# 47$^{th}$ CHEMISTRY OLYMPIAD
## Final National Competition

**2000**

**ESTONIA**

## Problems

### Form IX

1. The number of hydrogen atoms in the following compounds is the same as in the corresponding oxygen-containing acids of the non-metals contained in these compounds. The number of oxygen atoms in all of these acids is strictly determined according to a certain consistency.

   **a)** $H_2S_4$ – tetrasulfane;           **e)** HCl – hydrogen chloride;

   **b)** $HN_3$ – hydrogen azide;           **f)** HBr – hydrogen bromide;

   **c)** $H_2S_3$ – trisulfane;             **g)** $H_2C_2$ – acetylene.

   **d)** HI – hydrogen iodide;

Write formulas of the corresponding oxygen-containing acids and give the names to any five of them.

2. The content of the water in 25$\underline{0}$ grams of the $FeSO_4$ solution is equal to 82%. When some part of the water was evaporated, then the solution was cooled to 0 $^o$C. After some time an equilibrium was obtained between dissolved and crystallized salts. The mass of the final solution is 103 g. The content of $FeSO_4$ in the saturated solution is 13.6% at 0 $^o$C.

**a)** Estimate the mass of $FeSO_4$ in the initial solution.

**b)** Calculate the mass of **i)** $FeSO_4 \cdot 7H_2O$ and **ii)** water needed to prepare 25$\underline{0}$ g of the initial solution.

**c)** Estimate the mass of $FeSO_4 \cdot 7H_2O$ crystallized after described procedure.

3. The amounts of metals **A, B** and **C** in the mixture are in the ratio of 4:2:1. Their molar masses are 3x g/mol; 5x g/mol and 7x g/mol respectively (molar masses are in the ratio of 3:5:7). When 4.64 g of the mixture of metals **A**, **B** and **C** react with hydrochloric acid then 3.136 dm$^3$ of hydrogen is released. The oxidation states of metals in the formed salts is II.

a) Write a general equation for the reaction of metal (**Me**) with hydrochloric acid, that would show the reaction of metals with hydrochloric acid described above.

b) Estimate the amount of released hydrogen.

c) Estimate the amounts of metals **i) A**, **ii) B** and **iii) C**.

d) Work out an equation for the calculation of the molar masses of the metals and solve it.

e) Calculate the molar masses of the metals **i) A**, **ii) B** and **iii) C**; identify these metals and give their names.


4. The total content of $Ba(OH)_2$ and NaOH in 25$\underline{0}$ g of the solution is 10.5%. 25$\underline{0}$ g of 10.0% $H_2SO_4$ solution was added. 14.0 g of a white precipitate is formed. Consider that only normal salts are formed.

a) Write the equation for the reactions of **i)** $Ba(OH)_2$ and **ii)** NaOH with sulfuric acid.

b) Calculate the masses of **i)** $Ba(OH)_2$ and **ii)** NaOH in the initial solution.

c) Calculate the amount of sulfuric acid added for neutralization.

d) What compounds left in the final solution? Estimate their amounts.


5. 11.2 dm$^3$ of the mixture of propane ($C_3H_8$) and butane ($C_4H_{10}$) were burnt in the excess of the oxygen. The obtained carbon dioxide was blown through the solution of NaOH. 95.4 g of sodium carbonate and 84.0 g of sodium bicarbonate were formed.

a) Write the equations for the reactions of combustion of **i)** propane and **ii)** butane.

b) Write the equations for the reactions of formation of **i)** sodium carbonate and **ii)** sodium bicarbonate

c) Calculate the amount of the released $CO_2$ .

d) Calculate the mass of **i)** propane and **ii)** butane in the mixture.

**6.** A metal **X** is able to reduce three-atomic compound **A** only at extremely high temperatures. Thus an element **B** and a seven-atomic compound **C** are formed. The fine mixture of metal **Y** and compound **C** ignites producing a five-atomic compound **D** and the metal **X**. If the metal **X** reacted with an element **E** then four-atomic compound **F** is formed which consists of the same elements as compound **G**. Compound **G** is formed in the reaction of hydrochloric acid with the metal **X**. If an element compound **H** takes part in this process, compounds **F** and **A** are formed. Compound **C** can be formed under certain conditions in the reaction between elements **X** and **H,** though usually a five-atomic compound **I** is formed. All given compounds consist of two elements (binary compounds). The density and the molar volume of metal **X** are 7.87 g/cm$^3$ and 7.09 cm$^3$/mol respectively.

**a)** Estimate the molar mass of the metal **X** and identify this metal.

**b)** Write formulas of the compounds **Y, A, B, C, D, E, F, G, H** and **I** and give their names.

**c)** Write equations for the reactions: **i)** **X + A**; **ii)** **C + Y**; **iii)** **X + E**; **iv) X + HCl → G**; **v) X + HCl + H → F**; **vi) X + H → I**.

## Form X

**1.** Rat-venom, the efficient ingredient of which is a salt **A**, was patented in 1920. The number of atoms of non-metal **Z** relates to the number of oxygen atoms as 1 to 4 and the content of the metal **X** (an element of a main group) is 80.97% by mass. The metal **X** has three electron layers. The state of oxidation of the metal **Z** in the salt **A** is equal to the number of its group. If **Z** is reacted with an element **L** a two-atomic red solid compound **Y** is produced. The nuclear charge of the metal **X** differs from the nuclear charge of the element **L** by one. **L** and **X** form compound **R** which solidifies at 235 K. The metal **X** is covered with a layer of oxide in the air. **X** reacts with water only in the presence of oxygen and as a result compound XOH is formed, which is a well-soluble in water base **Q**. An oxidation state of the metal **X** is usually equal to I in both hydroxides and salts, though its not typical for the element of the same main group.

**a)** Write formulas of oxygen-containing acids with four oxygen atoms, an oxidation state of non-metal the same as a number of this non-metal's group and which has three electron layers.

**b)** Which non-metal **Z,** contained in the acids given in **a)**, forms red two-atomic compound **I** when joined with the element **L**? Write an equation of the reaction.

**c)** Explain **i)** what chemical element is the metal **X** and **ii)** what compound is the salt **A**.

**d)** Write equations for the reactions where **i)** the base **Q**; **ii)** the compound **A** are formed.

**e)** Give a general name for the substance **R**.

**f)** Check percentage by weight of **X** in **A**.

**2.** According to the text-book copper reacts with water solution of the acid **X** and it doesn't react either with the acid **Y**, or cold diluted water solution of the acid **Z**. To check the resistance to corrode of the stirrers made of copper, one of them was put into an open chemical glass which contained a solution of a moderate concentration of the acid **Y**, and the other one into an open chemical glass with a diluted solution of the acid **Z**. In a day the mass of these stirrers hasn't changed. When stirrer engine had been turned on both solutions began to turn blue. After few hours of stirring the mass of the stirrer in the solution of **Y** decreased by 0.496 g and in the acid **Z** by 0.248 g. The compounds **B** and **C** were formed in the solutions, which are crystallohydrates **E** and **F** in a solid state. Their mass was 1.33 g and 0.98 g respectively. The solutions of $AgNO_3$ and $BaCl_2$ were added excessively to the solutions prepared from these crystallohydrates correspondingly. A white precipitate **G** was formed in the first solution and another white precipitate in the second one. Afterwards a compound **A** remains in the first solution and the mass of the crystallohydrate formed from it is 1.89 g. The compound **A** is also produced when copper reacts with the acid **X**. A compound, which gives the crystallohydrate **E,** remains in the solution (prepared from **F**) after adding $BaCl_2$. The oxidation state of copper in all described compounds is II.

**a)** Write formulas for the acids **X, Y** and **Z** and give their names.

**b)** Write formulas for the compounds **A, B** and **C** and give their names.

**c)** Write an equation for the reaction **Cu + conc. acid X**.

**d)** Why does copper begin to corrode when the solutions **Y** and **Z** are stirred? Give the equations for the reactions which occur while stirring **i)** $Cu \rightarrow B$; **ii)** $Cu \rightarrow C$.

**e)** Write equations for the following reactions: **i) B + AgNO₃; ii) C + BaCl₂** and give names for the compounds **G** and **H**.

**f)** Estimate formulas of the crystallohydrates **i) D; ii) E** and **iii) F** taking into considerations masses given above.

**g)** What formulas for the crystallohydrates **i) D; ii) E** and **iii) F** would be if they're complexes with the coordination number of $Cu^{2+}$-ions 4 in all of them?

**3.** It's comfortable to use propane $(C_3H_8)$ as liquid gas on summer houses in winter because its evaporation temperature is lower than that of butane $(C_4H_{10})$. Enthalpies of formation $(\Delta H_f)$ for water vapour, carbon dioxide and propane are – 242kJ/mol; -394 kJ/mol and –104 kJ/mol respectively. Enthalpy of combustion for butane is –2655 kJ/mol.

**a) i)** Write an equation for combustion of propane and **ii)** calculate enthalpy of combustion for one mol of propane.

**b) i)** Write an equation of the formation of butane and **ii)** calculate enthalpy of formation for butane.

**c)** Calculate the mass of propane needed to be combusted to produce as much energy as one balloon (21 kg) of butane does.

**d)** Does the consumer gets more or less energy by burning liquid gas if water vapour is condensed?

**4.** A compound **A** is a solid which gives in water an intensively colored (dark) solution. **A** is a strong oxidizer, especially in acids. If the solid compound **A** is heated, then the products of decomposition are **B, C** and **D**, which are all quite strong oxidizers. If a green solution of **B** reacts with gaseous chlorine the intensively colored solution of **A** is formed. If solid **C** and is fused with alkali in a presence of oxygen, a green melt of **B** is produced. If solid **C** is heated with

sulfuric acid, gas **D** is educed and a pink solution of **E** is formed. The compound **E** is a product of reduction of **A** when gaseous chlorine is produced from KCl in a presence of sulfuric acid. The compounds **A, B** and **C** contain the same metal.

a) Give formulas for the compounds **A, B, C, D** and **E** and their names.

b) Write equations for the following reactions: **i) A → B + C + D; ii) B → A; iii) C → B; iv) C → E; v) B + H₂O → A + C; vi) A → Cl₂ + E.**

5. The pressure of 1000 atm and the temperature up to 400 $^o$C is used during the synthesis of ammonia. The molar volume of a gas under these conditions is 50 cm$^3$/mol. Under some fixed conditions the equilibrium concentrations are the following: $[H_2]$=5 mol/dm$^3$; $[N_2]$=3 mol/dm$^3$ and $[NH_3]$=2 mol/dm$^3$.

a) Calculate the possible value of molar concentration of gas in the synthesis of ammonia.

b) **i)** Write an equation for the reverse reaction of the synthesis of ammonia. **ii)** Calculate the equilibrium constant of the reaction.

c) Calculate initial concentrations of **i)** hydrogen – $c(H_2)$ and **ii)** nitrogen – $c(N_2)$ if $c(NH_3)$=0

6. The metal **M** is one of the additions in the production of duraluminium. Unlike most metals **M** reacts vigorously with gases **X, Y** and **Z** under fixed conditions. In the reaction between **M** and **X** a black solid mixture of compounds **A** and **B** is formed (one of them is an element). The compound **A** possess basic properties. The compound **B** is insoluble in any solution. The compound **A** is the only product in the reaction between **M** and **Y**. In the reaction between **M** and **Z** a compound **C** is formed. If the compound **C** reacts with water, a slightly soluble compound **D** and a gas **E** with a strong smell are formed. The gas **E** is well soluble in water and the solution gets basic reaction. If the compound **D** is heated then compound **A** and water are produced. If the compound **F** is heated then compound **A** and the gas **X** are formed.

a) Write formulas of the compounds **M, X, Y, Z, A, B, C, D, E** and **F** and give their names.

**b)** Write equations for the reactions **i) M + X; ii) M + Y; iii) M + Z.**

**c)** Write equations for the reactions **i) C + H$_2$O; ii) D → A; iii) F → A + X.**
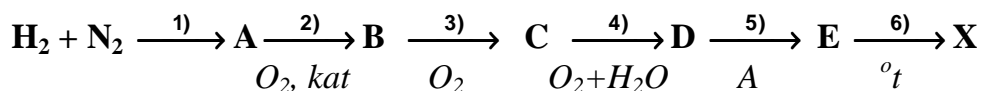
# Form XI

**1.** Plastic polyester is denoted by PPE. Bottles made of PPE can stand pressure up to 6 atm, that's why sode drinks are sold in PPE bottles. The correct name for this polyester is polyethyleneterephthalate. This is an ester formed from ethylene glycol and terephthalic acid with the following formula:
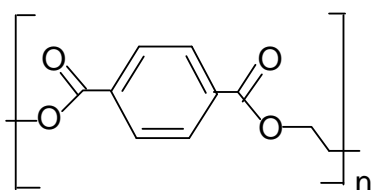


**a)** Write the structure of terephthalic acid and give its systematic name.

**b)** Write the structure of ethylene glycol and give its systematic name.

**c)** Write the formula of polyester's monomer, which is obtained in the reaction of one acid molecule and one alcohol molecule.

**d)** Write the formula of the cyclic ester, which could form in the reaction of one acid molecule and one alcohol molecule (neither acid nor alcohol will contain free functional groups after reaction).

**e)** How many moles of air (maximum) could be kept in a 530 mL limonade bottle so, that the bottle would remain unbroken?

**2.** Organic peroxides are very dangerous oxidants. Their storing and use is recomended only in solutions. To determine the mass of tert-butylhydroperoxide (TBHP, brutto-formula C$_4$H$_{10}$O$_2$) in 1,00 dm$^3$ of the solution of toluene 25,00 cm$^3$ of this solution was taken. The excess of KI solution was added to the solution and then it was acidified with hydrochloric acid. The obtained red solution was titrated with 0,2039 M Na$_2$S$_2$O$_3$ solution until colour disappeared. Starch was used as an indicator. The volume of the required titrant was 10,20 mL. Assume, that 1,1-di-methylethanol and Na$_2$S$_4$O$_6$ form in the course of the titration.

**a)** Write structures of **i)** toluene **ii)** TBHP and **iii)** 1,1-dimethylethanol.

**b)** Write (using empirical formulas) the equations of the two titration reactions.

**c)** Calculate the mass of TBHP, which contained in $1,00$ dm$^3$ of toluene solution.

**3.** Substance **X** $[D_{H_2}(X)=22]$ has a sedative effect on human body in low concentrations and stimulating effect - in high concentrations. Substance **X** can be synthesized from hydrogen and nitrogen by the following scheme:

$$H_2 + N_2 \xrightarrow{\text{1)}} A \xrightarrow[\substack{O_2,\ kat}]{\text{2)}} B \xrightarrow[\substack{O_2}]{\text{3)}} C \xrightarrow[\substack{O_2+H_2O}]{\text{4)}} D \xrightarrow[\substack{A}]{\text{5)}} E \xrightarrow[\substack{^o t}]{\text{6)}} X$$

Substance **X** can be formed in a reaction of magnesium with acid **D** taken in certain concentrations. Reaction of substance **A** with sodium gives substance **F**. It is known, that **F** + **X** = **G** + **H₂O**. Salt **G** is a salt of the weak acid. Both the acid **L** and its salts (except salt **G**) are very explosive. Aqueous solution of salt **G** reacts with lead(ll) ions to give water-insoluble salt **Q**, which is used in the manufacture of detonators.

**a)** Calculate the molar mass of substance **X**.

**b)** Write the equations for the reactions **1-6** and give names of the substances **A**-**E**.

**c)** Write the equation for the reaction **D** + **Mg** and give name for the substance **X**.

**d)** Write equations for the formation reactions of the substances **i) F, ii) G** and **iii) Q**.

**e)** Write the possible structures for the tautomeric forms of acid **L**.

**4.** Density of an organic compound **A** is $1,1607$ g/dm$^3$ at normal conditions and it contains 7,7% of hydrogen and 92,3% of carbon. In the presence of catalyst it yields compound **B** on reaction with water. In alkaline medium 2 molecules of compound **B** combine to form unstable compound **X**. On heating **X** releases $H_2O$ and forms crotonaldehyde **D**, which has one double bond. Reaction of compound **D** with hydrogen chloride yields chlorobutanal **E** that possess R,S-isomerism.

**a)** Find for the compound **A**: **i)** molar mass, **ii)** empirical formula and **iii)** structure.

**b)** Write reactions using structures for the following scheme:

$$A \xrightarrow[\substack{+H_2O}]{\text{i}} B \xrightarrow[\substack{OH}]{\text{ii}} X \xrightarrow[\substack{^o t,\ -H_2O}]{\text{iii}} D \xrightarrow[\substack{HCl}]{\text{iv}} E$$
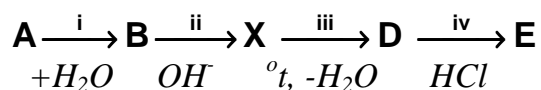
**c)** Write structures for R- and S-stereoisomers of compound **E**.

**5.** Galvanic cell consists of copper and zinc rods that are in copper(II) sulfate and zinc sulfate solutions respectively at standard conditions. Concentration of both solutions is 0,100 M, their volume is 1,00 dm$^3$ and they are in contact through a spongy membrane. The amounts of metals in the rods are much higher than their amounts in solutions. Standard electrode potentials of copper and zinc electrodes are 0,340 V and 0,763 V respectively. F=96500 A·sec/mol; (RT/F)ln C = 0,0591·lgC (V).

**a)** Write the equation for the galvanic cell reaction: **i)** anode process and **ii)** cathode process.

**b)** Draw the scheme of the described galvanic cell. The positive pole should be placed on the right side.

**c)** Calculate the electromotive force for the galvanic cell at the start of the work.

**d)** Find the theoretical amount of electricity, which can be obtained from the galvanic cell.

**6.** In analytical chemistry EDTA is used for the determination of various elements. This reactant is a sodium salt of ethylenediaminetetraacetic acid (EDTA). EDTA forms with metal ions only stable complexes with well-defined composition. In these complexes metal and EDTA are in a ratio of 1:1 independently from the charge of the metal. Complex with barium is stable at pH≥9, however, Ba(OH)$_2$ is slightly soluble in cold water and therefore, usually, complex of barium with EDTA is prepared at lower pH and then the pH is increased until complex become stable. Yttrium and copper ions form stable complexes at pH≥3. EDTA doesn't react with yttrium ions if they are in the form of stable fluoride complex formed using NH$_4$F·HF.

The analysis of a compound, which contains barium, oxygen, copper and yttrium, is carried out. 0,2317 g of the sample is dissolved in concentrated hydrochloric acid. The volume of the solution is made up to 100,0 cm$^3$. 10,00 cm$^3$ of the solution is taken and transfered to the conical flask **A** and 10,00 cm$^3$ of the solution is transfered to flask **B**.

**1)** 1 g of NH₄F·HF is added to the flask **A**, pH of the solution is adjusted to 3-5. $10,20\ \text{cm}^3$ of 0,0100 M EDTA solution is required for the titration of the solution.

**2)** pH in the flask **B** is adjusted to 3-5. The solution is titrated with $13,60\ \text{cm}^3$ of 0,0100 M EDTA solution.

**3)** After the step **2)** $20,00\ \text{cm}^3$ of 0,0100 M EDTA solution is added to the flask **B**, pH is adjusted to 9-10. The volume of the titrant (0,0150 M copper ethanate solution) required for the titration is $8,80\ \text{cm}^3$.

a)  Find the percentage content of **i)** Cu, **ii)** Y, **iii)** Ba and **iv)** O in the sample.

b)  Find the empirical formula of the analyzed substance.

c)  Write planar structures for **i)** EDTA and **ii)** copper(ll) ethanate.

# Form XII

**1.**  Some derivatives of azoalkanes are used as initiators of polymerization reactions, because they are source of free radicalls.

1,1'-dicyano-1,1'-dimethylazoethane can be synthesized as follows:

$$\text{acetone} \xrightarrow{\ X\ } \textbf{A} \xrightarrow{\ hydrazine\ } \textbf{B} \xrightarrow{\ Cl_2+H_2O\ } \underset{NC}{\overset{}{\diagup}}\hspace{-0.2em}{-}N=N{-}\hspace{-0.2em}\underset{CN}{\overset{}{\diagdown}}$$
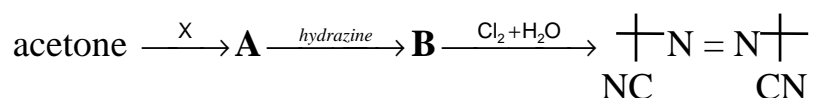
Compound **A** has a hydroxyl group, compound **B** doesn't contain oxygen.

a)  What is the role of the reagent $Cl_2+H_2O$?

b)  Draw the structures of **i)** acetone and **ii)** hydrazine.

c)  Write **i)** formula of the compound **X** and its name; **ii)** draw structural formula of the compound **A** and **iii)** structural formula of the compound **B**.

d)  Write (using structural formulas) the equation of the decomposition reaction of 1,1'-dicyano-1,1'-dimethylazoethane, if two free radicals are formed and gas **Y** is released (its density by oxygen is equal to 0,875).

e)  **i)** Calculate the molar mass of gas **Y**; **ii)** substantiate that only gas **Y** fits.

**2.**  Sulfates **A** and **B** have similar formulas ($X_2SO_4$ and $Y_2SO_4$), but their molecules contain different number of atoms. The content of sulfur in compound **A** is equal

to 22,6% and in compound **B** - 25,4%. Compound **A** is a quite harmless solid, compound **B** is very poisonous carcinogenic liquid. In the reaction of **B** with compound **C**, compound **D** is obtained in the beginning and if excess of compound **C** is added, then compound **A** is formed. In both cases the compound **E** is also formed, its aqueous solution is neutral. Compound **E** reacts with metal **F** to give compound **G**, its hydrolysis gives compounds **C** and **E**.

a) Find molar masses of the substituents **i) X** and **ii) Y**.

b) Write the formulas and names of the compounds **A, B, C, D, E, F** and **G**.

c) Write the equations of the reactions **i) B → D; ii) B → A; iii) E → G; iv) G → C**.

d) To what class of compounds does **B** belong? Draw its structural formula.


3. Compound **X** is a derivative of propane. It possess R,S-isomerism and belongs to the class of compounds that form proteins. Compound **X** can be obtained using Shrecker's reaction.

$$A \xrightarrow{\text{+NH}_3} B \xrightarrow{\text{+HCN}} C \xrightarrow{hydrolysis} X$$

Compound **A** is acetaldehyde, compound **B** contains imino group, compound **C** contains nitrile group and compound **X** is a mixture of R and S isomers. Compound **X** reacts with copper salts to give complex compound **Q**, that is dark blue. Copper in this compound has two covalent bonds and two coordinate bonds.

a) Draw the structural formulas of the compounds **A, B, C** and **X**.

b) Write the equations for the reactions (use structural formulas) **i) A → B; ii) B → C; iii) C → X**.

c) For the compound **X: i)** write its name and **ii)** draw three-dimensional R,S configurations.

d) Write the equation for the reaction between $Cu^{2+}$ and compound **X**.

e) Draw the structural formula of the compound **Q**, showing coordinate bonds.


4. Pyrolysis of 1 mole of acetone (650-700°C) produces 1 mole of substance **A** and 1 mole of substance **B**. Both these compounds are gaseous at room temperature. Compound **A** is not chemically reactive. Compound **B** contains 4,76% of hydrogen and 38,1% of oxygen. Substance **B** reacts with ethanol to give

compound **C**, that gives compound **D** and ethanol on hydrolysis. Compound **D** can also be obtained from reaction of compound **B** with water. Aqueous solution of **D** reacts with aqueous solution of NaOH to form salt **E** and water. Heating of the solid salt **E** with solid NaOH leads to formation of gas **A** and soda.

**a)** For gases **i) B** and **ii) A** calculate their molar masses and write the empirical formulas of the molecules.

**b)** Write structural formulas of the compounds **A**, **B**, **C**, **D** and **E** and write the names of the compounds **A**, **C**, **D** and **E**.

**c)** Write the equations for the reactions **i) B → C; ii) C → D; iii) B → D; iv) D → E; v) E → A**.

**d)** Write the equation for the reaction **B + D** and give the name of the product.

**e)** Write the structural formula of the product of the dimerisation of the compound **B**.

**5.** Radioactivity can be expressed in curie (Ci) per amount of the preparate (Ci/mol; Ci/mmol). 1 Ci = $3{,}700 \cdot 10^{10}$ nuclear disintegrations per second. Researchers also use the term "specific activity", that gives the radioactivity of the preparate per unit of mass, volume or surface (for example Ci/ml). Activity and specific activity of the preparate, that is prepared from the radioactive compound, can be regulated by varying the content of radioactive molecules. Assume, that the radioactivity of the preparate is 1250 Ci/mmol and specific activity is 1,00 Ci/ml. Period of decay of the radioactive nuclei is 89,0 days.

**a)** Calculate the radioactivity of the preparate in dpm/mmol (dpm means disintegrations per minute).

**b)** Calculate the radioactivity of the preparate (in dpm/mmol) if it contains 100% of radioactive molecules. In this case $5{,}41 \cdot 10^{-6}$ mmol of substance decayes during the first minute from 1 mmol.

**c)** Calculate the initial amount of the radioactive molecules in 1 mmol of preparate.

**d)** What period of time is required for the desintegration of 0,1 mmol of radioactive molecules, if initially 1 mmol of the preparate was taken.

**e)** Calculate the specific activity (Ci/ml) after 203 days.

**6.** The solubility of silver chloride in distilled water at a certain temperature is equal to 1,81 mg/dm$^3$ (in solution) . The pH of this solution was changed to 2,35 after addition of HCl. The volume of the solution after acidification remains the same as before it and it's equal to 1,00 dm$^3$.

**a)** Calculate the concentration of Cl$^-$-ions in solution **i)** before and **ii)** after addition of HCl.

**b)** Calculate the solubility product of silver chloride (with dimension units).

**c)** Calculate, how many times did the solubility of AgCl decrease after acidification of the initial solution to pH=2,35.

**d)** Calculate the masses of **i)** NaCl and **ii)** of the silver dissolved in 10 m$^3$ of $1,0 \cdot 10^{-3}$ M solution of NaCl.

# Solutions

## Form IX

**1. a)** $H_2SO_4$ – sulfuric acid

   **b)** $HNO_3$ – nitric acid

   **c)** $H_2SO_3$ – sulfurous acid

   **d)** $HIO$ – hypojodous acid

   **e)** $HClO$ – hypochlorous acid

   **f)** $HBrO$ – hypobromous acid

   **g)** $H_2CO_2$ – methanoic acid  (HCOOH)


**2. a)** $m'(\textbf{FeSO}_4) = 250 \text{ g} \cdot (1{,}00-0{,}82) = \textbf{45 g}$

   **b)   i)** $m'(\textbf{FeSO}_4 \cdot \textbf{7H}_2\textbf{O}) = 45 \text{ g} \cdot \dfrac{278}{152} = 82{,}3 \text{ g} \approx \textbf{82 g}$

      **ii)** $m(\textbf{H}_2\textbf{O}) = 250 \text{ g} - 82 \text{ g} = \textbf{168 g}$

   **c)** $m''(FeSO_4) = 103 \text{ g} \cdot 0{,}136 = 14 \text{ g}$

      $m(FeSO_4) = 45 \text{ g} - 14 \text{ g} = 31 \text{ g}$

      $\textbf{m(FeSO}_4 \cdot \textbf{7H}_2\textbf{O)} = 31 \text{ g} \cdot \dfrac{278}{152} = 56{,}7 \text{ g} \approx \textbf{57 g}$


**3. a)** $Me + 2HCl = MeCl_2 + H_2\uparrow$

      $Me \Leftrightarrow H_2$

   **b)** $\textbf{n(H}_2\textbf{)} = 3{,}136 \text{ dm}^3 \cdot \dfrac{1 \text{ mol}}{22{,}4 \text{ dm}^3} = \textbf{0,14 mol}$

   **c)**   4  :  2  :  1

      $n(A) + n(B) + n(C) = 0{,}14 \text{ mol}$

      **i)** $\textbf{n(A)} = \dfrac{4}{7} \cdot 0{,}14 = \textbf{0,08 mol}$

      **ii)** $\textbf{n(B)} = \dfrac{2}{7} \cdot 0{,}14 = \textbf{0,04 mol}$

**iii) n(C)** $= \frac{1}{7} \cdot 0{,}14 =$ **0,02 mol**

**d)** $0{,}08 \text{ mol} \cdot 3x \text{ g/mol} + 0{,}04 \text{ mol} \cdot 5x \text{ g/mol} + 0{,}02 \text{ mol} \cdot 7x \text{ g/mol} = 4{,}64 \text{ g};$ **x = 8**

**e)** **i)** $M(A) = 3 \text{ g/mol} \cdot 8 = 24 \text{ g/mol}$ **A** − Mg, magnesium

**ii)** $M(B) = 5 \text{ g/mol} \cdot 8 = 40 \text{ g/mol}$ **B** − Ca, calcium

**iii)** $M(C) = 7 \text{ g/mol} \cdot 8 = 56 \text{ g/mol}$ **C** − Fe, iron


**4. a)** **i)** $Ba(OH)_2 + H_2SO_4 = BaSO_4\downarrow + 2H_2O$

**ii)** $2NaOH + H_2SO_4 = Na_2SO_4 + 2H_2O$

**b)** $Ba(OH)_2 \Leftrightarrow BaSO_4$
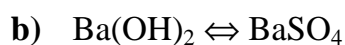
171 g/mol    233 g/mol

$$\mathbf{m[Ba(OH)_2]} = \frac{1}{1} \cdot 14{,}0 \text{ g} \cdot \frac{1 \text{ mol}}{233 \text{ g}} \cdot 171 \text{ g/mol} = \mathbf{10{,}3 \text{ g}}$$

$m(\text{bases}) = 25\underline{0} \text{ g} \cdot 0{,}105 = 26{,}3 \text{ g}$

**m(NaOH)** = 26,3 g - 10,3 g = **16,0 g**

**c)** $\mathbf{n(H_2SO_4)} = 25\underline{0} \text{ g} \cdot 0{,}100 \cdot \dfrac{1 \text{ mol}}{98{,}1 \text{ g}} = \mathbf{0{,}255 \text{ mol}}$

**d)** $Ba(OH)_2 \Leftrightarrow H_2SO_4$
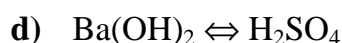
171 g/mol

$n'(H_2SO_4) = 10{,}3 \text{ g} \cdot \dfrac{1 \text{ mol}}{171 \text{ g}} = 0{,}0602 \text{ mol} \approx 0{,}060 \text{ mol}$

For neutralization of NaOH remains

$n''(H_2SO_4) = 0{,}255 \text{ mol} - 0{,}060 \text{ mol} = 0{,}195 \text{ mol}$

For neutralization of NaOH would be spent

$2NaOH \Leftrightarrow H_2SO_4$
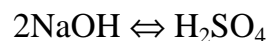
40,0 g/mol

$n(H_2SO_4) = \dfrac{1}{2} \cdot 16{,}0 \text{ g} \cdot \dfrac{1 \text{ mol}}{40{,}0 \text{ g}} = 0{,}200 \text{ mol}$

$Na_2SO_4 \Leftrightarrow H_2SO_4$    (n'' = 0,195 mol)

$\mathbf{n(Na_2SO_4)} = \dfrac{1}{1} \cdot 0{,}195 \text{ mol} = \mathbf{0{,}195 \text{ mol}}$

$2NaOH \Leftrightarrow H_2SO_4$ (n = 0,200 mol - 0,195 mol = 0,005 mol)
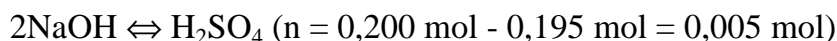
$$n(\textbf{NaOH}) = \frac{2}{1} \cdot 0{,}005 \text{ mol} = \textbf{0,010 mol}$$

**5. a)** **i)** $C_3H_8 + 5O_2 = 3CO_2 + 4H_2O$

**ii)** $2C_4H_{10} + 13O_2 = 8CO_2 + 10H_2O$

**b)** **i)** $2NaOH(\text{excess}) + CO_2 = Na_2CO_3 + H_2O$

**ii)** $NaOH + CO_2(\text{excess}) = NaHCO_3$

ehk $Na_2CO_3 + CO_2 + H_2O = 2NaHCO_3$
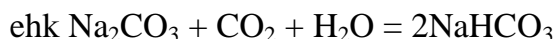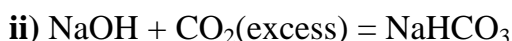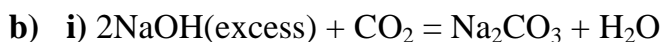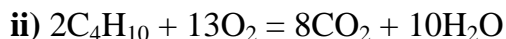
**c)** $n'(CO_2) = \frac{1}{1} \cdot 95{,}4 \text{ g} \cdot \dfrac{1 \text{ mol}}{106 \text{ g}} = 0{,}900 \text{ mol}$

$n''(CO_2) = \frac{1}{1} \cdot 84{,}0 \text{ g} \cdot \dfrac{1 \text{ mol}}{84{,}0 \text{ g}} = 1{,}00 \text{ mol}$

$\textbf{n(CO}_2\textbf{)} = n' + n'' = \textbf{1,90 mol}$

**d)** $n(\text{gaase}) = 11{,}2 \text{ dm}^3 \cdot \dfrac{1 \text{ mol}}{22{,}4 \text{ dm}^3} = 0{,}500 \text{ mol}$

Let the amount of butane be x

$(0{,}500 \text{ mol} - x) \cdot 3 + x \cdot 4 = 1{,}90 \text{ mol}$

$1{,}50 \text{ mol} - 3x + 4x = 1{,}90 \text{ mol}; \qquad x = 0{,}40 \text{ mol}$

$n(C_4H_{10}) = 0{,}40 \text{ mol}$

$n(C_3H_8) = 0{,}50 \text{ mol} - 0{,}40 \text{ mol} = 0{,}10 \text{ mol}$

**i) m(C₃H₈)** $= 0{,}10 \text{ mol} \cdot 44{,}0 \text{ g/mol} = \textbf{4,4 g}$

**ii) m(C₄H₁₀)** $= 0{,}40 \text{ mol} \cdot 58{,}0 \text{ g/mol} = \textbf{23,2 g}$

**6. a)** $M(X) = 7{,}87 \text{ g/cm}^3 \cdot 7{,}09 \text{ cm}^3/\text{mol} = 55{,}8 \text{ g/mol}$

**X** – Fe, iron

**b)** **Y** – Al, aluminum

**A** – $H_2O$, water

**B** – $H_2$, hydrogen

**C** – $Fe_3O_4$, iron(II,III)oxide

**D** – $Al_2O_3$, aluminum oxide

**E** – $Cl_2$, chlorine

**F** – $FeCl_3$, iron(III)chloride

**G** – $FeCl_2$, iron(II)chloride

**H** – $O_2$, oxygen

**I** – $Fe_2O_3$, iron(III)oxide

c)  i) $3Fe + 4H_2O \xrightarrow{\text{t}^\circ} Fe_3O_4 + 4H_2\uparrow$

ii) $3Fe_3O_4 + 8Al = 9Fe + 4Al_2O_3$

iii) $2Fe + 3Cl_2 = 2FeCl_3$

iv) $Fe + 2HCl = FeCl_2 + H_2\uparrow$

v)  $4Fe + 12HCl + 3O_2 = 4FeCl_3 + 6H_2O$

vi) $4Fe + 3O_2 = 2Fe_2O_3$
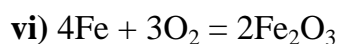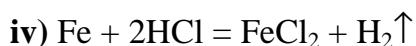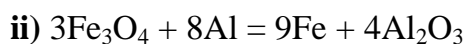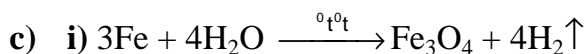
## Form X

**1. a)**  $H_4SiO_4$, $H_3PO_4$, $H_2SO_4$, $HClO_4$

**b)**  $S + Hg = HgS$

**c)**  i) If **L** is **Hg**, then **X** can be only Tl as it's a element of the main group, whose oxidation state

should be III. Au don't match, as it's not a main group element and don't react with water either.

ii) The compound **A** must be **$Tl_2SO_4$**, as oxidation state of Tl is usually I. An extra high percentage of thallium in the compound **A** also shows that its salt (sulfate) contains two thallium ions.

**d)**  i) $4Tl + 2H_2O + O_2 = 4TlOH$

ii) $2TlOH + H_2SO_4 = Tl_2SO_4 + 2H_2O$

**e)**  amalgam

**f)**  $\%(Tl) = \dfrac{2 \cdot 204,4}{504,9} \cdot 100 = \mathbf{80,97}$

**2. a)**  **X** – $HNO_3$, nitric acid;  **Y** – HCl, hydrogen chloride;  **Z** – $H_2SO_4$, sulfuric acid

**b)** **A**– $Cu(NO_3)_2$, copper(II)nitrate; **B** – $CuCl_2$, copper(II)chloride; **C** – $CuSO_4$, copper(II)sulfate

**c)** $Cu + 4HNO_3 = Cu(NO_3)_2 + 2NO_2 + 2H_2O$
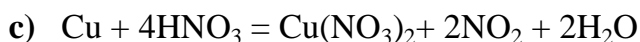
                compound **A**

**d)** **i)** oxygen takes part in the reaction if the solutions are stirred

    **ii)** $2Cu + 4HCl + O_2 = 2CuCl_2 + 2H_2O$

              compound **B**

    **iii)** $2Cu + 2H_2SO_4 + O_2 = 2CuSO_4 + 2H_2O$

              compound **C**

**e)** **i)** $CuCl_2 + 2AgNO_3 = Cu(NO_3)_2 + 2AgCl\downarrow$
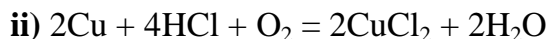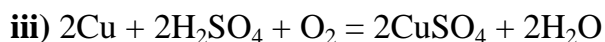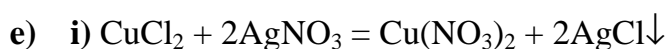
                      compound **G**, silver chloride

    **ii)** $CuSO_4 + BaCl_2 = CuCl_2 + BaSO_4\downarrow$
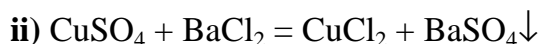
                compound **H**, barium sulfate

**f)**   Cu     $\Leftrightarrow$     $Cu(NO_3)_2$   $\Leftrightarrow$   $CuCl_2$   $\Leftrightarrow$   $CuSO_4$
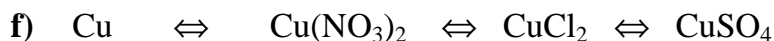
    63,5 g/mol    188 g/mol     134 g/mol    16$\underline{0}$ g/mol

    **i)** crystallohydrate **D** – $Cu(NO_3)_2 \cdot n'H_2O$

$$n'(H_2O) = 1\,mol \cdot \frac{63,5\ g/mol}{0,496\ g}\left[1,89\ g - \frac{0,496\ g}{63,5\ g/mol} \cdot 188\ g/mol\right] \cdot \frac{1\,mol}{18\ g} = 3\ mol$$

      **D** – $Cu(NO_3)_2 \cdot 3H_2O$

    **ii)** **E** – $CuCl_2 \cdot n''H_2O$

$$n''(H_2O) = 1\,mol \cdot \frac{63,5\ g/mol}{0,496\ g}\left[1,33\ g - \frac{0,496\ g}{63,5\ g/mol} \cdot 134\ g/mol\right] \cdot \frac{1\,mol}{18\ g} = 2\ mol$$

      **E** – $CuCl_2 \cdot 2H_2O$

    **iii)** crystallohydrate **F** – $CuSO_4 \cdot n'''H_2O$

$$n'''(H_2O)=1\,mol \cdot \frac{63,5\ g/mol}{0,248\ g}\left[0,98\ g - \frac{0,248\ g}{63,5\ g/mol} \cdot 160\ g/mol\right] \cdot \frac{1\,mol}{18\ g} = 5$$

mol

      **F** – $CuSO_4 \cdot 5H_2O$

**g)** **i)** $[Cu(H_2O)_2Cl_2]$

    **ii)** $[Cu(H_2O)_3NO_3]NO_3$

    **iii)** $[Cu(H_2O)_4]SO_4(H_2O)$

**3. a)** **i)** $C_3H_8 + 5O_2 = 3CO_2 + 4H_2O$
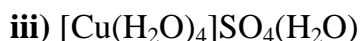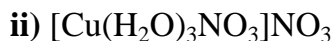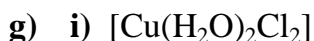
**ii)** $\Delta H_c(C_3H_8) = 3 \cdot (-394 \text{kJ/mol}) + 4 \cdot (-242 \text{kJ/mol}) - 1 \cdot (-104 \text{kJ/mol}) - 5 \cdot 0 = \mathbf{-2046 \text{kJ/mol}}$

**b)** **i)** $4C + 5H_2 = C_4H_{10}$
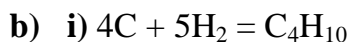
**ii)** $\Delta H_f(C_4H_{10}) = 4 \cdot (-394 \text{kJ/mol}) + 5 \cdot (-242 \text{kJ/mol}) - 1 \cdot (-2655 \text{kJ/mol}) = \mathbf{-131 \text{kJ/mol}}$

**c)** $\Delta H(C_4H_{10}) = 21{,}0 \text{ kg} \cdot \dfrac{1000 \text{ g}}{1 \text{ kg}} \cdot \dfrac{1 \text{ mol}}{58{,}1 \text{ g}} \cdot (-2655 \text{ kJ/mol}) = -9{,}60 \cdot 10^5 \text{ kJ}$

$\mathbf{m(C_3H_8)} = -9{,}60 \cdot 10^5 \text{ kJ} \cdot \dfrac{1 \text{ mol}}{-2046 \text{ kJ}} \cdot \dfrac{0{,}0440 \text{ kg}}{\text{mol}} = \mathbf{20{,}6 \text{ kg}}$

**d)** More, because vapor condensation is an exothermic process.

**4. a)** **A** − $KMnO_4$, potassium permanganate

**B** − $K_2MnO_4$, potassium manganate

**C** − $MnO_2$, manganese dioxide or manganese(IV)oxide

**D** − $O_2$, oxygen

**E** − $MnSO_4$, manganese sulfate

**b)** **i)** $2KMnO_4 \xrightarrow{\text{t}^o} K_2MnO_4 + MnO_2 + O_2\uparrow$

**ii)** $2K_2MnO_4 + Cl_2 = 2KMnO_4 + 2KCl$

compound **A**

**iii)** $2MnO_2 + 4KOH + O_2 = 2K_2MnO_4 + 2H_2O$

compound **B**

**iv)** $2MnO_2 + 2H_2SO_4 = 2MnSO_4 + O_2\uparrow + 2H_2O$

compound **E**　gas **D**

**v)** $3K_2MnO_4 + 2H_2O = 2KMnO_4 + MnO_2 + 4KOH$

compound **A**　compound **C**

**vi)** $10KCl + 8H_2SO_4 + 2KMnO_4 = 2MnSO_4 + 5Cl_2\uparrow + 6K_2SO_4 + 8H_2O$
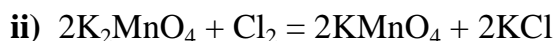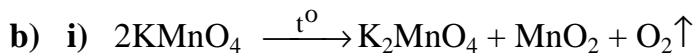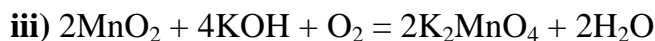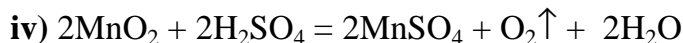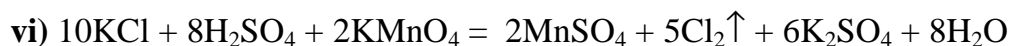
compound **E**

**5. a)** $c(\text{gas}) = \dfrac{n(\text{gaas})}{1 \text{ dm}^3} \Rightarrow \dfrac{1}{\text{dm}^3} \cdot 1 \text{ dm}^3 \cdot \dfrac{1 \text{ mol}}{0{,}05 \text{ dm}^3} = \mathbf{20 \text{ mol/dm}^3}$

**b)  i)** $N_2 + 3H_2 \rightleftharpoons 2NH_3$
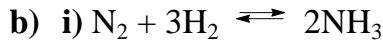
**ii)** $K_{equilibr} = \dfrac{[NH_3]^2}{[N_2][H_2]^3} \Rightarrow \dfrac{(2M)^2}{3M \cdot (5M)^3} = \dfrac{4M^2}{3M \cdot 125M^3} = 0{,}0107 \cdot \dfrac{1}{M^2} \approx \mathbf{1 \cdot 10^{-2}} \cdot \dfrac{\mathbf{1}}{\mathbf{M^2}}$

**c)  i)** $c(H_2) = 5M + \dfrac{3}{2} \cdot 2M = \mathbf{8M}$

**ii)** $c(N_2) = 3M + \dfrac{1}{2} \cdot 2M = \mathbf{4M}$

**6.  a)  M** – Mg, magnesium

**X** – $CO_2$, carbon dioxide

**Y** – $O_2$, oxygen

**Z** – $N_2$, nitrogen

**A** – MgO, magnesium oxide

**B** – C, carbon

**C** – $Mg_3N_2$, magnesium nitride

**D** – $Mg(OH)_2$, magnesium hydroxide

**E** – $NH_3$, ammonia

**F** – $MgCO_3$, magnesium carbonate
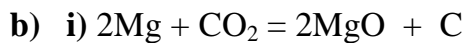
**b)  i)** $2Mg + CO_2 = 2MgO + C$

         compound **A** compound **B**

**ii)** $2Mg + O_2 = 2MgO$

         compound **A**

**iii)** $3Mg + N_2 = Mg_3N_2$

         compound **C**

**c)  i)** $Mg_3N_2 + 6H_2O = 3Mg(OH)_2 + 2NH_3$

         compound **D** compound **E**

**ii)** $Mg(OH)_2 \xrightarrow{t^o} H_2O + MgO$

         compound **A**

**iii)** $MgCO_3 \xrightarrow{t^o} MgO + CO_2\uparrow$
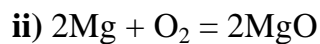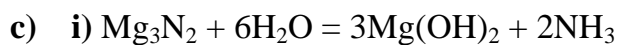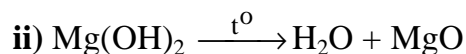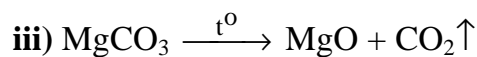
         compound **A** gas **X**

# Form XI

**1. a)**
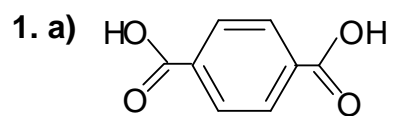


1,4–bensenedicarboxylic acid, para–bensenedicarboxylic acid

**b)**



1,2–ethanediol

**c)**



**d)**
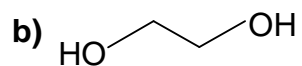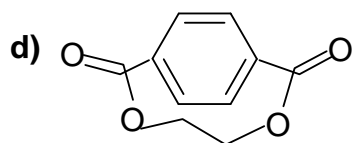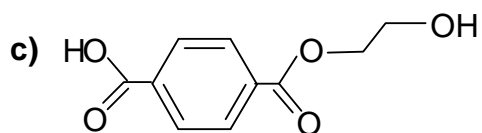


**e)** $p_1 \cdot V_1 = p_2 \cdot V_2$

6 atm · 530 ml = 1 atm · V

$$V = 530 \text{ ml} \cdot \frac{6 \text{ atm}}{1 \text{ at}} \cdot \frac{1 \text{ dm}^3}{1000 \text{ ml}} = 3{,}18 \text{ dm}^3$$

$$\textbf{n(air)} = 3{,}18 \text{ dm}^3 \cdot \frac{1 \text{ mol}}{22{,}4 \text{ dm}^3} = \textbf{0,142 mol}$$
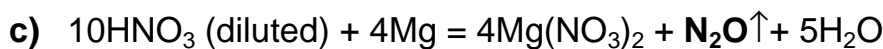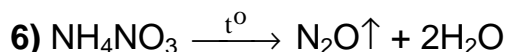
**2. a) i)**



**ii)** $C(CH_3)_3OOH$

**iii)** $C(CH_3)_3OH$

**b) i)** $C(CH_3)_3OOH + 2KI + 2HCl = C(CH_3)_3OH + I_2 + 2KCl + H_2O$

**ii)** $2Na_2S_2O_3 + I_2 = Na_2S_4O_6 + 2NaI$

**c)**    $25{,}0$ cm$^3$        $10{,}20$ cm$^3$·$0{,}2039$ mol/dm$^3$

$C(CH_3)_3OOH$   $\Leftrightarrow$    $2Na_2S_2O_3$
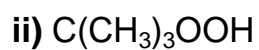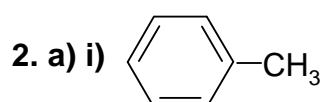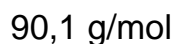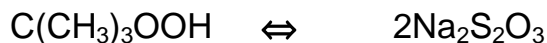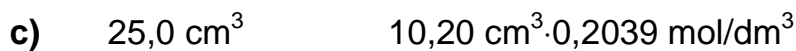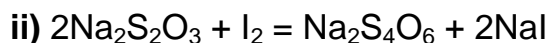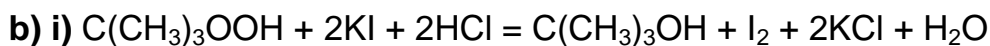
$90{,}1$ g/mol

**m[C(CH₃)₃OOH]** $= \dfrac{1}{2} \cdot 10{,}20$ cm$^3 \cdot 0{,}2039$ mol$/$dm$^3 \cdot \dfrac{1}{25{,}0 \text{ cm}^3} \cdot 1$ dm$^3 \cdot 90{,}1$ g/mol $=$

$= \mathbf{3{,}74\ g}$

**3. a)** $M(X) = 2{,}0$ g/mol·$22 = 44$ g/mol

**b)**  **1)** $3H_2 + N_2 \xrightarrow{\text{p, t}^o} 2NH_3$ (substance **A** is ammonia)

   $Pt$

**2)** $4NH_3 + 5O_2 = 4NO + 6H_2O$ (substance **B** is nitric oxide)

**3)** $2NO + O_2 = 2NO_2$ (substance **C** is nitrogen dioxide)

**4)** $4NO_2 + O_2 + 2H_2O = 4HNO_3$ (substance **D** is nitric acid)

**5)** $HNO_3 + NH_3 = NH_4NO_3$ (substance **E** is ammonium nitrate)

**6)** $NH_4NO_3 \xrightarrow{\text{t}^o} N_2O\uparrow + 2H_2O$

**c)**  $10HNO_3$ (diluted) $+ 4Mg = 4Mg(NO_3)_2 + \mathbf{N_2O}\uparrow + 5H_2O$
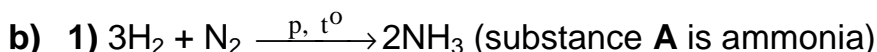
                    compound **X** is nitrogen(I) oxide

**d)  i)** $2NH_3 + 2Na = 2NaNH_2 + H_2$

**ii)** $NaNH_2 + N_2O = NaN_3 + H_2O$

**iii)** $2NaN_3 + Pb^{2+} = Pb(N_3)_2\downarrow + 2Na^+$

**e)**  $H–N–N \equiv N \rightleftharpoons H–N=N=N$
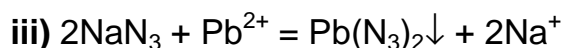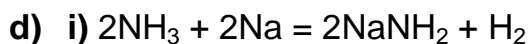
**4. a)  i)** $M(A) = 1{,}1607$ g/dm$^3$·$22{,}4$ dm$^3$/mol $= \mathbf{26{,}0\ g/mol}$

**ii)** $n(C) = 26{,}0 \text{ g} \cdot 0{,}923 \cdot \dfrac{1 \text{ mol}}{12 \text{ g}} = 2 \text{ mol}$

$n(H) = 26{,}0 \text{ g} \cdot 0{,}077 \cdot \dfrac{1 \text{ mol}}{1 \text{ g}} = 2 \text{ mol}$

**$C_2H_2$**

**iii) HC $\equiv$ CH**

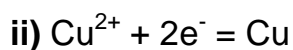**b) i)** $HC\equiv CH + H_2O \overset{\text{cat.}}{=} CH_3CHO$ (compound **B**)

**ii)** $2CH_3CHO \overset{OH^-}{=} CH_3CH(OH)CH_2CHO$ (compound **X**)

**iii)** $CH_3CH(OH)CH_2CHO \xrightarrow{\ t^o\ } CH_3CH=CHCHO$ (crotonaldehyde)

compound **E**

**iv)** $CH_3CH=CHCHO + HCl \overset{+\sigma \ -\sigma}{=} CH_3CHClCH_2CHO$ (3–chlorobutanal–1)

**c)**
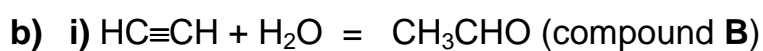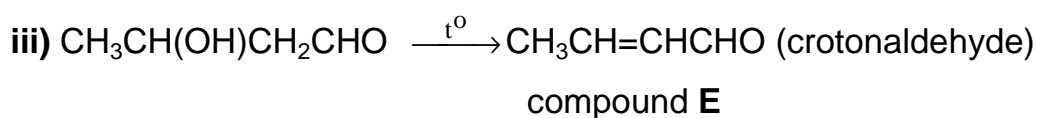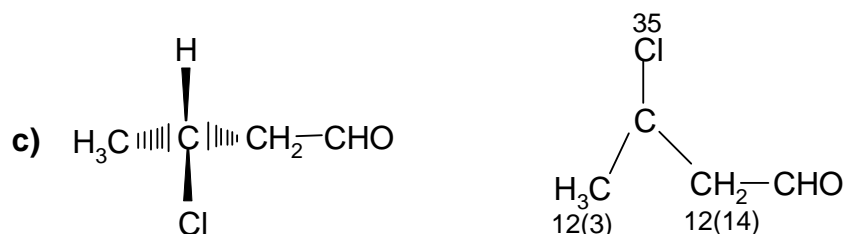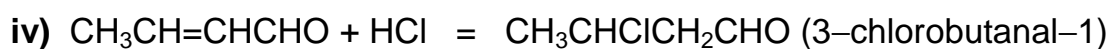


R, 3-chlorobutanal-1



S, 3-chlorobutanal-1

**5. a) i)** $Zn = Zn^{2+} + 2e^-$

**ii)** $Cu^{2+} + 2e^- = Cu$

**b)** $Zn \mid ZnSO_4 \mid\mid CuSO_4 \mid Cu$
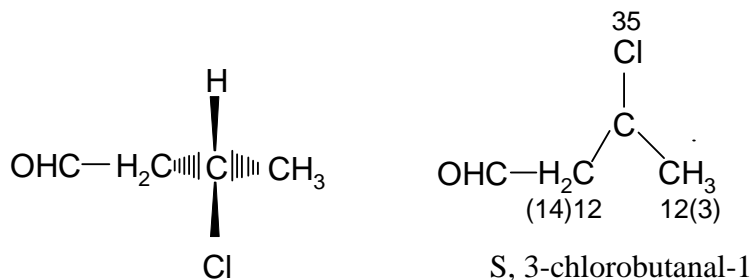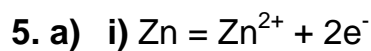
c) $E = E^0(Cu^{2+}/Cu) - E^0(Zn^{2+}/Zn) + \dfrac{0,0591}{2}\left[\lg c(Cu^{2+}) - \lg c(Zn^{2+})\right] =$

$$= 0,340V - (-0,763\ V) + 0,0296\ [-1 - (-1)]\ V = \mathbf{1,103\ V}$$

d) Galvanic cell will work until all the $Cu^{2+}$ is reduced

$Cu^{2+} \Leftrightarrow 2e^-$
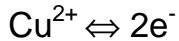
$\mathbf{Q} = \dfrac{2}{1} \cdot 1,00\ dm^3 \cdot 0,100\ mol/dm^3 \cdot 96500\ A \cdot s/mol \cdot \dfrac{1\ h}{3600\ s} = \mathbf{5,36\ A{\cdot}h}$

6. a)  i) $n(Cu) = 10,20 \cdot 10^{-3}\ dm^3 \cdot 0,0100\ mol/dm^3 \cdot 10 = 1,02 \cdot 10^{-3}\ mol$

$m(Cu) = 1,02 \cdot 10^{-3}\ mol \cdot 63,5\ g/mol = 0,0648\ g$

$\mathbf{\%(Cu)} = \dfrac{0,0648}{0,2317} \cdot 100 = \mathbf{28,0}$

ii) $n(Y+Cu) = 13,70 \cdot 10^{-3}\ dm^3 \cdot 0,0100\ mol/dm^3 \cdot 10 = 1,36 \cdot 10^{-3}\ mol$

$n(Y) = 1,36 \cdot 10^{-3}\ mol - 1,02 \cdot 10^{-3}\ mol = 3,4 \cdot 10^{-4}\ mol$

$m(Y) = 3,4 \cdot 10^{-4}\ mol \cdot 88,9\ g/mol = 0,0302\ g \approx 0,030\ g$

$\mathbf{\%(Y)} = \dfrac{0,0302}{0,2317} \cdot 100 = \mathbf{13}$

iii) $n(Ba) = (20,00 \cdot 10^{-3}\ dm^3 \cdot 0,0100\ mol/dm^3 -$

$- 8,80 \cdot 10^3 dm^3 \cdot 0,0150\ mol/dm^3) \cdot 10 = 6,8 \cdot 10^{-4}\ mol$

$m(Ba) = 6,8 \cdot 10^{-4}\ mol \cdot 137\ g/mol = 0,0932\ g \approx 0,093\ g$

$\mathbf{\%(Ba)} = \dfrac{0,0932}{0,2317} \cdot 100 = \mathbf{4\underline{0}}$

iv) $m(O) = 0,2317\ g - 0,0648\ g - 0,0302\ g - 0,0932\ g = 0,0434\ g \approx 0,043\ g$

$\mathbf{\%(O)} = \dfrac{0,0434}{0,2317} \cdot 100 = \mathbf{19}$

b)      Cu                         Y              Ba                              O

$1,02 \cdot 10^{-3}\ mol$     $3,4 \cdot 10^{-4}\ mol$     $6,8 \cdot 10^{-4}\ mol$     $\dfrac{0,0434\ g}{16 g/mol} = 2,71 \cdot 10^{-3}\ mol$

$\dfrac{1\ mol}{3,4 \cdot 10^{-4}\ mol} = 2941$

$n(Cu) = 2941 \cdot 1{,}02 \cdot 10^{-3}$ mol $= 3$ mol
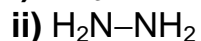
$n(Ba) = 2941 \cdot 6{,}8 \cdot 10^{-4}$ mol $= 2$ mol

$n(O) = 2941 \cdot 2{,}71 \cdot 10^{-3}$ mol $= 8$ mol

**$Cu_3Y_1Ba_2O_8$**

**c) i)**



**ii)**



# Form XII

**1. a)** $Cl_2 + H_2O = HCl + HClO$         HClO is an oxidizer

**b) i)** $CH_3COCH_3$
   **ii)** $H_2N–NH_2$

**c) i)** HCN (hydrogen cyanide) – compound **X**

**ii)**



– compound **A**

**iii)**



– compound **B**

**d)**



– compound **Y**

**e) i) M(Y)** $= 32$ g/mol $\cdot 0{,}875 =$ **28,0 g/mol**

25
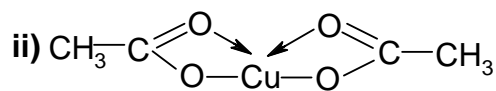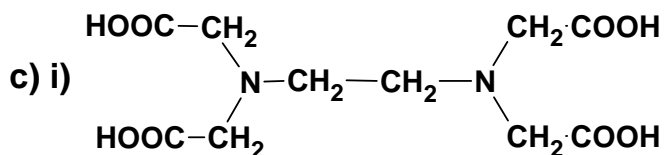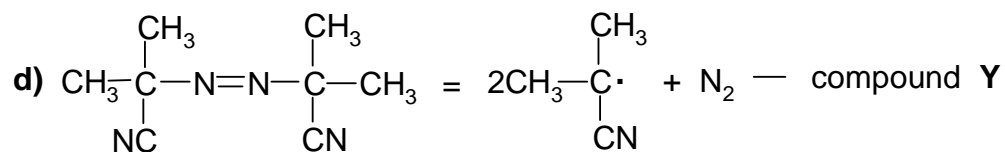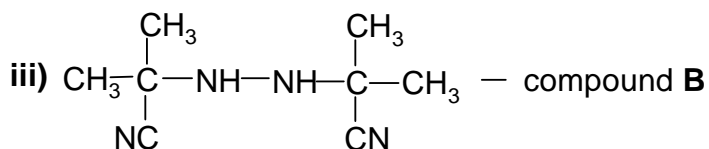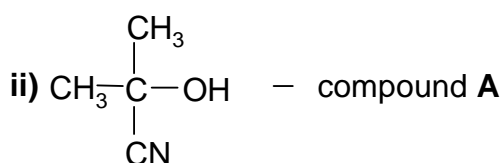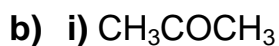
**ii)** The molar masses of nitrogen ($N_2$), carbon monooxide (CO) and ethene ($CH_2=CH_2$) are the same (28,0 g/mol). CO can not be obtained because

1,1′–dicyano–1,1′–dimethylazoethane doesn't contain oxygen, ethyl group doesn't decompose to give ethene.

**2. a) i)** $M(X) = \dfrac{1}{2}\left(\dfrac{32,1}{0,226} - 32,1 - 4 \cdot 16,0\right) g/mol = $ **23,0 g/mol**

**ii)** $M(Y) = \dfrac{1}{2}\left(\dfrac{32,1}{0,254} - 32,1 - 4 \cdot 16,0\right) g/mol = $ **15,1 g/mol**

**b) A** – $Na_2SO_4$, sodium sulfate
**B** – $(CH_3)_2SO_4$, dimethylsulfate
**C** – NaOH, sodium hydroxide
**D** – $CH_3NaSO_4$, sodium methylsulfate
**E** – $CH_3OH$, methanol
**F** – Na, sodium
**G** – $CH_3ONa$, sodium metanolate

**c) i)** $(CH_3)_2SO_4 + NaOH = CH_3NaSO_4 + CH_3OH$
**ii)** $(CH_3)_2SO_4 + 2NaOH = Na_2SO_4 + 2CH_3OH$
**iii)** $2CH_3OH + 2Na = 2CH_3ONa + H_2\uparrow$
**iv)** $CH_3ONa + H_2O = CH_3OH + NaOH$

**d)** dimethylsulfate is an ester $CH_3–O–SO_2–O–CH_3$

**3. a) A** – $CH_3CHO$
**B** – $CH_3–CH=NH$
**C** – $CH_3CH(NH_2)–C{\equiv}N$
**X** – $CH_3CH(NH_2)COOH$

**b) i)** $CH_3CHO + NH_3 = CH_3CH=NH + H_2O$
**ii)** $CH_3CH=NH + HCN = CH_3–CH(NH_2)–C{\equiv}N$
**iii)** $CH_3–CH(NH_2)–C{\equiv}N + 2H_2O = CH_3–CH(NH_2)COOH + NH_3$

**c) i)** $\alpha$–aminopropionic acid, alanine

**ii)**



**R**



**S**

**d)** $2CH_3CH(NH_2)COOH + Cu^{2+} = [CH_3CH(NH_2)COO]_2Cu + 2H^+$

**e)**
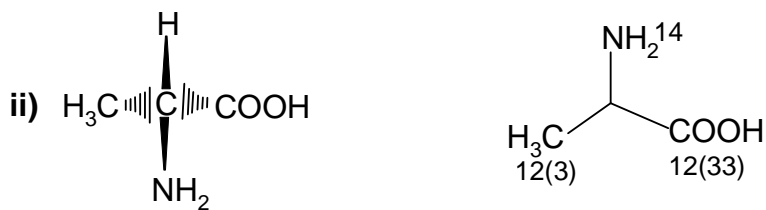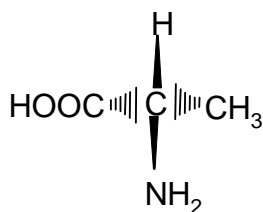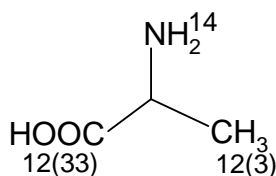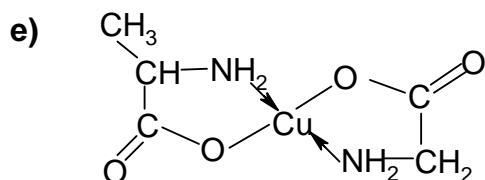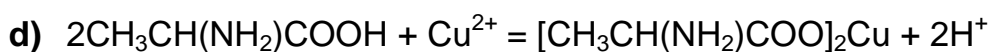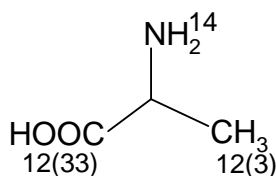


**4. a) i)** Molecule of acetone contains only 1 atom of oxygen, that´s why we can calculate the molar mass of compound **B** using the percentage of oxygen

leida hapniku protsendilise sisalduse järgi

$$M(B) = \frac{16,0 \text{ g}/\text{mol}}{0,381} = 42,0 \text{ g/mol}$$

Compound **B**: $n(H) = 42,0 \text{ g} \cdot 0,0476 \cdot \dfrac{1 \text{ mol}}{1 \text{ g}} = 2 \text{ mol}$

$$n(C) = (42 - 16 - 2) \text{ g} \cdot \dfrac{1 \text{ mol}}{12 \text{ g}} = 2 \text{ mol}$$

The empirical formula of compound **B** is $C_2H_2O$

**ii)** $M$(acetone) = 58 g/mol

$M(\textbf{A}) = M$(acetone) - $m(\textbf{B})$ = 58 g/mol - 42 g/mol = 16 g/mol

The empirical formula of compound **A** is $C_3H_6O - C_2H_2O = CH_4$

**b)** **A** – $CH_4$, methane

**B** – $CH_2=C=O$, ketene

**C** – $CH_3COOC_2H_5$, ethylacetate

**D** – $CH_3COOH$, acetic acid

**E** – $CH_3COONa$, sodium acetate

**c) i)** $CH_2=C=O + C_2H_5OH = CH_3COOC_2H_5$ (**C**)

**ii)** $CH_3COOC_2H_5 + H_2O = C_2H_5OH + CH_3COOH$ (**D**)

**iii)** $CH_2=C=O + H_2O = CH_3COOH$  **(D)**
**iv)** $CH_3COOH + NaOH = H_2O + CH_3COONa$  **(E)**
**v)** $CH_3COONa + NaOH = Na_2CO_3 + CH_4$  **(A)**

**d)** $CH_2=C=O + CH_3COOH = CH_3COOCOCH_3$
acetic anhydride

**e)** $2(CH_2=C=O)$ =



diketene
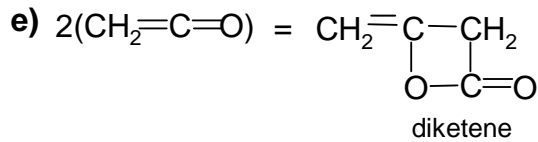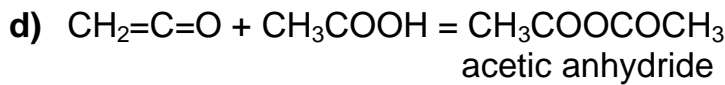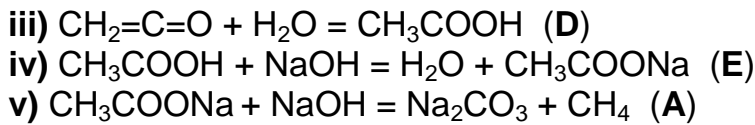
**5. a)** $N(prep) = 1250 \text{ Ci/mmol} \cdot 3,700 \cdot 10^{10} \dfrac{decays}{sek} \cdot \dfrac{60\,sek}{1\,min}$ = **2,775·10¹⁵**

**dpm/mmol**

**b)** $N(100\%) = 5,41 \cdot 10^{-6} \dfrac{mmol}{mmol \cdot min} \cdot 6,02 \cdot 10^{20} \dfrac{decays}{mmol}$ = **3,26·10¹⁵ dpm/mmol**

**c)** $n(100\%) = 1\,mmol \cdot \dfrac{2,78 \cdot 10^{15}}{3,26 \cdot 10^{15}}$ = **0,853 mmol**

**d)** $t = \dfrac{89,0\,days}{\ln 2} \cdot \ln \dfrac{0,853}{0,853 - 0,100} \Rightarrow 128,4\,days \cdot 0,1249$ = **16,0 days**

**e) specific activity** (203 days) = $1,000\,Ci/ml \cdot e^{\frac{-\ln 2}{89,0\,days}} \cdot 203\,days$ = **0,205 Ci/ml**

**6. a)  i)**  $[Cl^-] = [AgCl] = \dfrac{1,81 \cdot 10^{-3}\ g/dm^3}{143\ g/mol}$ = **1,26·10⁻⁵ mol/dm³**

**ii) c(Cl⁻)** = $c(H^+) = 10^{-pH} = 10^{-2,35}$ mol/dm³ = **4,47·10⁻³ mol/dm³**

**b)  LK(AgCl)** = $[Ag^+][Cl^-] = (1,26 \cdot 10^{-5}\ mol/dm^3)^2$ = **1,59·10⁻¹⁰ mol²/dm⁶**

**c)**  in solution of HCl:    $[AgCl] = [Ag^+] = \dfrac{1,59 \cdot 10^{-10}}{4,47 \cdot 10^{-3}}$ = **3,56·10⁻⁸ mol/dm³**

$L(AgCl) = 3,56 \cdot 10^{-8}\ mol/dm^3 \cdot 143\ g/mol = 5,09 \cdot 10^{-6}\ g/dm^3$

The ratio of solubilities is    $\dfrac{1,81 \cdot 10^{-3}}{5,09 \cdot 10^{-6}}$ = **356**

**d)  i) m(NaCl)** = $1,0 \cdot 10^4\ dm^3 \cdot 1,0 \cdot 10^{-3}\ mol/dm^3 \cdot 58,5\ g/mol$ = **585 g**

**ii) m(Ag)** = $\dfrac{1,59 \cdot 10^{-10}}{1,0 \cdot 10^{-3}}\ mol/dm^3 \cdot 1,0 \cdot 10^4\ dm^3 \cdot 108\ g/mol$ = **0,17 g**