

15th



International Chemistry Olympiad

**7 theoretical problems
3 practical problems**

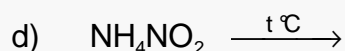
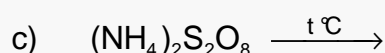
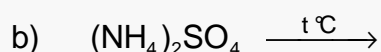
THE FIFTEENTH INTERNATIONAL CHEMISTRY OLYMPIAD

**TIMISOARA 1983
ROMANIA**

THEORETICAL PROBLEMS

PROBLEM 1

A) Describe the thermal decomposition of the following ammonium salts in terms of chemical equations:



B) Indicate the right answer:

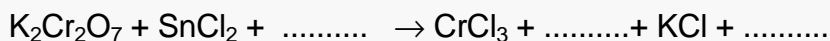
a) Can the molar mass be determined by measuring the density of a gaseous compound at a given temperature and pressure?

1. Yes, under any conditions.
2. Yes, if the gaseous compound does not dissociate and associate.
3. Yes, if the gaseous compound does not dissociate.
4. Yes, if the gaseous compound does not associate.

b) Is a liquid boiling at a constant temperature (at a given pressure) a pure substance?

1. Yes, if the liquid is not azeotropic.
2. Yes, if the liquid is azeotropic.

C) Complete and balance the following equation: (in H_2O)



- D) The solubility of Hg_2Cl_2 in water is 3.0×10^{-5} g/100 ml solution.
- What is the solubility product?
 - What is the solubility (in mol dm^{-3}) of this substance in a 0.01 M NaCl solution?
 - What is the volume of a 0.01 M NaCl solution which dissolves the same quantity of mercurous chloride as that dissolved in one litre of pure water?
- $A_r(\text{Hg}) = 200.61$ $A_r(\text{Cl}) = 35.45$
- E) Which of the following groups contains solid compounds at 10 °C?
- H_2O , NH_3 , CH_4
 - F_2 , Cl_2 , Br_2
 - SO_3 , I_2 , NaCl
 - Si, S_8 , Hg
- F) Which of the following salts forms an acidic aqueous solution?
- CH_3COONa
 - NH_4Cl
 - Na_2HPO_4
 - Na_2CO_3
 - NaHCO_3
- G) Write the electronic formulas for the following compounds so that the nature of the chemical bonds is evident:
- a) NaClO_3 , b) HClO_3 , c) SiF_4 , d) NH_3 , e) CaF_2 , f) H_2O
- H) Solid perchloric acid is usually written as $\text{HClO}_4 \cdot \text{H}_2\text{O}$. Based on experimental data showing four equal bonds, suggest a structure accounting for the experimental result.
- I) The compounds of the second row elements with hydrogen are as follows: LiH, BeH_2 , B_2H_6 , CH_4 , NH_3 , H_2O , HF.
- Which compounds are solid at room temperature? Explain.
 - Which of them are ionic?

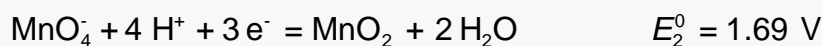
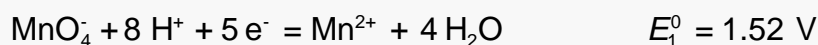
- c) Which are polymeric?
 d) Which ones do not react with water under normal conditions?
 e) Give products of the following reactions.

$$\text{BeH}_2 + \text{H}_2\text{O} \rightarrow$$

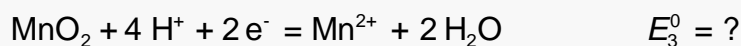
$$\text{B}_2\text{H}_6 + \text{H}_2\text{O} \rightarrow$$

$$\text{B}_2\text{H}_6 + \text{LiH}$$
 f) Supposing that NH_3 , H_2O and HF are acids under some conditions, write their corresponding conjugated bases and arrange them in order of increasing basic strength.

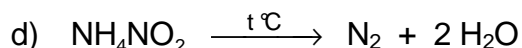
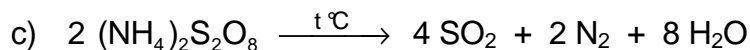
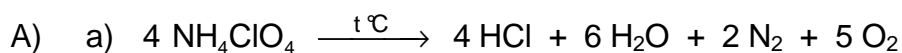
J) The following E^0 values are given for the half-reactions:



Calculate E^0 for the following reaction:

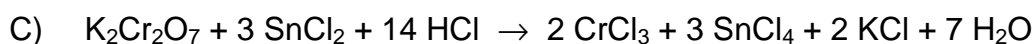


SOLUTION



B) a) 1, 2, 3, 4

b) 1, 2



D) a) $s = 3.0 \times 10^{-5} \text{ g}/100 \text{ cm}^3 = 3.0 \times 10^{-4} \text{ g dm}^{-3} =$
 $= \frac{3.0 \times 10^{-4} \text{ g dm}^{-3}}{472 \text{ g mol}^{-1}} = 6.3 \times 10^{-7} \text{ mol dm}^{-3}$



$$K_s = 4 s^3 = 4 (6.3 \times 10^{-7})^3 = 1.0 \times 10^{-18}$$

b) $c(\text{Cl}^-) = 0.01 \text{ mol dm}^{-3}$

$$s = \frac{K_s}{[\text{Cl}^-]^2} = \frac{1.0 \times 10^{-18}}{(0.01)^2} = 1.0 \times 10^{-14}$$

$$s = 1.0 \times 10^{-14} \text{ mol dm}^{-3}$$

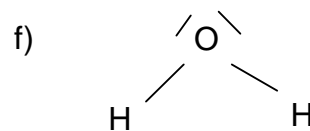
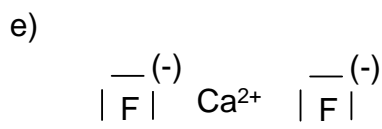
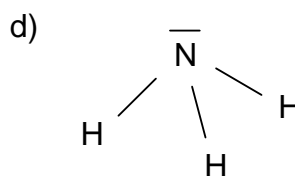
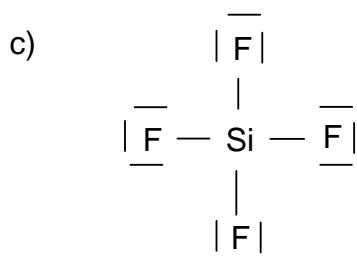
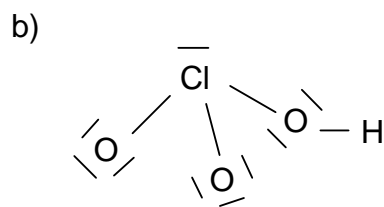
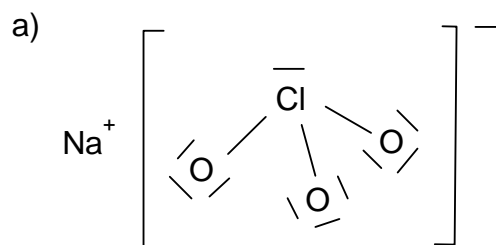
c) The volume of 0.01 M NaCl solution in which dissolves the same quantity of Hg_2Cl_2 as in 1 dm³ of water, is as follows:

$$V = \frac{6.3 \times 10^{-7}}{1.0 \times 10^{-14}} = 6.3 \times 10^7 \text{ dm}^3$$

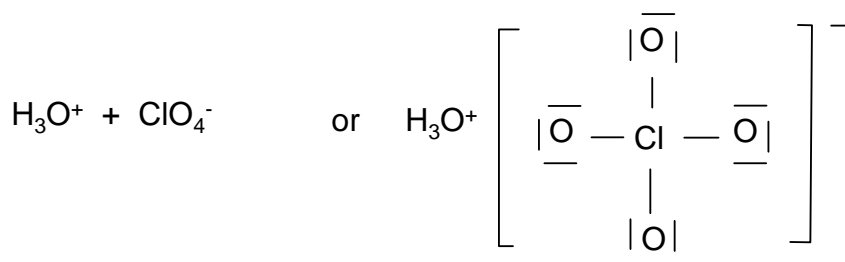
E) c) $\text{SO}_3, \text{I}_2, \text{NaCl}$

F) b) NH_4Cl

G)



H)



I) a) LiH, (BeH₂)_n polymer

b) LiH

c) (BeH₂)_n

d) CH₄

e) BeH₂ + 2 H₂O → Be(OH)₂ + 2 H₂

B₂H₆ + 6 H₂O → 2 B(OH)₃ + 6 H₂

B₂H₆ + 2 LiH → 2 Li[BH₄]

f) NH₂⁻ > OH⁻ > F⁻

J) MnO₄⁻ + 4 H⁺ + 3 e⁻ = MnO₂ + 2 H₂O E₂⁰ = 1.69 V

MnO₂ + 4 H⁺ + 2 e⁻ = Mn²⁺ + 2 H₂O E₃⁰ = ?

MnO₄⁻ + 8 H⁺ + 5 e⁻ = Mn²⁺ + 4 H₂O E₁⁰ = 1.52 V

5 E₁⁰ = 3 E₂⁰ + 2 E₃⁰

7.60 = 5.07 + 2 x

x = 1.26 V

PROBLEM 2

In a gaseous mixture of CO and CO₂, a mass ratio of carbon : oxygen = 1 : 2 was determined.

- Calculate the mass percent composition.
- Calculate the volume percent composition.
- Indicate values of the carbon: oxygen ratios for which both gases cannot be present simultaneously.

SOLUTION

Write x = number of moles of CO in 100 g

y = number of moles of CO₂ in 100 g

$$28x + 44y = 100$$

$$\frac{12(x+y)}{16(x+2y)} = \frac{1}{2}$$

$$x = 1.389 \text{ mol CO}$$

$$y = 1.389 \text{ mol CO}_2$$

$$\text{a) } \frac{1.389 \times 44}{100} \times 100 = 61.11 \% \text{ CO}_2$$

$$\frac{1.389 \times 28}{100} \times 100 = 38.89 \% \text{ CO}$$

$$\text{b) } X = y \quad 50 \% \text{ CO}_2 + 50 \% \text{ CO (by volume)}$$

c) The two gases cannot be simultaneously present in the mixture if:

$$\frac{\text{carbon mass}}{\text{oxygen mass}} = \frac{12}{16} \text{ which corresponds to pure CO}$$

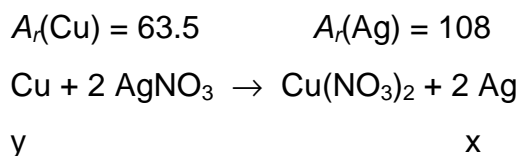
$$\frac{12}{32} \text{ which corresponds to pure CO}_2$$

PROBLEM 3

A sample containing a mixture of sodium chloride and potassium chloride weighs 25 g. After its dissolution in water 840 ml of AgNO_3 solution ($c = 0.5 \text{ mol dm}^{-3}$) is added. The precipitate is filtered off and a strip of copper weighing 100.00 g is dipped into the filtrate. After a given time interval the strip weighs 101.52 g.

Calculate the mass percent composition of the mixture.

SOLUTION



x = the quantity of deposited silver
 y = the quantity of dissolved copper

$$\frac{63.5}{y} = \frac{2 \times 108}{x}$$

$$x - y = 101.52 - 100 \quad x = 1.52 + y$$

$$\frac{63.5}{y} = \frac{2 \times 108}{1.52 + x} \quad y = 0.63 \quad x = 2.15 \text{ g Ag}^+$$

Mass of silver nitrate:

$$\frac{840}{1000} \times 0.5 \times 170 = 71.4 \text{ g AgNO}_3$$

$$\frac{170 \text{ g AgNO}_3}{108 \text{ g Ag}} = \frac{71.4}{x} \quad x = 45.36 \text{ g Ag}^+$$

Silver consumed for participation

$$45.36 - 2.15 = 43.21 \text{ g Ag}^+$$

Total mass of chloride

$$\frac{108 \text{ g Ag}^+}{35.5 \text{ g Cl}^-} = \frac{43.2}{x} \quad x = 14.2 \text{ g Cl}^-$$

$$M_r(\text{NaCl}) = 58.5 \quad M_r(\text{KCl}) = 74.6$$

x = mass of NaCl in the mixture

y = mass of KCl in the mixture

$$\text{mass of Cl}^- \text{ in NaCl: } \frac{35.5 x}{58.5}$$

$$\text{mass of Cl}^- \text{ in KCl: } \frac{35.5 y}{74.6}$$

$$\frac{35.5 x}{58.5} + \frac{35.5 y}{74.6} = 14.2$$

$$x + y = 25$$

$$x = 17.6 \text{ g NaCl} \quad 70.4 \% \text{ NaCl}$$

$$y = 7.4 \text{ g KCl} \quad 29.6 \% \text{ KCl}$$

PROBLEM 4

The following data were gathered for the alkaline hydrolysis of certain chlorinated compounds:

- a) A certain volume of a solution of the neutral potassium salt of chlorosuccinic acid is mixed with an equal volume of hydroxide solution. The initial concentration of each solution is 0.2 mol dm^{-3} . The potassium hydroxide concentration in the reaction mixture was determined at different time intervals at $25 \text{ }^\circ\text{C}$. The following values were obtained:

t (minutes)	10	20	30	45	60	80	100
c(KOH) (mol dm^{-3})	0.085	0.074	0.065	0.056	0.049	0.042	0.036

The experiment was repeated with the same initial solutions at $35 \text{ }^\circ\text{C}$. The hydroxide concentration is reduced to one half after 21 minutes.

- b) In the hydrolysis of 3-chloro-3-methylhexane with potassium hydroxide, the concentration of potassium hydroxide was found to have been reduced to one half after 32 minutes at $25 \text{ }^\circ\text{C}$ or 11 minutes at $35 \text{ }^\circ\text{C}$, regardless of the initial reactant concentrations (identical).
- c) In the alkaline hydrolysis of 3-chloro-2,4-dimethyl-3-isopropylpentane an identical reaction mechanism as for reaction b was found but the reaction rate was about 100 times faster under the same reaction conditions.

Considering the above data answer the following questions:

1. What is the reaction order in cases a, b, and c?
2. What is the rate constant at $25 \text{ }^\circ\text{C}$ for reaction a? Indicate the units.
3. Calculate the activation energies for reactions a and b.
4. If in reaction a dipotassium salt of L-chlorosuccinic acid (which is levorotatory,) is used, what type of optical rotation will be exhibited by the corresponding salt of malic acid formed by hydrolysis?

5. If the levorotatory isomer is also used in reaction b, what optical rotation will be exhibited by 3-methyl-3-hexanol formed in the hydrolysis reaction?
6. Why is the rate of reaction c much faster than that of reaction b when both reactions are of the same type and occur under the same temperature and concentration conditions?

SOLUTION

1. For reaction a the reaction order is estimated as follows:

- assuming the first-order reaction:

$$k = \frac{1}{t} \ln \frac{a}{a-x}$$

t (°C)	10	20	30	45	60	80	100
k · 10 ²	1.625	1.505	1.436	1.288	1.189	1.084	1.022

k is not constant, hence the reaction is not of the first-order.

- for the second-order reaction (with reactant concentrations equal at time zero):

$$k = \frac{1}{t} \left(\frac{a}{a-x} - \frac{1}{a} \right)$$

t (°C)	10	20	30	45	60	80	100
k	0.176	0.176	0.179	0.175	0.173	0.173	0.178

As k has almost a constant value the condition for a second-order reaction is fulfilled.

The half-life of reaction b is independent on the initial concentrations, i. e. it is a first-order reaction:

$$k = \frac{1}{t} \ln \frac{a}{a-x} = \frac{1}{t_{1/2}} \ln \frac{a}{a - \frac{a}{2}} = \frac{1}{t_{1/2}} \ln 2$$

Reaction c has the same mechanism as reaction b. Therefore, it will also be a first-order reaction.

2. The rate constant of reaction a is an average of the above calculated values.

$$k = 0.176 \text{ dm}^3 \text{ mol}^{-1} \text{ min}^{-1}$$

3. In order to determine the activation energy, the rate constant, k' , at 35 °C is to be calculated.

For the second-order reactions the relationship between the rate constants and half-lives is as follows:

$$k = \frac{1}{t} \left(\frac{a}{a-x} - \frac{1}{a} \right) = \frac{1}{t_{1/2}} \left(\frac{1}{a - \frac{a}{2}} - \frac{1}{a} \right) = \frac{1}{t_{1/2}} \frac{1}{a}$$

The half-life at 35 °C and the initial concentration, $a = 0.1 \text{ mol dm}^{-3}$, are known. (By mixing equal volumes of the two solutions the concentration of each reacting species is reduced to a half.)

Calculation of the rate constant at 35 °C:

$$k' = \frac{1}{21} \times \frac{1}{0.1} = 0.476 \text{ dm}^3 \text{ mol}^{-1} \text{ min}^{-1}$$

The activation energy of reaction a will be:

$$E_a = R \ln \frac{k'}{k} \times \frac{T' \cdot T}{T' - T} = 8314 \ln \frac{0.476}{0.176} \times \frac{308 \times 298}{308 - 298} = 7.592 \times 10^7 \text{ J mol}^{-1}$$

For reaction b that is a first-order reaction, the rate constants at the two temperatures are calculated from the half-lives:

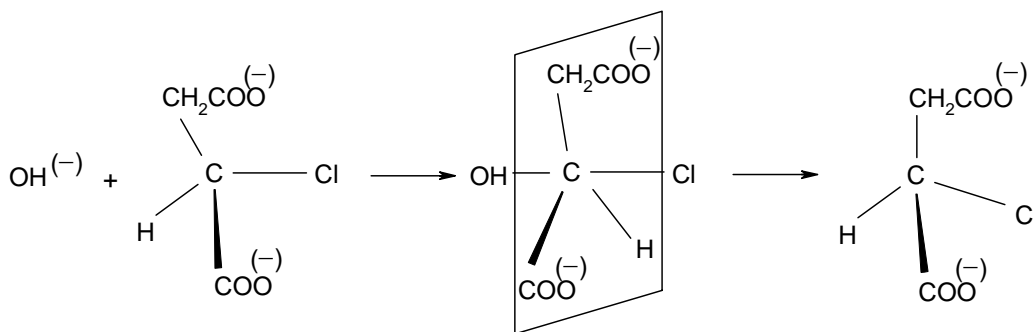
$$\text{at } 25 \text{ °C: } k = \frac{\ln 2}{32} = 2.166 \times 10^{-2} \text{ min}^{-1}$$

$$\text{at } 35 \text{ °C: } k' = \frac{\ln 2}{11} = 6.301 \times 10^{-2} \text{ min}^{-1}$$

Hence the activation energy is:

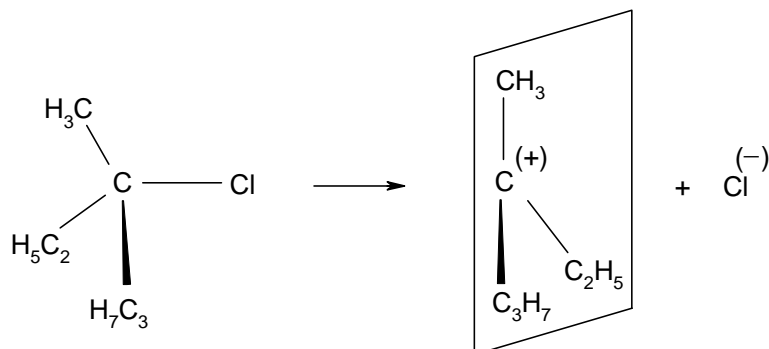
$$E_a = 8314 \ln \frac{6.301 \times 10^{-2}}{2.166 \times 10^{-2}} \times \frac{308 \times 298}{308 - 298} = 8.149 \times 10^7 \text{ J mol}^{-1}$$

4. The product of the hydrolysis reaction a will become dextrorotatory as a result of configuration inversion.



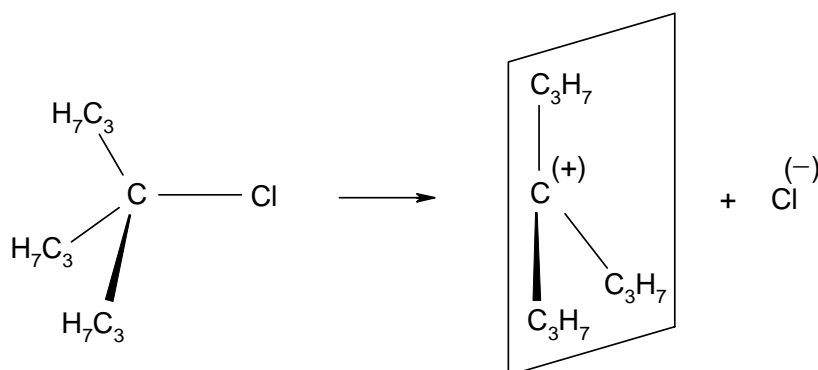
As an S_N2 type reaction, it involves a transition state in which the inversion of the configuration of the asymmetric carbon atom occurs. Thus, if the substrate is levorotatory, the product will become dextrorotatory.

5. The reaction b is a unimolecular S_N1 reaction and involves the transient formation of an almost stable carbonium ion in the rate-determining step.



The most probable structure of the carbonium ion is planar. The carbonium ion may be attacked by the nucleophilic reagent (the OH^- ion) on both sides of the plane with the same probability. The product will result as a racemic mixture, with no optical activity, inactive by intermolecular compensation.

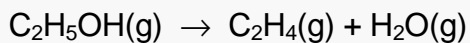
6. The same is true for the reaction c, the only difference being a more marked repulsion among bulkier substituents. The tendency towards carbonium ion formation with a planar structure and reduced repulsions is increased.



The rate of the carbonium ion formation, and therefore the overall reaction rate, is consequently increased.

PROBLEM 5

On passing ethanol over a catalyst at 400 K, a dehydration reaction occurs resulting in the formation of ethylene:



At the above temperature and $p_0 = 101.325 \text{ kPa}$, the conversion of ethyl alcohol is 90.6 mol %.

1. Calculate the equilibrium constant K_p of the reaction under given conditions.
2. Calculate the values of the equilibrium constants K_x and K_c at the above temperature.
3. Calculate the ethanol conversion at the following pressures:
5 p_0 , 10 p_0 , 50 p_0 , 100 p_0 , and 200 p_0 .
4. Plot the graph for the variation of conversion vs. pressure.

SOLUTION

The reaction: $\text{C}_2\text{H}_5\text{OH} \rightarrow \text{C}_2\text{H}_4 + \text{H}_2\text{O}$

Moles:

initial:	1	0	0	
at equilibrium:	$1 - x$	x	x	total: $1 + x$

	Molar fraction	Partial pressure
Ethanol	$\frac{1-x}{1+x}$	$\frac{1-x}{1+x} p$
Ethylene	$\frac{x}{1+x}$	$\frac{x}{1+x} p$
Water	$\frac{x}{1+x}$	$\frac{x}{1+x} p$

$$p = \frac{p'}{p} \quad p' - \text{total pressure, } p_0 = 101.325 \text{ kPa}$$

$$K_p = \frac{p_{\text{C}_2\text{H}_4} \cdot p_{\text{H}_2\text{O}}}{p_{\text{C}_2\text{H}_5\text{OH}}} = \frac{\left(\frac{x}{1+x} p\right) \left(\frac{x}{1+x} p\right)}{\frac{1-x}{1+x} p} = \frac{x^2}{1-x^2} p$$

1. $p' = 101.325 \text{ kPa}$

$$K_p = \frac{x^2}{1-x^2} = \frac{0.906^2}{1-0.906^2} = 4.56$$

2. $K_x = K_p p^{-\Delta n}$; $p' = 101.325 \text{ kPa}$; $\Delta n = 1$; $K_x = 4.56$

$$K_c = K_p \left(\frac{c_0 RT}{p_0} \right)^{\Delta n} \quad R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}; \quad c^0 = 1 \text{ mol dm}^{-3}; \quad T = 400 \text{ K}$$

$$K_c = 0.139$$

3. $\frac{x^2}{1-x^2} = \frac{K_p}{p} = \frac{4.56}{p}$

a) $\frac{x^2}{1-x^2} = \frac{4.56}{5} = 0.912 \quad x = 0.69$

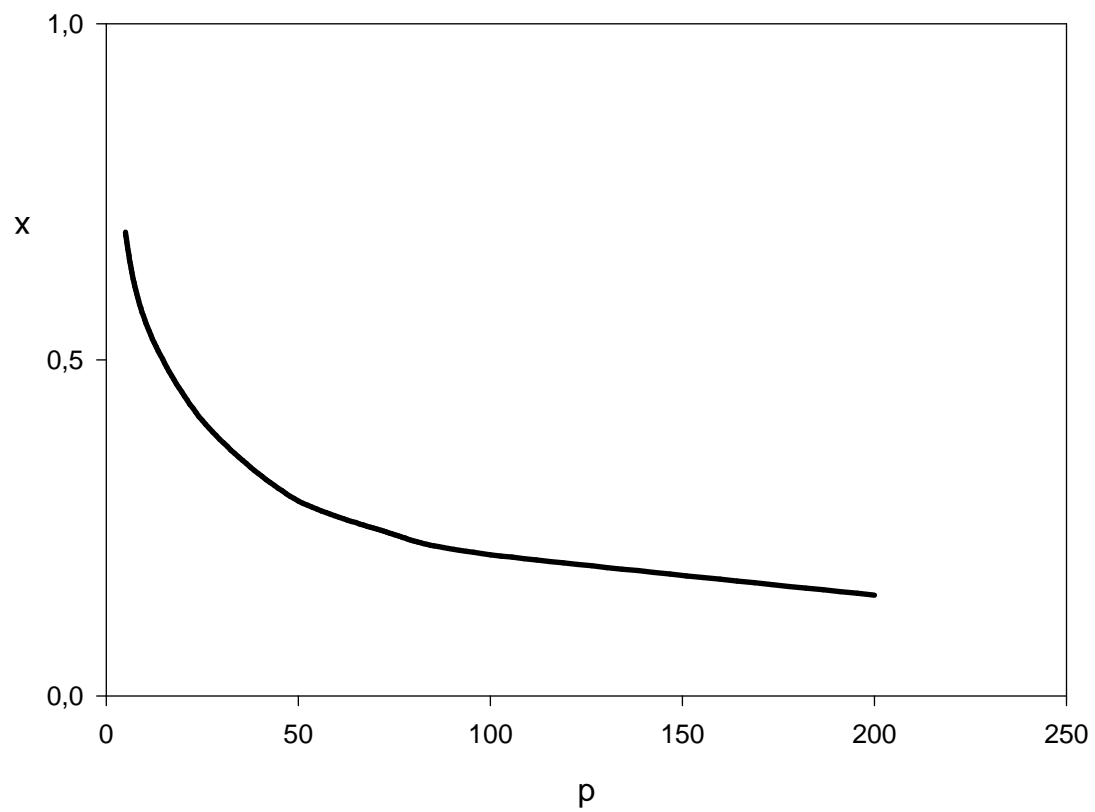
b) $\frac{x^2}{1-x^2} = \frac{4.56}{10} = 0.456 \quad x = 0.56$

c) $\frac{x^2}{1-x^2} = \frac{4.56}{50} = 0.0912 \quad x = 0.29$

d) $\frac{x^2}{1-x^2} = \frac{4.56}{100} = 0.0456 \quad x = 0.21$

e) $\frac{x^2}{1-x^2} = \frac{4.56}{200} = 0.0228 \quad x = 0.15$

4.

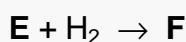


PROBLEM 6

One mole of compound **A** reacts successively with 3 moles of compound **B** in aqueous solution in the presence of a basic catalyst (such as $\text{Ca}(\text{OH})_2$):



Hydrogenation of compound **E** yields compound **F**:



F has the composition: C = 44.18 %, H = 8.82 %, O = 47.00 %.

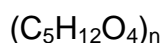
Its molar mass: $M = 136 \text{ g mol}^{-1}$

Knowing that 13.6 g of **F** reacts with 40.8 g acetic anhydride to form product **G** and acetic acid write down all chemical equations and assign the letters **A**, **B**, **C**, **D**, **E**, **F**, and **G** to particular formulas of compounds.

SOLUTION

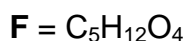
The molecular formula of **F**:

$$\text{C} : \text{H} : \text{O} = \frac{44.18}{12} : \frac{8.82}{1} : \frac{47.00}{16} = 1.25 : 3 : 1 = 5 : 12 : 4$$



Since $M(\mathbf{F}) = 136$

$$\text{and } (5 \times 12) + (12 \times 1) + (4 \times 16) = 136$$



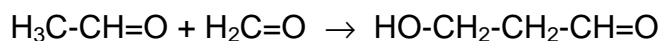
Since **F** reacts with acetic anhydride it could be a mono- or polyhydroxy alcohol. If it were a monohydroxy alcohol, 136 g of **F** (1 mol) could react with 102 g (1 mol) of acetic anhydride. In fact 13.6 g of **F** (i. e. 0.1 mol) reacts with 40.8 g of acetic anhydride ($40.8 / 102 = 0.4 \text{ mol}$), i. e. **F** is a polyol (tetrahydroxy alcohol).

F is formed by the reduction of **E**, so that **E** has one carbonyl and three OH groups.

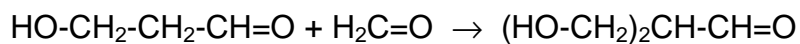
E is formed from 3 molecules of **B** and one molecule of **A**.

Since compound **E** has three OH groups and one CO group and the reaction conditions used are typical for aldol condensation, it is clear that **A** is acetaldehyde and **B**

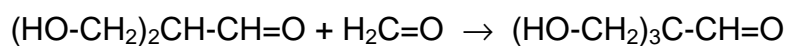
is formaldehyde. **C** and **D** are the products of successive aldol condensation of acetaldehyde with formaldehyde:



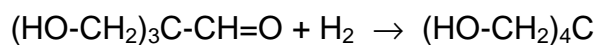
A **B** **C**



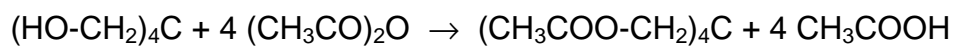
C **B** **D**



D **B** **E**



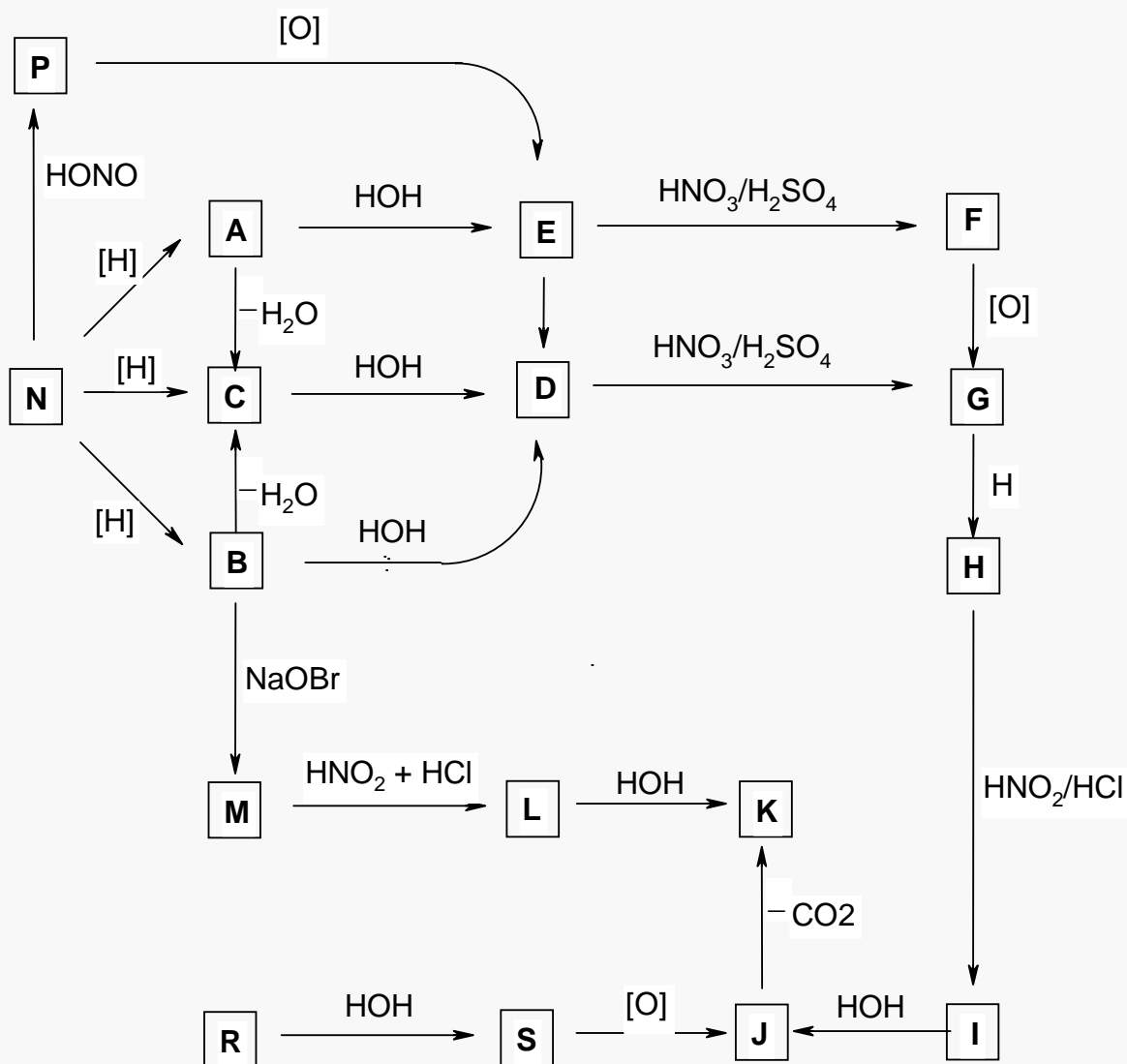
E **F**



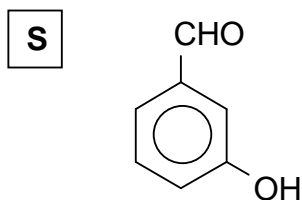
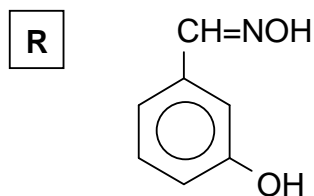
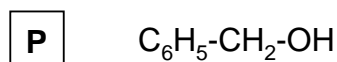
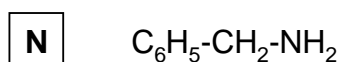
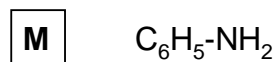
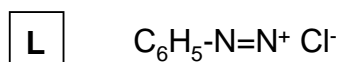
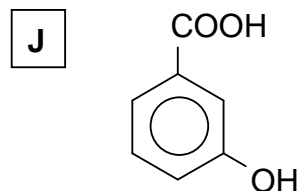
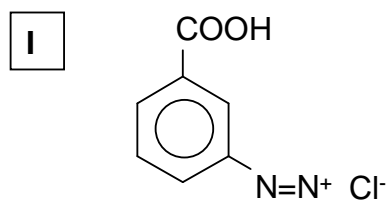
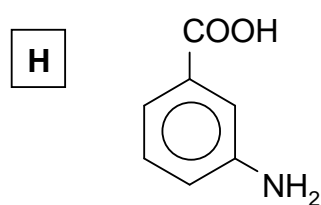
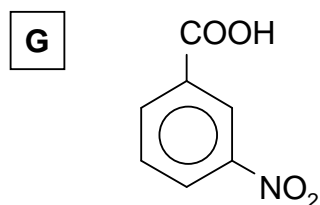
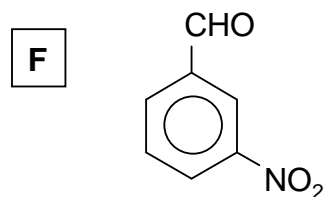
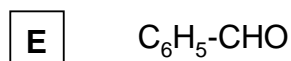
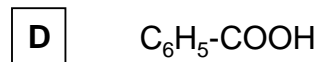
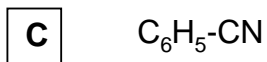
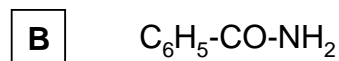
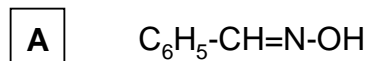
G

PROBLEM 7

Knowing that compounds **A** and **B** are isomers with the molecular formula C_7H_7NO and the relative molecular mass of compound **M** is 93, determine the formulae of compounds **A** to **S** taking in account the reactions given in the following reaction scheme:



SOLUTION



PRACTICAL PROBLEMS

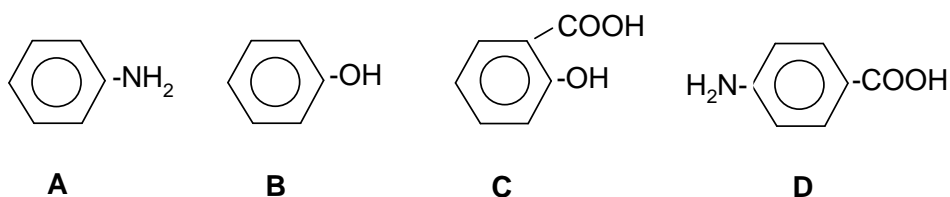
PROBLEM 1

In test tubes **A**, **B**, **C**, and **D** there are four benzene derivatives containing one or two functional groups of three distinct types. Identify the functional groups of compounds **A**, **B**, **C**, and **D** using the available reagents.

- Justify your choice by writing down the identification reactions.
- Using as reagents the four compounds **A**, **B**, **C**, and **D** synthesize four organic dyes and write the equations for the reactions performed.

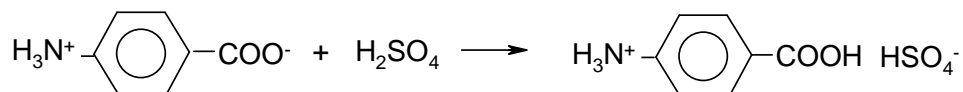
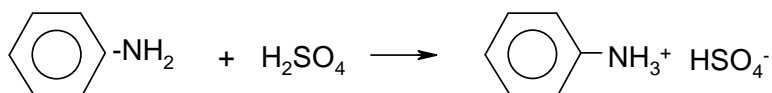
SOLUTION

The four compounds are as follows:

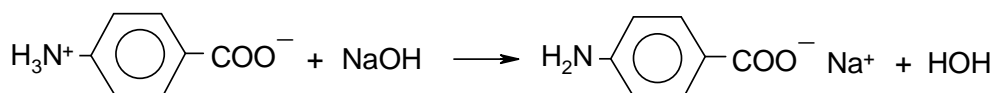
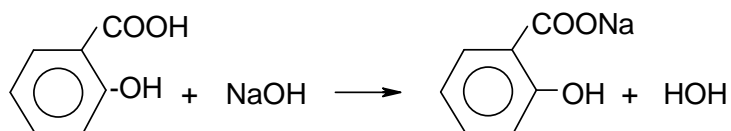
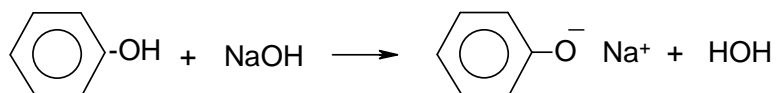


The identification reactions:

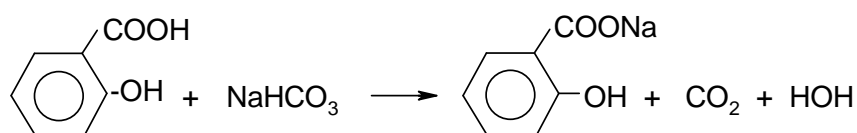
a) With H₂SO₄:



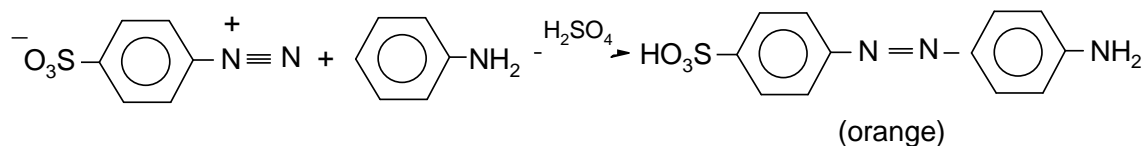
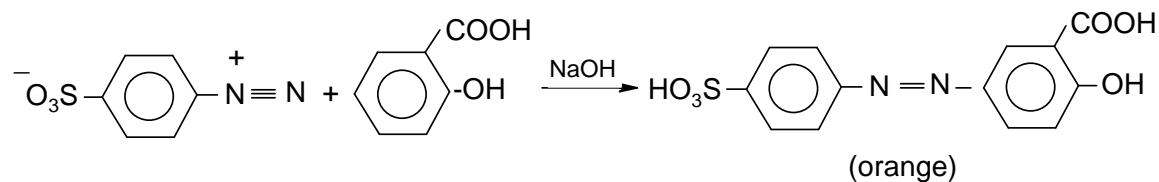
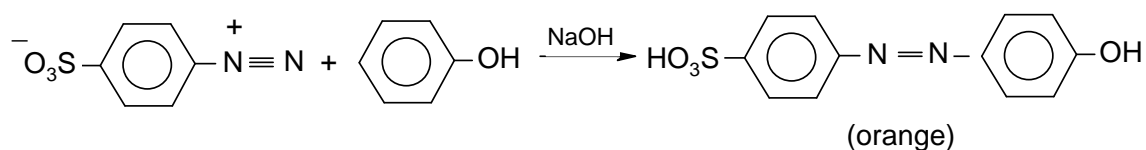
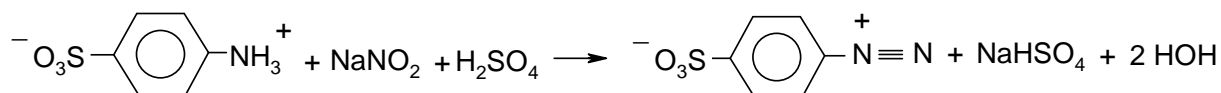
b) With NaOH:



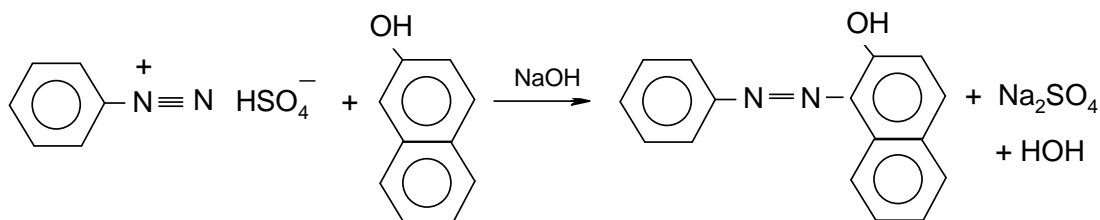
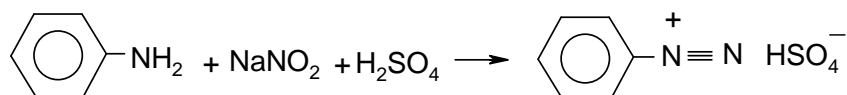
c) With NaHCO₃:



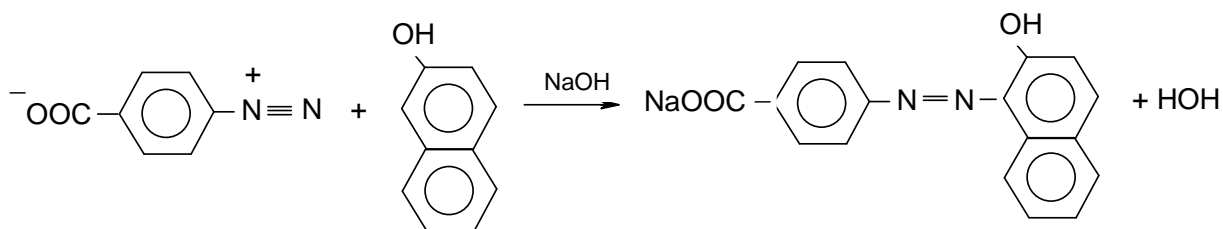
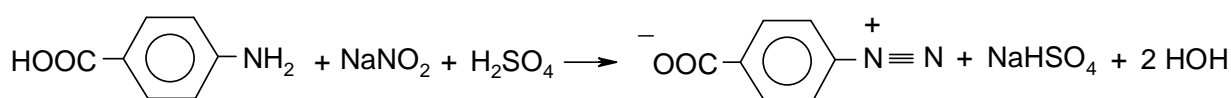
d) With $\text{NH}_2\text{-C}_6\text{H}_4\text{-SO}_3\text{H}$



II. e) With β -naphthol:

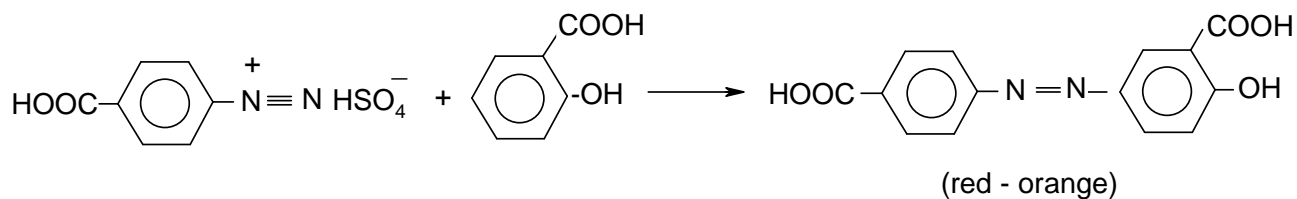
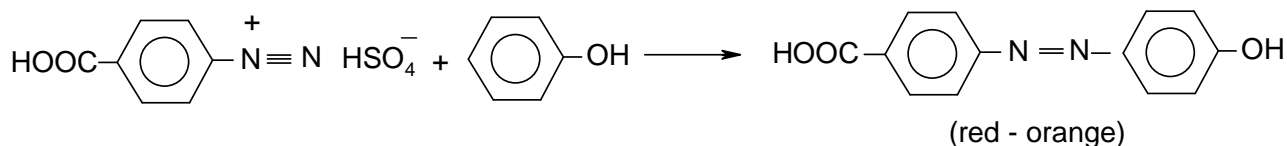
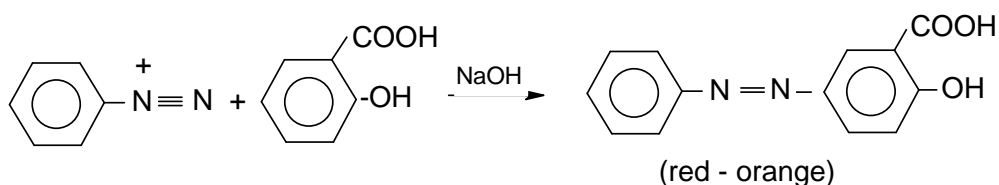
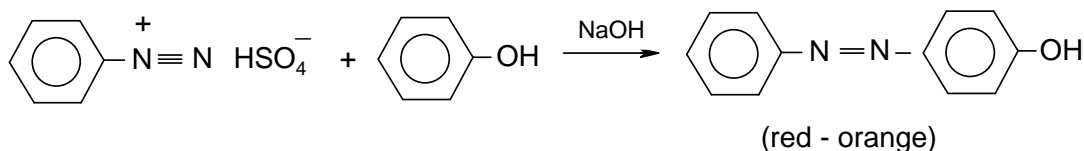


yellow - orange



red

The following dyes can be obtained:



PROBLEM 2

A solution in a graduated flask contains a mixture of oxalic acid and ammonium oxalate.

One of the bottles denoted X, Y, and Z contains a solution of a calibration substance with reducing character at a concentration of $0.1000 \text{ mol dm}^{-3}$.

You are required to solve the following tasks:

- Determine the quantity of oxalic acid and of ammonium oxalate in the solution in the graduated flask. (The result will be given in grams.)
- Write the formula for the substance with reducing character and the equations of the chemical reactions which led to its determination.

In order to carry out the analyses the following solutions are available:

HCl ($c = 0.1000 \text{ mol dm}^{-3}$), NaOH ($c = 2 \text{ mol dm}^{-3}$), KMnO_4 ($c = 0.02 \text{ mol dm}^{-3}$), 25 % H_2SO_4 , HNO_3 ($c = 2 \text{ mol dm}^{-3}$), 5 % BaCl_2 , 5 % AgNO_3 , 5 % $\text{Hg}_2(\text{NO}_3)_2$, phenolphthalein 0.1 %, methyl red 1 %.

- Describe the procedure used in the individual steps, indicators employed and partial results.

$$M_r(\text{H}_2\text{C}_2\text{O}_4) = 90.04$$

$$M_r((\text{NH}_4)_2\text{C}_2\text{O}_4) = 124.11$$

SOLUTION

ANSWER SHEET:

A₁ – Identification of the solution with the reducing substance X, Y, Z: $\text{Fe}(\text{NH}_4)_2(\text{SO}_4)_2$

A₂ – Identification reactions for the ions of the substance

- $\text{Fe}^{2+} + 2 \text{NaOH} \rightarrow \text{Fe}(\text{OH})_2 + 2 \text{Na}^+$
- $\text{NH}_4^+ + \text{NaOH} \rightarrow \text{NH}_3 \uparrow + \text{H}_2\text{O} + \text{Na}^+$
- $4 \text{NH}_3 + 2 \text{Hg}_2(\text{NO}_3)_2 + \text{H}_2\text{O} \rightarrow \text{O}(\text{Hg})_2\text{NH}_2.\text{NO}_3 + 3 \text{NH}_4\text{OH}$
- $\text{SO}_4^{2-} + \text{BaCl}_2 \rightarrow \text{BaSO}_4 + 2 \text{Cl}^-$

B₁ – Preparation of the 0.1 M NaOH solution

..... cm^3 in 200.0 cm^3

B₂ – Concentration of the NaOH in its solution: M

Indicator used:

C – Concentration of KMnO₄ in its solution M

D₁ – Mass of oxalic acid in the initial solution g

Indicator used

D₂ – Mass of ammonium oxalate in the initial solution g

Solution

A₁ – 1-2 cm³ of solution X, Y and Z are put into three test tubes. 6 N H₂SO₄ and a drop of KMnO₄ solution are added. The solution which loses colour is the one with reducing character.

A₂ – Establishment of the formula:

. + NaOH – greenish white precipitate ⇒ Fe²⁺

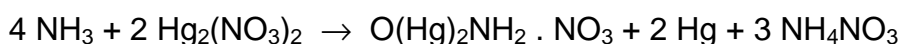
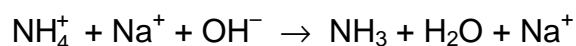
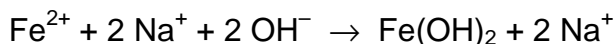
. + NaOH at the upper end of the test-tube, filter paper with a drop of Hg₂(NO₃)₂, black spot ⇒ NH₄⁺

. + BaCl₂ – white precipitate ⇒ SO₄²⁻

. + AgNO₃ + HNO₃ ⇒ Cl⁻ is absent

Accordingly the substance used is Fe(NH₄)₂(SO₄)₂.

The chemical reactions:



B₁ – 5 cm³ 2 M solution ⇒ 100 cm³ 0.1 M solution

B₂ – V cm³ 0.1000 N HCl + 0.1 N NaOH in the presence of phenolphthalein.

C – $V \text{ cm}^3$ solution X + $10.0 \text{ cm}^3 \text{ H}_2\text{SO}_4 + \text{H}_2\text{O}$ is titrated at elevated temperature with KMnO_4 .

D₁ – The solution which is to be analyzed is filled to the mark; $V \text{ cm}^3$ of this solution is titrated with NaOH in the presence of methyl red. The quantity of oxalic acid (moles and g) is calculated.

D₂ – $V \text{ cm}^3$ solution to be analyzed + $10.0 \text{ cm}^3 \text{ 6 N H}_2\text{SO}_4 + \text{H}_2\text{O}$ are heated and titrated with KMnO_4 solution.

The total amount of oxalate is calculated (in mol).

The difference gives the amount of ammonium oxalate (moles and g).

PROBLEM 3

Six test-tubes contain aqueous solutions of FeSO_4 , H_2SO_4 , $\text{Mn}(\text{NO}_3)_2$, H_2O_2 , $\text{Pb}(\text{NO}_3)_2$, NaOH .

- a) Identify the content of each test-tube without using other reagents. Write the results in tabular form. Write the equations for the chemical reactions used for the identification.
- b) After identification, perform four reactions each time using three of the identified compounds and write the equations.

SOLUTION

	FeSO_4	H_2SO_4	$\text{Mn}(\text{NO}_3)_2$	H_2O_2	$\text{Pb}(\text{NO}_3)_2$	NaOH
1) FeSO_4		–	–	$\text{Fe}(\text{OH})\text{SO}_4$ yellowish	$\text{PbSO}_4 \downarrow$ white	$\text{Fe}(\text{OH})_2 \downarrow$ white-greenish \downarrow $\text{Fe}(\text{OH})_3 \downarrow$ brown-redish
2) H_2SO_4	–		–	–	$\text{PbSO}_4 \downarrow$ white	–
3) $\text{Mn}(\text{NO}_3)_2$	–	–		–	–	$\text{Mn}(\text{OH})_2 \downarrow$ white \downarrow $\text{MnMnO}_3 \downarrow$ brown black
4) H_2O_2	$\text{Fe}(\text{OH})\text{SO}_4$ yellowish	–	–		–	–
5) $\text{Pb}(\text{NO}_3)_2$	$\text{PbSO}_4 \downarrow$ white	$\text{PbSO}_4 \downarrow$ white	–	–		–
6) NaOH	$\text{Fe}(\text{OH})_2 \downarrow$ white-greenish \downarrow $\text{Fe}(\text{OH})_3 \downarrow$ brown-redish	–	$\text{Mn}(\text{OH})_2 \downarrow$ white \downarrow $\text{MnMnO}_3 \downarrow$ brown black	–	$\text{Pb}(\text{OH})_2 \downarrow$ white \downarrow $\text{Pb}(\text{OH})_4^{2-}$	

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Timisoara 1983, Romania

	Reactions	Observation
(1) + (4)	$\text{FeSO}_4 + \text{H}_2\text{O}_2 \rightarrow 2 \text{Fe}(\text{OH})\text{SO}_4$	Colour change - yellowish (Fe^{3+})
(1) + (5)	$\text{FeSO}_4 + \text{Pb}(\text{NO}_3)_2 \rightarrow \text{PbSO}_4 \downarrow + \text{Fe}(\text{NO}_3)_2$	Appearance of a white precipitate.
(1) + (6)	$\text{FeSO}_4 + 2 \text{NaOH} \rightarrow \text{Fe}(\text{OH})_2 \downarrow + \text{Na}_2\text{SO}_4$ $\text{Fe}(\text{OH})_2 + \frac{1}{2} \text{O}_2 + \text{H}_2\text{O} \rightarrow \text{Fe}(\text{OH})_3$	Appearance of a greenish white precipitate $\text{Fe}(\text{OH})_2$ which after oxidation by air turns into a reddish brown precipitate $\text{Fe}(\text{OH})_3$.
(2) + (5)	$\text{H}_2\text{SO}_4 + \text{Pb}(\text{NO}_3)_2 \rightarrow \text{PbSO}_4 \downarrow + 2 \text{HNO}_3$	Appearance of a white precipitate PbSO_4 .
(3) + (6)	$\text{Mn}(\text{NO}_3)_2 + 2 \text{NaOH} \rightarrow \text{Mn}(\text{OH})_2 + 2 \text{NaNO}_3$ $2 \text{Mn}(\text{OH})_2 + \frac{1}{2} \text{O}_2 \rightarrow \text{MnMnO}_3 + 2 \text{H}_2\text{O}$ $\text{Mn}(\text{OH})_2 + \frac{1}{2} \text{O}_2 \rightarrow \text{MnO}_2 + \text{H}_2\text{O}$	Appearance of a white precipitate $\text{Mn}(\text{OH})_2$ which after oxidation by air converts into a brown-black precipitate MnMnO_3 which eventually changes into MnO_2 – a black-brown precipitate.
(5) + (6)	$\text{Pb}(\text{NO}_3)_2 + 2 \text{NaOH} \rightarrow \text{Pb}(\text{OH})_2 + 2 \text{NaNO}_3$ $\text{Pb}(\text{OH})_2 + 2 \text{NaOH} \rightarrow \text{Na}_2\text{Pb}(\text{OH})_4$	Appearance of a white precipitate $\text{Pb}(\text{OH})_2$ which dissolves in excess reagent.
b)		
(1) + (2) + (4)	$2 \text{FeSO}_4 + \text{H}_2\text{O}_2 + \text{H}_2\text{SO}_4 \rightarrow \text{Fe}_2(\text{SO}_4)_3 + 2 \text{H}_2\text{O}$	Colour change \rightarrow yellowish (Fe^{3+})
(1) + (4) + (6)	$2 \text{FeSO}_4 + \text{H}_2\text{O}_2 + 4 \text{NaOH} \rightarrow \text{Fe}(\text{OH})_3 + 2 \text{Na}_2\text{SO}_4$	Appearance of a brown-reddish precipitate $\text{Fe}(\text{OH})_3$
(3) + (4) + (6)	$\text{Mn}(\text{NO}_3)_2 + \text{H}_2\text{O}_2 + 2 \text{NaOH} \rightarrow \text{MnO}_2 + 2 \text{NaNO}_3 + 2 \text{H}_2\text{O}$	Appearance of a brown precipitate MnO_2
(5) + (4) + (6)	$\text{Pb}(\text{NO}_3)_2 + \text{H}_2\text{O}_2 + 2 \text{NaOH} \rightarrow \text{PbO}_2 + 2 \text{NaNO}_3 + 2 \text{H}_2\text{O}$	Appearance of a brown precipitate PbO_2 .