

Tartu University

**49<sup>th</sup> CHEMISTRY OLYMPIAD**  
**Final National Competition**

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*ESTONIA*

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# Problems

## Form IX

**1.** Blue vitriol ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) and green vitriol ( $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ ) are used to control plant diseases. For these purposes the solutions with a required percentage of these salts have to be prepared.

- How many kilograms of i) blue vitriol and ii) water are needed for the preparation of 5,0 kg of 4,0% solution of  $\text{CuSO}_4$  (160 g/mole)?
- How many kilograms of green vitriol are needed to add to 9,0 kg of 3,0% solution in order to obtain 5,0% solution of  $\text{FeSO}_4$  (152 g/mole)?

**2.** A chemistry teacher decided to show an interesting demonstration. He took a teaspoon made of metal X, slightly polished it with a sandpaper and put it for a moment into a colourless solution A, that contained salt  $\text{Y}(\text{NO}_3)_2$ . After that he took an "activated" spoon from a solution, rinsed it once with water and put it on a glass plate. After a short period of time this spoon got covered with a white soft powder and after some more minutes this spoon completely disappeared and only a small pile of this white soft powder B and some little grey drops C left. One cause of the corrosion of the wet "activated" spoon in the air is a compound D. The initial active reagent of the corrosion of the polished teaspoon in the air is an element E. During the corrosion of the "activated" spoon an element F is formed. The reaction between the elements E and F gives compound D.

- What metal was this teaspoon made of? Show a symbol of an element and give its name.
  - Why doesn't this teaspoon become destroyed when we use it for stirring tea?
- Show symbol of an element Y and give its name.
  - What happened to spoon when it was polished with a sandpaper?
  - Which compound was formed on a surface of a spoon when it was treated with solution A, if this teaspoon began to corrode after that?
  - What is a chemical composition of these drops C?
- Why does the corrosion of the polished teaspoon stop in the air and in the water?
  - Write equation for the reaction that describes formation of the protective layer on a surface of metal X.
- Write equations for the reactions:
  - $\text{X} + \text{A} \rightarrow$ ;
  - $\text{X}_{\text{act}} + \text{D} \rightarrow \text{B} + \text{F}$ ;
  - $\text{X}_{\text{act}} + \text{D} + \text{E} \rightarrow \text{B}$ ;
  - $\text{E} + \text{F} \rightarrow$ .Give the names for the compounds A, B, D, E, F.

**3.** Depending on a season the balloons with a bottled gas (21 kg of gas) may contain propane ( $C_3H_8$ ) or butane ( $C_4H_{10}$ ). The heat of combustion of a propane (44,1 g/mole)  $\Delta H = -2221$  kJ/mole and the heat of combustion of a butane (58,1 g/mole)  $\Delta H = -2889$  kJ/mole. Minus mark shows that during combustion gas loses its energy.

- Write the equation for the reaction of combustion of
  - propane and
  - butane.
- Calculate the amount of energy that is released during the combustion of the gas from one balloon of
  - propane and
  - butane.
- The cost of the balloon does not depend on its content and is equal to 250 kronas.
  - Which gas gives the cheapest energy at its combustion?
  - Calculate an average cost of the production of 1 gigajoule of energy starting from propane and butane ( $GJ=10^9$  J).

**4.** A grinded limestone in a first crucible was heated for a long period of time at a temperature  $900^\circ C$ , powdered gypsum in another crucible was heated at a temperature  $120^\circ C$ . After heating the obtained powders were cooled down. These powders were mixed in the different pots with water and the obtained mixtures were left on a table. In the second experiment both finely powdered minerals were heated at a temperature  $300^\circ C$  and after that the obtained powder was mixed with water.

- Write equations for the reactions and give trivial names for compounds:
  - limestone  $\xrightarrow{900^\circ C}$  ;
  - limestone  $\xrightarrow{300^\circ C}$  ;
  - gypsum  $\xrightarrow{120^\circ C}$  ;
  - gypsum  $\xrightarrow{300^\circ C}$
- Write equations for the reactions that occur between water and
  - a limestone burnt at  $900^\circ C$  ;
  - a limestone burnt at  $300^\circ C$ ,
  - a gypsum burnt at  $120^\circ C$  ;
  - a gypsum burnt at  $300^\circ C$ .
- What substances should we mix in order to prepare a plaster?  
Write equations for the reactions that are responsible
  - for the initial consolidation of a plaster and
  - for the additional consolidation of a plaster in the course of centuries.

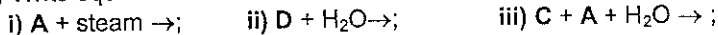
**5.** When an excess of a steam was passed over the salt **A** heated to  $500\text{--}600^\circ C$ , then 8,00 grams of base **B** and  $2,24$  dm<sup>3</sup> of the colourless and odourless triatomic gas **C** were obtained. The same amount of this base **B** can be obtained in the reaction of 0,100 mole of the oxide **D** of the alkaline metal **X** with water.  $2,24$  dm<sup>3</sup> of gas **C** completely reacts with a diluted aqueous solution, containing an initial amount of salt **A**, to give 16,8 g of salt **E**. After the evaporation of the obtained solution till dryness on a water-bath the initial amount of compound **A** was obtained. Salts **A**

and **E** can also be formed as a result of the reaction of gas **C** with an aqueous solution of base **B**.

a) For the base **B** and for the metal **X** find molecular masses; draw formulae, symbols of elements and also give the names.

b) Identify gas **C** (substantiate your answer).

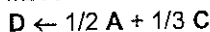
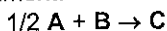
c) Write equations for the reactions:



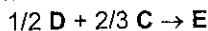
d) Calculate mass of the salt **A**.

**6.** Two 200-ml glasses were put on a table for demonstrations. One of them contained 100 ml of the solution **A** and another one contained 100 ml of the solution **B**. Some parts of the volumes (1, 1/2, 1/3 or 2/3) of these solutions were taken and mixed together to give new solutions in an order and manner described below. The volumes of the solutions **C**, **E** and **G** are equal to 150 ml and the volumes of the solutions **D**, **F** and **H** are equal to 100 ml.

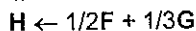
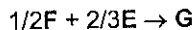
I experiment:



II experiment:



III experiment:



Solutions **A**, **B**, **D** and **F** are colourless; solutions **C**, **E**, **G** and **H** are coloured purple. One of the initial solutions (1,011 g/cm<sup>3</sup>) contains 3,24% of HCl, another initial solution (1,012 g/cm<sup>3</sup>) contains 4,15% of NaOH. One of the initial solutions contains indicator.

a) Which indicator was used in the experiments and to which solution was it added?

b) Write equation for the occurred reaction.

c) For the initial solutions calculate

i) the amount of an acid and ii) the amount of a base.

d) Calculate the amounts of an acid and a base in the solutions

i) **C**;    ii) **D**;    iii) **E**.

e) What compounds are dissolved in a solution **H**?

## Form X

- 1.** At a temperature 20°C the solubility of  $\text{CuSO}_4$  (160 g/mole) is equal to 17,2 g (in exactly 100 g of water).
- How many grams of  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  (250 g/mole) are needed to dissolve in exactly 100 g of water in order to obtain the saturated at 20°C solution of copper sulphate?
  - Calculate the percentage of the dissolved compound in this solution.
  - What is the mass of the obtained saturated solution?
  - What is the mass of the water-free salt found in this saturated solution?

**2.** Molecule of gas **X** is pentatomic. 67,2 ml of gas **X** were hydrolyzed in a water to give a solution of two acids **A** and **B** in a molar ratio 1:1. 60,0 ml of 0,100 M solution of  $\text{KOH}$  were spent for the neutralization of each acid **A** and **B**. The addition of the calcium chloride solution to acid **A** produces 408 mg of precipitate, the addition of calcium chloride solution to acid **B** gives 234 mg of precipitate. Oxidation states of the elements in acids **A** and **B** are the same as for the elements in gas **X**.

- Using given data find the formulae of the compounds **A**, **B** and **X**.
- Write equations for the reactions and give names to all the products:
  - $\text{X} \rightarrow \text{A} + \text{B}$ ;
  - $\text{A} + \text{KOH} \rightarrow$ ;
  - $\text{B} + \text{KOH} \rightarrow$ ;
  - $\text{A} + \text{CaCl}_2$ ;
  - $\text{B} + \text{CaCl}_2 \rightarrow$ .

**3.** Compounds **A**, **B**, **C**, **D** and **E** consist only of three elements. One of these compounds is a solid, three of them are poisonous, three of them are elements and four of them are gases. One litre of compound **A** can react with 3 litres of compound **B**. 8 grams of compound **A** can completely react with 3 grams of compound **C**. 1 mole of compound **C** can completely react with 1920 grams of compound **E**. 150 grams of compound **B** reacts with 2,5 moles of compound **E** to give 112 litres of compound **D**. It is known that compound **B** can be obtained in a reaction of the diluted solution of acid **F** with a red solid element **G**. Compound **D** can be obtained starting the same reagents with a help of the concentrated solution of acid **F**. Reaction of compound **G** with compound **A**, as well as with compound **E**, proceeds at a high temperatures and produces a black solid element **H** as the only product.

- Draw formulae and give the names for the compounds **A**, **B**, **C**, **D**, **E**, **F**, **G**, **H**. Show aggregate states for the compounds **A**, **B**, **C**, **D** and **E**. Which gases are poisonous?
- Draw equations for the reactions:
  - $\text{A} + \text{B} \rightarrow$ ;
  - $\text{A} + \text{C} \rightarrow$ ;
  - $\text{C} + \text{E} \rightarrow$ ;
  - $\text{B} + \text{E} \rightarrow$ ;
  - $\text{G} + \text{F}(\text{diluted}) \rightarrow$ ;
  - $\text{G} + \text{F}(\text{conc.}) \rightarrow$ ;
  - $\text{G} + \text{A} \rightarrow$ ;
  - $\text{G} + \text{E} \rightarrow$

**4.** Professor Snape gave to Harry Potter an assignment to prepare precisely a quarter of an ounce of a special powder **A**. Inhalation of little amounts of the vapours, that are formed at a heating of a powder **A**, makes you laugh, inhalation of large amounts of these vapours sets your mind at rest. For the preparation of this magic powder professor advised to Harry to took some crystals of urea, add some amount of a gastric juice to it and boil this mixture until the bubbling stops. To the obtained mixture he advised to add a solution of lunar caustic and after that to collect formed precipitate **B**. These last experiments should be performed in the moonlight. After the removal of precipitate the liquid phase should be evaporated and that obtained white solid is a desired product.

a) Help Harry to recall

i) structural formula of the urea ( $\text{CH}_4\text{N}_2\text{O}$ );

ii) what is the another name for the urea?

Hermione found that this powder contains by mass 35% of nitrogen, 60% of oxygen and also a hydrogen.

b) Help Harry to discover i) formula and ii) name of the powder **A**.

c) Help Harry to understand: what substances are contained in vapours, obtained at a heating of the powder **A**? (Tip: two binary compounds with the same numbers of atoms).

i) Draw formulae and

ii) Give the trivial names of these compounds.

d) Help Harry to write the equations of these reactions:

i) urea + gastric juice  $\rightarrow$ ;      ii)  $\dots \rightarrow \text{B} + \text{A}$ ;      iii)  $\text{A} \xrightarrow{?} \dots$

e) Help Harry to calculate how many ounces of urea should he take in order to obtain the desired amount of the powder **A**, if the reaction yield is equal to 40,0%?

1 ounce  $\approx$  28,5 grams.

f) Is it possible for Harry to use his usual tin pot for these experiments?

g) Why is it so important for the last reactions to proceed in the moonlight?

**5.** Element **A** belongs to the main sub-group of the Periodic Table of the Elements. The number of neutrons in its nucleus exceeds the number of protons by 11. Elementary substance **A** melts at a temperature of  $38^\circ\text{C}$  and the element itself and its compounds colour a flame red. In its compounds with oxygen (**B**, **C**, **D** and **E**) the average oxidation states of the oxygen are equal to -II, -I, -1/2 and -1/3 respectively. The element **A** can explode if it comes to contact with water. Element **A** reacts with compound **E** to give compound **D**; it reacts with compound **D** to give compound **C** and it also reacts with compound **C** to produce compound **B**. Contacts of the compounds **B**, **C**, **D** and **E** with the organic substances may lead to explosions, especially in a case of compounds **D** and **E**. In the reaction of compounds **D** and **E** with triatomic gas **F**, which

is contained in dry air, compound **G** and gas **I** are formed. The last reaction can be utilized for the regeneration of the exhaled air in closed rooms. Assume that the oxidation state of the element **A** in all the compounds is equal to 1.

- a) i) Identify the element **A** and  
 ii) Substantiate your answer with calculations.

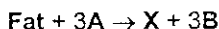
b) Write equations for the following reactions:



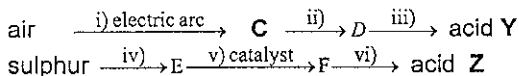
Give the names for the compounds **B**, **C**, **F**, **G** and **I**.

**6.** Swedish engineer Alfred Nobel patented in a year 1867 a method for the transformation of highly explosive nitroglycerine (NG) into more safe dynamite. For the production of nitroglycerine ( $C_3H_5O_9N_3$ ) it is necessary to take compound **X** and nitrating acid, that consists of acids **Y** and **Z**. Compound **X** can be obtained from fat, acid **Y** can be obtained starting from air and acid **Z** can be prepared starting from sulphur.

- a) Describe the idea of the Nobel's patent.  
 b) In the reaction of fat with compound **A** the compounds **X** and **B** are formed. The scheme of this reaction with coefficients is:



- i) Write the formulae and give the names for the compounds **A** and **X**.  
 ii) Give trade name for the compound **B**. To what class of compounds does it belong?  
 c) Write equations for the reactions of syntheses of the acids **Y** and **Z**, that are used in the nitrating mixture. Give the names for the compounds. Tip: compounds **C**, **D**, **E** and **F** are oxides.



- d) Write equation for the reaction of synthesis of nitroglycerine. Acid **Z** acts as a catalyst. Use simplified structural formulae for the compound **X** and NG.  
 e) Write equation for the explosion of NG (use brutto formula).  
 Tip: one product of this reaction is nitrogen; assume also, that carbon is oxidized to give monoxide.

## Form XI

**1.** Compounds X, Y, Z and Q are binary organic compounds. Atoms of the element A possess high electronegativity, atoms of element B possess low electronegativity. Some consecutive reactions between compounds X and A can proceed, compound C can be obtained at a first stage and compound D – at a last stage of the process. Vapour density of the compound D is equal to 9,6 compared to vapour density of the compound X. Salt E, that colours a flame yellow, can be formed at the reaction of the compound C with an element B. Second product of this reaction is compound Y. Compound Z can be obtained as a product of pyrolysis of the compound X, and also at a heating of the compound Y in the presence of Pt-catalyst. Ratio of molar masses of the compounds Z and Y is equal to 0,867. Reaction between molecules of the compound Z can give the compound Q (78 g/mole).

- a) Identify the compounds X, Y, Z, Q, A, B, C, D, E (formulae and names).  
b) Write equations for the reactions:  
i)  $X + A \rightarrow C$ ;                      ii)  $X + A \rightarrow D$ ;                      iii)  $C + B \rightarrow Y$ ;  
iv)  $X \xrightarrow{-?} Z$ ;                              v)  $Y \xrightarrow{Pt} Z$ ;                              vi)  $Z \rightarrow Q$ .  
c) Use these data i) 9,6; ii) 0,867; iii) 78 to control the appropriateness of your solution.

**2.** Combustion products of alkane X are 9,55 dm<sup>3</sup> of CO<sub>2</sub> and 8,95 g of water (18,0 g/mole). Alkane X was treated up with AlCl<sub>3</sub> and its isomers A, B, C and D were obtained. Every isomer was separately treated up with bromine in the presence of ultraviolet radiation for a short period of time. It was found that masses of isomers A and B increased equally by 5,59 times and masses of isomers C and D increased equally by 2,84 times. Isomers B and C are symmetrical, isomers A and D are asymmetrical. Assume that carbon atoms, that are least reactive, do not take part in the reaction at the given conditions.

- a) i) Calculate the ratio of the number of hydrogen atoms to the number of carbon atoms in this alkane X.  
ii) Find brutto formula of alkane X.  
b) Draw schematically graphical formulae of the isomers of alkane X.  
c) i) Write brutto formulae and draw structural formulae for the bromo-derivatives A\*, B\*, C\* and D\* of alkane X that were obtained at the described conditions. Give their names.  
ii) Check, whether the increase of mass for found bromo-derivatives is in agreement with a provided data.  
d) Write equation for the reaction of bromination of isomer A using brutto formulae.



**3.** Four metals **X**, **Y**, **Z** and **Q** of the Periodic Table of the Elements stay in the same period one after another. They determine an iridescent play of colours in many jewels. Formulae of the minerals are generally given by the formulae of the respective oxides.

Jewel	Percentage of components (%)				Typical colour	Additions that determine colour
	O	Si	Al	Be		
Ruby	47,1	–	52,9	–	Red	Y,Q
Sapphire	47,1	–	52,9	–	Blue	Q, Ti, Co
Alexandrite	50,4	–	42,5	7,1	changes colour from green in daylight to red in incandescent light	Y,Q
Emerald	53,6	31,4	10,0	5,0	Deep green	Y,X
Aquamarine	53,6	31,4	10,0	5,0	Pale blue	Q <sup>2+</sup> , Q <sup>3+</sup>
Chialtolite	49,4	17,3	33,3	–	Brown (opaque)	Z

- a) Calculate and find chemical formulae for
- ruby and sapphire;
  - alexandrite;
  - emerald and aquamarine;
  - chialtolite.
- b) i) Identify elements **X**, **Y**, **Z** and **Q**;  
 ii) Substantiate your choice.

**4.** Sodium hydroxide can be produced using the electrolysis of an aqueous solution of NaCl. The other obtained products of this process are hydrogen and chlorine, which is a starting material for the production of hydrochloric acid. Voltage in the electrolyzer is equal to 3,80 V and the electrolysis current yield is equal to 90,0%. The electricity rates for the factory are 80 cents/kWh.

- a) Write equations for the
- total reaction of electrolysis of the aqueous solution of NaCl,
  - anodic process,
  - cathodic process,
  - reaction of the formation of hydrogen chloride.
- b) Calculate charges for the electricity that was used for the production of one kilogram of i) NaOH and ii) 36,5% hydrochloric acid.
- c) How many kilograms of i) NaOH and of ii) 36,5% solution of hydrochloric acid can be produced using the electricity, for which 100 kroner were paid. 1 kWh  $\leftrightarrow$  kA·V·3600 s; 1 mole (e<sup>-</sup>)  $\leftrightarrow$  96500 A·s

**5.** The concentration of ammonium chloride in a solution **A** is the same as the concentration of sodium chloride in solution **X**. The concentration of silver-ions in solution **X** is equal to  $1,56 \cdot 10^{-9}$  mole/dm<sup>3</sup>. Concentration

of ammonium hydrate in the solution **B** is equal to  $0,125 \text{ mole/dm}^3$ . Buffer solution **Y** was prepared by mixing  $0,750 \text{ dm}^3$  of solution **A** with the same volume of solution **B**.  $1,50 \text{ dm}^3$  of  $0,125 \text{ M}$  solution of hydrochloric acid were added to the buffer solution **Y** and as a result solution **Z** was obtained.

- Calculate concentration of NaCl in the solution **X**.
- Calculate pH of the buffer solution **Y**.
- Calculate pH of the solution **Z**.

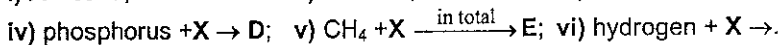
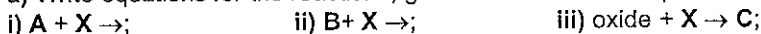
Assume that contraction of solutions does not occur.

$$K_{sp}(\text{AgCl}) = 1,56 \cdot 10^{-10} \text{ mole}^2/(\text{dm}^3)^2; K(\text{NH}_3 \cdot \text{H}_2\text{O}) = 1,79 \cdot 10^{-5} \text{ mole/dm}^3$$

$$\text{In a basic buffer solution } [\text{OH}^-] = K(\text{base}) \cdot \frac{c(\text{base})}{c(\text{salt})}$$

**6.** Non-metal **X** and sodium compounds **A** and **B** are used to produce a liquid element **Y** and a solid element **Z** respectively. Element **X** can react with an oxide of an element (lowest oxidation state), which is located near it in the Periodic Table of the Elements, to give compound **C**, which consists of three elements, and in which this neighbour element is oxidized to the maximum oxidation state. Phosphorus can be oxidized in the presence of an excess of element **X** to give compound **D** with a maximal oxidation state of phosphorus in it. Element **X** reacts with methane in a stepwise replacement reaction, which final product is compound **E**. Compound **E** is a liquid, which vaporizes at  $80^\circ\text{C}$  and it can be utilized for the extinguishing of the burning liquid fuel. If irradiated, mixture of the compound **X** and hydrogen may explode to form compound **F**. Compound **F** is formed also at the reaction of compound **X** with water or methane, and also at the hydrolysis of the compounds **C** and **D**. Hydrolysis of **C** and **D** also produces well-known oxygen-containing acids **G** and **H** respectively. Compound **X** reacts with almost all the metals forming binary compounds, which can produce compound **F** under the treatment of sulphuric acid. Compound **X** can react with a hot solution of KOH to give compound **I** (Berthollet' salt). Heating of the compound **I** in the presence of  $\text{MnO}_2$  produces an oxygen. Careful heating without catalyst leads to disproportionation, one of the products of which is salt **J** (salt of one of the strongest inorganic acid).

a) Write equations for the reactions, give names for the compounds:



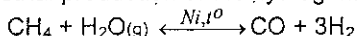
b) Write equations for the reactions of hydrolysis, give names for the compounds: i)  $\text{C} + \text{H}_2\text{O} \rightarrow$ ;    ii)  $\text{D} + \text{H}_2\text{O} \rightarrow$ .

c) Write equations for the redox reactions, give names for the compounds:



## Form XII

1. Reaction of the catalytic conversion of methane is the first stage of the industrial production of the hydrogen:



Standard values of the formation enthalpy and the entropy for the reagents are presented in the following table:

	CH <sub>4</sub>	H <sub>2</sub> O(g)	CO	H <sub>2</sub>
$\Delta H_f^\circ$ (kJ/mole)	-75,0	-242	-110	0
$S^\circ$ [J/ (mole·K)]	186	189	197	131

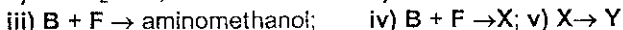
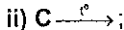
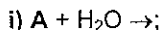
- a) Calculate the standard value of the enthalpy for this reaction  $\Delta H^\circ$ .
- b) i) Calculate the standard value of the free energy for this reaction  $\Delta G^\circ$ .  
ii) Is the forward reaction spontaneous?
- c) Calculate equilibrium constant  $K_f$  for this reaction (standard conditions).
- d) i) What would be the requirement for the equilibrium state?  
ii) At what temperature ( $^\circ\text{C}$ ) would be this requirement filled?

Assume that enthalpy  $\Delta H$  and entropy  $\Delta S$  of the reaction do not depend on temperature.

2. Trivial name for the compound **A** is oxamide. It consists of carbon, hydrogen, nitrogen and oxygen. Molecular weight of **A** is equal to 88. In its molecule the number of atoms of three elements is the same, the number of atoms of the fourth element is smaller by two then the sum of the rest three. Hydrolysis of compound **A** produces gas **B** with acrid smell, that changes colour of a wet litmus paper to blue. The second product of the hydrolysis is organic acid **C**, that gives at heating scentless gas **D** (1,52 times heavier then air) and organic acid **E** with a most smallest molecular weight. Acid **E** can be obtained by the oxidation of gas **F**, which can be readily dissolved in water and possesses a sharp smell. Both organic compounds **E** and **F** give the positive result at the silver mirror test. The reaction between gases **B** and **F** gives aminomethanol as an unstable intermediate. In the result of a total reaction compound **X** (urotropine,  $\text{C}_6\text{H}_{12}\text{N}_4$ ) and water are obtained. The reaction of compound **X** with nitric acid produces compound **Y** (hexogen,  $\text{C}_3\text{H}_6\text{N}_6\text{O}_6$ ) and compound **G**, which is a salt, that can be obtained as a product of the reaction between gas **B** and nitric acid. In the compound **Y** and salt **G** nitrogen possesses different oxidation states.

- a) i) Substantiate the brutto formula of the compound **A**.  
ii) Draw structural formula of the compound **A**.

b) Write equations for the reactions and give the names to all reagents and products. (Draw structural formulae for the organic compounds):



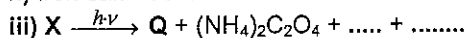
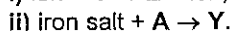
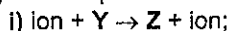
c) Write equation for the reaction of the explosion of hexogen (use brutto formulae), assuming that hexogen is the only source of an oxygen.

**3.** Blueprinting of the architectural drawings was invented by English astronomer Sir John Herschel in 1840. This method is based on the initiation of the intramolecular redox reaction of the light-sensitive iron salt **X** by quanta of light. The obtained cation reacts with a potassium salt **Y** to give insoluble blue compound **Z**. The paper is usually covered with the solutions of salts **X** and **Y** and dried after that. If the drawing is highlighted then white lines remain on a blue background on such paper. Unreacted salts are washed away. Salt **X** is an organic double salt of iron and ammonium, its molecule crystallizes with three molecules of water. After lightning a double salt **Q** is formed, which is of the same qualitative composition but crystallizes with two molecules of water. During the intramolecular redox reaction of salt **X** some oxalate-ions are decomposed with the formation of carbon dioxide. Salt **Y** can be obtained with a use of the reaction of iron with a concentrated solution of salt **A**. Salt **A** can be obtained using reaction of KOH with a very poisonous volatile weak monoprotic acid **B**. Density of the vapours of acid **B** is 13,5 times larger than that of hydrogen. Oxidation states of iron in salts **X** and **Y** are the same and their molecules contain one atom of an iron. The composition of the anions of salts **Y** and **Z** are identical, iron (56,0 g/mole) takes 26,4% from the mass of anion. The iron contents in the crystalline hydrates **X** and **Q** are 13,1% and 18,4% respectively and in salts **Y** and **Z** - 17,0% and 47,3% respectively.

a) Deduce and substantiate qualitative and quantitative compositions of the anions of salts **Y** and **Z** using the provided data.

b) Write formulae of crystalline hydrates **X** and **Q**, and also formulae of compounds **Y**, **Z**, **A** и **B**.

c) Write equations for the reactions:

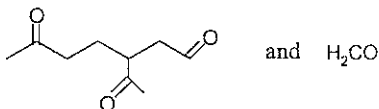


**4.** In a year 2001 the Nobel Prize in chemistry was presented to scientists who worked out the methods of the catalytic asymmetric synthesis. Different stereoisomers of the compound may possess very different properties. Asymmetric synthesis provides the possibility for the production of the effective medicines and biologically active compounds.

All the amino acids (except glycine) have R and S enantiomeric forms (stereoisomers). Let's take, for example, 2-aminopropanoic acid.

- a) Draw Fischer projections of R and S forms of amino acid alanine (2-aminopropanoic acid). Show seniority of the atoms in the S-isomer.

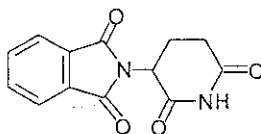
Good example for the demonstration of the differences of the properties is limonene ( $C_{10}H_{16}$ ). R-isomer smells like orange, but S-isomer smells like lemon. Molecule of limonene contains six-membered cycle



and the products of its ozonolysis shown nearby are obtained in ratio 1:1.

- b) Write equation for the reaction of ozonolysis of limonene using structural formulae. Draw R- and S-isomers of limonene and show the seniority of the atoms.

The most tragic example of the differences of properties of isomers is thalidomide. This compound appeared in 1961 and it was claimed that thalidomide is a very effective medicine against insomnia, depression and petulance. But after the numerous occurrences of teratogenesis (disturbance of an embryonic growth) the extensive tests revealed that all the positive properties were only due to the presence of R-isomer, at the same time S-isomer was proved to be a very strong teratogen.



Thalidomide

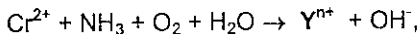
But after the numerous occurrences of teratogenesis (disturbance of an embryonic growth) the extensive tests revealed that all the positive properties were only due to the presence of R-isomer, at the same time S-isomer was proved to be a very strong teratogen.

- c) In the molecule of thalidomide designate the chiral carbon atom with asterisk (\*). Draw R- and S-isomers of thalidomide and for S-isomer show the seniority of the atoms.

**5.** Compound **A** ( $C_{14}H_{12}O_2$ ) can be obtained from benzaldehyde ( $C_6H_5CHO$ ) in the presence of a catalyst (KCN). Reduction of this compound with  $NaBH_4$  gives compound **B** ( $C_{14}H_{14}O_2$ ), whereas oxidation with  $CrO_3$  produces compound **C** ( $C_{14}H_{10}O_2$ ). Reduction of compound **C** using  $NaBH_4$  produces compound **B**. Oxidation of benzaldehyde with the use of  $Ag_2O$  gives compound **D**. Compound **B** reacts with an excess of compound **D** in the presence of concentrated sulphuric acid to give at first compound **E** ( $C_{21}H_{18}O_3$ ) and after that compound **F** ( $C_{28}H_{22}O_4$ ) is formed from **E**. In all the mentioned syntheses the reactions involve modifications of the side chains.

- a) Draw structural formulae of the compounds **A** – **F**.  
 b) Designate with asterisk (\*) chiral atoms in the compounds **A** and **B**.  
 c) Draw Fischer projections for all the stereoisomers of compound **F**.  
 Phenyl group can be written as Ph.

**6.** Rhodo chromium chloride (**X**) is a binuclear complex compound of chrome (III) in which two nuclei are connected by hydroxyl group. IUPAC nomenclature provides a name for the compound **X** as  $\mu$ -hydroxo-bis[pentaammine chrome(III)]. Synthesis of the compound **X** proceeds in the medium of the concentrated solution of  $\text{NH}_4\text{Cl}$  as follows:



where  $\text{Y}^{n+}$  designates the cation of rhodo chromium. During the synthesis rhodo chromium chloride precipitates out in a form of red fine-grained water-soluble crystals. If the compound **X** is boiled with hydrochloric acid then purpureo-chromium **Z** –  $[\text{CrCl}(\text{NH}_3)_5]\text{Cl}_2$  precipitates out.

- Draw structural formula for the cation  $\text{Y}^{n+}$ .
- Write the described reaction scheme in a form of equation showing the ionic form of the product. Cation should be written in a simplified structural form.
- Why is rhodo chromium chloride synthesized in a concentrated solution of  $\text{NH}_4\text{Cl}$ ?
- Write equation for the reaction of the synthesis of compound **Z** starting from compound **X**.
- Write a name for the compound **Z** using IUPAC nomenclature rules.
- Which volume of 0,1 M solution of  $\text{AgNO}_3$  should be spent for the titration of 10  $\text{cm}^3$  of 0,05 M solution of compound **Z**?

# Solutions

## Form IX

1. a)  $M(\text{CuSO}_4 \cdot 5\text{H}_2\text{O}) = 250 \text{ g/mole}$   
 $m(\text{CuSO}_4) = 5,0 \text{ kg} \cdot 0,040 = 0,20 \text{ kg}$   
 $m(\text{CuSO}_4 \cdot 5\text{H}_2\text{O}) = 0,20 \text{ kg} (\text{CuSO}_4) \cdot \frac{250 (\text{CuSO}_4 \cdot 5\text{H}_2\text{O})}{160 (\text{CuSO}_4)} = 0,312 \text{ kg} \approx$   
0,31 kg

$m(\text{H}_2\text{O}) = 5,0 \text{ kg} - 0,31 \text{ kg} = 4,69 \text{ kg} \approx 4,7 \text{ kg}$

b)  $M(\text{FeSO}_4 \cdot 7\text{H}_2\text{O}) = 278 \text{ g/mole}$

Let  $m(\text{FeSO}_4 \cdot 7\text{H}_2\text{O}) = x$

$$0,050 = \frac{9,0 \text{ kg} \cdot 0,030 + x \cdot \frac{152}{278}}{9,00 \text{ kg} + x}$$

$0,45 \text{ kg} + 0,05 x = 0,27 \text{ kg} + x \cdot 0,547$

$0,18 \text{ kg} = 0,497x$

$x = 0,362 \text{ kg} \approx 0,36 \text{ kg}$

$m(\text{FeSO}_4 \cdot 7\text{H}_2\text{O}) = 0,36 \text{ kg.}$

2. a) i) X – Al, aluminium.

ii) Aluminium surface is covered with a firm layer of oxide  $\text{Al}_2\text{O}_3$ .

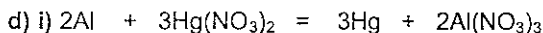
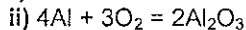
b) i) Y – Hg, mercury.

ii)  $\text{Al}_2\text{O}_3$  protective layer is removed.

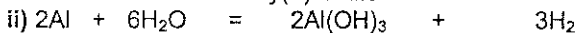
iii) Aluminium amalgam is formed on a surface of a teaspoon.

iv) Drops C consist of metallic mercury.

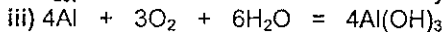
c) i) Aluminium becomes covered with a firm protective layer of  $\text{Al}_2\text{O}_3$ .



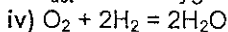
X                      A – mercury(II)nitrate



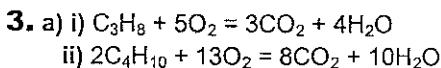
$X_{\text{act}}$     D – water    B – aluminium hydroxide    F – hydrogen



$X_{\text{act}}$     E – oxygen    D                      B



E    F              D



b) i)  $n(C_3H_8) = 21,0 \cdot 10^3 \text{ g} \cdot \frac{1 \text{ mole}}{44,1 \text{ g}} = 4,76 \cdot 10^2 \text{ mole}$

$\Delta H(C_3H_8) = 4,76 \cdot 10^2 \text{ mole} \cdot (-2221 \text{ kJ/mole}) = -1,06 \cdot 10^6 \text{ kJ} = -1,06 \cdot 10^3 \text{ MJ} =$   
 $= -1,06 \text{ GJ}$

ii)  $n(C_4H_{10}) = 21,0 \cdot 10^3 \text{ g} \cdot \frac{1 \text{ mole}}{58,1 \text{ g}} = 3,61 \cdot 10^2 \text{ mole}$

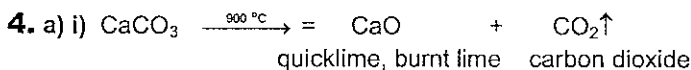
$\Delta H(C_4H_{10}) = 3,61 \cdot 10^2 \text{ mole} \cdot (-2,889 \cdot 10^3 \text{ kJ/mole}) = -1,04 \cdot 10^6 \text{ kJ} =$   
 $= -1,04 \cdot 10^3 \text{ MJ} = -1,04 \text{ GJ}$

c) Amount of energy that is produced for the same money in this case is in inverse relationship with a cost of the unit of energy.

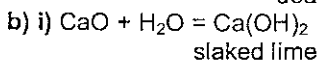
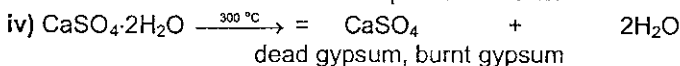
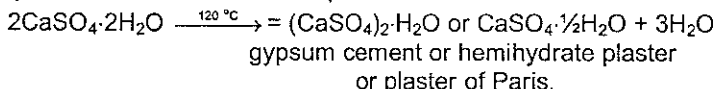
i) Combustion of propane produces the same amount of energy for the less money. Propane is less expensive.

ii) Combustion of one balloon of any gas produces in average 1,05 GJ of energy (from the point of view of consumer mark is +).

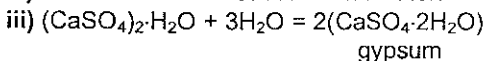
$\text{Cost} = \frac{250 \text{ kronas}}{1,05 \text{ GJ}} = 238 \text{ kronas/GJ}$



ii) Limestone does not decompose at 300°C.

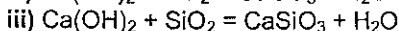
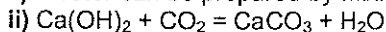


ii) Limestone does not react with water.

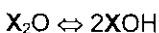


iv) Dead gypsum does not react with water.

c) i) Plaster can be prepared by mixing sand, slaked lime and water.



5. a) Formula of the alkaline metal oxide D is  $X_2O$ .





$$n(\text{XOH}) = \frac{2}{1} \cdot 0,100 \text{ mole} = 0,200 \text{ mole}$$

$$M(\text{XOH}) = \frac{8,00 \text{ g}}{0,200 \text{ mole}} = 40,0 \text{ g/mole}$$

$$M_r(\text{X}) = 40,0 - 16,0 - 1,0 = 23$$

X – Na, sodium

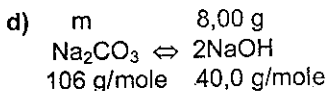
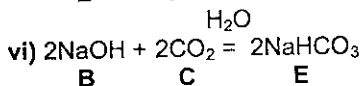
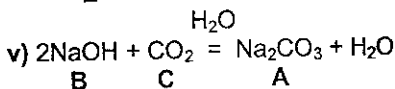
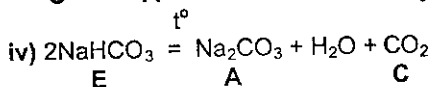
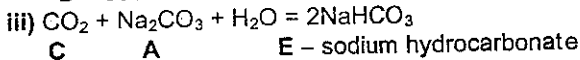
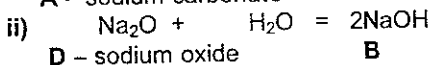
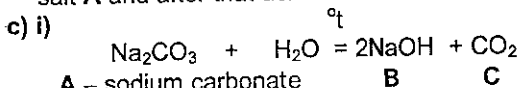
B – NaOH, sodium hydroxide

b) Gas C can be CO<sub>2</sub> because it is triatomic odourless and colourless.

CO<sub>2</sub> reacts with a normal salt of carboxylic acid A to give acid salt E. Acid salt E is decomposed at a temperature lower than

water boiling temperature to give normal salt A. CO<sub>2</sub> (C) passes through the aqueous solution of NaOH (B) to give at first normal

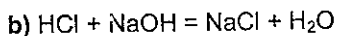
salt A and after that acid salt E.



$$m(\text{Na}_2\text{CO}_3) = \frac{1}{2} \cdot 8,00 \text{ g} \cdot 1 \text{ mole} / 40,0 \text{ g} \cdot 106 \text{ g/mole} = 10,6 \text{ g}$$

6. a) i) Phenolphthalein was used as an indicator.

ii) Indicator was added to the solution of acid A.



c) i) 
$$n(\text{HCl, in solution A}) = 100 \text{ cm}^3 \cdot 1,011 \text{ g/cm}^3 \cdot 0,0325 \cdot \frac{1 \text{ mole}}{36,5 \text{ g}} =$$
  

$$= 0,0900 \text{ mole}$$

$$\text{ii) } n(\text{NaOH, in solution B}) = 100 \text{ cm}^3 \cdot 1,012 \text{ g/cm}^3 \cdot 0,0415 \cdot \frac{1 \text{ mole}}{40,0 \text{ g}} =$$

$$= \mathbf{0,105 \text{ mole}}$$

d) i) In solution C:

$$n(\text{HCl}) = \mathbf{0}$$

$$n(\text{NaOH}) = 0,105 \text{ mole} - \frac{1}{2} \cdot 0,0900 \text{ mole} = \mathbf{0,060 \text{ mole}}$$

ii) In solution D:

$$n(\text{HCl}) = \frac{1}{2} \cdot 0,0900 \text{ mole} - \frac{1}{3} \cdot 0,060 \text{ mole} = \mathbf{0,025 \text{ mole}}$$

$$n(\text{NaOH}) = \mathbf{0}$$

iii) In solution E:

$$n(\text{HCl}) = \mathbf{0}$$

$$n(\text{NaOH}) = \frac{2}{3} \cdot 0,060 \text{ mole} - \frac{1}{2} \cdot 0,025 \text{ mole} = 0,0275 \text{ mole} \approx$$

$$\approx \mathbf{0,028 \text{ mole}}$$

e) Solution H can not contain acid, because the solution is coloured. It means that this solution must contain base and formed sodium chloride, of course.

## Form X

1. a)  $m(\text{CuSO}_4 \cdot 5\text{H}_2\text{O}) = x$

In a saturated solution:  $m(\text{CuSO}_4) = x \cdot \frac{160}{250} = 0,640x$

$$m(\text{H}_2\text{O}) = 100 \text{ g} + x \cdot \frac{5 \cdot 18}{250} = 100 \text{ g} + 0,360x$$

$$L(\text{CuSO}_4) = 17,2 \text{ g}$$

$$L(\text{CuSO}_4) = \frac{0,640x}{100 \text{ g} + 0,360x} \cdot 100 \text{ g}$$

Solubility means mass of the dissolved substance in exactly 100 g of water.

$$\frac{0,640x}{100 \text{ g} + 0,360x} = 0,172$$

$$17,2 \text{ g} = 0,578x$$

For the saturated solution it is required

$$m(\text{CuSO}_4 \cdot 5\text{H}_2\text{O}) = x = 29,76 \text{ g} \approx \mathbf{29,8 \text{ g}}$$

b) Percentage can be calculated using the solubility data.

$$\%(\text{CuSO}_4) = \frac{17,2}{100 + 17,2} \cdot 100 = 14,67 \approx 14,7$$

c)  $m(\text{saturated solution}) = 100 \text{ g} + 29,8 \text{ g} = 129,8 \text{ g}$

d)  $m(\text{CuSO}_4) = 129,8 \cdot 0,147 = 19,08 \approx 19,1 \text{ g}$

$m(\text{CuSO}_4) = 29,8 \text{ g} \cdot 0,64 = 19,07 \approx 19,1 \text{ g}$

2. a)  $n(\text{X}) = 67,2 \cdot 10^{-3} \text{ dm}^3 \cdot \frac{1 \text{ mole}}{22,4 \text{ dm}^3} = 3,00 \cdot 10^{-3} \text{ mole}$

$n(\text{KOH}) = 60,0 \cdot 10^{-3} \text{ dm}^3 \cdot 0,100 \text{ mol/dm}^3 = 6,00 \cdot 10^{-3} \text{ mole}$

Both acids are diprotic.

$M(\text{calcium salt of acid A}) = 408 \cdot 10^{-3} \text{ g} \cdot \frac{1}{3,00 \cdot 10^{-3} \text{ mole}} = 136 \text{ g/mole}$

$M(\text{anion A}) = 136 \text{ g/mole} - 40 \text{ g/mole} = 96 \text{ g/mole}$

anion A =  $\text{SO}_4^{2-}$

acid A –  $\text{H}_2\text{SO}_4$

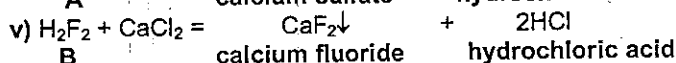
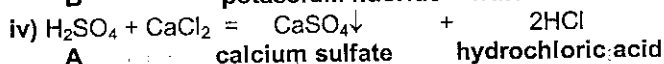
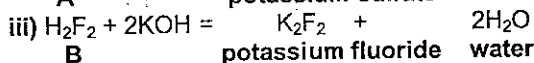
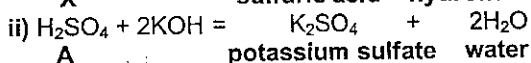
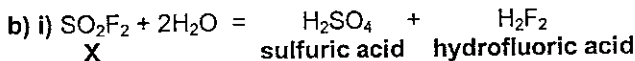
$M(\text{calcium salt of acid B}) = 234 \cdot 10^{-3} \text{ g} \cdot \frac{1}{3,00 \cdot 10^{-3} \text{ mole}} = 78 \text{ g/mole}$

$M(\text{anion B}) = 78 \text{ g/mole} - 40 \text{ g/mole} = 38 \text{ g/mole}$

anion B =  $\text{F}_2^{2-}$

acid B –  $\text{H}_2\text{F}_2$

Compound X –  $\text{SO}_2\text{F}_2$ , because gas X was pentatomic and the oxidation states of the elements remained unchanged.



3. a) A –  $\text{O}_3$ , ozone, gas, elementary substance, poisonous

B –  $\text{NO}$ , nitrogen monoxide, gas, poisonous

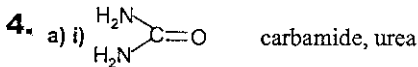
C –  $\text{C}_{60}$ , fullerene, solid, elementary substance

D –  $\text{NO}_2$ , nitrogen dioxide, gas, poisonous

E –  $\text{O}_2$ , oxygen, gas, elementary substance

- F – HNO<sub>3</sub>, nitric acid  
 G – Cu, copper  
 H – CuO, copper(II) oxide

- b) i)  $O_3 + 3NO = 3NO_2$   
           A     B         D  
 ii)  $C_{60} + 40O_3 = 60CO_2$   
       C     A  
 iii)  $C_{60} + 60O_2 = 60CO_2$   
       C     E  
 iv)  $2NO + O_2 = 2NO_2$   
       B     E     D  
 v)  $3Cu + 8HNO_3(\text{diluted}) = 3Cu(NO_3)_2 + 2NO + 4H_2O$   
       G         F                                         B  
 vi)  $Cu + 4HNO_3(\text{concentrated}) = Cu(NO_3)_2 + 2NO_2 + 2H_2O$   
       G         F                                         D  
 vii)  $3Cu + O_3 = 3CuO$   
       G     A     H  
 viii)  $2Cu + O_2 = 2CuO$   
       G     E     H

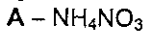


b) i)  $n(N) = 35 \text{ g} \cdot \frac{1 \text{ mol}}{14 \text{ g}} = 2,5 \text{ mole}$

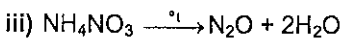
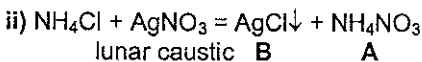
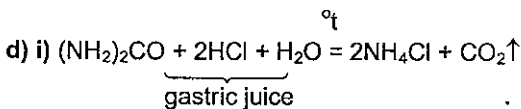
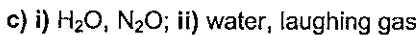
$n(O) = 60 \text{ g} \cdot \frac{1 \text{ mol}}{16 \text{ g}} = 3,75 \text{ mole}$

$n(H) = 5 \text{ g} \cdot \frac{1 \text{ mol}}{1 \text{ g}} = 5 \text{ mole}$

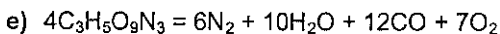
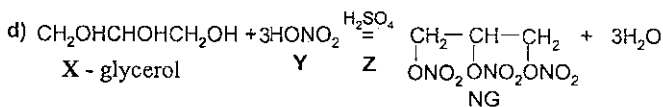
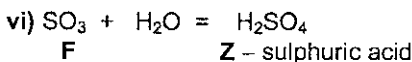
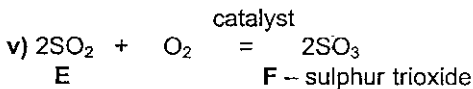
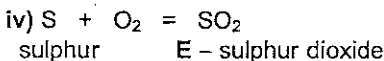
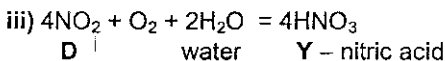
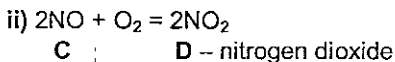
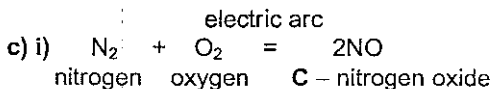
The smallest integers can be obtained if we divide amount of moles by 1,25. The simplest brutto formula is therefore N<sub>2</sub>H<sub>4</sub>O<sub>3</sub>.



ii) ammonium nitrate

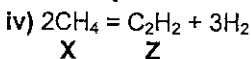
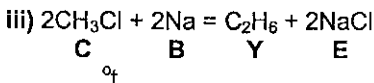
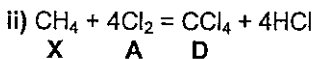
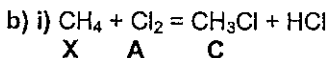




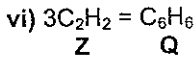
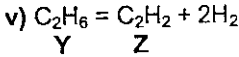


## Form XI

1. a) X – CH<sub>4</sub>, methane                      B – Na, sodium  
 Y – C<sub>2</sub>H<sub>6</sub>, ethane                        C – CH<sub>3</sub>Cl, chloromethane or methyl chloride  
 Z – C<sub>2</sub>H<sub>2</sub>, ethyne, acetylene            D – CCl<sub>4</sub>, tetrachloromethane  
 Q – C<sub>6</sub>H<sub>6</sub>, benzene                        E – NaCl, sodium chloride  
 A – Cl<sub>2</sub>, chlorine



<sup>o</sup>t,Pt



c) i)  $M_r(CCl_4) = 154$

$M_r(CH_4) = 16$

$D(CCl_4)_{CH_4} = \frac{154}{16} = 9,6$

ii)  $M_r(C_2H_2) = 26$

$M_r(C_2H_6) = 30$

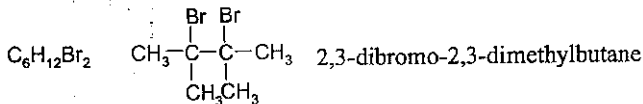
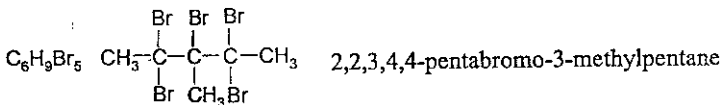
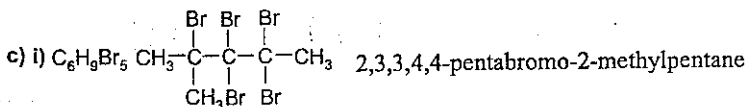
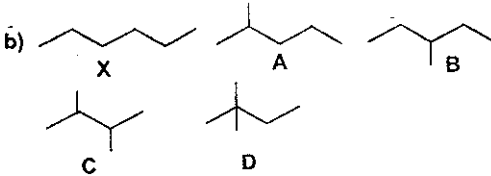
$D(C_2H_6)_{C_2H_2} = \frac{26}{30} = 0,867$

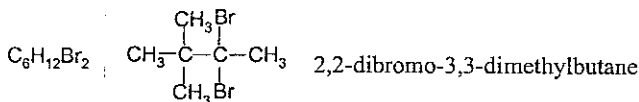
iii)  $M(C_6H_6) = 78 \text{ g/mole}$

2. a) i)  $\frac{n(H)}{n(C)} = \frac{2 \cdot 8,95 \text{ g}}{18,0 \text{ g/mole}} \cdot \frac{22,4 \text{ dm}^3 / \text{mole}}{9,55 \text{ dm}^3} = 2,333 \approx 2,33$

ii)  $2,333n = 2n + 2$

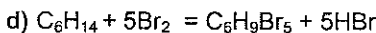
$n = \frac{2}{0,333} = 6,006 \approx 6$





$$ii) \frac{M(C_6H_9Br_5)}{M(C_6H_{14})} = \frac{81 + 5 \cdot 80}{86} = 5,59$$

$$\frac{M(C_6H_{12}Br_2)}{M(C_6H_{14})} = \frac{84 + 2 \cdot 80}{86} = 2,84$$



$$3. a) i) N(O) = \frac{47,1}{16} = 2,94 \quad N(Al) = \frac{52,9}{27,0} = 1,96$$

$$\text{If } N(Al) = 1, \quad \text{then} \quad N(O) = \frac{2,94}{1,96} = 1,5$$



$$ii) N(O) = \frac{50,4}{16} = 3,15 \quad N(Al) = \frac{42,5}{27} = 1,57$$

$$N(Be) = \frac{7,1}{9,01} = 0,788$$

$$\text{If } N(Be) = 1, \text{ then } N(Al) = \frac{157}{0,788} \approx 2 \quad \text{and} \quad N(O) = \frac{3,15}{0,788} = 4$$



$$iii) N(O) = \frac{53,6}{16} = 3,35 \quad N(Si) = \frac{314}{28} = 1,12$$

$$N(Al) = \frac{10}{27} = 0,37 \quad N(Be) = \frac{5,0}{9,01} = 0,555$$

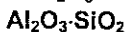
$$\text{If } N(Al) = 1, \quad \text{then} \quad N(O) = \frac{3,35}{0,37} \approx 9,$$

$$N(Si) = \frac{112}{0,37} \approx 3 \quad N(Be) = \frac{0,555}{0,37} \approx 1,5$$



$$iv) N(O) = \frac{49,4}{16} = 3,09 \quad N(Si) = \frac{17,3}{28} = 0,618 \quad N(Al) = \frac{33,3}{27} = 1,23$$

$$\text{If } N(Si) = 1, \text{ then } N(Al) = \frac{123}{0,618} \approx 2 \quad \text{and} \quad N(O) = \frac{3,09}{0,618} = 5$$

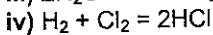
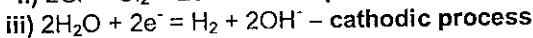
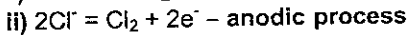
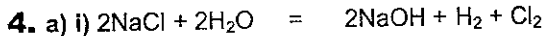




--b) i) X – V, vanadium                      Z – Mn, manganese  
           Y – Cr, chrome                        Q – Fe, iron

ii) Neither Ti nor Co can be the desired metals. Between them there are four metals that meet the conditions, because iron ions can be bivalent and trivalent. It is known that compounds of manganese are brown-coloured and compounds of chrome are green-coloured.

electrolysis



b) i) 1000 g             $I \cdot t = 0,9$   
           1NaOH =  $1\text{e}^-$   
       40,0 g/mole    96500 A·s/mole

$$I \cdot t = \frac{1}{1} \cdot 1000 \frac{\text{g}}{\text{kg}} \cdot \frac{1 \text{ mole}}{40,0 \text{ g}} \cdot 96500 \frac{\text{A} \cdot \text{s}}{\text{mole}} \cdot \frac{1}{0,9} \cdot \frac{1 \text{ kA}}{1000 \text{ A}} \cdot \frac{1 \text{ h}}{3600 \text{ s}} = 0,745 \frac{\text{kA} \cdot \text{h}}{\text{kg}}$$

$$E = 0,745 \frac{\text{kA} \cdot \text{h}}{\text{kg}} \cdot 3,80 \text{ V} \cdot \frac{1 \text{ kW}}{\text{kA} \cdot \text{V}} = 2,829 \text{ kWh/kg}$$

$$\text{Cost}(\text{NaOH}) = 2,829 \frac{\text{kWh}}{\text{kg}} \cdot 80 \frac{\text{cents}}{\text{kWh}} = 226,4 \text{ cents/kg} \approx 226 \text{ cents/kg}$$

ii) 40,0 g NaOH  $\Leftrightarrow$  100 g 36,5% hydrochloric acid

$$\text{Cost}(36,5\% \text{ HCl}) = 226,4 \text{ cents} \cdot \frac{1}{\text{kg}(\text{NaOH})} \cdot \frac{0,04 \text{ kg}(\text{NaOH})}{0,1 \text{ kg}(36,5\% \text{ hydrochloric acid})} = 90,56 \text{ cents/kg} \approx 90,6 \text{ cents/kg}$$

c) i)  $m(\text{NaOH}) = 100 \text{ kroner} \cdot \frac{1 \text{ kg}}{2,264 \text{ kroner}} = 44,2 \text{ kg}$

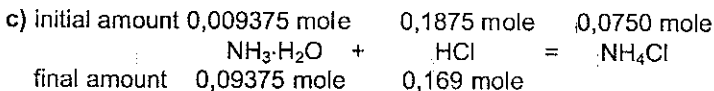
ii)  $m(36,5\% \text{ HCl}) = 100 \text{ kroner} \cdot \frac{1 \text{ kg}}{0,9056 \text{ krone}} = 110 \text{ kg}$

5. a)  $c(\text{NaCl}) = c(\text{Cl}^-) = \frac{1,56 \cdot 10^{-10} \text{ mole}^2 / (\text{dm}^3)^2}{1,56 \cdot 10^{-9} \text{ mole} / \text{dm}^3} = 1,00 \cdot 10^{-1} \text{ mole} / \text{dm}^3$

b)  $[\text{OH}^-] = 1,79 \cdot 10^{-5} \text{ mole} / \text{dm}^3 \cdot \frac{125 \cdot 10^{-1}}{100 \cdot 10^{-1}} = 2,238 \cdot 10^{-5}$

$\text{pOH} = -\lg 2,238 \cdot 10^{-5} = 4,65$

$\text{pH} = 14 - 4,65 = 9,35$

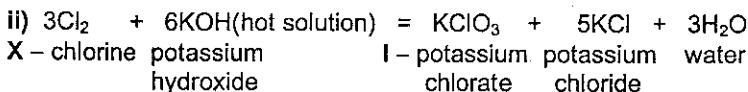
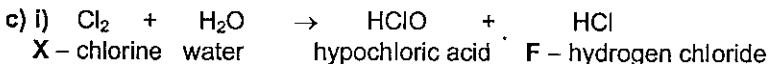
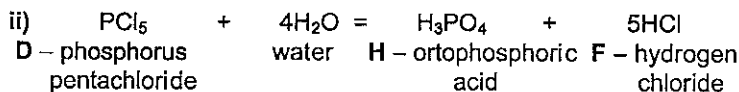
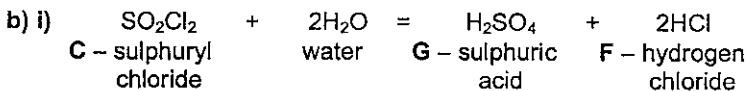
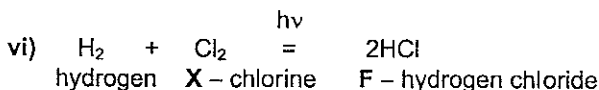
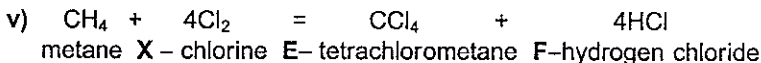
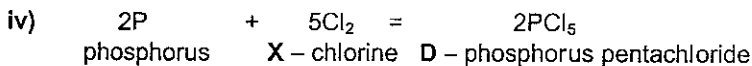
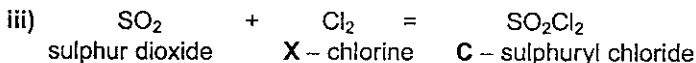
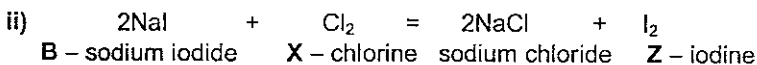
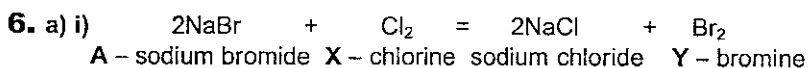


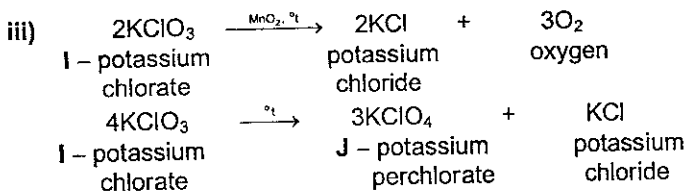
initial amount:  $n(\text{NH}_3 \cdot \text{H}_2\text{O}) = 0,750 \text{ dm}^3 \cdot 0,125 \text{ mole/dm}^3 = 0,09375 \text{ mole}$   
 $n(\text{HCl}) = 1,50 \text{ dm}^3 \cdot 0,125 \text{ mole/dm}^3 = 0,1875 \text{ mole}$

final amount :  $n(\text{HCl}) = 0,1875 \text{ mole} - 0,09375 \text{ mole} = 0,09375 \text{ mole}$   
 Volume of solution Z is  $1,50 \text{ dm}^3 + 1,50 \text{ dm}^3 = 3,00 \text{ dm}^3$  and this solution contains 0,09375 mole of strong acid, which does not form a buffer system with a salt of a weak base.

$$[\text{H}^+] = \frac{0,09375 \text{ mole}}{3,00 \text{ dm}^3} = 3,125 \cdot 10^{-2} \text{ mole/dm}^3$$

$$\text{pH} = -\lg 3,125 \cdot 10^{-2} \text{ mole/dm}^3 = 1,51$$





## Form XII

1. a)  $\Delta H^\circ = \Sigma \Delta H_f^\circ(\text{products}) - \Sigma \Delta H_f^\circ(\text{reagents})$   
 $\Delta H^\circ = 1 \text{ mole} \cdot (-110 \text{ kJ/mole}) - 1 \text{ mole} \cdot (-242 \text{ kJ/mole}) - 1 \text{ mole} \cdot (-75 \text{ kJ/mole}) =$   
 $= 207 \text{ kJ}$

b) i)  $\Delta G^\circ = \Delta H^\circ - T \cdot \Delta S^\circ$   
 $\Delta S^\circ = \Sigma S^\circ(\text{products}) - \Sigma S^\circ(\text{reagents})$   
 $\Delta S^\circ = 3 \text{ mole} \cdot 131 \text{ J/(mole}\cdot\text{K)} + 1 \text{ mole} \cdot 197 \text{ J/(mole}\cdot\text{K)} -$   
 $- 1 \text{ mole} \cdot 189 \text{ J/(mole}\cdot\text{K)} - 1 \text{ mole} \cdot 186 \text{ J/(mole}\cdot\text{K)} = 215 \text{ J/K} =$   
 $= 0,215 \text{ kJ/K}$

$\Delta G^\circ = 207 \text{ kJ} - 298 \text{ K} \cdot 0,215 \text{ kJ/K} = 207 \text{ kJ} - 64 \text{ kJ} = 143 \text{ kJ}$

ii) Forward reaction is impossible to proceed spontaneously.

c)  $K_t = e^{-\frac{\Delta G}{RT}}$   
 $K_t = e^{-\frac{143000}{8,314 \cdot 298}} = e^{-57,7} = 8,73 \cdot 10^{-26}$

d) i) Requirement for the equilibrium:  $\Delta G = 0$

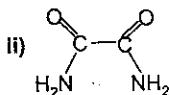
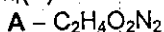
ii)  $0 = \Delta H - T \cdot \Delta S$

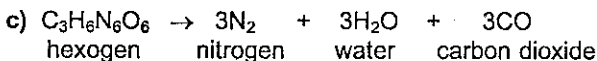
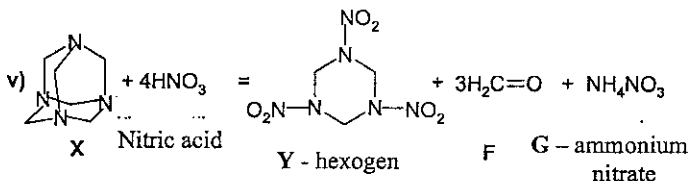
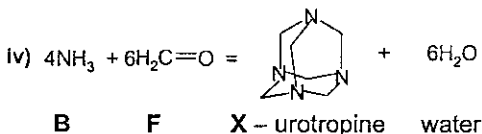
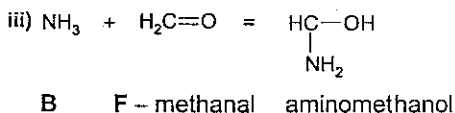
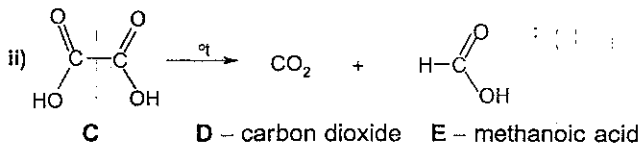
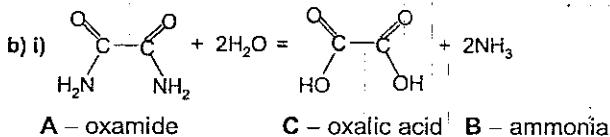
$T = 207 \text{ kJ} \cdot \frac{\text{K}}{0,215 \text{ kJ}} = 963 \text{ K}$

$^\circ\text{t} = T - 273 = 963 - 273 = 690 \text{ }^\circ\text{C}$

2. a) i) Number of atoms of the elements can not be equal to one, because in this case numbers of all elements would be the same ( $3 \cdot 1 - 2 = 1$ ). If the numbers of atoms of carbon, oxygen and nitrogen are equal to two, then the number of hydrogen atoms would be equal to four ( $3 \cdot 2 - 2 = 4$ ).

$M_r(\text{A}) = 2 \cdot 12 + 4 \cdot 1 + 2 \cdot 16 + 2 \cdot 14 = 88$





3. a) Salts Y and Z contain complex anion(s), in which Fe<sup>3+</sup> is a central atom.

Ligands are the anion(s), which molar mass is equal to  
2,0 g/mole · 13,5 - 1,0 g/mole = 26 g/mole

$$n(\text{ligands}) = 56,0 \text{ g} \cdot \frac{0,736}{0,264} \cdot \frac{1 \text{ mole}}{26 \text{ g}} = 6 \text{ mole}$$

Poisonous volatile monoprotic weak acid is HCN (27 g/mole)

Complex anion is [Fe(CN)<sub>6</sub>]<sup>3-</sup>

b) X – (NH<sub>4</sub>)<sub>3</sub>Fe(C<sub>2</sub>O<sub>4</sub>)<sub>3</sub>·3H<sub>2</sub>O

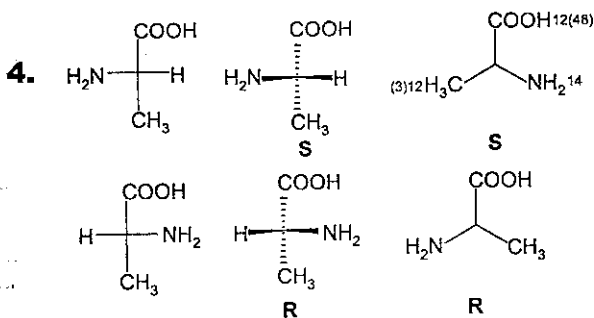
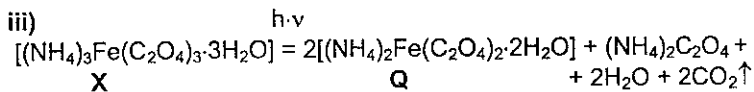
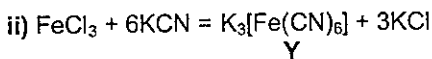
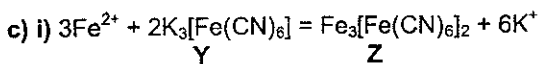
Z – Fe<sub>3</sub>[Fe(CN)<sub>6</sub>]<sub>2</sub>

Q – (NH<sub>4</sub>)<sub>2</sub>Fe(C<sub>2</sub>O<sub>4</sub>)<sub>2</sub>·2H<sub>2</sub>O

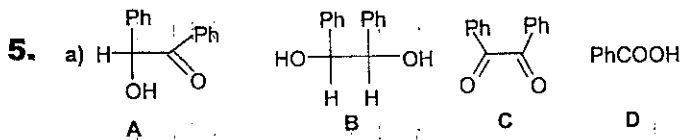
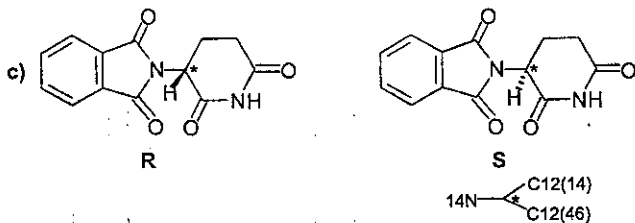
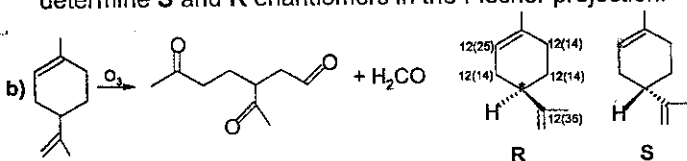
A – KCN

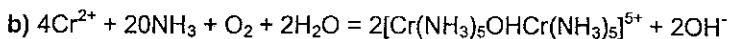
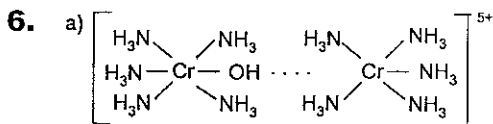
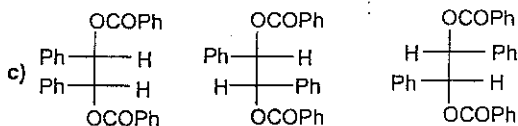
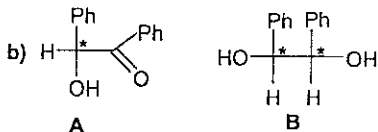
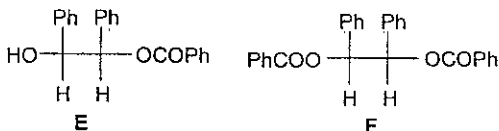
Y – K<sub>3</sub>[Fe(CN)<sub>6</sub>]

B – HCN

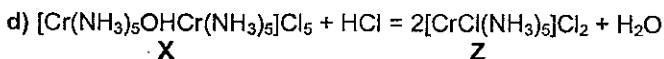


If it is not marked which groups are projecting behind the plane and which are projecting out of the plane, then it is impossible to determine **S** and **R** enantiomers in the Fischer projection.

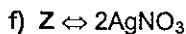




c) Large excess of chloride ions causes the formation of chloride instead of hydroxide.



e) Pentaamminechlorochrome(2+) chloride.



$$V(\text{AgNO}_3) = \frac{2 \cdot 10 \text{ cm}^3 \cdot 0,05 \text{ mole/dm}^3}{0,1 \text{ mole/dm}^3} = 10 \text{ cm}^3$$

Complex cation does not dissociate.