

1st BChO, 1993, Riga, Latvia

Problem 1 – ABC – A wet crystal

The hydrate of a stable salt **X** contains 2.79% H, 9.97% C, and 38.48% of element **A**. When **X** is heated at 800 °C, an oxide **Y** ($w_0 = 14.73\%$) is formed. When **X** is heated at a lower temperature, compound **Z** containing 5.80% C, 27.07% O, and 67.13% of element **A** is formed.

- Write the chemical formulas of compounds **X–Z**.
- Write equations of the described reactions.

Problem 2 – ABC, CALC – So similar but not the same

A solution contains sulfates of four metals. The metals are located in the same period (of the periodic table), next to each other, and in sulfates, their oxidation number is equal to +2. The quantities of the salts are 0.0100, 0.0100, 0.0200, and 0.0200 mole. $\text{NH}_3 \cdot \text{H}_2\text{O}$ and H_2O_2 were added to the solution in excess. The resulting precipitate **A** was filtered and calcined to a constant mass of 2.47 g. After the filtrate was boiled, 2.36 g of precipitate **B** was obtained. The remaining solution contained no metal ions. Precipitate **A** was dissolved in an HCl solution, releasing 224 cm³ of chlorine (STP). When precipitate **B** was dissolved in an HCl solution, 150 cm³ of chlorine (STP) was released.

- Write the chemical formulas of metal sulfates.
- Calculate the mole amounts of these sulfates.
- Write equations of the described reactions.

Problem 3 – ABC – Do not drink it

5.000 g of the characteristic odorless liquid **A** was burned in oxygen. The resulting products were absorbed in excess NaOH. The mass of the alkali solution increased by 16.41 g. $\text{Ba}(\text{OH})_2$ was added to the solution, resulting in 59.74 g of precipitate. The precipitate was dissolved by heating in hydrochloric acid, and 6.660 dm³ of gas (STP) was released.

- Write the empirical formula of compound **A**.
- Write all the possible structures of substance **A**.

Problem 4 – STRUCT – Organic siblings

Write the structures of all such neutral, stable organic compounds whose molecules consist of C, H, and O (with empirical formulas C_mH_n and $\text{C}_m\text{H}_n\text{O}_x$) in which the number of carbon atoms is between 2 and 6, and all are in sp^2 hybridization and structurally equivalent to each other.

Problem 5 – ABC, SPECTRA – Organic riddle

Substance **A** consists of 69.77% carbon and 11.63% hydrogen. Two peaks are recorded in the mass spectrum of substance **A**: $m/z = 86$ (molecular ion) and $m/z = 57$. In the infrared spectrum, the line is around 1740–1720 cm⁻¹. In ¹H NMR spectrum, two singlet $\delta_1 = 1\text{--}1.5$ ppm and $\delta_2 = 9.5\text{--}10$ ppm. The ratio of peak intensities is 9 : 1.

- Write the structural formula of substance **A**.
- Write reaction equations in which substance **A** reacts with i) formaldehyde, ii) acetaldehyde in an alkaline medium, and iii) aluminum isopropanolate in the presence of isopropanol.

Problem 6 – BIO, STRUCT – Hemerythrin

The protein hemoglobin is widely known as an oxygen transporter. Less well-known are other natural proteins capable of transporting oxygen. One of these, hemerythrin, has been found in some vertebrates. The oxygen-binding center of hemerythrin contains two iron atoms that form a complex by interacting with the side chains of amino acid residues. X-ray structural analysis showed that the distance between iron atoms in hemerythrin is 3.57 Å (in the crystal of metallic iron, the interatomic distance is 2.48 Å). One of the atoms is linked by coordination bonds with three, the other with two amino acid side chains (each chain contains a five-membered cycle). In addition, the iron atoms are linked to two other different amino acid residues by FeO coordination bonds.

- a) What amino acid residues are included in the complex?
- b) Draw the spatial structure of the oxygen-binding center.
- c) How and where can oxygen be bound in this center?
- d) What features of oxygen binding by hemoglobin do you know?

Problem 7 – INORG – Toxic gold

During the electrolysis of a gold cyano complex in an alkaline solution, 0.460 g of gold is precipitated at the cathode, and 13.06 cm³ of oxygen (STP) is released at the anode. Write the electrode reactions and determine the degree of oxidation of gold in the complex, assuming that all reactions occur in 100% yield.

Problem 8 – EQUIL – Basic acid reactions

1 dm³ of solution contained 0.365 g HCl and 6.00 g CH₃COOH ($K_a = 1.75 \cdot 10^{-5}$). 2.00 g of solid sodium hydroxide was added to the solution. Calculate the pH of the solution before and after adding NaOH.