CCO Problem Set #2. Inorganic Chemistry. **Date: Nov 1, 2024**

Questions 1-3 should be solved together.

Among the products of the treatment of an aqueous suspension of mineral **A** with a solution of acid **B**, only binary substance **C** and gas **D**, which is one of the compounds released by plants, were found. Thermal decomposition of **C** at certain conditions (evacuated ampoule, 120°C) can lead to the formation of pure metal **X** and release of N_2 (mass loss = 38.0%).

1. Write the chemical formula of the gas **D**.

2. Write the chemical symbol of the metal **X**.

3. Write the chemical formula of the acid **B**.

Questions 4-7 should be solved together.

Highly toxic compound **A**, often used as a poison in murder mysteries, can react with a hot solution of blue vitriol with a release of toxic gas **B**. If bubbled through the KOH solution, gas **B** forms substances **A** and **C. C** can also be obtained directly from **A** via a reaction with PbO upon heating. The fusion of compound **A** with sulfur gives salt **D**, which shows a characteristic bright blood-red coloration if mixed with iron (III) salts.

4. Write the chemical formula of **A**.

5. Write the chemical formula of the gas **B**.

6. Write the chemical formula of **C**.

7. Write the chemical formula of the salt **D**.

Questions 8-11 should be solved together.

A certain white crystalline substance **A** undergoes a series of transformations when heated in air, successively forming white crystalline substances **B**–**D**. A 5 g sample of substance **A** was successively heated to temperatures corresponding to the complete transformation into compounds **B**, **C**, and **D**, after which the mass of the sample was determined. The results of the experiments are summarized in the table below:

Compound	**Mass, g**	**Temperature, K**
A	5.0000	273
B	4.3475	423
C	4.0213	573
D	2.5717	723

In another experiment, samples of substances **A**–**D**, each weighing 5 g, were dissolved in 95 g of water and the pH of the resulting solutions was determined. It was observed that solutions of **A**–**C** had a pH of about 2.5, while the solution of **D** was neutral.

8. Write the chemical formula of **A**.

9. Write the chemical formula of **B**.

10. Write the chemical formula of **C**.

11. Write the chemical formula of **D**.

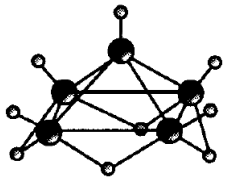
12. 393 mL of an aqueous solution of silver nitrate (0.70 M) was added to 35.05 g of a mixture of sodium and rubidium bromides. The precipitate was filtered off, and an iron plate was put into the filtrate. After the reaction was complete, the mass of this plate changed by 2 g. Calculate the mass fraction of rubidium bromide in the initial mixture.

a) 29%
b) 37%
c) 63%
d) 71%
e) 88%

13. A certain metal, when heated, reacts with a colorless gas **A**. When carbon dioxide acts on the product of this reaction, gas **A** is again released. Write the chemical formula of the gas **A**.

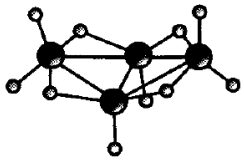
14. For each structure below, identify the type of borane geometry. Note: types can be repeated or missing completely.

a) $B_{10}H_{10}^{2-}$



b)

c) $B_7H_{11}^{4-}$



d)

e) B_2H_6

I. closo-
II. nido-
III. arachno-
IV. hypho-

A 55 g sample of a binary oxygen compound **A** of metal **X** was treated with 1 L of water. The resulting solution was boiled with a reflux condenser and 998 mL of a solution with a density of 1.049 g/mL were obtained.

15. Write the chemical formula of **A**.

Questions 16-17 should be solved together.

1) 1.000 g of silvery-white substance **A** was dissolved in 100 g of 12% KOH solution. This resulted in the release of 1.24 L of gas (at STP) with a density relative to nitrogen of 0.0714.

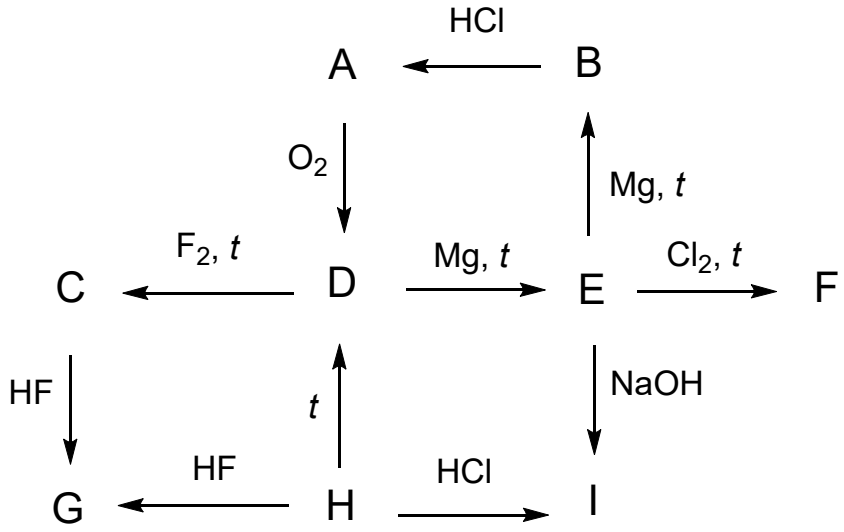
2) 1.000 g of a colorless salt **B** of a monovalent metal was added to a potassium hydroxide solution; **B** completely dissolved, forming an uncolored solution. Adding 1.000 g of substance **A** to this solution resulted in the formation of 0.715 L of a gas mixture with a density relative to air of 0.259. Part of the gas mixture (0.368 part of the total volume) was absorbed by the sulfuric acid solution.

16. Write the chemical formula of **A**.

17. Write the chemical formula of **B**.

Questions 18-21 should be solved together.

The diagram below shows the chemical transformations of substances containing element **E**, which is widespread on Earth. Substances **A** and **C** are colorless gases; their densities under normal conditions are 1.432 g/L and 4.647 g/L, respectively. It is known that **F** is a colorless liquid fuming in air, **G** is a strong acid.



18. Write the chemical symbol of the element **E**.

19. Write the chemical formula of the gas **A**.

20. Write the chemical formula of the acid **G**.

21. Write the chemical formula of **I**.

Questions 22-25 should be solved together.

Salts **A**, **B,** and **C** are white powders with the same qualitative composition. It is known that one of the elements in their composition is Na, the mass fraction of which in salt **A** is 32.39%, in salt **B** - 36.50%, in salt **C** - 26.13%.
When an aqueous solution of $AgNO_3$ interacts with solutions of these salts, the following phenomena are observed:

- with salt **A**: a yellow precipitate forms;
- with salt **B**: a white precipitate forms, and subsequent heating of the solution with the precipitate leads to its darkening due to the formation of silver particles
- with salt **C**: silver particles begin to form immediately, and the process is significantly accelerated when heated to 50 °C.

Anhydrous acids corresponding to salts **A**, **B**, and **C** are uncolored, low-melting solids (at 20 °C), well-soluble in water. Upon heating, melted acids corresponding to **B** and **C** release gas **D** with the smell of rotten fish. Its density under STP is 1.518 g/mL.

22. Write the chemical formula of **A**.

23. Write the chemical formula of **B**.

24. Write the chemical formula of **C**.

25. Write the chemical formula of the gas **D**.

Questions 26-29 should be solved together.

Compounds **I**-**IV** consist of elements **A** and **B**. Some properties of these compounds are given below.

Compound	**mol % of A**	**Color, state (at STP)**	**Melting point, °C**
I	81.61	yellow-orange gas	-121
II	52.59	yellow-brown gas	-59
III	42.51	red liquid	+3.5
IV	38.80	colorless liquid	-90

Compounds **I**-**IV** can be obtained by the following processes:

$HgB + A_2 = Hg_2BA_2 + I$
$A_2 + AgAB_3 = II + AgA + B_2$ (90^oC)
$II + B_3 = III$
$HAB_4 = IV + H_2B$ (P_2O_5, -30^oC)

26. Write the chemical formula of **I**.

27. Write the chemical formula of **II**.

28. Write the chemical formula of **III**.

29. Write the chemical formula of **IV**.

When two simple substances **A** and **B**, formed by elements of the same group of the periodic table, interact under certain conditions, compound **X** is formed. Under STP, **A** exists in the form of shiny dark-gray crystals, and **B** in the form of yellow-green poisonous gas with a sharp odor. When **X** is hydrolyzed in hot water, substance **Y**, simple substance **A**, and substance **Z**, which is highly soluble in water, are formed. The molar ratio of **Y**:**A** obtained in this reaction is 3:1. When a concentrated solution of **Z** interacts with solid potassium permanganate, simple substance **B** is formed.

30. Write the chemical formula of **X**.