# Draft recommendations

# Paragraph 10 of the regulations

(1) The organizer distributes a set of preparatory tasks written in English to all participating countries in the January of the competition year. The preparatory tasks are intended to give students a good idea of the type and difficulty of the competition tasks, including safety aspects (see §12 and Appendix “B”). SI units must be used throughout the preparatory tasks.

(2) Leave as it is.

(3) Appendix C of the regulations contains a list of concepts and skills expected to be mastered by the participants. Organizers may freely include questions and tasks in the theoretical or experimental competition based on the knowledge listed there.
The organizer can include problems in the exams based on the use of concepts and skills from not more than 6 theoretical and 2 practical fields outside this list, if a minimum of 2 tasks from each field is included and the necessary skills demonstrated in the set of preparatory problems. Examples of such external fields are also listed in Appendix C. Fields not already listed should have a breadth similar to the examples. These 6 theoretical and 2 practical fields must be stated explicitly at the beginning of the Preparatory problems. If an equation not covered by the listed fields is required for the solution of the exam questions, then this should be defined in the exam text.

(4) Appendix D contains an outline of the factual knowledge supposedly familiar to the competitors. If specific facts not included here are required for the solution of the exam questions, then these should be included in the exam text or in the preparatory problems and their solutions.

(5) Leave as it is

# 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 principle;
Electronic configuration of main group and the first row transition metal atoms and their ions;

Periodic table and trends (electronegativity, electronaffinity, 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 e pairs);

Balancing equations, empirical formulae, mole concept and Avogadro's number, 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, hydrolyis 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 tiration (back titration);
Acidi and alkalimetry, acidimetric titration curves, choice and colour 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);

## 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 thiosulphate 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: $S_N1$ and $S_N2$ 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;

## *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 hydrolysing 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;