

45th CHEMISTRY OLYMPIAD

Final National Competition

1998

ESTONIA

PROBLEMS

Form IX

- The mixture, which contained equal amounts of two carbonates of the elements of the 2nd main group, was heated. The mass of the remaining mixture is 62% of the initial one.
 - Determine the mass of two moles of the formed mixture.
 - What metals formed carbonates in the mixture?
 - Write equations for the decomposition reactions.
- A determined amount of the mixture of phosphane (PH_3) and hydrogen was passed through two hot consecutively united tubes. The first was filled with the copper shavings, and the second – with copper(II)oxide. The mass of the first tube increased by 4.96 grams, and the mass of the second one decreased by 5.76 grams. In these conditions phosphane is an oxidizer.
 - Write the equations of the reactions.
 - Determine the amounts of phosphane and hydrogen that were in the initial mixture.
 - Determine the volume of one mole of the gas under standard conditions (1 atm, 25 °C).
 - Determine the density of the source mixture under standard conditions.
- Chloric lime is a mixture, which contains equal amount of calcium chloride and calcium gipochloride. Lime milk (a substance of $\text{Ca}(\text{OH})_2$), solid KMnO_4 and 69.8 cm³ of 36.5% solution HCl (1.189 g/cm³) are source compounds for obtaining chloric lime.
 - Write the two equations for the reactions, which are used to get chloric lime.
 - Balance these equations.
 - Determine the mass of the chloric lime if the yield of the product by hydrochloric acid is 26.0%.
- An alloy consists of the metals **A** and **B**. Pulverized alloy was processed by diluting hydrochloric acid (in excess). The received solution was evaporated and 37.99 g of the solid substance was formed. A part of this solid substance formed the solution of the compound **C** in distilled water. The second compound which was formed – red compound **D** – didn't dissolve. Compound **D** is dissoluble in concentrated nitric acid and yields a blue-greenish solution of the compound **E** and a brown gas **F**. A solution of potassium sulfide was added to the solution of compound **C** and 14.45 grams of yellow sediment **G** was formed, in which the degree of the oxidation of metal is II.
 - Write the equations for the reactions 1) $\text{A} + \text{HCl} \rightarrow$; 2) $\text{B} + \text{HCl} \rightarrow$; 3) $\text{D} + \text{HNO}_3 \rightarrow$; 4) $\text{C} + \text{K}_2\text{S} \rightarrow$.
 - Write the formulas and the names of the compounds **A**, **B**, **C**, **D**, **E**, **F** and **G**.
 - Calculate the masses of the compounds **C** and **D**.
 - Calculate the percentage of each metal in the alloy.
- 20.0 cm³ of 0.100 M solution of KMnO_4 was added to a solution of 100 cm³ of H_2O_2 (1.02 g/cm³) and 2.016 dm³ (under normal conditions) of oxygen (O_2) was formed. Though the decomposition of H_2O_2 is a catalytic process, where MnO_2 serves as a catalyst, a part of the oxygen is formed in the reaction of KMnO_4 with H_2O_2 .
 - Write the equation for the reaction of KMnO_4 with H_2O_2 and the equation of the catalytic decomposition of H_2O_2 .
 - Calculate the total amount of the oxygen formed.

- c) Calculate the amount of KMnO_4 participated in the reaction and the amount of oxygen formed in this reaction.
 - d) Calculate the amount of H_2O_2 reacted with KMnO_4 and the amount of H_2O_2 decayed catalytically.
 - e) Calculate the percentage H_2O_2 if all of KMnO_4 is reduced and all of H_2O_2 is distributed.
6. The volume of reactionary container is 1.000 liters. 100 grams of 36.5% hydrochloric acid (1.180 g/cm^3) was flowed into the container. The container was hermetically closed, when upon 9.00 grams of Zn (7.14 g/cm^3) came into contact with the hydrochloric acid. To calculate the exercises, assume that the volume of the initial solution and metal are equal to the volume of the final solution. At the beginning of the reaction the air was under normal conditions in the reactor.
- a) Write the equation for the reaction.
 - b) Calculate the amount of gas which was in the reactor at the beginning of the reaction.
 - c) Calculate the amount of the gas that was in the reactor at the end of the reaction.
 - d) Calculate the pressure in the reactor at the end of the reaction at 20°C .

Form X

1. Oxide **A** can be in two polymorphic forms; one is active and the second is quite inert. Upon heating the active form goes into the inert form. Orange compound **B** is known as strong oxidizing agent. It reacts with sulfur giving compound **A**, a positive form, and salt **C**, where sulfur has a maximum oxidation state. Melting compound **A** (inert form) with compound **D** yields salt **E** and water. Dissolving salt **E** in an aqueous solution of **E** yields compound **K** which coordination number is 6. Acidification of solution **K** yields the precipitation of **F**. **F** can very easily chip off one molecule of water and yield compound **G**. Heating ($\sim 150^\circ\text{C}$) of **G** yields compound **A** (active form). Reduction of **A** with aluminum yields metal **H**. The reduction of **H** with sodium carbonate in air yields yellow compound **I**. Compounds **B**, **E** and **I** have the same qualitative but different quantitative structure.

- a) Write the formulas and names of **A**, **B**, **C**, **D**, **E**, **F**, **G**, **H** and **I**.
 - b) Write the equations for the following reactions: 1) $\text{B} + \text{S} \rightarrow$; 2) $\text{A} + \text{D} \rightarrow$; 3) $\text{E} + \text{D} \rightarrow$; 4) $\text{K} + \text{H}^+ \rightarrow$; 5) $\text{F} \rightarrow \text{G}$; 6) $\text{G} \rightarrow \text{A}$; 7) $\text{A} + \text{Al} \rightarrow$; 8) $\text{H} + \text{Na}_2\text{CO}_3 + \text{O}_2 \rightarrow$.
2. Compound **A** is a red, high polymer. Condensation of its steams yields a white compound **B** that doesn't dissolve in water. However, it's a strong poison and can inflame in air. Its compound with hydrogen can produce both forms **A** and **B** yielding 14-atomic molecule **C** that yields acids **D** and **E** by reacting with water. Compound **B** oxidizes with air forming compound **F** which consists of the same elements as compound **C**. $M_r(\text{C}) : M_r(\text{F}) = 1.29$. One mole of **A** can react with 6 moles of water. At low temperatures it yields two-basic acid **G** which has 3 hydrogen atoms. The same reaction at high temperatures yields a 3-basic acid, which could also be produced from **C** and water, and poison gas **H** that has the same molecular structure as NH_3 .
- a) Draw the molecular structure of **A**, **B** and **H** (they have a similar structure).
 - b) Calculate the molar masses of **C** and **F**.
 - c) What structure does acid **C** have?
 - d) Write the reactions for: 1) $\text{A} + \text{O}_2 \rightarrow$; 2) $\text{C} \rightarrow \text{D}$; 3) $\text{C} \rightarrow \text{E}$; 4) $\text{B} \rightarrow \text{F}$; 5) $\text{F} + 6\text{H}_2\text{O} \rightarrow \text{G}$; 6) $\text{F} + 6\text{H}_2\text{O} \rightarrow \text{H} + \dots$
 - e) Write the formulas and names of **A**, **B**, **C**, **D**, **E**, **F**, **G**, **H**.

Form XII

1. The solution of acetic acid was electrolyzed to give off 40.0 dm^3 of gas (25°C and 761 mm Hg). Its density is equal 0.476 relative to the density of the air. The yield by the current is 85%. $W = 0.393 \text{ kWh}$. You can neglect the solubility of gasses. During the electrolysis, radical isn't destroyed. Molar mass of the air is 29.0 g/mol .

- a) What substances are produced by the electrolysis of acetic acid and water? Determine the average molar masses of the exuding gaseous mixture.

- b) Write the equations for the anode and cathode processes describing the electrolysis of the solution of the acetic acid.
- c) Determine the amount of the exuding gaseous mixture.
- d) Determine the amounts of the acetic acid and the water in electrolysis.
- e) Determine the quality of electricity used in electrolysis and the tension on the electrode cell.
2. 0.499 g of an equimolecular mixture of organic compounds has a volume equal to 230 ml under standard conditions. Both gases are from one class of organic compounds consisting of carbon, hydrogen and oxygen. Under normal conditions they don't react with sodium and the solution of Br_2 . The equimolecular mixture was lead to the STP and 0.497 g of the sample ($V = 24.0$ ml) from the gaseous phase was taken.
- a) Determine the molar masses of the both gases.
- b) Determine the formulas of the both gases and give their names.
- c) Why do the molar masses taken from the experimental data differ from the calculation's data?
3. Metal **A** reacts with chlorine forming oxidizing agent **B** which consist of 45.5% metal and 54.5% chlorine. The reaction of the compound **B** with methyl magnesium iodide (in diethyl ether) yields the tetraalkyl compound **C** The reaction of 1.0 g of compound **C** with 4.4 g of compound **B** yields 5.4 g of compound **D** which has one atom of metal **A**. The basic hydrolysis of **D** forms the compound **E** which is similar in structure to carboxylic acid. However, it is an amphoteric compound: the reaction with alkali yields a salt, with concentrated HCl yields the compound **D**. In all these compounds metal **A** has the same oxidation number.
- a) Determine the molar mass of metal **A**.
- b) Write the equations for the reactions: 1) $\text{A} \rightarrow \text{B}$; 2) $\text{B} \rightarrow \text{C}$; 3) $\text{C} + \text{B} \rightarrow \text{D}$; 4) $\text{D} \rightarrow \text{E}$; 5) $\text{E} + \text{NaOH} \rightarrow$; 6) $\text{E} + \text{HCl} \rightarrow$.
- c) Identify the compounds **A**, **B**, **C**, **D**, **E** and give their names.
4. The quantitative composition of two minerals is the same. They consist of four elements; one of which is metal whose oxidation number is +II. When these minerals are heated (~ 300 °C), they both decompose to the same products which consist of two elements. Both in the first and second cases, amount of the formed gaseous mixture is equal to the amount of the formed solid compound. The decomposition of 10.00 g of mineral **1** yields 3.56 dm^3 of gaseous mixture. Its density is 0.788 g/cm^3 (200 °C and normal pressure). The decomposition of mineral **2** under the same condition yields 3.42 dm^3 of a gaseous mixture with a density equal to 0.898 g/dm^3 .
- a) What compounds are formed after the decomposition of these minerals (formulas and names)?
- b) Calculate the mass and amount of gaseous mixtures formed after the decomposition of 10.00 g of minerals **1** and **2**.
- c) Determine the molar mass of metal.
- d) Calculate the ratio of the gaseous compound formed after the decomposition of 1 mole of minerals **1** and **2**.
- e) Write the formulas of minerals **1** and **2**.
5. Acyclic organic compound **X** consists of carbon, hydrogen and oxygen. Compound **X** is quite stable and its standard heat of formation is -344.2 kJ/mol . Heat of combustion of 3.00 g of compound **X** is equal to $\Delta H = -46.32 \text{ kJ}$. Compound **X** doesn't contain O-O and O-H bonds. Standard enthalpy of burning of compound **X** (gases are formed) is equal to -926.4 kJ/mol . Standard heats of formation ($\Delta_f H^\circ$) for CO_2 and H_2 are -393.5 and -241.8 kJ/mol respectively.
- a) Determine the molar mass of **X**.
- b) Write the enthalpy of burning of **X** using the heats of formation of the initial compounds and substances.
- c) Write the empirical formula of **X** (check to see if it corresponds to its enthalpy).
- d) Write the formulas of the possible isomers of **X**.
- e) Write the formula and the name of its isomer that corresponds to the given data.
6. The reaction of alkene with ozone and following hydrolysis yields decomposition with double bond and forms carbonyl groups at both sides.
- a) Draw 4 isomers for one alkene (don't confide optical and geometric isomers) which has 3-, 4-, 5- and 6-membered cycle. The reaction of these isomers with ozone and water yields the

same amounts of the following compounds:

CH_2O ; $(\text{CHO})_2$; $(\text{CHO})\text{CH}(\text{CH}_3)\text{C}(\text{CH}_3)(\text{CHO})_2$.

- b)** Mark the asymmetric carbons in this compound with an asterisk.
- c)** Determine the optical active compound among the substances. Draw their enantiomers and give their names.

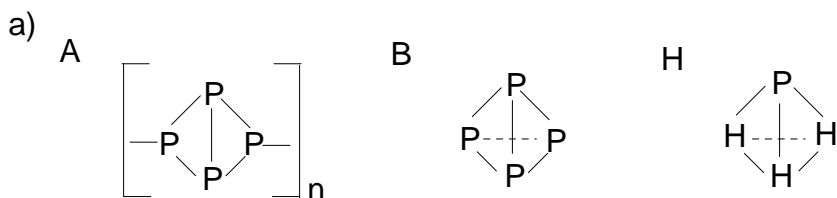
Solutions.

Form X

1. a) A - Cr_2O_3 (chrome(III)oxide); B - $\text{Na}_2\text{Cr}_2\text{O}_7$ (sodium dichromate) C - Na_2SO_4 (sodium sulfate); D - NaOH (sodium hydroxide); E - NaCrO_2 (sodium chromite); F - $\text{Cr}(\text{OH})_3$ (chrome(III)hydroxide); K = $\text{Na}_3[\text{Cr}(\text{OH})_6]$ (sodium hexahydroxochromate(III)); G - $\text{CrO}(\text{OH})$ (chrome(III)hydroxyoxide); H - Cr (chrome); I - Na_2CrO_4 (sodium chromate).

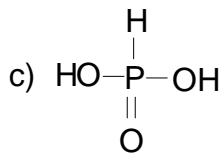
- b) 1) $\text{Na}_2\text{Cr}_2\text{O}_7 + \text{S} \rightarrow \text{Cr}_2\text{O}_3 + \text{Na}_2\text{SO}_4$
 2) $\text{Cr}_2\text{O}_3 + 2\text{NaOH} \rightarrow 2\text{NaCrO}_2 + \text{H}_2\text{O}$
 3) $\text{NaCrO}_2 + 2\text{H}_2\text{O} + 2\text{NaOH} \rightarrow \text{Na}_3[\text{Cr}(\text{OH})_6]$
 4) $\text{Na}_3[\text{Cr}(\text{OH})_6] + 3\text{H}^+ \rightarrow 3\text{Na}^+ + \text{Cr}(\text{OH})_3 \downarrow + 3\text{H}_2\text{O}$
 5) $\text{Cr}(\text{OH})_3 \rightarrow \text{CrO}(\text{OH}) + \text{H}_2\text{O}$
 6) $2\text{CrO}(\text{OH}) \xrightarrow{150^\circ\text{C}} \text{Cr}_2\text{O}_3 + \text{H}_2\text{O}$
 7) $\text{Cr}_2\text{O}_3 + 2\text{Al} \rightarrow \text{Al}_2\text{O}_3 + 2\text{Cr}$
 8) $2\text{Cr} + 2\text{Na}_2\text{CO}_3 + 3\text{O}_2 \rightarrow 2\text{Na}_2\text{CrO}_4 + 2\text{CO}_2$

2.

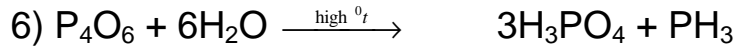
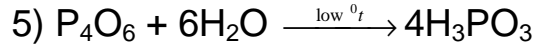


b) compound C: $M(\text{P}_4\text{O}_{10}) = 284 \text{ g/mol}$; compound F: $M(\text{P}_4\text{O}_6) = 220 \text{ g/mol}$

$$\frac{284}{220} = 1.29$$



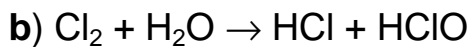
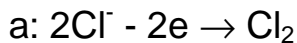
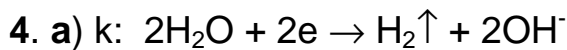
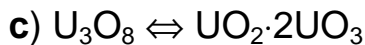
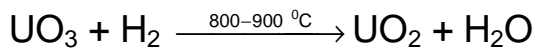
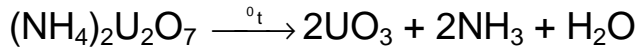
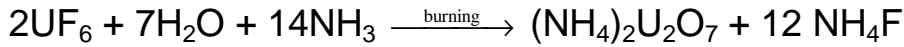
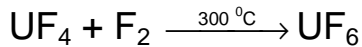
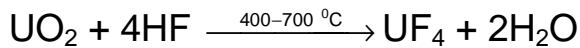
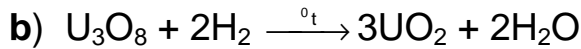
- d) 1) $4\text{P} + 5\text{O}_2 \rightarrow \text{P}_4\text{O}_{10}$
 2) $\text{P}_4\text{O}_{10} + 2\text{H}_2\text{O} \rightarrow 4\text{HPO}_3$
 3) $\text{P}_4\text{O}_{10} + 6\text{H}_2\text{O} \rightarrow 4\text{H}_3\text{PO}_4$
 4) $\text{P}_4 + 3\text{O}_2 \rightarrow \text{P}_4\text{O}_6$



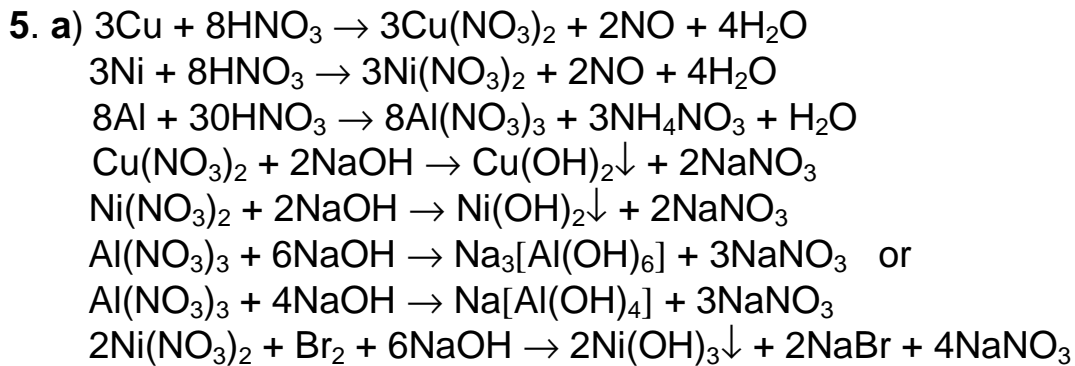
e) A - P (red phosphorus); B - P₄ or P (white phosphorus); C - P₄O₁₀ (tetraphosphorusdecaoxide); D - HPO₃ (metaphosphorous acid); E - H₃PO₄ (orthophosphorous acid); F - P₄O₆ (tetraphosphorushexaoxide); G - H₃PO₃ (phosphorous acid); H - PH₃ (phosphine or phosphan).

3. a) 16/3 IV
 U₃O₈ (triuraniumoktaoxide); UO₂ (uranium dioxide); UF₄ (uranium(IV)fluoride); IV

VI VI
 VI
 UF₆ (uranium(VI)fluoride); (NH₄)₂U₂O₇ (ammonium diuranate(VI)); UO₃ (uranium trioxide).



$$m(\text{KClO}_3) = \frac{1}{3} \cdot \frac{1}{2} \cdot \frac{0,35 \text{ A} \cdot 3600 \text{ s}}{96500 \text{ A} \cdot \text{s}} \cdot 123 \text{ g/mol} = 0.27 \text{ g}$$



b) $m[\text{Cu}(\text{OH})_2] + m[\text{Ni}(\text{OH})_2] = 21.310 \text{ g}$
 $m[\text{Cu}(\text{OH})_2] + m[\text{Ni}(\text{OH})_3] = 21.395 \text{ g}$
 $n(\text{Ni}) = \Delta n(\text{OH}^-) = (21.395 - 21.310) \text{ g} \cdot \frac{1 \text{ mol}}{17 \text{ g}} = 0.0050 \text{ mol}$

c) $m(\text{Ni}) = 0.0050 \text{ mol} \cdot \frac{2.92}{14.60} \cdot 58.7 \text{ g/mol} = 0.0587 \text{ g} \approx 0.059 \text{ g}$

$$m[\text{Ni}(\text{OH})_2] = 0.0050 \text{ mol} \cdot 92.7 \text{ g/mol} = 0.4635 \text{ g}$$

$$m[\text{Cu}(\text{OH})_2] = 21.310 - 0.4635 = 20.846 \text{ g}$$

$$m(\text{Cu}) = \frac{1}{1} \cdot 20.846 \text{ g} \cdot \frac{63.54}{97.55} \cdot \frac{2.92}{14.60} = 2.716 \text{ g} \approx 2.72 \text{ g}$$

$$m(\text{Al}) = 2.92 \text{ g} - 0.059 \text{ g} - 2.716 \text{ g} = 0.145 \text{ g}$$

d) $\%(\text{Ni}) = \frac{0.059}{2.92} \cdot 100 = \approx 2$

$$\%(\text{Cu}) = \frac{2.72}{2.92} \cdot 100 = \approx 93$$

$$\%(\text{Al}) = \frac{0.145}{2.92} \cdot 100 = \approx 5$$

6. a) $n(\text{CH}_4) = 3.60 \text{ MJ} \cdot \frac{1}{0.300} \cdot \frac{1 \text{ mol}}{802 \text{ kJ}} \cdot \frac{1000 \text{ kJ}}{1 \text{ MJ}} \approx 15.0 \text{ mol}$

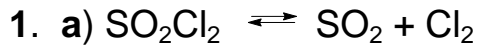
b) $m(\text{CO}_2) = \frac{1}{1} \cdot 15.0 \text{ mol} \cdot 44.0 \text{ g/mol} = 660 \text{ g} = 0.660 \text{ kg}$

$$\mathbf{c)} \quad n(\text{natural gas}) = 14.96 \text{ mol} \cdot \frac{100}{99} = 15.11 \text{ mol}$$

$$V(\text{natural gas in summer}) = 15.11 \text{ mol} \cdot 22.4 \text{ dm}^3 / \text{mol} \cdot \frac{293}{273} = 363.2 \text{ dm}^3 \approx \\ \approx 0.363 \text{ m}^3$$

$$V(\text{natural gas in winter}) = 15.11 \text{ mol} \cdot 22.4 \text{ dm}^3 / \text{mol} \cdot \frac{253}{273} = 313.7 \text{ dm}^3 \approx \\ \approx 0.314 \text{ m}^3$$

Solutions 11. Form



$$K_c = \frac{[\text{SO}_2][\text{Cl}_2]}{[\text{SO}_2\text{Cl}_2]}$$

b) equilibrium I $0,0811 = \frac{x \cdot x}{0,0200 - x}$, where x is equilibrium concentration of as SO_2 as Cl_2

$$x^2 + 0,0811x - 0,001622 = 0$$

$$x = \frac{-0,0811 \pm \sqrt{0,00658 + 0,00648}}{2} \Rightarrow 0,0166$$

$$[\text{SO}_2] = [\text{Cl}_2] = 0,0166 \text{ mol/dm}^3 \quad [\text{SO}_2\text{Cl}_2] = 0,0034 \text{ mol/dm}^3$$

Equilibrium II $0,0811 = \frac{y^2}{0,0200}$, where y is equilibrium concentration of as SO_2 as Cl_2

$$y^2 = 0,001622; \quad y = 0,04027$$

$$[\text{SO}_2] = [\text{Cl}_2] = 0,04027 \text{ mol/dm}^3, \quad [\text{SO}_2\text{Cl}_2] = 0,02 \text{ mol/dm}^3$$

c) $K_c' = \frac{[\text{SO}_2\text{Cl}_2]}{[\text{SO}_2][\text{Cl}_2]} = \frac{0,0034}{0,0166^2} = 12,3 \text{ dm}^3/\text{mol} \quad \text{or}$

$$K_c' = \frac{1}{K_c} = \frac{1}{0,0811} = 12,3 \text{ dm}^3/\text{mol}$$

d) $K_p = \frac{p(\text{SO}_2) \cdot p(\text{Cl}_2)}{p(\text{SO}_2\text{Cl}_2)}$

$$p = \frac{n}{V} \cdot R \cdot T \Rightarrow c(R \cdot T)$$

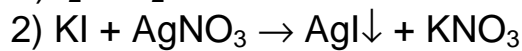
$$K_p = \frac{[\text{SO}_2] \cdot RT \cdot [\text{Cl}_2] \cdot RT}{[\text{SO}_2\text{Cl}_2] \cdot RT} \Rightarrow K_c RT =$$

$$= 0,0811 \text{ mol/dm}^3 \cdot 0,0820 \frac{\text{atm} \cdot \text{dm}^3}{\text{mol} \cdot \text{K}} \cdot 446 \text{ K} = 2,97 \text{ atm}$$

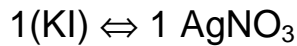
2. a) $k \cdot t = \ln \frac{c_0}{c_t}$, whence $k = \frac{\ln 2}{T} = 0,0861 \text{ day}^{-1}$

b) $t = \frac{1}{0,0861} \cdot \ln \frac{100}{0,01} = 107 \text{ days}$

c) Iodine



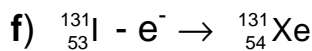
e) Let the mass be 1,000 grams



$$n(\text{KI}) = \frac{1}{1} \cdot 1,000 \text{ g} \cdot \frac{1 \text{ mol}}{169,9 \text{ g}} = 0,005886 \text{ mol}$$

$$m(\text{K}) = 0,005886 \text{ mol} \cdot \frac{39,1 \text{ g}}{1 \text{ mol}} = 0,230 \text{ g}$$

$$M(\text{I}) = \frac{(1,000 - 0,230) \text{ g}}{0,005886 \text{ mol}} = 130,8 \text{ g/mol} \approx 131 \text{ g/mol}$$



3. i) $K_{\text{diss}} = \frac{c \cdot \alpha \cdot c \cdot \alpha}{c(1-\alpha)} = c \cdot \alpha^2$, whence $\alpha = \sqrt{\frac{K_{\text{diss}}}{c}}$

$$[\text{H}^+] = c \cdot \alpha = \sqrt{K_{\text{diss}} \cdot c}$$

$$\text{or } K_{\text{diss}} = \frac{[\text{A}^-] \cdot [\text{H}^+]}{[\text{AH}]} \approx \frac{[\text{H}^+]^2}{c_h} \quad ; \quad [\text{H}^+] = \sqrt{c \cdot K_{\text{diss}}}$$

$$\text{ii) } [\text{OH}^-] = \sqrt{K_{\text{diss}} \cdot c}$$

$$[\text{H}^+] = \frac{10^{-14}}{[\text{OH}^-]}$$

$$\text{iii) a) } [\text{H}^+] = 10,00 \text{ cm}^3 \cdot \frac{1 \text{ dm}^3}{1000 \text{ cm}^3} \cdot \frac{0,0100 \text{ mol}}{\text{dm}^3} \cdot \frac{1}{100 \text{ cm}^3} \cdot \frac{1000 \text{ cm}^3}{1 \text{ dm}^3} = 1,00 \cdot 10^{-3} \text{ mol/dm}^3$$

$$\text{pH} = -\lg. 1,00 \cdot 10^{-3} = 3,00$$

$$\text{b) } [\text{H}^+] = \sqrt{5,01 \cdot 10^{-8} \cdot 2,00 \cdot 10^{-2}} = \sqrt{10,02 \cdot 10^{-10}} = 3,17 \cdot 10^{-5}$$

$$\text{pH} = -\lg. 3,17 \cdot 10^{-5} = 4,50$$

$$\text{c) } [\text{OH}^-] = \sqrt{1,79 \cdot 10^{-5} \cdot 6,00 \cdot 10^{-2}} = \sqrt{1,074 \cdot 10^{-6}} = 1,04 \cdot 10^{-3}$$

$$[\text{H}^+] = \frac{10^{-14}}{1,04 \cdot 10^{-3}} = 9,61 \cdot 10^{-12}$$

$$\text{pH} = -\lg. 9,61 \cdot 10^{-12} = 11,0$$

$$\text{d) } [\text{OH}^-] = 5,00 \cdot 10^{-3} \text{ mol/dm}^3 \cdot \frac{1}{100} = 5,00 \cdot 10^{-5} \text{ mol/dm}^3$$

$$[\text{H}^+] = \frac{10^{-14}}{5,00 \cdot 10^{-5}} = 2,00 \cdot 10^{-10}$$

$$\text{pH} = -\lg. 2,00 \cdot 10^{-10} = 9,70$$

e) Ethanol hardly dissociates in water. That's why its aqueous solution's pH is ~7. Because of the tendency for atmospheric CO₂ to dissolve, this solution can be slightly acidic.

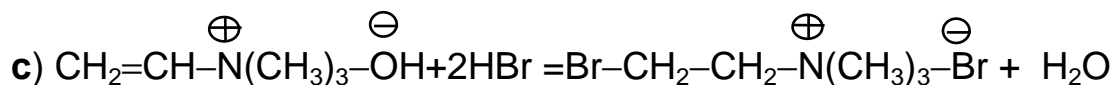
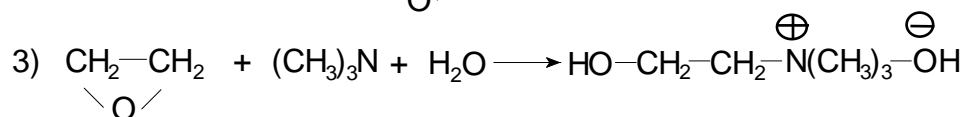
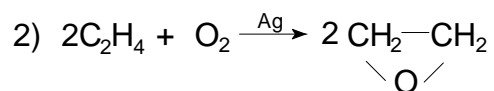
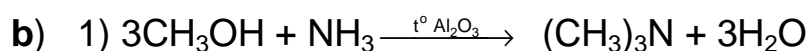
iv) No 1 MO - red, solution a

No 2 PP - red, **d or c**
 TP - blue, solution **c**
 No 3 MR - yellow, **e or d**
 PP - colorless, solution **e**
 No 4 PP - red
 TP - colorless, solution **d**
 No 5 MR – orange-red (transition area), solution **b**

4. a) **A** – NH₃ (ammonia); **B** – CH₃NH₂ (methylamine);

D – (CH₃)₃N (trimethylamine);

E – $\begin{array}{c} \text{CH}_2\text{---CH}_2 \\ \diagdown \quad \diagup \\ \text{O} \end{array}$ ethylene oxide



5. a) Let the mass be 100 grams

$$n(\text{Cl}) = 100 \text{ g} \cdot 0,722 \cdot \frac{1 \text{ mol}}{35,5 \text{ g}} = 2,03 \text{ mol}$$

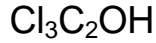
$$n(\text{C}) = 100 \text{ g} \cdot 0,163 \cdot \frac{1 \text{ mol}}{12,0 \text{ g}} = 1,36 \text{ mol}$$

$$n(\text{O}) = 100 \text{ g} \cdot 0,1082 \cdot \frac{1 \text{ mol}}{16,0 \text{ g}} = 0,676 \text{ mol}$$

$$n(\text{H}) = 100 \text{ g} \cdot 0,0687 \cdot \frac{1 \text{ mol}}{1,008 \text{ g}} = \approx 0,677 \text{ mol}$$

If the number of hydrogen and oxygen atoms is one, then

$$n(\text{C}) = \frac{1}{0,677} \cdot 1,36 \text{ mol} = 2,0 \text{ mol} \quad \text{and} \quad n(\text{Cl}) = \frac{1}{0,677} = 3,0 \text{ mol}$$



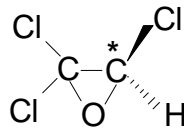
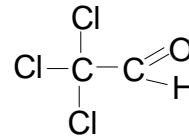
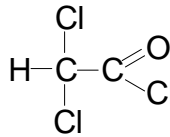
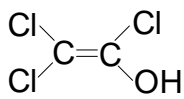
b)

$$M(\text{monohydrate}) = 1,86 \frac{\text{K} \cdot \text{kg}}{\text{mol}} \cdot \frac{1}{0,372 \text{ K}} \cdot 3,31 \text{ g} \cdot \frac{1}{0,100 \text{ kg}} = 165,5 \text{ g/mol}$$

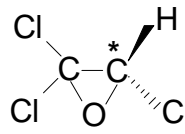
$$M(\text{A}) = 165,5 \text{ g/mol} - 18,0 \text{ g/mol} = 147,5 \text{ g/mol}$$

Compound A's bruttoformula is equal to the minimal integer-numbered ratio of atoms in the molecule.

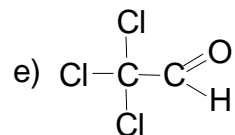
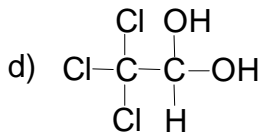
c)



R



S



d) 2,2,2-trichloroethan-1,1-diol

e) 2,2,2-trichloroethanal

6. a) $m(\text{anthracite}) = \frac{1 \text{ kg}}{28,5 \text{ MJ} \cdot 0,3} \cdot \frac{3,60 \text{ MJ}}{1 \text{ kW}} = 0,421 \text{ kg/kW}$

$$m(\text{schist}) = \frac{1 \text{ kg}}{10,5 \text{ MJ} \cdot 0,3} \cdot \frac{3,60 \text{ MJ}}{1 \text{ kW}} = 1,14 \text{ kg/kW}$$

b) $\text{S} \Leftrightarrow \text{SO}_2 \Leftrightarrow \text{CaO} \Leftrightarrow \text{CaSO}_3$

$$n(\text{S fixed}) = 1140 \text{ g} \cdot 0,88 \cdot 0,018 \cdot 0,8 \cdot \frac{1 \text{ mol}}{32 \text{ g}} = 0,451 \text{ mol}$$

$$m(\text{CaO}) = 0,451 \text{ mol} \cdot 56,1 \text{ g/mol} = 25,3 \text{ g} \sim 25,0 \text{ g}$$

c) In the anthracite:

$$m(\text{CO}_2) = 421 \text{ g} \cdot 0,94 \cdot 0,85 \cdot \frac{44}{12} = 1233 \text{ g} \approx 1200 \text{ g}$$

In the schist : $m(\text{CO}_2) = 1140 \text{ g} \cdot 0,88 \cdot 0,27 \cdot \frac{44}{12} = 993 \text{ g} \approx 990 \text{ g}$

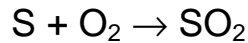
+ CaCO_3 decayed $1140 \text{ g} \cdot 0,88 \cdot 0,41 \cdot 0,95 \cdot \frac{44}{100} = 172 \text{ g}$

Total: **1162 g**

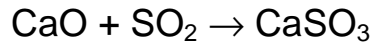
d) $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$

$$\Delta H = -636 \text{ kJ} - 394 \text{ kJ} - (-1207 \text{ kJ}) = +177 \text{ kJ}$$

$$\Delta H (\text{CaO received}) = 0,451 \text{ mol} \cdot 177 \text{ kJ/mol} = 79,8 \text{ kJ}$$



$$\Delta H (\text{SO}_2 \text{ received}) = 0,451 \text{ mol} \cdot (-297 \text{ kJ/mol}) = -133,9 \text{ kJ}$$



$$\Delta H = -1346 \text{ kJ} - (-636 \text{ kJ} - 297 \text{ kJ}) = -413 \text{ kJ}$$

$$\Delta H (\text{CaSO}_3 \text{ received}) = 0,451 \text{ mol} \cdot (-413 \text{ kJ/mol}) = -186,3 \text{ kJ}$$

$$\Sigma \Delta H (\text{sulfur (80 %) fixed}) = 79,8 \text{ kJ} - 133,9 \text{ kJ} - 186,3 \text{ kJ} = -240,4 \text{ kJ} \approx -240 \text{ kJ}$$

e) From the anthracite $m(\text{SO}_2) = 421 \text{ g} \cdot 0,94 \cdot 0,015 \cdot \frac{64}{32} = 11,87 \approx 12 \text{ g}$

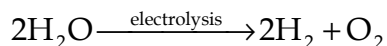
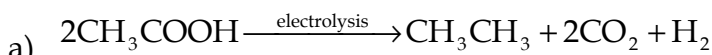
From the schist

$$m(\text{SO}_2) = 1140 \text{ g} \cdot 0,88 \cdot 0,018 \cdot 0,2 \cdot \frac{64}{32} = 7,22 \text{ g} \approx 7,2 \text{ g}$$

SOLUTIONS

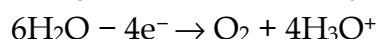
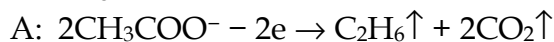
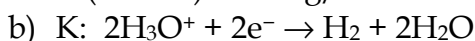
Form IX

Solution 1.



$M(\text{C}_2\text{H}_6 \cdot 2\text{CO}_2 \cdot \text{H}_2) = 30.0 \text{ g/mole}$

$M(2\text{H}_2 \cdot \text{O}_2) = 12.0 \text{ g/mole}$



c) $n(\text{gases}) = \frac{761}{760} \text{ atm} \cdot \frac{40.0 \text{ dm}^3 \cdot 1 \text{ mole} \cdot \text{K}}{0.0820 \text{ atm} \cdot \text{dm}^3 \cdot 298 \text{ K}} = 1.64 \text{ mole}$

d) $M(\text{gases}) = 29.0 \text{ g/mole} \cdot 0.476 = 13.8 \text{ g/mole}$

If the amount of the formed mixture of the gases is x moles then the amount of the gases formed from the acetic acid is $(1.64 - x)$ moles.

$x \cdot 12.0 \text{ g/mole} + (1.64 \text{ mol} - x) \cdot 30.0 \text{ g/mole} = 1.64 \text{ mole} \cdot 13.8 \text{ g/mole}$

$12.0x \text{ g/mole} + 49.2 \text{ g} - 30.0x \text{ g/mole} = 22.6 \text{ g}$

$18x \text{ g/mole} = 26.6 \text{ g}$

$x \approx 1.48 \text{ mole}$

$n(\text{CH}_3\text{COOH}) = \frac{1}{2} \cdot (1.64 - 1.48) \text{ mole} = 0.080 \text{ mole}$

$n(\text{H}_2\text{O}) = \frac{2}{3} \cdot 1.48 \text{ mole} = 0.987 \text{ mole}$

e) $Q(\text{CH}_3\text{COOH}) = 0.080 \text{ F}$

$Q(\text{H}_2\text{O}) = 2 \cdot 0.987 \text{ F} = 1.97 \text{ F}$

$\Sigma[Q(\text{CH}_3\text{COOH}) + Q(\text{H}_2\text{O})] = 2.05 \text{ F}$

$U = 0.393 \text{ kWh} \cdot \frac{1000 \text{ A} \cdot \text{V/kW} \cdot 3600 \text{ s/h}}{96485 \text{ A} \cdot \text{s/F}} \cdot \frac{0.85}{2.05 \text{ F}} = 6.1 \text{ V}$

Solution 2.

a) $M(25^\circ \text{C gases}) = \frac{0.499 \text{ g}}{0.230 \text{ dm}^3} \cdot \frac{8.314 \text{ J} \cdot \text{mole}^{-1} \cdot \text{K}^{-1} \cdot 298 \text{ K}}{100 \text{ kPa}} = 53.8 \text{ g/mole}$

$M(0^\circ \text{C gases}) = \frac{0.0497 \text{ g}}{0.024 \text{ dm}^3} \cdot \frac{8.314 \text{ J} \cdot \text{mole}^{-1} \cdot \text{K}^{-1} \cdot 273 \text{ K}}{100 \text{ kPa}} = 47.0 \text{ g/mole}$

The molar mass of the mixture of the gases decreases only because of the condensation of one gas. At the low boiling point, the molar mass of the gas G' is $M(G') \approx 47 \text{ g/mole}$

$0.5 \cdot [M(G') + M(G'')] = 53.8 \text{ g/mol}$

$M(G'') = 2 \cdot 53.8 \text{ g/mole} - 47 \text{ g/mole} = 60.6 \text{ g/mole}$

b) Because the molar masses of C, H and O are close to integral numbers, we may round the molar mass of the gas G' to 46 g/mol. The equation $12x + 1y + 16z = 46.0$ satisfies the number of moles of carbon 1 and 2, then the mole number of hydrogen (y) and oxygen (z) is the following:

x	y	z	M(g/mol)	formula
2	6	1	46	$\text{C}_2\text{H}_6\text{O} \rightarrow \text{CH}_3\text{OCH}_3$ or $\text{C}_2\text{H}_5\text{OH}$
1	2	2	46	$\text{CH}_2\text{O}_2 \rightarrow \text{HCOOH}$

Only dimethylether (methoxymethane) satisfies this condition, because ethylalcohol and methane acid are liquids under normal conditions and they are not chemically active.

G'' is CH₃OC₂H₅ (methylethylether, or methoxyethane)

M(CH₃OC₂H₅) = 60.0 g/mol

- c) Ethers are volatile compounds $t_{\text{boil}}(\text{CH}_3\text{OC}_2\text{H}_5) = 7.6^\circ\text{C}$, therefore they are mostly in a gaseous state under normal conditions.

Solution 3.

- a) If a metal reacts with chlorine and yields tetraalkyl compound, then its degree of oxidation in its compounds should be IV.

$$M(\text{A}) = 4 \cdot 35.5 \text{ g/mole} \cdot \frac{45.5}{54.5} \approx 119 \text{ g/mole}$$

A is Sn (tin)

- b) 1) $\text{Sn} + 2\text{Cl}_2 \rightarrow \text{SnCl}_4$
 2) $\text{SnCl}_4 + 4\text{CH}_3\text{MgI} \rightarrow (\text{CH}_3)_4\text{Sn} + 4\text{MgICl}$
 3) $(\text{CH}_3)_4\text{Sn} + 3\text{SnCl}_4 \rightarrow 4\text{CH}_3\text{SnCl}_3$, because
 $n[(\text{CH}_3)_4\text{Sn}] = 1 \text{ g} / (179 \text{ g/mole}) = 0.0056 \text{ mole}$
 $n(\text{SnCl}_4) = 4.4 \text{ g} / (260 \text{ g/mole}) = 0.017 \text{ mole}$, whence mole ratio is 3 : 1
 4) $\text{CH}_3\text{SnCl}_3 + \text{NaOH} \rightarrow \text{CH}_3\text{Sn}(\text{OH})_3 + 3\text{NaCl}$
 5) $\text{CH}_3\text{SnOOH} + \text{NaOH} \rightarrow \text{CH}_3\text{SnOONa} + \text{H}_2\text{O}$
 6) $\text{CH}_3\text{SnOOH} + 3\text{HCl} \rightarrow \text{CH}_3\text{SnCl}_3 + 2\text{H}_2\text{O}$
- c) A - Sn (tin); B - SnCl₄ (tin(IV)chloride), C - (CH₃)₄Sn (tetramethyl tin), D - CH₃SnCl₃ (methyltin(IV)chloride), E - CH₃SnOOH (methyltinooxyhydroxide).

Solution 4.

- a) CuO (copper(II)oxide); CO₂ (carbon dioxide); H₂O (water or hydrogen dioxide).

b) $m^1(\text{gas}) = 3.56 \text{ dm}^3 \cdot 0.788 \text{ g/dm}^3 = 2.81 \text{ g}$

$m^2(\text{gas}) = 3.38 \text{ dm}^3 \cdot 0.898 \text{ g/dm}^3 = 3.04 \text{ g}$

$$n^1(\text{gas}) = 3.56 \text{ dm}^3 \cdot \frac{100 \text{ kPa}}{8.314 \text{ J} \cdot \text{mole}^{-1} \cdot \text{K}^{-1} \cdot 473 \text{ K}} = 0.0905 \text{ mole}$$

$$n^2(\text{gas}) = 3.42 \text{ dm}^3 \cdot \frac{100 \text{ kPa}}{8.314 \text{ J} \cdot \text{mole}^{-1} \cdot \text{K}^{-1} \cdot 473 \text{ K}} = 0.0871 \text{ mole}$$

- c) $m(\text{MeO}) = 10.00 \text{ g} - 3.04 \text{ g} = 6.96 \text{ g}$
 $M(\text{MeO}) = 6.96 \text{ g} / (0.0871 \text{ mole}) = 79.9 \text{ g/mole}$
 $M(\text{Me}) = 79.9 \text{ g/mol} - 16.0 \text{ g/mol} = 63.9 \text{ g/mole}$
 Metal's oxide is CuO

In order to check the result:

$$m(\text{MeO}) = 10.00 \text{ g} - 2.81 \text{ g} = 7.19 \text{ g}$$

$$M(\text{MeO}) = 7.19 \text{ g} / (0.0905 \text{ mole}) = 79.4 \text{ g/mole}$$

$$M(\text{Me}) = 79.4 \text{ g/mol} - 16.0 \text{ g/mol} = 63.4 \text{ g/mole}$$

- d) $M(\text{gas I}) = 2.81 \text{ g} / (0.0905 \text{ mole}) = 31.0 \text{ g/mol}$

At decomposition, the amounts of the formed compounds are always referred to integral numbers. The middle molar mass of 31 g/mol makes the amount of H₂O and CO₂ in 1 : 1 ratio
 $M(\text{gas II}) = 3.04 \text{ g} / (0.0871 \text{ mole}) = 34.9 \text{ g/mole}$; a 1:2 ratio of H₂O and CO₂ satisfies it.

- e) $2\text{CuO} \cdot \text{H}_2\text{O} \cdot \text{CO}_2 \Leftrightarrow \text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$ (malachite)
 $3\text{CuO} \cdot \text{H}_2\text{O} \cdot 2\text{CO}_2 \Leftrightarrow 2\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$ (azurite)

Solution 5.

a) $n(\mathbf{X}) = -46.32 \text{ kJ} / (-926.4 \text{ kJ/mole}) = 0.05000 \text{ mole}$

$M(\mathbf{X}) = 3.00 \text{ g} / (0.05000 \text{ mole}) = 60.0 \text{ g/mole}$

b) $-926.4 \text{ kJ/mole} = -393.5 \text{ kJ/mole} \cdot n(\text{C}) + (-241.8 \text{ kJ/mole}) / 2 \cdot n(\text{H}) - (-344.2 \text{ kJ})$

c) $12 \text{ g/mole} \cdot n(\text{C}) + 1 \text{ g/mole} \cdot n(\text{H}) + 16 \text{ g/mole} \cdot n(\text{O}) = 60.0 \text{ g/mol}$

$n(\text{O}) \leq 3$

$n(\text{O}) = 3 \text{ mol}$ doesn't work, because $60 - 48 = 12$, $n(\text{C}) = 1$ and $n(\text{H}) = 0$

$n(\text{O}) = 2 \text{ mol}$, then $60 - 32 = 12n(\text{C}) + n(\text{H})$, whence $n(\text{C}) = 2 \text{ mol}$ and $n(\text{H}) = 4 \text{ mol}$.

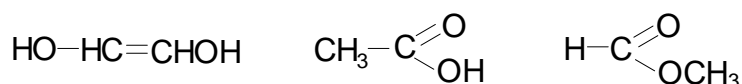
The simplest formula is $\text{C}_2\text{H}_4\text{O}_2$

$n(\text{O}) = 1 \text{ mol}$ doesn't work.

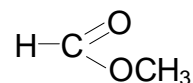
In order to check the result:

$-393.5 \text{ kJ/mol} \cdot 2 \text{ mol} - 241.8 \text{ kJ/mol} \cdot 2 \text{ mol} + 344.2 \text{ kJ/mol} \cdot 1 \text{ mol} = -926.4 \text{ kJ}$

d)

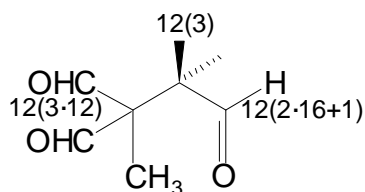
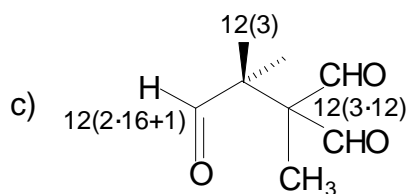
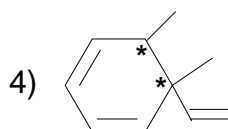
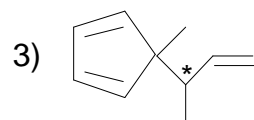
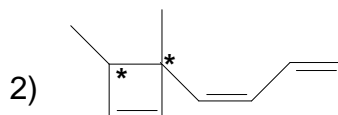
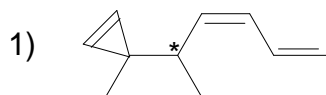


e) Only methyl formate (or methyl methanate) satisfies to the problem's conditions.



Solution 5.

a,b)



R

S

3-2-formyl-2,3-dimethylbutandial

SOLUTIONS

Form IX

Solution 1.

- a) When the carbonates of the metals of the II main group are heated, oxides MeO and CO₂ are formed. Let one carbonate's amount be 1 mole.

$$M(\text{Me}^{\text{I}}\text{O} + \text{Me}^{\text{II}}\text{O}) = 2 \cdot 44 \text{ g/mole} \cdot \frac{1}{38} \cdot 62 \approx 144 \text{ g/mole}$$

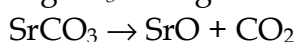
- b) $M(\text{Me}^{\text{I}} + \text{Me}^{\text{II}}) = 144 \text{ g/mole} - 32 \text{ g/mole} = 112 \text{ g/mole}$

II main group Be Mg Ca Sr Ba Ra

$M(\text{g/mole})$ 9 24.3 40.1 87.6 137 226

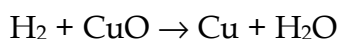
$$M(\text{Mg} + \text{Sr}) = 24.3 \text{ g/mole} + 87.6 \text{ g/mole} = 111.9 \sim 112 \text{ g/mole}$$

- c) $\text{MgCO}_3 \rightarrow \text{MgO} + \text{CO}_2$

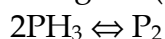


Solution 2.

- a) $3\text{Cu} + 2\text{PH}_3 \rightarrow \text{Cu}_3\text{P}_2 + 3\text{H}_2$

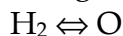


- b) *I tube* $4.96 \text{ g} = m(\text{Cu}_3\text{P}_2) - m(3\text{Cu}) \Leftrightarrow m(\text{P}_2)$



$$n(\text{PH}_3) = \frac{2}{1} \cdot 4.96 \text{ g} \cdot \frac{1 \text{ mole}}{2 \cdot 31.0 \text{ g}} = 0.160 \text{ mole}$$

- II tube* $5.76 \text{ g} = m(\text{CuO}) - m(\text{Cu}) \Leftrightarrow m(\text{O})$



$$n(\text{H}_2 \text{ total}) = 5.76 \text{ g} \cdot \frac{1 \text{ mole}}{16.0 \text{ g}} = 0.360 \text{ mole}$$

$$n(\text{H}_2 \text{ in phosphate}) = \frac{3}{2} \cdot 0.160 \text{ mole} = 0.240 \text{ mole}$$

$$n(\text{H}_2 \text{ initial}) = 0.360 \text{ mole} - 0.240 \text{ mole} = 0.120 \text{ mole}$$

- c) $V = \frac{8.314 \text{ J} \cdot \text{mole}^{-1} \cdot \text{K}^{-1} \cdot 298 \text{ K}}{100 \text{ kPa}} \approx 24.8 \text{ dm}^3/\text{mol}$

- d) $M(\text{PH}_3) = 34.0 \text{ g/mole}$; $m(\text{H}_2) = 2.02 \text{ g/mole}$

$$m(\text{initial mixture}) = 0.16 \text{ mole} \cdot 34 \text{ g/mole} + 0.12 \text{ mole} \cdot 2.02 \text{ g/mole} = 5.44 \text{ g} + 0.24 \text{ g} = 5.68 \text{ g}$$

$$V = (0.160 + 0.120) \text{ mole} \cdot 24.8 \text{ dm}^3/\text{mol} = 6.94 \text{ dm}^3$$

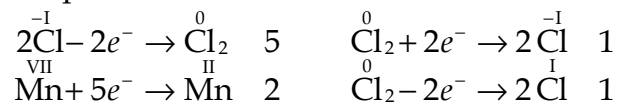
$$\rho = \frac{5.68 \text{ g}}{6.94 \text{ dm}^3} = 0.818 \text{ g/dm}^3$$

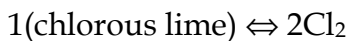
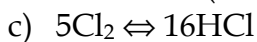
Solution 3.

- a) $\text{KMnO}_4 + \text{HCl} \rightarrow \text{KCl} + \text{MnCl}_2 + \text{Cl}_2 + \text{H}_2\text{O}$



- b) To determine the indexes for the equation of chlorine's receipt reaction, it's better to start with the products, because all of the Cl₂ atoms change their degree of oxidation.

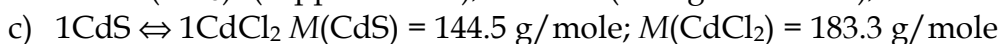
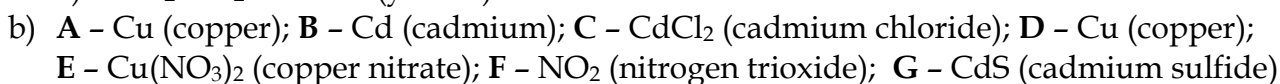
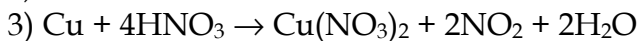
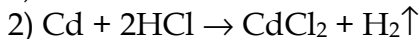




$$M[\text{CaCl}_2 \cdot \text{Ca}(\text{ClO})_2] = 254 \text{ g/mole}$$

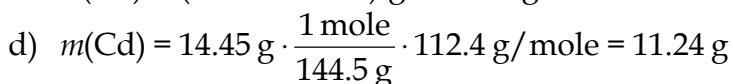
$$m(\text{chlorous lime}) = \frac{1}{2} \cdot \frac{5}{16} \cdot 69.8 \text{ cm}^3 \cdot 1.189 \text{ g/cm}^3 \cdot 0.365 \cdot 0.260 \cdot \frac{1 \text{ mol}}{36.5 \text{ g}} \cdot 254 \text{ g/mol} = 8.56 \text{ g}$$

Solution 4.



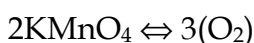
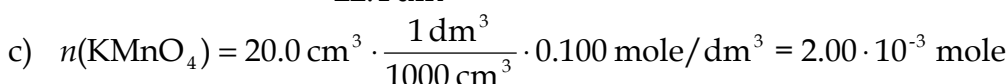
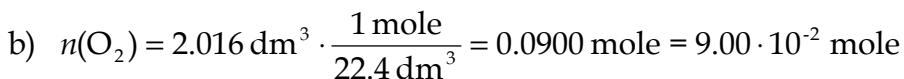
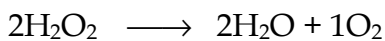
$$m(\text{CdCl}_2) = \frac{1}{1} \cdot 14.45 \text{ g} \cdot \frac{1 \text{ mole}}{144.5 \text{ g}} \cdot 183.3 \text{ g/mole} = 18.33 \text{ g}$$

$$m(\text{Cu}) = (37.99 - 18.33) \text{ g} = 19.66 \text{ g}$$

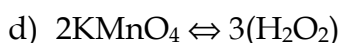


$$\%(\text{Cd}) = \frac{11.24}{11.24 + 19.66} \cdot 100 = 36.38\% \quad \text{and} \quad \%(\text{Cu}) = \frac{19.66}{30.90} \cdot 100 = 63.62\%$$

Solution 5.

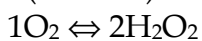


$$n(\text{O}_2) = \frac{3}{2} \cdot 0.002 \text{ mol} = 3.00 \cdot 10^{-3} \text{ mole}$$

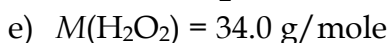


$$n(\text{H}_2\text{O}_2)_r = \frac{3}{2} \cdot 0.002 = 3.00 \cdot 10^{-3} \text{ mole}$$

$$n(\text{O}_2 \text{ catal}) = 0.0900 \text{ mole} - 0.0030 \text{ mole} = 0.0870 \text{ mole}$$



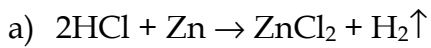
$$n(\text{H}_2\text{O}_2) = \frac{2}{1} \cdot 0.087 = 0.174 \text{ mole}$$



$$n(\text{H}_2\text{O}_2) = (0.174 + 0.003) \text{ mole} = 0.177 \text{ mole}$$

$$m(\text{H}_2\text{O}_2) = 0.177 \text{ mole} \cdot 34.0 \text{ g/mole} = 6.02 \text{ g}$$

$$\%(\text{H}_2\text{O}_2) = \frac{6.02 \text{ g}}{100 \text{ cm}^3 \cdot 1.02 \text{ g/cm}^3} \cdot 100 = 5.90\%$$

Solution 6.

b)
$$V = 1000 \text{ cm}^3 - 100 \text{ g} \cdot \frac{1 \text{ cm}^3}{1.180 \text{ g}} - 9.00 \text{ g} \cdot \frac{1 \text{ cm}^3}{7.14 \text{ g}} = 914 \text{ cm}^3$$

$$n(\text{air}) = 0.914 \text{ dm}^3 \cdot \frac{1 \text{ mole}}{22.4 \text{ dm}^3} = 0.0408 \text{ mole}$$

c) By what initial compound should we calculate the amount of hydrogen

$$m(\text{Zn}) = 100 \text{ g} \cdot 0.365 \cdot \frac{1 \text{ mole}}{36.5 \text{ g}} \cdot 65.4 \text{ g/mole} = 65.4 \text{ g}$$

Properly HCl is in excess

$$n(\text{H}_2) = \frac{1}{1} \cdot 9.00 \text{ g} \cdot \frac{1 \text{ mole}}{65.4 \text{ g}} = 0.1376 \text{ mole}$$

$$n(\text{gases}) = 0.0408 \text{ mole} + 0.1376 \text{ mole} = 0.178 \text{ mole}$$

d)
$$p = 0.178 \text{ mole} \cdot 0.0820 \frac{\text{atm} \cdot \text{dm}^3}{\text{mole} \cdot \text{K}} \cdot 293 \text{ K} \cdot \frac{1}{0.914 \text{ dm}^3} = \approx 4.68 \text{ atm}$$