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## ASSESSMENT TOOLS CHEMISTRY

Curriculum	31.05.01 General Medicine
Qualification	General Medicine
Form of education	Full-time
Designer Department	Chemistry
Graduate Department	Internal Diseases

## TYPICAL TASKS FOR THE CONTROL WORK

### Stage I: Formative assessment.

#### 1.1 Points for oral quiz.

#### Topic 4. Physical chemistry of dispersed systems.

1. What are a dispersed phase and a dispersion medium?
2. What are the main properties of colloidal solutions, what is the difference between them and true solutions?
3. List the basic conditions necessary to obtain colloidal solutions.
4. What are the main methods of obtaining lyophobic sols?
5. What is the essence of the condensation method? Give examples of sols production by physical and chemical condensation methods.
6. What is dialysis, and for what purpose is it used? How does the simplest dialyzer works? What factors determine dialysis rate?
7. Describe the principle of ultrafiltration. Give an example of using ultrafiltration in biomedical research.
8. From what impurities colloidal solutions can be cleared by electrodialysis?
9. Explain the essence of the capillary method for determining the charge of colloidal particles.
10. To obtain a silver iodide sol, 15 cm<sup>3</sup> of a solution of potassium iodide were mixed with a concentration of 0.025 mol / dm<sup>3</sup> and 85 cm<sup>3</sup> of a solution of silver nitrate with a concentration of 0.005 mol / dm<sup>3</sup>. Write the micelle structure of the resulting sol.
11. The iron hydroxide sol Fe(OH)<sub>3</sub> was obtained by adding to 15 cm<sup>3</sup> of boiling distilled water a 15 cm<sup>3</sup> of ferric chloride solution with a mass fraction of 2%. At the same time, the ferric chloride is partially hydrolyzed:  $\text{FeCl}_3 + 3\text{H}_2\text{O} \leftrightarrow \text{Fe(OH)}_3 + 3\text{HCl}$ . Write the micelle structure of the resulting sol.

#### Topic 5. Chemistry of biogenic elements. Complex compounds.

1. General characteristics of organogen p-elements and their compounds by their position in the periodic system of D.I. Mendeleev.
2. Features of complexation reactions and protolytic properties of p-element compounds.
3. Regularities of stable oxidation states of p-elements.
4. Give the features of the electronic structure of d-elements and their ions. What biological functions are related to their structure?
5. What ions of d-elements are parts of metalloenzymes? Give examples. Describe the biological role of d-metal biocomplexes.
6. Describe the complexing properties of d-elements. What complexes with bioligands do they form?
7. Determine what is the charge of the complex ion and the degree of oxidation of the complexing agent in the following compounds: a) Mg[CuI<sub>4</sub>], b) [Pd(NH<sub>3</sub>)<sub>4</sub>]SO<sub>4</sub>, c) [Al(H<sub>2</sub>O)<sub>5</sub>Cl]Br<sub>2</sub>. Name the compounds.
8. Write the formulas of the following complex compounds: a) potassium tetracyanodiamine platinate (II), b) dinitrotetraaquaaluminium (III) bromide. Indicate the charge of the complex ion and the coordination number of the complexing agent in your answer.
9. Write the dissociation equation for the complex ion [Zn(NH<sub>3</sub>)<sub>3</sub>CN]<sup>+</sup>. Indicate the total number of ions and molecules formed during dissociation.

#### Topic 10. Nucleic acids. Lipids.

1. Write the structure of the nucleic bases that make up the DNA and RNA, name them.

2. After heating the compound in the presence of a mineral acid, phosphoric acid, deoxyribose, and guanine were obtained in a 1: 1: 1 ratio. Write the structure of this compound, name it. Specify N-glycosidic and ester linkages.
3. Write the tautomeric forms of uracil, thymine and name them.
4. Write the structure of adenine and its base complementary to DNA and RNA.
5. What is the secondary structure of DNA (Watson and Crick model)? How does it stabilize?
6. What is DNA replication (reduplication)? What enzyme is it carried out?
7. Give the concept of the secondary structure of t-RNA ("clover leaf"). Show the location of the anticodon and the site that connects with the corresponding amino acid.
8. What characterizes the iodine number of fat? Arrange the descending order of the iodine number the following triacyls: tripalmitate, oleodistearate, linoleodiolein.
9. What characterizes the number of saponification?
10. Draw the configuration of oleic acid; specify the location of the double bond.
11. Draw the configuration of linoleic acid; specify the location of double bonds.

### Topic 11. Steroids and terpenoids. Enzymes.

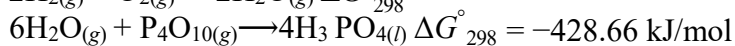
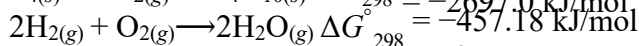
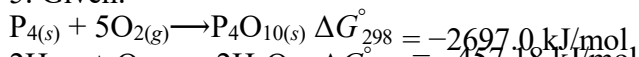
1. Write the formula of cyclopentanpergidrofenanthrene (steran, gonan), number the atoms. What biologically important substances have same structure?
2. What is cholesterol? What is its chemical structure? What diseases lead to excessive accumulation of cholesterol in the body?
3. What is the relationship between sterols and vitamins of D group? Give an explanation. What disease occurs with vitamin D deficiency?
4. What is the connection between cholesterol and bile acids? What are the functions of bile acids in the body?
5. What is paired bile acids? Write the glycocholic acid formula. Give the name of the bond connecting both parts of the molecule.
6. What are steroid hormones? What chemical structure underlies them? List steroid hormones.
7. What is the chemical structure of corticosteroids? Where is their synthesis?
8. Name the female sex hormones; write the structure of estrone.
9. Name male sex hormones; write the structure of testosterone. Show the difference in the structure of estrone and testosterone.
10. What are isoprenoids? Write a fragment of isoprene and name the biologically active substances that make it up.
11. Explain the structure of  $\text{NAD}^+$ , show the fragment involved in the hydride transfer.

### 1.2. Sample of case-studies for formative assessment

#### Topic 1. Basics of chemical thermodynamics and bioenergy. Chemical equilibrium.

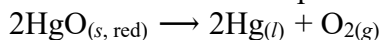
1. Write a thermochemical equation for the reaction of dissolution of copper (II) oxide in hydrochloric acid. How much heat is released when 100 g of oxide is dissolved?
2. Calculate the  $\Delta G_{0298}$  value of the following reactions and determine what direction they can spontaneously proceed spontaneously at 25°C:
  1.  $\text{NiO}_{(s)} + \text{Pb}_{(s)} = \text{Ni}_{(s)} + \text{PbO}_{(s)}$
  2.  $8\text{Al}_{(s)} + 3\text{Fe}_3\text{O}_{4(s)} = 9\text{Fe}_{(s)} + 4\text{Al}_2\text{O}_{3(s)}$
3. Determine the thermal effect of the reaction:
 
$$2\text{Mg}_{(s)} + \text{CO}_{2(g)} = 2\text{MgO}_{(s)} + \text{C}_{(s, \text{ graphite})}$$
 Calculate how much heat is released when 1 kg of magnesium is burned by this reaction.
4. Determine the direction of the spontaneous reaction in standard conditions (system is not isolated):
  1.  $\text{N}_2\text{O}_{(g)} + \text{NO}_{2(g)} = 3\text{NO}_{(g)}$
  2.  $\text{CH}_{4(g)} + 3\text{CO}_{2(g)} = 4\text{CO}_{(g)} + 2\text{H}_2\text{O}_{(g)}$

5. Given:



Determine the standard free energy of formation,  $\Delta G_f^\circ$ , for phosphoric acid.

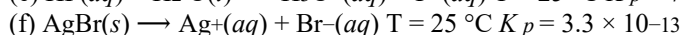
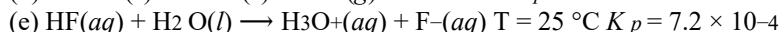
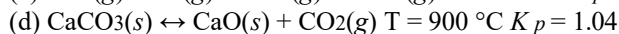
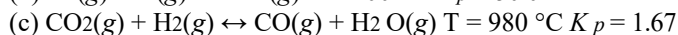
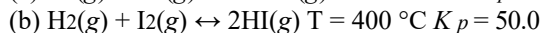
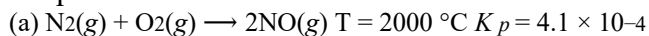
6. Consider the decomposition of red mercury (II) oxide under standard state conditions.



(a) Is the decomposition under standard state conditions spontaneous?

(b) What temperature does the reaction become spontaneous at?

7. Calculate  $\Delta G^\circ$  for every following reactions from the equilibrium constant at the given temperature.



**Topic 2.** Solutions. Protolytic reactions. Buffer solutions. Colligative properties of solutions.

1. In the laboratory there are solutions with a mass fraction of 10% and 20% NaCl. What mass of each solution should be taken to obtain a solution with a salt mass fraction of 12% by weight 300 g?

2. A water-alcohol solution containing 20% alcohol ( $\rho = 0.97 \text{ g / ml}$ ) freezes at  $-10.26^\circ\text{C}$ . Find the molecular mass of the alcohol ( $K_{H_2O} = 1.86$ ).

3. To neutralize 50 ml of 0.1 N KOH solutions, 15 ml of acid was required. Determine the equivalent (normal) molar concentration of the acid and the KOH titer.

4. At a certain temperature, the vapor pressure over the solution contains 31 g of aniline  $\text{C}_6\text{H}_5\text{NH}_2$  in 30 mol of ether is 72.09 kPa. Calculate the pressure of the ether at the same temperature.

5. Calculate  $K_a$  and  $\text{p}K_a$  of formic acid, if the degree of dissociation of its 0.2 M solution is 0.03.

6. Calculate the pH of 100 ml of a 0.01 M solution of carbonic acid ( $K_a = 6.5 \times 10^{-7}$ ) and the pH with the addition of 10 ml of a 0.02 M solution of sodium hydroxide.

7. Calculate the osmotic pressure and freezing point of 3.7% glycerin aqueous solution ( $\rho = 1.02 \text{ g / ml}$ ).

**Topic 3.** Chemical kinetics and catalysis. Basics of Electrochemistry.

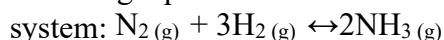
1. How many times will the rate of direct reaction in the system change:  $\text{CaO}_{(s)} + \text{CO}_{2(g)} \leftrightarrow \text{CaCO}_{3(s)}$ , if:

a) the concentration of CaO increases 5 times?

b) the pressure is reduced by 2 times?

2. What is the activation energy of the reaction, if its speed is increased with the temperature increase from 290 to 300 K by 2 times?

3. After reaching equilibrium in the



the equilibrium concentrations of the substances involved in the reaction were (mol / l):  $[\text{N}_2]_p = 1$ ;  $[\text{H}_2]_p = 6$ ;  $[\text{NH}_3]_p = 2$ . Determine the equilibrium constant and initial concentrations of nitrogen and hydrogen.

4. How many times does the reaction rate increase if the temperature rises from 50 to 70 ° C and the temperature coefficient is 3?

5. Determine which of the electrodes is a cathode in a galvanic cell formed by standard electrodes:  $\text{Ag}|\text{Ag}^+$  or  $\text{Mn}|\text{Mn}^{2+}$ ;

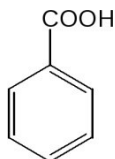
$\text{Co}|\text{Co}^{2+}$  or  $\text{Na}|\text{Na}^+$ .

6. Calculate the electrode potential of magnesium immersed in a solution of  $\text{MgSO}_4$  with an  $\text{Mg}^{2+}$  ion concentration of 0.01 mol/l.

7. Calculate the EMF of a galvanic cell consisting of two electrodes:  $\text{Ti} | \text{Ti}^{2+} (0,01 \text{ mol/l}) || \text{Ni}^{2+} (1 \text{ mol/l}) | \text{Ni}$ .

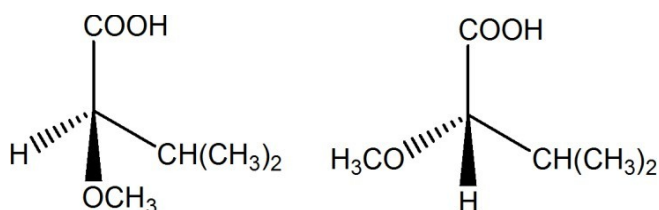
**Topic 6.** Organic compounds. Mutual influence of atoms and reaction mechanisms. Stereochemistry.

1. Show electronic effects and determine the direction of attack of the electrophile in the benzoic acid molecule:



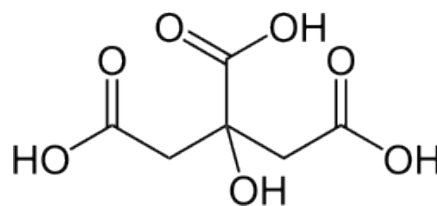
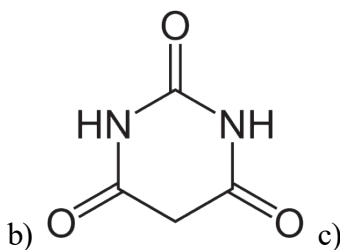
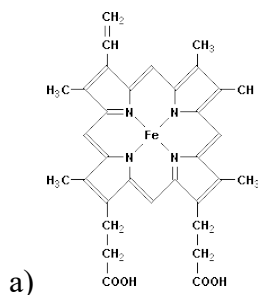
2. Show the mechanism of free radical substitution on the example of the reaction of chlorination of isobutene.

3. Write the Fisher formulas; name the enantiomers according to the D-, L- and R-, S-nomenclature:



**Topic 7.** Structure, biomedical properties of poly- and heterofunctional compounds. Chemistry of biologically active heterocyclic compounds. Alkaloids.

1. Give the names of these compounds and describe their biomedical meaning:



2. Write the formula of these compounds and describe their medical and biological significance: salicylic acid, acetylcholine, morphine,  $\gamma$ -hydroxybutyric acid, adrenaline, caffeine.

3. Write the formulas of heterocyclic compounds with six-membered ring – pyran, pyridine, and pyrimidine. What derivatives have its fragments, which properties do they have?

4. Write the formula of tartaric acid. How much stereoisomers it has? Draw their Fisher's formula.

**Topic 8.** Amino acids, peptides and proteins.

1. Based on the structure of the amino acids alanine, phenylalanine and valine predict which isoelectric point they will have ( $\text{pI} = 7.0$ ,  $\text{pI} > 7.0$ , or  $\text{pI} < 7.0$ ). Calculate the values of isoelectric points.

2. Do all proteins produce: a) biuret reaction; b) xantoprotein reaction; c) sulfhydryl reaction (Foul reaction)? Explain your answer.
3. Write the reaction equations: a) interactions of alanine with potassium hydroxide (to form salt); b) interaction of valine with freshly precipitated  $\text{Cu}(\text{OH})_2$  with the formation of a complex compound; c) the interaction of leucine with ethyl alcohol (esterification).

**Topic 9.** Carbohydrates: mono-, oligo- and polysaccharides.

1. Write the reaction equations of maltose disaccharide interaction with the following substances: a) bromine water; b) an excess of methyl bromide. Make a hydrolysis equation for maltose. Does maltose give a positive Trommer test? Justify your answer.
2. Write a cyclo-oxo-tautomerism scheme for D-galactose.
3. Write the reaction equations of lactose disaccharide interaction with the following substances: a) bromine water; b) an excess of iodomethane; c) an excess of acetic anhydride. Does lactose react with Tollens reagent? Justify your answer.

## STANDARD EXAM QUESTIONS (2th semester)

List of theoretical points for oral quiz

1. The relationship between metabolic processes and energy in living organisms. Chemical thermodynamics as a theoretical basis for bioenergy. The concept of thermodynamic systems, their classification.
2. The first law of thermodynamics, its formulation and mathematical expression. The concept of thermodynamic quantities used to express the beginning of thermodynamics: heat, work, internal energy of the system. Functions of the system state.
3. Thermodynamic process. Isochoric and isobaric processes. The 1<sup>st</sup> state of thermodynamics for isobaric and isochoric processes. Enthalpy as a function of system state. Standard system status.
4. The concept of thermochemistry. Chemical reaction as a thermodynamic process. Exo- and endothermic reactions, their importance for biological systems.
5. Thermochemical equations. The Hess law and its consequences. Standard enthalpies (heat) of formation and combustion of substances. Thermodynamic calculations and their use for the energy characteristics of biochemical processes.
6. The second law of thermodynamics. The concept of entropy. Entropy as a measure of system disorder. Patterns of entropy change during phase transitions and chemical reactions.
7. Thermodynamic potentials: Gibbs energy (isobaric-isothermal potential).
8. The subject of chemical kinetics. Chemical kinetics as a basis for studying the rates and mechanism of biochemical processes. Simple (one-step) and complex (multi-step), homogeneous and heterogeneous reactions.
9. The dependence of the reaction rate on temperature. Vant Hoff's rule and temperature coefficient of reaction rate. Features of the dependence of biochemical processes rate on temperature.
10. Reversible and irreversible chemical reactions. Chemical equilibrium constant. Prediction of chemical equilibrium bias based on the Le Chatelier principle.
11. Solutions. Liquid solutions. Water as solvent. The role of solutions in the vital activity of organisms.
12. Saturated steam; saturated steam pressure; relative decrease in the pressure of saturated vapor over diluted solutions of nonvolatile non-electrolytes. Raul's law. Lowering the freezing temperature and raising the boiling point of non-electrolyte solutions and their dependence on concentration. Cryoscopic and ebullioscopic constants.
13. Diffusion in solutions. Factors affecting the diffusion rate. Fick's Law. The role of diffusion in biological processes.

14. Osmosis. Osmotic pressure and methods for its determination. Osmotic pressure of diluted solutions of non-electrolytes. The Van't Hoff's law. Hypo-, hyper- and isotonic solutions and its use in medicine. Formation of edema. Hemolysis, plasmolysis. The role of osmosis and osmotic pressure in biological systems.
15. Theory of electrolytic dissociation. The degree of dissociation. Strong and weak electrolytes. Deviation from the Raul and Van't Hoff laws. Isotonic coefficient. The relationship of the isotonic coefficient with the degree of dissociation. Electrolytes in humans.
16. Solutions of weak electrolytes. Application of the law of masses to the process of dissociation of weak electrolytes. Dissociation constant. The Ostwald's law of dilution.
17. The main points of the strong electrolytes solutions theory. Activity and activity ratio. The ionic strength of the solution.
18. Water as electrolyte. Ionic product of water. Hydrogen indicator (pH). The pH range of various fluids of the human body.
19. Buffer solutions: composition, classification, properties. pH buffer solutions. Henderson-Hasselbach equation, its application to blood buffer systems.
20. The mechanism of action of buffer solutions. Buffer capacity, its dependence on various factors. The value of buffer solutions for the human body. Major blood buffer systems.
21. Polarization of bonds. Electronic effects - inductive, mesomeric, their effect on the reactivity of organic compounds. Electron-donating and electron-withdrawing substituents.
22. Classification of organic compounds. Functional groups and organic radicals.
23. Basic rules of the IUPAC systematic nomenclature for organic compounds. Substitution and radical functional nomenclature.
24. Basics of the nomenclature of aliphatic, alicyclic hydrocarbons and their polyfunctional derivatives.
25. Types of conjugation. Conjugate systems with open and closed chains. Aromatic benzoid and heterocyclic compounds.
26. Classification of organic reactions by mechanism and end result. Homolytic and heterolytic rupture of covalent bonds. Electronic and spatial structure of the formed intermediates. Electron-donor and electron- accepting substituents.
27. Acid-base properties of organic compounds. Acidity and basicity of organic compounds. Theories of Bronsted and Lewis. General regularities of changes in acidic and basic properties depending on the nature of the atom in the acid and mainly centers, the electronic effects of the substituents and the solvation effects.
28. Stereoisomerism of organic molecules. Spatial structure of organic compounds. Conformation and configuration of molecules. Conformations of open chains. Conformation of cyclic compounds. Configuration. Fisher's projection formulas. General principles of stereochemical nomenclature. Optical activity. Causes of the chirality of organic compounds. Types of stereoisomers. Diastereomers. The problem of the interrelation of the stereochemical structure with the manifestation of biological activity.
29. Structure, chemical properties and reactivity of poly- and heterofunctional compounds. Polyhydric alcohols. Diatomic phenols. Hydroquinone-quinone system as a chemical basis of ubiquinones in redox processes. Phenols and antioxidants.
30. Dibasic carboxylic acids. Aminoalcohols: choline, acetylcholine. Aminophenols: dopamine, norepinephrine, adrenaline. Monobasic (lactic  $\beta$ - and  $\gamma$ -hydroxybutyric), dibasic (malic, tartaric), tribasic (citric) hydroxy acids. Aldehyde and ketone acids.
31. Heterofunctional derivatives of the benzene series as drugs. Salicylic acid and its derivatives. p-Aminobenzoic acid and its derivatives. Sulfanilamide drugs.
32. Chemistry of biologically active heterocyclic compounds and drugs. Heterocycles with one heteroatom. Pyrrole, indole, pyridine, quinoline. The concept of the structure tetrapirrol compounds (porphyrin, hem). Biologically important pyridine derivatives. 8-hydroxyquinoline derivatives are antibacterial agents of complexing action. Heterocycles with several heteroatoms.

Pyrazole, imidazole thiazole, pyrazine, pyrimidine, purine. Barbituric acid and its derivatives. Hydroxypurine.

33. Monosaccharides. Structure and classification. Stereoisomerism and cyclooxo-tautomerism of monosaccharides on the example of pentoses, hexoses and amino sugars. Fisher and Heuors formulas. Conformation of pyranose forms of monosaccharides. The most important representatives of pentoses, hexoses, deoxy sugars, amino sugars. Nucleophilic substitution at the anomeric center on the example of the formation of O- and N-glycosides. Oxidation and reduction of monosaccharides. Interdisposition aldoz and ketosis. Reactions of the aldol type in a series of monosaccharides.

34. Polysaccharides. Oligosaccharides. Disaccharides. Features in the chemical structure of reducing and non-reducing disaccharides. Homopolysaccharides: starch, glycogen, dextran, cellulose. Pectins. Primary structure, hydrolysis. The concept of secondary structure (amylose, cellulose). Heteropolysaccharides: hyaluronic acid, chondritine sulfates. Structure and biomedical significance of heparin.

35. Amino acids. Peptides and proteins. Proteinogenic amino acids. Structure. Stereoisomerism. Acid-base properties. Chemical properties of  $\alpha$ -amino acids as heterofunctional compounds. Biologically important reactions of  $\alpha$ -amino acids. Peptides. The structure of the peptide group. Peptide hydrolysis. Proteins. The concept of primary and secondary structures. Complex proteins.

36. Nucleic acids. Pyrimidine and purine bases. Lactim-lactam tautomerism. Deamination reactions. Nucleosides, hydrolysis. Nucleotides, structure. Nucleotide hydrolysis. The primary structure of nucleic acids. Structure and function of DNA and RNA. The concept of the secondary structure of DNA. Drugs based on modified nucleic bases (fluorouracil, mercaptopurine). Nucleosides are antibiotics.

37. Lipids saponification. Fat Oils. Natural higher fatty acids. Peroxide oxidation of fatty acid fragments in cell membranes. Phospholipids - as structural components of cell membranes. Sphingolipids. Glycolipids. The concept of antioxidant protection. The interaction of organic compounds with oxygen as a chemical basis of the peroxidation of lipid-containing systems. Peroxidation inhibitors.

38. Non-saponificated lipids. Steroids. Conformational structure, biological role. Steroid groups based on hydrocarbons: estran, androstan, pregnan, holan, cholestan. Steroid hormones. Bile acids. Sterols. Cholesterol and ergosterol. Cardiac glycoside aglycones: digitoxigenin, strophanthidine. Characteristics of the main groups of steroids.

39. Terpenoids. Mono and bicyclic terpenes. Limonene, menthol, camphor. Conjugated polyenes: carotenoids, vitamin A.