EUROPEAN BACCALAUREATE 2013

CHEMISTRY

DATE: 11 June 2013

DURATION OF THE EXAM :

3 hours (180 minutes)

PERMITTED EQUIPMENT :

Calculator used in mathematics, in 'Press-to-Test' mode

or

Calculator (non-programmable and non-graphing)

INSTRUCTIONS :

- Answer two A questions and two B questions.
- Indicate which four questions you have answered by putting crosses in the appropriate place on the sheet supplied.
- Use a separate answer sheet for each of the four main questions.

Question A1

Page 1/3 | **Marks**

a) Ascorbic acid, known as vitamin C, is present in many fruits and vegetables.

A prolonged deficiency in vitamin C can lead to scurvy, a disease which particularly leads to loss of teeth.

For simplicity, ascorbic acid, which has the molecular formula $C_6H_8O_6$, will be depicted as the monoprotic acid HA.

i. Give the definition of an acid according to Brønsted-Lowry theory. — 1 mark

ii. Write the equation for the reaction of HA with water. — 2 marks

iii. Give the expression for the acid dissociation constant, K_a, for HA(aq). — 1 mark

b) The pH of a solution of ascorbic acid, HA(aq), is 2.00.

Calculate the ratio $\frac{[A^-(aq)]}{[HA(aq)]}$ at equilibrium and deduce which of the two species is predominant in this solution. — 3 marks

Given: pK_a of HA(aq) = 4.10

c) During a practical session a student determined the average amount (percentage by mass) of ascorbic acid in one tablet in a certain brand of vitamin supplements.

She used the following method :

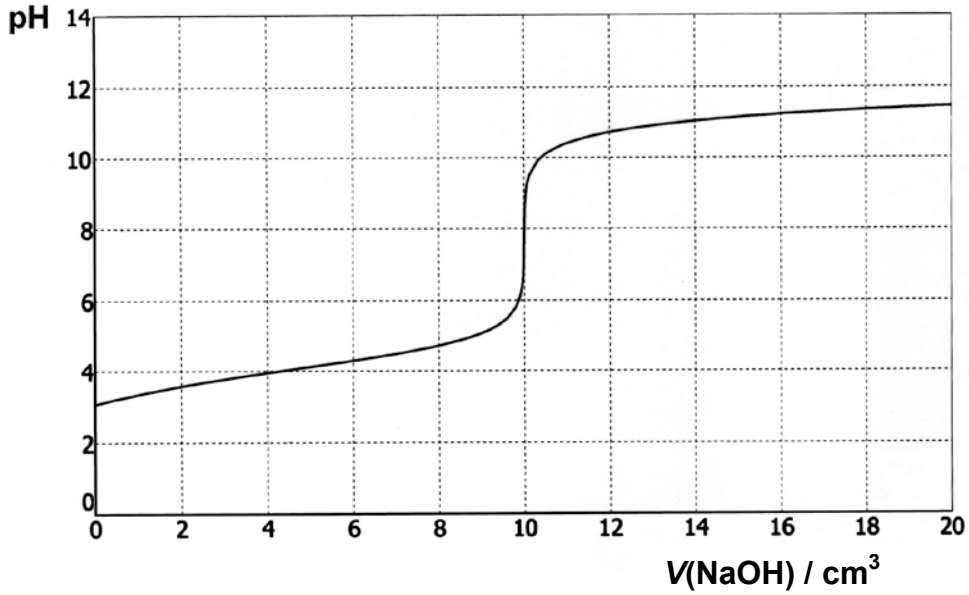
- She dissolved **five** tablets, with a total mass of 2.50 g, in distilled water and made up the total volume of the solution to exactly 1.00 dm^3 at a temperature of 25 °C.
- She titrated 20.0 cm^3 of this solution with a 1.00 x 10^{-2} mol dm^{-3} aqueous solution of sodium hydroxide, NaOH(aq), and followed the reaction with a pH meter.

i. Give two reasons to explain why is it sensible to carry out the titration using a solution prepared from several tablets of this brand of vitamin supplements. — 2 marks

Question A1

Page 2/3 | **Marks**

The titration graph below shows the change in pH as a function of volume of sodium hydroxide solution added, *V*(NaOH).



With the aid of this titration graph, determine:

ii. the initial pH of the titrated solution. — 1 mark

iii. the pH at the half-equivalence point. — 1 mark

iv. the pH at the equivalence point. — 1 mark

v. the most appropriate indicator, from the following, for this titration. Justify your choice. — 2 marks

Indicator	pH range
Bromophenol blue	3.0 – 4.6
Cresol red	7.2 – 8.8
Alizarin yellow	10.2 – 12.0.

By carrying out the necessary calculations, determine:

vi. the initial molar concentration of ascorbic acid in the titrated solution. — 2 marks

vii. the initial mass (in g) of ascorbic acid in 1.00 dm^3 of the titrated solution. — 2 marks

Question A1	
Page 3/3	**Marks**
viii. the mass (in g) of ascorbic acid on average in **one** tablet of this brand of vitamin tablets.	1 mark
ix. the average percentage by mass of ascorbic acid in **one** tablet of this brand of vitamin supplements.	1 mark
Given: Molar atomic masses (g mol^{-1}): H : 1.01 C : 12.0 O : 16.0	
d) Certain tablets of vitamin C come in effervescent form. They contain a mixture of ascorbic acid, HA(s) and sodium hydrogencarbonate, $NaHCO_3(s)$. The effervescence occurs when the tablet is dissolved in water. This is the result of a reaction which takes place between these two constituents.	
i. Give the equation for this reaction.	2 marks
ii. Identify the gas responsible for the effervescence.	1 mark
iii. Identify the two acid-conjugate base couples concerned.	2 marks

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Question A2

	Page 1/3	Marks
a)	Calcium ions, $Ca^{2+}(aq)$, are involved in the biochemical mechanisms associated with blood clotting. Calcium oxalate, $CaC_2O_4(s)$, is a salt which is insoluble in water. Use is made of this property when determining the amount of calcium ions, $Ca^{2+}(aq)$, present in blood. The following method is used to determine this amount: • The calcium ions are extracted from blood serum by precipitating them as calcium oxalate. • The precipitate of calcium oxalate, is reacted with a strong acid which converts it into a soluble calcium salt and oxalic acid, $H_2C_2O_4(aq)$. The solution obtained is colourless. • The oxalic acid released during the course of this reaction is titrated with an acidified solution of potassium permanganate, $KMnO_4(aq)$. During this titration manganese(II) ions, $Mn^{2+}(aq)$, and carbon dioxide, $CO_2(g)$, are formed. It was established that the titration of the oxalic acid obtained from one 5.00 cm^3 sample of blood required 24.2 cm^3 of 2.00 x 10^{-4} mol dm^{-3} potassium permanganate solution.	
i.	Give the two half-equations and the overall redox equation for the reaction taking place during the titration.	3 marks
ii.	Describe the observation which shows that the equivalence point has been reached during the titration.	1 mark
iii.	Calculate the initial amount (in mol) of oxalic acid, present in the titrated sample.	2 marks
iv.	Calculate the concentration by mass of calcium ions, expressed in mg cm^{-3}, in the blood serum.	2 marks
	Given: Molar atomic mass (g mol^{-1}): Ca : 40.0	

Question A2

Page 2/3 | **Marks**

b) Iodine, I_2, in either aqueous or alcoholic solution, is used as disinfectant in surgery.
Oxalic acid, $H_2C_2O_4(aq)$, can be used to remove iodine stains on surgical material and clothing.

The reaction between oxalic acid and iodine produces carbon dioxide, $CO_2(g)$, and iodide ions, $I^-(aq)$.

i. Determine the oxidation numbers of carbon and iodine in the following species : — 2 marks

$$\mathbf{H_2C_2O_4} \qquad \mathbf{CO_2} \qquad \mathbf{KI} \qquad \mathbf{I_2}$$

ii. Give the half-equation for the conversion of iodine, $I_2(aq)$, into iodide ions and the overall equation for the redox reaction between iodine and oxalic acid . — 3 marks

iii. Explain why iodine is only slightly soluble in water but very soluble in many organic solvents such as octane, $C_8H_{18}(l)$. — 2 marks

iv. Refer to the table of standard electrode potentials below to choose **one** reactant that could theoretically be used instead of oxalic acid to remove iodine stains. Justify your choice and give the equation for the half-reaction that involves your chosen reactant. — 3 marks

Redox couple	$E^\ominus$ / V
$Cl_2(aq) / Cl^-(aq)$	+ 1.36
$O_2(g) / H_2O(l)$	+ 1.23
$I_2(aq) / I^-(aq)$	+ 0.54
$ClO^-(aq) / Cl_2(aq)$	+ 0.42
$S_4O_6^{2-}(aq) / S_2O_3^{2-}(aq)$	+ 0.08

Question A2

Page 3/3 | **Marks**

c) A solution of potassium iodide, KI(aq), was electrolysed using inert electrodes.

i. Give the half-equations for the reactions occurring at each electrode and specify the polarity of the electrode concerned. — 3 marks

ii. What is the minimum theoretical voltage that must be applied in order for the electrolysis to occur? — 1 mark

iii. Calculate the volume of hydrogen gas, $H_2(g)$, that will be obtained when a current of 2.00×10^{-1} A is passed for 30.0 minutes. — 3 marks

Given :

Standard redox potentials:

Redox couple	$E^{\ominus}$ / V
$O_2(g) / H_2O(l)$	+ 1.23
$I_2(aq) / I^-(aq)$	+ 0.54
$H_2O(l) / H_2(g)$	− 0.83
$K^+(aq) / K(s)$	− 2.92

1 Faraday (F) = 9.65×10^4 C mol^{-1}

Molar volume of a gas measured under the conditions of the experiment = 24.5 dm^3 mol^{-1}.

Question A3

Page 1/3 | **Marks**

a) Methanoic acid, HCOOH(aq), commonly known as formic acid, is present in the venom of ants in proportions ranging from 25 to 72% by mass, depending upon the species of ant.

i. Show that an aqueous solution of methanoic acid containing 72 g of methanoic acid in 100 cm^3 of solution has a concentration of approximately 16 mol dm^{-3}. — 2 marks

A dilute solution of ammonia, $NH_3(aq)$, can be used to relieve the effect of ant bites.

ii. Explain this property and give the corresponding equation. — 2 marks

iii. Calculate the mass of ammonia required to prepare 100 cm^3 of an aqueous solution with a pH of 11.4. — 4 marks

Given: Molar atomic masses (g mol^{-1}):
H : 1.01 C : 12.0 N: 14.0 O : 16.0
pK_b of ammonia = 4.75
pK_w of water = 14.0

b) When calculating the pH of an aqueous solution of methanoic acid with an initial concentration of 1.00 x 10^{-1} mol dm^{-3} it is usual to approximate that the equilibrium concentration of the methanoic acid is unchanged at 1.00 x 10^{-1} mol dm^{-3}.

i. Explain qualitatively why the use of this approximation is justified. — 2 marks

ii. Calculate the pH of 1.00 x 10^{-1} mol dm^{-3} methanoic acid. — 2 marks

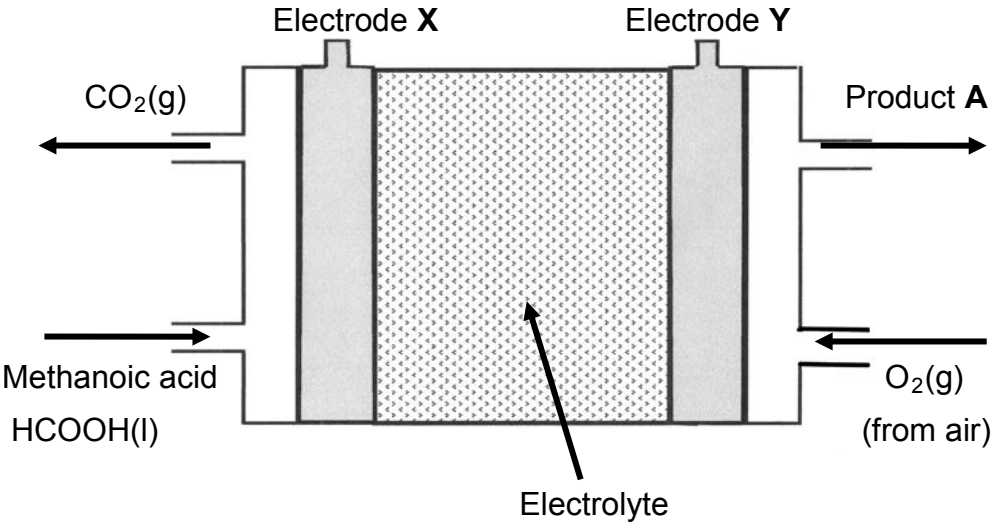
Given : K_a of methanoic acid = 1.78 x 10^{-4}.

Question A3	
Page 2/3	**Marks**

c) A fuel cell using methanoic acid is constructed.

Methanoic acid has several advantages over using traditional fuels such as methanol or hydrogen. It is less toxic than methanol and is easier to store than hydrogen.

The diagram below represents a simplified version of a functioning fuel cell which uses methanoic acid.



i. Determine the oxidation number of carbon in methanoic acid, HCOOH. — 1 mark

ii. Knowing that carbon dioxide is formed at electrode **X**, give the half equation for the reaction which produces it, and state whether this is an oxidation or reduction process. — 2 marks

iii. State the polarity of electrode **X** and explain your answer. — 1 mark

iv. Give the half-equation for the reaction taking place at electrode **Y** and identify product **A**. — 3 marks

Question A3

Page 3/3	Marks
v. Identify the chemical species which is transferred from one electrode to the other through the electrolyte, and state the direction of its movement.	2 marks
vi. Give the overall equation for the reaction taking place in the working cell.	1 mark
vii. Calculate the e.m.f. of the cell when it is functioning under standard conditions.	1 mark
viii. Knowing that the fuel cell consumes 1.00 x 10^{-1} g of methanoic acid per hour determine the current (in mA) produced by the cell.	2 marks

Given : The standard redox potentials of the relevant couples.

Redox couple	E^{θ} / V
$O_2(g)$ / $H_2O(l)$	+ 1.23
$CO_2(g)$ / HCOOH(l)	− 0.20

1 Faraday (F) = 9.65 x 10^4 C mol^{-1}

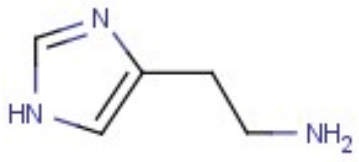
Question B1

Page 1/2	Marks
a) Propanone, also known as acetone, is a constituent of some nail varnish removers.	
i. Give the structural formula of propanone.	1 mark
ii. Give the structural formulas of the two isomeric alcohols with the molecular formula C_3H_8O.	2 marks
iii. State the name of the isomer that can be oxidised to propanone and name the two possible organic oxidation products of the other isomer.	3 marks
b) Four carboxylic acids have the molecular formula $C_5H_{10}O_2$.	
i. Give the structural formula of the isomer which is chiral and identify its asymmetric carbon atom with an asterisk (∗).	2 marks
Two of the four acids considered in this question are valeric acid and isovaleric acid.	
$CH_3CH_2CH_2CH_2COOH$ **Valeric acid**	**$(CH_3)_2CHCH_2COOH$** **Isovaleric acid**
ii. Give the IUPAC name of isovaleric acid.	1 mark
The boiling points of valeric acid and isovaleric acid are 186°C and 176°C respectively.	
iii. Explain the difference between the boiling points.	2 marks
Valeric acid and isovaleric acid occur in the roots of the medicinal plant valerian. They can be extracted using an aqueous solution of sodium carbonate, $Na_2CO_3(aq)$.	
iv. Give the equation for the reaction between valeric acid and sodium carbonate.	2 marks

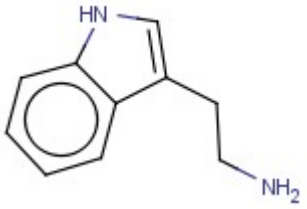
Question B1	
Page 2/2	**Marks**
Isovaleric acid is produced in the human body as a result of amino acid metabolism. It can cause feet to smell bad.	
v. Calculate the concentration of isovaleric acid (in mol dm^{-3}) if 5.00×10^{-6} dm^3 of liquid isovaleric acid is vaporised in 80.0 dm^3 of air at 20.0 ^oC at a pressure of one atmosphere.	3 marks
Given : Molar atomic masses (g mol^{-1}): H : 1.01 C : 12.0 O : 16.0	
Density of liquid isovaleric acid = 9.50×10^{-1} kg dm^{-3} at 20.0 ^oC, 1 atm.	
Carboxylic acids react with alcohols to form esters, which can be used in flavourings and perfumes.	
vi. Give the equation for the reaction between valeric acid and ethanol using simplified structural formulas.	2 marks
vii. State the necessary conditions for this esterification reaction.	2 marks
viii. Describe the mechanism of this reaction by using appropriate equations and by using curly arrows to show the movement of electron pairs.	3 marks
ix. Show how the isotope ^{18}O can be used to support this mechanism.	2 marks

Question B2	
Page 1/2	**Marks**

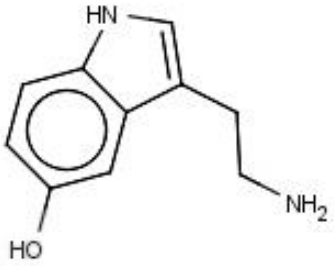
a) Biogenic amines are a group of substances that are present in several foods e.g. smoked salmon and chocolate. Lack of the enzyme diamino oxidase, known by the acronym of DAO, can produce problems breaking down biogenic amines. This can lead to high concentrations of histamine, which can cause an allergic reaction.



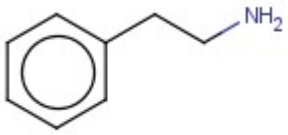
Histamine



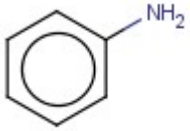
Tryptamine



Serotonin

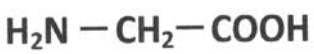
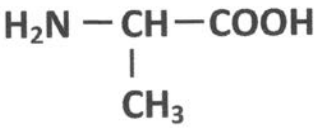


Phenylethylamine



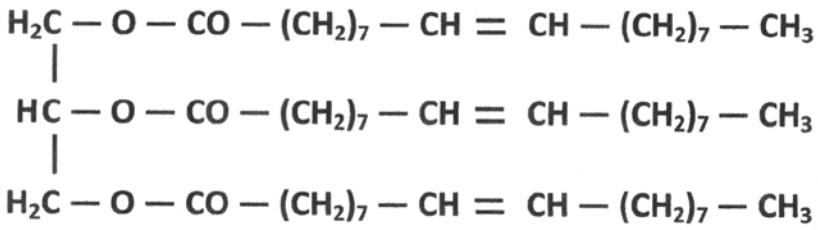
Phenylamine or **aniline**

i.	Describe the difference between a primary amine, a secondary amine and a tertiary amine.	3 marks
ii.	Copy the formula for tryptamine, circle and name the two types of amine present in the molecule.	2 marks
iii.	Compared to tryptamine, serotonin has another functional group. Name this functional group.	1 mark
iv.	Explain why histamine is more soluble in water than phenylethylamine.	2 marks
v.	Explain why phenylethylamine is a stronger base than phenylamine.	2 marks

Question B2	
Page 2/2	**Marks**
b) The structural formulas of glycine and alanine are given below.  **Glycine**  **Alanine**	
i. Give the IUPAC names for glycine and alanine.	2 marks
ii. The iso-electric point for glycine is 5.97. Give the structural formula of the predominant form of glycine at pH 2.00 and explain your answer.	2 marks
One of the two amino acid molecules above is chiral	
iii. Define the term *chiral* and identify which of the two amino acid molecules is chiral.	2 marks
iv. Describe how the enantiomers of a chiral amino acid can be distinguished practically.	2 marks
v. Give the structural formulas of the two possible dipeptides which can be formed when one molecule of glycine and one molecule of alanine react together.	2 marks
c) A polyamide is formed by the reaction between 1,6-diaminohexane and hexane-1,6-dioic acid.	
i. Give the structural formulas of 1,6-diaminohexane and hexane-1,6-dioic acid.	2 marks
ii. Give the structural formula of the repeating unit in this polymer.	2 marks
iii. State the common name of this polyamide.	1 mark

Question B3	
Page 1/3	**Marks**

a) One of the principle constituents of animal fat is glyceryl trioleate (or triolein).



Glyceryl trioleate

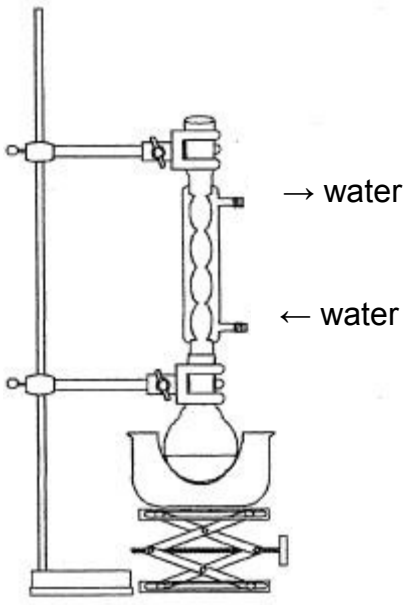
Hydrolysis of this fat with an excess of a solution of potassium hydroxide, KOH(aq) produces potassium oleate.

i. Give the equation for this reaction using structural formulas. — 2 marks

This preparation of soap is carried out in two stages.

Stage 1: Production of the potassium oleate
Stage 2: Extraction and purification

During the first stage the following apparatus is used :



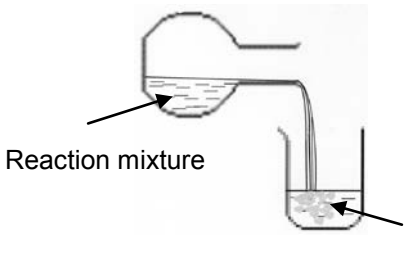
Reflux apparatus

ii. Suggest two advantages of using the reflux apparatus. — 2 marks

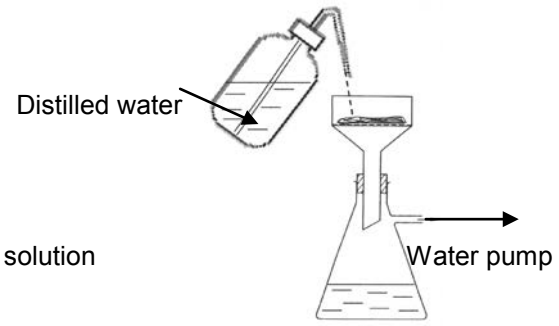
Question B3

Page 2/3 | **Marks**

In the second stage the reaction mixture is added to a salt solution. The precipitate formed is then filtered under reduced pressure, washed with a small amount distilled water, and then dried.



Extraction of potassium oleate as a precipitate



Washing the potassium oleate precipitate

iii. Using the information given in the table below explain why salt solution is used in the second stage and not ethanol. — 2 marks

	Glyceryl trioleate	**Potassium hydroxide**	**Potassium oleate**
Solubility in distilled water	insoluble	soluble	soluble
Solubility in ethanol	soluble	soluble	soluble
Solubility in salt solution	insoluble	soluble	slightly soluble

iv. Explain why distilled water is used to wash the precipitate and why as small amount of distilled water as possible should be used. — 2 marks

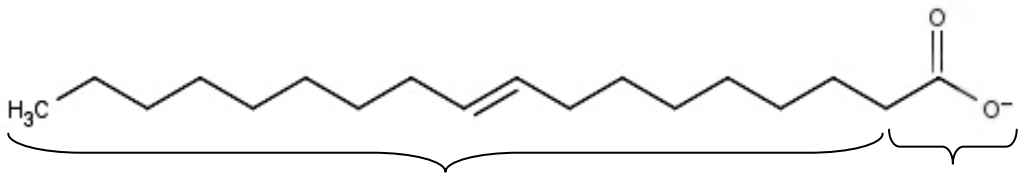
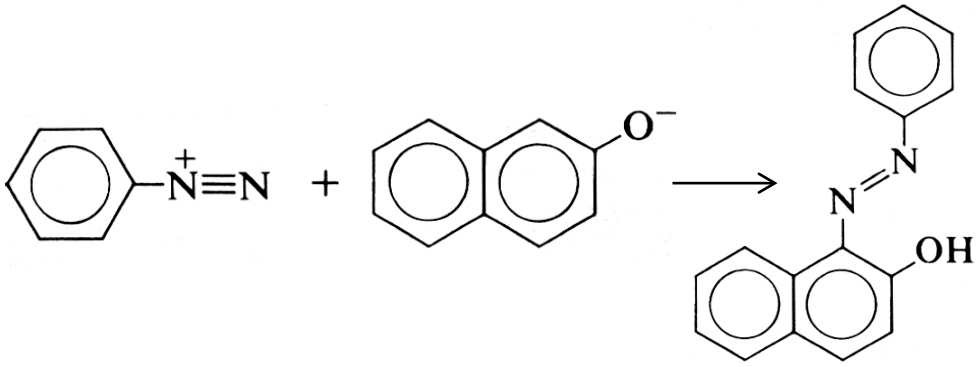
v. Calculate the maximum mass of potassium oleate (in g) that can be obtained during the saponification of 8.85 g of glyceryl trioleate. — 2 marks

vi. Knowing that 8.64 g of potassium oleate were formed calculate the percentage yield by mass of this saponification reaction. — 1 mark

Given : Molar molecular masses (g mol^{-1}): Glyceryl trioleate = 885

Molar atomic masses (g mol^{-1}):

H : 1.01 C : 12.0 O : 16.0 K : 39.1

Question B3	
Page 3/3	**Marks**
b) The oleate ion can be represented as:  **Part 1** **Part 2**	
i. Explain why **Part 1** is hydrophobic and why **Part 2** is hydrophilic.	2 marks
ii. Explain the cleaning action of soap. Support your explanation with relevant diagrams.	3 marks
iii. Explain what happens when a solution of potassium oleate is added to hard water and give the relevant equation.	3 marks
c) Compound **C** is a red compound formed in the following reaction  **Compound A** **Compound B** **Compound C**	
i. Name the group of dyes that compound **C** belongs to.	1 mark
ii. Name three functional groups present in a molecule of compound **C.**	3 marks
iii. Give two reasons to explain why Compound **C** is coloured.	2 marks