

1.

- I can define the term *constitution* in organic chemistry.
- I can explain the octet rule, and I can apply it. I can convert the structural formula into Lewis's structure (*i.e.*, add lone electron pairs and formal charges to atoms in a molecule).
- I can characterize the properties and origin of σ - and π -bonds.
- I can infer the hybridization of an atom from the types of bonds in which the atom participates (including possible conjugation). I can propose spatial arrangements of small molecules based on the hybridization of an atom.
- I can discern systems of conjugated π -bonds, lone electron pairs, and empty p-orbitals. (*i.e.*, which π -bonds/electron pairs/orbitals are in conjugation).
- I can write relevant resonance structures, and I can interpret them. I can infer properties and the electron density distribution in conjugated π -system using the resonance structures.
- I can identify the allylic system in the amide, and characterize the consequences of the conjugation of the lone electron pair on the nitrogen atom and C=O (properties of the peptide bond).
- I can determine the polarization of σ bond using electronegativity values (typically bonds carbon-metal, carbon-halogen, carbon-oxygen, and carbon/nitrogen).
- I can explain the difference between polarization and polarizability of a bond/atom. I can explain the implication of the polarizability in reactivity (ease of the bond heterolysis).
- I can define the inductive and mesomeric (resonance) effects. I can determine the effects and their sign for a given atom or substituent using electronegativity values and resonance structures (*i.e.*, which substituent is electron-donating and electron-withdrawing).
- I can distinguish addition, elimination, substitution, and rearrangement reactions. I can describe and discern the condensation reaction.
- I can describe and discern electrophiles and nucleophiles.
- I can use curved arrows to describe the movement of electrons in mechanisms of organic reactions.
- I can determine the oxidation number (oxidation state) of an atom in a molecule. I can identify reduction-oxidation reactions and determine the number of electrons that are exchanged.

2.

- I can characterize acids and bases according to Brønsted-Lowry and Lewis's theory. I can identify pairs of conjugated acids and bases in acid-base reactions.
- I can apply the significant factors that contribute to the acidity (or basicity) and assess the acid-base properties of a molecule. The factors are (arranged with concerning their importance):
 1. Electronegativity and size of the deprotonated atom.
 2. Stabilization of a conjugated base by conjugation.
 3. Stabilization of a conjugated base by the negative inductive effect.
 4. Effect of the hybridization of a deprotonated atom.
 5. Solvation of molecules in aqueous solution.
- I can compare the relative acidity/basicity of two molecules and determine whose conjugated base prevails in acid-base equilibrium.
- I can recall approximate values of pK_a of selected essential (organic) acids, which are provided on slide 11 in the presentation.

- I can use Newman projection, wedge-and-dash image, and Fischer projection to represent the spatial arrangement of atoms in a molecule. I can mutually interconvert the projections/formulae.
- I can define conformation, conformer, and torsional (dihedral) angle. I can describe the origin of the barrier to conformational movement. I can draw the dependence of the internal energy of a molecule on the dihedral angle for small alkanes. I can find the conformers on the curve.
- I can account for the origin of the barrier to conformational movement in amide C-N and C-C bonds in conjugated π -systems.
- I can explain the origin of an internal strain in molecules of cycloalkanes (torsional, angle, and transannular strain).
- I can name conformers of cyclohexane. I can find axial and equatorial bonds (hydrogen atoms) in the chair conformer of cyclohexane. I can describe the practical implications of rapid mutual interconversion of two chair conformers at room temperature. I can describe more stable conformers of monosubstituted cyclohexanes (equatorial vs. axial orientation of a group).
- I can define the stereogenic center, isomer, constitutional isomer, stereoisomer, enantiomer, and diastereomer. I can recognize the type of isomerism in a pair of molecules. I can define the configuration.
- I can define the phenomenon of chirality, enantiomer, and racemate. I can describe the practical consequences of energetic degeneration of the enantiomers. I can characterize methods used to prepare the enantiomers (separation of enantiomers from racemate, enantioselective synthesis).
- I can find a stereogenic center in a molecule (double bond C=C, center of chirality) and describe its configuration with a proper stereodescriptor (*E/Z*, *cis/trans*, *R/S*). I can distinguish basic functional groups in organic molecules (their overview is provided in the presentation).
- I can generate a name of substituted derivatives of hydrocarbons according to IUPAC rules. The table listing suffixes and prefixes for selected functional groups arranged in the decreasing order of their priority will be available at the exam test.

3.

- I can write the mechanisms of monomolecular and bimolecular nucleophilic aliphatic substitution. I can describe either mechanism with a rate equation. I can explain the change in the configuration when the substitution reaction takes place on a center of chirality. I can characterize and find good leaving groups.
- I can derive structures of products for a given combination of a substrate and a nucleophile. This includes the nucleophilic substitution of the activated -OH group of alcohols.
- I can propose an expected nucleophilic substitution mechanism for a given combination of substrate and nucleophile, considering fundamental factors that facilitate or suppress either mechanism (steric hindrance, carbocation stability, nucleophile quality, solvation).
- I can assess qualitatively the basicity and nucleophilicity of basic nucleophiles and bases (their list is provided in the presentation).
- I can distinguish more stable alkene isomers concerning the configuration of the double bond (*cis/trans*) and the number of alkyls attached to the atoms of the double bond.
- I can write the mechanisms of monomolecular and bimolecular elimination of HX. I can describe either mechanism with a rate equation.

- I can derive structural formulae of products for a given combination of a substrate and a base, including regioselectivity consideration based on the product stability (Zaitsev's rule) and steric hindrance of the base (Hofmann's rule).
- I can propose an expected mechanism of the elimination reaction for a given combination of substrate and base, considering fundamental factors that facilitate or suppress either mechanism (the stability of a carbocation intermediate, quality of a base).
- I can assess qualitatively the basicity and nucleophilicity of basic nucleophiles and bases (their list is provided in the presentation).
- I can describe conditions under which the elimination prevails against the substitution reaction (structure of the substrate, temperature, property of nucleophile/base).

4.

- I can describe conditions under which addition to unsaturated hydrocarbons is preferred and conditions under which this preference can be reversed (temperature, coupling with exergonic reaction).
- I can write the mechanism of electrophilic additions of hydrogen halides, water, halogens (X_2), and hypohalous acids (HXO) to unsaturated hydrocarbons. I can rationalize Markovnikov's rule.
- I can derive structures of main products (including their configuration) from the structure of reacting molecules for the following reactions: the addition of hydrogen halides (HX), free radical chain addition of HBr, the acid-catalyzed addition of water, oxymercuration, addition of water to alkynes, hydroboration-oxidation, hydrogenation (including reduction of a triple carbon-carbon bond to either *cis* or *trans*-alkenes), the addition of halogens (X_2) and hypohalous acids (HXO), epoxidation, and syn-dihydroxylation with OsO_4 .
- I can write down products of ozonolysis of alkenes.
- I can characterize the acidity of terminal alkynes and write the structure formula of its deprotonation and subsequent alkylation.
- I can describe the properties of conjugated π -systems.
- I can write a mechanism of electrophilic addition to conjugated diene, explain the formation of 1,2- and 1,4-adduct, and characterize conditions under which either product is formed.
- I can write down the products of the photochemical [2+2] cycloaddition reaction and Diels-Alder reaction.

5.

- I can characterize the unique properties of aromatic hydrocarbons. I can apply Hückel's criteria of aromaticity to identify aromatic and antiaromatic hydrocarbons and heterocycles.
- I can write and describe the general mechanism of the electrophilic aromatic substitution reaction (S_EAr). I can explain how electrophiles are formed in nitration, Friedel-Crafts alkylation, acylation, and sulfonation. I can write down the structural formulae of the mentioned reactions.

- I can consider the effect of substituents attached to the aromatic ring on SEAr (activation/deactivation of the ring, preferred position for electrophile attack) using the inductive and mesomeric (resonance) effects of the substituents.
- I can write structural formulae of the products of the oxidation of alkylated aromatic hydrocarbons.
- I can write and describe the mechanism of the bimolecular nucleophilic aromatic substitution reaction (S_N2Ar) proceeding via the addition-elimination mechanism. I can write and describe the mechanism of the nucleophilic aromatic substitution reaction proceeding via the elimination-addition mechanism (with benzyne as an intermediate). I can consider factors that favor either mechanism. I can derive structural formulae of the products of the nucleophilic aromatic substitution reactions.

6.

- I can characterize often-used methods to synthesize aldehydes and ketones.
- I can explain the reactivity of aldehydes and ketones towards nucleophiles. I can qualitatively assess how the reaction is affected by steric hindrance and the electron-donating or electron-withdrawing nature of the substituents.
- I can characterize the reactivity of the enolizable aldehydes and ketones toward electrophiles. I can determine nucleophilic atoms in enols and enolates.
- I can write and describe the mechanism of the reaction of aldehydes and ketones with alcohols under either basic or acidic catalysis (formation of hemiacetals and acetals) and with water (formation of hydrates – geminal diols).
- I can characterize the formation of glycosides and the importance of naturally occurring hemiacetals, acetals, and glycosides.
- I can write and describe the mechanism of the reaction of aldehydes and ketones with amines (formation of imines and enamines).
- I can write structural formulae of the products of reactions in which aldehydes and ketones react with organometallic compounds, lithium aluminum hydride, sodium borohydride, and HCN.
- I can write structural formulae of the products of 1,2- and 1,4-addition of nucleophiles to α,β -unsaturated carbonyl compounds and related systems with electron-deficient C-C double bonds (Michael addition).
- I can write structural formulae of the products of Wittig reaction, including the formation of phosphonium ylides.
- I can attribute approximate values of pK_a to various carbonyl compounds. I can assess the position of enol-keto equilibrium. I can write and describe the mechanism of either acid- or base-catalyzed enolization of aldehydes and ketones. I can distinguish thermodynamic and kinetic enolate/enol. I can suggest reagents and conditions for the generation of thermodynamic or kinetic enolate.
- I can write structural formulae of the alkylation products of aldehydes and ketones (*O*- and *C*-alkylation), halogenation products, and haloform reaction products.
- I can write and describe the mechanism and products of aldol reaction and aldol condensation, including crossed aldol reaction and directed aldol reaction. I can characterize the importance of aldol-like reactions in biochemistry.

7.

- I can characterize the properties of carboxylic acids and infer the effect of substituents on their acidity. I can write down reactants or products of the reactions that are often used to prepare carboxylic acids.
- I can identify basic functional derivatives of carboxylic acids (acyl halide, anhydride, ester, and amide). I can write down and describe the mechanism of nucleophilic acyl substitution and its products. I can arrange the functional derivatives of carboxylic acids according to their reactivity toward nucleophiles. I can write down the mechanism and products of a reaction of functional derivatives of carboxylic acids with organometallic compounds and LiAlH_4 . I can write down the mechanism and products of acid-catalyzed esterification.
- I can write down the products of a reaction of carboxylic acid, amide, and nitrile with LiAlH_4 .
- I can write down the mechanism and products of the Claisen reaction and crossed Claisen reaction.
- I can characterize carboxylic acids that are thermally unstable and prone to decarboxylation (β -oxo acids, acids bearing electron-withdrawing groups on their α -carbon atom). I can write down structural formulae of the product of the malonic ester syntheses.
- I can characterize stable functional derivatives of carbonic acid (urea, phosgene, carbamates) and their properties.

8.

- I can characterize the structure and properties of alcohol and phenols (their boiling points affected by hydrogen bonding, their acidity and basicity, and solubility in water). I can evaluate the effect of the hydrocarbon group on these properties.
- I can write down structures of reacting compounds, reagents, and products of the reactions that are often used to prepare alcohols.
- I can describe the methods that are used to convert the alcoholic -OH group into a good leaving group (protonation of the -OH group, conversion of an alcohol into an ester of a strong acid, exchange of the -OH group for halogen).
- I can write down the structural formulae of products of oxidation of the primary and secondary alcohols. I can offer reasons for the tendency of the primary alcohols to undergo overoxidation to carboxylic acids in aqueous media. I can characterize oxidation methods and reagents that avoid overoxidation and allow the conversion of the primary alcohols into aldehydes.
- I can describe the redox pair quinone-hydroquinone, including its relevance to biochemical processes.
- I can characterize the structure and properties of ethers (their boiling points affected, their Brønsted and Lewis basicity, solubility in water, and propensity to act as an acceptor of the hydrogen bond).
- I can write down structures of reacting compounds, reagents, and products of the reactions that are often used to prepare ethers.
- I can describe the reactivity of epoxides. I can write down structures of reacting compounds, reagents, and products of the reactions that are often used to prepare epoxides.
- I can write down the structures of products of unsymmetrically substituted epoxide with a nucleophile without catalysis or under acidic activation of an epoxide.
- I can characterize the properties of thiols and sulfides (ability to form the hydrogen bond, the acidity of the -SH bond, and nucleophilicity). I can write down structures of reacting compounds, reagents, and products of the reactions that are often used to prepare thiols and sulfides.
- I can write down structural formulae of products of oxidation of thiols (disulfides) and sulfides (sulfoxides and sulfones).

9.

- I can characterize the structure and properties of amines (boiling point, basicity, acidity) and the effect of hydrocarbon groups on these properties.
- I can write down products of reactions that are typically used to prepare amines. I can explain the causes of the low selectivity of the direct alkylation reaction of ammonia/amines. I can describe the procedure of reductive amination; I can write structural formulae of reductive amination products. I can suggest starting compounds that can be used to prepare a given amine via reductive amination.
- I can write down structural formulae of products of the Hofmann elimination of quaternary ammonium hydroxides and explain the regioselectivity of this reaction.
- I can write down structural formulae of products of the reaction of the nitrous acid with primary and secondary amines. I can describe the properties and usage of the diazonium salts. I can write down structural formulae of products of the diazo coupling reaction (the electrophilic aromatic substitution with electron-rich aromatic compounds) and the nucleophilic substitution reactions that use the diazonium salts.
- I can characterize the properties of nitro compounds, their preparation methods, and their reduction products.
- I can characterize the structure of the organometallic compounds. I can describe the reactivity of the compounds with a carbon-metal bond (basicity, nucleophilicity, and ability to reduce carbonyl compounds).
- I can write down structural formulae of the starting compounds and products of the reactions that are used to prepare organometallic substances (the reaction of organohalogen compounds with metals, deprotonation of the acidic C-H bonds, and transmetallation). I can rationalize the incompatibility of carbon-metal bonds with some functional groups.
- I can write down structural formulae of the starting compounds and products of the reactions of organometallic compounds with acids, aldehydes, ketones, epoxides, nitriles, carbon dioxide, and functional derivatives of carboxylic acids.
- I can characterize the reactivity of organometallic compounds containing a transition metal.
- I can write down structural formulae of the products of the Gilman reagents (R_2CuLi) reactions with acyl halides and α,β -unsaturated aldehydes and ketones.

10.

- I can characterize effects that stabilize alkyl radicals. I can arrange the alkyl radicals according to their stability (or homolytic bond dissociation energy of C-H bonds).
- I can describe the mechanism and rationalize the selectivity of the radical halogenation of hydrocarbons. I can characterize how the selectivity of the reaction is affected by the dissociation energy of various C-H bonds and the number of chemically equivalent hydrogen atoms for chlorination and bromination. I can explain the selectivity of halogenation reaction in terms of halogen's reactivity.
- I can characterize methods and reagents used in the halogenation of unsaturated hydrocarbons in which the addition of halogen competes with radical substitution.
- I can describe reactants, products, and mechanism of the autooxidation of organic compounds. I can characterize the occurrence and use of these compounds.

11.

- I can characterize the chemical structure and properties of monosaccharides, oligosaccharides, and polysaccharides.
- I can define and explain the following terms: D- and L-sugar, epimer, anomer, reducing and nonreducing sugars, and mutarotation.
- I can transform the Fischer projection of monosaccharide into the Haworth projection of its furanose or pyranose form (including both anomers).
- I can characterize the structure and occurrence of the derivatives of saccharides (acetals, *O*- and *N*-glycosides, esters, amines, sugar alcohols, and carboxylic acids derived from carbohydrates).
- I can explain the mechanism of the monosaccharide epimerization/isomerization and retro-aldol reaction in the basic solution.
- I can describe the structure, properties, function, and occurrence of selected mono-, oligo- and polysaccharides (information provided in the lecture slides).
- I can describe the structure of heterocyclic compounds. I can recognize and assign trivial names to essential heterocyclic compounds (a list of the compounds is provided in the lecture slides).
- I can characterize the properties and reactivity of five-membered aromatic heterocycles. I suggest suitable reagents for electrophilic aromatic substitution with these heterocycles. I can write down structural formulae of the products of these reactions.
- I can describe the properties of pyridine and its derivatives toward electrophiles and nucleophiles. I can write down structural formulae of the products of these reactions.
- I can characterize the occurrence, function, and significance of porphine, pyrimidine, and purine derivatives.
- I can characterize the structure and (acid-base) properties of amino acids. I can describe the properties of the peptide (amide) bond.
I can describe methods used to synthesize peptides in the laboratory – protection and deprotection of the amino and carboxylic groups and activation of the carboxylic group to accomplish the coupling of amine and the acid. I can describe the solid-phase synthesis of peptides.

12.

- I can characterize the lipids and their properties.
- I can describe the chemical structure of the lipid categories (waxes, triacyl glycerides, phospholipids, sphingolipids, terpenes, steroids, and prostaglandins). I can assign the structure of the lipid to the appropriate category.
- I can characterize the structure of the fatty acids. I can describe the effect of the carbon atom number and the presence of the double bond of the properties of the fatty acid and their derivatives.
- I can describe the function and biological effects of the lipid categories.
- I can characterize chemical transformations of the lipids and the fatty acids (hydrolysis, autooxidation, transesterification, hydrogenation) and write down structural formulae of these reactions.
- I can explain the surface activity of soap, the formation of micelles and the lipid bilayers.