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# CHEMISTRY

## UNIT 3 & 4

### 2017

## MARKING GUIDE

### Section One: Multiple-choice

25% (50 marks)

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20	a <input type="checkbox"/> b <input type="checkbox"/> c <input checked="" type="checkbox"/> d <input type="checkbox"/>

(2 marks per question)

**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.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 60 minutes.

**Question 26****(7 marks)**

Nitrosyl bromide ( $\text{NOBr}_2$ ) decomposes and reaches equilibrium according to the equation below.



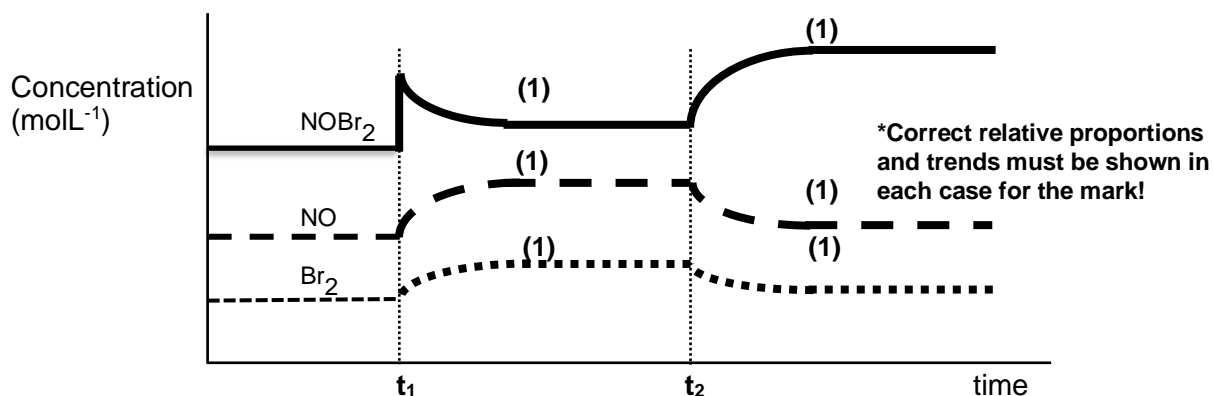
- (a) Write the equilibrium expression for this reaction. (1 mark)

$$K = \frac{[\text{NO}]^2[\text{Br}_2]}{[\text{NOBr}_2]^2} \quad (1)$$

- (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  $\text{NOBr}_2$  was introduced into the vessel at time  $t_1$ , at constant temperature. (3 marks)

- (ii) At time  $t_2$ , the temperature in the reaction vessel was increased. (3 marks)



**Question 27****(12 marks)**

- (a) Calculate the pH of a solution of  $0.250 \text{ mol L}^{-1}$  nitric acid. (2 marks)

$$[\text{H}^+] = [\text{HNO}_3] = 0.250 \text{ mol L}^{-1} \quad (1)$$

$$\text{pH} = -\log[\text{H}^+] = -\log(0.250) = 0.602 \quad (1)$$

- (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)

$$[\text{H}^+] = \text{pH}^{-1.5} = 3.1623 \times 10^{-2} \text{ mol L}^{-1} \quad (1)$$

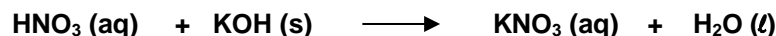
$$c_1 \times V_1 = c_2 \times V_2$$

$$(0.25 \times 0.025) = (3.1623 \times 10^{-2}) \times V_2 \quad (1)$$

$$V_2 = 0.198 \text{ L} \quad (1)$$

$$\text{Volume of water to add} = 0.198 - 0.025 = 0.173 \text{ L or } 173 \text{ mL} \quad (1)$$

- (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)



$$n(\text{HNO}_3) = cV = (0.250)(0.025) = 0.00625 \text{ mol} \quad (1)$$

$$n(\text{KOH}) = m/M = 0.02317 \text{ mol} \quad (1)$$

$$\text{Thus } n(\text{KOH}) \text{ excess} = 0.02317 - 0.00625 = 0.0169 \text{ mol} \quad (1)$$

$$[\text{OH}^-] = [\text{KOH}] = n/V = 0.0169/0.025 = 0.6768 \text{ mol L}^{-1} \quad (1)$$

$$\text{Hence } [\text{H}^+] = 10^{-14} / 0.6768 = 1.478 \times 10^{-14} \text{ mol L}^{-1} \quad (1)$$

$$\text{pH} = -\log[\text{H}^+] = -\log(1.478 \times 10^{-14}) = 13.8 \quad (1)$$

**(11 marks)**

CC(N)C(=O)NC(C)C(=O)NC(CO)C(=O)O

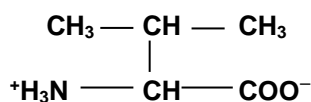
- (2 marks)

(1) (1)

- (1 mark)

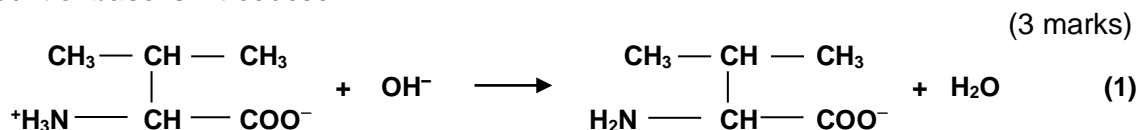
(1)

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



(1) both charges 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.



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

In this way the  $\text{OH}^-$  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.

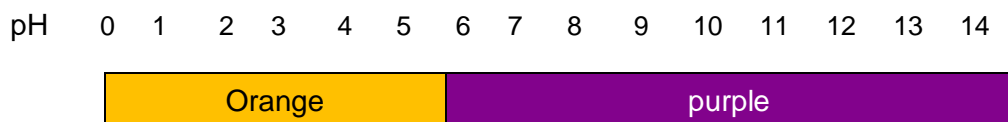
(3 marks)

- The secondary structures of a protein, such as  $\alpha$ -helices and  $\beta$ -sheets, form due to H-bonding between the amino acid side chains. (1)
- The various tertiary structures (eg. disulfide bridges), also form due to amino acid side chain interactions. (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.



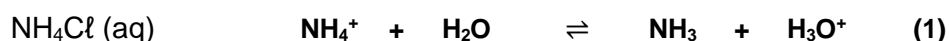
A few drops of kalanolein were added to separate solutions of sodium hydrogencarbonate, ( $\text{NaHCO}_3$ ) and ammonium chloride, ( $\text{NH}_4\text{Cl}$ ).

- (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)



Colour: **Purple** (1)



Colour: **Orange** (1)

A typical acid/base titration between a standardised solution of sodium hydroxide,  $\text{NaOH}(\text{aq})$  and an unknown solution of ethanoic acid,  $\text{CH}_3\text{COOH}(\text{aq})$  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 ( $\text{CH}_3\text{COONa}$ ) hydrolyses with water, it produces a slightly basic solution, thus the equivalence point will be above pH 7. (1)**

**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)**

**Question 30****(7 marks)**

Aluminium is refined in a two-part process from the mineral 'bauxite' and extracted directly from alumina, ( $\text{Al}_2\text{O}_3$ ) using electrolysis 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  $1.00 \text{ mol L}^{-1}$  solutions and asked to find out whether any of them could be safely stored in an aluminium cup.

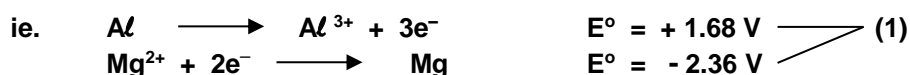
The solutions were:  $\text{Fe}(\text{NO}_3)_2$ ,  $\text{Mg}(\text{NO}_3)_2$ ,  $\text{Cu}(\text{NO}_3)_2$  and  $\text{Ni}(\text{NO}_3)_2$

- (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  $\text{Mg}(\text{NO}_3)_2$ . (1)**

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

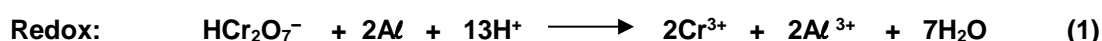
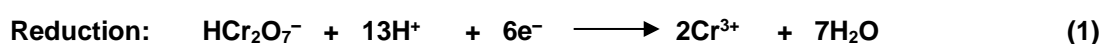
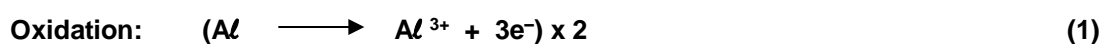


**The EMF is  $-0.68 \text{ V}$  thus reaction will not occur. (1)**

**All the remaining cations, ( $\text{Fe}^{2+}$ ,  $\text{Cu}^{2+}$  and  $\text{Ni}^{2+}$ ), 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 ( $\text{HCr}_2\text{O}_7^-$ ), a deep green solution containing chromium (III) ions is formed, and the aluminium metal dissolves producing aluminium ions.

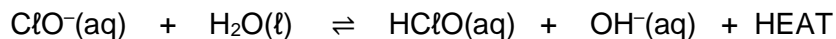
- (b) In the space below, write separate oxidation and reduction half-equations, and then the overall redox equation for this reaction.

**(3 marks)**

## Question 31

(8 marks)

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



- (a) Complete the following table by predicting, with reasoning, the effect that the following changes will have on the concentration of the hypochlorous acid ( $\text{HClO}$ ) in the treated water. (4 marks)

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

- (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)

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

$$n(\text{HClO}) = m/M = 2.625/52.458 = 0.0500 \text{ mol} \quad (1)$$

$$n(\text{NaClO}) = n(\text{HClO}) = 0.0500 \text{ mol}; \text{ Thus mass (NaClO)} = nM = 0.0500 \times 74.44 = 3.72 \text{ g} \quad (1)$$

$$\text{But process is only 65\% efficient, so actual mass NaClO needed} = 100/65 \times 3.72 = 5.73 \text{ g} \quad (1)$$

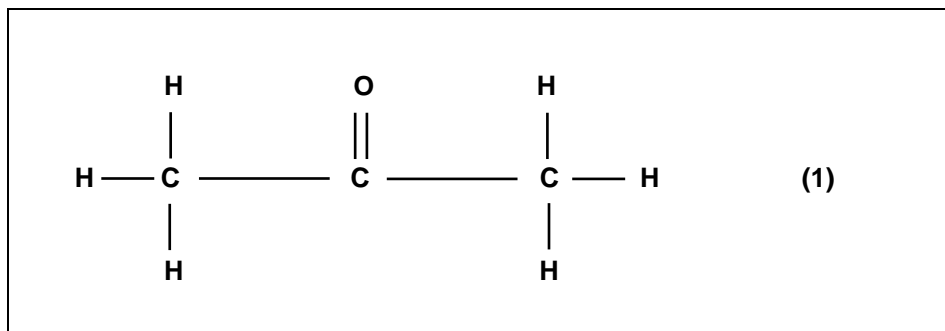


## Question 32

(8 marks)

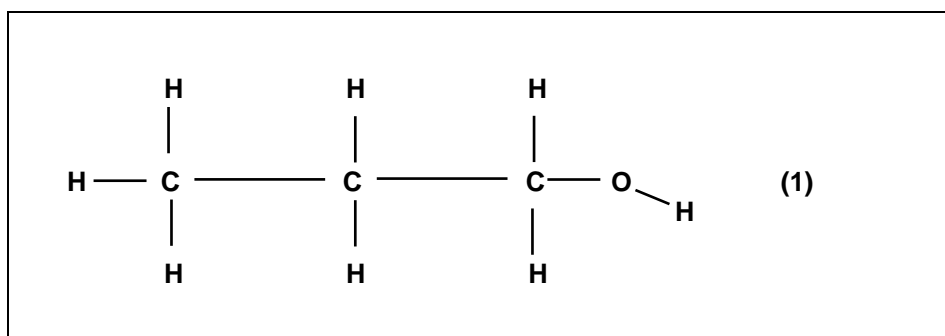
Propan-2-ol can be readily oxidised using an acidified potassium permanganate solution.

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



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)

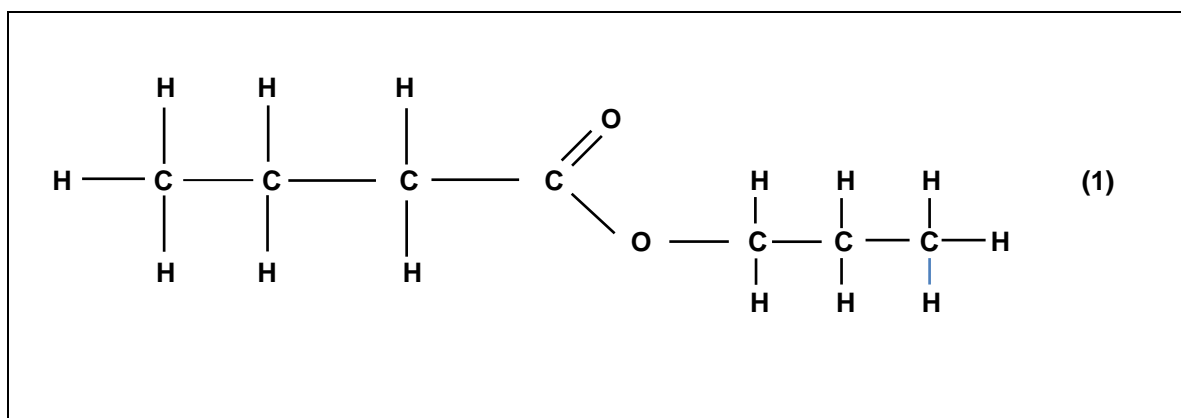


Name \_\_\_\_\_ **Propan-1-ol** \_\_\_\_\_ (1)

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



- (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)



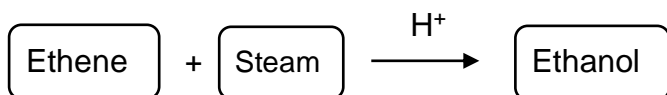
Name \_\_\_\_\_ **Propylbutanoate** \_\_\_\_\_ (1)

### Question 33

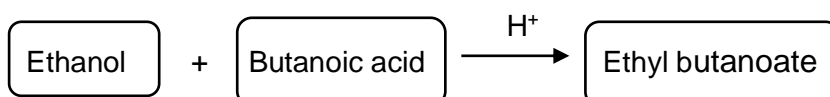
(11 marks)

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

#### STEP 1



#### STEP 2



- (a) The hydrogen ions ( $\text{H}^+$ ) 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.

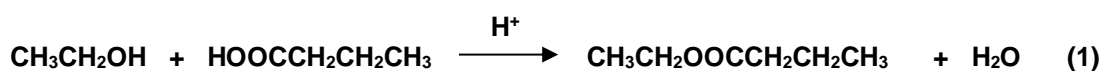
(2 marks)



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)



This is a **CONDENSATION** reaction because two molecules combine to form one larger molecule, with the elimination of a smaller molecule, ( $\text{H}_2\text{O}$  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)

$$\begin{aligned} n(\text{C}_2\text{H}_4) &= m/M = 585\,000/28.052 \\ &= 20\,854 \text{ mol} \end{aligned} \quad (1)$$

$$n(\text{C}_2\text{H}_5\text{OH}) = n(\text{C}_2\text{H}_4) = 20\,854 \text{ mol} \quad (1)$$

$$m(\text{C}_2\text{H}_5\text{OH})_{\text{expected}} = nM = 20\,854 \times 46.068 = 960\,708 \text{ g} = 961 \text{ kg} \quad (1)$$

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

**End of Section Two**

**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.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

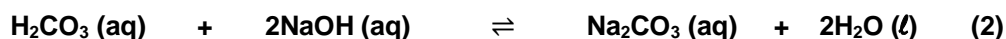
Suggested working time: 70 minutes.

**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<sub>2</sub>, 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)



- (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  $0.1150 \text{ mol L}^{-1}$ . 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)



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

- (d) Complete the table and calculate the average titre of  $\text{H}_2\text{SO}_4$

(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)	<b>16.10</b>	<b>15.2</b>	<b>15.85</b>	<b>15.80</b>	<b>15.85</b>

(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)

$$n(\text{H}_2\text{SO}_4) = cV = 0.0565 \times 0.01583 = 0.0008944 \text{ mol} \quad (1)$$

$$n(\text{NaOH}) \text{ in } 20 \text{ mL} = 2 \times n(\text{H}_2\text{SO}_4) \quad (1)$$

$$= 2 \times 0.0008944 = 0.00179 \text{ mol} \quad (1)$$

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

(1 mark)

$$c(\text{NaOH}) = n/V = 0.001789/0.020 = 0.0894 \text{ mol L}^{-1} \quad (1)$$

**\*Deduct 1 x mark for incorrect number of sig. figures!**

(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)

$$n(\text{NaOH})_{\text{original}} = cV = 0.115 \times 0.250 = 0.0288 \text{ mol} \quad (1)$$

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

(2 marks)

$$n(\text{NaOH})_{\text{from titration}} = \frac{250}{20} \times 0.00179 = 0.0224 \text{ mol} \quad (2)$$

- (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)

$$n(\text{NaOH})_{\text{difference}} = 0.0288 - 0.0224 = 0.00640 \text{ mol} \quad (1)$$

- (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)

$$\text{From the reactions sequence, } n(\text{CO}_2) = \frac{1}{2} \times n(\text{NaOH}) = 0.003195 \text{ mol} \quad (1)$$

$$\text{Thus the moles of CO}_2 \text{ that reacted with the NaOH} = 0.003195 \text{ mol} \quad (1)$$

$$\text{Hence the mass of CO}_2 = nM = 0.003195 \times 44.01 = 0.141 \text{ g} \quad (1)$$

**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)

$$n(\text{CO}_2) = m/M = 4.10/44.01 = 0.09316 \text{ mol} = n(\text{C}) \quad (1)$$

$$m(\text{C}) = nM = 0.09316 \times 12.01 = 1.11885 \text{ g}$$

$$\%(\text{C}) = (1.11885/1.68) \times 100 = 66.60\% \quad (1)$$

$$n(\text{H}_2\text{O}) = m/M = 1.99/18.016 = 0.11046 \text{ mol}, \quad n(\text{H}) = 2 \times 0.11046 = 0.2209 \text{ mol} \quad (1)$$

$$m(\text{H}) = nM = 0.2209 \times 1.008 = 0.2227 \text{ g}$$

$$\%(\text{H}) = (0.2227/1.99) \times 100 = 11.19\% \quad (1)$$

$$\text{Thus } \%(\text{O}) = (100 - (66.60 + 11.19)) = 22.21\% \quad (1)$$

		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)

$$\text{Empirical Formula} = \text{C}_4\text{H}_8\text{O} \quad (1)$$

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)

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

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

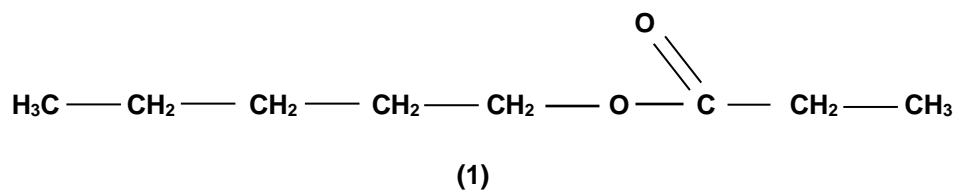
$$\text{Emp Formula mass (C}_4\text{H}_8\text{O)} = 72.104 \text{ g/mol} \quad (1)$$

$$\begin{aligned} \text{Thus, MF} &= \text{Mol Formula mass/ Emp Formula mass} \times \text{EF} \\ &= 144.49/72.104 \times \text{C}_4\text{H}_8\text{O} \\ &= 2 \times \text{C}_4\text{H}_8\text{O} \\ &= \text{C}_8\text{H}_{16}\text{O}_2 \quad (1) \end{aligned}$$

- (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)

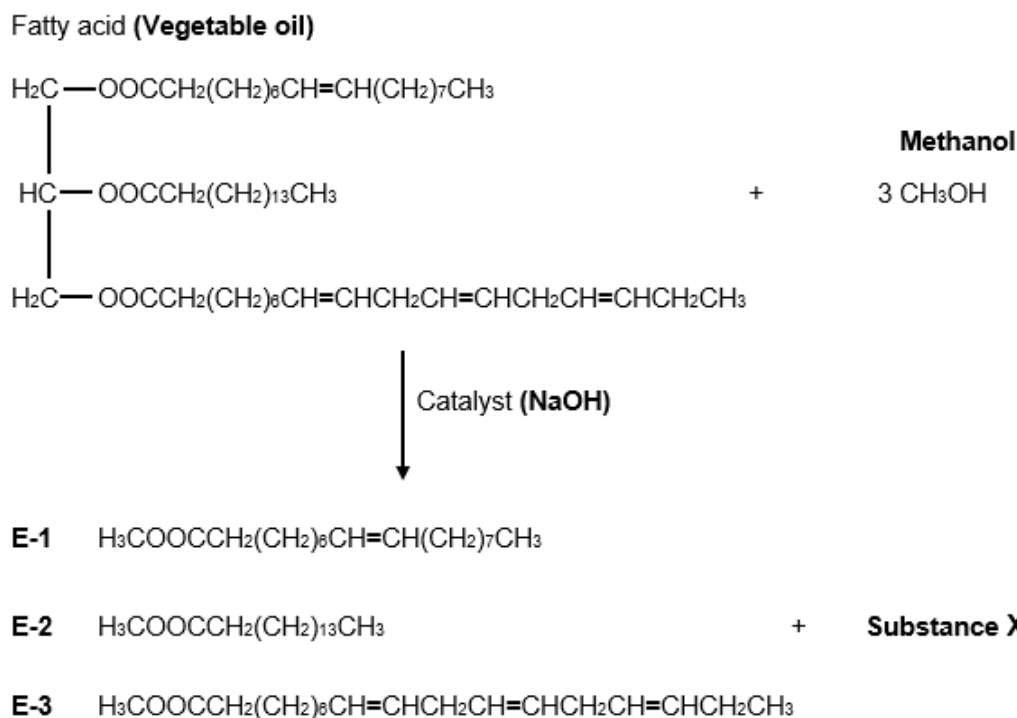




### Question 36

**(12 marks)**

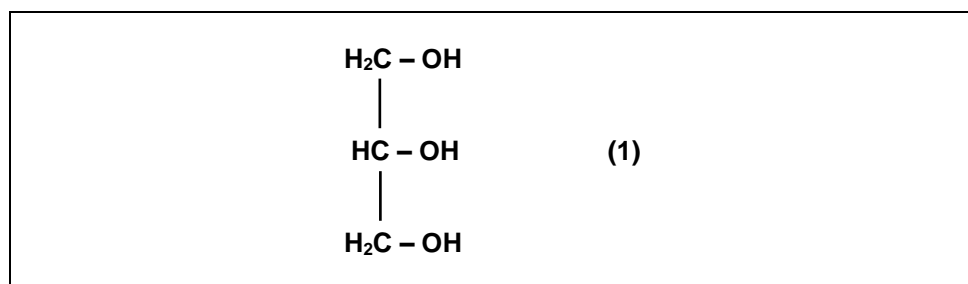
Biodiesel is a fuel that can be synthesised from a variety of natural oils and fats. The molecule below is a triglyceride present in vegetable oils that can be used for this process. In this case, the biodiesel can be synthesised using a base-catalysed reaction with methanol, as shown by the incomplete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



- (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)



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 (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  $855.334 \text{ g mol}^{-1}$ .  
(1 tonne =  $1 \times 10^6 \text{ g}$ ). (3 marks)

$$n(\text{veg oil}) = m/M = 1.75 \times 10^6 / 855.334 = 2046 \text{ mol} \quad (1)$$

$$\text{From equation process, } n(\text{CH}_3\text{OH}) = 3 \times n(\text{veg oil}) = 3 \times 2046 = 6138 \text{ mol} \quad (1)$$

$$\begin{aligned} \text{Thus mass of methanol} &= nM = 6138 \times 32.042 = 196\,674 \text{ g} \quad (1) \\ &\text{or} = 197 \text{ kg} \end{aligned}$$

- (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)

$$\text{Molar mass of ester A (C}_{17}\text{H}_{34}\text{O}_2) = 270.442 \text{ g/mol} \quad (1)$$

$$n(\text{C}_{17}\text{H}_{34}\text{O}_2) = n(\text{veg oil}) = 2046 \quad (1)$$

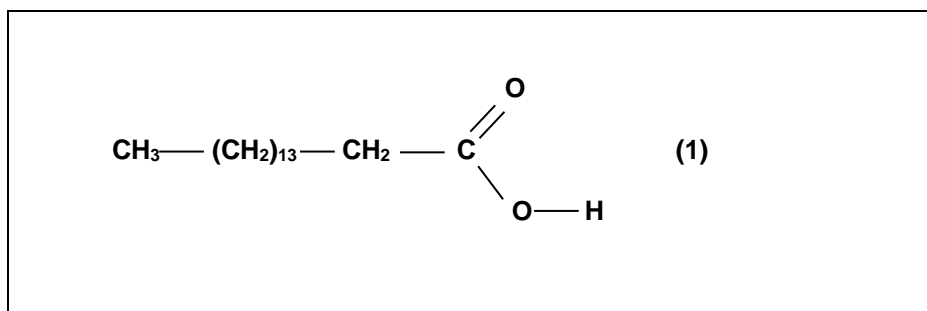
$$m(\text{C}_{17}\text{H}_{34}\text{O}_2) = nM = 2046 \times 270.442 = 553\,324 \text{ g} \quad (1)$$

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

$$\text{ie Actual mass of the ester (A)} = 553\,324 \times 80/100 = 442\,659 \text{ g} \quad (1)$$

$$\text{or} = 443 \text{ kg}$$

- (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)

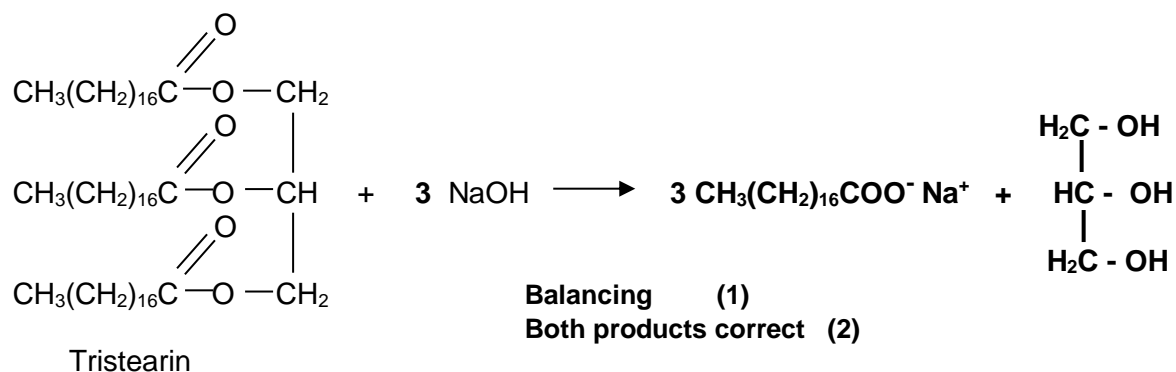


## Question 37

(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.

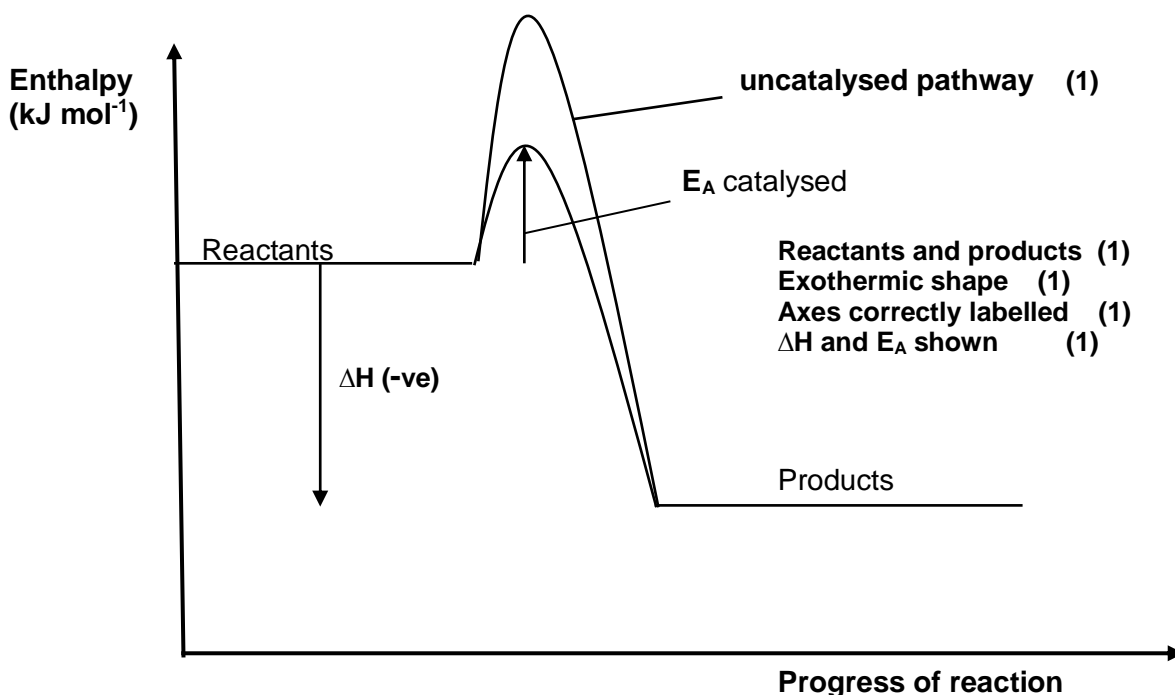
A typical soap like sodium stearate,  $(\text{CH}_3(\text{CH}_2)_{16}\text{COO}^- \text{Na}^+)$ , which can be produced from a reaction between tristearin and sodium hydroxide, is shown in the partially completed 'saponification' reaction below.



- (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°C. 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)**

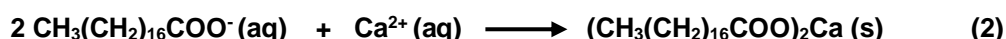
**The hydrophobic "tails" which exhibit dispersion forces, are compatible with similar dispersion forces in the grease or fat, thus can interact and become imbedded in the grease or fat. (1) While the polar end can interact with the H-bonding in the water molecules. (1)**

**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,  $(\text{CH}_3(\text{CH}_2)_{16}\text{COO}^-)$ , are unable to clean effectively when placed in hard water. (2 marks)



**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)

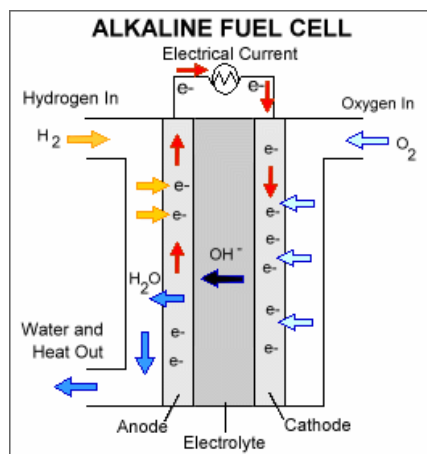
**Unlike soaps, detergent anions do not form insoluble (scum) in hard water. (1)**

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

## Question 38

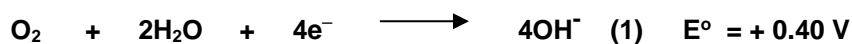
(17 marks)

An alkaline version of a typical fuel cell is shown below. It utilises the oxidation of hydrogen gas ( $\text{H}_2$ ) and the reduction of oxygen gas ( $\text{O}_2$ ). Both reactants are constantly and continuously 'fed into' the cell during normal operation. The major product from the overall redox reaction is water, ( $\text{H}_2\text{O}$ ).



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

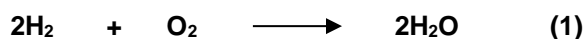
(i) at the cathode. (1 mark)



(ii) at the anode. (1 mark)



(iii) for the cell. (1 mark)



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

(1 mark)

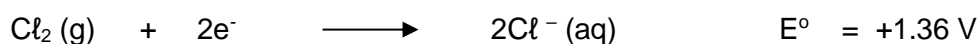
$$\text{EMF} = (+0.40) + (+0.83) = +1.23 \text{ V} \quad (1)$$

(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)

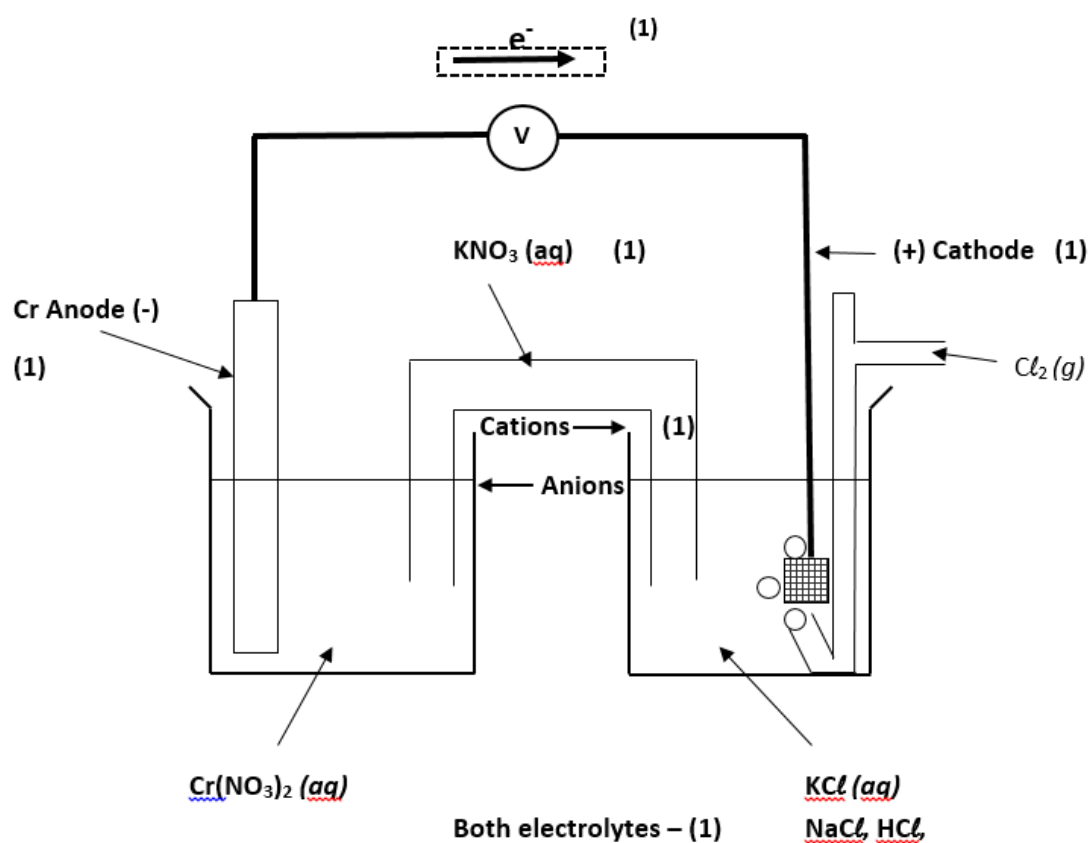
Disadvantage: **Much more expensive, reactants need to be constantly fed-into the cell, etc.**  
Accept any one valid disadvantage. (1)

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



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)

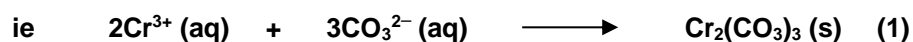


$$\text{Cell EMF} = +2.10 \text{ V} \quad (1)$$

- (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)**



**End of questions**