Final exam items
MSc in Chemistry
University of Pécs, Faculty of Science

Note: the candidate selects two of the four topics at random and draws 1-1 items from the topics. The details include the areas that the student is expected to explicate. Additional questions may arise during the exam.

TOPIC 1. INORGANIC CHEMISTRY

1. Describe the most important inorganic compounds of alkali and alkaline earth metals, their organometallic derivatives and bio-inorganic, chemically significant complexes! (hydrides, halides, oxygen-containing derivatives; complexes with crown ethers and cryptands, as well as biologically important multidentate ligands; alkaline earth metal organics and their synthetic applications)

2. Describe the most important inorganic compounds of boron and aluminum, and their organic derivatives! (hydrides, halides, oxygen-containing derivatives; organoboron compounds and their synthetic applications; synthesis of organoaluminum compounds and their practical applications)

3. Describe the most important inorganic compounds of silicon, tin and lead, and their organic derivatives! (hydrides, halides, oxygen-containing derivatives, silicates; organosilicon derivatives of practical importance; synthesis of organotin compounds and their application in catalysis; lead derivatives, lead binding in biological systems)

4. Describe the oxygen-containing compounds of nitrogen, phosphorus and arsenic. How nitrogen and phosphorus are incorporated into biological systems? (oxygen compounds, complexes, oxoacids; important esters of oxoacids; nitrogen fixation in biological systems; phosphanes, phosphites as ligands in transition metal complexes)

5. Describe the oxygen, sulfur and selenium compounds as well as compounds of practical interest! (derivatives formed with hydrogen; oxoacids, esters; strength of acids; incorporation of elements into biological systems; oxygen complexes, organoselenium derivatives)

6. Compare halogens and their compounds in terms of their redox reactions! Describe the significant fluorine and iodine compounds! (halides, interhalogens, oxoacids; the role of chloride ion in biological systems; iodine-containing compounds possessing hormone action)

7. Describe the most important complexes of the titanium and vanadium and their practical (catalytic) application! (oxides, hydrides, organometallic derivatives; complexes containing organic and inorganic ligands; practical applications)

8. Describe the compounds of the chromium group elements. (halides, oxygen-containing derivatives; iso- and heteropolyacids; their carbonyl, alkylidene, alkylidine complexes; complexes with neutral organic ligands)
9. Describe the most important complexes of the elements of the iron group, and their biocoordination chemistry! (halogen, carbonyl, phosphane complexes; hydrogen derivatives; heme and heme proteins; enzymes; vitamin B12)

10. Describe platinum metals! Describe some organometallic derivatives of platinum metals; give some examples of oxidative addition and reductive elimination! Describe some important reactions catalyzed by platinum metal complexes! (wilkinson complex; palladium complexes; platinum complexes; isomerization, hydrogenation, carbonylation reactions; Suzuki, Heck, Sonogashira, Stille coupling reactions)

TOPIC 2. ORGANIC CHEMISTRY

1. Aromaticity and aromatic nature - interpretation of aromaticity in cyclic compounds from 3 to 8 members. Description and interpretation of the reactions of aromatic compounds in the nucleus and side chain. Hammett equation, aromatic electrophilic substitution, interpretation of direction rules; Nucleophilic substitution of aromatic compounds.

2. Reactions of carbonyl compounds, in particular the formation of carbon-carbon bonds, substitution reactions in the α-position and transformations of the carbonyl group. Reactions of carbonyl compounds - aldol condensation, Wittig reaction, hydride ion migration reactions (Cannizzaro reaction, reduction of carbonyl compounds with metal hydrides); Stable enolates, Umpolung reactions (benzoin condensation); α- Position substitution reactions (alkylation of malonate, acetic acid ester and further reactions).

3. Stereoselective syntheses and basic concepts related to chirality and their significance in synthetic organic chemistry. Stereocchemical descriptors. Stereoselective syntheses - basic concepts related to chirality (enantiomers, enantiomeric excess, diastereomers, stereoselective and stereospecific reactions, concept of prochirality), chiral aldehydes, conformation of chiral aldehydes (using the Felkin-Ahn model), stereoselective enol chiral catalysts.

4. Formation of carbon-carbon bonds by the reaction of nucleophilic and electrophilic centers and using organometallic reactions. Formation of a carbon-carbon bond by the reaction of nucleophilic and electrophilic centers and using organometallic reactions. Michael reaction; alkylation and acylation of enamines; reactions starting from carbanions stabilized by an adjacent sulphur, phosphorus and silicium atoms. Formation of carbon-carbon bond on aromatic systems (Friedel-Crafts, Gatterman-Koch, Vilsmeier reaction, Mannich reaction). Organolithium reagents; Grignard reaction; Organic reagents Cu, Cd and Zn; Pd-catalyzed coupling reactions; olefin metathesis.

5. The use of nucleophilic substitution in organic chemistry, with particular reference to the description of mechanism types and factors influencing substitution reactions. Application of nucleophilic substitution in organic chemistry. Interpretation of S_N1 and S_N2 processes including their main features. The Hammond principle. The effects of the substrate, the leaving group, the nucleophilic partner and the solvent on the outcome of the substitution
reaction. Relations between mechanism and stereochemical outcome of the reactions. The neighborhood effect. Application of phase transfer catalysis in nucleophilic substitution.


7. Electronic structure, synthesis, occurrence, role and significance of five- and six-membered oxygen and nitrogen heterocycles containing one and more heteroatoms in biochemical processes. Electronic structure, synthesis and occurrence of five- and six-membered oxygen and nitrogen heterocycles containing one and more heteroatoms. Occurrence of heterocycles in amino acids, nucleic acids, drugs (with some examples), vitamins and coenzymes (biotin, ATP, tetrahydrofolate, lipoic acid, pyridoxal, thiamine, NAD, FMN).


Recommended reading:

TOPIC 3: ANALYTICAL CHEMISTRY

1. Planning and implementation of sampling. Sample preparation, dissolving techniques, enrichment methods. Performance characteristics of analytical methods. Sampling
aspects, dissolution methods, extraction, solid phase extraction, supercritical fluid extraction. Selectivity, linearity, sensitivity, accuracy, precision, repeatability, reproducibility, detection effect.


7. Use of instrumental analytical methods (NMR, ESR, IR, MS, XRD) in the analysis of inorganic and organic compounds. Advanced 1D and 2D NMR methods for determining the structure of organic compounds. The electron and the NMR spectroscopy. Magnetic properties of the nuclei, principle of the NMR measurement, qualitative description of a spectrum, chemical shift, spin-spin coupling, applications.

8. Principles and applications of mass spectrometry. General setup of mass spectrometers; formation of the mass spectrum. Ion sources (EI, CI, ESI, APCI, FAB and MALDI) and analyzer types (quadrupole, ion trap and TOF). Electrospray methods (ESI, APCI, APPI). Online LC-ESI MS. MALDI MS / MS and ESI-MS / MS methods and their application (peptides, oligosaccharides and determination of the structure of low molecular mass
compounds). Applications of coupled techniques (ICP-MS, GC-MS, LC-MS). Comparison of experimental techniques in terms of performance and applicability.


10. Principles, tools of the most important electrophoretic methods, and their applications. Capillary electrophoresis, instrumentation, electrophoretic mobility, electroosmotic flow, capillary zone electrophoresis, capillary gel electrophoresis, isoelectric focusing, isotachophoresis, micellar electrokinetic chromatography.

Literature:
Daniel C. Harris: Quantitative Chemical Analysis
Douglas A. Skoog, F. James Holler, Stanley R. Crouch: Principles of Instrumental Analysis

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TOPIC 4: PHYSICAL CHEMISTRY


