



# **THE COMPETITION PROBLEMS FROM THE INTERNATIONAL CHEMISTRY OLYMPIADS**

## **Volume 2**

**21<sup>st</sup> – 40<sup>th</sup> ICHO  
1989 – 2008**

**Edited by Anton Sirota**

IUVENTA, Bratislava, 2009

THE COMPETITION PROBLEMS FROM THE INTERNATIONAL CHEMISTRY OLYMPIADS,

Volume 2

21<sup>st</sup> – 40<sup>th</sup> ICHO (1989 – 2008)

Editor: Anton Sirota

ISBN 978-80-8072-092-6

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Issued by IUVENTA in 2009  
with the financial support of the Ministry of Education of the Slovak Republic

Number of copies: 250  
Not for sale.

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## Preface

This publication contains the competition problems (Volume 2) from the 21<sup>st</sup> – 40<sup>th</sup> International Chemistry Olympiads (ICHO) organized in the years 1989 – 2008 and is a continuation of the publication that appeared last year as Volume 1 and contained competition problems from the first twenty ICHOs. The whole review of the competition tasks set in the ICHO in its forty-year history is a contribution of the ICHO International Information Centre in Bratislava (Slovakia) to the development of this world known international competition. This Volume 2 contains 154 theoretical and 46 practical competition problems from the mentioned years. The review as a whole presents altogether 279 theoretical and 96 practical problems.

In the elaboration of this collection the editor had to face certain difficulties because the aim was not only to make use of past recordings but also to give them such a form that they may be used in practice and further chemical education. Consequently, it was necessary to make some corrections in order to unify the form of the problems. However, they did not concern the contents and language of the problems.

Unfortunately, the authors of the particular competition problems are not known and due to the procedure of the creation of the ICHO competition problems, it is impossible to assign any author's name to a particular problem. As the editor I would appreciate many times some discussion with the authors about any critical places that occurred in the text. On the other hand, any additional amendments to the text would be not correct from the historical point of view. Therefore, responsibility for the scientific content and language of the problems lies exclusively with the organizers of the particular International Chemistry Olympiads.

Some parts of texts, especially those gained as scanned materials, could not be used directly and thus, several texts, schemes and pictures had to be re-written or created again. Some solutions were often available in a brief form and necessary extent only, just for the needs of members of the International Jury.

Recalculations of the solutions were made in some special cases only when the numeric results in the original solutions showed to be obviously not correct. Although the numbers of significant figures in the results of several solutions do not obey the criteria generally accepted, they were left without change.

In this publication SI quantities and units are used and a more modern method of chemical calculations is introduced. Only some exceptions have been made when, in an effort to preserve the original text, the quantities and units have been used that are not SI. There were some problems with the presentation of the solutions of practical tasks, because most of the relatively simple calculations were based on the experimental results of contestants. Moreover, the practical problems are accompanied with answer sheets in the last years and several additional questions and tasks have appeared in them that were not a part of the text of the original experimental problems. Naturally, answer sheets could not be included in this publication and can only be preserved as archive materials.

When reading the texts of the ICHO problems one must admire and appreciate the work of those many known and unknown people – teachers, authors, pupils, and organizers – who contributed so much to development and success of this important international competition.

I am sure about the usefulness of the this review of the ICHO problems. It may serve not only as archive material but, in particular, this review should serve to both competitors and their teachers as a source of further inspiration in their preparation for this challenging competition.

Bratislava, July 2009

Anton Sirota, editor

**21<sup>st</sup>**



**International Chemistry Olympiad**

**6 theoretical problems  
2 practical problems**

# THE TWENTY-FIRST INTERNATIONAL CHEMISTRY OLYMPIAD 2–10 JULY 1989, HALLE, GERMAN DEMOCRATIC REPUBLIC

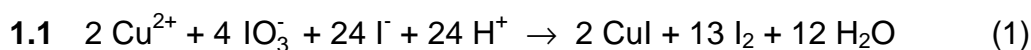
## THEORETICAL PROBLEMS

### PROBLEM 1

To determine the solubility product of copper(II) iodate,  $\text{Cu}(\text{IO}_3)_2$ , by iodometric titration in an acidic solution (25 °C) 30.00 cm<sup>3</sup> of a 0.100 molar sodium thiosulphate solution are needed to titrate 20.00 cm<sup>3</sup> of a saturated aqueous solution  $\text{Cu}(\text{IO}_3)_2$ .

- 1.1 Write the sequence of balanced equations for the above described reactions.
- 1.2 Calculate the initial concentration of  $\text{Cu}^{2+}$  and the solubility product of copper(II) iodate. Activity coefficients can be neglected.

### SOLUTION



- 1.2 From (2):

$$n(\text{S}_2\text{O}_3^{2-}) = c V = 0,100 \text{ mol dm}^{-3} \times 0,03000 \text{ dm}^3 = 3,00 \times 10^{-3} \text{ mol}$$

From (2) and (1):

$$n(\text{I}_2) = 1,50 \times 10^{-3} \text{ mol}$$

$$n(\text{Cu}^{2+}) = \frac{1,50 \times 10^{-3} \text{ mol}}{13} \times 2 = 2,31 \times 10^{-4} \text{ mol}$$

$$c(\text{Cu}^{2+}) = \frac{2,31 \times 10^{-4} \text{ mol}}{0,02000 \text{ dm}^3} = 1,15 \times 10^{-2} \text{ mol}$$

$$[\text{Cu}^{2+}] = 1,15 \times 10^{-2}$$

$$[\text{IO}_3^-] = 2 [\text{Cu}^{2+}]$$

$$K_{sp} = [\text{Cu}^{2+}] [\text{IO}_3^-]^2 = 4 [\text{Cu}^{2+}]^3 = 4 \times (1.15 \times 10^{-2})^3 = 6.08 \times 10^{-6}$$

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**PROBLEM 2**

A mixture of gases containing mainly carbon monoxide and hydrogen is produced by the reaction of alkanes with steam:



**2.1** Using equations (1) and (2) write down an overall reaction (3) so that the net enthalpy change is zero.

**2.2** The synthesis of methanol from carbon monoxide and hydrogen is carried out either

a) in two steps, where the starting mixture corresponding to equation (3) is compressed from  $0.1 \times 10^6$  Pa to  $3 \times 10^6$  Pa, and the mixture of products thereof compressed again from  $3 \times 10^6$  Pa to  $6 \times 10^6$  Pa

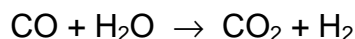
or

b) in one step, where the mixture of products corresponding to equation (3) is compressed from  $0.1 \times 10^6$  Pa to  $6 \times 10^6$  Pa.

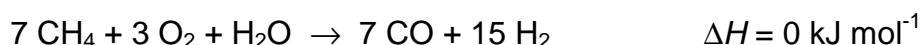
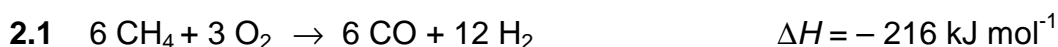
Calculate the work of compression,  $W_a$ , according to the two step reaction for  $100 \text{ cm}^3$  of starting mixture and calculate the difference in the work of compression between the reactions 1 and 2.

Assume for calculations a complete reaction at constant pressure. Temperature remains constant at 500 K, ideal gas behaviour is assumed.

To produce hydrogen for the synthesis of ammonia, a mixture of 40.0 mol CO and 40.0 mol of hydrogen, 18.0 mol of carbon dioxide and 2.0 mol of nitrogen are in contact with 200.0 mol of steam in a reactor where the conversion equilibrium is established.



**2.3** Calculate the number of moles of each gas leaving the reactor.

**SOLUTION**

- a) For a pressure increase in two steps under the conditions given, the work of compression is:

$$W_2 = n_1 RT \ln \frac{p_1}{p_2} + n_2 RT \ln \frac{p_2}{p_1} = n_1 RT \left( \ln \frac{p_1}{p_0} + 2 \ln \frac{p_2}{p_1} \right)$$

$$= 100 \text{ mol} \times 8.314 \text{ J mol}^{-1} \text{ K}^{-1} \times 500 \text{ K} \times \left( \ln \frac{3.0 \text{ MPa}}{0.1 \text{ MPa}} + 2 \ln \frac{6.0 \text{ MPa}}{3.0 \text{ MPa}} \right) = 1.99 \text{ MJ}$$

- b) For a pressure increase in one step the work of compression only depends on  $n_2$ ,  $p_2$  and  $p_0$ :

$$W_1 = n_2 RT \ln \frac{p_2}{p_0} = 100 \text{ mol} \times 8.314 \text{ J mol}^{-1} \text{ K}^{-1} \times 500 \text{ K} \times \ln \frac{6.0 \text{ MPa}}{0.1 \text{ MPa}} = 3.40 \text{ MJ}$$

It means

$$\Delta W = W_1 - W_2 = \underline{1.41 \text{ MJ}}$$

**2.3** With  $K = 3.3$ , the following equilibrium is valid:

$$K = \frac{n_{\text{CO}_2} \times n_{\text{H}_2}}{n_{\text{CO}} \times n_{\text{H}_2\text{O}}} = \frac{(18 + x)(40 + x)}{(40 - x)(200 - x)}$$

$$x_{1/2} = 184 \pm 151.6; \quad x_1 = 33.2; \quad x_2 = 336.4$$

The composition of the leaving gas is:

6.8 mol CO, 51.2 mol CO<sub>2</sub>, 2.0 mol CH<sub>4</sub> and N<sub>2</sub>, 73.2 mol H<sub>2</sub> and 166.8 mol H<sub>2</sub>O.

**PROBLEM 3**

Sulphur dioxide is removed from waste gases of coal power stations by washing with aqueous suspensions of calcium carbonate or calcium hydroxide. The residue formed is recovered.

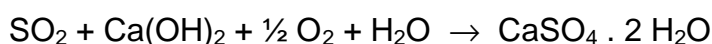
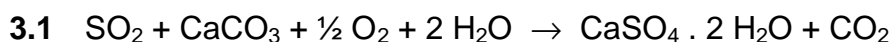
- 3.1** Write all reactions as balanced equations.
- 3.2** How many kilograms of calcium carbonate are daily consumed to remove 95 % of the sulphur dioxide if 10000 m<sup>3</sup>/h of waste gas (corrected to 0 °C and standard pressure) containing 0.15 % sulphur dioxide by volume are processed? How many kilograms of gypsum are recovered thereby?
- 3.3** Assuming that the sulphur dioxide is not being removed and equally spread in an atmospheric liquid water pool of 5000 m<sup>3</sup> and fully returned on earth as rain, what is the expected pH of the condensed water?
- 3.4** If a sodium sulphite solution is used for absorption, sulphur dioxide and the sulphite solution can be recovered. Write down the balanced equations and point out possible pathways to increase the recovery of sulphur dioxide from an aqueous solution.

Note:

Protolysis of sulphur dioxide in aqueous solutions can be described by the first step dissociation of sulphurous acid. The dissociation constant  $K_{a,1}(\text{H}_2\text{SO}_3) = 10^{-2.25}$ .

Assume ideal gases and a constant temperature of 0 °C at standard pressure.

$M(\text{CaCO}_3) = 100 \text{ g mol}^{-1}$ ;  $M(\text{CaSO}_4) = 172 \text{ g mol}^{-1}$ .

**SOLUTION**

**3.2** Under given conditions:

$$n(\text{SO}_2)/\text{h} = v(\text{SO}_2/\text{h}) / V = 669.34 \text{ mol h}^{-1}$$

$$m(\text{CaCO}_3/\text{d}) = n(\text{SO}_2/\text{h}) \times M(\text{CaCO}_3) \times 24 \text{ h} \cdot \text{d}^{-1} \times 0.95 = 1.53 \times 10^3 \text{ kg/d}$$

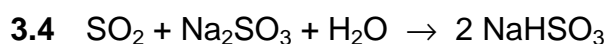
$$m(\text{CaSO}_4 \cdot 2 \text{H}_2\text{O}) = \frac{M(\text{CaSO}_4 \cdot 2 \text{H}_2\text{O})}{M(\text{CaCO}_3)} \times m(\text{CaCO}_3) / d = 2.63 \times 10^3 \text{ kg/d}$$

$$3.3 \quad pH = -\log[\text{H}_3\text{O}^+]; \quad K_a = \frac{[\text{H}_3\text{O}^+]^2}{[\text{SO}_2] - [\text{H}_3\text{O}^+]}$$

$$[\text{H}_3\text{O}^+]_{1/2} = -\frac{K_a}{2} \pm \sqrt{\frac{K_a^2}{4} + K_a [\text{SO}_2]}$$

Solving for  $[\text{H}_3\text{O}^+]$ :

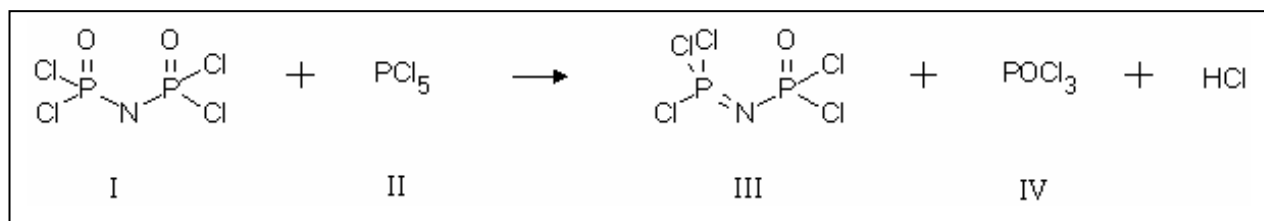
If  $[\text{SO}_2] = n(\text{SO}_2) / V = 1.34 \times 10^{-4}$  and  $K_a = 1 \times 10^{-2.25}$ , then  $[\text{H}_3\text{O}^+] = 1.32 \times 10^{-4}$  and  $pH = 3.88$



Possibilities to increase the recovery of  $\text{SO}_2$  are: temperature rise, reduced pressure, lower  $pH$ -value.

**PROBLEM 4**

<sup>32</sup>P labelled phosphorus pentachloride (half-life  $t_{1/2} = 14.3$  days) is used to study the electrophilic attack of a  $\text{PCl}_4^+$  cation on nitrogen or on oxygen.



The reaction is carried out in  $\text{CCl}_4$  and the solvent and product **IV** distilled off. Samples of **III** (remaining in the distillation flask), of **IV** (in the distillate) and samples of the starting material **II** are hydrolyzed by heating with a strong sodium hydroxide solution. The phosphate ions formed are precipitated as ammonium magnesium phosphate. Purified samples of the three precipitates are then dissolved by known volumes of water and the radioactivity measured.

- 4.1 Write the balanced equations for the reaction of red phosphorus forming  $\text{PCl}_5$
- 4.2 Write the reaction equations for complete hydrolysis of the compounds **II** and **III** using sodium hydroxide.
- 4.3 How long does it take in order to lower the initial radioactivity to  $10^{-3}$  of the initial value?
- 4.4 Write two alternative mechanisms for the reaction of labelled  $\text{PCl}_4^-$  with the anion of **I**.
- 4.5 After hydrolysis the precipitated ammonium magnesium phosphates show the following values for radioactivity:
  - II. 2380 Bq for 128 mg of  $\text{Mg}(\text{NH}_4)\text{PO}_4$
  - III. 28 Bq for 153 mg of  $\text{Mg}(\text{NH}_4)\text{PO}_4$
  - IV. 2627 Bq for 142 mg of  $\text{Mg}(\text{NH}_4)\text{PO}_4$

Using these data, what can you say about the nucleophilic centre attacked by  $\text{PCl}_4^-$ ?

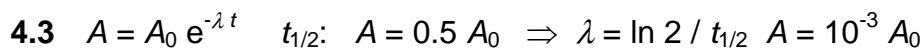
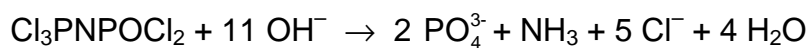
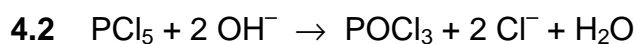
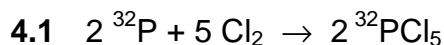
Data: For  $\text{H}_3\text{PO}_4$ :  $pK_1 = 2.2$ ;  $pK_2 = 7.2$ ;  $pK_3 = 12.4$

Solubility product of  $\text{Mg}(\text{NH}_4)\text{PO}_4$ :  $pK_s = 12.6$

Equilibrium concentration of  $\text{NH}_4^+ = 0.1 \text{ mol dm}^{-3}$

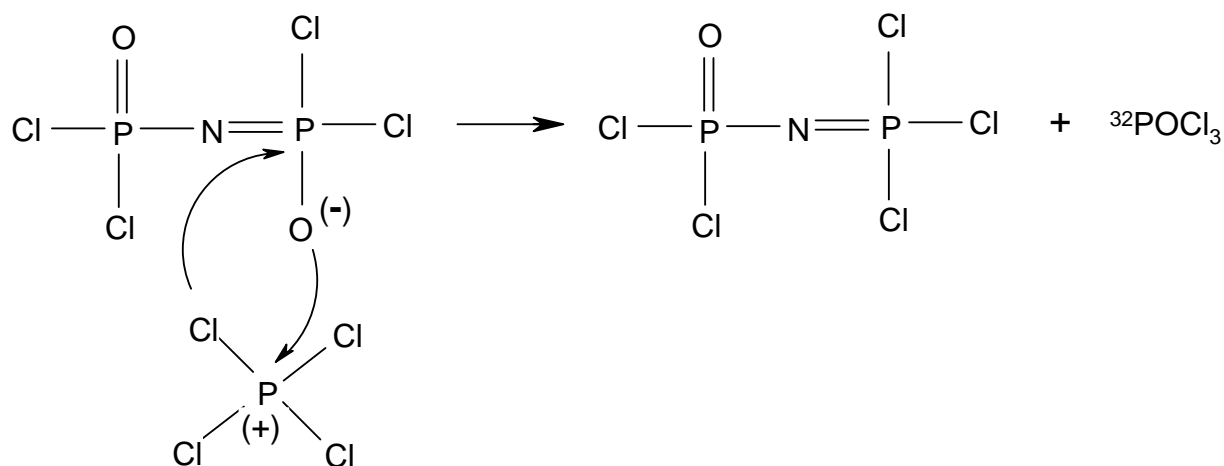
4.6 Calculate the solubility for  $\text{Mg}(\text{NH}_4)\text{PO}_4$  at pH equal to 10 under idealized conditions (activity coefficients can be neglected).

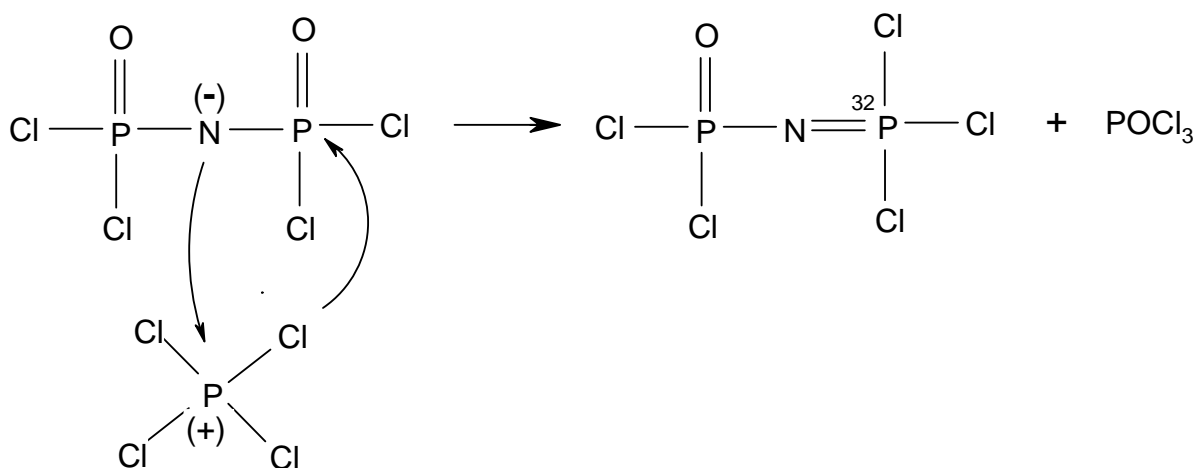
## SOLUTION



$$t = \frac{\ln A \ln A_0}{\lambda} = \frac{\ln 10^3}{\frac{\ln 2}{14.3}} \text{ d} = 142.5 \text{ d}$$

4.4





2nd mechanism

- 4.5 Specific activities  $A_{\text{sp}}(\text{II}) = 18.6 \text{ Bq/mg}$ ,  
 $A_{\text{sp}}(\text{III}) = 0.18 \text{ Bq/mg}$ ,  
 $A_{\text{sp}}(\text{IV}) = 18.5 \text{ Bq/mg}$ .

Because of  $A_{\text{sp}}(\text{II}) \approx A_{\text{sp}}(\text{IV})$  the first mechanism, proposed in d), is probable and therefore it is  $\text{PCl}_4^+$  that attacks the O-atom.

- 4.6 Given data:  $K_{\text{sp}} = [\text{Mg}^{2+}][\text{NH}_4^+][\text{PO}_4^{3-}] = 10^{-12.6}$ ;  $[\text{NH}_4^+] = 0.1$ ;  $\text{pH} = 10$ ;  $\text{p}K_1 = 2.2$ ;  
 $\text{p}K_2 = 7.2$ ;  $\text{p}K_3 = 12.4$ .

Exact solution:

$$2 [\text{Mg}^{2+}] + [\text{NH}_4^+] + [\text{H}_3\text{O}^+] = [\text{H}_2\text{PO}_4^-] + 2 [\text{HPO}_4^{2-}] + 3 [\text{PO}_4^{3-}] + [\text{OH}^-]$$

$$[\text{HPO}_4^{2-}] = \frac{[\text{PO}_4^{3-}][\text{H}^+]}{K_3}$$

$$[\text{H}_2\text{PO}_4^-] = \frac{[\text{HPO}_4^{2-}][\text{H}^+]}{K_2} = \frac{[\text{PO}_4^{3-}][\text{H}^+]^2}{K_2 K_3}$$

$$[\text{PO}_4^{3-}] = \frac{K_{\text{sp}}}{[\text{NH}_4^+][\text{Mg}^{2+}]}$$

$$\Rightarrow 2 [\text{Mg}^{2+}] = \left( \frac{[\text{H}^+]^2}{K_1 K_3} + \frac{2 [\text{H}^+]}{K_3} + 3 \right) \frac{K_{\text{sp}}}{[\text{NH}_4^+]} - [\text{Mg}^{2+}] ([\text{NH}_4^+] + [\text{H}^+] - [\text{OH}^-])$$

etc.

A simpler solution:

At pH = 10 the main component is  $\text{HPO}_4^{2-}$ :

$$[\text{HPO}_4^{2-}] = \frac{[\text{PO}_4^{3-}][\text{H}^+]}{K_3} = 10^{2.4} [\text{PO}_4^{3-}]$$

$$[\text{H}_2\text{PO}_4^-] = \frac{[\text{HPO}_4^{2-}][\text{H}^+]}{K_2} = 10^{-2.8} [\text{HPO}_4^{2-}]$$

$$S = [\text{Mg}^{2+}] [\text{HPO}_4^{2-}] \text{ and } K_{sp} = [\text{NH}_4^+] \times S \times K_3 \times \frac{S}{[\text{H}^+]}$$

$$pS = 0.5 (pK_{sp} + pH - pK_3 - p[\text{NH}_4^+]) = 0.5 (12.6 + 10.0 - 12.4 - 1.0) = 4.6;$$

$$S = 2.5 \times 10^{-5} \text{ mol dm}^{-3}$$



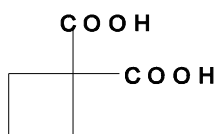
**PROBLEM 5**

Carboxylic acids are a chemically and biologically important class of organic compounds.

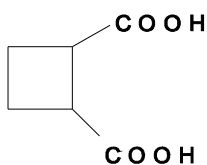
- 5.1 Draw the constitutional (structural) formulae of all isomeric cyclobutanedicarboxylic acids and give the systematic names for these compounds.
- 5.2 There are three stereoisomers, I, II and III, of cyclobutane-1,2-dicarboxylic acid. Draw perspective or stereo formulas of I, II and III indicating the relative configuration of each molecule.
- 5.3 Which pairs of stereoisomers I, II and III are diastereoisomers and which are enantiomers of each other?
- 5.4 Which reaction can be used to determine the relative configuration of diastereoisomers?
- 5.5 How may the enantiomers of cyclobutane-1,2-dicarboxylic acid be separated?
- 5.6 Indicate the absolute configurations of each asymmetric centre on the structures of the stereoisomers I, II and III using the Cahn-Ingold-Prelog rules (*R,S* system).

**SOLUTION**

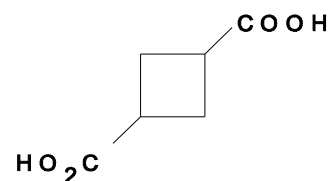
- 5.1 Constitutional isomers:



1,1 - cyclobutane -  
dicarboxylic acid

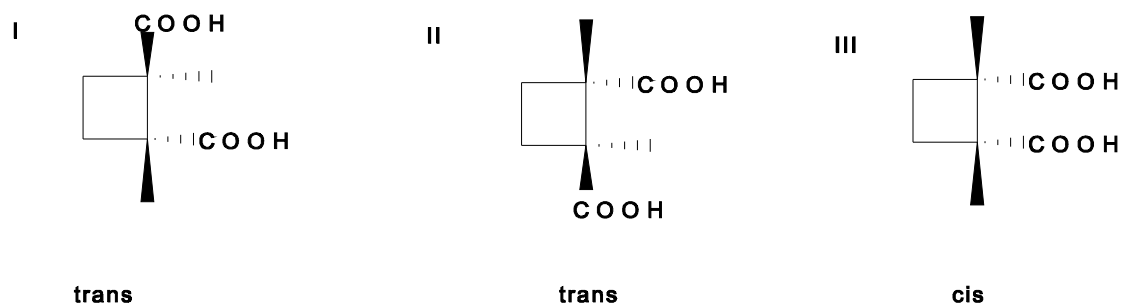


1,2 - cyclobutane -  
dicarboxylic acid



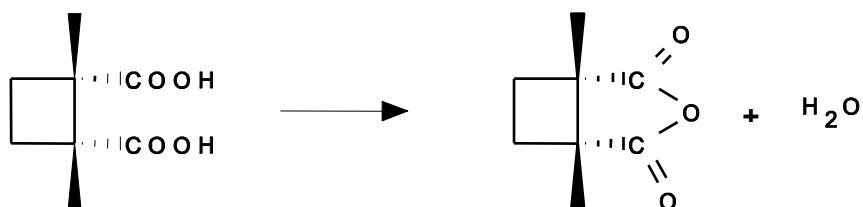
1,3 - cyclobutane -  
dicarboxylic acid

- 5.2 Stereoisomers:



5.3 Diastereomers are I, III and II, III. Enantiomeric pairs are I and II.

5.4 On losing water the *cis*-diastereomer forms the corresponding anhydride according to:



5.5 The *trans*-diastereomer can be precipitated with a optically active base.

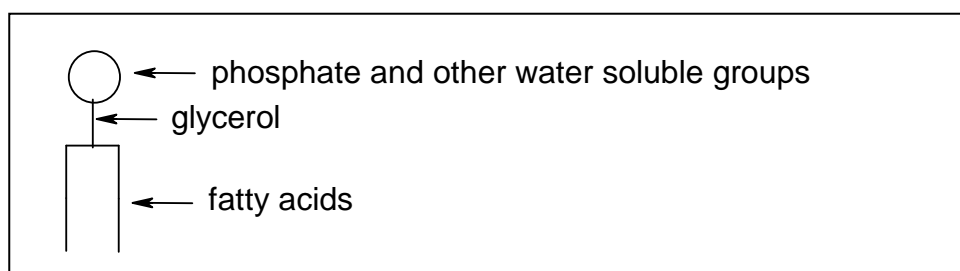
5.6 Stereoisomers absolute configuration:

I: *R,R*;    II: *S,S*;    III: *R,S*

**PROBLEM 6**

Fats (lipids) contain a non-polar (hydrophobic) and a polar (hydrophilic) group. The lipids insoluble in water, have important biological functions.

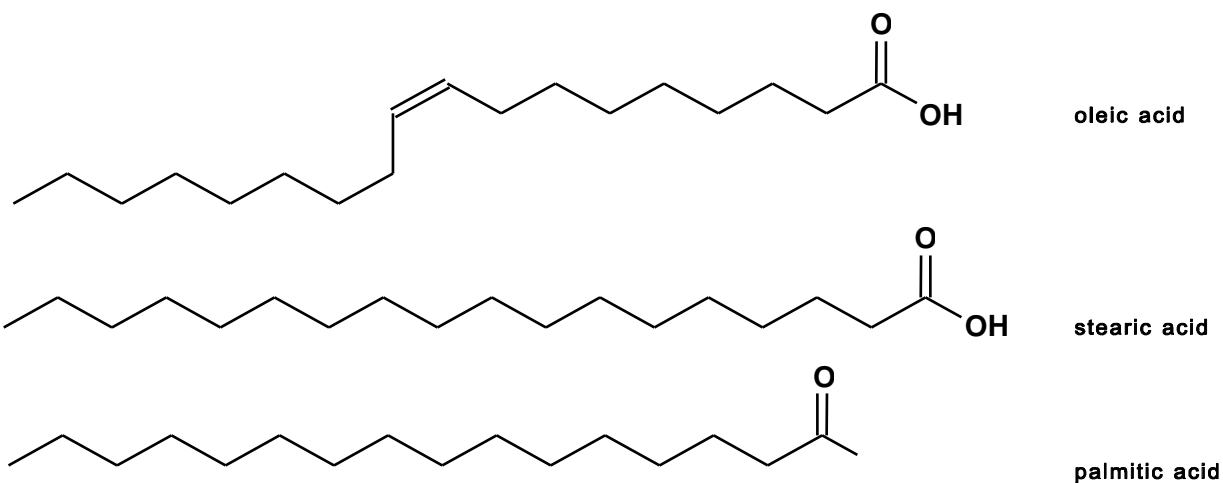
- 6.1 Draw the structures of *Z*-octadec-9-enoic acid (oleic acid), octadecanoic acid (stearic acid), and hexadecanoic acid (palmitic acid).
- 6.2 Using these three fatty acids in part 6.1 draw one possible structure of a triacyl glyceride.
- 6.3 Write the equation for the hydrolysis reaction of your triacyl glyceride in part 6.2 in aqueous NaOH solution. Give the mechanism of the hydrolysis of one of the fatty acids from your glyceride.
- 6.4 Which of the following fatty acids,  $C_{21}H_{43}COOH$ ,  $C_{17}H_{35}COOH$  or  $C_5H_{11}COOH$ , is the least soluble in water?
- 6.5 Phospholipids are an important class of bioorganic compounds. Draw the structure of the phosphatidic acid derived from your triacyl glyceride in part 6.2.
- 6.6 Phospholipids are frequently characterized by the diagram:



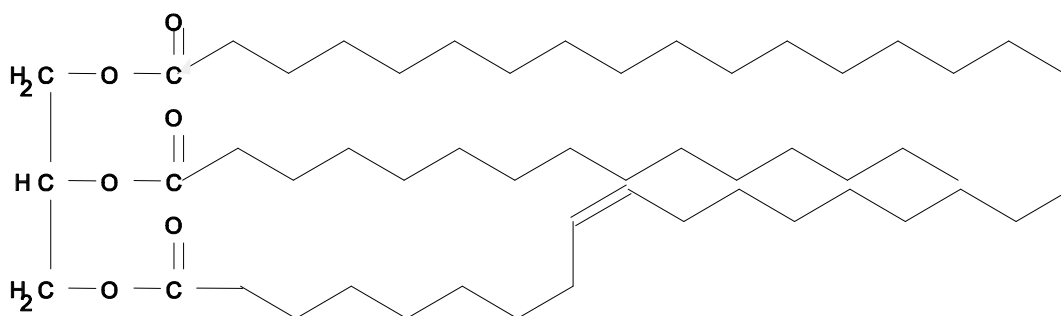
- Mark the hydrophilic and hydrophobic groups on a copy of the above diagram.
- Draw two possibilities for the association of six identical molecules of a phospholipid in water using the above diagram.
- Biomembranes consist of a phospholipid bi-layer. Draw such a model for a membrane using the above diagram.
- Such a model (iii) is incomplete. What other bio-macromolecules are contained in such biomembranes?

**SOLUTION**

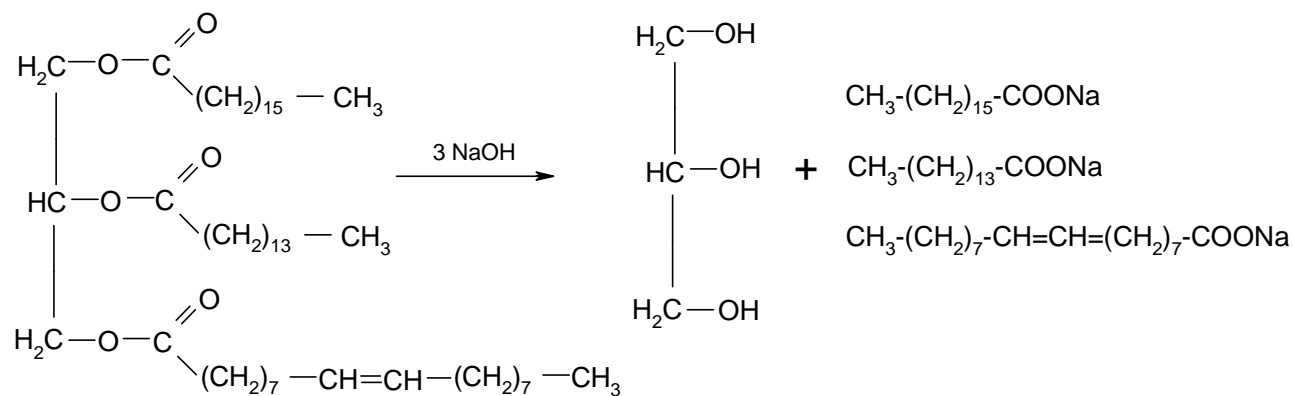
6.1

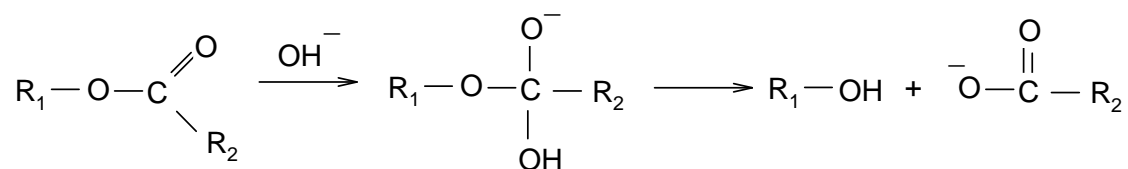


6.2 A possible structure of a triacyl glyceride with the fatty acids mentioned is:



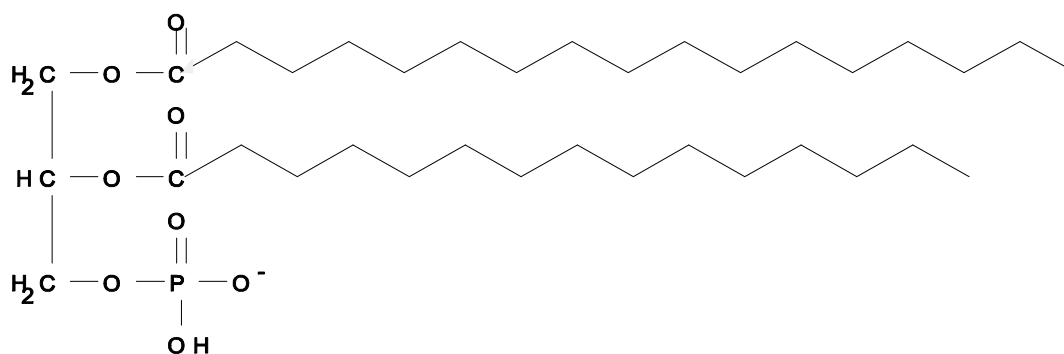
6.3



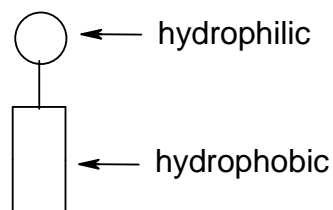


6.4 It is C<sub>21</sub>H<sub>43</sub>COOH.

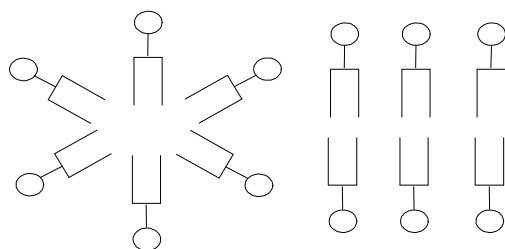
6.5 An example for a phospholipid is:



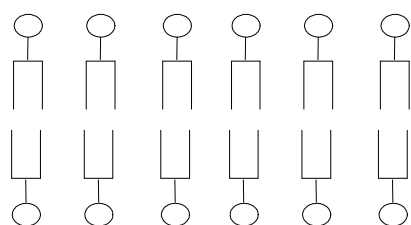
6.6 i)



ii)



iii)



phospholipid bilayer

iv) For example, proteins (enzymes)

**PRACTICAL PROBLEMS****PROBLEM 1 (Practical)****Synthesis**

Preparation of 2-Ethanoxybenzoic Acid (Acetylsalicylic Acid, also known as Aspirin) by Ethanoylation (Acetylation) of 2-Hydroxybenzoic Acid (Salicylic Acid) with Ethanoic Anhydride (acetic anhydride).

Relative atomic masses: C: 12.011; O: 15.999; H: 1.008

*Reagents*

2-hydroxybenzoic acid (melting point 158 °C)

Ethanoic anhydride (boiling point 140 °C)

Phosphoric acid (85 % H<sub>3</sub>PO<sub>4</sub>)

Ethanol

Deionised/distilled water

*Procedure*

In a 100 cm<sup>3</sup> Erlenmeyer flask mix 2.760 g of 2-hydroxybenzoic acid (from weighing bottle A) with 5.100 g of ethanoic anhydride (from flask B), and with cautious swirling add 5 – 7 drops of 85 % phosphoric acid. Heat the flask to 70 – 80 °C in a beaker of near boiling water and maintain the mixture at this temperature for 15 minutes. Remove the flask from the water bath and, with gentle swirling, add dropwise 1 cm<sup>3</sup> of deionised water to the still hot flask; then immediately add 20 cm<sup>3</sup> of the cold deionised water all at once to the reaction flask. Place the flask in an ice bath. If no crystals are deposited, or if oil appears, gently scratch the inner surface of the flask with a glass rod while the flask remains in the ice bath.

Using a Büchner funnel, filter the product under suction. Rinse the flask twice with a small amount of cold deionised water. Recrystallize the crude product in the 100 cm<sup>3</sup> Erlenmeyer flask using suitable amounts of water and ethanol. If no crystals form or if oil appears, scratch gently the inner surface of the flask with a glass rod. Filter the crystals under suction and wash with a small amount of cold deionised water. Place the

crystals on the porous plate to draw water from them. When the crystals have been air dried, transfer the product to the small glass dish labeled C. This dish has previously been weighed. The dish containing the product should be given to a technician who will dry it in an oven for 30 minutes at 80 °C.

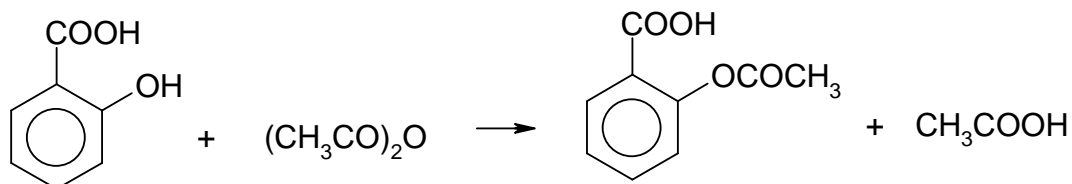
A technician should then weigh the cooled dish containing your product in your presence. Record the mass. The melting point will subsequently be taken by a technician to check the purity of your product.

Questions:

1. Write the balanced chemical equation for the reaction using structural formulae.
2. What is the percentage yield?

## SOLUTION

1.



**PROBLEM 2 (Practical)****Analysis**

Determination of Mass of a given Sample of 2-Ethanoyl-oxybenzoic Acid (Acetylsalicylic Acid, or Aspirin) by Volumetric Back Titration after Hydrolysis with Excess of Sodium Hydroxide.

**Reagents**

Aqueous solution of sodium hydroxide (about  $0.5 \text{ mol dm}^{-3}$ )

Standard aqueous solution of hydrochloric acid ( $0.4975 \text{ mol dm}^{-3}$ )

Ethanolic phenolphthalein solution (indicator dropping bottle II)

Deionised/distilled water

**Part 1:**

Determine accurately the concentration of the about  $0.5 \text{ mol dm}^{-3}$  sodium hydroxide solution using the standard hydrochloric acid solution. (Record the answer as  $\text{mol dm}^{-3}$  with four places after decimal point.)

**Procedure:**

Pipette  $20.00 \text{ cm}^3$  of the sodium hydroxide solution into a  $300 \text{ cm}^3$  Erlenmeyer flask and dilute it to about  $100 \text{ cm}^3$  with deionized water. Titrate the obtained solution with the standard  $0.4975 \text{ mol dm}^{-3}$  hydrochloric acid solution using the phenolphthalein indicator. Repeat the procedure to produce three acceptable values and calculate the mean volume.

**Part 2:**

Determine accurately the mass of aspirin in Erlenmeyer flask I. Record your answer in g with three places after the decimal point.

**Procedure:**

Pipette  $50.00 \text{ cm}^3$  of your standardized sodium hydroxide solution into the Erlenmeyer flask I (with a ground glass joint) which contains your unknown mass of aspirin. Add 3 – 5 boiling stones to the flask and boil the reaction mixture for 15 minutes using a reflux condenser and the electrical hot plate. After cooling, remove the reflux



condenser and rinse it with a small quantity of deionised water into Erlenmeyer flask I. Pour the whole solution into a 100.0 cm<sup>3</sup> volumetric flask and fill it exactly to the mark with deionised water. Pipette 20.00 cm<sup>3</sup> of this solution into a 300 cm<sup>3</sup> Erlenmeyer flask and dilute to about 100 cm<sup>3</sup> with deionised water. Back titrate the residual sodium hydroxide with the standard hydrochloric acid solution (0.4975 mol dm<sup>-3</sup>) using a 10 cm<sup>3</sup> burette and phenolphthalein indicator. Repeat the volumetric procedure to produce three acceptable values and calculate the mean volume.

*Questions:*

- 1) Write the balanced chemical equation for the ester hydrolysis of aspirin by sodium hydroxide using structural formulae. Note that 1000 cm<sup>3</sup> aqueous solution of 0.5000 mol dm<sup>-3</sup> sodium hydroxide is equivalent to 0.0450 g of aspirin.
- 2) Calculate the mass of aspirin that you were given.

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## SOLUTION

1.

