and turbidity in water, C.O.D. and B.O.D., Chlorination of water.

2. **Soap and detergents**

Soaps - Types of soaps. Cleansing action of soaps. Synthetic detergents - Classification.

Detergent additives. Comparison between soaps and detergents, Classification of detergents Anionic detergents, Cationic detergents, Non – ionic detergents; Amphoteric detergents. Soaps, Alkyl Sulphate; Alkyl Sulphonates; Alkyl Aryl Sulphonates, Amide Sulphonates, Ecofriendly Detergents.

**UNIT – 3: Food chemistry** **(5 Hrs)**

Food additives: Enhancers, sugar substitutes, sweeteners, food colors, antioxidants, acids and bases used in food.

Food chelating agents, emulsifiers, thickening agents, gel builders, stabilizers, common food toxicants, flavors, Biomaterial: Uses of bacteria, yeasts and moulds in food industry

**UNIT – 4: Introduction to Polymers & Adhesives** **(5 Hrs)**

1. **Polymers**

Definition: Monomer, Polymer, Polymerization, Classification of Polymers

2. **Adhesives**

Types of Bonding, Classification of adhesive, Preparation of adhesive, Starch adhesive, Protein adhesive. Synthetic resin adhesive, Use of Adhesive.

## IV. Suggestive Readings


1. Environmental Chemistry – II Edition by A.K. De
2. Environmental Science by Turk A., Turk, J. Wittes J.T. and Wittes, R.E. (1978)

3. Ecology & Environment by P.D. Sharma.
4. Environmental Science: An Introduction by G. T. Miller-1991
5. Ajay Kr. Gupta, Handbook on Soaps, Detergents & Acid Slurry, 3rd revised edition; NIIR Board publication. ISBN: 9789381039472
6. P. K. Chattopadhyay, Modern Technology of Soaps, Detergents & Toiletries (with Formulae & Project Profiles) 4th Revised Edition, NIIR Board publication; ISBN: 9789381039700
7. H. Panda, Herbal Soaps & Detergents Handbook, NIIR Board publication; ISBN: 9789381039007
8. V.K. Ahluwalia, Green Chemistry: Environmentally Benign Reactions, CRC, 2008.
9. Food Chemistry Meyer L.H., 2006 publication
10. Fundamentals of Polymers - Raw Materials to Finish Products, Niranjan Karak
11. Adhesive Technology and Formulations Handbook.

## SEC-2: COURSE CODE SEC45CHM102(T) 25

## BIOFERTILIZER

**(30 lectures of 60 minutes each)**

| L | T | P | Cr |
|---|---|---|---|
| 2 | 1 | 0 | 3 |

**Learning outcomes:**

On the completion of this course, the students will be able to;

1. Develop their understanding on the concept of bio-fertilizer
2. Identify the different forms of biofertilizers and their uses
3. Compose the Green manuring and organic fertilizers
4. Develop the integrated management for better crop production by using both nitrogenous and phosphate bio fertilizers

**UNIT-1: Biofertilizer (10 Lectures: 60 mins each)**

General account about the microbes used as biofertilizer – Rhizobium – isolation, identification, mass multiplication, carrier based inoculants, Actinorrhizal symbiosis. *Azospirillum:* isolation and mass multiplication – carrier based inoculant, associative effect of different microorganisms. *Azotobacter*: classification, characteristics–crop response to *Azotobacter* in oculum, maintenance and mass multiplication.

**UNIT-2: Cyanobacteria (5 Lectures: 60 mins each)**

Cyanobacteria (blue green algae), *Azolla* and *Anabaena azollae* association, nitrogen fixation, factors affecting growth, blue green algae and *Azolla* in rice cultivation.

**UNIT-3: Mycorrhizal association (10 Lectures: 60 mins each)**

Mycorrhizal association: Types of mycorrhizal association, taxonomy, occurrence and distribution, phosphorus nutrition, growth and yield – colonization of VAM – isolation and inoculum production of VAM, and its influence on growth and yield of crop plants.

**UNIT-4: Organic farming (5 Lectures: 60 mins each)**

Green manuring and organic fertilizers, Recycling of bio-degradable municipal, agricultural and Industrial wastes – biocompost making methods, types and method of vermin composting– field Application.

**Suggested Readings**


1. Dubey,R.C. (2005). *A Textbook of Biotechnology,* S. Chand & Co, NewDelhi.
2. John Jothi Prakash, E. (2004). *Outlines of Plant Biotechnology*. Emkay Publication, NewDelhi.
3. Kumaresan,V. (2005). *Biotechnology*, Saras Publications, NewDelhi.
4. NIIR Board. (2012). *The complete Technology Book on Biofertilizer and organic farming*. 2nd Edition. NIIR Project Consultancy Services.
5. Sathe, T.V. (2004) *Vermiculture and Organic Farming*. Daya publishers.
6. Subba Rao N.S. (2017). *Biofertilizers in Agriculture and Forestry*. Fourth Edition, Medtech.


## SEMESTER – III

**CHEMISTRY MAJOR -3** **COURSE CODE: MJC50CHM203(T)25**

**ORGANIC CHEMISTRY: GREEN CHEMISTRY**

| L | T | P | Cr |
|---|---|---|---|
| 3 | 0 | 1 | 4 |

**Learning objective:** **(45 Hours)**

After completion of the course, the learner shall be able to understand:

1. Green chemistry and its principles.
2. Green synthesis and reactions.
3. Green chemistry for sustainable solutions.
4. Understanding principles of green chemistry.
5. Understanding design of chemical reactions/chemical synthesis using green chemistry principles.
6. Atom economy and design of chemical reactions using the principle.
7. Understanding the use of green chemistry principle and processes in laboratory reactions.

*Self-study:*

1. Use of green chemistry in designing new laboratory experiments.
2. Use of principle of atom economy and design experiments using the principle.
3. Use of green chemistry in combinatorial chemistry and biomimetic catalyst.

**UNIT-1: Introduction to Green Chemistry** **(7 Hours)**

Basic introduction and explaining goals of Green Chemistry. Limitations/Obstacles in the pursuit of the goals of Green Chemistry

**UNIT-2: Principles of Green Chemistry and Designing a Chemical synthesis (12 Hours)**

Twelve principles of Green Chemistry with their explanations and examples and special emphasis on Designing a Green Synthesis using these principles (Prevention of Waste/byproducts; maximum incorporation of the materials used in the process into the final products.

Atom Economy, calculation of atom economy of the rearrangement, addition, substitution and
elimination reactions).

**UNIT-3: Green Synthesis /Reactions:** **(16 Hours)**

1. Green Synthesis of adipic acid, catechol, disodium iminodiacetate (alternative to Strecker synthesis).
2. Microwave assisted reactions in water: (Hofmann Elimination, methyl benzoate to benzoic acid, oxidation of toluene and alcohols) and reactions in organic solvents (Diels-Alder reaction and Decarboxylation reaction).
3. Ultrasound assisted reactions: Sonochemical Simmons-Smith Reaction (Ultrasonic alternative to Iodine)

4. Surfactants for carbon dioxide–replacing smog producing and ozone depleting solvents with CO2 for precision cleaning and dry cleaning of garments.
5. Designing of Environmentally safe marine antifoulant.
6. An efficient, green synthesis of a compostable and widely applicable plastic (polyl actic acid) made from corn.
7. Healthier Fats and oil by Green Chemistry: Enzymatic Interesterification for production of no Trans-Fats and Oil

**UNIT-4: Future Trends in Green Chemistry (10 Hours)**

Oxidation reagents and catalysts; Biomimetic, multifunctional reagents; Combinatorial green chemistry; Proliferation of solvent less reactions; cocrystal controlled solid state synthesis (C2S3); Green chemistry in sustainable development.

**Recommended Books/References:**


1. Ahluwalia, V. K., Kidwai, M. R. *New Trends in Green Chemistry*, Anamalaya Publishers (2005).
2. Anastas, P.T. & Warner, J.K, *Green Chemistry-Theory and Practical*, Oxford University Press (1998).
3. Matlack, A.S. *Introduction to Green Chemistry*, Marcel Dekker (2001).
4. Cann, M.C. and Connely, M.E. *Real-World cases in Green Chemistry*, ACS (2000).
5. Ryan, M.A. and Tinnes and, M. *Introduction to Green Chemistry*, American Chemical Society, (2002).
6. Lancaster, M. Green Chemistry: An Introductory Text RSC Publishing, Second Edition, 2010.


**CHEMISTRY MAJOR -3(P) COURSE CODE: MJC50CHM203(P) 25**

**GREEN CHEMISTRY LABORATORY**

| L | T | P | Cr |
|---|---|---|---|
| 0 | 0 | 1 | 1 |

**(30 lectures; 60 each)**

(Following is the list of suggestive experiments. Six experiments may be conducted)

1. Field Study Tour: Collection of Medicinal Plants and submit their reports
2. Preparation of biodiesel from vegetable/waste cooking oil.
3. Use of molecular model kit to stimulate the reaction to investigate how the atom

economy illustrates Green Chemistry.

4. Preparation of Compost: Use of Biodegradable waste to prepare compost and study decomposition learning outcome, waste to resource conversion

5. Determination of soil and water, pH from different sources

6. Survey of medicinal plant: Extraction of natural dye from beat root, turmeric etc.

**Recommended Books/References:**


1. Anastas, P.T & Warner, J.C. *Green Chemistry: Theory and Practice,* Oxford University Press (1998).
2. Kirchoff, M. & Ryan, M.A. *Greener approaches to undergraduate chemistry experiment*. American Chemical Society, Washington DC (2002).
3. Ryan, M.A. *Introduction to Green Chemistry*, Tinnesand; (Ed), American Chemical Society, Washington DC (2002).
4. Sharma, R.K.; Sidhwani, I.T. and Chaudhari, M.K.I.K. *Green Chemistry Experiment: Amonograph,* International Publishing ISBN 978-93-81141-55-7 (2013).
5. Cann, M.C. and Connelly, M.E. *Real world cases in Green Chemistry*, American Chemical Society (2008).
6. Lancaster, M. *Green Chemistry: An Introductory Text,* RSC Publishing, Second Edition, 2010.
7. Pavia, D.L., Lampman, G.M., Kriz, G.S. & Engel, R.G. Introduction to Organic Laboratory Techniques: A Microscale and Macro Scale Approach, W.B. Saunders,1995


**CHEMISTRY MAJOR - 4** **COURSE CODE: MJC50CHM204(T)25**

**A. Inorganic Chemistry**

**B. Physical Chemistry**

| L | T | P | Cr |
|---|---|---|---|
| 3 | 0 | 1 | 4 |

*Learning objective:* **(45 Hours)**

After completion of the course, the learner shall be able to understand:

1. Oxidation-Reductions and their use in metallurgy.
2. Structure, bonding of sand p-block elements and their oxides/compounds.
3. Understanding chemistry of boron compounds and their structures.
4. Chemistry of noble gases and their compounds; application of VSEPR theory in explaining structure and bonding.

5. Understanding chemistry of inorganic polymers, their structures and uses.

*Self-study:*

1. Extraction of metals through metallurgical operations and their uses.
2. Bonding of various s- and p- block elements.
3. Use of boron compounds.
4. Chemistry of inorganic polymers and their uses.

**SECTION A: INORGANIC CHEMISTRY**

**UNIT-1: Acids and Bases (6 Hours)**

Brönsted-Lowry concept of acid-base reactions, solvated proton, relative strength of acids, types of acid-base reactions, levelling solvents, Lewis acid-base concept, Classification of Lewis acids, Hard and Soft Acids and Bases (HSAB), Application of HSAB principle.

**UNIT-2: General principle of metallurgy (8 Hours)**

Occurrence of metals based on standard electrode potentials. Ellingham diagrams for reduction of metal oxides using carbon or carbon monoxide as reducing agent. Electrolytic Reduction, Hydrometallurgy. Methods of purification of metals: Electrolytic Kroll process, Parting process, van Arkel- de Boer process and Mond's process, Zone refining.

**UNIT-3: Chemistry of s- and p-Block Elements (14 Hours)**

Inert pair effect, Relative stability of different oxidation states, diagonal relationship and anomalous behavior of first member of each group. Allotropy and catenation. Complex formation tendency of *s*- and *p*- block elements. Hydrides and their classification ionic, covalent and interstitial. Basic beryllium acetate and nitrate.

Studies on structure, bonding, preparation, properties and uses: Boric acid and borates, boron nitrides, borohydrides (diborane) carboranes and graphitic compounds, silanes, Oxides and oxoacids of nitrogen, Phosphorus and chlorine. Per-oxo acids of Sulphur inter-halogen compounds, poly-halideions, pseudo-halogens, properties of halogens.

**UNIT-4: Noble Gases (7 Hours)**

Occurrence and uses, rationalization of inertness of noble gases, Clathrates; preparation and properties of $XeF_2$, $XeF_4$ and $XeF_6$; Bonding in noble gas compounds (Valence bond and MO treatment for $XeF_2$), Shapes of noble gas compounds (VSEPR theory).

**Section B: Physical Chemistry**

**UNIT-5: Solutions and Colligative Properties (10 Hours)**

Dilute solutions; lowering of vapour pressure, Raoult's and Henry's Laws and their applications. Excess thermodynamic functions. 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. Applications in calculating molar masses of normal, dissociated and associated solutes in solution.

***Recommended books/references:***


1. Lee, J.D. *Concise Inorganic Chemistry*, ELBS,1991.
2. Douglas,B.E; McDaniel, D.H. & Alexander, J.J. *Concepts & Models of Inorganic Chemistry,3rd Ed.*, John Wiley Sons, N.Y. 1994.
3. Greenwood, N.N., Earnshaw. *Chemistry of the Elements*, Butterworth-Heinemann. 1997.
4. Cotton, F.A.& Wilkinson, G. *Advanced Inorganic Chemistry*, Wiley, VCH, 1999.
5. Rodger, G.E. *Inorganic and Solid State Chemistry*, Cengage Learning India Edition, 2002.
6. Miessler, G.L. & Donald, A. Tarr. *Inorganic Chemistry* Fourth Ed., Pearson, 2010.
7. Atkins, P.W. and Shriver D.N. *Atkins' Inorganic Chemistry* 5th Ed. Oxford University Press (2010).
8. Atkins, P. and De Paula, J. *Physical Chemistry* 10th Ed. (2014).


**CHEMISTRY MAJOR – 4(P)** **COURSE CODE: MJC50CHM204(P)25**

**Inorganic Chemistry Laboratory**

| L | T | P | Cr |
|---|---|---|---|
| 0 | 0 | 1 | 1 |

**(30 Hours; 1 Credit)**

**(A) Iodo/Iodimetric Titrations**

(i) Chromatography: Paper Chromatography, separation of $Fe^{+3}$, $Al^{+3}$, $Cr^{+3}$ and determination of Rf values.

(ii) Estimation of available chlorine in bleaching powder iodometrically.

***(B) Inorganic Preparations***

(i) Cuprous Chloride, $Cu_2Cl_2$

(ii) Preparation of Aluminium potassium sulphate (Potash alum) or Chrome alum.

***Recommended books/references:***

1. Mendham,J., A.I.Vogel's *Quantitative Chemical Analysis* Sixth Edition, Pearson, 2009.

(List of experiments and references are suggestive. However, more experiments can be added/list of experiments can be revised as per available facilities).

## SEMESTER III

**CHEMISTRY MINOR: 3** **COURSE CODE: MNC50CHM203(T)25**

**Atomic structure, bonding, general organic chemistry and stereochemistry (40 lectures of 60 minutes each)**

| L | T | P | Cr |
|---|---|---|---|
| 3 | 0 | 1 | 4 |

**Learning Objectives:** **(45 Hours)**

1. To provide basic knowledge about ionic, covalent and metallic bonding and the Periodicity in properties with reference to the *s*- and *p*- block
2. To introduce a new concept of visualizing the organic molecules in a three-dimensional space with the recapitulation of fundamentals of organic chemistry and to establish the applications of these concepts.

**Learning Outcomes:**

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

1. Solve the conceptual questions using the knowledge gained by studying the quantum mechanical model of the atom, quantum numbers, electronic configuration, radial and angular distribution curves, shapes of s, p, and d orbitals, and periodicity in atomic radii, ionic radii, ionization energy and electron affinity of elements.
2. Draw the plausible structures and geometries of molecules using radius ratio rules, VSEPR theory and MO diagrams (homo- & hetero-nuclear diatomic molecules).
3. Understand and explain the differential behavior of organic compounds based on

fundamental concepts learnt.

**Section A: Inorganic Chemistry**

**UNIT-1: Atomic Structure (10 Hours)**

Bohr's theory and its limitations, Heisenberg uncertainty principle, Dual behavior of matter and radiation, De-Broglie's relation, Hydrogen atom spectra, need of a new approach to atomic structure. Schrodinger equation and meaning of various terms in it. Significance of ψ and ψ2, Schrödinger equation for hydrogen atom, 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, radial distribution functions and the concept of the most probable distance with special reference to 1s and 2s atomic orbitals. Significance of quantum numbers, orbital angular momentum and quantum numbers $m_l$ and $m_s$. Shapes of s, p and d atomic orbitals, nodal planes, discovery of spin, spin quantum number (s) and magnetic spin quantum number (ms).
Rules for filling electrons in various orbitals, electronic configurations of the atoms, stability of half-filled and completely filled orbitals, concept of exchange energy, relative energies of atomic orbitals, anomalous electronic configurations.

**UNIT- 2: Chemical Bonding and Molecular Structure (13 Hours)**

Ionic Bonding: General characteristics of ionic bonding, energy considerations in ionic bonding, lattice energy and solvation energy and their importance in the context of stability and solubility of ionic compounds, statement of Born-Landé equation for calculation of lattice energy (no derivation), Born Haber cycle and its applications, covalent character in ionic compounds, polarizing power and polarizability, Fajan's rules. Ionic character in covalent compounds, bond moment, dipole moment and percentage ionic character.
Covalent bonding: VB Approach: Shapes of some inorganic molecules and ions on the basis of VSEPR and hybridization ($H_2O$, $NH_3$, $PCl_5$, $SF_6$, $ClF_3$, $SF_4$)
MO Approach: Rules for the LCAO method, bonding and antibonding MOs and their characteristics for ss, s-p and p-p combinations of atomic orbitals, nonbonding combination of orbitals.

**Section B: Organic Chemistry**

**UNIT-3: Fundamentals of Organic Chemistry (10 Hours)**

Electronic displacements: Inductive effect, electromeric effect, resonance, hyperconjugation. Cleavage of bonds: homolysis and heterolysis. Reaction intermediates: carbocations,

carbanions and free radicals. Electrophiles and nucleophiles, Aromaticity: benzenoids and Hückel's rule.

**UNIT 4: Stereochemistry (12 Hours)**

Conformations with respect to ethane, butane and cyclohexane, interconversion of Wedge Formula, Newmann, Sawhorse and Fischer representations, concept of chirality (upto two carbon atoms). configuration: geometrical and optical isomerism; enantiomerism, diastereomerism and meso compounds). Threo and erythro; D and L; *cis* – *trans* nomenclature; CIP Rules: R/ S (for upto 2 chiral carbon atoms) and E / Z nomenclature (for upto two C=C systems).

**COURSE CODE: MNC50CHM203(P)25**

**CHEMISTRY MINOR: 3(P)**
**INORGANIC CHEMISTRY LABORATORY**

| L | T | P | Cr |
|---|---|---|---|
| 0 | 0 | 1 | 1 |

**(30 Hours; 1 Credit)**

**Volumetric Analysis**

1. Estimation of oxalic acid by titrating it with $KMnO_4$.
2. Estimation of Mohr's salt by titrating it with $KMnO_4$.
3. Estimation of Fe(II) ions by titrating it with $K_2Cr_2O_7$ using internal indicator.
4. Estimation of Cu(II) ions iodometrically using $Na_2S_2O_3$.

**Section B: Organic Chemistry**

1. Purification of organic compound by crystallisation (from water and alcohol) and distillation.
2. Criteria of purity: Determination of M.P./B.P.
3. Separation of mixtures by chromatography (Thin Layer Chromatography): Measure the Rf value in each case (combination of two compounds to be given)

(The above course structure/number of classes and list of experiments are suggestive. Faculty/academic bodies may incorporate revision /may incorporate text and reference books as per need).

**References:**


1. Lee., J. D. (2010), *A new Concise Inorganic Chemistry*, Pearson Education.
2. Huheey, J.E.; Keiter, E.; Keiter, R. (2009), *Inorganic Chemistry: Principles of Structure and Reactivity*, Pearson Publication.

3. Atkins, P.W.; Overton, T.L.; Rourke, J.P.; Weller, M.T.; Armstrong, F.A. (2010), *Shriver and Atkin's Inorganic Chemistry*, Oxford
4. Sykes, P. (2005), *A Guide Book to Mechanism in Organic Chemistry*, Orient Longman.
5. Eliel, E. L. (2000), *Stereochemistry of Carbon Compounds*, Tata McGraw Hill.
6. Morrison, R. N.; Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
7. Bahl, A; Bahl, B. S. (2012), *Advanced Organic Chemistry*, S. Chand.
8. Jeffery, G.H.; Bassett, J.; Mendham, J.; Denney, R.C. (1989), *Vogel's Textbook of Quantitative Chemical Analysis,* 5th Edn.**,** John Wiley and Sons Inc,.
9. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. (2012), *Vogel's Textbook of Practical Organic Chemistry*, Pearson.

**MDC-3 MULTI-DISCIPLINARY COURSE** **COURSE CODE: MDC50CHM203(T)25**

**ENVIRONMENTAL SCIENCE**

| L | T | P | Cr |
|---|---|---|---|
| 2 | 1 | 0 | 3 |

**(30 Lectures of 60 mins each)**

After completion of the course, the learner can be able to understand:

1. Composition of atmosphere
2. Biogeochemical cycles
3. Hydrological cycle
4. Water quality parameters
5. Atmospheric chemical phenomenon and environmental pollution
6. Water pollution, parameters of water pollution, treatment of polluted water

**UNIT-1: Environment** **(5 Hours)**

Composition of atmosphere, temperature variation of earth atmospheric system (temperature vs. altitude curve), biogeochemical cycles of C,N,P,S and O system.

**UNIT-2: Hydrosphere:** **(8 Hours)**

Hydrological cycle, aquatic pollution and water quality parameters – Dissolve oxygen, biochemical oxygen demand, chemical oxygen demand, Analytical methods for the determination fluoride, chromium and arsenic, residual chlorine and chlorine demand, purification and treatment of municipal water and waste water.

**UNIT-3: Atmosphere (7 Hours)**

Chemical composition of atmosphere – particle, ions, and radicals in their formation, chemical and photochemical reactions in atmosphere, smog formation, oxides of N, C, S, and O and their effect, pollution by chemicals, CFC, Green House Effect, acid rain, air pollution and control.

**UNIT-4: Aquatic chemistry (10 Hours)**

Water and its necessities, various water quality parameters (DO, BOD, COD, conductivity, pH, alkalinity, hardness) and its determination, Industrial, municipal water treatment processes, Waste water treatment procedure (primary, secondary and tertiary), Solid waste treatment. Soil pollution and Noise pollution.

Recommended Books/References:


1. De. A.K. *Environmental Chemistry*, Wiley Eastern Ltd, 1990.
2. Miller T.G.Jr., *Environmental Science*, Wadsworth publishing House, Meerut Odum.E.P., 1971.
3. Odum, E.P. (1971) *Fundamentals of Ecology*, Third Edition, W.B. Saunders Co., Philadelphia
4. Sharma and Kaur, *Environmental Chemistry*, Krishna publishers, 2016.
5. S.M. Khopker, *Environmental Pollution, Monitoring and control*, New Age International,2007.
6. G. S. Sodhi, *Fundamental Concepts of Environmental Chemistry* (Third Edition) Narosa (2009).


**SEC-3 COURSE CODE SEC50CHM203(T)25**

**RENEWABLE ENERGIES (SOLAR AND BIOGAS)**

**(30 lectures of 60 minutes each)**

| L | T | P | Cr |
|---|---|---|---|
| 2 | 1 | 0 | 3 |

**Learning objectives:**

1. To know the importance of renewable energy resources in the present context.

2. To learn various aspects of renewable energy.

4. To learn about solar mapping and basics of biomass sources

3. To familiarize with the techniques associated with the measurement and analysis of various renewable energy sources and studies of the composition of biomass.

**UNIT-1: Renewable energy sources (15 lectures, 60 mins each)**

Introduction to renewable energy sources – solar, wind, small hydro, biomass, geothermal and ocean energy, energy low in ecosystem, Solar Energy Resources, Solar radiation: Spectrum of EM radiation, sun structure and characteristics, extraterrestrial radiation, solar constant, air mass, beam, diffused and total solar radiation, spectral distribution.

Measurement of solar radiation Instruments: Sunshine recorder, Pyranometer, Pyrheliometer, Albedometer. Radiation measurement stations in India (NIWE, IMD etc.), solar radiation data, graphs, Metronome and NASA-SSE databases Hands-on measurement of beam, diffuse and total radiation

**UNIT-2**: **Solar mapping (5 lectures, 60 mins each)**

Solar mapping using satellite data, Typical Meteorological Year.

Models and methods for estimating solar radiation, estimation of global radiation, estimation of diffused components.

**UNIT-3: Biomass (10 lectures, 60 min each)**

Basics Biomass resources: plant derived, residues, aquatic and marine biomass, various wastes, photosynthesis. Biomass resource assessment, Estimation of woody biomass, non woody biomass and wastes, ASTM standards.
Bulk chemical properties Moisture content, proximate and ultimate analyses, calorific value, waste water analysis for solids.

Chemical composition of biomass: Cellulose, hemicelluloses and lignin content in common agricultural residues and their estimation, protein content in biomass, extractable, COD. Structural properties, Physical structure, particle size and size distribution, permeability.
Properties of microbial biomass: Protein estimation, flocculating ability, relative hydrophobicity of sludge, sludge volume index.

**Suggested Readings**

1. Mehmet Kanoglu, Yunus A. Cengel, John M. Cimbala; *Fundamentals and Applications of Renewable Energy*, 1st Edition, 2020 McGraw-Hill Education.
2. S. C. Bhatia, R. K. Gupta; *Textbook of Renewable Energy,* 2019 Woodhead

Publishing India PVT. Limited.
3. Paul Matthews; *Introducing Renewable Energy*, 2015 Greenstream Publishing, United Kingdom.
4. S.R. Kalbande, V. M. Bhale, S.R. Sedani; *Textbook of Green Energy Technologies*, 2022 Narendea Publishing House.

**SEMESTER -IV**

**CHEMISTRY MAJOR -5 CORE COURSE MJC50CHM205(T) 25**

**Molecular Spectroscopy and Photochemistry**

| L | T | P | Cr |
|---|---|---|---|
| 3 | 0 | 1 | 4 |

**Learning objectives:**

**(45 Hours)**

1. To understand the interaction of electromagnetic radiation with molecules.
2. To understand basic principles of spectroscopy.
3. Franck-Condon principles and electronic transitions.
4. Photochemical reactions.

**UNIT-1: (15 Hours)**

**Interaction of electromagnetic radiation with molecules and various types of spectra**; Born-Oppenheimer approximation. Rotation spectroscopy: Selection rules, intensities of spectral lines, determination of bond lengths of diatomic and linear triatomic molecules, isotopic substitution.

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

**UNIT-2: (15 Hours)**

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

**Electronic spectroscopy**: Franck-Condon principle, electronic transitions, singlet and triplet states, fluorescence and phosphorescence, dissociation and pre-dissociation.

**UNIT-3: Photophysical and photochemical processes (15 Hours)**

Laws of photochemistry, quantum yield. Jablonski diagrams: Franck-Condon principle, Law of photochemical equivalence, quantum efficiency, low and high quantum efficiency. Kinetics of photochemical reactions ($H^{2+}$ $Br_2$=HBr, 2HI=$H_2$+$I_2$), energy transfer in photochemical reactions (photosensitization and quenching), fluorescence, phosphorescence, chemiluminescence, Discussion of Electronic spectra and photochemistry (Lambert-Beer law and its applications).

**Recommended books/References:**


1. Laideler, K.J. and Meiser, J.M. *Physical Chemistry* Third Edition (International) 1999
2. Levine, I.N., *Physical Chemistry,* Fourth Edition, McGraw-Hill (International),1995.
3. McQuarrie, D.A. and Simon, J.D. *Physical Chemistry-A Molecular Approach,* University Science Books, 1998.
4. Rohatgi-Mukherjee K. K. *Fundamentals of Photochemistry*, New age (revised second edition).
5. Banwell, C.N. & McCash, E.M. *Fundamentals of Molecular Spectroscopy* 4th Ed.Tata McGraw-Hill: New Delhi (2006).


**CHEMISTRY MAJOR -5(P) CORE COURSE MJC50CHM205(P)25**

| L | T | P | Cr |
|---|---|---|---|
| 0 | 0 | 1 | 1 |

**(30 Hours; 1 credit)**

**Molecular Spectroscopy and Photochemistry Laboratory**

1. Recording of IR spectra of some samples and their interpretation
2. Recording of UV-Vis spectra of some samples and their interpretation.
3. Verification of Beer-Lamberts Law and determination of unknown concentrations

**Recommended books/References:**


1. K. Nakamoto, *"Infrared and Raman Spectra of inorganic and coordination compound"*,

third edition; **(1997)** 524.
2. Khosla, B.D.; Garg, V.C.; Gulati, A.(2015), *Senior Practical Physical Chemistry*, R. Chand & Co.
3. D N Sathyanarayana, Electronic Absorption Spectroscopy and Related Techniques (2001).

**CHEMISTRY MAJOR -6** **CORE COURSE MJC50CHM206(T) 25**

**INORGANIC CHEMISTRY**

| L | T | P | Cr |
|---|---|---|---|
| 3 | 0 | 1 | 4 |

**Learning objectives:** **(45 Hours)**

After completion of the course, the learner shall be able to understand:

1. Coordination compounds– its nomenclature, theories, d-orbital splitting in complexes, chelate.
2. Transition metals, its stability, color, oxidation states and complexes.
3. Lanthanides, Actinides–separation, color, spectra and magnetic behavior
4. Bioinorganic chemistry–metal ions in biological system, its toxicity; hemoglobin.
5. Molecular orbital theory, d-orbital splitting in tetrahedral, octahedral, square planar complexes, chelate effects.
6. Hemoglobin and its importance in biological systems.

**Self-study:**

1. IUPAC nomenclature of coordination compounds/complexes.
2. Prediction of structure of complexes using various theories; color and magnetic properties of different complexes.
3. Use of lanthanide/actinide compounds in industries.
4. Toxicity of various metals and mechanism of metal-biological system interactions.

**UNIT-1: Coordination Chemistry** **(15 Hours)**

Werner's theory, EAN rule, IUPAC nomenclature of coordination compounds, isomerism in coordination compounds. Stereochemistry of complexes with the coordination number 4 and 6, Chelate effect. Valence bond theory (inner and outer orbital complexes), Crystal field theory, d-orbital splitting, weak and strong fields, pairing energies, factors affecting the magnitude of (Δ). Octahedral vs. tetrahedral

coordination, tetragonal distortions from octahedral geometry, Jahn-Teller theorem, square planar complexes, d-orbital splitting in trigonal bipyramidal, square pyramidal and cubic ligand field environments, CFSE, Variation of lattice energies, enthalpies of hydration and crystal radii variations in halides of first and second row transition metal series, Qualitative aspect of Ligand field theory, MO diagrams of metal complexes,

**UNIT-2: Transition Elements (12 Hours)**

General group trends with special reference to electronic configuration, colour, variable valency, magnetic and catalytic properties, and ability to form complexes. Stability of various oxidation states and e.m.f. (Latimer & Bsworth diagrams). Difference between the first, second and third transition series. Chemistry of Ti, V, Cr Mn, Fe and Co in various oxidation states (excluding their metallurgy)

**UNIT-3: Lanthanides and Actinides (8 Hours)**

Electronic configuration, oxidation states, color, spectra and magnetic behavior, lanthanide contraction, separation of lanthanides (ion-exchange method only).

**UNIT-4: Bioinorganic Chemistry (10 Hours)**

Metal ions present in biological systems, classification of elements according to their action in biological system. Geochemical effect on distribution of metals. Sodium / K-pump, carbonic anhydrase and carboxy peptidase. Excess and deficiency of some trace metals. Toxicity of metalions (Hg, Pb, Cd and As), toxicity, chelating agents in medicine. Iron and its application in bio-systems, Haemoglobin; Storage and transfer of iron.

**Recommended textbooks/References:**


1. Purcell, K.F & Kotz, J.C. *Inorganic Chemistry* W.B. Saunders Co, 1977.
2. Huheey, J.E., *Inorganic Chemistry*, Prentice Hall,1993.
3. Lippard, S.J. & Berg, J.M. *Principles of Bioinorganic Chemistry* Panima Publishing Company 1994.
4. Cotton, F.A. & Wilkinson, G, *Advanced Inorganic Chemistry* Wiley-VCH,1999.
5. Greenwood, N.N. & Earnshaw, A. *Chemistry of the Elements*, Butterworth-Heinemann,1997.

**CHEMISTRY MAJOR -6(P)** **COURSE CODE: MJC50CHM206(P)25**

**INORGANIC CHEMISTRY LABORATORY**

| L | T | P | Cr |
|---|---|---|---|
| 0 | 0 | 1 | 1 |

**(30 Hours; 1 Credit)**

((List of experiments and references are suggestive. However, more experiments can be added/list of experiments can be revised as per available facilities).

1. Qualitative semimicro analysis of mixtures containing 3 anions and 3 cations. Emphasis should be given on understanding of the chemistry of different reactions. Following radicals may be analyzed:
   Carbonate, nitrate, nitrite, sulphide, sulphate, sulphite, acetate, fluoride, chloride, bromide, iodide, borate, oxalate, phosphate, ammonium, potassium, lead, copper, cadmium, bismuth, tin, iron, aluminum, chromium, zinc, manganese, cobalt, nickel, barium strontium, calcium, magnesium. Mixtures containing one interfering anion, or insoluble component (BaSO4, SrSO4, $PbSO_4$, $CaF_2$ or $Al_2O_3$) or combination of anions e.g. $CO_3^{2-}$ and $SO_3^{2-}$, $NO_2^-$ and $NO_3^-$, $Cl^-$ and $Br^{--}$ and $I^-$. Spot analysis/tests should be done whenever possible.
2. Controlled synthesis of two copper oxalate hydrate complexes: kinetic *vs* thermodynamic factors.
3. Preparation of acetylacetanato complexes of $Cu^{2+}$/$Fe^{3+}$. (Also find the λmax of the prepared complex using instrument).
4. Synthesis of ammine complexes of Ni(II) and its ligand exchange reactions (e.g. bidentate ligands like acetylacetone, DMG, glycine) by substitution method.
5. Preparation of any two of the following complexes and measurement of their conductivity measurement:
   i). Tetraammine carbonato cobalt(III) nitrate
   ii). Tetraammine copper(II) sulphate
   iii). Potassium trioxalato ferrate(III) trihydrate

**Recommended books/reference books**


1. S. Komiya, *Synthesis of organometallic compounds: A practical guide*, Wiley.
2. A.I.Vogel: *Qualitative Inorganic Analysis*, Prentice Hall,7th Edn.
3. Vogel's *Qualitative Inorganic Analysis,* Revised by G.Svehla, Pearson Education, 2002.

**CHEMISTRY MAJOR -7** **COURSE CODE: MJC50CHM207(T) 25**

**Organic Chemistry**

| L | T | P | Cr |
|---|---|---|---|
| 3 | 0 | 1 | 4 |

**(45 Hours)**

***Learning objectives:***

After completion of the course, the learner shall be able to understand:

1. Familiarization about classes of organic compounds and their methods of preparation.
2. Basic uses of reaction mechanisms.
3. Name reactions, uses of various reagents and the mechanism of their action.
4. Preparation and uses of various classes of organic compounds.
5. Organometallic compounds and their uses.
6. Organic chemistry reactions and reaction mechanisms.
7. Use of reagents in various organic transformation reactions.

***Self-study:***

1. Elucidating reaction mechanisms for organic reactions.
2. Organometallic compounds and their uses.
3. Use of active methylene groups in organic mechanism and preparation of new organic compounds.

**UNIT-1: Chemistry of Halogenated Hydrocarbons (10 Hours)**

*Alkyl halides:* Methods of preparation, nucleophilic substitution reactions – SN1, SN2 and $SN^i$ mechanisms with stereochemical aspects and effect of solvent, etc.; nucleophilic substitution vs. elimination.

*Aryl halides:* Preparation, including preparation from diazonium salts. nucleophilic aromatic substitution; SNAr, Benzyne mechanism.

Relative reactivity of alkyl, allyl / benzyl, vinyl and aryl halides towards nucleophilic substitution reactions. Organometallic compounds of Mg and Li and their use in synthesis.

**UNIT-2: Alcohols, Phenols, Ethers and Epoxides (10 Hours)**

*Alcohols:* preparation, properties and relative reactivity of 1°, 2°, 3° alcohols, Bouvaelt-Blanc Reduction; Preparation and properties of glycols: Oxidation by

periodic acid and lead tetraacetate, Pinacol-Pinacolone rearrangement.
*Phenols:* Preparation and properties; Acidity and factors effecting it, Ring substitution reactions, Reimer–Tiemann and Kolbe's–Schmidt Reactions, Fries and Claisen rearrangements with mechanism.
*Ethers and Epoxides:* Preparation and reactions with acids. Reactions of epoxides with alcohols, ammonia derivatives and LiAlH4

**UNIT-3: Carbonyl Compounds (10 Hours)**

Structure, reactivity and preparation; Nucleophilic additions, Nucleophilic addition-elimination reactions with ammonia derivatives with mechanism; Mechanisms of Aldol and Benzoin condensation, Knoevenagel condensation, Claisen-Schmidt, Perkin, Cannizzaro and Wittig reaction, Beckmann and Benzil-Benzilic acid rearrangements, haloform reaction and Baeyer Villiger oxidation, α-substitution reactions, oxidations and reductions (Clemmensen, Wolff-Kishner, LiAlH4, NaBH4, MPV, PDC and PGC); Addition reactions of unsaturated carbonyl compounds: Michael addition; Active methylene compounds: Keto-enol tautomerism. Preparation and synthetic applications of diethylmalonate and ethylacetoacetate.

**UNIT-4: Carboxylic Acids and their Derivatives (10 Hours)**

Preparation, physical properties and reactions of monocarboxylic acids: Typical reactions of dicarboxylic acids, hydroxyl acids and unsaturated acids: succinic/phthalic, lactic, malic, tartaric, citric, maleic and fumaric acids; Preparation and reactions of acid chlorides, anhydrides, esters and amides; Comparative study of nucleophilic substitution at acyl group-Mechanism of acidic and alkaline hydrolysis of esters, Claisen condensation, Dieckmann and Reformatsky reactions, Hofmann bromamide degradation and Curtius rearrangement.

**UNIT-5: Sulphur containing compounds 5(5 Hours)**

Preparation and reactions of thiols, thioethers and sulphonic acids.

**Recommended Books/references:**


1. Solomons,T.WG., Fryhle, B.Craig, *Organic Chemistry,* John Wiley & Sons, Inc (2009).
2. McMurry, J.E. *Fundamentals of Organic Chemistry*, Seventh edition Cengage Learning, 2013.
3. P. Sykes, *A Guide Book to Mechanism in Organic Chemistry*, 6th Edition (1997), Orient Longman, New Delhi.
4. Morrison R.T. and Boyd R.N.*Organic Chemistry*, Sixth Edition, Prentice Hall, India,
   2003.

**CHEMISTRY MAJOR -7(P)** **COURSE CODE: MJC50CHM207(P)25**

**ORGANIC CHEMISTRY LABORATORY**

| L | T | P | Cr |
|---|---|---|---|
| 0 | 0 | 1 | 1 |

**(30 Hours; 1 Credit)**

(List of experiments and references are suggestive. However, more experiments can be added/list of experiments can be revised as per available facilities).

(One experiment from each group to be demonstrated)

1. Field study tour: Water analysis (pH, turbidity, $Ca^{2+}$, $SO_4^{2-}$, $Cl^-$, etc)
2. Identification of elements (N, S, and halogen) and Functional group tests for alcohols, phenols, carbonyl, carboxylic acid and amine group of compounds.
3. Organic preparations:

i). Acetylation of one of the following compounds: amines (aniline, *o*-, *m*-, *p*-toluidines and *o*-, *m*-, *p*-anisidine) and phenols (β-naphthol, vanillin, salicylic acid) by any one method: (Using conventional method and Using green chemistry approach)

ii). Benzolyation of one of the amines (aniline, *o*-, *m*-, *p*- toluidines and *o*-, *m*-, *p*-anisidine) and one of the phenols (*β*-naphthol, resorcinol, *p*-cresol) by Schotten-Baumann reaction.

iii). Oxidation of ethanol/isopropanol (Iodoform reaction).

iv) Bromination (anyone)

(a) Acetanilide by conventional methods

(b) Acetanilide using green approach (Bromate-bromide method)

v) Nitration: (anyone)

(a) Acetanilide / nitrobenzene by conventional method

(b) Salicylic acid by green approach (using ceric ammonium nitrate).

vi). Selective reduction of *meta* dinitrobenzene to *m*-nitroaniline.

vii). Reduction of *p*-nitrobenzaldehyde by sodium borohydride.

viii). Hydrolysis of amides and esters.

ix). Semicarbazone of any one of the following compounds: acetone, ethylmethyl ketone,
cyclohexanone, benzaldehyde.

x). *S*-Benzyl isothiouronium salt of one each of water soluble/insoluble acids (benzoic acid,

oxalic acid, phenyl acetic acid and phthalic acid).

xi). Aldol condensation with either conventional or green method.

xii). Benzil-Benzilic acid rearrangement.

**Recommended Books/References:**


1. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry,* Pearson Education (2009)
2. Furniss, B.S., Hannaford, A.J., Smith,P.W.G. & Tatchell,A.R. *Practical Organic Chemistry, 5th Ed.* Pearson (2012)
3. Ahluwalia,V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis,* University Press (2000)
4. Ahluwalia, V.K. & Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis,* University Press (2000).


**CHEMISTRY MAJOR - 8** **COURSE CODE: MJC50CHM208(T)25**

**PHYSICAL CHEMISTRY**

| L | T | P | Cr |
|---|---|---|---|
| 3 | 0 | 1 | 4 |

**(45 Hours)**

**Learning Objectives:**

1. Laws of thermodynamics and concepts.
2. Partial molar quantities and its attributes.
3. Dilute solution and its properties.
4. Understanding the concept of system, variables, heat, work, and laws of thermodynamics.
5. Understanding the concept of heat of reactions and use of equations in calculations of bond energy, enthalpy, etc.
6. Understanding the concept of entropy; reversible, irreversible processes. Calculation of entropy using 3rd law of thermodynamics.
7. Understanding the application of thermodynamics: Joule Thompson effects, partial molar quantities.
8. Understanding theories/thermodynamics of dilute solutions.

**Self-study:**

1. Use of thermochemical equations for calculation of energy and related terms.
2. Use of thermodynamics in explaining chemical behavior of solute/solvent and reactions.
3. Study of calorimeter principle and its use.

**UNIT-1: Introduction to Thermodynamics (20 Hours)**

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

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

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), pressure on enthalpy of reactions.

Second Law: 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: Third Law of thermodynamics, residual entropy, calculation of absolute entropy of molecules.

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

**UNIT-2: Partial Molar Quantities (6 Hours)**

Partial molar quantities, dependence of thermodynamic parameters on composition; Gibbs- Duhem equation, chemical potential of ideal mixtures, change in thermodynamic functions in mixing of ideal gases.

**UNIT-3: Chemical Equilibrium (10 Hours)**

Criteria of thermodynamic equilibrium, degree of advancement of reaction, chemical equilibria in ideal gases; concept of fugacity. Thermodynamic 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 various equilibrium constants $K_p$, $K_c$ and $K_x$. Le Chatelier principle; equilibrium between ideal gases and pure condensed phase.

**UNIT-4: Solutons and Colligative Properties (9 Hours)**

Dilute solutions; lowering of vapour pressure, Raoult's and Henry's Laws and their applications. Excess thermodynamic functions. 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. Applications in calculating molar masses of normal, dissociated and associated solutes in solution.

**Recommended Books:**


9. Atkins, P. and De Paula, J. *Physical Chemistry* 10th Ed. (2014).
10. Castellan, G. W. *Physical Chemistry* 4th Ed., Narosa (2004).
11. Engel, T. and Reid, P. *Physical Chemistry* 3rd Ed., Prentice Hall (2012).
12. McQuarrie, D. A. and Simon, J. D. *Molecular Thermodynamics* Viva Books (2004).
13. Roy, B. N. *Fundamentals of Classical and Statistical Thermodynamics* Wiley (2001).
14. Assael, M.J.; Goodwin, A. R. H.; Stamatoudis, M.; Wakeham, W. A.; Will, S. *Commonly Asked Questions in Thermodynamics*. CRC Press (2011).
15. Levine, I. N. *Physical Chemistry* 6th Ed., Tata Mc Graw Hill (2010).
16. Metz, C.R. *2000 Solved problems in chemistry*, Schaum Series (2006).


**CHEMISTRY MAJOR – 8(P)** **COURSE CODE: MJC50CHM208(P)25**

**Physical Chemistry Laboratory**

| L | T | P | Cr |
|---|---|---|---|
| 0 | 0 | 1 | 1 |

**(30 Hours: I Credit)**

(List of experiments and references are suggestive. However, more experiments can be added/list of experiments can be revised as per available facilities).

1. Thermochemistry

(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 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 calculation of the enthalpy of neutralization of the first step.

(e) Determination of enthalpy of hydration of salt such as copper sulphate.

(f) Study of the solubility of benzoic acid in water and determination of change in enthalpy.

(g) Study of the effect of concentration of solute on elevation of boiling point of water.

2. Determination of critical solution temperature and composition of the phenol-water system and to study the effect of impurities on it.

3. Study the equilibrium of at least one of the following reactions by the distribution method:

(a) $I_2$ (aq) + I $\longrightarrow$ $I_3^-$(aq)

(b) $Cu^{2+}$ (aq) + $n$$NH_3 \rightarrow Cu(NH_3)_n$

4. Study the kinetics of the following reactions.

(a) Acid hydrolysis of methyl acetate with hydrochloric acid.

(b) Saponification of ethyl acetate.

5. Adsorption: Verification of Freundlich and Langmuir isotherms for adsorption of acetic acid and selected organic dye(s) on activated charcoal. (Use of calorimeter for calculation of heat of reactions may be demonstrated)

**Recommended Books:**


1. Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand, New Delhi (2011).
2. Garland, C. W.; Nibler, J. W.; Shoemaker, D. P. *Experiments in Physical Chemistry*, 8th Ed., McGraw-Hill (2003).
3. Halpern, A. M.; McBane, G. C. *Experimental Physical Chemistry*, 3rd Ed., W, H. Freeman (2003).

**CHEMISTRY MINOR – 4** **COURSE CODE: MNC50CHM204(T)25**

**Chemical Energetics, Equilibria, Solutions and Hydrocarbons (40 lectures of 60 minutes each)**

| L | T | P | Cr |
|---|---|---|---|
| 3 | 0 | 1 | 4 |

**Learning Objectives:** **(45 Hours)**

1. To develop basic understanding of the chemical energetics, laws of thermodynamics, chemical and ionic equilibrium.
2. To acquaint the students with the functional group approach to study organic chemistry.
3. To establish applications of this concept structure, methods of preparation and reactions for the following classes of compounds: Aromatic hydrocarbons, alkyl and aryl halides, alcohols, phenols and ethers, aldehydes and ketones are described.

**Learning Outcomes:**

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

1. Understand the laws of thermodynamics, thermochemistry and equilibria.
2. Use the concepts learnt to predict feasibility of chemical reactions and to study the behaviour of reactions in equilibrium.
3. Use concepts learnt to understand stereochemistry of a reaction and predict the reaction outcome.
4. Design newer synthetic routes for various organic compounds.
5. Learn and identify many organic reaction mechanisms including free radical substitution,
   electrophilic addition and electrophilic aromatic substitution.

**Section A: Physical Chemistry (Lectures:20)**

**UNIT-1: Chemical Energetics and equilibrium** **(15 Hours)**

Review of thermodynamics and the laws of thermodynamics, important principles and definitions of thermochemistry, concept of standard state and standard enthalpies of formations, integral and differential enthalpies of solution and dilution, calculation of bond energy, bond dissociation energy and resonance energy from thermochemical data, variation

of enthalpy of a reaction with temperature – Kirchhoff's equation, statement of third law of thermodynamics and calculation of absolute entropies of substances.
Free energy change in a chemical reaction, Thermodynamic derivation of the law of chemical equilibrium, distinction between G and Go, Le Chatelier's principle, relationships between Kp, Kc and Kx for reactions involving ideal gases.

**UNIT-2: Solutions (7 Hours)**

Thermodynamics of ideal solutions: Ideal solutions and Raoult's law, deviations from Raoult's law- nonideal solutions. Vapour pressure, composition and temperature-composition curves of ideal and non-ideal solutions. Distillation of solutions, Lever rule, Azeotropes. Partial miscibility of liquids: Critical solution temperature; effect of impurity on partial miscibility of liquids. Immiscibility of liquids: principle of steam distillation, Nernst distribution law and its applications, solvent extraction.

**Section B: Organic Chemistry**

**UNIT-3: Aliphatic Hydrocarbons (15 Hours)**

**Alkanes:**

Preparation: catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis, Grignard reagent.
Reactions: Free radical substitution: Halogenation.

**Alkenes:**

Preparation: Elimination reactions: Dehydration of alcohols and dehydrohalogenation of alkyl halides (Saytzeff's rule); cis alkenes (Partial catalytic hydrogenation) and trans alkenes (Birch reduction). Reactions: cis-addition (alk. $KMnO_4$) and trans-addition (bromine), addition of HX (Markownikoff's and anti-Markownikoff's oxidation addition), Hydration, Ozonolysis, oxymecuration-demercuration, Hydroboration

**Alkynes:**

Preparation: Acetylene from $CaC_2$ and conversion into higher alkynes; by dehalogenation of tetrahalides and dehydrohalogenation of vicinal-dihalides. Reactions: formation of metal acetylides and acidity of alkynes.

**UNIT-4: Aromatic Hydrocarbons (8 Hours)**

Structure and aromatic character of benzene, methods of preparation of benzene from phenol, benzoic acid and acetylene. Reactions**:** electrophilic substitution reactions in benzene citing examples of nitration, halogenation, sulphonation and Friedel-Craft's alkylation and acylation.

**CHEMISTRY MINOR – 4(P)** **COURSE CODE: MNC50CHM204(P)25**

| L | T | P | Cr |
|---|---|---|---|
| 0 | 0 | 1 | 1 |

**Section A: Physical Chemistry** **(30 Hours: I Credit)**

1. Construction of the phase diagram of a binary system (simple eutectic) using cooling curves.
2. Determination of critical solution temperature and composition of phenol water system and study the effect of impurities on it.
3. Perform the following conductometric titrations:
a) Strong acid vs strong base
b) Weak acid vs strong base.

**Section B: Organic Chemistry**

**Preparations:** Recrystallization, determination of melting point and calculation of quantitative yields to be done in all cases

1. Benzoylation of amines/phenols
2. Oxime of aldehydes and ketones
3. 2,4-dinitrophenylhydrazone of aldehydes and ketones

**References:**


1. Castellan, G. W. (2004), *Physical Chemistry*, Narosa.
2. Kapoor, K.L. (2015), *A Textbook of Physical Chemistry*, Vol 1& 2, 6th Edition, McGraw Hill Education.
3. B. R. Puri, L. R. Sharma, M. S. Pathania, (2017), *Principles of Physical Chemistry,* Vishal Publishing Co.
4. Finar, I. L. *Organic Chemistry (Volume 1 & 2)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
5. Morrison, R. N.; Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
6. Bahl, A; Bahl, B. S. (2012), *Advanced Organic Chemistry*, S. Chand.
7. Khosla, B.D.; Garg, V.C.; Gulati, A.(2015), *Senior Practical Physical Chemistry*, R. Chand & Co.
8. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. (2012), *Vogel's Textbook of Practical Organic Chemistry*, Pearson.


(The above course structure/number of classes and list of experiments are suggestive. Faculty/academic bodies may incorporate revision /may incorporate text and reference books as per need).