Tartu University

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ESTONIA

Translated by Tarmo Tamm

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Form IX

1. 130 grams of sodium hydroxide solution was completely neutralized with 100 grams of sulfuric acid solution. The solution crystallized completely on cooling below 32 °C. The heating of 1.61 grams of crystals gave 0.710 grams of anhydrous salt.
   a) Write equations of all reaction.
   b) Calculate the total mass of the anhydrous salt formed.
   c) Determine the formula of the salt with crystal water.
   d) Determine the percentage of the initial solutions.

2. The hydrogen form electrolysis of water contains also some oxygen and water vapor in addition. 1.12 m^3 of this kind of gas (n.c.) was passed through a tube filled with P_4O_{10}, then passed over a heated catalyst (platinated asbestos) and finally through another P_4O_{10} tube. The mass of the first tube was increased by 3.36 grams and the second one by 3.60 grams.
   a) What is the humidity of the electrolytic hydrogen (g/dm^3)?
   b) Write the equation of the reaction proceeding on the catalyst.
   c) How much hydrogen (volume percentage) does the electrolytically produced hydrogen contain?

3. A balloon with a volume of 1500 m^3 has a hull with a mass of 600 kg and it can lift 450 kg (under the conditions of 20 °C and 1.00 atm). The balloon is filled with a mixture of nitrogen and hydrogen. Take the molar mass of air as 29 g/mole.
   a) Calculate the molar volume of air on these conditions.
   b) Calculate the average molar mass of the gas mixture inside the balloon.
   c) Calculate the volume percentage of hydrogen and nitrogen in the balloon.

4. How many grams of NaOH must be dissolved in 200 cm^3 of 6 % solution of sodium hydroxide, to obtain
   a) a 30 per cent solution.
   b) a 2.77 M (mol/dm^3) solution. The density of that solution is 1190 kg/m^3.

5. A mixture of $NaNO_3$, Na_2CO_3 and NaCl weighs 15.0 grams. This mixture was dissolved in 85.0 grams of water. Then 100 grams of 7.30 % HCl solution was added to the solution obtained. A gas evolved, with a volume of 1.12 dm^3 (n.c.) after drying. After that an excess of $AgNO_3$ solution was added to the solution. A precipitate formed with a mass of 42.75 grams after drying.
   a) Write equations of all reactions.
   b) Calculate the mass of all the salts in the mixture.
   c) Calculate the percentile composition of the solution after HCl was added.

6. For safety reasons ethanethiol (C_2H_5SH) as a smelly compound is added to liquid gas. Liquid gas contains 40.0 % propane (C_3H_8) and 60.0 % butane (wt. %). 1.00 ton of liquid gas contains 20.0 g of ethanethiol. Dry air contains 20.95 % O_2 and 0.03 % CO_2 (volume per cent). The amount of other gases in dry air remains constant during the reaction. The density of liquid gas at 20 °C is 615 kg/m^3. At that temperature 1.00 kg of saturated water vapor is contained in 57.8 m^3 of air. $R = 0.08206\ atm \cdot dm^3 \cdot mol^{-1} \cdot K^{-1}$.
   a) Calculate the mass of liquid gas that contains 1 mole of ethanethiol.
   b) How much (mole) of butane and propane is in that mass of liquid gas?
   c) Write the equations of the complete combustion reactions of the three components of liquid gas.
   d) Calculate the amount of gaseous products and initial compounds that were left after 2.00 dm^3 of liquid gas was completely burned in an airtight room (volume of 40.0 m^3) if the temperature before the reaction and also after it was 20.0 °C. In both cases the air is saturated with air vapor. Do not take into account the volumes of water and liquid gas. Consider only the ammount of SO_2 as the product of the burning of ethanethiol. The pressure is 1.00 atm before the burning.
   e) Calculate the concentration of SO_2 in the room (mol/dm^3).
   f) Calculate the pressure in the room after the burning of the liquid gas.

Form X

1. Liquid gas consists of (*wt* %) 40.0 % propane and 60.0 % butane. 1.00 ton of liquid gas contains 30.0 g of smelling agent ethanethiol (C_2H_5SH). The density of liquid gas is 615 kg/m^3. The heat of combustion of propane and butane are -2219 kJ/mole and -2877

kJ/mole respectively. The heat of evaporation of water is 44.0 kJ/mole.

a) Calculate the volume of liquid gas that contains 1.00 g of sulfur.
b) Calculate the volume of the amount of liquid gas from point a) under the pressure of 745 mm Hg and at the temperature of 20 °C.
c) Write the reaction equations for the combustion process of liquid gas.
d) How many moles of CO_2 is formed on the complete combustion of the amount of liquid gas from point a)?
e) How many kg of water can be evaporated with the heat of the complete combustion of the amount of liquid gas from point a) if the loss of heat in the evaporation process is 28.0 %?

2. A Leclanché dry cell consists of a graphite rod in a moist paste of MnO_2-$ZnCl_2$-NH_4Cl, surrounded with a zinc shell.
   a) Write the equations for the half-reactions on cathode and anode.
   b) How long can you use the cell if the currant strength is 1.00×10^{-2} A, the cell contains 25.0 g of paste holding 20.0 % MnO_2 (wt %) and manganese loses one electron in the process.
   c) How many grams of Zn is necessary to reduce the amount of MnO_2 stated in point b) ?

3. A mixture containing one mole fraction of hydrazine (N_2H_4) and two mole fractions of hydrogen peroxide (H_2O_2). The heat of formation for H_2O(g), N_2H_4(l) and H_2O_2(l) at 25 °C are -242, 50.6 and -188 kJ/mole respectively.
   a) Write equations of all the reactions.
   b) Calculate the amount of heat that is produced in the reaction of 10 kg of this mixture at 25 °C.
   c) How many times does the amount of heat calculated in point b) differ from the amount of heat evolving on the combustion of 10 kg of a mixture of H_2 and O_2 (2:1 in volume)?

4. A room with the dimensions of 2.50 m × 3.00 m × 5.00 m, contains 0.100 %(vol.) of CO. The temperature is 15.0 °C and the air pressure is 780 mm Hg. I_2O_5 is used for the removal of CO, turning it to free iodine.
   a) Write the equation of the reaction, pointing out the oxidizer and the reducer.
   b) Calculate the molar volume of gas under those conditions.
   c) Calculate the amount of CO in the room (number of moles).
   d) Calculate the mass of I_2O_5 necessary to remove that amount of CO.

5. A mixture of gas, containing (volume %) 7.00 % of sulfuric dioxide, 11.0 % of oxygen and 82.00 % of nitrogen was passed over a catalyst heated to a high temperature. The flow rate was slow enough to guarantee equilibrium, as a result 90.0 % of sulfuric dioxide was oxidized to sulfuric trioxide.
   a) Write the equation of the reaction.
   b) Calculate the composition of the product gas mixture (in vol. %).
   c) How would the increase or decrease of the gas flow rate change the composition of the gas mixture?

6. An alloy of silver and gold was "dissolved" in a solution of KCN and HCN with the presence of oxygen. Zinc was used to precipitate gold and silver from the soluble cyanide complex. The mass of the precipitate after the reaction (Au+Ag+Zn) was bigger than that of Zn used for the reaction. "The increment of the mass of zinc" formed 75 % of the mass of the initial alloy. The central atom of the complex(es) formed have the oxidation number the same as their group number and the coordination number is the double of it.
   a) Write the equations for the reactions.
   b) Calculate the percentage of the initial alloy mass that "the increment of the mass of Zn" would make, if we had pure gold or silver instead.
   c) Calculate the percentage of gold and silver in the alloy.

Form XI

1. 10.00 grams of an alloy of copper, silver and zinc, was "dissolved" in nitric acid. The excess of nitric acid was neutralized. After that KI solution was added carefully to this solution until nothing more precipitated. The precipitate was then separated and dried in an desiccator, filled with a strong hygroscopic agent. The mass of the precipitate was 19.35 g. The precipitate was then heated under a fume hood until the sharp smell disappeared. The mass of the precipitate decreased by 6.00 grams. It was dusk in the laboratory.
   a) Write the equations for the reactions (5).
   b) Calculate the masses of the metals in the alloy.

2. One solution contains 42.6 g of aluminum nitrate, another one contains 37.1 g of sodium carbonate. The two solutions were poured together. The precipitate that formed was separated and heated.

a) Write equations for the reactions that proceed in the first and second solution before they are poured together.
b) Write equations for the reactions that proceed when they are poured together.
c) Write the total reaction equation.
d) How many grams of which substance is obtained after the precipitate is heated?

3. A compound consists of 5.43% carbon, 0.910 % hydrogen, 36.2 % oxygen and an element havingthe same number of moles as hydrogen.
   a) Determine the formula of the molecule.
   b) Which class of compounds does it belong to ?
   c) Write the equation of the thermal destruction reaction of the compound.

4. Compound A reacts with water in alkaline media, yielding compounds B and C. Compound C reacts with diluted hydrochloric acid to give compound D. Compound D can also be obtained by oxidizing compound B. Heating D in the presence of sulfuric acid gives carbon monoxide.
   a) Identify the compounds A,B,C,D and give their nomenclaturic and popular names.
   b) Write the equations for the corresponding reactions.

5. 1.00 m^3 of gas (p=0.300 MPa, t°=10 °C) was transformed to STP and burned in a sufficient amount ox oxygen. The gas consisted of (vol. %) 95% CH_4 , 1.5% C_2H_6 , 0.5% C_3H_8 and 2.2% N_2. The heats of formation of the following compounds :

ΔH_f^0	CH_4	C_2H_6	C_3H_8	$H_2O(g)$	CO_2
kJ/mole	-74.4	-83.8	-104.7	-285.8	-393.5

The heat of combustion ΔH_f^0 of C_3H_8 is -2219kJ/mole. The heat capacity of water is 4.18J/g·K.
   a) Calculate the volume of gas under normal conditions.
   b) Write the chemical equations of the combustion reaction of the gas.
   c) Determine the minimal volume of air (STP), necessary
   d) Determine the heat of combustion of CH_4 and C_2H_6.
   e) Calculate the amount of water (l), the temperature of which can be raised 11 degrees with the heat, if the loss of heat is 24%.

6. 2-methyl-2-phenyl-ethanoic acid is synthesized.
   a) Which reagents can the compound be synthesized from (write the names and draw the structures).

b) Write the equation of the synthesis reaction.
c) Draw the structure of the S and R forms of 2-methyl-2-phenyl-ethanoic acid. (using ━ and ┈) and determine the "seniority" of the groups.

Form XII

1. A flask with the volume of 1.00 dm^3 is connected to another of 3.00 dm^3 through a closed stopcock. 1.00 mole of N_2O_4 is in equilibrium with 0.086 mole NO_2 in the first flask. The other flask is empty (vacuum). Both flasks are in a thermostat at 25 °C. The equilibrium constant for the reaction of these gases at 298 K is $K_c = 4.62 \cdot 10^{-3}$ mol/dm^3. After the cock is opened a new equilibrium is composed, for which :
   a) Derive the concentrations of N_2O_4 and NO_2.
   b) Calculate the amount of N_2O_4 and NO_2.
   c) Calculate the partial pressures of both the gases.

2. Due to an electrolysis reaction a layer of Cd ($1.00 \cdot 10^{-2}$ mm) was formed on an iron detail. In order to calculate the amount of charge a iodine-coulometer was connected to the circuit (KI oxidizes to iodine due to electric currant). The solution in the coulometer was diluted to 250 cm^3 and for the titration of 20 cm^3 of that solution 23.2 cm^3 of 0.100 M $Na_2S_2O_3$ was required. $\rho(Cd) = 8.70$ g/cm^3.
   a) Write equations for the reactions proceeding on the anode and cathode of the electrolyser and the coulometer.
   b) Calculate the amount of electricity consumed for the electrolysis (A·sek).
   c) Calculate the area of the iron detail.

3. A compound A may be described with the formula: $CoCl_3 \cdot 5NH_3 \cdot H_2O$. Both the compound A and its solution in water are pink. On the titration of 1 mole of A in a water solution with $AgNO_3$ 3 moles of AgCl precipitate is formed quickly. On the heating of 1 mole of A 18 grams of water is segregated and a compound B is formed. The compound B is a purple solid. On the titration of 1 mole of B in water solution with $AgNO_3$ 2 moles of AgCl precipitate is formed quickly. If the suspension is diluted a great deal one more mole of AgCl precipitates due to $AgNO_3$ (though very slowly). The complex part of A and B is octaedric, the ligands are placed in maximal symmetry.

a) Write the compounds A and B as complex compounds and give their nomenclaturic names.
b) Write the reactions with $AgNO_3$.
c) Which complex particle formed before the third mole of Ag^+ ions slowly reacted with the diluted solution of B? Name it.
d) Draw the inner sphere of A and B in space using ━ and ···· .

4. The products on the complete combustion of 1.34 grams of an unknown organic compound in oxygen are 0.806 g of water and 1.00 dm^3 of CO_2 (Normal Conditions). The difference between the melting point of a 10% water solution of the compound and the melting point of the solvent is 1.148 K. A red precipitate forms from an alkaline solution of the compound due to Cu^{2+} . One mole of the compound reacts with 5 moles acetic anhydride forming esters. The compound can also be obtained from the hydrolysis of another compound from the same class of compounds, the hydrolysis proceeds with inversion. $K_{kr} = 1.86$ K·kg/mole.
a) Determine the molar mass and gross formula of the unknown compound.
b) Write the equations for the reactions proceeding between the functional groups and the reagents.
c) Write the equation of the inversion reaction, writing the reactant with a gross formula but drawing the structures (as chain structures) of the products. Name the compounds.
d) Draw the structures for the R and S isomers of the compound (α carbon) using ━ and ···· and determine the "seniority" of the groups.

5. A primary 12 carbon alcohol unsaturated in position 7 (compound A) is partially reduced (with $LiAlH_4$) to give compound B. B gives compound C in a reaction with bromine. Compound C in a reaction with strong alkali gives a mixture of compounds A and D (having equal gross formulas). Reacting with zinc the compound C gives back compound B. On the partial reduction of the mixture of A and D (with $H_2/Pd/CaCO_3$) compound E is formed as the main product, having the same gross formula as compound B. Write the schemes for the reactions and the formulae of the compounds. Name the compounds.

6. Liquid gas contains (wt %) 40.0% of propane and 60% of butane. The density of the liquid gas is 0.615 kg/dm^3. Air contains 21.0% of oxygen (vol. %). The density of air at 25 °C is 1.249 kg/m^3 and the molar mass of air is 28.84 g/mole. The standard heats of formation are given in the table:

ΔH_f^0	C_3H_8	C_4H_{10}	H_2O	CO_2
kJ/mole	-104.7	-125.6	-285.8	-393.5

The heat of combustion of C_3H_8 ΔH_f^0 is -2219 kJ/mole.

a) Write the equations describing the combustion of liquid gas.
b) Determine the volume of 30.0 l of liquid gas at STP.
c) Determine the air pressure and the volume of air required for the combustion of 30.0 l of liquid gas under the conditions stated in the problem.
d) Determine the volume of CO_2 (in m^3) that evolves on the combustion of 30.0 l of liquid gas under the conditions of the problem.
e) Determine the heat of combustion of butane.
f) How many MJ of useful mechanical energy can be obtained on the complete combustion of 30.0 l of CO_2 in a combustion engine if the efficiency of the engine is 31 %.

Answers.

Form IX

1. b) 230g
   c) $Na_2SO_4 \cdot 10H_2O$
   d) 43.9%, 70%

2. a) $3.00 \cdot 10^3$ g/dm^3
   c) 99.4%

3. a) 24.0 dm^3/mol
   b) 12.2 g/mol
   c) 60.9% H_2; 39.1% N_2

4. a) 73g
   b) 7.78g

5. b) 3.85g $NaNO_3$, 5.30g Na_2CO_3, 5.85 g NaCl
   c) 5.92% NaCl, 1.85% HCl; 1.95% $NaNO_3$; 90.3% H_2O

6. a) 3.10 t.
   b) $2.81 \cdot 10^4$ mole C_3H_8; $3.20 \cdot 10^4$ mole C_4H_{10}
   d) before: 341 mole O_2; 0.5 mole CO_2; 11.16 mole C_3H_8; 12.17 mole C_4H_{10}; after: 84.8 mole CO_2; $4 \cdot 10^4$ mole SO_2
   e) $1 \cdot 10^{-8}$ mol/dm^3 SO_2

Form X

1. a) 105 dm^3
   b) 30.7 m^3
   d) 4420 mole
   e) 946 kg

2. b) 154 h
   c) 1.88 g

3. b) -64260 kJ
   c) 2.1 times

4. b) 23.0 dm^3/mole
   c) 1.63 mole
   d) 109g

5. b) 0.72% SO_2; 8.11% O_2; 6.50% SO_3; 84.7% N_2
6. b) In case of Ag: 69.7 %; in case of Au: 83.4 %
   c) 39% Au, 61% Ag

Form XI

1. b) 3.00 g Cu; 5.00 g Zn, 2.00 g Ag

2. d) 10.2 g Al_2O_3.

3. a) $(CuOH)_2CO_3$

4. a) A = $HCOOCH_3$; B = CH_3OH; C = HCOONa; D = HCOOH.

5. a) 3.12 m^3
   c) 29.4 m^3
   d) CH_4 ΔH_c^0 = -890.7 kJ/mole; C_2H_6 ΔH_c^0 = -1560.6 kJ/mole
   e) 1856 l

Form XII

1. b) 0.967 mole N_2O_2, 0.134 mole NO_2
   c) 5.91 atm. N_2O_4; 0.819 atm. NO_2

2. c) 2240 A·sek
   d) 150 cm^2

3. c) $[Co(NH_3)_5Cl]^{2+}$

4. a) 180 g/mole, $C_6H_{12}O_6$;

5. A= $H_3C\text{-}(CH_2)_3\text{-}C{\equiv}C\text{-}(CH_2)_6OH$, B= $H_3C\text{-}(CH_2)_3\text{-}CH{=}CH\text{-}(CH_2)_6OH$ (trans); C= $H_3C\text{-}(CH_2)_3\text{-}CHBr\text{-}CHBr\text{-}(CH_2)_6OH$; D= $H_3C\text{-}(CH_2)_2\text{-}CH{=}CH\text{-}CH{=}CH\text{-}(CH_2)_4OH$; E= $H_3C\text{-}(CH_2)_3\text{-}CH{=}CH\text{-}(CH_2)_6OH$ (cis).

6. b) 8.77 m^3
   c) 1.06 atm.; 228 m^3
   d) 1270 m^3
   e) $\Delta H_c^0 = -2877.4$ kJ/mole
   f) 286 MJ