Ministry of Science and Higher Education of the Russian Federation Federal State Budgetary Educational Institution of Higher Education "Yaroslavthe-Wise Novgorod State University"

STATED BY: Vice-Rector for Educational ctivities of NovSU Yu.V. Daneykin 2022

PROGRAM of entrance examination in Chemistry

#### **DEVELOPED BY:**

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Chemistry Chenen 2022

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The program of the entrance examination is compiled on the basis of the requirements of the federal state educational standard of general secondary education.

The purpose of the entrance examination is to conduct an objective and reliable assessment of the level of training of applicants entering undergraduate/specialist programs of NovSU and to select the best trained applicants.

The program contains the procedure for the conduct of the entrance examination, criteria for evaluating the examination paper, program content, a list of recommended literature, an example of an examination test.

# The procedure for the conduct of the entrance examination

The entrance examination is conducted in written or remote form and involves answers to the questions of an examination test, which allow to determine the level of training of applicants entering undergraduate/specialist programs of NovSU. The duration of the entrance examination is 2 astronomical hours (120 minutes).

# Criteria for evaluating the examination paper

The maximum possible number of points that an applicant can receive on the entrance examination is 100 points.

The minimum number of points confirming successful completion of the entrance examination is 40 points. Applicants who receive 39 or less points are not allowed to participate in the competition.

An examination test contains:

20 tasks in part A 4 tasks in part B

Evaluation criteria	Points
1. Part A	3 points
	for each correctly completed task
2. Part B	10 points
	for each correctly completed task
Total:	100

# **Program content**

#### Theory of the structure of matter

Atom. Composition of atomic nuclei. Chemical element. The constancy of the composition of matter. Relative atomic and relative molecular weight. The law of conservation of mass, its significance in chemistry. Mole. Molar mass. Avogadro's number. Isotopes.

# The doctrine of periodicity. D.I. Mendeleev's periodic law and periodic system of elements

D.I. Mendeleev's periodic law of chemical elements. Distribution of electrons in atoms of elements of the first four periods. Small and large periods, groups and subgroups. Characterization of individual chemical elements of the main subgroups based on the position in the periodic system and the structure of the atom. The value of the periodic law for understanding the scientific picture of the world, the development of science and technology.

## **Chemical bond**

Types of chemical bond. Atomic bond and methods of its formation. Bond length and energy. The concept of the electronegativity of chemical elements. The degree of oxidation. Ionic bond and its formation. Ion charge. Metal bond.

# **Chemical reactions**

Types of chemical reactions: reactions of connection, decomposition, substitution, ion exchange. Redox reactions. Thermal effect of chemical reactions. Conservation and transformation of energy in chemical reactions. The rate of chemical reactions. The dependence of the rate on the nature of the reacting substances, on concentration, temperature. Catalysis. Reversibility of chemical reactions. Chemical equilibrium and conditions for its displacement.

# Solutions. Electrolytic dissociation

Solutions. Solubility of substances. The dependence of the solubility of substances on their nature, on temperature, pressure. Thermal effect during dissolution. The concentration of solutions. The value of solutions in industry, agriculture, everyday life. Electrolytic dissociation. Degree of dissociation. Strong and weak electrolytes. Ion exchange reactions. Electrolytic dissociation of inorganic and organic acids, alkalis and salts.

# Halogens

General characteristics of halogens. Chlorine. Physical, chemical properties. Reactions with inorganic and organic substances. Production of chlorine in industry. Chlorine compounds. The use of chlorine and its compounds.

## **Oxygen subgroup**

General characteristics of the elements of the main subgroup of group VI. Oxygen. Chemical, physical properties. Allotropy. The use of oxygen. The oxygen cycle in nature. Sulfur, its physical and chemical properties. Sulfur compounds: hydrogen sulfide, sulfur oxides. Sulfuric acid, its properties, chemical bases of production.

Water. Physical, chemical properties. Crystallohydrates. The value of water in industry, agriculture, everyday life, nature. Protection of water bodies from pollution.

#### Nitrogen subgroup

Nitrogen. Nitrogen compounds. Physical and chemical properties. Ammonia production. The use of ammonia, nitric acid and its salts. Phosphorus, its allotropic forms, physical and chemical properties. Phosphorus (V) oxides, phosphoric acid and its salts. Phosphorus fertilizers.

#### **Carbon subgroup**

General characteristics of the elements of group IV of the main subgroup. Physical and chemical properties. Carbon, its allotropic forms. Carbon compounds: oxides (II, IV), carbonic acid and its salts. Silicon. Silicon compounds in nature, their use in technology.

#### Metals

Position in the periodic system. Features of the structure of metal atoms. Metal bond. Characteristic physical and chemical properties. Corrosion of metals.

Alkali metals. General characteristics based on the position in the periodic system. Compounds of sodium, potassium in nature, their application. Potassium fertilizers.

General characteristics of the elements of the main subgroups of groups II and III of the periodic system. Calcium, its compounds in nature. Water hardness and ways to eliminate it.

Aluminum. Characteristics of aluminum and its compounds. Amphotericity of aluminum oxide. The use of aluminum and its alloys.

Iron. Characterization of iron, oxides, hydroxides, salts of iron (II and III). Natural iron compounds. Iron alloys — cast iron and steel. The use of alloys and iron compounds.

Metallurgy. Metals in modern technology. Blast-furnace cast iron production. Steel production methods. The problem of low-waste production in metallurgy and environmental protection. The development of domestic metallurgy and its significance for the development of other industries.

#### The structure of organic compounds

The main provisions of A.M. Butlerov's theory of chemical structure. The dependence of the properties of substances on the chemical structure. Isomerism. The electronic nature of chemical bonds in the molecules of organic compounds, methods of breaking bonds, the concept of free radicals.

## Saturated hydrocarbons

Homologous series of saturated hydrocarbons, their electronic and spatial structure (sp<sup>3</sup> hybridization). Methane. Nomenclature, physical and chemical properties of saturated hydrocarbons. Cycloparaffins. Saturated hydrocarbons in nature.

#### **Unsaturated hydrocarbons**

Homologous series of ethylene hydrocarbons. Double bond- $\beta$  and  $\pi$ -bond, sp<sup>2</sup> hybridization. Physical properties. Isomerism of the carbon skeleton and the position of the double bond. Nomenclature of ethylene hydrocarbons. Chemical properties.

Obtaining hydrocarbons by the dehydrogenation reaction. The use of ethylene hydrocarbons. Natural rubber, its structure and properties.

Acetylene. Triple bond, sp hybridization. Homologous series of acetylene. Physical and chemical properties, application of acetylene. Obtaining it by the carbide method and from methane.

#### Aromatic hydrocarbons

Benzene, its electronic structure, chemical properties. Industrial production and use of benzene. The concept of pesticides, the conditions for their use in agriculture based on the requirements of environmental protection.

#### Natural sources of hydrocarbons

Oil, natural gas and associated petroleum gases, coal. Fractional distillation of oil. Cracking. Aromatization of petroleum products. Environmental protection in oil refining.

#### Alcohols. Phenols. Aldehydes

Alcohols, their structure, chemical properties. Isomerism. Nomenclature of alcohols. Chemical properties of alcohols. The toxicity of alcohols, their destructive effect on the human body. Genetic relationship between hydrocarbons and alcohols. Phenol, its structure, physical and chemical properties. The use of phenol. Environmental protection from industrial waste containing phenol. Aldehydes, their structure, chemical properties. Obtaining and application of formic and acetic aldehydes.

#### **Carboxylic acids**

Homologous series of saturated monobasic acids, their structure. Carboxyl group, mutual influence of carboxyl group and carbohydrate radical. Physical and chemical properties of carboxylic acids. Acetic, palmitic, stearic, oleic acids. Obtaining and application of carboxylic acids.

#### **Complex ethers. Fats**

Complex ethers. Their structure, obtaining by esterification reaction. Their chemical properties. Fats in nature, their structure and properties. Synthetic detergents, their importance. Protecting the environment from pollution by synthetic detergents.

#### Carbohydrates

Glucose, its structure, chemical properties, role in nature. Sucrose, its hydrolysis. Starch and cellulose, their structure, chemical properties, role in nature. The use of cellulose and its derivatives. The concept of artificial fibers.

#### Amines. Amino acids

The structure of amines. Their interaction with water and acids. Aniline. Obtaining aniline from nitrobenzene; practical significance of aniline.

Structure, chemical features, isomerism of amino acids.

Synthesis of peptides, their structure. The concept of nitrogen-containing heterocyclic compounds on the example of pyridine and pyrrole.

## **Proteins. Nucleic acids**

Structure, composition and properties of proteins. Advances in the study and synthesis of proteins. Importance of the microbiological industry. Nucleic acids, structure of nucleotides. The principle of complementarity in the construction of the DNA double helix. The role of nucleic acids in the life of the cell.

# List of recommended literature

# Main literature:

- 1. Kuzmenko N.E., Eremin V.V., Popkov V.A. Nachala khimii. Dlya postupayushchikh v vuzy [Fundamentals of chemistry. For university applicants]. Laboratoriya znaniy Publ., 2017. 704 p.
- 2. Khomchenko G.P. Posobiye po khimii dlya postupayushchikh v vuzy [Manual on chemistry for university applicants]. Moscow, Novaya volna Publ., 2018. 480 p.
- 3. Khomchenko G.P., Khomchenko I.G. Sbornik zadach po khimii dlya postupayushchikh v vuzy [Collection of chemistry tasks for university applicants]. Moscow, Novaya volna Publ., 2002. 288 p.

# **Additional literature:**

- 1. Vrublevsky A.I. Khimiya. Ves' shkol'nyy kurs [Chemistry. The entire school course]. Potpourri Publ., 2020. 688 p.
- 2. Eremin V.V., Antipin R.L. Khimiya. Uglublonnyy kurs podgotovki k YEGE [Chemistry. Enhanced training course of preparation for the Uniform State Exam]. Eksmo Publ., 2020. 608 p.
- 3. Cambridge International AS and A Level Chemistry Coursebook, Second edition, Ryan L., Norris R., 2014. 606 p.

## **Internet resources:**

- 1. http://rl.odessa.ua/media/ For Liceistu/Chemistry/Homchenko-2002.pdf
- 2. https://may.alleng.org/d/chem/chem04.htm
- 3. <u>https://scask.ru/f\_book\_chem.php?id=3</u>
- 4. <u>https://infourok.ru/prezentaciya-po-himii-na-temu-ted-rastvori-elektrolitov-klass-3992966.html</u>

# Examination test example CHEMISTRY

# Variant 1

Maximum number of points is 100.

# Part 1

Each correctly completed task is 3 points.

For tasks A1–A20, cl	hoose ONE correc	t answer, wri	te down the correspo	onding letter in		
	your	answer sheet		e		
A1. Number of protons in a Cu atom is:						
a) 35 b) 93	c) 29		d) 64			
<b>A2.</b> C and Si atoms have the same number of $\mathbf{A}^{\text{c}}$						
a) neutrons in the nucle	us b) energy leve	els				
c) electrons d) electrons in the outer energy level						
Á3. Select a non-polar	molecule:		27			
a) HCl b)	CF <sub>4</sub>	c) NH <sub>3</sub>	d) $H_2S$			
A4. C–C bond strength	in the series ethar	ne-benzene-e	thylene-acetylene:			
a) increases c)	first increases, the	n decreases				
b) decreases d)	first decreases, the	en increases				
A5. Copper (II) chlorid	le is formed by the	e action of hy	drochloric acid on:			
a) copper(II) bromide	b) copper(II) o	oxide				
c) copper	d) copper(II) o	carbonate				
A6. The formula of hyd	droxide, which rea	cts with aque	ous solutions of both	h acids and		
bases, is:						
a) $Mg(OH)_2$ b)	Zn(OH) <sub>2</sub>	c) B(OH)3	d) NH₄OH			
A7. In the list of formulas A) MgCl <sub>2</sub> B) K <sub>2</sub> SO <sub>4</sub> C) Fe(NO <sub>3</sub> ) <sub>3</sub> D) NaCl E) Na <sub>3</sub> PO <sub>4</sub> , F) KBr						
hydrolysis is not subjec	eted to:					
a) BDF b)	AEF	c) BDF	d) ACE			
A8. With the help of phenolphthalein, solutions of the following salts can be						
distinguished:						
a) $K_2CO_3$ and $KCl$	b) Na <sub>2</sub>	$CO_3$ and $K_2S$				
c) $K_2SO_4$ and $CuCl_2$	d) ZnS	O <sub>4</sub> and Fe(N	O <sub>3</sub> ) <sub>2</sub>			
A9. What mass of water must be added to 250 g of a solution containing 25 g of						
potassium sulfate so th	at the mass fractio	on of the solut	ion becomes 5%?			
a) 250 g b)	125 g	c) 500 g	<b>d</b> ) 200	g		
A10. Formula of the st	rongest acid is:		1) 17010			
a) HF b)	HCIO	c) $HClO_2$	d) $HClO_4$	e) HClO <sub>3</sub>		
A11. Processes occurri	ng during the elec	trolysis of so	dium sulfate solution	n on the		
cathode:						
a) Na' + I $\bar{e} \rightarrow Na'$		b) $2H_2O + 2e$	$H_2 + 2OH^-$			
c) $4OH^2 - 4e \rightarrow O_2 + 2$	$H_2O$	d) $Pt^{\circ} - 2e \rightarrow$	$\rightarrow Pt^{2}$			
A12. What will be released on inert electrodes if an aqueous solution of copper (II)						
sulfate is subjected to e	electrolysis?		$\rightarrow$ II $\rightarrow$ 10			
a) Cu and $SO_3$	b) Cu and $O_2$	41 - 1 - 16	c) H <sub>2</sub> and $O_2$	a) $H_2$ and $SO_3$		
Also now many electrons are involved in the nan reaction $10_3 \rightarrow 7/212$ ? a) 1 b) 5 c) 10 d) 2						
a) 1 D)	3	-	u) 2			
		7				

A14. The coefficient in front of the oxidizing agent formula in the equation for the reaction between aluminum and bromine is:

a) 1 b) 2 c) 3 d) 4 A15. If in the column for the synthesis of sulfur oxide (VI) at 600°C the equilibrium  $2SO_2(g) + O_2(g) = 2SO_3(g)$ ,  $\Delta H < 0$  is established, then with increasing temperature, the pressure in the system:

a) decreases b) does not change c) becomes equal to atmospheric d) increases A16. In the system  $CO_{2(g)} + C_{(sld)} \leftrightarrow CO_{(g)} + H_{2(g)} \Delta H > 0$  equilibrium is established. By changing what parameter can the equilibrium be shifted towards the formation of CO? a) an increase in CO<sub>2</sub> concentration b) decrease in temperature c) decrease in C mass d) increase in pressure A17. The number of  $\sigma$ -bonds in a butylene molecule is: a) 2 b) 5 d) 4 c) 3 A18. The hydrocarbon containing a triple bond: a)  $C_4H_6$ b)  $C_4H_8$ c) C<sub>4</sub>H<sub>10</sub> d) CH4 A19. To recognize glycerin and ethylene glycol, one can use the reagent: a)  $Cu(OH)_2$ b)  $Br_2(aq)$ c) KMnO<sub>4</sub> d)  $Ag_2O$  (am.) A20. When some organic substance is heated with copper (II) hydroxide, a red-brown precipitate is formed — this is the following organic substance: a) propanol b) propanal c) propane d) propanoic acid

## Part 2

Each correctly completed task is 10 points.

Tasks B1–B4 are to establish the correspondence of the concept and its definition. For each position given in the first column, match the corresponding position from the second column. Write your answers on the answer sheet.

**B1.** Match the crystal lattice names and the examples of substances corresponding to these crystal lattices:

- A. Ionic crystal lattice 1. diamond, silicon
  - 2. hydrogen, sulfur, water, hydrogen sulfide
- C. Molecular crystal lattice

B. Atomic crystal lattice

- 3. sodium, calcium, iron 4. most salts
- D. Metal crystal lattice 4. 1
- B2. Match the acids with their oxides:

Acids:	Oxides:
1. chromic	$A - CrO_2$
2. orthochromic	$B - Cr_2O_3$
	$C - CrO_3$

**B3.** Match the  $Fe_2(SO_4)_3$  hydrolysis products with the correct hydrolysis steps of the given salt:

Hydrolysis:	Products:
step 1	$A - [Fe(OH)_2]_2SO_4$
step 2	B - (FeOH) <sub>2</sub> SO <sub>4</sub>
step 3	$C - FeOHSO_4$

# $D - Fe(OH)_3$

**B4.** Match the reaction equations with the correct changes in the oxidation state of the reducing agent in these reactions (for each position indicated by a letter, select the corresponding position indicated by a number): Reaction equations:

A)  $PH_3 + 8HNO_{3(conc)} \rightarrow H_3PO_4 + 8NO_2 + 4H_2O$ b)  $2Fe(OH)_2 + H_2O_2 = 2Fe(OH)_3$ B)  $2NaBr + MnO_2 + 2H_2SO_4 =$  $= Br_2 + MnSO_4 + Na_2SO_4 + 2H_2O$ 

Changes in the oxidation state of the reducing agent:

 $\begin{array}{cccc} 1) -1 & \rightarrow 0 & 4) +2 \rightarrow +3 \\ 2) -3 & \rightarrow +5 & 5) & 0 \rightarrow +2 \\ 3) & 0 \rightarrow +1 & 6) +4 \rightarrow +2 \end{array}$