Tartu University

44th CHEMISTRY OLYMPIAD
Final National Competition

1997

ESTONIA

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Tartu 1997.

Form IX

Problem 1.

At 25°C and 1.01 atm *V* dm^3 of SO_2 was passed into 1.00 dm^3 of H_2O (0.997 g/cm^3), the gas was completely imbibed and formed a 5.00% (weight) solution of sulphurous acid.

a) Write equation for the reaction.

b) How many grams of SO_2 are needed to form a 5.00% solution?

c) Determine the molar volume of the gas under the conditions stated above.

d) Determine the volume of SO_2 *V* necessary for the formation of the solution.

Problem 2.

Testtubes **A**, **B**, **C**, **D** and **E** contain the solutions of HCl, KOH, K_2S, $NaNO_3$ and $CuSO_4$. If the solution from testtubes are poured together the following effects are seen: **A** + **B** → blue precipitate; **A** + **C** → black precipitate, **C** + **D** → unpleasant smell. The solution in testtube **E** dissolves the blue precipitate but does not dissolve the black one. Other combinations do not have visible results.

a) Determine the content of each testtube.

b) Write the equations for the reactions that resulted in the effects and give the names of the products.

Problem 3.

In order to completely neutralise a solution containing a mixture of 16.0 g of acetic acid (CH_3COOH) and oxalic acid [$(COOH)_2$], 300 cm^3 of 1.00 M (mol/dm^3) solution of NaOH was used.

a) Write equations for the reactions.

b) Calculate the amount (g) of each of the acids in the solution.

Problem 4.

In the reaction of 10.0 g of Al and Cu powder with hydrochloric acid 6.72 dm^3 (STP) of gases segregate. **A** 500 g mixture of the same ingredients reacts with NaOH solution.

a) Write equations for the reactions with acid and base.

b) How many grams of copper were in either of the mixtures?

c) Determine the volume of 20.0% solution of NaOH (1.22 g/cm^3) that is necessary to dissolve aluminium.

Problem 5.

In order to obtain 100 g of $CaCl_2·6H_2O$ a 10% solution of HCl (1.05 g/cm^3) and $CaCO_3$ is used. Assume the initial compounds to be in stoichiometric amounts.

a) Write the equations for the reactions.

b) Determine the necessary volume of hydrochloric acid.

c) Determine the necessary mass of $CaCO_3$.

d) Calculate the mass and volume of the solution that formed (1.12 g/cm^3).

e) How many grams of water must be evaporated in order to obtain the amount of salt with crystal water stated in the conditions above?

Problem 6.

Elements **A** and **B** form three compounds **X**, **Y** and **Z**. Compound **X** is a sharp smelling gas lighter than air and yields white smoke (compound **M**) in the reaction with gaseous HCl. Compound **X** is well dissoluble in water and turns a wet litmus paper blue. Compounds **X** and **Y** have the same number of atoms in their molecules. Compound **Y** is a colourless liquid with a sharp smell, it is most unstable in native form but its aqueous solution is quite stable and turns a litmus paper blue. The density of its vapour is only a few per cent lighter than that of CO_2. Compound **Z** is a colourless liquid fumeable by mixing two moles of **X** carefully with NaClO, yielding water as one of the three products. The reaction of one mole of compound **Z** with nitrous acid yields one mole of compound **Y** and water. Compound **Z** may react with both one and two moles of HCl yielding only one product in both cases. In the reaction of compound **X** and Mg one element and a salt **Q** corresponding to compound **X**. The reaction of compound **Q** with water yields compound **X** again. A Pb(II) salt of compound **Y** (compound **R**) is used as a detonator.

a) Are the solutions of compounds **Y** and **Z** acidic, neutral or basic?

b) Write the formulae of the compounds **M** and **X** and give the names.

c) Determine the gross formula of compound **Y** on the basis of the number of atoms in the molecules of compounds **Y** and **X** and the density of compound **Y**.

d) Write equations for the following reactions: 1) **X** $\rightarrow$ **M**; 2) 2**X** $\rightarrow$ **Z**; 3) **Z** $\rightarrow$ **Y**; 4) **Z** + HCl $\rightarrow$; 5) **X** $\rightarrow$ **Q**; 6) **X** $\rightarrow$ **Q**.

e) Write the formulae of compounds **Y**, **Z**, **Q** and **R** and give their names.

Form X

Problem 1.

In the reaction of 10.0 g of cuprite [copper(I) oxide] and nitric acid copper(II) nitrate, nitric(II) oxide and water are formed.

a) Write equation for the reaction and balance it.

b) Determine the amount (g) of copper(II) nitrate formed.

c) How big is the yield of nitric(II) oxide if 0.900 dm^3 of nitric(II) oxide (STP) is formed.

Problem 2.

A solution of 1.00 dm^3 of 0.500 M NaOH was added to a solution of 1.00 dm^3 of 1.00 V acetic acid (CH_3COOH). The solution obtained was divided into equal halves **A** and **B**. 0.200 dm^3 of 0.500 M sulphuric acid was added to solution **A** and 0.200 dm^3 of 0.500 M NaOH was added to solution **B**. There is no volume contraction on the addition of the solutions. The acetic acid has the dissociation constant $K_d = 1.75 \cdot 10^{-5}$.

a) Write equations for the reactions.

b) Calculate the amount of dissolved compounds in solutions **A** and **B** after the addition of H_2SO_4 and NaOH, respectively.

c) Calculate pH of the solution of the acetic acid and the pH of the solution before it was divided.

d) Calculate the pH of the solutions **A** and **B** after the addition of acid and base, respectively.

e) Write the equilibrium constant of the dissociation of acetic acid and derive from there the equilibrium concentration of hydrogen ions in the buffer.

Problem 3.

Element **A** has in its ground state 8s electrons altogether and 6d electrons in its last but one shell. The same element as its β-radioactive isotope has 7 more neutrons than protons. Element **B** is formed as the result of the radioactive decomposition.

a) Determine the period and group (short table of elements) where element **A** belongs to. What is its atomic number?

b) Write equation for the synthesis of element **B**, mark the charge and mass-number of each particle taking part of the reaction.

c) Is the isotope **B** stable and widespread in the nature or is it radioactive. Motivate your answer.

Problem 4.

Concentrated solution of $FeCl_3$ is used to etch (remove the copper without lacquer cover) printing plates (a plastic sheet, covered with a metallic copper film) for electronics. If a very highly concentrated solution is made a brown jelly-like precipitate will form at the bottom of the solution.

a) Write the equation for the dissociation reaction of $FeCl_3$.

b) Write the gross equations for all the three steps of $FeCl_3$ dissociation. Name the salt that precipitated, provided that the precipitate comes from the second step of hydrolysis.

c) Write an equation with a compound that would dissolve the precipitate (a compound that prevents the precipitate formation on the desolation of $FeCl_3$.

d) Write the equation that describes the etching of the printing plate.

e) Write equations for the reactions with compounds that can be used to regain the etching solution.

Problem 5.

It is impossible to obtain fluorine as a result of an ordinary chemical reaction. In 1986 was found a reaction that gives fluorine as one of its products.

$K_2MnF_6 + SbF_5 \rightarrow KSbF_6 + MnF_3 + F_2$

a) Balance the equation.

b) Calculate the amount of K_2MnF_6 necessary for the reaction with 500 g of SbF_5.

c) Calculate the volume of F_2 that formed at 25°C and 765 mm Hg.

Problem 6.

In most cases the solubility of solids in water increases with the increase of temperature. 100 g of saturated (at 20°C) solution of $NaHCO_3$ was poured into flask equipped with a Allihn condenser, the temperature was raised to 100°C and after that 5.51 g of solid $NaHCO_3$ was added. After heating during 15 minutes the solution was cooled down to 20°C. No precipitate formed and the concentration of the dissolved compound was the same as before the reaction – 9.00%.

a) Which compound was the dissolved one after the reaction?

b) Write the equation for the reaction.

c) How many grams of dissolved compound and water these in the solution after the reaction.

d) Derive (do not calculate) an equation for the calculation of the percentage of the dissolved compound ($\omega = 0.09$) basing on the initial data and the reaction equation.

Form XI

Problem 1.

Ethanol was heated with concentrated sulphuric acid during a long period of time. The vapour that formed was separated at 50°C from the initial compounds and water. The density of the vapour at standard pressure and 50°C was 1.49 g/dm^3, and 1.25 g/dm^3 at STP.

a) Write the equation for the reaction of ethanol and sulphuric acid and give the names for the compounds that formed.

b) Use calculations to determine the compound in the vapour phase at STP.

c) Which compounds and in which molar percentage were in the vapour phase at 50°C?

d) Write an equation with one of the compounds where its molar mass grows 6.7 times.

Problem 2.

Compounds **A** and **B** belong to the same class but are different types of compounds. Their molecules consist of three different elements and their molecular masses are related as 1 : 1.45. Both **A** and **B** are unpleasantly smelly gases at room temperature, they are both able to react with equimolecular amount of hydrochloric acid. Compound **B** is a stronger base than compound **A**. Compound **A** may be obtained at high temperature and pressure with methanol of diethylether as one of the initial compounds. In the latter case methanol is obtained as a side product. The reaction of compound **A** and a carboxylic acid amide yields amide. Compound **B** may be obtained from compound **A** in the reaction with: 1) methanol on a catalyst; 2) methylbromide.

a) Draw the structural formulae of compounds **A** and **B** and give their names.

b) Write equations for the reactions: 1) A + HCl →; 2) **B** + HCl →; 3) methanol → **A**; 4) dimethylether → **A**; 5) **A** + ... → amide; 6) **A** + methanol →; 7) **A** + methylbromide.

Problem 3.

A charged lead accumulator has lead and lead dioxide as electrodes. The electrolyte is 3 dm^3 of 33.0% solution of sulphuric acid (1.243 g/cm^3).

a) Write the equations of the electrode processes describing the discharge of the accumulator.

b) Write the gross equation of charging and discharging of the lead accumulator.

c) Calculate the change of cathode and anode weight during a 45 second car starting if the average current passing through the circuit is 250 A.

d) Determine the amount of charge (in A·h) that has been used if the density of the acid in the accumulator has been reduced to 1.194 g/cm^3 (the corresponding concentration of the solution is 27.0%, disregarding the change in volume).

Problem 4.

How many grams of NaOH aqueous solution of which concentration (weight %) must be added to 10.0 cm^3 of 95.0% solution of H_2SO_4 (1.83 g/cm^3) to obtain a normal salt with 10 molecules of crystal water as the only product.

a) How many per cent of the crystal water is made up of the solvent of either of the initial compounds?

b) Write the equation for the reaction.

Problem 5.

A solution in an organic solvent of an organic compound **A** is mixed with an excess of metal powder **B** resulting in a fast reaction with the dissolution of some of the metal powder and the formation of compound **C**. Compound **C** is then separated and processed with hydrochloric acid. An organic compound **D** segregates and an inorganic compound **E** remains in the solution. If NaOH is added to the solution a precipitate **F** forms, heating of which yields oxide **G**. The molar masses of **E**, **D** and **G** relate as 5.96 : 1 : 2.52.

a) Identify the compounds **A**, **B**, **C**, **D**, **E**, **F**, **G**.

b) Write equations for the reactions: 1) **A** + **B** →; 2) **C** → **D** + **E**; 3) **E** → **F**; 4) **F** → **G**.

c) Determine the molar masses of the metal **B** and compound **G**.

Problem 6.

A mixture of two gaseous acylic hydrocarbons has a density of 17 in reference of hydrogen. On the processing of 200 cm^3 (STP) of the same mixture of gases with 200 cm^3 of 0.1 M solution of Br_2 the volume of the gases was reduced to 120 cm^3 (STP). 2.06 g of Br_2 remained unreacted.

a) Determine the molar mass of the mixture and the molar percentage of both gases.

b) Use calculations to show the structure of the gases and give their common formulae (C_mH_n).

c) Determine the gross formulae of both gases.

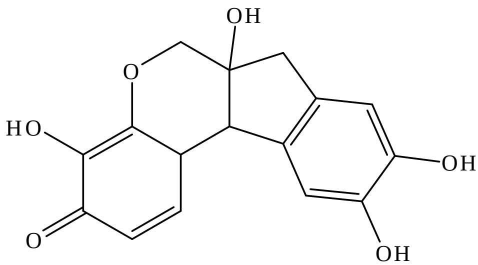
d) Draw the structures of all suitable compounds and give their names.

e) Write the equations for all possible reactions with the solution of bromide and name the products.

Form XI

Problem 1.

A tropical plant contains a colour agent hematoxylin:



a) How many phenolic hydroxyl groups are present in the structure given above?

b) Draw the structures of the isomers with the same carbon skeleton and with oxygen atoms bonded to the same carbon atoms as in the structure given above but with 0 and 4 phenolic hydroxyl groups respectively.

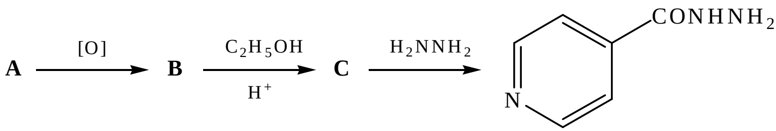
c) Mark the asymmetric carbons in the hematoxylin molecule with a star.

d) Determine the end of the molecule where water would segregate from on heating and the place for the formation of the corresponding double bond.

e) Does this molecule belong to esters of ethers?

Problem 2.

A well known antituberculosis drug, *isoniazis* is synthesised in the following way:



The Carbon skeleton remains unchanged during the synthesis and compound **A** does not contain oxygen.

a) Draw the structures of compounds **A**, **B** and **C**.

b) How many grams of $KMnO_4$ is needed to oxidise 9.3 g of compound **A** to compound **B**, the yield corresponding to the oxidant is 75% ($KMnO_4$ is reduced to MnO_2). Write the equation for the reaction.

c) Will the final product of the synthesis remain the same if propanol is used instead in step two (**B** $\rightarrow$ **C**). Write the equation for the reaction (mark the radical with R).

d) Give another initial compound to replace compound **A** without changing the rest of the reaction scheme.

Problem 3.

Compound **A**, **B**, **C** and **D** have formulae: $R_1CH{=}CH_2$; R_1COR_2; R_1CHClR_2 and R_2CHO. All these can be used to obtain compound **X**, which exists as two enantiomers. It is known that compound **X** can be obtained from hydrolysis of the reaction of compound **D** with ethylmagnesiumbromide.

a) Which radicals are R_1 and R_2? Give the names of compounds **A**, **B**, **C** and **D**.

b) Determine the structure of compound **X** and give the name.

c) Draw the structures of the two isomers and give the names.

d) Write schemes for the processes yielding compound **X**.

Problem 4.

Gaseous N_2O_5 decomposes at 55°C in a 10.0 dm^3 closed flask. The rate constant for the reaction is $k = 1.42{\cdot}10^{-3}\ s^{-1}$. At the starting moment t_0 0.01 mole of N_2O_5 had decomposed and its partial pressure was 2.84 atm. At the end of the experiment (time t) the partial pressure had dropped to 0.355 atm.

a) Write the equation for the decomposition reaction of N_2O_5.

b) Determine the half-life of the decomposition reaction.

c) Determine the time period t.

d) Which amounts of compounds were in the flask at time t and how big was the pressure, assumed that only a monomeric nitrogen compound was obtained.

Problem 5.

Sn and Pb electrodes were sunk in the solutions of 0.150 M $Sn(NO_3)_2$ and 0.550 M $Pb(NO_3)_2$, respectively. These electrodes have standard redox potentials of -0.137 V and -0.125 V, respectively. An electrochemical element made up of these electrodes is working at STP.

a) Which of the electrodes is negative and which is positive, write the equation for the reaction proceeding in the element.

b) Calculate the initial electromotive force *E*.

c) Give reasons for the change of *E* on current consumption.

d) Calculate *E* on the case that the concentration of Pb^{2+} ions has dropped to 0.500 M due to current consumption.

e) Calculate concentrations of the potential determining ions at which the element stops working.

Problem 6.

A mixture of 2.00 g of powdered metals **A** and **B** was processed with a liquid **C**, yielding a solution **D**, which was then separated from the rest of the compounds and heated. The solid residuum was dissolved in concentrated nitric acid. Water, ~0.7 dm^3 of NO_2 (STP) and 3.80 g of a salt **E** with crystal water ($\mathbf{E}\cdot 3H_2O$) was formed as the result of the reaction. Waterless salt **E** contains 33.9 weight per cent of metal. Metal **B**, which did not react with liquid **C** was separated and processed with chlorine at (moderately) high temperature. A salt **F** was formed, containing 34.4 weight per cent of metal.

a) Identify compounds **A**, **B**, **C**, **D**, **E** and **F**.

b) Write equations for the reactions: 1) **A** + **C** →; 2) **D** →; 3) … → **F**; 4) **B** + … → **F**.

c) How many grams of metal **A** were in the mixture?

d) Determine the molar mass of metal **B** based on the weight per cent of metal in salt **F**.

e) Calculate the weight and molar percentage of metals **A** and **B** in the initial mixture.

c) How many grams of metal **A** was in the mixture?
d) Determine the molar mass of metal **B** based on the weight per cent of metal in salt **F**.
e) Calculate the weight and molar percentages of metals **A** and **B** in the initial mixture.

Solutions
Form IX

1. a) $SO_2 + H_2O \rightarrow H_2SO_3$
64,1 g/mol   82,1 g/mol

b) $$0{,}0500 = \frac{m(H_2SO_3)}{m(H_2O)+m(SO_2)} \Rightarrow \frac{\frac{1}{1}m(SO_2)\cdot\frac{1\ mol}{64{,}1\ g}\cdot 82{,}1\ g/mol}{1{,}00\ dm^3\cdot 997\ g/dm^3 + m(SO_2)}$$
$$m(SO_2) = 40{,}5\ g$$

c) $$V_M = 1\ mol\cdot 0{,}08206\frac{atm\cdot dm^3}{mol\cdot K}\cdot 298\ K\cdot\frac{1}{1{,}01\ atm} = 24{,}2\ dm^3/mol$$

d) $$V = 40{,}5\ g\cdot\frac{1\ mol}{64{,}1\ g}\cdot 24{,}2\ dm^3/mol = \sim 15{,}3\ dm^3$$

2. a) A - $CuSO_4$; B - KOH; C - K_2S; D - $NaNO_3$; E - HCl
b) $CuSO_4$ (A) + 2KOH (B) $\rightarrow Cu(OH)_2\downarrow$ (blue) + K_2SO_4
copper(II)hydroxide   potassium sulphate

$CuSO_4$ (A) + K_2S (C) $\rightarrow$ CuS $\downarrow$ (black) + K_2SO_4
copper(II)sulphide

K_2S (C) + 2HCl (E) $\rightarrow H_2S\uparrow$ (unpleasant smell) + 2KCl
dihydrogen sulphide   potassium chloride

$Cu(OH)_2$ + 2HCl (E) $\rightarrow CuCl_2$ + $2H_2O$
copper (II)chloride   water

3. a) $CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$
$(COOH)_2 + 2NaOH \rightarrow (COONa)_2 + 2H_2O$
b) The amount of sodium hydroxide needed for the titration:
$n(NaOH) = 0{,}300\ dm^3\cdot 1{,}00\ mol/dm^3 = 0{,}300\ mol.$
For the neutralisation of acetic acid (of x g) out of that:
$$n'(NaOH) = \frac{1}{1}\cdot x\ g\cdot\frac{1\ mol}{60{,}0\ g}$$
and for the neutralisation of oxalic acid [of (16,0-x) g]
$$n''(NaOH) = \frac{2}{1}(16{,}0 - x)\ g\cdot\frac{1\ mol}{90{,}0\ g}$$

It is possible to formulate an equation basing on these relations:

$$\frac{x}{60,0} + \frac{2 \cdot (16,0 - x)}{90,0} = 0,300$$

x = 10,0 g

m(CH_3COOH) = 10,0 g

m[$(COOH)_2$] = 16,0 - 10,0 = 6,0 g

4. a) Both HCl and NaOH react only with aluminium

$2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2$

$2Al + 2NaOH + 6H_2O \rightarrow 2Na[Al(OH)_4] + 3H_2$

or

$2Al + 6NaOH + 6H_2O \rightarrow 2Na_3[Al(OH)_6] + 3H_2$

b) 2Al → $3H_2$

27,0 g/mol 22,4 dm^3/mol

$$m'(Al) = \frac{2}{3} \cdot 6,72\ dm^3 \cdot \frac{1\ mol}{22,4\ dm^3} \cdot 27,0\ g/mol = 5,40\ g$$

$$m'(Cu) = 10,0 - 5,4 = 4,6\ g$$

$$m''(Al) = 50\underline{0}\ g\ (mixture) \cdot \frac{5,40\ g}{10,0\ g\ (mixture)} = 270\ g$$

$$m''(Cu) = 50\underline{0}\ g - 270\ g = 230\ g.$$

c) 270 g V cm^3·1,22 g/cm^3·0,200

2Al ⇔ 2NaOH

27,0 g/mol 40,0 g/mol

$$V(NaOH) = \frac{2}{2} \cdot \frac{270\ g}{27,0\ g/mol} \cdot 40,0\ g/mol \cdot \frac{1}{0,200} \cdot \frac{1\ cm^3}{1,22\ g} = 1639 \sim 2220\ cm^3$$

5. a) $2HCl + CaCO_3 \rightarrow CaCl_2 + CO_2\uparrow + H_2O$

36,5 g/mol 100,1 g/mol 111 g/mol

$CaCl_2 + 6H_2O \rightarrow CaCl_2 \cdot 6H_2O$

219 g/mol

Vcm^3·1,05 g/cm^3·0,100 10$\underline{0}$ g

b) 2HCl → $CaCl_2 \cdot 6H_2O$

$$V(HCl) = \frac{2}{1} \cdot 10\underline{0}\ g \cdot \frac{1\ mol}{219\ g} \cdot 36,5\ g/mol \cdot \frac{1}{0,100} \cdot \frac{1\ cm^3}{1,05\ g} = 317\ cm^3$$

c) $$m(CaCO_3) = \frac{1}{1} \cdot 10\underline{0}\ g \cdot \frac{1\ mol}{219\ g} \cdot 100,1\ g/mol = 45,7\ g$$

d) $$m(solution) = 317\ cm^3 \cdot 1,05\ g/cm^3 + 45,7\ g - \frac{1}{1} \cdot 100\ g \cdot \frac{1\ mol}{219\ g} \cdot 44\ g/mol =$$

$$= 333 + 46 - 20 = 359\ g$$

$$V(\text{solution}) = 359 \cdot \frac{1\ cm^3}{1{,}12\ g} = 321\ cm^3$$

e) $m(H_2O) = 359 - 100 = 259\ g$

6. a) X - basic, Y - acidic, Z - basic
   b) X - NH_3 (ammonia); M - NH_4Cl (ammonium chloride)
   c) The molar mass and density of gases are in linear relationship
   Therefore $M(Y) = \sim 0{,}98 \cdot 44\ g/mol = \sim 43\ g/mol$.
   As compound Y has the same number of atoms as ammonia, the calculated approximate molar mass corresponds to HN_3.
   $M(HN_3) = 43\ g/mol$
   d) 1) $NH_3 + HCl \rightarrow NH_4Cl$
   2) $2NH_3 + NaOCl \rightarrow NH_2{-}NH_2 + NaCl + H_2O$
   3) $NH_2{-}NH_2 + HNO_2 \rightarrow HN_3 + 2H_2O$
   4) $NH_2{-}NH_2 + HCl \rightarrow NH_2NH_3Cl$
   5) $NH_2{-}NH_2 + 2HCl \rightarrow ClNH_3{-}NH_3Cl$
   6) $2NH_3 + 3Mg \rightarrow Mg_3N_2 + 3H_2$
   7) $Mg_3N_2 + 6H_2O \rightarrow 3Mg(OH)_2 + 2NH_3$
   e) Y - HN_3; Z - $NH_2{-}NH_2$; Q - Mg_3N_2 (magnesium nitride); R - $Pb(N_3)_2$

Form X

1. a) $3Cu_2O + 14HNO_3 \rightarrow 6Cu(NO_3)_2 + 2NO + 7H_2O$
   b) $3Cu_2O \Leftrightarrow 6Cu(NO)_3)_2$
   143 g/mol　　188 g/mol

$$m[Cu(NO_3)_2] = \frac{6}{3} \cdot 10{,}0\ g \cdot \frac{1\ mol}{143\ g} \cdot 188\ g/mol = 26{,}3\ g$$

   c) One may take the yield percentage as the part of initial compounds that reacted (p/100)
   10,0 p/100　　0,900 dm^3
   $3Cu_2O \rightarrow 2NO$

$$p = \frac{3}{2} \cdot 0{,}900\ dm^3 \cdot \frac{1\ mol}{22{,}4\ dm^3} \cdot 143\ g/mol \cdot \frac{100}{10{,}0} = 86{,}18 \sim 86{,}2\ \%$$

2. a) $CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$
   A　$2CH_3COONa + H_2SO_4 \rightarrow 2CH_3COOH + Na_2SO_4$
   B　$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$
   b) before　1,00 mol　0,5 mol　　0 mol
   $CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$
   after　0,50 mol　0 mol　　0,50 mol
   Both solutions A and B contain the following amounts of compounds:

$$n(CH_3COOH) = \frac{0{,}50\ mol}{2} = 0{,}25\ mol$$

$$n(CH_3COONa) = \frac{0,50 \text{ mol}}{2} = 0,25 \text{ mol}$$

A $n(CH_3COOH) = 0,25 + 2 \cdot 0,200 \text{ dm}^3 \cdot 0,500 \text{ mol/dm}^3 = 0,45 \text{ mol}$

$n(CH_3COONa) = 0,25 - 2 \cdot 0,200 \text{ dm}^3 \cdot 0,500 \text{ mol/dm}^3 = 0,05 \text{ mol}$

B $n(CH_3COOH) = 0,25 - 0,10 = 0,15 \text{ mol}$

$n(CH_3COONa) = 0,25 + 0,10 = 0,35 \text{ mol}$

c) $pH = -\lg\sqrt{k \cdot c} = -\lg\sqrt{1,75 \cdot 10^{-5} \cdot 1,00} = -\lg 4,18 \cdot 10^{-3} = 2,37 \sim 2,4$

Before the division into two there it is a buffer solution.

$$pH = -\lg K_{diss} \cdot \frac{n(\text{acid})}{n(\text{salt})} = -\lg 1,75 \cdot 10^{-5} \cdot \frac{0,50}{0,50} = 4,76 \sim 4,8$$

d) A $pH = -\lg 1,75 \cdot 10^{-5} \cdot \frac{0,45}{0,05} = 3,80 \sim 3,8$

B $pH = -\lg 1,75 \cdot 10^{-5} \cdot \frac{0,15}{0,35} = 5,12 \sim 5,1$

e) $$K_{diss} = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$$

In the buffer solution $[CH_3COO^-] \sim c_{salt}$

$[CH_3COOH] \sim c_{acid}$

$$[H^+] = K_{diss} \cdot \frac{[CH_3COOH]}{[CH_3COO^-]} = K_{diss} \cdot \frac{c_{salt}}{c_{acid}}$$

3. a) If there are less than 10 electrons in the last but one shell of an atom then the atom must be one of the d-elements. As there were 8 s electrons altogether, the element must belong to the 4th period, with a filled 4 s orbital and 6 electrons on the following 3 d orbital. Accordingly, the element belongs to the 8th group in the short table and has the atomic number: 2+8+8+8=26. It is the first element of the iron triad - $_{26}Fe$.

b) Isotope A' has 26+7=33 neutrons and a mass number of 59

$${}^{59}_{26}Fe \rightarrow {}^{59}_{27}Co + {}^{0}_{-1}e$$

c) The average atomic masses of the natural isotopes are given in the table: M(Co)=58,93 g/mol. It is reasonable to assume, that natural Co mostly consists of the isotope ${}^{59}_{27}Co$. It is improbable, that there is 50 % of isotope ${}^{(59+k)}Co$ and 50 % of isotope ${}^{(59-k)}Co$, where k is an integer.

4. a) $FeCl_3 \rightleftharpoons Fe^{3+} + 3Cl^-$

b) $FeCl_3 + H_2O \rightleftharpoons FeOHCl_2 + HCl$

$FeOHCl_2 + H_2O \rightleftharpoons Fe(OH)_2Cl\downarrow$ (iron chloride hydroxide) $+ HCl$

$Fe(OH)_2Cl + H_2O \rightleftharpoons Fe(OH)_3\downarrow + HCl$

c) $Fe(OH)_2Cl + 2HCl \rightleftharpoons FeCl_3 + 2H_2O$

d) $2FeCl_3 + Cu \rightarrow 2FeCl_2 + CuCl_2$

e) Cu^{2+}-ions must precipitate so there will remain only Fe^{3+}- and Cl^-ions in the solution.

$Cu^{2+} + H_2S \rightarrow CuS\downarrow + 2H^+$

As the solutions is acidic due to HCl, FeS will not precipitate

$FeS + 2HCl \rightarrow FeCl_2 + H_2S\uparrow$

$2Fe^{2+} + Cl_2 \rightarrow 2Fe^{3+} + 2Cl^-$

5. a) 2·0 2·(-1)

$F_2 + 2e \rightarrow 2F$ 1

III IV 2

$Mn - 1e \rightarrow Mn$ 2

$2K_2MnF_6 + 4SbF_5 \rightarrow 4KSbF_6 + 2MnF_3 + 1F_2$

247 g/mol 217 g/mol

b) $m(K_2MnF_6) = \frac{2}{4} \cdot \frac{500\ g}{217\ g/mol} \cdot 247\ g/mol = \sim 285\ g$

c) $V(F_2) = \frac{1}{4} \cdot \frac{500\ g}{217\ g/mol} \cdot 1\ mol \cdot 298\ K \cdot \frac{0{,}08206\ atm \cdot dm^3}{mol \cdot K} \cdot \frac{760}{765} \cdot \frac{1}{atm} = 13{,}99 \sim$

$\sim 14{,}0\ dm^3$

6. a) $NaHCO_3$ decomposes on heating and Na_2CO_3 is formed.

b) $2NaHCO_3 \xrightarrow{t^\circ} Na_2CO_3 + CO_2\uparrow + H_2O$

84,0 g/mol 106 g/mol 44 g/mol

c) $m_1(Na_2CO_3) = \frac{1}{2} \cdot 100 \cdot 0{,}09\ g \cdot \frac{1\ mol}{84\ g} \cdot 106\ g/mol = 5{,}678\ g$

$m_2^*(Na_2CO_3) = \frac{1}{2} \cdot 5{,}51\ g \cdot \frac{1\ mol}{84\ g} \cdot 106\ g/mol = \underline{3{,}476\ g}$

9,154 ~ 9,15 g

$m(H_2O) = 9{,}15\ g \cdot \frac{91}{9} = 92{,}52 \sim 92{,}5\ g$

d) $\omega = \dfrac{\frac{1}{2} \cdot \frac{100 \cdot \omega + 5{,}51}{84} \cdot 106}{100 + 5{,}51 - \frac{1}{2} \cdot \frac{100 \cdot \omega + 5{,}51}{84} \cdot 44}$

Form XI

1. a) $2C_2H_5OH \xrightarrow{H_2SO_4} C_2H_5{-}O{-}C_2H_5$ (diethyl ether) $+ H_2O$

$C_2H_5OH \xrightarrow{H_2SO_4} CH_2{=}CH_2$ (ethene) $+ H_2O$

b) $1{,}25\ g/dm^3 \cdot 22{,}4\ dm^3/mol = 28{,}0\ g/mol$ (ethene)

c) molar volume

$V_M = 1\ mol \cdot 0{,}08206 \frac{atm \cdot dm^3}{mol \cdot K} \cdot 323\ K \cdot \frac{1}{1\ atm} = 26{,}5\ dm^3/mol$

$M(gases) = 1{,}49\ g/dm^3 \cdot 26{,}5\ dm^3/mol = 39{,}49 \sim 39{,}5\ g/mol$

x mol $C_2H_5OC_2H_5$ + (1-x) mol $CH_2{=}CH_2$ = 1 mol of gases

74,1 g/mol 28,0 g/mol 39,5 g/mol

$74,1x + 28,0 - 28,0x = 39,5$

$x = 25,0\ \%$

$\%\ (C_2H_5OC_2H_5) = 25,0$

$\%\ (CH_2{=}CH_2) = 75,0$

d) $CH_2{=}CH_2 + Br_2 \rightarrow CH_2Br{-}CH_2Br$ (1,2-dibromoethane)

28 g/mol 188 g/mol

$188 : 28 = 6,7$

2. a) A - CH_3NH_2 methylamine (31,1 g/mol)

B - $(CH_3)_2NH$ dimethylamine (45,1 g/mol)

$31,1 : 45,1 = 1 : 1,45$

b) 1) $CH_3NH_2 + HCl \rightarrow CH_3NH_3^+Cl^-$

2) $(CH_3)_2NH + HCl \rightarrow CH_3NH_2^+Cl$

3) $CH_3OH + NH_3 \rightarrow CH_3NH_2 + H_2O$

4) $CH_3OCH_3 + NH_3 \rightarrow CH_3NH_2 + CH_3OH$

5) $CH_3NH_2 + HOOCCH_3 \rightarrow CH_3CONHCH_3 + H_2O$

6) $CH_3NH_2 + HOCH_3 \xrightarrow{catal} (CH_3)_2NH + H_2O$

7) $CH_3NH_2 + BrCH_3 \rightarrow (CH_3)_2NH + HBr$

3. a) anode(-) $Pb - 2e + SO_4^{2-} \rightarrow PbSO_4$

cathode (+) $PbO_2 + 2e + 4H^+ + SO_4^{2-} \rightarrow PbSO_4 + 2H_2O$

b) $Pb + PbO_2 + 2H_2SO_4 \rightleftarrows 2PbSO_4 + 2H_2O \quad \rightleftarrows \quad 2\,e$

c) $n(e) = 250\ A \cdot 45\ s \cdot \frac{1\ mol}{96500\ A \cdot s} = 0,11658 \sim 0,117\ mol$

$\Delta m(anode) = \frac{1}{2} \cdot 0,11658\ mol \cdot 96\ g/mol = 5,595 \sim 5,60\ g$

$\Delta m(cathode) = -\frac{1}{2} \cdot 0,11658\ mol \cdot 32\ g/mol + 5,595\ g = 3,72\ g$

d) $\Delta m(H_2SO_4) = 3,00\ dm^3 \cdot 1243\ g/dm^3 \cdot 0,33 - 3,00\ dm^3 \cdot 1194\ g/dm^3 \cdot 0,27 = 263\ g$

$$Q = \frac{2}{2} \cdot \frac{263\ g}{98,1\ g/mol} \cdot 96500 \frac{A \cdot s}{mol} \cdot \frac{1\ hour}{3600\ s} = 71.9\ A \cdot hour$$

4. a) $n(H_2SO_4) = \frac{10,0\ cm^3 \cdot 1,83\ g/cm^3 \cdot 0,95}{98,1\ g/mol} = 0,1772 \sim 0,117\ mol$

$n(NaOH) = 2 \cdot 0,1772 = 0,354\ mol$

$n(H_2O) = 10 \cdot 0,1772 = 1,772\ mol$

$n'(H_2O) = \frac{10,0\ cm^3 \cdot 1,83\ g/cm^3 \cdot 0,05}{18\ g/mol} = 0,0508\ mol\ (H_2SO_4)$

$n''(H_2O) = 0,354\ mol$ (is formed in the reaction)

n''' in the solution $(H_2O) = 1,772 - 0,354 - 0,051 = 1,367\ mol$ (NaOH in the solution)

m(solution of NaOH) $= 0,354\ mol \cdot 40\ g/mol + 1,367\ mol \cdot 18,0\ g/mol = 38,8\ g$

$$\%(NaOH) = \frac{0,354\ mol \cdot 40,0\ g/mol}{38,8\ g} = 36,5\ \%$$

b) $\%(H_2O$ from the sulphuric acid$) = \frac{0,0508}{1,772} \cdot 100 = 2,87$

$$\%(H_2O\ NaOH) = \frac{1,367}{1,772} \cdot 100 = 75,4$$

c) $2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$

$Na_2SO_4 + 10H_2O \rightarrow Na_2SO_4 \cdot 10H_2O$

5. a) A - CH_3Cl; B - Mg; C - CH_3MgCl; D - CH_4; E - $MgCl_2$; F - $Mg(OH)_2$; G - MgO

b) $CH_3Cl + Mg \rightarrow CH_3MgCl$

$CH_3MgCl + HCl \rightarrow CH_4 + MgCl_2$

$MgCl_2 + 2NaOH \rightarrow Mg(OH)_2 + 2NaCl$

$Mg(OH)_2 \xrightarrow{t^\circ} MgO + H_2O$

c) Compound E can be a chloride, and form hydroxide F on the addition of NaOH. Compound F decomposes to oxide G on heating.

$\frac{M(E)}{M(G)} \Rightarrow \frac{5,96}{2,52} = \frac{M(B) + 35,5x}{M(B) + x \cdot \frac{16}{2}}$; M(B) = 12,15x. If x=2, then M(B)=24,3 g/mol

B on Mg.

M(G) = M(MgO) = 24,3 + 16,0 = 40,3 g/mol

$$M(D) = \frac{40,3}{2,52} = 16\ g/mol;$$

Compound D is methane CH_4.

6. a) M(mixture) = 17,0·2,02 g/mol = 34,3 g/mol

$$\%(I) = \frac{120}{200} \cdot 100 = 60$$

$$\%(II) = \frac{200 - 120}{200} \cdot 100 = 40$$

b) Gas(I) does not react with bromine water , consequently, it must be an alkane (C_xH_{2x+2})

$$n(II) = 0,080\ dm^3 \cdot \frac{1\ mol}{22,4\ dm^3} = 0,00357\ mol$$

$$n(Br_2) = 0,200\ dm^3 \cdot 0,100\ mol/dm^3 - 2,06\ g \cdot \frac{1\ mol}{160\ g} = 0,0200 - 0,0129 = 0,0071\ mol$$

As there is twice as much bromine as gas(II) [$n(Br_2) \sim 2n(II)$], the gas(II) must be a diene or alkyne (C_yH_{2y-2}).

c) The molar mass of gas(I) is (14x+2) and of gas (II) is (14y-2)

0,6·(14x+2) + 0,4(14y-2)=34,0, which can be reduced to:

$3x + 2y = 12$

The integer extensions of this equations are $x = 2$ and $y = 3$

Gas(I) - C_2H_6

Gas(II) - C_3H_4

d) Gas(I) $CH_3{-}CH_3$ ethane

Gas(II) $CH_2{=}C{=}CH_2$ propadiene

$CH{\equiv}C{-}CH_3$ propyne

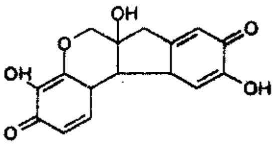
e) $CH_2{=}C{=}CH_2 + 2Br_2 \rightarrow CH_2BrCBr_2CH_2Br$ 1,2,2,3-tetrabromopropane

$CH{\equiv}C{-}CH_3 + 2Br_2 \rightarrow CHBr_2CBr_2CH_3$ 1,1,2,2-tetrabromopropane

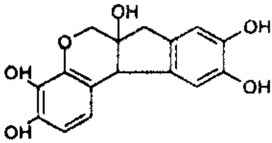
Form XII

1. a) There are two phenolic hydroxyls.

b)

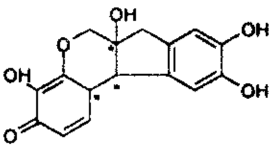


phenolic hydroxyls: 0



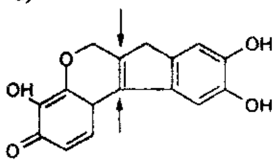
phenolic hydroxyls: 4

c)

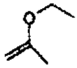


phenolic hydroxyls: 2

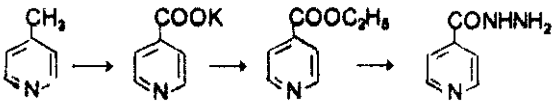
d)



phenolic hydroxyls: 2

e) It is an ether: 

2. a)



A B C

b)

$\overset{-III}{C} - 6e \rightarrow \overset{III}{C}$ 1

6

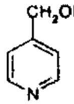
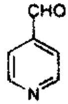
$\overset{VII}{Mn} + 3e \rightarrow \overset{IV}{Mn}$ 2

$\underset{93\ g/mol}{\overset{9,3\ g}{A}} \Leftrightarrow \underset{158\ g/mol}{\overset{m\text{-}0,75}{2KMnO_4}}$

$$m(KMnO_4) = \frac{2}{1} \cdot \frac{9{,}3\ g}{93\ g/mol} \cdot 158\ g/mol \cdot \frac{1}{0{,}75} = 42{,}1 \sim 42\ g$$

c) $RCOOK + C_3H_7OH \longrightarrow R{-}C(=O)OC_3H_7$

$R{-}C(=O)OC_3H_7 + H_2NNH_2 \longrightarrow R{-}C(=O)NHNH_2 + C_3H_7OH$

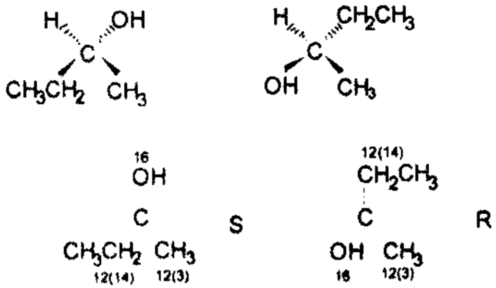
d) Both  , and  may be used as initial compounds

3. a) R_1 is an ethyl group and R_2 is a methyl group.

A - $CH_3CH_2CH{=}CH_2$ 1-butene; B - $CH_3CH_2COCH_3$ ethylmethylketone e. butanone; C - $CH_3CH_2CHClCH_3$ 2-chlorobutane, D - CH_3CHO acetaldehyde

b) $CH_3CH_2CH(OH)CH_3$ 2-butanol

c)



d) $CH_3CH_2CH{=}CH_2 \xrightarrow{H_2O} CH_3CH_2CH(OH)CH_3$

$CH_3CH_2COCH_3 \xrightarrow[NaBH_4]{[H]} CH_3CH_2CH(OH)CH_3$

$CH_3CH_2CHClCH_3 \xrightarrow{KOH} CH_3CH_2CH(OH)CH_3$

$CH_3CHO \xrightarrow{CH_3CH_2MgBr} CH_3CH_2CH(OH)CH_3$

4. a) $N_2O_5(g) \rightarrow N_2O_4(g) + 0{,}5\ O_2\ (g)$

$N_2O_5(g) \rightarrow 2NO_2(g) + 0{,}5\ O_2\ (g)$

b) $\tau = \frac{\ln 2}{k} = \frac{0{,}693}{1{,}42 \cdot 10^{-3}} = 488\ s = 8{,}13\ min = 8\ min\ 8\ s$

c) Partial pressure is proportional to concentration.

$$t = \frac{1}{k} \ln\frac{p_0}{p} = \frac{1}{1{,}42 \cdot 10^{-3}} \ln\frac{2{,}84}{0{,}355} = 1464\ s \sim 24{,}4\ min \sim 24\ min\ 20\ s$$

The following calculations may also be used:

$$\frac{2{,}84}{0{,}355} = 8{,}00$$ (concentration decreased 8 times, in three half life times)

$t = 3 \cdot 488 = 1464 \text{ s} = 24{,}4 \text{ min}$

d) $$n^{t_0}(N_2O_5) = \frac{2{,}84 \text{ atm} \cdot 10{,}0 \text{ dm}^3}{0{,}08206 \frac{\text{atm} \cdot \text{dm}^3}{\text{mol} \cdot \text{K}} \cdot 323 \text{ K}} = 1{,}071 \text{ mol}$$

$$n^t(N_2O_5) = \frac{0{,}355 \cdot 10{,}0}{0{,}08206 \cdot 323} = 0{,}1339 \sim 0{,}134 \text{ mol}$$

$$n^{t_0}(N_2O_5) - n^t(N_2O_5) = 1{,}071 - 0{,}134 = 0{,}937 \text{ mol}$$

$$n^t(NO_2) = \frac{2}{1} \cdot 0{,}937 + \frac{2}{1} \cdot 0{,}01 = 1{,}87 + 0{,}02 = 1{,}89 \text{ mol}$$

$$n^t(O_2) = \frac{0{,}5}{1} \cdot 0{,}937 + \frac{0{,}5}{1} \cdot 0{,}01 = 0{,}4685 + 0{,}005 = 0{,}474 \text{ mol}$$

5. a) $(-)Sn(t) + Pb^{2+}(l) \rightarrow Sn^{2+}(l) + Pb(t)\ (+)$

$$E_{Me^{2+}/Me} = E^{\circ}_{Me^{2+}/Me} + \frac{RT}{zF}\ln\left[Me^{2+}\right]$$

b) In the electrode process: $Me^{2+} + 2e \rightleftharpoons Me$ Me is the reducing agent $[Me] = 1$

$$\frac{RT}{zF}\ln\left[Me^{2+}\right] = \frac{2{,}3 \cdot 8{,}314 \frac{\text{A} \cdot \text{V} \cdot \text{s}}{\text{mol} \cdot \text{K}} \cdot 298 \text{ K}}{2 \cdot 96500 \text{ A} \cdot \text{s/mol}} \cdot \lg\left[Me^{2+}\right] = 0{,}0295 \lg\left[Me^{2+}\right]$$

$$E = E_{Pb^{2+}/Pb} - E_{Sn^{2+}/Sn} = -0{,}125 + 0{,}0295 \lg 0{,}550 - (-0{,}137 + 0{,}0295 \cdot \lg 0{,}150) =$$

$$= 0{,}012 + 0{,}0295 \lg \frac{0{,}550}{0{,}150} = 0{,}012 + 0{,}017 = 0{,}029 \text{ V}$$

c) On the consumption of current the concentration of Sn^{2+} ions increases and the concentration of Pb^{2+} ions decreases. As the logarithms in the equation of EMF are with opposite signs, the EMF decreases constantly.

d) If the concentration of Pb^{2+} ions has decreased to 0,500 mol/dm^3, the concentration of Sn^{2+} ions has increased to 0,200 mol/dm^3.

$$E = 0{,}012 + 0{,}0295 \lg \frac{0{,}500}{0{,}200} = 0{,}012 + 0{,}012 = 0{,}024 \text{ V}$$

e) The element stops working, when the electromotive force between the electrodes is zero:

$$0 = 0{,}012 + 0{,}0295 \lg\frac{\left[Pb^{2+}\right]}{\left[Sn^{2+}\right]}, \text{ from where } \lg\frac{\left[Pb^{2+}\right]}{\left[Sn^{2+}\right]} = \frac{-0{,}012}{0{,}0295} = -0{,}4068$$

The relation $[Pb^{2+}]/[Sn^{2+}]=0{,}40$ can be derived from there. As the gross concentration of the potential determining ions is constant, we get another equation:

$[Pb^{2+}]+[Sn^{2+}]$ = 0,70 mol/dm³, which enables us, together with the previous relation, to determine the concentrations of both ions.

$$\frac{[Pb^{2+}]}{0{,}70-[Pb^{2+}]}=0{,}40 \quad [Pb^{2+}] = 0{,}20\ mol/dm^3;\ [Sn^{2+}] = 0{,}50\ mol/dm^3$$

6. a) A - Cu; B - Fe; C - Hg; D - Cu(Hg) copper amalgam; E - $Cu(NO_3)_2$; F - $FeCl_3$

b) 1) $Cu + Hg \rightarrow Cu(Hg)$; 2) $Cu(Hg) \xrightarrow{t°} Cu + Hg\uparrow$; 3) $Cu + 4HNO_3 \rightarrow$ $\rightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$; 4) $2Fe + 3Cl_2 \rightarrow 2FeCl_3$

c)
$$\underset{63{,}54\ g}{\overset{m\ g}{Cu}} \rightarrow \underset{242\ g/mol}{\overset{3{,}80\ g}{Cu(NO_3)_2\cdot 3H_2O}}$$

$$m(Cu)=\frac{3{,}80\ g}{242\ g/mol}\cdot 63{,}5\ g/mol = 0{,}997 = 1{,}00\ g$$

$$V(NO_2)=\frac{2}{1}\cdot\frac{3{,}80}{242}\cdot 22{,}4\ dm^3/mol = 0{,}703\ dm^3$$

$M(Cu(NO_3)_2)$ = 187,6 g/mol; M(Cu) = 187,6·0,339 = 63,6 g/mol

d) If Fe reacts with chlorine, $FeCl_3$ (M = 162 g/mol) must form
M(Fe) = 162·0,344 = 55,7 g/mol

e) The mass percentage of both metals is 50,0 $\left(\frac{1{,}00}{2{,}00}\cdot 100 = 50{,}0\right)$

$$n(Cu)=\frac{1{,}00\ g}{63{,}5\ g/mol}=0{,}0157\ mol; \qquad n(Fe)=\frac{1{,}00\ g}{55{,}8\ g/mol}=0{,}0179\ mol$$

$$\%(Cu)=\frac{0{,}0157}{0{,}0336}\cdot 100 = 46{,}7\ \% \qquad \%(Fe)=\frac{0{,}0179}{0{,}0336}=53{,}3\ \%$$