

Chemistry — Optional Syllabus

UPSC Civil Services (Main) Examination

The molecular world — atomic structure, bonding, reactions and spectroscopy.

Paper I	250 marks	3 hours
Paper II	250 marks	3 hours
Optional total	500 marks	Counts toward the Mains merit

Paper I syllabus 250 marks · 3 hours

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 , 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, semi-conductors.

4. The gaseous state and Transport Phenomenon :

- Equation of state for real gases, intermolecular interactions, and 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 , C_p and C_v , and ; J-T effect and inversion temperature; criteria for equilibrium, relation between equilibrium constant and thermodynamic quantities; Nernst heat theorem, introductory idea of 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, their significance and determination; excess thermodynamic functions and their determination.

8. Electrochemistry :

- Debye-Huckel theory of strong electrolytes and 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 and their role in ion-transport across the membranes (molecular mechanism), oxygen-uptake proteins, cytochromes and ferredoxins.

13. Coordination chemistry :

- (i) Bonding in transition of metal complexes. Valence bond theory, crystal field theory and its modifications; applications of theories in the explanation of magnetism and electronic spectra of metal complexes.
- (ii) 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.
- (iii) EAN rule, Synthesis structure and reactivity of metal carbonyls; carboxylate anions, carbonyl hydrides and metal nitrosyl compounds.
- (iv) 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.

Paper II syllabus 250 marks · 3 hours

1. Delocalised covalent bonding :

- Aromaticity, anti-aromaticity; annulenes, azulenes, tropolones, fulvenes, sydnones.

2. (i) Reaction mechanisms : General methods (both kinetic and non-kinetic) of study of

- mechanisms of organic reactions : isotopies, method cross-over experiment, intermediate trapping, stereochemistry; energy of activation; thermodynamic control and kinetic control of reactions.
- (ii) Reactive intermediates : Generation, geometry, stability and reactions of carbonium ions and carbanions, free radicals, carbenes, benzyne and nitrenes. (iii) Substitution reactions :—SN 1, SN 2, and SN i, mechanisms ; neighbouring group participation; electrophilic and nucleophilic reactions of aromatic compounds including heterocyclic compounds—pyrrole, furan, thiophene and indole.
- (iv) Elimination reactions :—E1, E2 and E1cb mechanisms; orientation in E2 reactions— Saytzeff and Hoffmann; pyrolytic syn elimination—acetate pyrolysis, Chugaev and Cope eliminations.
- (v) Addition reactions :—Electrophilic addition to C=C and CC; nucleophilic addition to C=O, CN, conjugated olefins and carbonyls.
- (vi) Reactions and Rearrangements :—(a) Pinacol-pinacolone, Hoffmann, Beckmann, Baeyer-Villiger, Favorskii, Fries, Claisen, Cope, Stevens and Wagner—Meerwein rearrangements.
- (b) Aldol condensation, Claisen condensation, Dieckmann, Perkin, Knoevenagel, Witting, 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. (i) Preparation and Properties of Polymers: Organic polymers polyethylene, polystyrene,

- polyvinyl chloride, teflon, nylon, terylene, synthetic and natural rubber.
- (ii) 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

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

Syllabus as per the official UPSC Civil Services (Main) Examination notification. Study notes for this optional are being added on RaahUPSC — raahupsc.com.