# LEARNING OUTCOMES

# SUBJECT: CHEMISTRY

# STREAM: HONOURS

# CONTENTS

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## SUBJECT: CHEMISTRY

## STREAM: HONOURS

## SEMESTER: 1

**Course Code: CC-1**

**Course Title:** ***Organic Chemistry-I: Basics of Organic Chemistry***

**Topic:** ***Bonding and Physical Properties***

*Upon completion of this topic, learners should be able to:*

- Classify and identify different types of organic reactions.
- Gain concepts about hybridization, resonance and hyperconjugation.
- Calculate formal charges and degree of unsaturation (DBE or IHD) in organic compounds.
- Draw orbital diagram of different types of bonding in organic compounds.
- Get knowledge about various electronic displacement phenomena *e.g.* inductive effect, field effect, mesomeric effect, electromeric effect, steric effect, steric inhibition of resonance (SIR).
- Understand the concept of aromaticity and Hückel's rules.
- Differentiate among aromatic, antiaromatic, non-aromatic and homoaromatic organic compounds.
- Get elementary idea about σ, σ*, π, π *, n – Mos and Frontier MOs (FMO).
- Sketch π MOs of conjugated diene, triene, allyl and pentadienyl systems.
- Identify HOMO, LUMO and SOMO in ground state & excited state and interactions between HOMO and LUMO.
- Draw Frost diagram of cyclic aromatic compounds.

- Get elementary idea about α and β and calculate delocalization energies in terms of β.
- Get idea about bond dissociation energy (BDE), bond energy, concept of bond angle strain (Baeyer's strain theory) in small ring systems.
- Conceptualize melting point/boiling point and solubility of common organic compounds in terms of covalent & non-covalent intermolecular and intramolecular forces.
- Explain relative stabilities of isomeric hydrocarbons in terms of heat of hydrogenation, heat of combustion and heat of formation.

**Topic: *General Treatment of Reaction Mechanism I***

*Upon completion of this topic, learners should be able to:*

- Identify mechanistically ionic, radical and pericyclic reactions.
- Draw curly arrow symbol in representation of mechanistic steps of organic reactions.
- Get idea about organic reactive intermediates *e.g.* carbocations (carbenium and carbonium ions), carbanions, carbon radicals, carbenes, nitrenes and benzynes.
- Write down different procedures for the generation of the above mentioned reactive intermediates and rationalize their stability & electrophilic/nucleophilic behavior.
- Exemplify different organic reactions involving various reactive intermediates

**Topic: *Stereochemistry-I***

*Upon completion of this topic, learners should be able to:*

- Represent the molecules in different projection formulae (*e.g.* Fischer, sawhorse, flying-wedge and Newman).
- Exemplify the chirality, symmetry elements and point groups.

- Illustrate the asymmetric and dissymmetric molecules; enantiomers and diastereomers.
- Describe relative and absolute configuration: D/L, E/Z and R/S descriptors; erythro/threo; syn/anti nomenclatures.
- Describe optical rotation, specific rotation and molar rotation.
- Elucidate racemic compounds, racemisation and resolution of acids, bases and alcohols *via* diastereomeric salt formation.
- Epitomize optical purity and enantiomeric excess.
- Recognize the natural amino acids and nucleosides are enantiomerically pure as these are the basis of all life *via* DNA and/or RNA.
- Understand the high price of single enantiomeric drugs.

**Course Code: CC-2**

**Course Title:** ***Physical Chemistry-I***

**Topic:** ***Kinetic Theory and Gaseous state***

*Upon completion of this topic, learners should be able to:*

- Outline the historical developments of kinetic theory of gas.
- State the basic postulates of kinetic theory of gas.
- .Describe and mathematically derive the collision of gas molecules, collision diameter, collision number, mean free path, frequency of binary collisions, wall collision and rate of effusion .
- Describe Maxwell’s law of molecular speed and nature of distribution of velocities.
- Represent graphically Maxwell's speeds and kinetic energy distribution of molecules in one, two and three dimensions.
- Calculate the average, root mean square and most probable values with help of Maxwell's distribution of molecular speeds in one, two and three dimensions.
- Calculate the number of molecules having energy $\geq \varepsilon$.
- Describe the principle of equipartition of energy and its application to calculate of molar heat capacity of gases.
- Know about the behaviors and different law of ideal gases.
- Describe the deviation of gases from ideal behavior and derive van der Waals equation.;
- Derive compressibility factor; Boyle temperature and explain real gas behavior.
- Represent Andrew's and Amagat's plots and explain real gas behavior.
- Describe other equations of state (Berthelot, Dietrici).
- Know about critical state, critical constants in terms of van der Waals constants.

- Describe the van der Waals equation expressed in virial form and significance of second virial coefficient.
- Know about intermolecular forces (Debye, Keesom and London interactions; Lennard-Jones potential - elementary idea).

**Topic: *Chemical Thermodynamics***

*Upon completion of this topic, learners should be able to:*

- Explain with suitable examples that laws of thermodynamics are based on the experiences gathered from natural phenomena.
- Justify the necessity of the knowledge of calculus in dealing with the laws of thermodynamics and their application.
- Exemplify the idea of system, surrounding and boundary. CO 4 Mention salient features of different thermodynamic processes. CO 13 Mention the importance of considering FRICTIONLESS WEIGHTLESS PISTON and THERMOSTAT.
- Classify different properties as extensive and intensive; also make a correlation among the two.
- Explain that a thermodynamic function is called a state function only if it is a perfect differential.
- Write a brief review on internal energy.
- Explain why dq and dw are not state function but their sum is a state function.
- Interpret 1st law of thermodynamics while applying to different processes.
- State the outcomes of Joule's experiment.
- Derive expression for work involved with different processes.
- Criticise: It is more convenient to use change in enthalpy with compare to the change in internal energy.

- State the difference between SINGLE /FINITE STEP process and QUASI STATIC/INFINITE STEP process.
- Derive expression of work involved with different thermodynamic processes for ideal and real gases.
- Compare between work involved with different thermodynamic processes.
- Represent the concept of SPECIFIC HEAT and explain how these have been used in thermodynamic derivations.
- State the reason for the change in enthalpy during chemical reactions and physical processes.
- Define with examples various types of enthalpy change associated with chemical reactions and physical changes. Also comment on their temperature dependence.
- Justify the necessity of the 2nd law of thermodynamics.
- Explain the concept of engine.
- Understand the conclusions drawn from Carnot Cycle.
- Prove Carnot theorems.
- Derive Maxwell equations.
- Compare and contrast between work function and Gibbs' free energy.
- Set the parameters for spontaneity of a thermodynamic process with the help of Gibbs-Helmholtz equation.

**Topic: *Chemical kinetics***

*Upon completion of this topic, learners should be able to:*

- List reasons for studying chemical kinetics.
- Discuss the factors that affect the rate of chemical reactions.
- Differentiate between order and molecularity of a chemical reaction.

- Describe the general form of a (differential) rate law and how the rate of a chemical reaction depends on the concentrations of species that appear in the rate law.
- Determine the "overall reaction order" for a chemical reaction using the (differential) rate law.
- Derive a general expression for the unit of rate constant and to find the unit of rate constant for zero, $1^{st}$, $2^{nd}$ and $3^{rd}$ order reaction.
- State the basis for the “Collision Model” and “Transition State Model” of Chemical Kinetics.
- Explain why reactant molecules must have a certain minimum amount of kinetic energy when they collide in order for a chemical reaction to occur.
- Describe "activation energy" and how it can be experimentally determined.
- Define a catalyst and describe the effect of a catalyst on the energy requirements for a reaction.
- Sketch a potential energy profile showing the activation energies for the forward and reverse reactions and show how they are affected by the addition of a catalyst.
- Exemplify ‘kinetically controlled and thermodynamically controlled’ product.
- Explain how enzymes act as biological catalysts and how they interact with specific substrate molecules.

## SEMESTER: 2

**Course Code: CC-3**

**Course Title:** ***Inorganic Chemistry-I***

**Topic:** ***Atomic Structure***

*Upon completion of this topic, learners should be able to:*

- Outline the historical developments of atomic theory.
- Describe the structure of the atom.
- Write the postulates of different atomic theory.
- Derive the Rydberg equation using Bohr's atomic model.
- Determine the wavelength and frequency of radiation of emission spectrum.
- Write Heisenberg's uncertainty principle and its significance.
- Write Scrodinger's wave equation and significance of $\Psi$ and $\Psi^2$.
- Describe four quantum numbers and their significance.
- Draw s, p, d and f orbitals.
- Write Pauli's exclusion principle, Hund's rules of maximum multiplicity, Aufbau principle.
- Write the electronic configuration of atoms.
- Derive the term symbols of atoms.

**Topic: *Chemical Periodicity***

*<u>Upon completion of this topic, learners should be able to:</u>*

- Outline the historical developments of Periodic Table.
- Describe the modern IUPAC periodic table.
- Calculate the effective nuclear charge using Slater's rule.
- Write the variation of atomic and ionic radius down the groups and along the periods.
- Write the variation of ionization energy down the groups and along the periods.
- Write the variation of electron affinity down the groups and along the periods.
- Write the variation of electronegativity down the groups and along the periods.
- Describe the different scales of electronegativity.
- Explain relativistic effect, secondary periodicity, lanthanide contraction and diagonal relationship.

**Topic: *Acid-Base***

*<u>Upon completion of this topic, learners should be able to:</u>*

- Write down auto-ionization equilibrium and acid-base neutralization reactions in liquid sulfur dioxide, liquid ammonia and liquid hydrogen fluoride.
- Define acid and base as enumerated in different concepts on acid-base.
- State the merits and demerits of different concepts on acid-base.
- Exemplify the following terms: amphi-protic solvent, conjugate acid-base pair, differentiating and leveling solvents, co-solvating agent.
- Justify the statement, "conjugate base of a weak acid is strong and vice

versa".

- Classify the following as acid, base and neutral species according to electronic theory of acid-base: N2, BCl3, NH4+, SO2, DMF, DMSO, RCN
- Explain the utility of acidity function. State its relation with pH of dilute solution.
- Write the equation taking care of the ionic and covalent contribution in relation to the acid-base interaction. State the significance of the equation.
- Enumerate the rules used to predict the successive pKa values and thus the
  acid strength of the oxy-acids. Give examples how these rules could be used to
  predict the structure of oxy-acids.
- Comment on the statement, "Steric factors and dative Π-bond formation have significant influence on acid-base behavior of certain species".
- Correlate the hard and soft nature of donor and acceptor atoms with their polarizing power and polarizability.
- Explain the SHAB principle in the light of FMO diagram.
- Describe briefly the periodic variation of acid-base behavior with plausible explanation.
- Explain with suitable examples: hardness of transition metal ions vary with oxidation state.
- Apply pauling rules to calculate the acid dissociation constant(s) of different oxo-acids.
- Clarify the statement with suitable examples, "Acidity of aqua ions are function of their charge and radius".
- Explain with the help of suitable concept on acid-base, the distribution of different elements in the nature.

- State how catalytic behavior of certain oxides could be related with the Lewis and Brönsted acid nature of certain oxides.

**Topic: *Redox Reactions and Precipitation Reactions***

*Upon completion of this topic, learners should be able to:*

- Describe briefly the electronic theory of oxidation and reduction with suitable examples.
- State the difference between electrolytic cell and galvanic cell.
- Define the terms: Positive electrode, Negative electrode, Standard potential, and Formal potential.
- Narrate a brief account on salt bridge.
- Construct the galvanic cell and write electrode reactions.
- Derive the cell reaction and determine the value of cell emf, and equilibrium
  constant from given standard electrode potential values.
- Establish Nernst equation for any galvanic cell.
- Show how concentration affects the direction of reaction in a galvanic cell.
- Explain the effect of change of pH, precipitation and complex formation on formal potential of different redox couples using appropriate examples.
- Follow the course of a redox titration and to calculate the potential values at different stages of the titration.
- Justify the role of a redox indicator and the use of phosphoric acid in the titration of ferrous iron by potassium permanganate and potassium dichromate.
- Enumerate different information that is got from Latimer and Frost

diagrams.

- Comment on the possibility of comproportionation and disproportionation reactions.
- Understand the terms, solubility product, common ion effect, lattice energy and solvation energy and their relation with the solubility of different
compounds.
- Clarify the possibility and condition of precipitation.
- Explain the steps of group analysis in relation to inorganic qualitative analysis.

**Course Code: CC-4**

**Course Title:** ***Organic Chemistry-II***

*Upon completion of this course, learners should be able to:*

- Get knowledge about various thermodynamic parameters e.g. equilibrium,

  free energy, enthalpy and entropy factor of a chemical reaction.

- Calculate enthalpy change of a chemical reaction via bond dissociation

  energy (BDE).

- Apply the involvement of the thermodynamic parameters in case of

  intermolecular & intramolecular reactions.

- Concept of organic acids and bases.
- Understand the effect of structure, substituent and solvent on acidity and

  basicity of organic molecules.

- Compare between gas-phase and solution phase acidity and basicity of

  organic molecules.

- Compare between nucleophilicity and basicity.
- Apply HSAB principle in various chemical reactions.
- Explain thermodynamic principles in acid-base equilibria.
- Illustrate different types of tautomerism including prototropy,anionotropy,

  ring-chain tautomerism and valence tautomerism.

- Prove the presence of both keto and enol forms in solution.

- Apply thermodynamic principles in tautomeric equilibria.
- Get idea about various parameters in reaction kinetics – representation of rate law of a chemical reaction, rate constant, free energy of activation, order and molecularity of a reaction.
- Draw free energy profile diagrams for one-step, two-step and three-step chemical reactions.
- Draw energy profile diagrams for a catalyzed and uncatalyzed reaction and explain the role of a catalyst in a chemical reaction.
- Explain electrophilic and nucleophilic catalysis with proper examples.
- Make out kinetic control and thermodynamic control of reactions.
- Elaborate both primary and secondary kinetic isotopic effect with evidences.
- Describe principle of microscopic reversibility.
- Carry out halogenation of alkanes via free radical mechanism.
- Explain the formation of one regioisomer over the other in the light of Hammond's postulate.
- Learn nucleophilic substitution reactions at sp3 centre with mechanism.
- Explain the effects of solvent, substrate structure, leaving group and nucleophiles on substitution reactions.
- Explain the involvement of NGP in the treatment of cancer.
- Describe the role of crown ethers and phase transfer catalysts in nucleophilic substitution reactions.

- Perform synthesis of alkenes and alkynes involving different kinds of elimination reaction with mechanism.
- Explain the conditions leading to the formation of Saytzeff & Hofmann elimination products.
- Compare between substitution and elimination reactions.
- Represent the chirality arising out of stereoaxis.
- Exemplify the atropisomerism, buttressing effect and prostereoisomerism.
- Illustrate the concept of (pro) n-chirality: topicity of ligands and faces.
- Represent the pro-R/pro-S, pro-E/pro-Z and Re/Si descriptors; pro-r and pro-s descriptors of ligands.
- Describe conformational nomenclature.
- Elucidate eclipsed, staggered, gauche, syn and anti; dihedral angle, torsion angle; Klyne-Prelog terminology; P/M descriptors.
- Determine the conformation of conjugated systems (s-cis and s-trans)
- Describe gauche-butane interaction.
- Epitomize pro-r and pro-s descriptors of ligands on propseudoasymmetric centre.

## SEMESTER: 3

**Course Code: CC-5**

**Course Title: *Physical Chemistry-II***

**Topic: *Transport Processes***

*Upon completion of this topic, learners should be able to:*

- Describe different transport properties, Fick's law and phenomenological coefficients.
- Distinguish between the different types of fluid flow.
- Define the viscosity of fluid.
- Derive viscosity coefficient equation and explain its physical significance.
- Derive Poiseuille's equation.
- Describe the behavior of Newtonian and Non- Newtonian liquid.
- State the principle of determination of viscosity coefficient of liquids by falling sphere method and Ostwald method.
- Explain the variation of viscosity of liquids and gas with temperature
- Recognize cell constant, specific conductance, molar conductance; specific conductance, equivalent conductance.
- Illustrate the Ostwald's dilution law; Ionic mobility and conductance measurement.
- Determine the solubility product and ionic product of water. CO 7 Elucidate the principles of Hittorf's and Moving-boundary method.
- Describe Wien effect, Debye-Falkenhagen effect and Walden's rule.

**Topic: *Application of Thermodynamics -I***

*Upon completion of this topic, learners should be able to:*

- Define partial molar quantities chemical potential.

- Derive the relation between Chemical potential and Gibb's free energy and other thermodynamic state functions.
- Derive and explain the variation of chemical potential (μ) with temperature and pressure.
- Establish Gibbs-Duhem equation.
- Get idea about fugacity and fugacity coefficient.
- Derive the change of G, S, H and V during mixing for binary solutions.
- Define chemical potential of pure ideal gas.
- Derive and explain the change of thermodynamic parameters of mixing of pure ideal gases.
- Have a clear idea of standard states and choice of standard states of ideal gases.
- Understand chemical potential of pure solid and pure liquids.
- Define ideal solution.
- State Raoult's law.
- Explain the mixing properties of ideal solutions.
- Derive the chemical potential of a component in an ideal solution.
- Have a clear idea of standard states of solids and liquid.
- State Nernst's distribution law.
- Describe the application of Nernst's distribution law.
- Derive Keq using Nernst dist law for $KI+I_2 = KI_3$
- Explain and derive the distribution equation for association and dissociation of solute molecule.
- Write the thermodynamic conditions for equilibrium.
- Write the relationship between equilibrium constant and standard Gibbs free energy change.
- Define $K_p$, $K_c$ and $K_x$.
- Derive the relationship between the equilibrium constants ($K_p$, $K_c$ and $K_x$).

- Describe van’t Hoff’s reaction isotherm, isobar and isochore.
- Derive the van’t Hoff’s equation.
- Find the value of equilibrium constant at a particular temperature using van’t Hoff’s equation.
- Describe the effect on variation of temperature, pressure and concentration on equilibrium constant by Le Chatelier’s principle.
- Describe the effect on addition of inert gas(es) in a reaction system already in equilibrium.

**Topic:** ***Foundation of quantum Mechanics***

*Upon completion of this topic, learners should be able to:*

- Outline the historical developments of wave mechanics.
- Introduce the nature of black body radiation.
- Correlate Planck’s quantum theory with other theories on black body radiation.
- Explain photoelectric effect and Compton effect.
- Interpret de Broglie hypothesis and Uncertainty relations.
- Write Schrodinger wave equation.
- State the conditions imposed on an wave function to be an allowed wave function.
- Apply the conditions of normalization and orthogonality.
- Set up and solve the Schrodinger equation for one-dimensional box.
- Extend the problem of particle-in-one-dimensional box to two and three dimensions.
- Derive the expressions of $< x >$, $< p_x >$ and $< p_x^2 >$.
- State and explain the postulates of quantum mechanics.
- Deal with operator algebra.
- Understand the properties of Hermitian operators.

- Determine eigenvalues of eigenfunctions.
- Write Scrodinger's wave equation and significance of $\Psi$ and $\Psi^2$.

**Course Code: CC-6**

**Course Title: Inorganic Chemistry-II**

**Topic:** ***Chemical Bonding-I***

*Upon completion of this topic, learners should be able to:*

- Outline the general characteristics of ionic bonds.
- Describe the radius ratio rule and its applications.
- Find out the geometry of the cation and anion in an ionic crystal using radius ratio rule.
- Describe the packing (hcp or ccp) of ions in crystal.
- Calculate the packing efficiency of different types of packing.
- Derive the Born-Lande equation for determining the lattice energy of the ionic compounds.
- Draw the Born-Haber cycle and determine the thermodynamic parameters for different ionic compounds.
- Define the solvation energy and its application in dissolution process.
- Describe polarizing power and polarizability.
- Illustrate Fajan's rules, ionic character in covalent compounds, dipole moment and percentage ionic character.
- Elucidate VB Approach: Shapes of some inorganic molecules and ions on the basis of VSEPR.
- State Bent's rule.
- Describe and explain dipole moments.
- Define hybridization with suitable examples of linear, trigonal planar, square planar, tetrahedral, trigonal bipyramidal and octahedral arrangements.
- Know the general concept of resonance and resonating structures in various inorganic and organic compounds.

- Illustrate MO Approach: Rules for the LCAO method, bonding and antibonding MOs and their characteristics for s-s, s-p and p-p combinations of atomic orbitals.
- Define sigma, pi-bonds, delta interaction and multiple bonding.
- Identify the orbital designations: gerade and ungerade.
- Define HOMO and LUMO in MO diagrams.
- Describe the criteria of orbital mixing.
- Draw and explain the MO diagram of homodiatomic molecules ( $H_2$, $Li_2$, $Be_2$, $B_2$, $C_2$, $N_2$, $O_2$ and $F_2$) and bonding properties and magnetic behavior.
- Draw and explain the MO diagrams of heterodiatomic molecules (CO, NO, $NO^+$, $CN^-$, HF, $BeH_2$, $CO_2$ and $H_2O$) and bond properties and magnetic behavior.

**Topics : *Chemical Bonding-II (Metallic Bond and Weak Chemical Forces)***

*Upon completion of this topic, learners should be able to:*

- Rationalize the conductivity of metals, semiconductors and insulators based on the Band theory.
- Appreciate how metallic substances can be described in terms of structure and bond type.
- Understand the importance and application of weak chemical forces (inter-molecular and intramolecular) and their effect on melting points, boiling points, solubility and energetics of dissolution.

**Topic: *Radioactivity***

*Upon completion of this topic, learners should be able to:*

- Deliver a talk on the history of development of nuclear chemistry.
- Compare between alpha, bête and gamma radiations.

- Delineate the relationship of nuclear stability with neutron-to-proton ratio and the type(s) of radioactive decay.
- Narrate meson-exchange theory.
- State the postulates of liquid drop model and nuclear shell model.
- Conceptualize nuclear quantum numbers and write nuclear configuration(s) of different nuclides.
- Work out the spin and parity of different nuclides.
- Derive expressions of radioactive disintegration, half-life period, average-life-period.
- Elucidate different aspects of radioactive equilibrium.
- Demonstrate the function of different parts of a nuclear reactor.
- Unfold the mechanism of power generation in nuclear reactor.
- Illustrate different types of nuclear reactions.
- Get across different procedures of isotope separation.
- Correlate between group displacement laws and radioactive disintegration series.
- Apply the principles of age determination of rocks, minerals and archeological samples.

**Course Code: CC-7**

**Course Title:** ***Organic Chemistry-III***

**Topic:** ***Chemistry of alkenes and alkynes***

*Upon completion of this topic, learners should be able to:*

- Explain Markownikoff and anti-Markownikoff additions across olefinic carbon centers with mechanistic evidences.
- Be familiar with cyclopropanation reactions *e.g.* addition of single and triplet carbenes as well as carbenoids across C=C bonds.
- Get basic knowledge about hydrogenation, halogenations, iodolactonisation, hydrohalogenation, hydration, oxymercuration-demercuration, hydroboration-oxidation, epoxidation, syn and anti-hydroxylation, ozonolysis, mechanism of allylic and benzylic bromination in competition with brominations across C=C, use of NBS, Birch reduction of benzenoid aromatics, interconversion of E- and Z-alkenes.
- Explain Markownikoff and anti-Markownikoff additions across C≡C bond.

**Topic:** ***Aromatic Substitution***

*Upon completion of this topic, learners should be able to:*

- Understand mechanisms of electrophilic aromatic substitution evidences in favor of it *e.g.* nitration, nitrosation, sulfonation, halogenation, Friedel-Crafts reaction chloromethylation, Gatterman-Koch, Gatterman, Houben-Hoesch, Vilsmeier-Haack, Reimer-Tiemann, Kolbe-Schmidt and Ipso substitituion.

- Describe nucleophilic aromatic substitution and its mechanism including addition-elimination mechanism and benzyne mechanism (cine substitution), structure of benzyne and unimolecular mechanism.

**Topic: *Carbonyl and Related Compounds***

*Upon completion of this topic, learners should be able to:*

- Get details about structure, reactivity and preparation of carbonyl compounds Burgi-Dunitz trajectory in nucleophilic additions.
- Suggest reagents and mechanisms for reduction of C=O functionality.
- Write the mechanisms of condensation reactions of carbonyl compounds.
- Understand reactions at α- position of carbonyl compounds.
- Get idea about reducing properties of aldehyde functionality towards Tollens' reagent, Fehling's solution and Benedict's reagent.
- Explain mechanistically rearrangement reactions of carbonyl compounds.
- Be familiar with active methylene compounds (*e.g.* DEM and EAA), their preparations and synthetic applications in organic chemistry.
- Form small, medium and large size rings utilizing Robinson annulations and high dilution technique.
- Conceptualize $B_{AC}2$, $A_{AC}2$, $A_{AC}1$, $A_{AL}1$ mechanisms of ester hydrolysis.

**Topic: *Organometallics***

*Upon completion of this topic, learners should be able to:*

- Gain basic ideas about organometallic compounds *e.g.* (Grignard reagent, Organolithiums, Gilman cuprates) their preparations and reactions

Reformatsky reaction; concept of umpolung and base-nucleophile dichotomy in case of organometallic reagents

- Exemplify umpolung reactions in biological systems.

**Course Code: SEC-1**

**Course Title:** ***Basic Analytical Chemistry***

**Topic:** ***Introduction***

*Upon completion of this topic, learners should be able to:*

- Get an introduction on the interdisciplinary nature of analytical chemistry.
- Compare accuracy and precision.
- Calculate mean, median, standard deviation, relative standard deviation, variance, range, etc. from a given set of data.
- Identify significant figures.
- Round off results of numerical calculations up to correct number of significant figures.
- Calculate standard deviations of calculations.

**Topic:** ***Analysis of Soil***

*Upon completion of this topic, learners should be able to:*

- Gather knowledge about composition, texture, water content, pH of various types of soil.
- Understand the importance of soil pH and its determination.
- Know about the ways to control soil pH.
- Justify the use of EDTA as the complexone in the complexometric titration.
- Classify complexometric titrations.
- Point out the requirements of a chelometric indicator.
- State the importance of pH in complexometric titrations.
- Enumerate pM [negative logarithm of metal ion concentration] at different stages of complexometric titration.
- Determine the hardness of water sample by complexometric titration.

- Exemplify masking and demasking agents and their use in determination of more than one metal ion in a mixture.

**Topic:** ***Analysis of Water***

*Upon completion of this topic, learners should be able to:*

- Gather the knowledge about the contaminants/impurities and health issues resulted from these.
- Explain the importance of DO, BOD and COD.
- State the principle of the methods of determination of DO, BOD and COD.
- Describe the process of water purification.
- Narrate water sampling methods.

**Topic:** ***Analysis of Food Products***

*Upon completion of this topic, learners should be able to:*

- Discuss about the nutritional value of foods.
- Have the idea of food processing.
- Name different food preservatives, their function and adverse effects, if any, on the health of consumers.
- Name different food adulterants with examples.
- Mention the adverse effects of food adulteration.

**Topic:** ***Chromatography***

*Upon completion of this topic, learners should be able to:*

- Define chromatography.
- State the stationary and mobile phases employed in different types of chromatographic techniques.
- Classify chromatographic techniques in different categories.
- Expound the importance of retention factor ($R_f$) in chromatography.
- Write basic principles of adsorption and partition chromatography.

- Narrate the difference in basic principles of ion-exchange chromatography, thin layer chromatography and paper chromatography.
- Differentiate among different types of chromatographic techniques.

**Topic: *Ion-Exchange***

*<u>Upon completion of this topic, learners should be able to:</u>*

- Comment on the types of ion-exchange resins.
- Put down relevant chemical equations regarding the functioning of cation and anion exchangers.
- Elaborate the method of determination of exchange capacity of both cation and anion exchangers.
- Arrange cations/anions in the order of their elution by ion-exchange chromatographic technique.

**Topic: *Analysis of Cosmetics***

*<u>Upon completion of this topic, learners should be able to:</u>*

- Document the constituents, their function and toxic effects, if any, in the following cosmetics:-

  Nail polish, lipstick, eye liner, hair gel, shampoo, conditioner, nail polish remover, pedicure, manicure, face powder, sun screen lotion, cleansing lotion, cold cream, vaseline, lip gloss, fairness cream, vanishing cream, non-sticky hair oil, deodorant, anti-perspirant.
- Outline the analysis of deodorants and anti-perspirants.

## SEMESTER: 4

**Course Code: CC- 8**

**Course Title:** ***Physical Chemistry-III***

**Topic:** ***Colligative Properties***

*Upon completion of this topic, learners should be able to:*

- Define the ideal and non-ideal solution.
- Know about vapour pressure.
- State Raoult's Law.
- Define and explain colligative properties and nature of solute and solution.
- Define different type of colligative properties (relative lowering of vapour pressure, elevation of boiling point, depression o freezing point and osmotic pressure) and Raoult's law for each colligative property.
- Derive thermodynamic derivation using chemical potential for four colligative properties.
- Know the methods use for experimental determination of four colligative properties.
- Understand the important application of four colligative properties.
- Describe the abnormal colligative properties.
- Calculate Van't Hoff factor for associated and dissociated solutes.

**Topic:** ***Phase Rule***

*Upon completion of this topic, learners should be able to:*

- Understand the EXACT meaning of terms, viz. phase, component and degree of freedom.
- Use accurate values of C, P and F in practical cases.
- State and derive Gibb's phase rule.
- Explain phase diagrams of water, $CO_2$ and sulphur.

- Derive Clayperon, Clausius-Clayperon and Duhem-Margules equations.
- Interpret phase diagrams of two and three-component systems.
- Expound consolute temperature (CST), triple point, eutectic mixture, eutectic point, polymorphism, enantiotropy and monotropy.
- Derive Konowaloff's rule.
- Apply Lever rule to explain phase diagrams of different two-component systems.

**Topic:** ***Electrical Properties***

*Upon completion of this topic, learners should be able to:*

- Understand chemical potential, activity and activity coefficients of ions in solution.
- Describe Debye-Hückel limiting law qualitatively.
- Calculate the activity coefficient for electrolytes using Debye-Hückel limiting law.
- Derive the mean ionic activity coefficient from the expression of ion-atmosphere interaction potential.
- Write the applications and limitations of Debye-Hückel limiting law.
- Write Faraday's laws of electrolysis.
- Construct cell from half-cell potential.
- Determine the cell potential.
- Derive Nernst equation.
- Calculate the thermodynamic parameters G, H and S.
- Explain reversible and irreversible cells with examples.
- Define liquid junction potential and figure out its removal.
- Exemplify standard electrodes like hydrogen electrodes and calomel electrodes.
- Understand electrochemical series and its applications.

- Enumerate the advantages using calomel electrode over hydrogen electrode as standard electrodes.
- Describe the determination of pH of a solution using hydrogen electrode and quinhydrone electrode.

**Topic: *Quantum Chemistry***

*Upon completion of this topic, learners should be able to:*

- Have a clear idea about angular momentum, commutation rules and quantization of square of total angular momentum and z-component.
- Able to conceptualize the theory of rigid rotor model of diatomic molecules.
- Convert Cartesian coordinates into spherical polar coordinates.
- Gather knowledge about how to separate variables.
- Set up Schröidinger equation for He, Li, etc.
- Apply LCAO-MO treatment for $H_2^+$.
- Compare between LCAO-MO and VB treatments of $H_2$.
- Calculate average and most probable distances of electron from nucleus.
- Experience using mathematical tools to construct approximate quantum mechanical models.
- Apply principles of quantum mechanics to calculate observables on known wave functions
- Work independently with key questions and problems in quantum chemistry.
- Describe the shapes of orbitals, radial and angular nodes from complete wave equations.

**Course Code: CC-9**

**Course Title:** ***Inorganic Chemistry-III***

**Topic:** ***Chemistry of s and p Block Elements***

*Upon completion of this topic, learners should be able to:*

- Outline the relative stabilities of different oxidation states of representative elements.
- Point out the anomalous behaviour of first member of each group.
- Describe allotropy and catenation properties of elements.
- Describe the structure, bonding, preparation, properties and uses of beryllium hydrides, beryllium halides, boric acid, borates, boron nitrides, borohydrides (diborane) and graphitic compounds.
- List the oxides and oxoacids of nitrogen, phosphorus, sulphur and chlorine.
- Describe the structure and properties of sulphur-nitrogen compounds.
- Enumerate the basic properties of halides.
- Write the preparation, structure and properties of polyhalides, interhalogen compounds, polyhalides, pseudohalides.
- Write the properties and use of fluorocarbons and chlorofluorocarbons and their adverse effect on ozone layer.

**Topic:** ***Noble Gases***

*Upon completion of this topic, learners should be able to:*

- Describe the occurrence, uses and interest of nobel gases.
- Define and explain clathrate compounds of nobel gases and their application.
- Discuss the preparation, structure, nature of bonding and properties of $XeF_2$, $XeF_4$ and $XeF_6$.
- Know about xenon-oxygen compounds and their application.

**Topic: *Inorganic Polymers***

*<u>Upon completion of this topic, learners should be able to:</u>*

- Define inorganic polymer and differentiate with organic polymer.
- Discuss the synthesis and structure of some important inorganic polymer such as borazine, silicones, siloxanes, silicates and phosphazens.
- Understand the application of such inorganic polymers.

**Topic: *Coordination Chemistry-I***

*<u>Upon completion of this topic, learners should be able to:</u>*

- Present a brief history of the emergence of coordination chemistry.
- Differentiate between double and complex salts.
- Untangle Werner's theory of coordination complexes.
- Classify ligands into different categories.
- Define and furnish examples of various kinds of ligands.
- Explicate classical and non-classical binding modes of ligands and correlate denticity and hapticity.
- Show different binding modes of a ligand.
- Justify the binding of ambidentate ligands with the aid of SHAB principle, symbiotic effect and competitive pi-bonding.
- Rationalize synergic bonding and synergic effect.
- Compare and contrast between pi-acid ligands and pi-complexing ligands.
- Explain chelate effect and compare with the macrocyclic effect.
- Write a note on inner-metallic complexes.
- Name coordination complexes obeying the rules set by IUPAC.
- Expound different types of isomerism in square planar and octahedral complexes.

**Course Code: CC-10**

**Course Title:** ***Organic Chemistry-IV***

*Upon completion of this topic, learners should be able to:*

- How electromagnetic radiation interact with matters.
- Understand different types of electronic transition.
- Determine the degree of unsaturation from molecular formulae.
- Differentiate between the pair'schromophore/auxochrome and bathochromic/hypsochromic shifts.
- Calculate the $\lambda_{max}$ and $\varepsilon_{max}$
- Identify the functional group from an unknown compound.
- Enumerate change on IR stretching frequencies of the following effect e.g. conjugation, electronic effects, mass effect, bond multiplicity, ring-size, solvent effect, H-bonding.
- Understand basic principles of Proton Magnetic Resonance.
- Identify chemical and magnetic equivalence.
- Characterize different environment of hydrogen atoms in $^{1}$H-NMR spectra.
- How to determine the structure of organic molecules using UV-Vis, IR and NMR spectroscopic technique.

**Topic:** ***Nitrogen compounds, Rearrangement reactions, Retrosynthesis, Asymmetric synthesis & Ring synthesis***

*Upon completion of this topic, learners should be able to:*

- Be familiar with different types of nitrogen containing organic compounds *e.g.* amine, nitro, nitrile, isonitrile, diazonium salts and azo compounds.
- Synthesize (incorporate) those above mentioned nitrogen containing functionalities and encounter with various types of reactions they undergo.

- Interconvert between different functional groups.
- Differentiate between different types of amines and nitro compounds through visual colour change reactions.
- Understand different kind of rearrangement reactions including rearrangement to electron-deficient carbon, rearrangement to electron-deficient nitrogen, rearrangement to electron-deficient oxygen, aromatic rearrangements, migration from nitrogen to ring carbon, rearrangement reactions by green approach *etc*.
- Carry out retrosynthetic analysis to synthesize an unknown compound following FGI and FGA strategy.
- Identify synthon, synthestic equivalent and retron.
- Understand synthesis of an organic compound through protection-deprotection
  strategy and polarity-inversion technique.
- Understand the basic concepts of stereoselective and stereospecific reactions; diastereoselectivity and enantioselectivity.
- Understand asymmetric reduction and nucleophilic addition to carbonyl compounds using Felkin- Anh model.
- Synthesize large rings by applying high dilution technique.

**Course Code: SEC-2**

**Course Title:** ***Pharmaceutical Chemistry***

**Topic:** ***Pharmaceuticals Chemistry***

*Upon completion of this course, learners should be able to:*

- Understand how a drug is discovered and what are the different stages a molecule must successfully overcome to become a drug candidate.
- Easily classify drugs based on their mechanism of action.
- Follow retrosynthetic approach to synthesize analgesics agents, antipyretic agents, anti-inflammatory agents, antibiotics, antibacterial agents, antifungal agents, antiviral agents, Central Nervous System agents, cardiovascular drugs, anti-leprosy drugs, and HIV-AIDS related drugs.
- Differentiate between Aerobic and anaerobic fermentation.
- Understand the production of certain antibiotics *e.g.* Penicillin, Cephalosporin, Chloromycetin and Streptomycin; amino acids *e.g.* Lysine and Glutamic acid; Vitamins, *e.g.* Vitamin $B_2$, Vitamin $B_{12}$ and Vitamin C.

## SEMESTER: 5

**Course Code: CC-11**

**Course Title:** ***Inorganic Chemistry-IV***

**Topic:** ***Coordination Chemistry-II***

*Upon completion of this topic, learners should be able to:*

- Describe different bonding theories of coordination complexes.
- Draw the splitting diagrams of d-orbital under different geometry.
- Explain the terms CFSE, OSSE, SCO etc. in details.
- Write the spectrochemical series of ligands and explain their position in the series.
- Discuss Jahn-Teller distortions in coordination complexes.
- Explain the lattice energy and hydration energy curves of metal ions.
- Determine the normal and reverse spinel structures.
- Discuss the high spin and low spin complexes.
- Discuss the effect of sigma- and pi-bonding in octahedral complexes and their effects on the oxidation states of transitional metals.
- Describe the origin of magnetic moments
- Describe and explain orbital and spin magnetic moments and spin only moments of $d^n$ ions.
- Discuss and explain orbital contribution and -quenching of magnetic moment.
- Classify and explain magnetic properties of substance (Diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism and ferrimagnitsm).
- Explain the super exchange mechanism.
- Describe the origin of colour of the metal complexes.
- Draw Orgel diagrams for $3d^1$ to $3d^9$ ions.

- Get idea of Racah parameter.
- Explain electronic spectral transitions with help of Orgel diagrams.
- Explain spectrochemical series.
- Discuss and explain ligands charge transfer spectra of different metal complexes.

**Topic: *Transition Elements***

*<u>Upon completion of this topic, learners should be able to:</u>*

- Indicate the position of a particular transition element in the modern form of the Periodic Table.
- Write comparative study on the elements of a particular group (3 to 12) in respect of the following:-
  Electronic configuration, metallic and ionic radii, electronegativity, oxidation states with examples, oxides, halides, oxohalides, oxo-cations, oxo-anions, complex compounds.
- Justify the stability of one oxidation state over another.
- Study colour and magnetic behavior of complexes of transition elements in different oxidation states.
- Furnish preparation and structure of important compounds and complexes of d-block elements.
- Write important chemical reactions of transition elements and their compounds.
- State the uses of transition metals and of some their important compounds.

**Topic: *Lanthanoids and Actinoids***

*<u>Upon completion of this topic, learners should be able to:</u>*

- Describe the reason for placing f-block elements below the main periodic table.
- Describe the separation of lanthanoid elements by ion-exchange methodology.

- Compare the spectral, magnetic and complexing properties of the lanthanoids and actinoids elements with the d-block elements.
- Point out the reason why some f-block elements show oxidation states other than +3.
- Define lanthanide contraction and its effects in chemical and physical properties.
- Write the electronic configurations of lanthanoid and actinoid elements.

**Course Code: CC-12**

**Course Title:** ***Organic Chemistry-V***

**Topic:** ***Carbocycles, and Heterocycles Cyclic Stereochemistry, Pericyclic reactions, Carbohydrates, Biomolecules, Alkaloids and Terpenoids***

*Upon completion of this topic, learners should be able to:*

- Synthesize polynuclear hydrocarbons (PAH) *e.g.* naphthalene, anthracene, phenanthrene and their derivatives.
- Explain reactions of PAH.
- Synthesize five-membered heterocycles *e.g.* furan, pyrrole and thiophene; six-membered heterocycle *e.g.* pyridine and fused heterocycles *e.g.* indole, quinoline and isoquinoline.
- Explain the reactions of the above-mentioned heterocycles.
- Understand the importance of heterocyclic compounds in medicinal chemistry.
- Draw the chair and boat conformers of cyclohexane systems.
- Compare the energy contents between chair and boat conformers of cyclohexane systems. Understand the steric and stereoelectronic requirements for elimination, nucleophilic substitution, merged substitution-elimination, rearrangement reactions, oxidation-reduction reactions, esterification/saponification/ lactonisation/epoxidation/ pyrolytic syn elimination and fragmentation reactions in cyclohexane systems.
- Understand the mechanism, stereochemistry and regioselectivity of electrocyclic reactions, cycloaddition reactions and sigmatropic reactions.
- Classify carbohydrates into different categories.

- Represent carbohydrates into different projections.
- Carry out certain reactions and transformations in carbohydrate molecules.
- Degrade and upgrade carbohydrate molecules.
- Gain clear idea about amino acids, their synthesis, reactions, detection and resolution.
- Synthesize peptides.
- Detect C & N-terminals of peptide molecules.
- Cleave peptide bonds.
- Conceptualize nucleosides and nucleotides, structure of DNA and RNA.
- Have general ideas about terpenoids and alkaloids.
- Determine the structure of α-Terpenol and ephedrine.

**Course Code: DSE-1**

**Course Title:** ***Advanced Physical Chemistry***

**Topic:** ***Crystal Structure***

*Upon completion of this topic, learners should be able to:*

- Classify different solids.
- Write Laws of crystallography (Haüy's law and Steno's law).
- Define unit cell, lattice and space lattice.
- Find the symmetry elements in a unit cell.
- Draw the 7 crystal systems and possible14 variations (Bravais lattices).
- Discuss the close packing arrangements (fcc and hcp).
- Calculate the packing efficiency in fcc and hcp lattice.
- Define tetrahedral and octahedral holes.
- Find the interplanar distance($d_{hkl}$) from the h,k,l value.
- Derive Bragg's equation using Bragg's law.
- Explain theoretical basis of powder XRD and single crystal XRD.

**Topic:** ***Statistical Thermodynamics***

*Upon completion of this topic, learners should be able to:*

- Understand the difference between thermodynamic probability and mathematical probability.
- Work out macrostates, microstates, configuration and degeneracy.
- Determine configuration and equilibrium configuration.
- Elucidate canonical, micro canonical & grand canonical ensembles and relate them with three types of system in classical thermodynamics.
- Derive Boltzmann law and from this law to Maxwell-Boltzmann distribution.
- Apply barometric distribution law.
- Interpret partition function and its significance.
- Extract U, H, S, A, G, etc from molecular partition function.

- Obtain translational, rotational and vibrational partition functions and from these the corresponding energies.
- Explain Maxwell's speed distribution with the help of partition function.

**Topic:** ***Special selected topics***

*Upon completion of this topic, learners should be able to:*

- Expound Dulong-Petit's law.
- Derive heat capacity from partition function and apply the same at high and low temperature.
- Comment on the limitation of Einstein's theory on heat capacity.
- Interpret heat capacity at different temperatures by Debye's $T^3$ law.
- Work out numerical problems on heat capacity.
- Do a comparative study between different theories on heat capacity.
- State the third law of thermodynamics.
- Enumerate absolute entropy.
- Elucidate Nernst heat theorem.
- Differentiate between polymers and macromolecules.
- Classify polymers on the basis of :-

  (a)Source, (b) Structure of polymer chain, (c) Synthetic reaction, (d) Synthesis mechanism, (e) Tacticity, (f) Molecular forces.
- Write steps of mechanistic pathways of chain growth and step growth polymerization.
- Pen chemical reactions of polymer synthesis.
- Assign names to the polymers.
- Derive and interpret kinetic studies on step growth polymerization.
- Give examples and uses of conducting polymers.
- Explain the relationship between extent of reaction and degree of polymerization.
- Discuss the relationships between functionality.

- Define dipole moment.
- Work out the units of dipole moment and correlate them.
- Write the expressions of polarisability, dielectric constant, induced moment per volume.
- Pen the relation between refractive index and polarisability.
- Use Clausius-Mossotti equation and Debye equation to calculate dipole moments of different molecules by the following methods:-

  (a) Temperature method, (b) Ebert's method, (c) Refractivity method and (d) Solution method.

**Course Code: DSE-2**

**Course Title:** ***Analytical methods in chemistry***

**Topic:** ***Qualitative and quantitative aspects of analysis***

*Upon completion of this topic, learners should be able to:*

- Differentiate between sample mean and population mean.
- Distinguish between sample standard deviation and population standard deviation.
- Discriminate between accuracy and precision.
- Pen statistical formula of normal distribution.
- Depict normal error curve and label its characteristic features.
- Reject data based on Q-test and F-test.
- Calculate $S_{pooled}$ from a given data set.
- Apply values of *z* (*deviation from the mean stated in units of standard deviation*) and *t* (*student's t*) based on confidence intervals.
- Derive calibration curve based on least-squares method.

**Topic:** ***Optical methods of analysis***

*Upon completion of this topic, learners should be able to:*

- Describe origin of spectra.
- State Lambert –Beer's law and derive mathematically.
- Discuss and explain validity and application of Lambert –Beer's law.
- Have an idea the basic components of any spectroscopy.
- Describe basic principles of UV-Visible spectrophotometer and know about source light, monochromator and detector for single and double beam instrument.
- Discuss and explain quantitative analysis: estimation of metal ions from aqueous solution, geometrical isomers, keto-enol tautomers.
- Determine composition of metal complexes using Job's method of continuous variation and mole ratio method.

- Know about basic principles of Infrared Spectroscopy.
- Describe source of light, monochromator and detector for single and double beam IR instrument.
- Know the sampling techniques and structural illustration through interpretation of data.
- Discuss and explain the effect and importance of isotope substitution.
- Describe basic principles of Flame Atomic Absorption and Emission Spectroscopy and know source light, monochromator, and detector.
- Discuss and explain flame and Burner designs for Flame Atomic Absorption and Emission Spectroscopy
- Describe techniques of atomization and sample introduction;.
- Discuss different methods used for background correction.
- Discuss and explain sources of chemical interferences and their removal.
- Explain the techniques for the quantitative estimation of trace level of metal ions from environmental samples.

**Topics:** ***Separation techniques, Electroanalytical methods, Thermal methods of analysis***

*Upon completion of this topic, learners should be able to:*

- Illustrate the principles of chromatography.
- Demonstrate the fundamentals of different chromatographic techniques and their application.
- Demonstrate the principle of chromatographic techniques used in isolation, purification, identification analysis of compounds.
- Apply qualitative and quantitative chromatographic methods for identification, and standardization of natural products.
- Practice the isolation, identification and standardization of active ingredients from different natural sources.
- Purify and identify the newly isolated compounds, detect impurities.

- Explain the theoretical principles and important applications of electroanalytical methods within titration (acid/base titration, complexometric titration, redox titration), and various techniques ofcoulometric methods.
- Explain the theoretical principles of selected instrumental methods within electroanalytical methods, and main components in such analytical instruments.
- Explain the theoretical principles of various separation techniques in chromatography, and typical applications of chromatographic techniques.
- Familiar with the theoretical basis of thermogravimetry (TG).
- Understands the existence of various sample originating parameters that may effect to measuring conditions.
- Calculate the amount of calcium and magnesium from a mixture of them.

## SEMESTER: 6

**Course Code: CC-13**

**Course Title:** ***Inorganic Chemistry-V***

**Topic:** ***Bioinorganic Chemistry***

*Upon completion of this topic, learners should be able to:*

- Classify the biological elements into essential, beneficial, major, trace, ultratrace, hard and soft elements.
- Write the role of different metal ions in biological systems.
- Describe the metal ion transport across biological membrane( $Na^+/K^+$-ion pump).
- Draw the active site structures of Haemoglobin, Myoglobin, Hemocyanine and Hemerythrin and write their role in oxygen transport in biological systems.
- Write the functions and structures of different enzymes like Cytochromes, Ferredoxins, carbonic anhydrase, carboxyanhydrase and nitrogenase.
- Enumerate the effects of toxic metal ions.
- Define chelation therapy and write its application in removal of toxic metal ions from human body.
- Describe photosynthesis by Z-scheme.
- Draw the active site structures of Photosystem-I and Photosystem-II.

**Topic:** ***Organometallic Chemistry***

*Upon completion of this topic, learners should be able to:*

- Get acquainted with the history of organmetallic chemistry.
- Give a brief account of the important discoveries in the field of organmetallic chemistry.
- Explain the stabilization of lower oxidation states of metals in presence of pi-acid ligands.

- Exemplify pi-acid ligands and the prerequisites for the formation of complexes with such ligands.
- Apply 18 electron rule to explain the stability carbonyl and nitrosyl complexes.
- Justify the formulation of carbonyl and nitrosyl complexes.
- Draw the structural formula of complexes with CO and different oxidation states of NO.
- Furnish the binding modes of CO and NO.
- Unravel the tautomeric equilibria between bridged and non-bridged structures of carbony complexes.
- Differentiate between linear and bent nitrosyls.
- Comment on the criteria for the formation of bridging and non-bridging carbonyl complexes.
- Use the ir stretching frequency as the diagnostic tool to identify the nature of binding in carbonyl and nitrosyl complexes.
- Write reactions regarding the syntheses and reactivity of carbonyls and nitrosyls.

**Topic: *Organometallic Chemistry, Catalysis by Organometallic Compounds***

*Upon completion of this topic, learners should be able to:*

- Prepare Zeise's salt and ferrocene.
- Explain the structures of Zeise's salt and ferrocene.
- Show different electrophilic substitution reactions of ferrocene.
- Conceptualize reactions of organometallic complexes *e.g.* substitution, oxidative addition, reductive elimination and insertion reactions.
- Study the industrial processes *e.g.* alkene hydrogenation using Wilkinson's Catalyst, Hydroformylation reaction, Wacker Process, Fischer Tropsch reaction and Ziegler-Natta catalysis for olefin polymerization.

**Topic:** ***Reaction Kinetics and Mechanism***

*Upon completion of this topic, learners should be able to:*

- Classify inorganic reactions in respect of reaction pathways.
- Identify labile and inert complexes.
- Correlate lability and inertness with electronic configuration.
- Rationalise the apparent contradiction between themodynamic stabily and kinetic lability.
- Segregate ligand substitution reactions in terms of reaction rate.
- Characterise intimate and stoichiometric mechanisms.
- Differentiate between associative, dissociative and intermediate reactions.
- Explain relative lability and inertness of coordination complexes with LFSE while undergoing ligand substitution reactions.
- Apply different factors affecting intimate mechanism of octahedral substitution reaction in explaining different experimental observations.
- Clarify steric and electronic effects in identifying the mechanism of octahedral substitution reactions.
- Explicate linear free energy relationship.
- State the theories for the determination of activation parameters.
- Use the values of activation parameters to suggest mechanism of octahedral substitution reactions.
- Comment on DCB mechanism in respect of octahedral substitution reaction.
- Define trans effect, cis effect, spectator ligands.
- Expound the polarization theory and pi-bonding theory to explain trans effect.
- Explore the steric course of square planar substitution reactions.
- Interpret nucleophilicity parameter to explain sequence of rate of substitution reactions in square planar complexes.

**Course Code: CC-14**

**Course Title:** ***Physical Chemistry-IV***

**Topic:** ***Molecular Spectroscopy***

*Upon completion of this topic, learners should be able to:*

- Understand the mechanism of interaction of electromagnetic radiation with molecule.
- State Born-Oppenheimer approximation.
- Identify the different spectrum region and their corresponding name of molecular spectroscopy.
- Describe and explain the criteria of interaction mechanism with electromagnetic radiation and molecule for vibrational, rotational, Raman and proton NMR spectroscopy.
- Understand classical and quantum mechanical spectroscopic energy equation for vibrational, rotational spectroscopy of different type of diatomic molecules and their selection rules.
- Draw and explain the energy diagram and line appear in the spectrum.
- Know about anharmonicity, Morse potential, dissociation energy, fundamental frequency, overtone, hot band.
- Calculate the degree of freedom for polyatomic molecule.
- Understand the application of different spectroscopy in our real life and higher study.

**Topic:** ***Photochemistry***

*Upon completion of this topic, learners should be able to:*

- Understand the meaning of ptotochemistry and differentiate with thermal reaction
- State the laws of photochemistry.
- Differentiate between photophysical and photochemical process.

- Describe of vibrational-electronic spectra according to Franck-Condon principle.
- Determine of molar extinction coefficient from Lambert Beer law and limitation of Lambert Beer law.
- Understand the importance of quantum yield and the reasons behind high and low quantum yield.
- Write the steps of mechanistic pathways of decomposition of some organic and inorganic compounds in presence of light.
- Draw the Jablonsky diagram and justify the different processes.
- Discuss and explain the mechanism and essential conditions for fluorescence, phosphorescence process and decay of excited states.
- Have a clear idea about photosensitizer reaction and photochemical equilibrium.
- Understand the importance and applications of photochemical reactions in biological systems and industrial processes.

**Topic: *Surface Phenomena***

*Upon completion of this topic, learners should be able to:*

- Define surface tension, surface energy and surface free energy.
- Explain work of cohesion and work of adhesion.
- Apply capillary rise phenomena in explaining different problems.
- Justify spreading of liquid over other surfaces.
- Comment on temperature dependence of surface tension.
- State variation of surface tension with concentration.
- Know about the experimental determination of surface tension of a liquid.
- Use the surface tension phenomena to explain different incidents observed in nature.
- Differentiate between absorption and adsorption.
- Compare between physisorption and chemisorptions.

- Understand the transition from physisorption to chemisorptions.
- Explain potential energy diagram of physisorption and chemisorptions.
- Cassify adsorption isotherm.
- Derive Freundlich and Langmuir adsorption isotherms.
- Elaborate on B.E.T. equation (assumptions, significance, variation).
- Interpret different types of adsorption isotherms in the light of B.E.T. equation.
- Explain heterogeneous catalysis with the conception of adsorption.
- Draw the line of contrast between crystalloids, colloids and suspension.
- Exemplify colloids in terms of the physical states of the dispersion medium and dispersed phase.
- Identify the types of emulsions.
- Manifest the origin of charge and stability of lyophobic colloids.
- Compare between peptization, coagulation and flocculation.
- Analyze Stern double layer and zeta potential.
- Illustrate electrokinetic phenomena happening in colloidal mixtures.
- Unravel the method of determination of Avogadro Number by Perrin's method.
- Expound micelle formation.

**Course Code: DSE-3**

**Course Title:** ***Polymer Chemistry***

**Topic:** ***Introduction and history of polymeric materials, Functionality and its importance, Properties of Polymers***

*Upon completion of this topic, learners should be able to:*

- Classify polymers from different angles.
- Understand nomenclature of polymers.
- Identify molecular forces and chemical bonding present in polymers.
- Explain the basis of formation of synthetic polymers.
- Classify polymerization processes.
- Relate between functionality, extent of reaction and degree of polymerization.
- Introduce preparation, structure, properties and application of certain polymers *e.g.* polystyrene and styrene copolymers, poly(vinyl chloride) and related polymers, Polycarbonates, Polyamides and related polymers. Phenol-formaldehyde resins (Bakelite, Novolac).
- Have clear ideas about conducting polymers *e.g.* polyacetylene, polyaniline, poly(p-phenylene sulphide), polypyrrole, polythiophene.

**Topic:** ***Kinetics of Polymerization, Determination of Molecular Weight of Polymers, Glass Transition Temperature (Tg), Determination of Tg and Polymer Solution***

*Upon completion of this topic, learners should be able to:*

- Derive expressions of rate equations for step growth and radical chain growth polymerization.

- Write steps of mechanistic pathways for the formation of addition and condensation polymers.
- Determine degree of polymerization and kinetic chain length.
- Calculate number average and weight average molecular weights and also polydispersity index.
- Apply different methods for the determination of molecular weights of polymers.
- Understand distribution of molecular weights of polymers.
- Enumerate change of thermodynamic parameters of polymerization processes.
- Identify the factors that control solubility of polemers.
- Define glass transition temperature.
- Justify the variation of physical state of polymers of different kinds with temperature.
- State the significance of free volume theory in the application of polymers.
- Differentiate between $T_g$ and melting point.

**Course Code: DSE-4**

**Course Title:** ***Dissertation followed by power point presentation***

*Upon completion of this topic, learners should be able to:*

- Submit a brief write-up on the selected topic.
- Create a PPT using various computer tools.
- Deliver a lecture on a topic using power point presentation.
- Write a description on a particular topic.