

UPSC CSE Chemistry Syllabus 2024

The Chemistry optional syllabus covers inorganic, organic, physical, and analytical chemistry topics. Aspirants have to study chemical bonding, energetics, electrochemistry, stereochemistry, polymers, and spectroscopy for this paper. The UPSC CSE chemistry syllabus 2024 evaluates fundamental concepts and their applications relevant for civil services roles involving technology, environment, and industry.

UPSC CSE Chemistry Syllabus 2024 Paper 1

1. Atomic Structure:

- Heisenberg's uncertainty principle
- Schrodinger wave equation (time independent)
- Interpretation of wave function
- Particle in one-dimensional box
- Quantum numbers
- Hydrogen atom wave functions
- Shapes of s, p, and d orbitals

2. Chemical Bonding:

- Ionic bond
- Characteristics of ionic compounds
- Lattice energy
- Born-Haber cycle
- Covalent bond and its general characteristics
- Polarities of bonds in molecules and their dipole moments
- Valence bond theory
- Concept of resonance and resonance energy
- Molecular orbital theory (LCAO method)
- Bonding H_2^+ , H_2 , He_2^+ to Ne_2 , NO, CO, HF, CN^-
- Comparison of valence bond and molecular orbital theories
- Bond order, bond strength, and bond length

3. Solid State:

- Crystal systems
- Designation of crystal faces
- Lattice structures and unit cell
- Bragg's law
- X-ray diffraction by crystals
- Close packing
- Radius ratio rules
- Calculation of some limiting radius ratio values
- Structures of NaCl, ZnS, CsCl, CaF_2
- Stoichiometric and nonstoichiometric defects
- Impurity defects

- Semiconductors

4. The Gaseous State and Transport Phenomenon:

- Equation of state for real gases
- Intermolecular interactions
- Critical phenomena and liquefaction of gases
- Maxwell's distribution of speeds
- Intermolecular collisions
- Collisions on the wall and effusion
- Thermal conductivity and viscosity of ideal gases

5. Liquid State:

- Kelvin equation
- Surface tension and surface energy
- Wetting and contact angle
- Interfacial tension and capillary action

6. Thermodynamics:

- Work, heat, and internal energy
- First law of thermodynamics
- Second law of thermodynamics
- Entropy as a state function
- Entropy changes in various processes
- Entropy-reversibility and irreversibility
- Free energy functions
- Thermodynamic equation of state
- Maxwell relations
- Temperature, volume, and pressure dependence of U, H, A, G, Cp, and Cv
- J-T effect and inversion temperature
- Criteria for equilibrium
- Relation between equilibrium constant and thermodynamic quantities
- Nernst heat theorem
- Introductory idea of the third law of thermodynamics

7. Phase Equilibria and Solutions:

- Clausius-Clapeyron equation
- Phase diagram for a pure substance
- Phase equilibria in binary systems
- Partially miscible liquids
- Upper and lower critical solution temperatures
- Partial molar quantities
- Excess thermodynamic functions

8. Electrochemistry:

- Debye-Huckel theory of strong electrolytes

- Debye-Huckel limiting Law for various equilibrium and transport properties
- Galvanic cells
- Concentration cells
- Electrochemical series
- Measurement of e.m.f. of cells and its applications
- Fuel cells and batteries
- Processes at electrodes
- Double layer at the interface
- Rate of charge transfer
- Current density
- Overpotential
- Electroanalytical techniques: amperometry, ion selective electrodes, and their use

9. Chemical Kinetics:

- Differential and integral rate equations for zeroth, first, second, and fractional order reactions
- Rate equations involving reverse, parallel, consecutive, and chain reactions
- Branching chain and explosions
- Effect of temperature and pressure on rate constant
- Study of fast reactions by stop-flow and relaxation methods
- Collisions and transition state theories

10. Photochemistry:

- Absorption of light
- Decay of excited state by different routes
- Photochemical reactions between hydrogen and halogens and their quantum yields

11. Surface Phenomena and Catalysis:

- Adsorption from gases and solutions on solid adsorbents
- Langmuir and B.E.T. adsorption isotherms
- Determination of surface area
- Characteristics and mechanism of reaction on heterogeneous catalysts

12. Bio-inorganic Chemistry:

- Metal ions in biological systems
- Their role in ion-transport across the membranes (molecular mechanism)
- Oxygen-uptake proteins
- Cytochromes and ferredoxins

13. Coordination Chemistry:

- Bonding in transition metal complexes
- Valence bond theory
- Crystal field theory and its modifications
- Isomerism in coordination compounds
- IUPAC nomenclature of coordination compounds

- Stereochemistry of complexes with 4 and 6 coordination numbers
- Chelate effect and polynuclear complexes
- Trans effect and its theories
- Kinetics of substitution reactions in square-planar complexes
- Thermodynamic and kinetic stability of complexes
- EAN rule
- Synthesis structure and reactivity of metal carbonyls
- Carboxylate anions, carbonyl hydrides, and metal nitrosyl compounds
- Complexes with aromatic systems
- Synthesis, structure, and bonding in metal olefin complexes, alkyne complexes, and cyclopentadienyl complexes
- Coordinative unsaturation
- Oxidative addition reactions
- Insertion reactions
- Fluxional molecules and their characterization
- Compounds with metal-metal bonds and metal atom clusters

14. Main Group Chemistry:

- Boranes, borazines, phosphazenes, and cyclic phosphazene
- Silicates and silicones
- Interhalogen compounds
- Sulphur-nitrogen compounds
- Noble gas compounds

15. General Chemistry of 'f' Block Element:

- Lanthanides and actinides: separation, oxidation states, magnetic and spectral properties
- Lanthanide contraction

UPSC CSE Chemistry Syllabus 2024 Paper 2

1. Delocalised Covalent Bonding:

- Aromaticity, anti-aromaticity
- Annulenes, azulenes, tropolones, fulvenes, sydnones

2.1 Reaction Mechanisms:

- General methods (both kinetic and non-kinetic) of study of mechanisms or organic reactions:
 - Isotopies, method cross-over experiment, intermediate trapping, stereochemistry
 - Energy of activation
 - Thermodynamic control and kinetic control of reactions

2.2 Reactive Intermediates:

- Generation, geometry, stability, and reactions of:

- Carbonium ions and carbanions
- Free radicals
- Carbenes, benzyne, and nitrenes

2.3 Substitution Reactions:

- SN1, SN2, and SNi mechanisms
- Neighbouring group participation
- Electrophilic and nucleophilic reactions of aromatic compounds including heterocyclic compounds—pyrrole, furan, thiophene, and indole

2.4 Elimination Reactions:

- E1, E2, and E1cb mechanisms
- Orientation in E2 reactions—Saytzeff and Hoffmann
- Pyrolytic syn elimination—acetate pyrolysis, Chugaev, and Cope eliminations

2.5 Addition Reactions:

- Electrophilic addition to C=C and CC
- Nucleophilic addition to C=O, CN, conjugated olefins, and carbonyls

2.6 Reactions and Rearrangements:

- Pinacol-pinacolone, Hoffmann, Beckmann, Baeyer-Villiger, Favorskii, Fries, Claisen, Cope, Stevens, and Wagner—Meerwein rearrangements
- Aldol condensation, Claisen condensation, Dieckmann, Perkin, Knoevenagel, Wittig, Clemmensen, Wolff-Kishner, Cannizzaro, and von Richter reactions
- Stobbe, benzoin, and acyloin condensations
- Fischer indole synthesis, Skraup synthesis, Bischler-Napieralski, Sandmeyer, Reimer-Tiemann, and Reformatsky reactions

3. Pericyclic Reactions:

- Classification and examples
- Woodward-Hoffmann rules—electrocyclic reactions, cycloaddition reactions [2+2 and 4+2], and sigmatropic shifts [1, 3; 3, 3; and 1, 5]
- FMO approach

4.1 Preparation and Properties of Polymers:

- Organic polymers: polyethylene, polystyrene, polyvinyl chloride, Teflon, nylon, terylene, synthetic and natural rubber

4.2 Biopolymers:

- Structure of proteins, DNA, and RNA

5. Synthetic Uses of Reagents:

- OsO₄, HIO₄, CrO₃, Pb(OAc)₄, SeO₂, NBS, B₂H₆, Na-Liquid NH₃, LiAlH₄, NaBH₄, n-BuLi, MCPBA

6. Photochemistry:

- Photochemical reactions of simple organic compounds
- Excited and ground states, singlet and triplet states
- Norrish-Type I and Type II reactions

7. Spectroscopy:

- Principle and applications in structure elucidation:
 - Rotational—Diatomic molecules; isotopic substitution and rotational constants
 - Vibrational—Diatomic molecules, linear triatomic molecules, specific frequencies of functional groups in polyatomic molecules
 - Electronic—Singlet and triplet states, n and transitions; application to conjugated double bonds and conjugated carbonyls, Woodward-Fieser rules, Charge transfer spectra
 - Nuclear Magnetic Resonance (1H-NMR): Basic principle, chemical shift and spin-spin interaction, and coupling constants
 - Mass Spectrometry: Parent peak, base peak, metastable peak, McLafferty rearrangement

