

Regulations of the International Chemistry Olympiad (IChO)

(valid from August 1, 2023)

General Statement

§ 1 Aims of the competition

- (1) The International Chemistry Olympiad (IChO) is a chemistry competition for students at secondary school level with the aim of promoting international contacts in chemistry. It is intended to stimulate the activities of students interested in chemistry by way of the independent and creative solution of chemical problems. The IChO competitions help to facilitate cordial relations between young adults of different nationalities; they encourage cooperation and international understanding.
- (2) No country may have its team excluded from participation on reasons resulting from political tensions, lack of diplomatic relations or recognition by the government of the organizing country and similar reasons. When difficulties preclude formal invitation of a team representing a country, students from such a country should be invited to participate as individuals.
The competition is conducted in an atmosphere designed to promote collaboration and friendship in the scientific community. Conflicts outside the scope of the competition should not be reflected in any activity during the competition. Discrimination against any individuals, groups or countries based on nationality, race, gender or belief is prohibited.

Organization of the IChO

§ 2 Organization and invitation

- (1) The IChO is organized every year in July, in one of the participating countries by the Education Ministry or an appropriate institution of the organizing country (hereafter referred to as the organizer).
- (2) Unless directed otherwise by the International Jury, the organizer is obliged to invite all countries that participated with a team during either of the preceding two IChO competitions. The official invitation to participate in the forthcoming IChO should be sent to countries by the November preceding the competition. The countries invited must confirm their participation in the IChO according to the requirements of the organizer.
- (3) Countries not automatically invited to the IChO must apply to the organizer by the end of November preceding the Olympiad. The organizer invites these countries to the Olympiad based on the recommendation of the Steering Committee. Participating countries are expected to select representative teams in an open process.

Newly invited countries must send an observer to two consecutive Olympiads before its pupils can participate in the IChO. The observer participates in Jury meetings and all Olympiad procedures as a non-voting member in order to learn about the content and procedure of the competition.

§ 3 Delegations

- (1) Each participating country's delegation consists of competitors and accompanying persons (also known as mentors). It is expected that there are four competitors and two mentors in the delegation.
- (2) The competitors are secondary school students or recent graduates who have not started university education. The graduation date of participants must not be earlier than the most recent graduation before July 1st of the competition year. Exceptions can be made for special cases (e.g., compulsory military service) on the advice of the Steering Committee. Competitors must be under 20 years of age on the 1st of July of the year of the competition.
The competitors must be passport holders of the country they represent or have taken part in the secondary school educational system of this country for more than one academic year.
- (3) The mentors:
 - a) act as members of the International Jury (see § 6). One of the mentors is designated as the head of delegation (head mentor),
 - b) must guarantee the fulfillment of those conditions specified in section 2 of this paragraph,
 - c) must be capable of translating the text of the competition tasks from English into the language used by their students and be able to judge the set of tasks and correct the work of the students.
 - d) have the right to enter a protest which should be addressed to the Chair of the Steering Committee and, when necessary, ask for a resolution of the problem at the next meeting of the International Jury.
- (4) Each country's delegation with four registered students may register two scientific observers who assist in the work of the mentors. A delegation cannot have more adults than students participating live.
Members of the Steering Committee who are not mentors may register as additional scientific observers. Approved future organizers can also register two additional scientific observers from their organizing committee. Scientific observers pay an observer fee determined by the host country.
- (5) Participating countries may register translators who can remotely assist mentors in the exam translation and grading using electronic means. Translators are required to abide by the same secrecy rules as mentors, and they participate in no other IChO activity.
The size of a delegation (students, mentors, observers, and translators) should not exceed 10 persons.

§ 4 Obligations of the Organizer

- (1) The organizer provides:
 - a) the itinerary of the IChO,
 - b) transportation from/to an airport/station (which is designated by the host country) on the day of arrival and departure,
 - c) that the organization of the competition will adhere to the regulations,
 - d) accident insurance for all participants in connection with the itinerary,

- e) the opportunity for the mentors to inspect the working room and practical apparatus to be used for the practical tasks before the competition takes place,
 - f) all necessary arrangements for the observance of safety regulations,
 - g) the medals, certificates, and prizes, which are presented at the official closing ceremony,
 - h) a report on the competition to be distributed not later than six months after the competition.
- (2) A meeting of the Steering Committee must be hosted in the organizing country at least five months prior to the IChO. The organizing country will provide some travel assistance.

§ 5 Financing

- (1) The participating country covers the return travel costs of the students and the accompanying persons to the designated airport/station or to the location where the competition is held.
- (2) Participating countries must pay a participation fee, the amount of which must be approved by the International Jury. If the organizers request payment in a different currency than the predetermined amount, then the equivalent amount must be published at least 5 months prior to the IChO.
- (3) Scientific observers pay a participation fee determined by the organizer. The organizer must announce the amount at least one year ahead.
- (4) All members of a delegation must provide themselves with medical insurance for the journey to and from the organizing country and for the period of their stay in the organizing country.
- (5) All other costs incurred in connection with the organized program, including the costs of accommodation for all competitors and members of the International Jury, are covered by the organizer.
- (6) The organizers of the next two consecutive Olympiads may send two observers to the current IChO with their expenses covered by the host as mentioned in § 5, section 3.
- (7) Delegations that did not pay their participation fee, or are not insured, cannot participate in the IChO.

Institutions of the IChO

§ 6 International Jury

- (1) The International Jury of the IChO consists of the head mentors from the countries participating in the olympiads. The term of the Jury starts at the opening ceremony of the olympiad and finishes at the opening of the following olympiad. .
- (2) The chair of the Steering Committee or his/her delegate calls and chairs the meetings of the International Jury.
- (3) The working language of the International Jury is English.

- (4) Each participating country has one vote. Resolutions are passed with a simple majority of the votes cast. Changes in the regulations require a qualified majority of two thirds of all Jury members. The decisions of the International Jury are binding for both organizer and participants.
- (5) The discussion of the tasks may take place in two simultaneous meetings (split sessions) where the head mentors delegate a representative to discuss and vote on a subset of tasks.
- (6) The work of the International Jury can be assisted with secure electronic and online tools. The International Jury might fulfill some of its responsibilities (§ 7) through a remote vote when the Jury is not in session.

§ 7 Responsibilities of the International Jury

- (1) The International Jury:
 - a) is in charge of the actual competition and its supervision according to the regulations,
 - b) approves future organizers for the IChO,
 - c) discusses in advance the competition tasks presented by the organizer, their solutions and the marking guidelines, gives comments and takes decisions in case of changes,
 - d) supervises the marking of the examination papers and guarantees that all participants are judged by equal criteria,
 - e) monitors the competition and suggests changes to the regulations, organization and contents for future IChOs,
 - f) makes decisions on the exclusion of a participant or an entire team from the competition (see also § 11, section 7),
 - g) elects members of the Steering Committee of the IChO,
 - h) may form working groups to solve specific chemistry related problems of the IChO.
- (2) The members of the delegations and the organizers:
 - a) are obliged to maintain a professional discretion about any relevant information they receive during the IChO and must not assist any participants,
 - b) keep the marking and results secret until announced by the International Jury.

§ 8 Steering Committee

- (1) The long-term work involved in organizing the International Chemistry Olympiads is coordinated by the Steering Committee.
- (2) Six members of the Committee are elected by the International Jury by a secret ballot to serve a two-year term. The term of the elected committee begins on the 1st day after the IChO. Members are elected for no more than two consecutive terms.
- (3) There are the following ex-officio members of the Steering Committee:
 - a) a representative of the current IChO,
 - b) a representative of the immediately preceding IChO,

- c) a representative of each of the approved IChO organizers for the three subsequent years,
 - d) a representative of every other approved future IChO organizer as a non-voting member of the Steering Committee
 - e) the immediate past chair of the SC (for one year only)
- (4) The incoming Steering Committee elects its own Chair from among its elected members at a meeting held before the committee's term begins.
- The Chair:
- a) calls and chairs the meetings of the Steering Committee,
 - b) calls and chairs the meetings of the International Jury,
 - c) may invite non-voting guests to the meetings of the Steering Committee after consultation with the host of the meeting,
 - d) has the right to call extraordinary meetings of the International Jury when necessary.
- (5) The Steering Committee:
- a) provides organizational oversight for the International Chemistry Olympiad and gives recommendations for organizers,
 - b) proposes items for consideration at the International Jury sessions.
 - c) may co-opt 1–3 non-voting members for their particular expertise for periods of one year.
- (6) The Steering Committee is not empowered to make any decisions affecting the International Chemistry Olympiad that would interfere with the duties and responsibilities of the International Jury (see § 6 and 7).

§ 9 Associated organizations

- (1) There is an International Information Center of the International Chemistry Olympiads gathering and providing (when necessary) all the documentation of the IChOs from the beginning of the Olympiads to the present. The seat of the Office is in Bratislava, Slovakia.
- (2) The IChO Endowment Fund is a registered non-profit organization that supports activities related to the International Chemistry Olympiad and its participants. Its sole aim is to contribute to the organization and development of the Olympiad and its institutions in close cooperation with the International Jury and the Steering Committee. It gathers contributions from sponsors supporting the International Chemistry Olympiad.
- The Board of Trustees of the IChOEF consists of former or current elected members of the Steering Committee.

Competition

§ 10 Preparation for the IChO competition

- (1) The organizer distributes a set of preparatory tasks written in English to all participating countries in 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 A and B). SI units should be used throughout the preparatory tasks.

- (2) Organizers are required to engage members of the Steering Committee when finalizing preparatory questions to check the number of advanced topics and the proportions of the fields of chemistry.
- (3) The total number of theoretical and experimental tasks in the set of preparatory problems must be between 25-30 and 5-10, respectively.
- (4) Appendix C of the regulations contains a syllabus 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 3 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 listed in Appendix C. Fields not already listed should have a breadth similar to the examples. These 6 theoretical and 3 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.
If specific facts, not included in Appendix C, 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) Training or any other special instruction, that is carried out for a selected group of 50 or fewer students, containing the IChO team, must be no longer than two weeks.

§ 11 Organization of the IChO Competition

- (1) The competition consists of two parts:
 - a) part one, the practical (experimental) competition,
 - b) part two, the theoretical competition.
- (2) A working time of four to five hours is allotted for each part. There is at least one day of rest between the two parts.
- (3) Competitors receive all relevant information in the language of their choice.
- (4) There must be no contact between mentors and competitors once the mentors have received the competition tasks for consideration. Information regarding the competition tasks must not be passed to the competitors directly or indirectly prior or during the competition.
- (5) When pocket calculators are not provided by the organizer, only non-programmable pocket calculators may be used in the competition.
- (6) The safety regulations announced by the organizer are binding for all participants.
- (7) Breaking of any of the rules given in the preceding paragraphs (§ 3. section 2, § 10 section 5, § 11 sections 4, 5, and 6) has as its consequence exclusion from the whole or a part of the competition.

§ 12 Safety

- (1) During the experimental part, the competitors must wear laboratory coats and eye protection. The competitors are expected to bring their own laboratory coats. Other means of protection for laboratory work are provided by the organizer.
- (2) When handling liquids, each student must be provided with a pipette ball or filler. Pipetting by mouth is strictly forbidden.
- (3) The use of acutely toxic substances (GHS hazard statement H300, H310, H330) is strictly forbidden. The use of toxic substances is not recommended but may be allowed if special precautions are taken. Substances with GHS hazard statements H340, H350, H360 (proven mutagens, carcinogens, and teratogens) must not be used under any circumstances (see Appendix B for definitions of these categories).
- (4) Detailed recommendations involving students' safety and the handling and disposal of chemicals can be found in Appendices A 1, A 2, and B.
 - a) Appendix A 1: Safety Rules for Students in the laboratory.
 - b) Appendix A 2: Safety Rules and Recommendations for the Host Country of the IChO.
 - c) Appendix B contains a reference to the hazard symbols and statements of the Globally Harmonized System of Classification of Chemicals (GHS), the use of which is expected in labeling and classifying materials used at the IChO.

§ 13 Competition Tasks

- (1) The organizer is responsible for the preparation of competition tasks by competent experts/authors, who constitute the Scientific Board of the IChO. They propose the methods of solution and the marking scheme.
- (2) The tasks, their solutions and the marking schemes are submitted to the International Jury for consideration and approval. The authors of the tasks should be present during the discussion.
- (3) The host is to organize a mock exam immediately prior to the IChO with the participation of 5-10 volunteer outside experts familiar with the IChO (e.g., SC members, mentors). The mock exam should be held under the same conditions as the actual competition.
- (4) The total length of the theoretical or experimental tasks, including the additional text in the answer sheets, should be kept to a minimum and not exceed 25,000 characters not counting spaces, equations and structures in the official English version.
- (5) SI units should be used throughout the competition tasks.
- (6) In the experimental part of the competition the following conditions must be fulfilled:
 - a) The experimental part must contain at least two independent tasks.
 - b) The marking cannot require subjective interpretation by the staff.
 - c) Competitors must receive the same substances when solving the tasks from qualitative analytical chemistry.

- d) When solving tasks from quantitative analytical chemistry competitors must receive the same substances but with different concentrations.
- e) In evaluating the quantitative tasks the master values must not be based on an average of the results of the competitors.
- f) The great majority of the grade in quantitative tasks must be given to the mean value as reported by the competitors while some marks may also be given to the corresponding equations, calculations, or explanations directly related to the work. Points must not be awarded for reproducibility.

§ 14 Correcting and Marking

- (1) A maximum of 60 points is allocated to the theoretical tasks and 40 points to the practical tasks, making a total of 100 points. The points for the practical tasks include marks for the evaluation and interpretation of the results.
- (2) The competition tasks are corrected independently by the authors and by the mentors. Consequential marking should be used so that students are not punished twice for the same error. Both corrections are then compared; however, the authors present their evaluation first. After a discussion the final score for each participant is reached and agreed on by both sides. The organizer retains the original marked manuscripts.
- (3) The International Jury discusses the results and decides on the final scores.
- (4) In order to eliminate any doubts about possible mistakes in the processing of the results the organizer must provide the mentors with a list of their students' total results before the closing award ceremony.

§ 15 Results and Prizes

- (1) The best 10% to 12% of all competitors receive gold, the next 20% to 22% silver, and the following 30% to 32% bronze medals.
- (2) An honorable mention is received by non-medalists who are in the best 70 to 71% of all competitors.
- (3) The exact number of recipients for each award is determined automatically to yield the largest possible difference in the marks of students receiving different honors. In the case of identical differences, the one resulting in more medals will be selected.
- (4) Each medalist must receive the medal and a corresponding certificate from the organizer.
- (5) In addition to the medals other prizes may be awarded.
- (6) Each competitor receives a certificate of participation.
- (7) In the awarding ceremony, the non-medalists are called alphabetically.
- (8) Team classification is not made.
- (9) The organizer must provide a complete list of results as a part of the final report.

§ 16 Final Regulations

- (1) Those who take part in the competition acknowledge these regulations through their participation.
- (2) This version of regulations has been approved by the International Jury in Zürich, July 2023 and is issued to replace the former regulations approved remotely in June 2021.
- (3) The regulations are valid from the 1st of August, 2023. Changes to the regulations can be made only by the International Jury and require a qualified majority (two third of the votes with regard to total number of participating countries).

APPENDIX A

A 1: SAFETY RULES FOR STUDENTS IN THE LABORATORY

All students of chemistry must recognize that hazardous materials cannot be completely avoided. Chemists must learn to handle all materials in an appropriate fashion. While it is not expected that all students participating in the International Chemistry Olympiad know the hazards of every chemical, the organizers of the competition will assume that all participating students know the basic safety procedures. For example, the organizers will assume that students know that eating, drinking, or smoking in the laboratory or tasting a chemical is strictly forbidden. In addition to the commonsense safety considerations to which students should have been previously exposed, some specific rules, listed below, must also be followed during the Olympiad. If any question arises concerning safety procedures during the practical exam, the student should not hesitate to ask the nearest supervisor for directions.

Rules regarding personal protection

1. Eye protection must be worn in the laboratories at all times. If the student wears contact lenses, full protection goggles must also be worn. Eye protection will be provided by the host country.
2. A laboratory coat is required. Each student will supply this item for himself/herself.
3. Long pants and closedtoed shoes are recommended for individual safety. Long hair and loose clothing should be confined.
4. Pipetting by mouth is strictly forbidden. Each student must be provided with a pipette bulb or pipette filler.

Rules for Handling Materials

1. Specific instructions for handling hazardous materials will be included by the host country in the procedures of the practical exam. All potentially dangerous materials will be labeled using the GHS symbols. Each student is responsible for recognizing these symbols and knowing their meaning (see Appendix B).
2. Do not indiscriminately dispose chemicals in the sink. Follow all disposal rules provided by the host country.

A 2: SAFETY RULES AND RECOMMENDATIONS FOR THE HOST COUNTRY OF THE INTERNATIONAL CHEMISTRY OLYMPIAD

Certainly, it can be assumed that all students participating in the IChO have at least modest experience with safety laboratory procedures. However, it is the responsibility of the International Jury and the organizing country to be sure that the welfare of the students is carefully considered. Reference to the Safety Rules for Students in the Laboratory will show that the students carry some of the burden for their own safety. Other safety matters will vary from year to year, depending on practical tasks. The organizers of these tasks for the host country are therefore assigned responsibility in the areas listed below. The organizers are advised to carefully test the practical tasks

in advance to ensure the safety of the experiments. This can best be accomplished by having students of ability similar to that of IChO participants carry out the testing.

Rules for the Host Country (see also A 1):

1. Emergency firstaid treatment should be available during the practical examination.
2. Students must be informed about the proper methods of handling hazardous materials.
 - a) Specific techniques for handling each hazardous substance should be included in the written instructions of the practical examination.
 - b) All bottles (containers) containing hazardous substances must be appropriately labeled using internationally recognized symbols (see Appendix B).
3. Chemical disposal instructions should be provided to the students within the written instructions of the practical examination. Waste collection containers should be used for the chemicals considered hazardous to the environment.
4. The practical tasks should be designed for appropriate (in other words, minimum) quantities of materials.
5. The laboratory facilities should be chosen with the following in mind:
 - a) Each student should not only have adequate space in which to work, but should be at a safe distance from other students.
 - b) There should be adequate ventilation in the rooms and a sufficient number of hoods when needed.
 - c) There should be more than one emergency exit for each room.
 - d) Fire extinguishers should be nearby.
 - e) Electrical equipment should be situated in an appropriate spot and be of a safe nature.
 - f) There should be appropriate equipment available for cleanup of spills.
6. It is recommended that one supervisor be available for every four students in the laboratory to adequately ensure safe conditions.
7. The organizers should follow international guidelines for the use of toxic, hazardous or carcinogenic substances in the IChO.

APPENDIX B

HAZARD WARNING SYMBOLS AND HAZARD DESIGNATIONS

Chemicals used in the IChO laboratory experiments need to be labeled according to the Globally Harmonized System of Labelling of Chemicals (GHS) standard developed by the United Nations. The organizing country should use the locally legislated GHS system (pictograms, hazard statements, etc.) if it exists. If such rules do not exist, the original GHS directives (http://www.unece.org/trans/danger/publi/ghs/ghs_welcome_e.html) and the GHS compliant documentation by the chemical providers should be used.

Appendix C

Knowledge expected to be known by all participants:

Awareness of experimental errors, use of significant figures;

Mathematics skills commonly encountered at secondary school level, including solving quadratic equations, use of logarithms and exponentials, solving simultaneous equations with 2 unknowns, the meaning of sine and cosine, elementary geometry such as Pythagoras' theorem, plotting graphs (more advanced math skills such as differentiation and integration, if required must be included as one of the advanced topics)

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, coordination), intermolecular forces and relation to properties;

Lewis theory;

Molecular structures and VSEPR theory;

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;

Partition coefficients: definition and simple calculations;

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, Arrhenius-equation, catalysis, influence of a catalyst on thermodynamic and kinetic characteristics of a reaction;

Use of simple first-order and zeroth-order kinetic rate laws, exponential decay, half-lives;

Energy, heat and work, enthalpy and energy, heat capacity, Hess' law, Born-Haber cycle, standard formation enthalpies, solution, solvation and bond enthalpies;

Definition and concept of entropy and Gibbs' energy, second law of thermodynamics, direction of spontaneous change;

Calculation of equilibrium constants from standard enthalpy and entropy data

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;

Basic concepts of light and color, wavelength, frequency, wave numbers, photon energies, Lambert-Beer law;

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 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 and other centers;

Sigma and pi bonds, delocalization, aromaticity, resonance structures;

Isomerism (constitutional, configuration, conformation, tautomerism)

Stereochemistry (E/Z, cis/trans isomers, chirality, optical activity, Cahn-Ingold-Prelog

system, Fisher projections, D/L);
Cyclohexane conformations;

Common electrophiles and nucleophiles

Electrophilic addition: addition to double and triple bonds, regioselectivity (Markovnikoff/Kharasch 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 with 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)

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 forms;

Structures of glucose and fructose;

Lipids: general formulae of di- and triacyl glycerides, saturated and unsaturated fatty acids;

General structure of DNA and RNA, hydrogen bonding between bases, the concept of replication and transcription;

Use of common protecting groups in organic synthesis;

Simple multistep organic synthesis;

Hydrophilic and hydrophobic groups, micelle and bilayer formation;

Polymers and monomers, chain polymerizations, polyaddition and polycondensation;

Laboratory skills expected to be known by all participants:

Heating in the laboratory, heating under reflux;

Mass and volume measurement (with electronic balance, measuring cylinder, pipette and burette, volumetric flask);

Reading temperature from a non-digital thermometer;

Preparation and dilution of solutions and standard solutions;

Operation of a magnetic stirrer;

Carrying out of test tube reactions (e.g. qualitative testing for organic functional groups using a given procedure);

Volumetric determination, titrations, use of a pipette bulb or filler;

Measurement of pH (by pH paper or calibrated pH meter);

Gravity filtration;

Drying of precipitates;

Operation of simple semi-automatic digital instruments using detailed instructions (not application specific)
Plotting experimental data on graphs, analysis of graphs

Examples of concepts and skills allowed in the exam only if included and demonstrated in the preparatory problems (“Fields of advanced difficulty”)

6 theoretical and 3 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. The list below only contains examples. Problem authors are expected to include similar fields in their preparatory problems.

Theoretical

- Inorganic stereochemistry, isomerism in coordination compounds;
- Solid state structures, basic unit cells (metals, NaCl, CsCl), cell parameters, Bragg's law, solid sphere model, space filling ratios, ratios of ionic radii;
- Crystal field theory, calculation of magnetic moment;
- Thermodynamic cycles, adiabatic processes, work of adiabatic processes, adiabatic flame temperatures, heat engine efficiency;
- Variation of equilibrium constant with temperature, complex calculations of equilibrium constants from thermodynamic data;
- Calculations of electrochemical data (e.g. cell potentials) from thermodynamic data or equilibrium constants and vice versa;
- Latimer, Frost and Pourbaix diagrams;
- Rate laws beyond simple zeroth and first order reactions, kinetic isotope effects;
- 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, (also possibly applied to kinetics of enzyme catalysis);
- Kinetic theory of gases, collision theory;
- Phase diagrams, the Clausius-Clapeyron equation, triple and critical points;
- Advanced stereochemistry: axial chirality, planar chirality;
- Stereoselective transformations (diastereoselective, enantioselective), optical purity, enantiomeric and diastereomeric excess;
- Conformational analysis, use of Newman projections, anomeric effect;
- Aromatic nucleophilic substitution;
- Electrophilic substitution on polycyclic aromatic compounds and heterocycles;
- Pericyclic reactions (cycloadditions, sigmatropic rearrangements, electrocyclic reactions), regioselectivity, stereoselectivity and stereospecificity;
- Advanced polymers, rubbers, copolymers, thermosetting polymers. Polymerization types, stages and kinetics of polymerization;
- Monosaccharides, pyranoses and furanoses, Haworth projection and conformational formulae, oligo- and polysaccharides, glycosides, determination of structure;
- Amino acid side groups, reactions and separation of amino acids, protein sequencing;

- Biosynthesis of peptides and proteins: translation, genetic code, mRNA and tRNA, codone-anticodone interaction, aminoacyl tRNA synthetases,
- Nucleobases, nucleosides and nucleotides with formulae, Functional nucleotides, PCR, DNA chips;
- Secondary, tertiary and quaternary structures of proteins, non-covalent interactions, protein folding and processing; stability and denaturation, protein purification by precipitation, chromatography and electrophoresis;
- Enzymes and classification according to reaction types, active sites, coenzymes and cofactors, mechanisms of enzyme catalysis, catalytic constants, inhibitors and activators;
- Complex solubility calculations (with hydrolyzing anions, complex formation);
- Quantum mechanics: simple Schrödinger equations, particle in a box, calculation of orbital and spin angular momentum;
- Spectroscopic calculations: energetics of rotational, vibrational, and electronic transitions using simple model theories;
- Simple MO theory;
- Basics of mass spectrometry (molecular ions, isotope distribution);
- Basics of IR spectroscopy (types of vibrations, characteristic peaks)
- Interpretation of simple ^1H and ^{13}C NMR spectra (chemical shift, multiplicity, integrals);
- Interpretation of simple heteronuclear NMR spectra (e.g., ^{11}B , ^{19}F or ^{31}P);

Practical

- Synthesis techniques: vacuum filtration, thin layer chromatography;
- Synthesis in microscale equipment;
- Advanced inorganic qualitative analysis;
- Use of a spectrophotometer;
- Extraction with immiscible solvents;
- Column chromatography;
- Recrystallization;
- Distillation;
- Vacuum distillation, use of a nomogram;
- Viscometry;
- Analysis of experimental data with spreadsheet software;