

Chemistry Competition

The numbers in parentheses given after the numbers of the problems indicate grades of Russian school. The 8th grade pupils are supposed to solve 1 to 3 problems and 9th to 11th grade pupils solve 2 to 4 problems. The 8th grade is the first year of chemistry in Russian school and 11th grade is the last year before graduation. Solution of the problems meant for senior grades is welcome. The problems for junior grades do not affect the final score.

- (8) Compare the numbers of atoms contained in 1 g of carbon(IV) oxide and in 1 g of phosphorus(III) oxide. Which is greater and by what factor?
- (8–9) Some copper oxide CuO was placed in a glass tube, and hydrogen gas was passed through this tube with heating. After the reaction, the weight of the substance in the tube decreased by 12.8 g. What is the initial weight of the copper oxide sample if the reaction is known to proceed to completion. Write down the reaction equation.
- (8–10) In a solution of nitric acid in water, the number of hydrogen atoms is equal to the number of oxygen atoms.
 - What is the ratio of the numbers of moles of nitric acid and water in this solution?
 - What are the weights of nitric acid and water contained in 100 g of this solution?
- (9–10) A student analyzed five transparent aqueous solutions for cations and anions and found that the solutions contained the following ions (in amounts much exceeding their background contents in distilled water used to prepare the solutions):

Solution No	Detected ions
1	Cu^{2+} , Na^+ , H^+ , NO_3^-
2	Cu^{2+} , Na^+ , OH^- , NO_3^-
3	Cu^{2+} , Ba^{2+} , H^+ , SO_4^{2-}
4	Cu^{2+} , Ba^{2+} , Cl^-
5	Al^{3+} , Na^+ , Cl^- , CO_3^{2-}

Having had a look in the results, his friend immediately discovered some mistakes and gave advice to repeat the analysis. Why did he draw this conclusion? For which of the five solutions the analysis was certainly incorrect? Explain your answer.

- (9–10) Treatment of 5.00 g of an alloy consisting of two metals with an excess of aqueous NaOH resulted in 2.69 liters of a gas, and the weight of the sample decreased by 2.16 g. The remainder was completely dissolved in hydrochloric acid to give 1.084 liters of a gas. What metals may be the components of this alloy? Write down the equations of the mentioned reactions. The gas volumes were measured at 1 atm and 273 K.
- (10–11) A 5% aqueous solution of silver nitrate weighing 100.0 g was electrolyzed. The electrolysis was stopped when 5.6 liters of a gas had evolved at the cathode (the gas volume was measured at 1 atm and 273 K). What is the solution weight at the end of the electrolysis? Write down the reaction equations. (The electrodes were made of an inert material and no chemical reactions other than electrolysis took place on them).
- (9–11) Figure out what are substances **A**, **B**, **C**, **D**, **E**, **X**, **Y** and **Z** if they are known to undergo reactions presented below (and **A**, **B** and **D** are known to be elemental substances):

$$\begin{aligned} \mathbf{A} + \mathbf{B} &\rightarrow \mathbf{C} \\ \mathbf{A} + \mathbf{D} &\rightarrow \mathbf{E} \\ \mathbf{C} + \text{H}_2\text{O} &\rightarrow \mathbf{X} \\ \mathbf{E} + \text{H}_2\text{O} &\rightarrow \mathbf{X} + \mathbf{Y}\uparrow \\ \mathbf{X}_{\text{solution}} + \text{H}_2\text{SO}_4_{\text{solution}} &\rightarrow \mathbf{Z} + \text{H}_2\text{O} \end{aligned}$$
- (11) Heating of 3.6 g of n-propanol with sulfuric acid (140 C) gave two organic compounds and 0.65 g of water.
 - What are the organic compounds that formed?
 - Calculate their weights.
- (11) Aromatic compound having the molecular formula $\text{C}_9\text{H}_{10}\text{O}_2$ was heated in an aqueous solution of sodium hydroxide. This gave two products: compound **B** and ethanol. Fusing together compound **B** and sodium hydroxide yielded compound **C** and sodium carbonate.
 - Identify compounds **B** and **C**, write down the reaction equations.
 - Propose a synthetic route from compound **C** to **A** using only inorganic reagents. Write down the reaction equations for all intermediate stages and indicate the reaction conditions.