# Appendix C

## *Concepts and skills expected to be known by all participants:*

(predominantly equivalent to former number 1 and 2 topics)

### Concepts

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);

## *Examples of concepts and skills allowed in the exam only if included and demonstrated in the preparatory problems*

6 theoretical and 2 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;

# Appendix D

## *Outline of the factual knowledge supposed to be known by the competitors:*

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, $CO_2$, NO, $NO_2$, $N_2O_4$, $SO_2$, $SO_3$);
Common oxidation states of p-block elements, stoichiometry of common halides and oxoacids ($HNO_2$, $HNO_3$, $H_2CO_3$, $H_3PO_4$, $H_3PO_3$, $H_2SO_3$, $H_2SO_4$, HOCl, $HClO_3$, $HClO_4$);
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 $Ag^+$, $Ba^{2+}$, $Fe^{3+}$, $Cu^{2+}$, $Cl^-$, $CO_3^{2-}$, $SO_4^{2-}$ ;

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 $sp^3$ carbon centers, stereochemistry, acid-base catalysis, common leaving groups;
Nucleophilic substitution: SN1 and SN2 reactions at $sp^3$ 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;