CHURCHLANDS SENIOR HIGH SCHOOL

CHEMISTRY
UNIT 3 & 4
2017

MARKING GUIDE

Section One: Multiple-choice **25% (50 marks)**

1	a □ b □ c ■ d □
2	a ■ b □ c □ d □
3	a □ b □ c ■ d □
4	a □ b □ c ■ d □
5	a □ b □ c ■ d □

11	a □ b □ c ■ d □
12	a □ b □ c ■ d □
13	a □ b □ c □ d ■
14	a □ b □ c ■ d □
15	a □ b ■ c □ d □

21	a □ b □ c ■ d □
22	a □ b □ c □ d ■
23	a □ b ■ c □ d □
24	a □ b □ c □ d ■
25	a □ b ■ c □ d □

6	a □ b ■ c □ d □
7	a □ b ■ c □ d □
8	a ■ b □ c □ d □
9	a □ b □ c □ d ■
10	a □ b □ c □ d ■

16	a □ b □ c ■ d □
17	a □ b □ c □ d ■
18	a □ b ■ c □ d □
19	a □ b □ c □ d ■
20	a □ b □ c ■ d □

(2 marks per question)

Name: ____________________

Teacher (Circle): **COUMBE ELIAS/POLAND HARVEY POLAND SMITHIES**

Section Two: Short answer **35% (70 marks)**

This section has **eight (8)** questions. Answer **all** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

Suggested working time: 60 minutes.

Question 26 **(7 marks)**

Nitrosyl bromide ($NOBr_2$) decomposes and reaches equilibrium according to the equation below.

$$2NOBr_2(g) \rightleftharpoons 2NO(g) + 2Br_2(g) \qquad \Delta H < 0$$

The correct equation is as follows:

$$2NOBr(g) \rightleftharpoons 2NO(g) + Br_2(g) \qquad \Delta H < 0$$

(a) Write the equilibrium expression for this reaction. (1 mark)

As the equation was incorrect, the following expressions were acceptable:

$$K = \frac{[NO]^2[Br_2]}{[NOBr_2]^2}$$ **(1)**

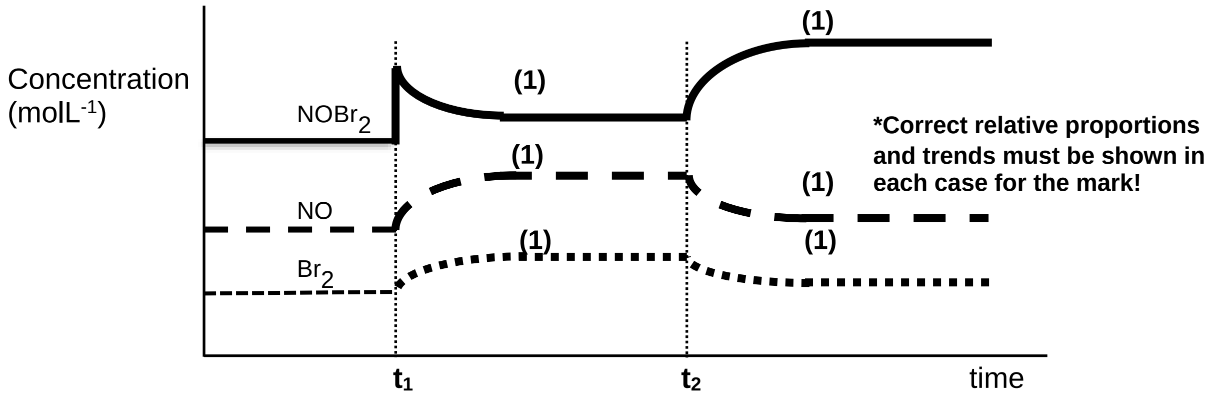
$$K = \frac{[NO]^2[Br_2]^2}{[NOBr_2]^2}$$ **(1)**

$$K = \frac{[NO][Br_2]}{[NOBr_2]}$$ **(1)**

(b) A number of changes were imposed on the equilibrium mixture, as described in (i) and (ii) below. Show the effects of these changes by extending the lines accordingly on the diagram below, as the system re-establishes a new equilibrium in each case.

(i) A quantity of $NOBr_2$ was introduced into the vessel at time $\mathbf{t_1}$, at constant temperature. (3 marks)

(ii) At time $\mathbf{t_2}$, the temperature in the reaction vessel was increased. (3 marks)



Question 27 **(12 marks)**

(a) Calculate the pH of a solution of 0.250 molL^{-1} nitric acid. (2 marks)

$[H^+]$ = $[HNO_3]$ = 0.250 molL^{-1} (1)

pH = -log$[H^+]$ = -log(0.250) = 0.602 (1)

(b) A student was asked to dilute 25.0 mL of this solution to produce a solution of nitric acid with a pH of 1.50. Calculate the volume of distilled water that she would need to add. (4 marks)

$[H^+]$ = pH$^{-1.5}$ = 3.1623 x 10^{-2} molL^{-1} (1)

c_1 x V_1 = c_2 x V_2
(0.25 x 0.025) = (3.1623 x 10^{-2}) x V_2 (1)
V_2 = 0.198 L (1)

Volume of water to add = 0.198 – 0.025 = 0.173 L or 173 mL (1)

(c) Another 25.0 mL sample of the original nitric acid solution was combined with 1.30g of KOH. Calculate the pH of the final mixture. (Assume no change to the volume). (6 marks)

HNO_3 (aq) + KOH (s) $\longrightarrow$ KNO_3 (aq) + H_2O (ℓ)

n(HNO_3) = cV = (0.250)(0.025) = 0.00625 mol (1)

n(KOH) = m/M = 0.02317 mol (1)

Thus n(KOH) excess = 0.02317 – 0.00625 = 0.0169 mol (1)

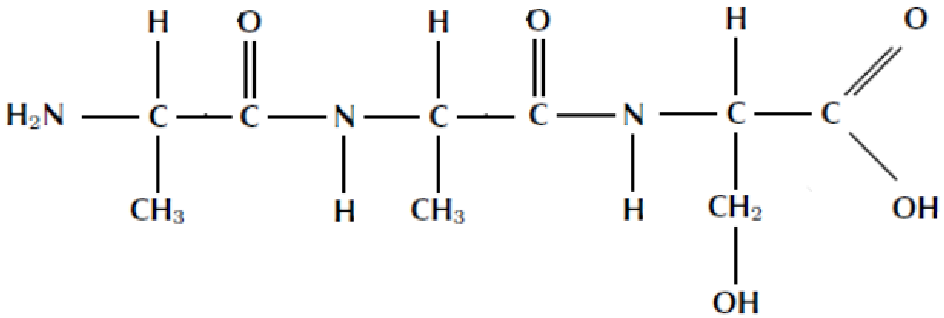
$[OH^-]$ = [KOH] = n/V = 0.0169/0.025 = 0.6768 molL^{-1} (1)

Hence $[H^+]$ = 10^{-14} / 0.6768 = 1.478 x 10^{-14} molL^{-1} (1)

pH = -log$[H^+]$ = -log(1.478 x 10^{-14}) = 13.8 (1)

Question 28 **(11 marks)**

Examine the following polypeptide structure.



(a) With reference to the structure shown above, complete the primary sequence of the amino acids in the spaces below using the standard three letter abbreviations, as given on the Chemistry Data Booklet. (One is done for you).

(2 marks)

ala – __**ala**__ – __**ser**__

(1) **(1)**

(b) With reference to relevant sections of the same structure shown above, describe what is meant by a peptide bond.

(1 mark)

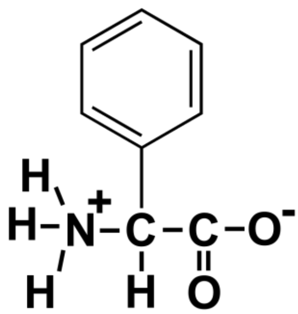
A peptide bond is the bond between the carbon atom in the (C=O) of one amino acid and a nitrogen atom in the (N-H) on an adjacent amino acid. (1)

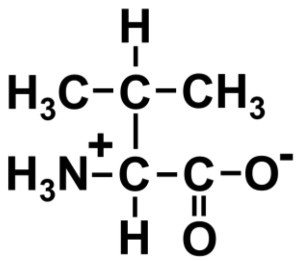
Valine is another amino acid which is commonly found in a range of different polypeptides. Like most amino acids, valine is able to self-ionise and produce a specialised structure called a zwitterion.

(c) Draw a diagram of valine in zwitterion form in the space below. (2 marks)

As there was a typo both structures below are accepted

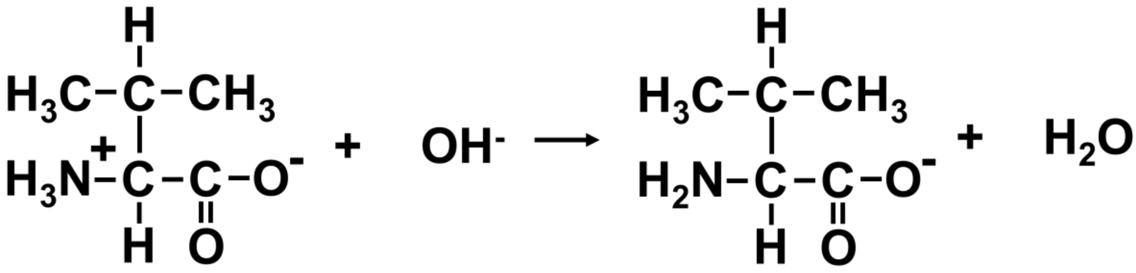
(1) both charges shown
(1) correct structure shown





(d) Making reference to the structure you have drawn above and with the aid of a relevant chemical equation, explain how the zwitterion is able to resist changes in pH when a small amount of **base** is introduced.

(3 marks)



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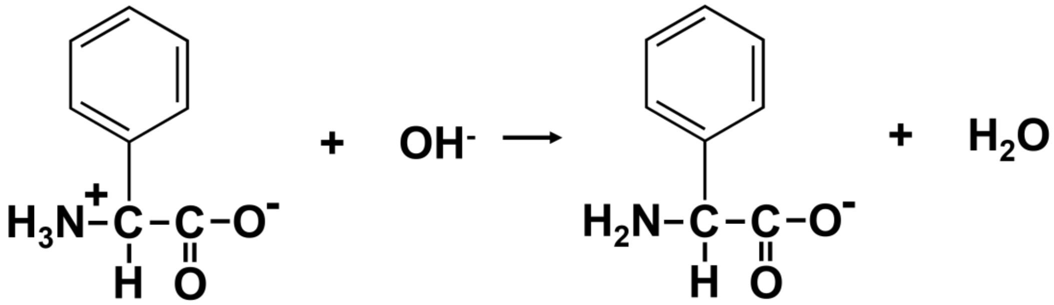


(1)

When a small amount of base (OH^-) is added, the zwitterion behaves as a proton donor, neutralising the OH^- ions and producing water. (1)

In this way the OH^- ions are 'absorbed' and the pH will not rise significantly. (1)

(e) Medical researchers are able to alter the primary sequence of amino acids in a protein and thus produce changes in their secondary and tertiary structures. Use relevant chemical theory to explain how these changes are produced and what effect they will have on the secondary and tertiary structures.

(3 marks)

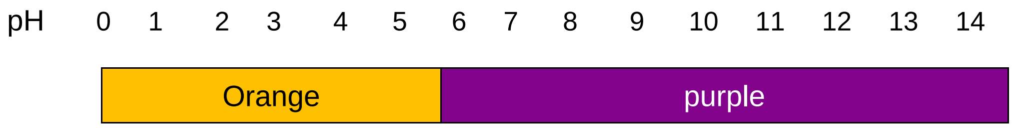
- **The secondary structures of a protein, such as α-helices and β-sheets, form due to H-bonding between the hydrogens attached to the nitrogens and the oxygens of the carbonyl in the amide (peptide) bond. (1)**

- **Tertiary structures are affected by the bonding of the specific amino acid side groups. Side groups can bond through dispersion forces, hydrogen bonding, ionic bonding and covalent bonding through disulphide bridges. (1)**

- **So the alteration of the primary structure of a protein means different amino acids with different side chains are incorporated, such that the same secondary and tertiary structures may not be able to form. (1)**

Question 29 **(6 marks)**

A newly discovered plant dye called kalanolein, can be used in biological laboratories to culture yeasts for home brewing kits. It has also been found that this same dye can be used for acid-base titrations as it displays two colours, orange and purple, as shown in the diagram below.



A few drops of kalanolein were added to separate solutions of sodium hydrogencarbonate, ($NaHCO_3$) and ammonium chloride, ($NH_4C\ell$).

(a) In the space below, write a balanced hydrolysis equation for each substance listed and also state the colour that would be observed in each case.

(4 marks)

$NaHCO_3$ (aq) **$HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH^-$ (1)**

Colour: **Purple (1)**

$NH_4C\ell$ (aq) **$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$ (1)**

Colour: **Orange (1)**

A typical acid/base titration between a standardised solution of sodium hydroxide, NaOH(aq) and an unknown solution of ethanoic acid, CH_3COOH(aq) was to be carried out, using common laboratory equipment.

(b) Using relevant chemical theory, explain whether kalanolein would be a suitable indicator for this titration?

(2 marks)

As the salt produced (CH_3COONa) hydrolyses with water, it produces a slightly basic solution, thus the equivalence point will be above pH 7. (0.5)

$CH_3COO^- + H_2O \rightleftharpoons CH_3COOH$ $+ OH^-$ (0.5)

Kalanolein changes colour in the acidic range, (around pH 5.5), so it would NOT be an appropriate indicator for this titration, as it would give an incorrect end point. (1)

Name: ______________________________

Teacher (Circle): **COUMBE ELIAS/POLAND HARVEY POLAND SMITHIES**

Question 30 **(7 marks)**

Aluminium is refined in a two-part process from the mineral 'bauxite' and extracted directly from alumina, ($A\ell_2O_3$) using electrorefining processes. Aluminium is used to make many different alloys due to its corrosion resistance, as well as finding application in the building industry and aviation, due to its light-weight and relatively strong properties.

A student was given the following sets of 1.00 mol L^{-1} solutions and asked to find out whether any of them could be safely stored in an aluminium cup.

The solutions were: $Fe(NO_3)_2$, $Mg(NO_3)_2$, $Cu(NO_3)_2$ and $Ni(NO_3)_2$

(a) Using relevant chemical equations, explain which of the solutions could be safely stored in a cup made of aluminium metal.

(4 marks)

The only solution that could be safely stored in the Aluminium cup is $Mg(NO_3)_2$. (1)

This is because $A\ell$ will not be oxidised by Mg^{2+} ions as they have a lower reduction potential.

ie. $A\ell \longrightarrow A\ell^{3+} + 3e^-$ $E^o = +1.68$ V

$Mg^{2+} + 2e^- \longrightarrow Mg$ $E^o = -2.36$ V **(1)**

The EMF is - 0.68 V thus reaction will not occur. (1)

All the remaining cations, (Fe^{2+}, Cu^{2+} and Ni^{2+}), in the other solutions have a higher reduction potential, thus they will oxidise aluminium and could not be stored in a cup made of aluminium metal. (1)

When aluminium metal is placed in an acidified solution of sodium hydrogendichromate, (containing the weakly acidic ion, hydrogendichromate ($HCr_2O_7^-$), a deep green solution containing chromium (III) ions is formed, and the aluminium metal dissolves producing aluminium ions.

(b) In the space below, write separate oxidation and reduction half-equations, and then the overall redox equation for this reaction.

(3 marks)

Oxidation: $(A\ell \longrightarrow A\ell^{3+} + 3e^-) \times 2$ **(1)**

Reduction: $HCr_2O_7^- + 13H^+ + 6e^- \longrightarrow 2Cr^{3+} + 7H_2O$ **(1)**

Redox: $HCr_2O_7^- + 2A\ell + 13H^+ \longrightarrow 2Cr^{3+} + 2A\ell^{3+} + 7H_2O$ **(1)**

Question 31 **(8 marks)**

Sodium hypochlorite (NaCℓO) is commonly used in the textile industry as a bleach. When added to water, hypochlorous acid (HCℓO) is formed. The solution can be considered as an equilibrium system as shown below, where hypochlorite ions are converted into hypochlorous acid.

$$C\ell O^-(aq) \;+\; H_2O(\ell) \;\rightleftharpoons\; HC\ell O(aq) \;+\; OH^-(aq) \;+\; \text{HEAT}$$

(a) Complete the following table by predicting, <u>with reasoning</u>, the effect that the following changes will have on the concentration of the hypochlorous acid (HCℓO) in the treated water. (4 marks)

Imposed change	**Predicted effect to the concentration of HCℓO(aq)**	**Brief justification for your prediction**
Addition of some hydrochloric acid to the water	**INCREASE (1)**	**Addition of H^+ ions will neutralise the OH^- on the product side thus favouring the F'wd reaction, due to higher rate of collisions amongst the reactants, leading to an increase in [HCℓO]. (1)**
Increasing the temperature of the water	**DECREASE (1)**	**Forward reaction is exothermic, thus increasing the temp. will favour the reverse, endothermic, reaction more than the f'wd reaction, hence decreasing the [HCℓO]. (1)**

(b) A 1 500 L tank needs to be filled with treated water that has a concentration of 1.75 ppm of hypochlorous acid. Calculate the mass of sodium hypochlorite that would be required to provide this level of hypochlorous acid, assuming that 65% conversion of sodium hypochlorite to hypochlorous acid will take place.
(Assume 1.00 L of the treated water has a mass of 1.00 kg) (4 marks)

1.75 ppm = $\dfrac{\text{mg}}{1\,500}$ Thus mass HCℓO = 1.75 x 1500 = 2625 mg = 2.625 g (1)

n(HCℓO) = m/M = 2.625/52.458 = 0.0500 mol (1)

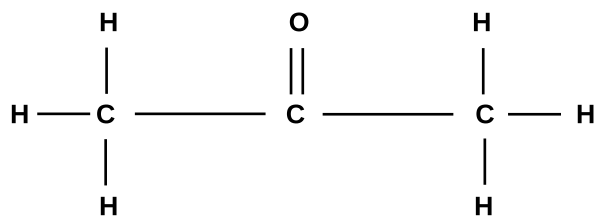
n(NaCℓO) = n(HCℓO) = 0.0500 mol; Thus mass (NaCℓO) = nM = 0.0500 x 74.44 = 3.72 g (1)

But process is only 65% efficient, so actual mass NaCℓO needed = 100/65 x 3.72 = 5.73 g (1)

Question 32 **(8 marks)**

Propan-2-ol can be readily oxidised using an acidified potassium permanganate solution.

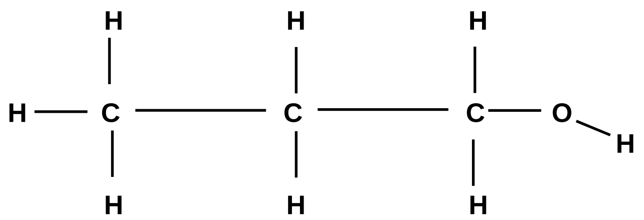
(a) In the space below, **draw** the structural formula and **name** the organic product formed. (2 marks)



(1)

Name ______**Propanone**_________ **(1)**

(b) In the space below, **draw** and **name** an isomer of propan-2-ol that will react with acidified potassium permanganate solution to produce a carboxylic acid. (2 marks)



(1)

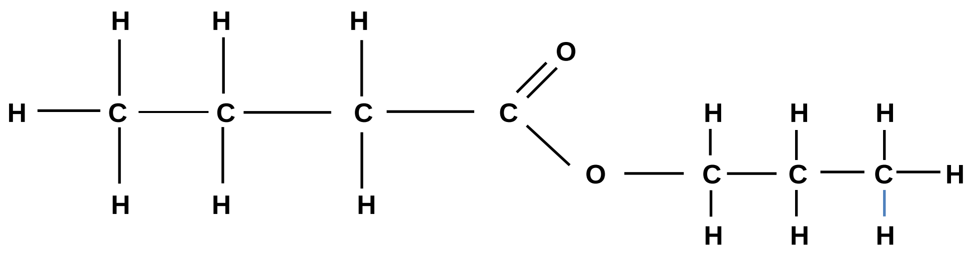
Name ________**Propan-1-ol**__________ **(1)**

(c) With reference to part (b) above, write a balanced redox equation for the reaction that will occur. (2 marks)

$$5CH_3CH_2CH_2OH + 4MnO_4^- + 12H^+ \longrightarrow 5CH_3CH_2COOH + 4\,Mn^{2+} + 11H_2O$$ **(2)**

(d) If some propan-1-ol and butanoic acid were mixed together and warmed in the presence of sulfuric acid, **draw** and **name** the major organic product formed in the space below.

(2 marks)



(1)

Name ____________**Propylbutanoate**____________ **(1)**

Question 33 **(11 marks)**

The following reaction sequence can be used to synthesise the ester, ethyl butanoate.

STEP 1

$$\text{Ethene} + \text{Steam} \xrightarrow{H^+} \text{Ethanol}$$

STEP 2

$$\text{Ethanol} + \text{Butanoic acid} \xrightarrow{H^+} \text{Ethyl butanoate}$$

(a) The hydrogen ions (H^+) needed for both steps originate from sulfuric acid and act as catalysts in this reaction sequence. Explain, using collision theory, how a catalyst speeds up a chemical reaction. (3 marks)

A catalyst provides an alternative pathway, (one with a lower Activation Energy, E_A). (1)

With a lower E_A, a greater proportion of reactant particles have sufficient energy to overcome the barrier. (1)

Thus more successful collision are possible and a faster rate of reaction will occur. (1)

(b) Write the relevant balanced chemical equation for **Step 1** of the process described above and also explain why it is described as an addition reaction.

(2 marks)

$$CH_2 = CH_2 + H_2O \longrightarrow CH_3CH_2OH \qquad \textbf{(1)}$$

This is an ADDITION reaction because the double bond breaks and the H and OH groups attach on adjacent carbons as shown. (1)

(c) Write the relevant balanced chemical equation for **Step 2** of the process and explain why this type of reaction is described as a 'condensation' reaction.

(2 marks)

$$CH_3CH_2OH + HOOCCH_2CH_2CH_3 \xrightarrow{H^+} CH_3CH_2OOCCH_2CH_2CH_3 + H_2O \qquad \textbf{(1)}$$

This is a CONDENSATION reaction because two molecules combine to form one larger molecule, with the elimination of a smaller molecule, (H_2O in this case). (1)

(d) In **Step 1** of the synthesis reactions above, 585 kg of ethene was reacted with excess steam. Given that an actual mass of 653 kg of ethanol was produced, calculate the percentage yield of this reaction.

(4 marks)

$n(C_2H_4)$ = m/M = 585 000/28.052
= 20 854 mol (1)

$n(C_2H_5OH)$ = $n(C_2H_4)$ = 20 854 mol (1)

$m(C_2H_5OH)$expected = nM = 20 8547 x 46.068 = 960 708 g = 961 kg (1)

Thus % yield = $\frac{\text{mass produced}}{\text{mass expected}}$ x 100 = $\frac{653}{961}$ x 100 = 68.0% (1)

End of Section Two

Name: ____________________

Teacher (Circle): **COUMBE ELIAS/POLAND HARVEY POLAND SMITHIES**

Section Three: Extended answer **40% (80 marks)**

This section contains **five (5)** questions. You must answer **all** questions. Write your answers in the spaces provided.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to the appropriate number of significant figures.

Suggested working time: 70 minutes.

Question 34 **(20 marks)**

Standard solutions of sodium hydroxide, NaOH, must be kept in airtight containers. This is because NaOH is a strong base and absorbs acidic oxides, such as carbon dioxide, CO_2, from the air and reacts with them. As a result, the concentration of NaOH is changed to an unknown extent.

Carbon dioxide in the air reacts with water to form carbonic acid. This acid can then react with sodium hydroxide to form sodium carbonate.

(a) Write two molecular equations to illustrate the chemical processes described in this reaction sequence. (4 marks)

$$\mathbf{CO_2\,(g) + H_2O\,(\ell) \rightleftharpoons H_2CO_3\,(aq)} \quad \textbf{(2)}$$

$$\mathbf{H_2CO_3\,(aq) + 2NaOH\,(aq) \rightleftharpoons Na_2CO_3\,(aq) + 2H_2O\,(\ell)} \quad \textbf{(2)}$$

(b) A freshly prepared solution of sodium hydroxide was titrated against a previously standardised solution of ethanoic acid, using standard laboratory volumetric glassware. What would be a suitable indicator for this titration?

Circle your choice from the list below. (1 mark)

(1)

Methyl orange **Phenolphthalein** **Universal indicator**

The freshly prepared sodium hydroxide solution, as described in (iii) above, was found to have a concentration of 0.1150 $molL^{-1}$. A 250.0 mL batch of the solution was left in a storage bottle on the laboratory bench over-night but a careless student forgot to replace the lid on the bottle. The next day, the chemistry teacher noticed this and thought it would be a good exercise for the students to determine the mass of carbon dioxide that was absorbed in the solution of sodium hydroxide. So she gave the students the task of carrying out a titration to determine this, by using a previously standardised sulfuric acid solution.

(c) Write a balanced chemical equation for the reaction between sulfuric acid and sodium hydroxide.

(2 marks)

H_2SO_4 (aq) + 2NaOH (aq) $\longrightarrow$ Na_2SO_4 (aq) + $2H_2O$ (ℓ) (2)

20.0 mL aliquots of the sodium hydroxide solution were taken and titrated using a suitable indicator with the standardised 0.0565 $molL^{-1}$ sulfuric acid solution from the burette. The results of the titration are tabulated below.

(d) Complete the table and calculate the average titre of H_2SO_4 (2 marks)

Final reading (mL)	20.60	19.65	21.10	20.80	19.05
Initial reading (mL)	4.50	4.45	5.25	5.00	3.20
Titration volume (mL)	**16.10**	**15.2**	**15.85**	**15.80**	**15.85**

(1)

Average titre __________**15.83 mL**___________ **(1)**

(e) Calculate the moles of acid titrated and thus the moles of sodium hydroxide in the 20.00 mL aliquots.

(3 marks)

$n(H_2SO_4)$ = cV = 0.0565 x 0.01583 = 0.0008944 mol (1)

n(NaOH) in 20 mL = 2 x $n(H_2SO_4)$ (1)

= 2 x 0.0008944 = 0.00179 mol (1)

(f) Thus calculate the concentration of the sodium hydroxide solution. (1 mark)

c(NaOH) = n/V = 0.001789/0.020 = 0.0894 $molL^{-1}$ (1)

(g) In view of your results in (f) above and considering that the original concentration of the sodium hydroxide solution:

(i) Calculate the number moles of sodium hydroxide that were originally present in the freshly made 250 mL solution.

(1 mark)

n(NaOH) original = cV = 0.115 x 0.250 = 0.0288 mol (1)

(ii) Calculate the actual number of moles of sodium hydroxide in the 250 mL solution using the results of the students' titration.

(2 marks)

n(NaOH) from titration $= \dfrac{250}{20} \times 0.00179 = 0.0224$ **mol (2)**

(iii) Using the results of (i) and (ii) above, calculate the moles of sodium hydroxide that reacted with the carbon dioxide as a consequence of the student leaving the storage bottle open over-night.

(1 mark)

n(NaOH) difference = 0.0288 – 0.0224 = 0.00640 mol (1)

(iv) Use the balanced chemical equation in part (a) on the previous pages as well as the titration data, to calculate the mass of carbon dioxide absorbed by the sodium hydroxide solution.

(3 marks)

From the reactions sequence, n(CO_2) = ½ x n(NaOH) = 0.003195 mol (1)

Thus the moles of CO_2 that reacted with the NaOH = 0.003195 mol (1)

Hence the mass of CO_2 = nM = 0.003195 x 44.01 = 0.141 g (1)

Question 35 **(13 marks)**

Coconut oil contains an ester which gives the oil its distinctive odour. The ester was extracted and a series of experiments were carried out to determine the formula of this ester, which was known to contain only carbon, hydrogen and oxygen.

A 1.680 g sample was combusted in excess oxygen and 4.100 g of carbon dioxide was produced.

A separate 1.990 g sample was combusted in excess oxygen and 1.990 g of water was produced.

(a) Calculate the empirical formula of the ester in the coconut oil. (8 marks)

$n(CO_2)$ = m/M = 4.10/44.01 = 0.09316 mol = n(C) (1)

m(C) = nM = 0.09316 x 12.01 = 1.11885 g

%(C) = (1.11885/1.68) x 100 = 66.60% (1)

$n(H_2O)$ = m/M = 1.99/18.016 = 0.11046 mol , n(H) = 2 x 0.11046 = 0.2209 mol (1)

m(H) = nM = 0.2209 x 1.008 = 0.2227 g

%(H) = (0.2227/1.99) x 100 = 11.19% (1)

Thus %(O) = (100 – (66.60 + 11.19)) = 22.21% (1)

		C	H	O	
Mass in 100g	**=**	**66.60**	**11.19**	**22.21**	
n	**=**	**66.60/12.01**	**11.19/1.008**	**22.21/16.00**	**(1)**
	=	**5.55**	**11.10**	**1.39**	
Ratio of mol	**=**	**5.55/1.39**	**11.10/1.39**	**1.39/1.39**	
	=				
	=	**4 :**	**8 :**	**1**	**(1)**

Empirical Formula = C_4H_8O (1)

A further sample weighing 0.8100 g was vaporised and the gas produced was found to occupy a volume of 226.0 mL at 140.0 °C and a pressure of 85.20 kPa.

(b) From this information, calculate the molecular formula of the ester. (4 marks)

$$n = \frac{PV}{RT} = \frac{85.20 \times 0.2260}{8.314 \times 413.15} = 0.005606 \text{ mol} \quad \textbf{(1)}$$

$$M = m/n = 0.810/0.005606 = 144.49 \text{ g/mol} \quad \textbf{(1)}$$

Emp Formula mass (C_4H_8O) = 72.104 g/mol (1)

Thus, MF = Mol Formula mass/ Emp Formula mass x EF

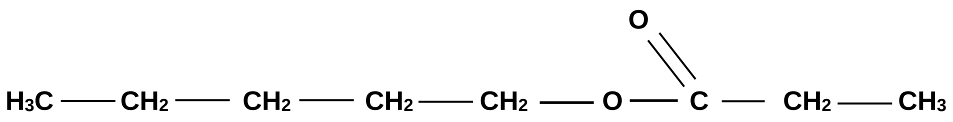
= 144.49/72.104 x C_4H_8O

= 2 x C_4H_8O

= $C_8H_{16}O_2$ (1)

(c) This same ester can also be synthesised in the laboratory by reacting pentan-1-ol and a carboxylic acid, using sulfuric acid as a catalyst.

Using this information, draw the structural formula of the ester present in coconut oil. (1 mark)



(1)

Name: ______________________________

Teacher (Circle): **COUMBE ELIAS/POLAND HARVEY POLAND SMITHIES**

Question 36 **(12 marks)**

Biodiesel is a fuel that can be synthesised from a variety of natural oils and fats. The molecule below is a triglyceride present in vegetable oils that can be used for this process. In this case, the biodiesel can be synthesised using a base-catalysed reaction with methanol, as shown by the incomplete equation below. The triglyceride undergoes transesterification with methanol to form the three methyl esters shown. These methyl esters are the main components of biodiesel.

Fatty acid **(Vegetable oil)**

$H_2C — OOCCH_2(CH_2)_6CH{=}CH(CH_2)_7CH_3$
|
$HC — OOCCH_2(CH_2)_{13}CH_3$ + **Methanol** $3\ CH_3OH$
|
$H_2C — OOCCH_2(CH_2)_6CH{=}CHCH_2CH{=}CHCH_2CH{=}CHCH_2CH_3$

↓ Catalyst **(NaOH)**

E-1 $H_3COOCCH_2(CH_2)_6CH{=}CH(CH_2)_7CH_3$

E-2 $H_3COOCCH_2(CH_2)_{13}CH_3$ + **Substance X**

E-3 $H_3COOCCH_2(CH_2)_6CH{=}CHCH_2CH{=}CHCH_2CH{=}CHCH_2CH_3$

(a) Explain why the vegetable oil above is described as an **unsaturated** oil. (1 mark)

It contains "double bonds" between carbon atoms in the chains (1)

(b) As well as the three methyl esters (the biodiesel), there is one other product of this reaction labelled only as **Substance X**. Name and draw the structural formula of this product. (2 marks)

$H_2C – OH$
|
$HC – OH$ **(1)**
|
$H_2C – OH$

Name _______**Glycerol** __or__**1,2,3-propanetriol**___or___**propane-1,2,3-triol**____ **(1)**

(c) Why is a large excess of methanol used in the reaction? (1 mark)

To ensure that the vegetable oil is the LR, such that it is used up as efficiently as possible or minimise soap production (1)

(d) During a typical production run for this synthesis reaction, 1.75 tonnes of the vegetable oil is used. Calculate the minimum mass of methanol that would be required to react with this much oil, given that the vegetable oil used has a molar mass of 855.334 g mol^{-1}.
(1 tonne = 1 x 10^6 g). (3 marks)

n(veg oil) = m/M = 1.75 x 10^6/855.334 = 2046 mol (1)

From equation process, n(CH_3OH) = 3 x n(veg oil) = 3 x 2046 = 6138 mol (1)

Thus mass of methanol = nM = 6138 x 32.042 = 196 674 g (1)

or = 197 kg

(e) As shown on page 25, three different esters, labelled **E-1**, **E-2** and **E-3**, are produced from this reaction. Calculate the mass of ester **E-2** produced in this process, given that the reaction is only 80% efficient during the production of the biodiesel. (4 marks)

Molar mass of ester A ($C_{17}H_{34}O_2$) = 270.442 g/mol (1)

n($C_{17}H_{34}O_2$) = n(veg oil) = 2046 (1)

m($C_{17}H_{34}O_2$) = nM = 2046 x 270.442 = 553 324 g (1)

or

But since process is only 80% efficient, only 80% of this will be produced in practice

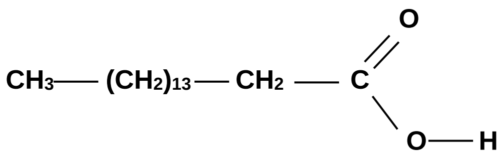
ie Actual mass of the ester (A) = 553 324 x 80/100 = 442 659 g (1)

or = 443 kg

or

n($C_{17}H_{34}O_2$)$_{yield}$ = 0.8 x 2046 mol = 1636.787 mol
m($C_{17}H_{34}O_2$) = nM = 1636.787 x 270.442
= 4.43 x 10^5 g
= 443 kg 3 SF

(f) As stated earlier, esters are also produced when a carboxylic acid reacts with an alcohol. Draw the structure of the carboxylic acid that would be needed to produce ester **E-2** in the reaction above. (1 mark)

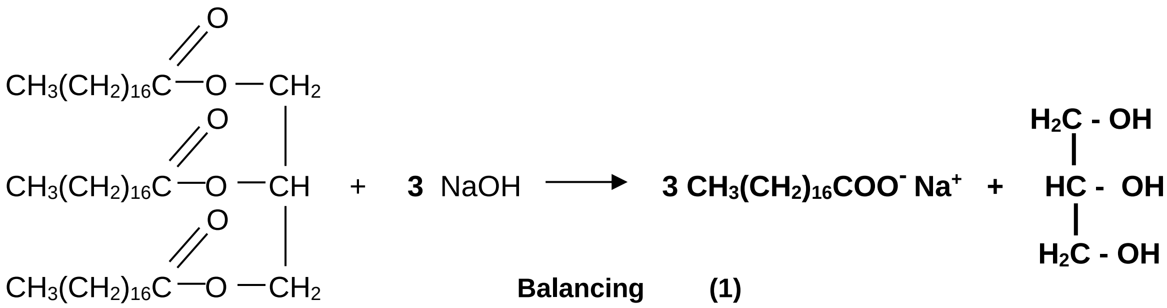


(1)

Question 37 **(18 marks)**

Soaps and detergents are common organic substances widely used in our daily lives. While they both consist of a relatively long hydrocarbon chain which is attached to a ‘polar end’, there are also significant differences between the two substances, particularly in their applications as cleaning agents.

A typical soap like sodium stearate, ($CH_3(CH_2)_{16}COO^- Na^+$), which can be produced from a reaction between tristearin and sodium hydroxide, is shown in the partially completed ‘saponification’ reaction below.



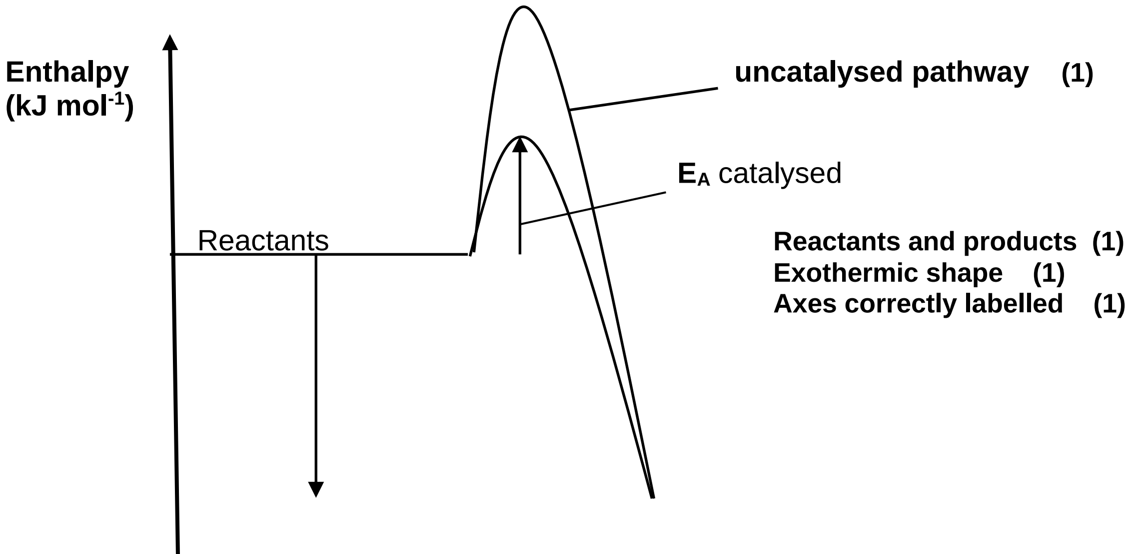
Balancing (1)
Both products correct (2)

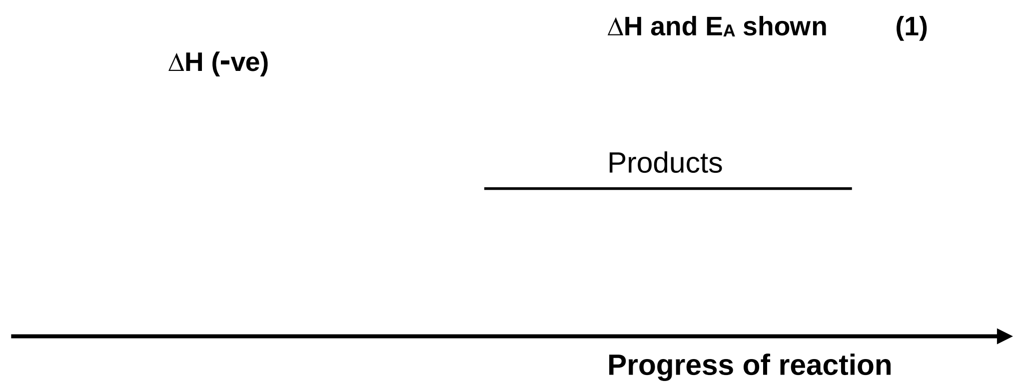
Tristearin

(a) Complete and balance the equation above, including any other organic products formed. (3 marks)

The reaction described above takes place at a moderate temperature range between 60-80^oC. As the reaction proceeds, heat energy is also released to the surroundings.

(b) On the set of axes drawn below, construct and fully label an appropriate enthalpy diagram to represent the saponification process described above. (4 marks)





The saponification reaction described on the previous page includes the use of a catalyst. Thus the enthalpy diagram you have drawn above includes the presence of a catalyst.

(c) Show on the same diagram that you have already drawn, how the reaction pathway would be different if a suitable catalyst was not used. Label this pathway clearly as the '**uncatalysed pathway'**. (1 mark)

Soaps and detergents function to remove fats and grease from objects as they clean.

(d) Using a simplified general representation a typical soap or detergent, explain in terms of their structure and polarity, how they are able to achieve their task as cleaners.
(6 marks)

Both soap and detergent exhibit a polar (hydrophilic) end (1) and a long hydrocarbon non-polar (hydrophobic) end. (1)
The hydrophobic "tails" which exhibit dispersion forces, are compatible with similar dispersion forces in the grease or fat, thus can interact and become imbedded in the grease or fat. (1) While the polar end can interact with the H-bonding in the water molecules. (1)
With a little agitation, the soap or detergent molecules are able to break up sections of grease or fat into "micelles", (1) these can be washed away and cleaning is achieved. (1)

***Also accept diagrammatic representation as part of explanation and other valid points!**

As previously stated, there are some differences between soaps and detergents. One significant difference between a soap and detergent molecule is in the limited ability of soap to clean effectively in hard water. The anions of soap molecules form a precipitate called 'scum' when they are added to hard water.

(e) Using a balanced chemical equation, show why stearate ions, ($CH_3(CH_2)_{16}COO^-$), are unable to clean effectively when placed in hard water.
(2 marks)

$$2\ CH_3(CH_2)_{16}COO^-\ (aq) + Ca^{2+}\ (aq) \longrightarrow (CH_3(CH_2)_{16}COO)_2Ca\ (s) \qquad \textbf{(2)}$$

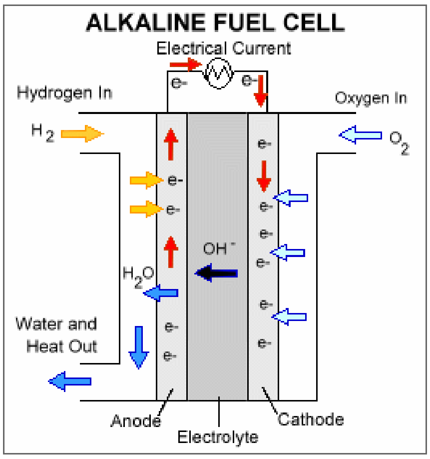
Deduct 1 x mark if unbalanced or states missing.

(f) Explain why detergents, unlike soaps, do not have this limitation in 'hard water'.
(2 marks)

Unlike soaps, detergent anions do not form insoluble (scum) in hard water. (1)
So even though both have a hydrophobic hydrocarbon chain and a hydrophilic polar end, the detergent will not form a precipitate with either Mg^{2+} or Ca^{2+} ions, thus remaining soluble in water, able to retain their full function as cleaning agents. (1)

Question 38 **(17 marks)**

An alkaline version of a typical fuel cell is shown below. It utilises the oxidation of hydrogen gas (H_2) and the reduction of oxygen gas (O_2). Both reactants are constantly and continuously 'fed into' the cell during normal operation. The major product from the overall redox reaction is water, (H_2O).



(a) During the normal operation of this cell, write the appropriate reactions that will occur:

(i) at the cathode. (1 mark)

$O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$ (1) E^o = + 0.40 V

(ii) at the anode. (1 mark)

$H_2 + 2OH^- \longrightarrow 2H_2O + 2e^-$ (1) E^o = + 0.83 V

(iii) for the cell. (1 mark)

$2H_2 + O_2 \longrightarrow 2H_2O$ (1)

(b) What is the maximum EMF that this fuel cell can generate under standard conditions? (1 mark)

EMF = (+0.40) + (+0.83) = + 1.23 V (1)

(c) List one advantage and one disadvantage of a typical fuel cell when compared to a dry cell. (2 marks)

Advantage: **More reliable, consistent EMF, no toxic emissions/products, etc.**
Accept any one valid advantage. (1)

Disadvantage: **Much more expensive, reactants need to be constantly fed-into the cell, etc.**
Accept any one valid disadvantage. (1)

Another type of electrochemical cell utilises the following standard half-cell reactions.

$$Cr^{3+}(aq) + 3e^- \longrightarrow Cr(s) \qquad E^o = -0.74\ V$$

$$C\ell_2(g) + 2e^- \longrightarrow 2C\ell^-(aq) \qquad E^o = +1.36\ V$$

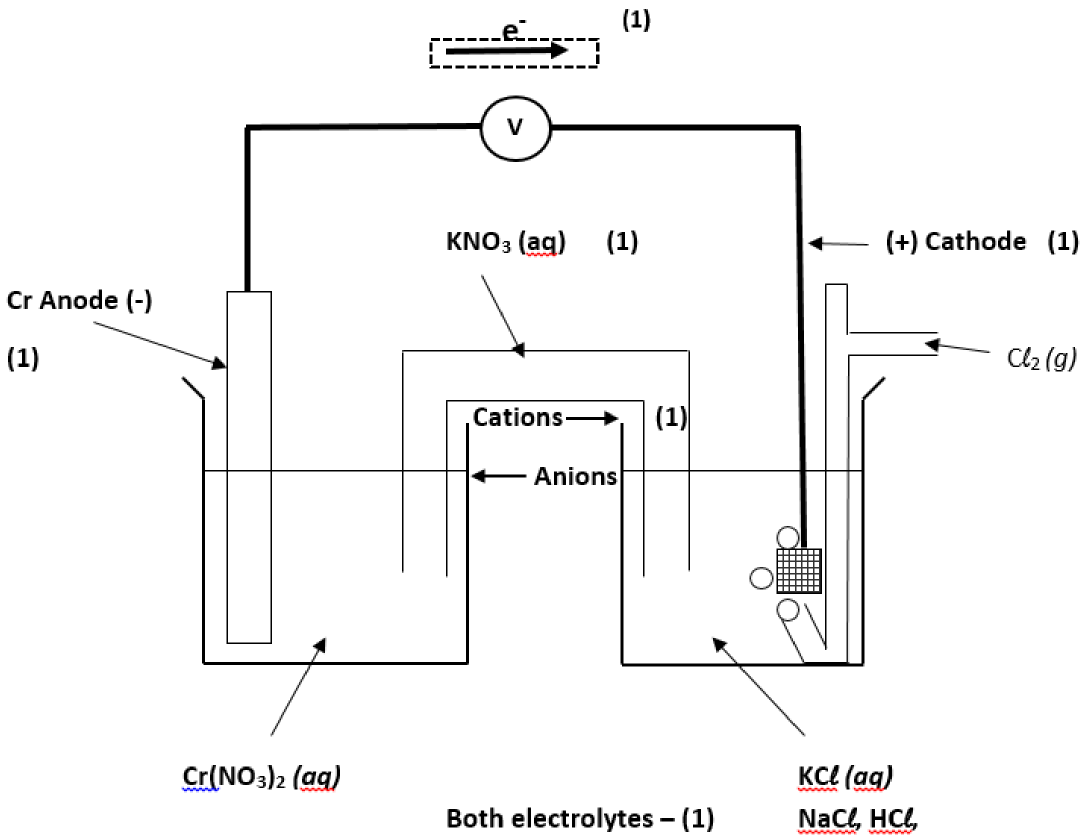
Complete the diagram below to show the construction and operation of this cell. Ensure that you fully label the cell to include:

(d) the anode and cathode, including their respective polarities. (2 marks)

(e) the electrolytes used. (2 marks)

(f) the direction of movement of cations and anions in the salt bridge. (1 mark)

(g) the direction of movement of electrons. (1 mark)



(h) Overall cell reaction and cell EMF under standard conditions.

(2 marks)

$3Cl_2$ + 2Cr $\longrightarrow$ $6Cl^-$ + $2Cr^{3+}$ (1)

Cell EMF = **+ 2.10 V (1)**

(i) With reference to the cell you constructed above, and using relevant chemical theory, explain clearly whether a solution of sodium carbonate would be a good choice for use as a salt bridge electrolyte. (Include a balanced chemical equation in your explanation).

(3 marks)

Using sodium carbonate as a salt bridge electrolyte would NOT be a good choice. (1)

This is because any carbonate ions that come in contact with the chromium ions would produce a precipitate, which may "block-up" the salt bridge and restrict the flow of charge carriers, thus rendering the salt bridge ineffective. (1)

ie $2Cr^{3+}$ (aq) + $3CO_3^{2-}$ (aq) $\longrightarrow$ $Cr_2(CO_3)_3$ (s) (1)

End of questions