

Any of the following concepts and skills can be used in the competition without necessarily being flagged in the preparatory problems. Topics not highlighted in this list may be in the exam only if included in the preparatory problems. The preparatory problems may only contain up to six such new concepts in the theoretical tasks and two in the practical tasks. Examples of concepts that might be included are given at the end of this page.

Concepts and Skills Participants Should Know

Concepts – Appendix C

- Estimation of experimental errors, use of significant figures
- Nucleons, isotopes, radioactive decay and nuclear reactions (alpha, beta, gamma)
- Quantum numbers (n,l,m) and orbitals (s,p,d) in hydrogen-like atoms
- Hund's rule, Pauli exclusion principle
- Electronic configuration of main group and the first row transition metal atoms and their ions
- Periodic table and trends (electronegativity, electron affinity, ionization energy, atomic and ionic size, melting points, metallic character, reactivity)
- Bond types (covalent, ionic, metallic), intermolecular forces and relation to properties
- Molecular structures and simple VSEPR theory (up to 4 electronpairs)
- Balancing equations, empirical formulae, mole concept and Avogadro constant, stoichiometric calculations, density, calculations with different concentration units
- Chemical equilibrium, Le Chatelier's principle, equilibrium constants in terms of concentrations, pressures and mole fractions
- Arrhenius and Bronsted acid-base theory, pH, self ionization of water, equilibrium constants of acid-base reactions, pH of weak acid solutions, pH of very dilute solutions and simple buffer solutions, hydrolysis of salts
- Solubility constants and solubility
- Complexation reactions, definition of coordination number, complex formation constants
- Basics of electrochemistry: Electromotive force, Nernst equation
- Electrolysis, Faraday's laws
- Rate of chemical reactions, elementary reactions, factors affecting the reaction rate, rate law for homogeneous and heterogeneous reactions, rate constant, reaction order, reaction energy profile, activation energy, catalysis, influence of a catalyst on thermodynamic and kinetic characteristics of a reaction
- Energy, heat and work, enthalpy and energy, heat capacity, Hess' law, standard formation enthalpies, solution, solvation and bond enthalpies
- Definition and concept of entropy and Gibbs' energy, second law of thermodynamics, direction of spontaneous change

- Ideal gas law, partial pressures
- Principles of direct and indirect titration (back titration)
- Acidi- and alkalimetry, acidimetric titration curves, choice and color of indicators for acidimetry
- Redox titrations (permanganometric and iodometric)
- Simple complexometric and precipitation titrations
- Basic principles of inorganic qualitative analysis for ions specified in factual knowledge, flame tests
- Lambert-Beer law
- Organic structure-reactivity relations (polarity, electrophilicity, nucleophilicity, inductive effects, relative stability)
- Structure-property relations (boiling point, acidity, basicity)
- Simple organic nomenclature
- Hybridization and geometry at carbon centers
- Sigma and pi bonds, delocalization, aromaticity, mesomeric structures
- Isomerism (constitutional, configuration, conformation, tautomerism)
- Stereochemistry (E-Z, cis-trans isomers, chirality, optical activity, Cahn-Ingold-Prelog system, Fisher projections)
- Hydrophilic and hydrophobic groups, micelle formation
- Polymers and monomers, chain polymerizations, polyaddition and polycondensation

Laboratory skills

- Heating in the laboratory, heating under reflux
- Mass and volume measurement (with electronic balance, measuring cylinder, pipette and burette, volumetric flask)
- Preparation and dilution of solutions and standard solutions
- Operation of a magnetic stirrer
- Carrying out of test tube reactions
- Qualitative testing for organic functional groups (using a given procedure)
- Volumetric determination, titrations, use of a pipette bulb
- Measurement of pH (by pH paper or calibrated pH meter)

Factual knowledge Students Should Know

- Reactions of s-block elements with water, oxygen and halogens, their color in flame tests
- Stoichiometry, reactions and properties of binary non-metal hydrides

- Common reactions of carbon, nitrogen and sulfur oxides (CO, CO₂, NO, NO₂, N₂O₄, SO₂, SO₃)
- Common oxidation states of p-block elements, stoichiometry of common halides and oxoacids (HNO₂, HNO₃, H₂CO₃, H₃PO₄, H₃PO₃, H₂SO₃, H₂SO₄, HOCl, HClO₃, HClO₄)
- Reaction of halogens with water
- Common oxidation states of first row transition metals (Cr(III), Cr(VI), Mn(II) Mn(IV), Mn(VII), Fe(II), Fe(III), Co(II), Ni(II), Cu(I), Cu(II), Ag(I), Zn(II), Hg(I), and Hg(II))and the color of these ions
- Dissolution of these metals and Al, amphoteric hydroxides (Al(OH)₃, Cr(OH)₃, Zn(OH)₂)
- Permanganate, chromate, dichromate ions and their redox reactions
- Iodometry (reaction of thiosulfate and iodine) Identification of Ag⁺, Ba²⁺, Fe³⁺, Cu²⁺, Cl⁻, CO₃²⁻, SO₄²⁻

Organic:

- Common electrophiles and nucleophiles
- Electrophilic addition: addition to double and triple bonds, regioselectivity
- (Markovnikoff's rule), stereochemistry
- Electrophilic substitution: substitution on aromatic rings, influence of substituents on the reactivity and regioselectivity, electrophilic species
- Elimination: E₁ and E₂ reactions at sp³ carbon centers, stereochemistry, acid-base catalysis, common leaving groups
- Nucleophilic substitution: SN₁ and SN₂ reactions at sp³ carbon centers, stereochemistry
- Nucleophilic addition: addition to carbon-carbon and carbon-hetero atom double and triple bonds, addition-elimination reactions, acid-base catalysis
- Radical substitution: reaction of halogens and alkanes
- Oxidations and reductions: switching between the different oxidation levels of common functional groups (alkyne – alkene – alkane – alkyl halide, alcohol – aldehyde, ketone – carboxylic acid derivatives, nitriles – carbonates)
- Cyclohexane conformations
- Grignard reaction, Fehling and Tollens reaction
- Simple polymers and their preparation (polystyrene, polyethylene, polyamides, polyesters)
- Amino acids and their classification in groups, isoelectric point, peptide bond, peptides and proteins
- Carbohydrates: open chain and cyclic form of glucose and fructose
- Lipids: general formulae of triacyl glycerides, saturated and unsaturated fatty acids

Examples of Concepts and Skills Allowed in the Exam (only if included and demonstrated in the preparatory problems)

Six theoretical and two practical topics from these or other topics of similar breadth are allowed in a preparatory problem set. It is intended that a topic can be introduced and discussed in a lecture of 2-3 hours before a prepared audience.

- VSEPR theory in detail (with more than 4 ligands)
- Inorganic stereochemistry, isomerism in complexes
- Solid state structures (metals, NaCl, CsCl) and Bragg's law
- Relation of equilibrium constants, electromotive force and standard Gibbs energy
- Integrated rate law for first order reactions, half-life, Arrhenius equation, determination of activation energy
- Analysis of complex reactions using steady-state and quasi-equilibrium approximations, mechanisms of catalytic reactions, determination of reaction order and activation energy for complex reactions

- Collision theory
- Simple phase diagrams and the Clausius-Clapeyron equation, triple and critical points
- Stereoselective transformations (diastereoselective, enantioselective), optical purity
- Conformational analysis, use of Newman projections, anomeric effect
- Aromatic nucleophilic substitution, electrophilic substitution on polycyclic aromatic compounds and heterocycles
- Supramolecular chemistry
- Advanced polymers, rubbers, copolymers, thermosetting polymers. Polymerization types, stages and kinetics of polymerization
- Amino acid side groups, reactions and separation of amino acids, protein sequencing
- Secondary, tertiary and quaternary structures of proteins, non-covalent interactions, stability and denaturation, protein purification by precipitation, chromatography and electrophoresis
- Enzymes and classification according to reaction types, active sites, coenzymes and cofactors, mechanism of catalysis
- Monosaccharides, equilibrium between linear and cyclic forms, pyranoses and furanoses, Haworth projection and conformational formulae
- Chemistry of carbohydrates, oligo- and polysaccharides, glycosides, determination of structure
- Bases, nucleotides and nucleosides with formulae, Functional nucleotides, DNA and RNA, hydrogen bonding between bases, replication, transcription and translation, DNA based applications

- Complex solubility calculations (with hydrolyzing anions, complex formation)
- Simple Schrödinger equations and spectroscopic calculations
- Simple MO theory
- Basics of mass spectrometry (molecular ions, isotope distributions)
- Interpretation of simple NMR spectra (chemical shift, multiplicity, integrals)
- Synthesis techniques: filtrations, drying of precipitates, thin layer chromatography.
- Synthesis in microscale equipment
- Advanced inorganic qualitative analysis
- Gravimetric analysis
- Use of a spectrophotometer
- Theory and practice of extraction with immiscible solvents
- Column chromatography