## Structure of Chemistry Syllabus Under CBCS

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<th>YEAR</th>
<th>SEMESTER</th>
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SEMESTER – I

Paper I - Inorganic & Organic Chemistry 60hrs (4h/w)

INORGANIC CHEMISTRY 30 hrs (2h / w)

UNIT –I
p-block elements –I 15h
Group-13: Synthesis and structure of diborane and higher boranes
(B₄H₁₀ and B₅H₉), boron-nitrogen compounds (B₃N₃H₆ and BN)
Group - 14: Preparation and applications of silanes and silicones.

UNIT-II
1. p-block elements -II 8h
Group - 16: Classifications of oxides based on (i) Chemical behaviour and
(ii) Oxygen content.
Group-17: Inter halogen compounds and pseudo halogens.
2. Organometallic Chemistry 7h
Definition - classification of Organometallic compounds - nomenclature, preparation,
properties and applications of alkyls of Li and Mg.

ORGANIC CHEMISTRY 30hrs (2h /w)

UNIT-III
Structural theory in Organic Chemistry 10 h
Types of bond fission and organic reagents (Electrophilic, Nucleophilic, and free radical
reagents including neutral molecules like H₂O,NH₃ & AlCl₃).
Bond polarization : Factors influencing the polarization of covalent bonds, electro
negativity - inductive effect. Application of inductive effect (a) Basicity of amines (b)
Acidity of carboxylic acids (c) Stability of carbonium ions. Resonance or Mesomeric
effect, application to (a) acidity of phenol, and (b) acidity of carboxylic acids. Hyper
conjugation and its application to stability of carbonium ions, Free radicals and alkenes,
carbanions, carbenes and nitrenes.
Types of Organic reactions : Addition - electrophilic, nucleophilic and free radical.
Substitution - electrophilic, nucleophilic and free radical. Elimination- Examples.
UNIT-IV
1. Acyclic Hydrocarbons 6 h

Alkynes - Preparation by dehydrohalogenation of dihalides, dehalogenation of tetrahalides, Properties; Acidity of acetylenic hydrogen (formation of Metal acetylides). Preparation of higher acetylenes, Metal ammonia reductions, Physical properties. Chemical reactivity - electrophilic addition of X₂, HX, H₂O (Tautomerism), Oxidation with KMnO₄, OsO₄, reduction and Polymerisation reaction of acetylene.

2. Alicyclic hydrocarbons (Cycloalkanes) 4 h

UNIT-V
Benzene and its reactivity 10 h
Concept of resonance, resonance energy. Heat of hydrogenation, heat of combustion of Benzene, mention of C-C bond lengths and orbital picture of Benzene. Concept of aromaticity - aromaticity (definition), Huckel's rule - application to Benzenoid (Benzene, Naphthalene) and Non - Benzenoid compounds (cyclopropenyl cation, cyclopentadienyl anion and tropyl cation)
Reactions - General mechanism of electrophilic substitution, mechanism of nitration, Friedel Craft's alkylation and acylation. Orientation of aromatic substitution - Definition of ortho, para and meta directing groups. Ring activating and deactivating groups with examples (Electronic interpretation of various groups like NO₂ and Phenolic). Orientation of (i) Amino, methoxy and methyl groups (ii) Carboxy, nitro, nitrile, carbonyl and sulphonic acid groups (iii) Halogens (Explanation by taking minimum of one example from each type)

List of Reference Books
1. Inorganic Chemistry by J.E.Huheey
2. Basic Inorganic Chemistry by Cotton and Wilkinson
3. A textbook of qualitative inorganic analysis by A.I. Vogel
4. Organic Chemistry by Morrisson and Boyd
5. A Text Book of Organic chemistry by I L Finar Vol I
6. Concise Inorganic Chemistry by J.D.Lee
LABORATORY COURSE-I
30 hrs (2 h / w)
Practical-I Simple Salt Analysis
(At the end of Semester-I)

Qualitative inorganic analysis

Analysis of simple salt containing one anion and cation from the following

**Anions:** Carbonate, sulphate, chloride, bromide, acetate, nitrate, borate, phosphate.

**Cations:** Lead, copper, iron, aluminum, zinc, manganese, nickel, calcium, strontium, barium, potassium and ammonium.
SEMESTER - II  
Paper II (Physical & General Chemistry)  
60 hrs. (4h/w)  

PHYSICAL CHEMISTRY  
30 hrs (2h / w)  

UNIT-I  
Solidstate  
10h  

UNIT-II  
1. Gaseous state  
6 h  

2. Liquid state  
4 h  
Structural differences between solids, liquids and gases. Liquid crystals, the mesomorphic state. Classification of liquid crystals into Smectic and Nematic. Differences between liquid crystal and solid/liquid. Application of liquid crystals as LCD devices.  

UNIT-III  
Solutions  
10h  

GENERAL CHEMISTRY  
30 hrs (2h / w)  

UNIT-IV  
1. Surface chemistry  
8 h  

2. Chemical Bonding
Valence bond theory, hybridization, VB theory as applied to ClF$_3$, Ni(CO)$_4$, Molecular orbital theory - LCAO method, construction of M.O. diagrams for homonuclear and heteronuclear diatomic molecules (N$_2$, O$_2$, CO and NO).

UNIT-V
Stereochemistry of carbon compounds
Molecular representations- Wedge, Fischer, Newman and Saw-Horse formulae.
Optical isomerism: Optical activity- wave nature of light, plane polarised light, optical rotation and specific rotation.
Chiral molecules- definition and criteria(Symmetry elements)- Definition of enantiomers and diastereomers – Explanation of optical isomerism with examples Glyceraldehyde, Lactic acid, Alanine, Tartaric acid, 2,3-dibromopentane.
D,L and R,S configuration methods and E.Z- configuration with examples.

List of Reference Books
1. Principles of physical chemistry by Prutton and Marron
2. Solid State Chemistry and its applications by Anthony R. West
3. Text book of physical chemistry by K L Kapoor
4. Text book of physical chemistry by S Glasstone
5. Stereochemistry of Organic compounds by E L Eliel
6. Advanced Organic Chemistry by F A Carey and R J Sundberg
7. Stereochemistry by P.S.Kalsi
8. Stereochemistry of Organic compounds by D. Nasipuri
9. Advanced physical chemistry by Bahl and Tuli
10. Advanced Inorganic Chemistry Vol-I by Satyaparakash, Tuli, Basu and Madan
**LABORATORY COURSE - II**

**Practical-II** Analysis of Mixture Salt
(At the end of Semester-II)

**Qualitative inorganic analysis**

Analysis of mixture salt containing two anions and two cations (From two different groups) from the following:

**Anions**: Carbonate, sulphate, chloride, bromide, acetate, nitrate, borate, phosphate.

**Cations**: Lead, copper, iron, aluminum, zinc, manganese, calcium, strontium, barium, potassium and ammonium.
SEMESTER - III
Paper III (INORGANIC & ORGANIC CHEMISTRY) 60 hrs (4 h / w)

INORGANIC CHEMISTRY 30 hrs (2h / w)

UNIT –I
1. Chemistry of d-block elements: 9h
Characteristics of d-block elements with special reference to electronic configuration, variable valence, magnetic properties, catalytic properties and ability to form complexes. Stability of various oxidation states

2. Theories of bonding in metals: 6h
Metallic properties and its limitations, Valence bond theory, Free electron theory, Explanation of thermal and electrical conductivity of metals, limitations, Band theory, formation of bands, explanation of conductors, semiconductors and insulators.

UNIT –II
3. Metal carbonyls: 7h
EAN rule, classification of metal carbonyls, structures and shapes of metal carbonyls of V, Cr, Mn, Fe, Co and Ni.

4. Chemistry of f-block elements: 8h
Chemistry of lanthanides - electronic structure, oxidation states, lanthanide contraction, consequences of lanthanide contraction, magnetic properties. Chemistry of actinides - electronic configuration, oxidation states, actinide contraction, comparison of lanthanides and actinides.

ORGANIC CHEMISTRY 30 h (2h/w)

UNIT – III
1. Halogen compounds 5 h
Nomenclature and classification of alkyl (into primary, secondary, tertiary), aryl, aryl alkyl, allyl, vinyl, benzyl halides. Nucleophilic aliphatic substitution reaction- classification into SN1 and SN2 – reaction mechanism with examples – Ethyl chloride, t-butyl chloride and optically active alkyl halide 2-bromobutane.
2. Hydroxy compounds

Nomenclature and classification of hydroxy compounds.
Alcohols: Preparation with hydroboration reaction, Grignard synthesis of alcohols.
Phenols: Preparation i) from diazonium salt, ii) from aryl sulphonates, iii) from cumene.
Physical properties- Hydrogen bonding (intermolecular and intramolecular). Effect of hydrogen bonding on boiling point and solubility in water.
Identification of alcohols by oxidation with KMnO₄, Ceric ammonium nitrate, Luca’s reagent and phenols by reaction with FeCl₃.
Chemical properties:
   a) Dehydration of alcohols.
   b) Oxidation of alcohols by CrO₃, KMnO₄.
   c) Special reaction of phenols: Bromination, Kolbe-Schmidt reaction, Riemer-Tiemann reaction, Fries rearrangement, azocoupling, Pinacol-Pinacolone rearrangement.

UNIT-IV
Carbonyl compounds

Nomenclature of aliphatic and aromatic carbonyl compounds, structure of the carbonyl group. Synthesis of aldehydes from acid chlorides, synthesis of aldehydes and ketones using 1,3-dithianes, synthesis of ketones from nitriles and from carboxylic acids.
Physical properties: Reactivity of carbonyl group in aldehydes and ketones.
Nucleophilic addition reaction with a) NaHSO₃, b) HCN, c) RMgX, d) NH₂OH, e)PhNH₂NH₂, f) 2,4 DNPH, g) Alcohols-formation of hemiacetal and acetal. Base catalysed reactions: a) Aldol, b) Cannizarro’s reaction, c) Perkin reaction, d) Benzoin condensation, e) Haloform reaction, f) Knoevenagel reaction. Oxidation of aldehydes-Baeyer-Villiger oxidation of ketones.
Reduction: Clemmensen reduction, Wolf-Kishner reduction, MPV reduction, reduction with LiAlH₄ and NaBH₄. Analysis of aldehydes and ketones with a) 2,4-DNPH test, b) Tollen’s test, c) Fehling test, d) Schiff’s test e) Haloform test (with equation)

UNIT-V
1. Carboxylic acids and derivatives

2. Active methylene compounds

**Acetoacetic ester**: keto-enol tautomerism, preparation by Claisen condensation, Acid hydrolysis and ketonic hydrolysis. Preparation of a) monocarboxylic acids. b) Dicarboxylic acids. c) Reaction with urea

**Malonic ester**: preparation from acetic acid. **Synthetic applications**: Preparation of a) monocarboxylic acids (propionic acid and n-butyric acid). b) Dicarboxylic acids (succinic acid and adipic acid) c) α,β-unsaturated carboxylic acids (crotonic acid). d) Reaction with urea.

**List of Reference Books**
1. Selected topics in inorganic chemistry by W.D.Malik, G.D.Tuli, R.D.Madan
2. Inorganic Chemistry by E Huheey, E A Keiter and R L Keiter
3. A Text Book of Organic Chemistry by Bahl and Arun bahl
4. A Text Book of Organic chemistry by I L Finar Vol I
5. Organic chemistry by Bruice
6. Organic chemistry by Clayden
7. Advanced Inorganic chemistry by Gurudeep Raj
8. Basic Inorganic Chemistry by Cotton and Wilkinson
9. Concise Inorganic Chemistry by J.D.Lee
LABORATORY COURSE -III

30 hrs. (2 h / w)

Practical Paper-III Titrimetric analysis and Organic Functional Group Reactions
(At the end of Semester-III)

Titrimetric analysis: 25M

1. Determination of Fe (II) using KMnO₄ with oxalic acid as primary standard.
2. Determination of Cu(II) using Na₂S₂O₃ with K₂Cr₂O₇ as primary standard.

Organic Functional Group Reactions 25M

3. Reactions of the following functional groups present in organic compounds
   (at least four) Alcohols, Phenols, Aldehydes, Ketones, Carboxylic acids and Amides
SEMESTER IV
Paper IV (SPECTROSCOPY & PHYSICAL CHEMISTRY)
60 hrs (4 h / w)

SPECTROSCOPY

UNIT-I


UNIT-II

Infra red spectroscopy
Different Regions in Infrared radiations. Modes of vibrations in diatomic and polyatomic molecules. Characteristic absorption bands of various functional groups. Interpretation of spectra-Alkanes, Aromatic, Alcohols carbonyls, and amines with one example to each.

Proton magnetic resonance spectroscopy (¹H-NMR)
Principles of nuclear magnetic resonance, equivalent and non-equivalent protons, position of signals. Chemical shift, NMR splitting of signals - spin-spin coupling, coupling constants. Applications of NMR with suitable examples - ethyl bromide, ethanol, acetaldehyde, 1,1,2-tribromo ethane, ethyl acetate, toluene and acetophenone.

PHYSICAL CHEMISTRY

UNIT-III
Dilute solutions
UNIT-IV
Electrochemistry-I  10h

UNIT-V
1. Electrochemistry-II  4h
Single electrode potential, sign convention, Reversible and irreversible cells Nernst Equation- Reference electrode, Standard Hydrogen electrode, calomel electrode, Indicator electrode, metal – metal ion electrode, Inert electrode, Determination of EMF of cell, Applications of EMF measurements - Potentiometric titrations.

2.Phase rule  6h
Concept of phase, components, degrees of freedom. Thermodynamic Derivation of Gibbs phase rule. Phase equilibrium of one component system - water system. Phase equilibrium of two- component system, solid-liquid equilibrium. Simple eutectic diagram of Pb-Ag system, simple eutectic diagram, desilverisation of lead., NaCl-Water system, Freezing mixtures.

List of Reference Books
1. Spectroscopy by William Kemp
2. Spectroscopy by Pavia
3. Organic Spectroscopy by J. R. Dyer
5. Advanced Physical Chemistry by Atkins
6. Introduction to Electrochemistry by S. Glasstone
7. Elementary organic spectroscopy by Y.R. Sharma
8. Spectroscopy by P.S.Kalsi
LABORATORY COURSE – IV
Practical Paper - IV Physical Chemisry and IR Spectral Analysis
(at the end of semester IV)

30 hrs (2 h / W)

**Physical Chemistry**

1. Critical Solution Temperature- Phenol-Water system
2. Effect of NaCl on critical solution temperature (Phenol-Water system)
3. Determination of concentration of HCl conductometrically using standard NaOH solution.
4. Determination of concentration of acetic acid conductometrically using standard NaOH Solution.

**IR Spectral Analysis**

5. IR Spectral Analysis of the following functional groups with examples
   a) Hydroxyl groups
   b) Carbonyl groups
   c) Amino groups
   d) Aromatic groups
SEMESTER-V

Paper - V (INORGANIC, PHYSICAL & ORGANIC CHEMISTRY)
45 hrs (3 h / w)

INORGANIC CHEMISTRY

UNIT - I
Coordination Chemistry: 8h
IUPAC nomenclature - bonding theories - Review of Werner's theory and Sidgwick's concept of coordination - Valence bond theory - geometries of coordination numbers 4-tetrahedral and square planar and 6-octahedral and its limitations, crystal field theory - splitting of d-orbitals in octahedral, tetrahedral and square-planar complexes - low spin and high spin complexes - factors affecting crystal-field splitting energy, merits and demerits of crystal-field theory. Isomerism in coordination compounds - structural isomerism and stereo isomerism, stereochemistry of complexes with 4 and 6 coordination numbers.

UNIT-II
1. Spectral and magnetic properties of metal complexes: 4h
Types of magnetic behavior, spin-only formula, calculation of magnetic moments, experimental determination of magnetic susceptibility-Gouy method.

2. Stability of metal complexes: 3h
Thermodynamic stability and kinetic stability, factors affecting the stability of metal complexes, chelate effect, determination of composition of complex by Job's method and mole ratio method.

ORGANIC CHEMISTRY

UNIT- III
Nitro hydrocarbons: 3h
Nomenclature and classification-nitro hydrocarbons, structure - Tautomerism of nitroalkanes leading to aci and keto form, Preparation of Nitroalkanes, reactivity - halogenation, reaction with HONO (Nitrous acid), Nef reaction and Mannich reaction leading to Micheal addition and reduction.

UNIT – IV
Nitrogen compounds: 12h
Amines (Aliphatic and Aromatic): Nomenclature, Classification into 1°, 2°, 3° Amines and Quaternary ammonium compounds. Preparative methods –
Reduction of Amides and Schmidt reaction. Physical properties and basic character - Comparative basic strength of Ammonia, methyl amine, dimethyl amine, trimethyl amine and aniline - comparative basic strength of aniline, N-methylaniline and N,N-dimethyl aniline (in aqueous and non-aqueous medium), steric effects and substituent effects.
Chemical properties: a) Alkylation b) Acylation c) Carbylamine reaction d) Hinsberg separation e) Reaction with Nitrous acid of 1°, 2°, 3° (Aliphatic and aromatic amines). Electrophillic substitution of Aromatic amines – Bromination and Nitration. Oxidation of aryl and Tertiary amines, Diazotization.

PHYSICAL CHEMISTRY

UNIT- V
Thermodynamics 15h

List of Reference Books
1. Concise coordination chemistry by Gopalan and Ramalingam
2. Coordination Chemistry by Basalo and Johnson
3. Organic Chemistry by G.Mare loudan, Purdue Univ
4. Advanced Physical Chemistry by
5. Text book of physical chemistry by S Glasstone
6. Concise Inorganic Chemistry by J.D.Lee
7. Advanced Inorganic Chemistry Vol-I by Satyaprakash, Tuli, Basu and Madan
8. A Text Book of Organic Chemistry by Bahl and Arun bahl
10. Advanced physical chemistry by Gurudeep Raj
SEMESTER-V
Paper - VI (INORGANIC, ORGANIC & PHYSICAL CHEMISTRY)
45 hrs (3 h / w)

INORGANIC CHEMISTRY

UNIT-I
1. Reactivity of metal complexes: 4h
Labile and inert complexes, ligand substitution reactions - SN1 and SN2, substitution reactions of square planar complexes - Trans effect and applications of trans effect.

2. Bioinorganic chemistry: 4h
Essential elements, biological significance of Na, K, Mg, Ca, Fe, Co, Ni, Cu, Zn and Cl-. Metalloporphyrins – Structure and functions of hemoglobin, Myoglobin and Chlorophyll.

PHYSICAL CHEMISTRY

UNIT-II
1. Chemical kinetics 8h
Rate of reaction - Definition of order and molecularity. Derivation of rate constants for first, second, third and zero order reactions and examples. Derivation for time half change. Methods to determine the order of reactions. Effect of temperature on rate of reaction, Arrhenius equation, concept of activation energy.

2. Photochemistry 5h

ORGANIC CHEMISTRY

UNIT- III
Heterocyclic Compounds 7h
UNIT-IV
Carbohydrates
8h
Monosaccharides: (+) Glucose (aldo hexose) - Evidence for cyclic structure of glucose (some negative aldehydes tests and mutarotation) - Proof for the ring size (methylation, hydrolysis and oxidation reactions) - Pyranose structure (Haworth formula and chair conformational formula).
(-) Fructose (keto hexose) - Evidence of 2-keto hexose structure (formation of pentaacetate, formation of cyanohydrin its hydrolysis and reduction by HI). Cyclic structure for fructose (Furanose structure and Haworth formula) - osazone formation from glucose and fructose – Definition of anomers with examples.
Interconversion of Monosaccharides: Aldopentose to Aldohexose (Arabinose to D-Glucose, D-Mannose) (Kiliani - Fischer method). Epimers, Epimerisation - Lobry de bruyn van Ekenstein rearrangement. Aldohexose to Aldopentose (D-Glucose to D-Arabinose) by Ruff degradation. Aldohexose to Ketohexose [(+) Glucose to (-) Fructose] and Ketohexose to Aldohexose (Fructose to Glucose)

UNIT- V
Amino acids and proteins
7h
Introduction: Definition of Amino acids, classification of Amino acids into alpha, beta, and gamma amino acids. Natural and essential amino acids - definition and examples, classification of alpha amino acids into acidic, basic and neutral amino acids with examples. Methods of synthesis: General methods of synthesis of alpha amino acids (specific examples - Glycine, Alanine, valine and leucine) by following methods: a) from halogenated carboxylic acid b) Malonic ester synthesis c) strecker's synthesis.
Physical properties: Zwitter ion structure - salt like character - solubility, melting points, amphoteric character, definition of isoelectric point.
Chemical properties: General reactions due to amino and carboxyl groups - lactams from gamma and delta amino acids by heating peptide bond (amide linkage). Structure and nomenclature of peptides and proteins.

List of Reference Books
1. Concise coordination chemistry by Gopalan and Ramalingam
2. Coordination Chemistry by Basalo and Johnson
3. Organic Chemistry by G.Mare loudan, Purdue Univ
4. Advanced Physical Chemistry by Atkins
5. Text book of physical chemistry by S Glasstone
6. Instrumentation and Techniques by Chatwal and Anand
7. Essentials of nano chemistry by pradeep
8. A Textbook of Physical Chemistry by Puri and Sharma
9. Advanced physical chemistry by Gurudeep Raj
LAboratory Course – V
Practical Paper – V Organic Chemistry
(at the end of semester V) 30 hrs (2 h / W)

Organic Qualitative Analysis: 50M
Analysis of an organic compound through systematic qualitative procedure for functional group identification including the determination of melting point and boiling point with suitable derivatives. Alcohols, Phenols, Aldehydes, Ketones, Carboxylic acids, Aromatic Primary Amines, Amides and Simple sugars.

Laboratory Course – VI
Practical Paper – VI Physical Chemistry
(at the end of semester V) 30 hrs (2 h/W)

1. Determination of rate constant for acid catalyzed ester hydrolysis.
2. Determination of molecular status and partition coefficient of benzoic acid in Benzene and water.
3. Determination of Surface tension of liquid
5. Adsorption of acetic acid on animal charcoal, verification of Freundlich isotherm.
SEMESTER-VI - Electives
ELECTIVE Paper – VII-(A) : ANALYTICAL METHODS
IN CHEMISTRY 45hrs (3h / w)

UNIT-I
Quantitative analysis: 10h
a) Importance in various fields of science, steps involved in chemical analysis. Principles of volumetric analysis : Theories of acid-base, redox, complexometric, iodometric and precipitation titrations - choice of indicators for these titrations.

b) Principles of gravimetric analysis: precipitation, coagulation, peptization, coprecipitation, post precipitation, digestion, filtration and washing of precipitate, drying and ignition.

UNIT-II
Treatment of analytical data: 7h
Types of errors, significant figures and its importance, accuracy - methods of expressing accuracy, error analysis and minimization of errors, precision - methods of expressing precision, standard deviation and confidence limit.

UNIT-III
SEPARATION TECHNIQUES IN CHEMICAL ANALYSIS: 8h
SOLVENT EXTRACTION: Introduction, principle, techniques, factors affecting solvent extraction, Batch extraction, continuous extraction and counter current extraction. Synergism.
ION EXCHANGE: Introduction, action of ion exchange resins, separation of inorganic mixtures, applications.

UNIT – IV
Chromatography: Classification of chromatography methods, principles of differential migration adsorption phenomenon, Nature of adsorbents, solvent systems, Rf values, factors effecting Rf values.

Paper Chromatography: Principles, Rf values, experimental procedures, choice of paper and solvent systems, developments of chromatogram - ascending, descending and radial. Two dimensional chromatography, applications.

UNIT -V


HPLC: Basic principles and applications.

List of Reference Books
1. Analytical Chemistry by Skoog and Miller
2. A textbook of qualitative inorganic analysis by A.I. Vogel
3. Nanochemistry by Geoffrey Ozin and Andre Arsenault
4. Stereochemistry by D. Nasipuri
5. Organic Chemistry by Clayden
LABORATORY COURSE – VI
Practical Paper – VII-(A) (at the end of semester VI) 30hrs (2 h / W)

50M

1. Identification of aminoacids by paper chromatography.
2. Determination of Zn using EDTA
3. Determination of Mg using EDTA
SEMESTER-VI
ELECTIVE PAPER – VII-(B) : ENVIRONMENTAL CHEMISTRY
45 hrs (3 h / w)

UNIT-I

Introduction
Concept of Environmental chemistry - Scope and importance of environment in nowadays – Nomenclature of environmental chemistry – Segments of environment - Natural resources – Renewable Resources – Solar and biomass energy and Nonrenewable resources – Thermal power and atomic energy – Reactions of atmospheric oxygen and Hydological cycle.

UNIT-II

Air Pollution
Definition – Sources of air pollution – Classification of air pollution – Acid rain – Photochemical smog – Green house effect – Formation and depletion of ozone – Bhopal gas disaster – Controlling methods of air pollution.

UNIT-III

Water pollution

UNIT-IV

Chemical Toxicology

UNIT-V

Ecosystem and biodiversity

Ecosystem
Biodiversity


List of Reference books

1. Fundamentals of ecology by M.C.Dash
3. Environmental Chemistry by Samir k. Banerji
LABORATORY COURSE – VI

Practical Paper – Elective VII B (at the end of semester VI)  30 hrs (2 h / W)

1. Determination of carbonate and bicarbonate in water samples (acidity and alkalinity)
2. Determination of hardness of water using EDTA
   a) Permanent hardness
   b) Temporary hardness
3. Determination of Acidity
4. Determination of Alkalinity
5. Determination of chlorides in water samples
SEMESTER-VI
ELECTIVE PAPER – VII-(C) GREEN CHEMISTRY
45 hrs (3 h / w)

UNIT-I
10h
Green Chemistry: Introduction- Definition of green Chemistry, need of green chemistry, basic principles of green chemistry. Green synthesis- Evaluation of the type of the reaction i) Rearrangements (100% atom economic), ii) Addition reaction (100% atom economic). Organic reactions by Sonication method: apparatus required examples of sonochemical reactions (Heck, Hundsdiecker and Wittig reactions).

UNIT-II
10h
Selection of solvent:i) Aqueous phase reactions ii) Reactions in ionic liquids, Heck reaction, Suzuki reactions, epoxidation. iii) Solid supported synthesis
Super critical CO_2: Preparation, properties and applications, (decaffeination, dry cleaning)

UNIT-III
10h
Microwave and Ultrasound assisted green synthesis: Apparatus required, examples of MAOS (synthesis of fused anthro quinones, Leukart reductive amination of ketones) - Advantages and disadvantages of MAOS. Aldol condensation-Cannizzaro reaction-Diels-Alder reactions-Strecker's synthesis

UNIT-IV
5h
Green catalysis: Heterogeneous catalysis, use of zeolites, silica, alumina, supported catalysis- biocatalysis: Enzymes, microbes Phase transfer catalysis (micellar/surfactant)

UNIT V
10h
Examples of green synthesis / reactions and some real world cases: 1. Green synthesis of the following compounds: adipic acid , catechol , disodium imino di acetate (alternative Strecker’s synthesis) 2. Microwave assisted reaction in water – Hoffmann elimination – methyl benzoate to benzoic acid – oxidation of toluene and alcohols – microwave assisted reactions in organic solvents. Diels-Alder reactions and decarboxylation reaction. 3. Ultrasound assisted reactions – sonochemical Simmons –Smith reaction(ultrasonic alternative to iodine)

Reference books:
3. Real world cases in Green Chemistry M.C. Cann and M.E. Connelly
5. Green Chemistry: Introductory Text, M.Lancaster
1. Determination of specific reaction rate of hydrolysis for methyl acetate catalysed by hydrogen ion at room temperature.

2. Determination of molecular status and partition coefficient of benzoic acid in Benzene and water.

3. Surface tension and viscosity of liquids.

4. Adsorption of acetic acid on animal charcoal, verification of Freundlich isotherm.
UNIT-I  
12h
Introduction of polymers:

UNIT-II  
10h
Techniques of Polymerization: Bulk polymerization, solution polymerization, suspension and Emulsion polymerization.
Molecular weights of polymers: Number average and weight average molecular weights
Determination of molecular weight of polymers by Viscometry, Osmometry and light scattering methods.

UNIT-III  
6h
Kinetics of Free radical polymerization, Glass Transition temperature (Tg) and Determination of Tg:
Free volume theory, WLF equation, factors affecting glass transition temperature (Tg).

UNIT-IV  
9h
Polymer additives:
Introduction to plastic additives – fillers, Plasticizers and Softeners, Lubricants and Flow Promoters, Anti aging additives, Flame Retardants, Colourants, Blowing agents, Cross linking agents, Photo stabilizers, Nucleating agents.

UNIT-V  
8h
Polymers and their applications:
Preparation and industrial applications of Polyethylene, Polyvinyl chloride, Teflon, Polyacrylonitrile, Terelene, Nylon6.6 silicons.

Reference Books:
SEMESTER-VI
PAPER – VIII-A-2: INSTRUMENTAL METHODS OF ANALYSIS
45 hrs (3 h / w)

UNIT – I
Introduction to spectroscopic methods of analysis: 4 h
Recap of the spectroscopic methods covered in detail in the core chemistry syllabus:
Treatment of analytical data, including error analysis. Classification of analytical methods and the types of instrumental methods. Consideration of electromagnetic radiation.

UNIT – II
Molecular spectroscopy: 8h
Infrared spectroscopy:
Interactions with molecules: absorption and scattering. Means of excitation (light sources), separation of spectrum (wavelength dispersion, time resolution), detection of the signal (heat, differential detection), interpretation of spectrum (qualitative, mixtures, resolution), advantages of Fourier Transform (FTIR). Samples and results expected. Applications: Issues of quality assurance and quality control, Special problems for portable instrumentation and rapid detection.

UNIT – III
UV-Visible/ Near IR – emission, absorption, fluorescence and photoacoustic. Excitation sources (lasers, time resolution), wavelength dispersion (gratings, prisms, interference filters, laser, placement of sample relative to dispersion, resolution), Detection of signal (photocells, photomultipliers, diode arrays, sensitivity and S/N), Single and Double Beam instruments, Interpretation (quantification, mixtures, absorption vs. fluorescence and the use of time, photoacoustic, fluorescent tags).

UNIT – IV
Separation techniques
Chromatography: Gas chromatography, liquid chromatography, supercritical fluids, Importance of column technology (packing, capillaries), Separation based on increasing number of factors (volatility, solubility, interactions with stationary phase, size, electrical field), Detection: simple vs. specific (gas and liquid), Detection as a means of further analysis (use of tags and coupling to IR and MS), Electrophoresis (plates and capillary) and use with DNA analysis. 46 Immunoassays and DNA techniques 8h

Mass spectroscopy: Making the gaseous molecule into an ion (electron impact, chemical ionization), Making liquids and solids into ions (electrospray, electrical discharge, laser desorption, fast atom bombardment), Separation of ions on basis of mass to charge ratio, Magnetic, Time of flight, Electric quadrupole. Resolution, time and multiple separations, Detection and interpretation (how this is linked to excitation). 8h
UNIT – V
Elemental analysis:  10h

Mass spectrometry (electrical discharges).
Excitation and getting sample into gas phase (flames, electrical discharges, plasmas),
Wavelength separation and resolution (dependence on technique), Detection of radiation
(simultaneous/scanning, signal noise), Interpretation (errors due to molecular and ionic
species, matrix effects, other interferences).

NMR spectroscopy: Principle, Instrumentation, Factors affecting chemical shift,
Spin coupling, Applications.  4h

Electroanalytical Methods: Potentiometry & Voltammetry  4h

Radiochemical Methods  4h

X-ray analysis and electron spectroscopy (surface analysis)  4h

Reference books:
   Cengage Learning India Ed.
2. Willard, H.H., Merritt, L.L., Dean, J. & Settoe, F.A. *Instrumental Methods of
   Analysis*, 7th Ed. Wadsworth Publishing Company Ltd., Belmont, California,
   USA, 1988.
7. W.J. Moore: Physical Chemistry
SEMESTER-VI
PAPER – VIII-A-3 : ANALYSIS OF DRUGS, FOODS , DAIRY PRODUCTS & BIO-CHEMICAL ANALYSIS
45 hrs (3 h / w)

UNIT- I
Analysis of the following drugs and pharmaceuticals preparations:
(Knowledge of molecular formula, structure and analysis)
Analysis of analgesics and antipyretics like aspirin and paracetamol
Analysis of antimonial drugs like chloroquine.
Analysis of drugs in the treatment of infections and infestations: Amoxycillin, chloramphenicol, metronidazole, penicillin, tetracycline, cephalexin (cefalexin).
Anti tuberculous drug- isoniazid.

UNIT - II
Analysis of the following drugs and pharmaceuticals preparations:
(Knowledge of molecular formula, structure and analysis)
Analysis of antihistamine drugs and sedatives like: allegra, zyrtec (citirizine), alprazolam, trazodone, lorazepam, ambien (zolpidem), diazepam.

UNIT - III
Analysis of anti epileptic and anti convulsant drugs like phenobarbital and phenacemide.
Analysis of drugs used in case of cardiovascular drugs: atenolol, norvasc (amlodipine),
Analysis of lipitor (atorvastatin) a drug for the prevention of productin of cholesterol.
Analysis of diuretics like: furosemide (Lasix), triamterene
Analysis of prevacid (lansoprazole) a drug used for the prevention of production of acids in stomach.

UNIT - IV
Analysis of Milk and milk products: Acidity, total solids, fat, total nitrogen, proteines, lactose, phosphate activity, casein, choride. Analysis of food materials:
Preservatives: Sodium carbonate, sodium benzoate sorbic acid
Coloring matters: - Brilliant blue FCF, fast green FCF, tartrazine, erythrosine, sunset yellow FCF.
Flavoring agents - Vanilla , diacetyl, isoamyl acetate, limonene, ethylpropionate, allyl hexanoate and Adulterants in rice and wheat, wheat flour, sago, coconut oil, coffee powder, tea powder, milk.

UNIT - V
Clinical analysis of blood: Composition of blood, clinical analysis, trace elements in the body. Estimation of blood cholesterol, glucose, enzymes, RBC & WBC, Blood gas analyser.

REFERENCE BOOKS:
1. F.J. Welcher - Standard methods of analysis,
2. A.I. Vogel - A text book of quantitative Inorganic analysis - ELBS,
3. F.D. Snell & F.M. Biffen - Commercial methods of analysis - D.B. Taraporavala & sons,
4. J.J. Elving and I.M. Kolthoff - Chemical analysis - A series of monographs on analytical chemistry and its applications -- Inter Science - Vol I to VII.

6. Quantitative analysis of drugs in pharmaceutical formulations by P.D. Sethi, CBS Publishers and Distributors, New Delhi

7. G. Ingram - Methods of organic elemental micro analysis - Chapman and Hall,

8. H. Wincciam and Bobbles (Henry J) - Instrumental methods of analysis of food additives,

9. H. Edward - The Chemical analysis of foods; practical treatise on the examination of food stuffs and the detection of adulterants,

10. The quantitative analysis of drugs - D.C. Garratt - Chapman & Hall,

11. A text book of pharmaceutical analysis by K.A. Connors - Wiley International,

12. Comprehensive medicinal chemistry - Ed Corwin Hansch Vol 5, Pergamon Press,
I. LABORATORY COURSE – VIII
Practical Paper – VIII-A-1: (at the end of semester VI) 30 hrs (2 h / W)

1. Preparation of Aspirin
2. Preparation of Paracetamol
3. Preparation of Acetanilide
4. Preparation of Barbutiric Acid
5. Preparation of Phenyl Azo β-naphthol

II. LABORATORY COURSE – VIII
Practical Paper – VIII-A-2 (at the end of semester VI)

30 hrs (2 h / W)

1. Green procedure for organic qualitative analysis: Detection of N, S and halogens
2. Acetylation of 1° amine by green method: Preparation of acetanilide
3. Rearrangement reaction in green conditions: Benzil-Benzilic acid rearrangement
4. Electrophilic aromatic substitution reaction: Nitration of phenol
5. Radical coupling reaction: Preparation of 1,1-bis -2-naphthol
6. Green oxidation reaction: Synthesis of adipic acid
7. Green procedure for Diels Alder reaction between furan and maleic anhydride

List of Reference Books
3. Real world cases in Green Chemistry M.C. Cann and M.E. Connelly
5. Green Chemistry: Introductory Text, M.Lancaster

VII-A-3 Practical: Project Work
UNIT –I 12h
Review of energy sources (renewable and non-renewable) – classification of fuels and their calorific value.

Coal:
- Uses of Coal (fuel and non-fuel) in various industries, its composition, carbonization of coal - coal gas, producer gas and water gas – composition and uses – fractionation of coal tar – uses of coal tar based chemicals, requisites of a good metallurgical coke, coal gasification (Hydro gasification and catalytic gasification) coal liquefaction and solvent refining.

UNIT-II 6h
Petroleum and petrol chemical industry:
Composition of crude petroleum, refining and different types of petroleum products and their applications.

UNIT-III 10h
Fractional distillation (principle and process), cracking (Thermal and catalytic cracking). Reforming petroleum and non petroleum fuels (LPG, CNG, LNG, biogas), fuels derived from biomass, fuel from waste, synthetic fuels (gaseous and liquids), clear fuels, petro chemicals: vinyl acetate, propylene oxide, isoprene, butadiene, toluene and its derivative xylene.

UNIT-IV 10h
Lubricants:
Classification of lubricants, lubricating oils (conducting and non conducting), solid and semi solid lubricants, synthetic lubricants. Properties of lubricants (viscosity index, cloud point, pour point) and their determination.

UNIT-V 7h
Batteries:
Primary and secondary batteries, battery components and their role, Characteristics of Battery. Working of following batteries: Pb acid, Li-Battery, Solid state electrolyte battery. Fuel cells, Solar cell and polymer cell.

Reference books:
1. E. Stochi: Industrial chemistry, Vol-1, Ellis Horwood Ltd. UK
UNIT - I
Recapitulation of s- and p-Block Elements 8h
Periodicity in s- and p-block elements with respect to electronic configuration, atomic and ionic size, ionization enthalpy, electronegativity (Pauling, Mulliken, and Alfred - Rochow scales). Allotropy in C, S, and P. Oxidation states with reference to elements in unusual and rare oxidation states like carbides and nitrides, inert pair effect, diagonal relationship and anomalous behaviour of first member of each group.

UNIT – II
15h
Silicate Industries
Glass: Glassy state and its properties, classification (silicate and non-silicate glasses). Manufacture and processing of glass. Composition and properties of the following types of glasses: Soda lime glass, lead glass, armoured glass, safety glass, borosilicate glass, fluorosilicate, coloured glass, photosensitive glass.
Ceramics: Important clays and feldspar, ceramic, their types and manufacture. High technology ceramics and their applications, superconducting and semiconducting oxides, fullerenes carbon nanotubes and carbon fibre.
Cements: Classification of cement, ingredients and their role, Manufacture of cement and the setting process, quick setting cements.

UNIT – III
8h
Fertilizers:
Different types of fertilizers. Manufacture of the following fertilizers: Urea, ammonium nitrate, calcium ammonium nitrate, ammonium phosphates; polyphosphate, superphosphate, compound and mixed fertilizers, potassium chloride, potassium sulphate.

UNIT – IV
8h
Surface Coatings:

UNIT – V
6h
Alloys:
Classification of alloys, ferrous and non-ferrous alloys, Specific properties of elements in alloys. Manufacture of Steel (removal of silicon decarbonization, demanganization, desulphurization dephosphorisation) and surface treatment (argon treatment, heat treatment, nitriding, carburizing). Composition and properties of different types of steels.
Chemical explosives:
Origin of explosive properties in organic compounds, preparation and explosive properties of lead azide, PETN, cyclonite (RDX). Introduction to rocket propellants.

Reference Books:
SEMESTER-VI
PAPER – VIII-B-3 : ANALYSIS OF APPLIED INDUSTRIAL PRODUCTS

45 hrs (3 h / w)

UNIT-I
Analysis of soaps: moisture and volatile matter, combined alkali, total fatty matter, free alkali, total fatty acid, sodium silicate and chlorides.
Analysis of paints: Vehicle and pigments, Barium Sulphate, total lead, lead chromate, iron pigments, zinc chromate.

UNIT-II
Analysis of oils: saponification value, iodine value, acid value, ester value, bromine value, acetyl value.
Analysis of industrial solvents like benzene, acetone, methanol and acetic acid,
Determination of methoxylic and N-methyl groups.

UNIT-III
Analysis of fertilizers: urea, NPK fertilizer, super phosphate,
Analysis of DDT, BHC, endrin, endosulfone, malathion, parathion,
Analysis of starch, sugars, cellulose and paper.

UNIT-IV
Gas analysis: carbon dioxide, carbon monoxide, oxygen, hydrogen, saturated hydrocarbon, unsaturated hydrocarbons, nitrogen, octane number, cetane number
Analysis of Fuel gases like: water gas, producer gas, kerosene (oil) gas.
Ultimate analysis: carbon, hydrogen, nitrogen, oxygen, phosphorus and sulfur.

UNIT - V
Analysis of Complex materials:
Analysis of cement - loss on ignition, insoluble residu, total silica, sesqui oxides, lime, magnesia, ferric oxide, sulphuric anhydrid.
Analysis of glasses - Determination of silica, sulphur, barium, arsinic, antimony, total R₂O₃, calcium, magnesium, total alkalies, aluminium, chloride, fluoride.

SUGGESTED BOOKS:
1. F.J.Welcher-Standard methods of analysis,
2. A.I.Vogel-A text book of quantitative Inorganic analysis-ELBS,
3. H.H.Willard and H.Deal- Advanced quantitative analysis- Van Nostrand Co,
4. F.D.Snell & F.M.Biffen-Commercial methods of analysis-D.B.Taraporavala & sons,
5. J.J.Elving and I.M.Kolthoff- Chemical analysis - A series of monographs on analytical chemistry and its applications -- Inter Science- Vol I to VII.,
6. G.Z.Weig - Analytical methods for pesticides, plant growth regulators and food additives - Vols I to VII,
8. AManual of soil, plant, water and fertilizer analysis, R.M.Upadhyay and N.L Sharma, Kalyani Publishers
I. LABORATORY COURSE – VIII
Practical Paper – VIII-B-1: (at the end of semester VI) 30 hrs (2 h / W)

1. Preparation of Aspirin
2. Preparation of Paracetamol
3. Preparation of Acetanilide
4. Preparation of Barbutiric Acid
5. Preparation of Phenyl Azo β-naphthol

II. LABORATORY COURSE – VIII
Practical Paper – VIII-B-2: (at the end of semester VI) 30 hrs (2 h / W)

1. Green procedure for organic qualitative analysis: Detection of N, S and halogens
2. Acetylation of \textit{1}^0\ amine by green method: Preparation of acetanilide
3. Rearrangement reaction in green conditions: Benzil-Benzilic acid rearrangement
4. Electrophilic aromatic substitution reaction: Nitration of phenol
5. Radical coupling reaction: Preparation of 1,1-bis -2-naphthol
6. Green oxidation reaction: Synthesis of adipic acid
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5. Green Chemistry: Introductory Text, M.Lancaster

VII-A-3 Practical:- Project Work / Intern Ship
UNIT-I
NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY
10h
Nuclear spin, Principles of NMR-Classical and Quantum Mechanical methods, Magnetic
moment and Spin angular momentum. Larmour Frequency. Instrumentation. Relaxation-
spin-spin & spin lattice relaxation. Shielding constants, Chemical shifts, Shielding and
Deshielding mechanism-Factors influencing Chemical shift. Spin-Spin interactions-AX,
AX\(_2\) and AB types. Vicinal, Geminal and Long range coupling- Factors influencing
coupling constants.

UNIT – II
5h
Spin decoupling, Spin tickling, Deuterium exchange, Chemical shift reagents and
Nuclear overhauser effect. Applications in Medical diagnostics, Reaction kinetics and
Mechanically induced dynamic nuclear polarization. FT NMR and its Advantages.

UNIT-III
10h
UV & VISIBLE SPECTROSCOPY
Electronic spectra of diatomic molecules. The Born-oppenheimer approximation.
Vibrational coarse structure: Bond association and Bond sequence. Intensity of
Vibrational-electronic spectra: The Franck-Condon principle. Rotational fine structure of
Types of transitions, Chromophores, Conjugated dienes, trienes and polyenes,
unsaturated carbonyl compounds-Woodward – Fieser rules.

UNIT-IV
5h
Electronic spectra of polyatomic molecules. Chemical analysis by Electronic
Spectroscopy – Beer-Lambert’s Law. Deviation from Beer’s law. Quantitative
determination of metal ions (Mn\(^{2+}\), Fe\(^{2+}\), NO\(_2^-\), Pb\(^{2+}\)). Simultaneous determination of
Chromium and Manganese in a mixture.
UNIT-V

Electron Spin Resonance Spectroscopy

Basic Principles, Theory of ESR, Comparison of NMR & ESR. Instrumentaion, Factors affecting the ‘g’ value, determination of ‘g’ value. Isotropic and Anisotropic constants. Splitting hyper fine splitting coupling constants. Line width, Zero field splitting and Kramer degeneracy. Crystal field splitting, Crystal field effects.

Applications:- Detection of free radicals; ESR spectra of (a) Methyl radical (CH₃), (b) Benzene anion (C₆H₆⁻) (c) Isoquinine (d) [Cu(H₂O)₆]^{+2} (e) [Fe(CN)₆NO]⁻³ (f)

REFERENCE BOOKS:

UNIT – I
ORGANIC PHOTOCHEMISTRY

Photochemical reactions: (a) Photoreduction, mechanism, influence of temperature, solvent, nature of hydrogen donors, structure of substrates on the course of photo reduction.

UNIT – II
ORGANIC PHOTOCHEMISTRY

UNIT – III
PROTECTING GROUPS AND ORGANIC REACTIONS

UNIT – IV

UNIT – V: NEW SYNTHETIC REACTIONS
Baylis–Hillman reaction, RCM olefm metathesis, Grubb catalyst, Mukayama aldol reaction, Mitsunobu reaction, McMurrey reaction, Julia–Lythgoe olefination, and Peterson’s stereoselective olefination, Heck reaction, Suzuki coupling, Stille coupling and Sonogishira coupling, Buchwald–Hartwig coupling. Ugi reaction, Click reaction.
**Recommended Books**

3. Importance of antibonding orbitals by Jaffe and Orchin.
10. Name Reactions by Jie Jack Li
11. Reagents in Organic synthesis by B.P. Mundy and others.
12. Tandem Organic Reactions by Tse–Lok Ho.
Cluster Elective –III
ORGANIC

PAPER – VIII-C-3 : PHARMACEUTICAL AND MEDICINAL CHEMISTRY
45 hrs (3 h / w)

UNIT-I
8h
Pharmaceutical chemistry Terminology: Pharmacy, Pharmacology, Pharmacophore, Pharmacodynamics, Pharmacokinetics (ADME, Receptors - brief treatment) Metabolites and Anti metabolites.

UNIT-II
8h
Drugs: Nomenclature: Chemical name, Generic name and trade names with examples Classification: Classification based on structures and therapeutic activity with one example each, Administration of drugs

UNIT-III
12h
Synthesis and therapeutic activity of the compounds:
a. Chemotherapeutic Drugs
b. Psycho therapeutic Drugs:
1.Anti pyretics(Paracetamol) 2.Hypnotics, 3.Tranquilizers(Diazepam) 4.Levodopa

UNIT-IV
8h
Pharmacodynamic Drugs:
1. Antiasthma Drugs (Solbutamol) 3. Antianginals (Glycerol Trinitrate)
4. Diuretics(Frusemide)

UNIT-V
9h
HIV-AIDS:

List of Reference Books:
1. Medicinal Chemistry by Dr. B.V.Ramana
2. Synthetic Drugs by O.D.Tyagi & M.Yadav
3. Medicinal Chemistry by Ashutoshkar
4. Medicinal Chemistry by P.Parimoo
5. Pharmacology & Pharmacotherapeutics R.S Satoshkar & S.D.Bhandenkar
6. Medicinal Chemistry by Kadametal P-I & P.II
7. European Pharmacopoeia
PART-A
Answer any FIVE of the following questions
Each carries FIVE marks
5x5 = 25 Marks

1. Define the electron deficient molecules and draw the structure of Borazole and Diborane.
2. Classify the Oxides based on the oxygen content with one example to each.
3. How the following are synthesized from Organo Lithium Compounds.
   a) Acetic acid  b) Ethyl alcohol
4. Define the Carbonium ion and explain the stability with no bond resonance.
5. Define the Markonikov’s rule and explain the addition of 1-Propene with HBr.
6. Explain the acidity of the Acetylinic hydrogen with example.
7. Draw the conformational structures of Cyclohexane.
8. Define aromaticity and apply the Huckel’s rule to benzene and naphthalene.

PART-B
Answer ALL the questions
Each carries TEN marks
5x10 = 50 Marks

   (OR)
   (b) Explain the Preparation and Oxidation-Reduction reactions of Hydroxylamine.

10. (a) Give an account on different types of interhalogen compounds.
    (OR)
    (b) How the following are prepared from the Methyl Magnesium bromide and methyl lithium
        1) Formaldehyde  2) Acetaldehyde  3) Acetone  4) t- butyl alcohol

11. (a) Describe different types of Organic Reactions with one example to each.
    (OR)
    (b) Write notes on the following
        1) Mesomeric effect  2) Hyper conjugation  3) Inductive effect

12. (a) Explain the addition of these reagents to alkenes with mechanism.
    1) H₂O  2) HOX  3) H₂SO₄
    (OR)
    (b) Explain Baeyer’s bond angle strain theory.

13. (a) Describe the Molecular Orbital structure of Benzene.
    (OR)
    (b) Explain the orientation in benzene with respect to alkyl and nitro groups.