Semester Two Examination, 2016

MARKING KEY

CHEMISTRY

Section One: Multiple-choice SOLUTIONS

Question	Correct response
1	B
2	B
3	A
4	B
5	C
6	A
7	C
8	A
9	A
10	C
11	B
12	C
13	D
14	B
15	D
16	D
17	A
18	C
19	D
20	C
21	C
22	D
23	C
24	A
25	B

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

This section has **25** questions. Answer **all** questions on the separate Multiple-choice Answer Sheet provided. For each question shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square, then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 50 minutes.

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1. Which one of the following substances is the strongest acid?

(a) HF
(b) HNO_3
(c) H_3PO_4
(d) CH_3COOH

2. Which one of the following substances is the strongest reducing agent?

(a) Au
(b) Sr
(c) FeI_3
(d) H_2O_2

3. Consider the following system at equilibrium.

$$Pb^{2+}(aq) + 2\ Br^-(aq) \rightleftharpoons PbBr_2(s) + heat$$

Which one of the following changes would cause the concentration of lead(II) ions to be lowered (compared to the original concentration) once equilibrium is re-established?

(a) Adding potassium iodide solution.
(b) Stirring the mixture.
(c) Warming the system.
(d) Adding solid lead(II) bromide to the system.

4. Which one of the following 1.0 mol L^{-1} solutions will have the lowest pH?

(a) sodium hydrogencarbonate
(b) ammomium chloride
(c) sodium ethanoate
(d) sodium hydrogenphosphate

5. In which one of the following reactions is the carbon-containing species acting as a Brønsted-Lowry acid?

(a) $NaHCO_3(s) + H^+(aq) \rightarrow Na^+(aq) + H_2O(\ell) + CO_2(g)$
(b) $CO_2(g) + H_2O(\ell) \rightarrow H_2CO_3(aq)$
(c) $H_2CO_3(aq) + NaOH \rightarrow NaHCO_3(aq) + H_2O(\ell)$
(d) $CO_3^{2-}(aq) + Ca^{2+}(aq) \rightarrow CaCO_3(s)$

MARKING KEY

6. Which of the following combinations will form a buffer solution?

i. $NH_3(aq)$ / $NH_4C\ell$ (aq)
ii. $NH_3(aq)$ / $HC\ell$ (aq)
iii. $HC\ell(aq)$ / $NH_4Cl(aq)$
iv. $H_2PO_4^-(aq)$ / $HPO_4^{2-}(aq)$
v. $H_2SO_4(aq)$ / $HSO_4^-(aq)$

(a) i and iv only
(b) i, iv and v only
(c) i, ii and iv only
(d) iv only

Question 7 and 8 relate the following equation:

One of the processes involved in the acidification of the oceans caused by increasing carbon dioxide levels is shown below:

$$HCO_3^-(aq) \rightleftharpoons CO_3^{2-}(aq) + H^+(aq)$$

7. Which one of the following statements is true?

(a) HCO_3^- is the conjugate base of the CO_3^{2-} ion.
(b) The HCO_3^- ion is the conjugate acid of the H^+ ion.
(c) HCO_3^- is the conjugate acid of the CO_3^{2-} ion.
(d) H^+ is the conjugate acid of the HCO_3^- ion.

8. Using this process and your knowledge of other chemical processes occurring in the ocean, which one of the following will reduce the acidity of the oceans?

(a) increased amount of sediments and shells that contain calcium carbonate.
(b) Increased concentration of carbon dioxide in the atmosphere
(c) Addition of more hydrogencarbonate ions into the ocean
(d) Increased extreme weather conditions causing wind and waves in the ocean

9. Water ionises according to the following reaction.

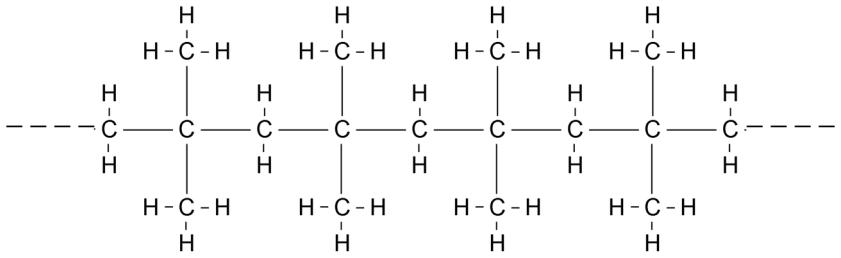
$$2\ H_2O(\ell) \rightleftharpoons OH^-(aq) + H_3O^+(aq)$$

At 25 ^oC the concentration of H^+ is 10^{-7} mol L^{-1} and the pH of pure water is 7.0. When the temperature is increased, the pH of water reduces. Which of the following statements below is correct?

(a) The forward reaction is endothermic.
(b) The concentration of $OH^-(aq)$ reduces, making the water more acidic.
(c) The water is no longer neutral, so the pH of water reduces.
(d) The concentration of the $H_3O^+(aq)$ reduces.

MARKING KEY

10. Consider the section of the polymer below.



Which one of the following is correct name for the monomer used to synthesise this polymer?

(a) but-1-ene
(b) but-2-ene
(c) 2-methylpropene
(d) 2,2-dimethylethene

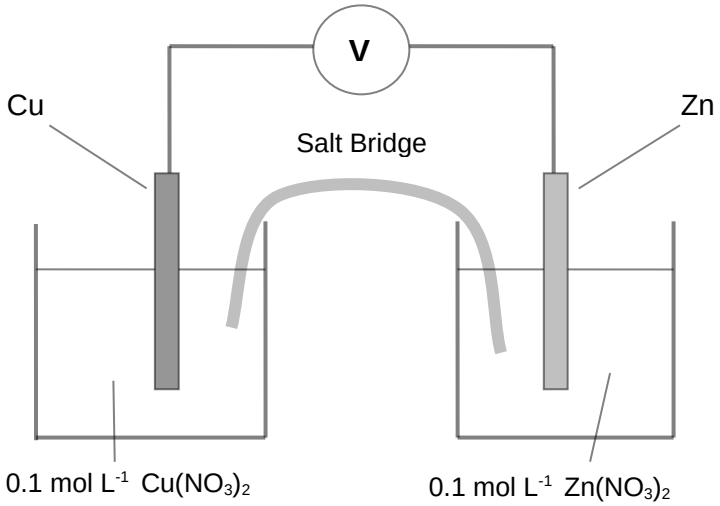
11. In which of the following processes is chlorine being oxidised?

i. $PC\ell_3 + C\ell_2 \rightarrow PC\ell_5$
ii. $C\ell_2 + H_2O \rightarrow C\ell^- + HC\ell O + H^+$
iii. $2\ C\ell^- \rightarrow C\ell_2 + 2\ e^-$
iv. $HC\ell O_3 + H_2O_2 \rightarrow HC\ell O_4 + H_2O$

(a) i, ii and iv only
(b) ii, iii and iv only
(c) i, ii, iii and iv
(d) ii and iv only

The following diagram relates to questions 12 and 13

The following galvanic cell was set up.



12. Which one of the following is the purpose of the salt bridge?

(a) To increase the concentration of the ions in order to speed up the rate of the reaction.
(b) To allow the flow of electrons between the two electrodes.
(c) To complete the circuit to allow ions to flow between the two half-cells.
(d) To copper ions to flow to the zinc electrode

13. Which one of the following statements is **false**?

(a) The zinc electrode is the anode.
(b) The electrons in the wire move towards the copper electrode.
(c) The mass of the copper electrode will increase.
(d) Positive ions in the salt bridge move towards the zinc electrode.

14. Which of the following reactions will occur spontaneously?

i. $2\ I^-(aq) + Br_2(aq) \rightarrow 2\ Br^-(aq) + I_2(aq)$
ii. $Cu(s) + 2\ HC\ell(aq) \rightarrow CuC\ell_2(aq) + H_2(aq)$
iii. $Sn(s) + Cd^{2+}(aq) \rightarrow Sn^{2+}(aq) + Cd(s)$
iv. $H_2O_2(aq) + Ni^{2+}(aq) \rightarrow O_2(g) + 2\ H^+(aq) + Ni(s)$

(a) i and iv only
(b) i only
(c) iii and iv
(d) iv only

Question 15, 16 and 17 relate to the following information

An aluminium-air battery is a fuel cell that involves aluminium reacting with oxygen in the air. The relevant half-equations are shown below.

$O_2(g) + 2\ H_2O(\ell) + 4\ e^- \rightleftharpoons 4\ OH^-(aq)$

$Al^{3+}(aq) + 3\ e^- \rightleftharpoons Al(s)$

15. This cell is described as a fuel cell because

(a) it is a sustainable power source that can be used to replace fossil fuels.
(b) both half-reactions are reversible so the cell can be recharged.
(c) it involves a gas as a reactant at one of the electrodes.
(d) it requires the reactants to be supplied to the cell during operation.

16. Which one of the following is the overall equation for the cell?

(a) $A\ell(s) + O_2(g) + 2\ H_2O(\ell) \rightarrow OH^-(aq) + A\ell^{3+}(aq)$
(b) $4\ A\ell^{3+}(aq) + 3\ O_2(g) + 6\ H_2O(\ell) \rightarrow 12\ OH^-(aq) + 4\ A\ell\ (s)$
(c) $A\ell^{3+}(aq) + O_2(g) + 2\ H_2O(\ell) \rightarrow 4\ OH^-(aq) + A\ell\ (s)$
(d) $4\ A\ell(s) + 3\ O_2(g) + 6\ H_2O(\ell) \rightarrow 12\ OH^-(aq) + 4\ A\ell l^{3+}(aq)$

17. The theoretical voltage obtainable from this cell is

(a) 1.88 V.
(b) 2.08 V.
(c) 2.91 V.
(d) 5.52 V.

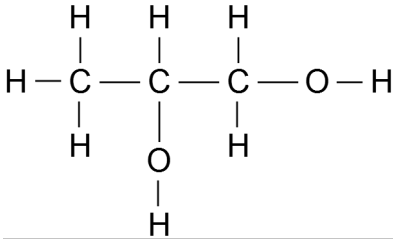
18. Substance **X** has an empirical formula of C_2H_4O. Which one of the following could **not** be substance **X**?

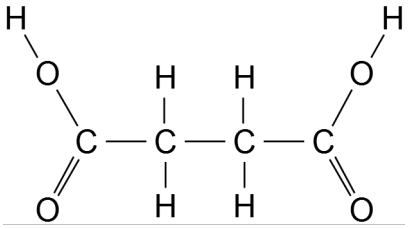
(a) butanoic acid
(b) ethyl ethanoate
(c) methyl methanoate
(d) methyl propanoate

19. Which one of the following compounds will be readily oxidised to form a carboxylic acid?

(a) $CH_3CH_2C(OH)CH_3$
(b) $HOC(CH_3)_3$
(c) $CH_3CH_2COOCH_3$
(d) CH_3CH_2CHO

20. The following two substances were reacted together:





Which one of the following would be the type of product produced?

(a) a soap
(b) a fatty acid
(c) a polyester
(d) a protein

21. Which one of the following pairs of compounds would form methyl propanoate when warmed with concentrated sulfuric acid?

(a) CH_4 and CH_3CH_2COOH
(b) CH_3OH and $CH_3CH_2CH_2OH$
(c) CH_3OH and CH_3CH_2COOH
(d) $HCOOH$ and $CH_3CH_2CH_2OH$

22. Consider the dipeptide below.

$HOOCCH(CH_3)NHCOCH(CH_2OH)NH_2$

Use your data sheet to identify which pair of amino acids below would form this dipeptide.

(a) alanine and valine
(b) valine and threonine
(c) glycine and serine
(d) serine and alanine

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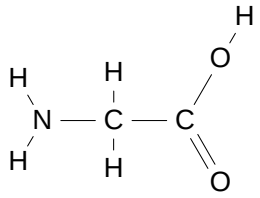
23. Consider the molecule below.



Which one of the following will this molecule **not** react with?

(a) dilute hydrochloric acid
(b) sodium hydrogencarbonate solution
(c) sodium chloride solution
(d) sodium hydroxide solution

24. Which one of the following are **not** bonds between sections of a protein that contribute to the tertiary structure of the protein?

(a) C=O bonds
(b) hydrogen bonds
(c) S–S bonds
(d) dispersion forces

25. Which one of the following is **not** an aim of the Protein Data bank? (PDB)?

(a) Standardising the way protein structures are represented.
(b) Allowing companies to patent new discoveries of protein structures.
(c) Informing medical research such as development of the use of antibodies.
(d) Sharing knowledge of protein structures from scientists across the world.

End of Section One

MARKING KEY

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

This section has **ten (10)** 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 that you are continuing to answer at the top of the page.

Suggested working time: 60 minutes.

Question 26 **(5 marks)**

(a) Calculate the pH of a solution of 0.500 mol L^{-1} hydrochloric acid. (2 marks)

Description	Marks
$c(H^+) = 0.500$ mol L^{-1}	1
$pH = -\log(H^+) = -\log(0.500)$ **= 0.300**	1
Total	**2**

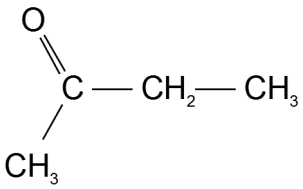
(b) A student was asked to dilute 50.0 mL of this solution to produce a solution of hydrochloric acid with a pH of 2.00. Calculate the volume of distilled water that she would she need to add. (3 marks)

Description	Marks
$c(H^+) = 10^{-2.00} = 0.0100$ mol L^{-1}	1
$V_2 = C_1V_1 / C_2 = 0.5 \times 0.050$ mL $/ 0.01$ $= 2.50$L	1
Required to add $2500 - 50 =$ **2.45L**	1
Total	**3**

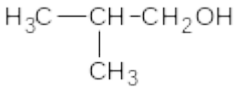
Question 27 **(6 marks)**

The alcohol butan-2-ol can be oxidised with acidified potassium dichromate solution.

(a) Draw the structural formula and name the organic product formed. (2 marks)

Description	Marks
	1
Butanone	1
Total	**2**

(b) (i) Draw and name an isomer of butan-2-ol that will react with the potassium dichromate solution to produce a carboxylic acid. (2 marks)

Description	Marks
$CH_3—CH_2—CH_2—CH_2—OH$ or 	1
Butan-1-ol or methylpropan-1-ol	1
Total	**2**

(ii) Write a balanced redox equation for this reaction. (2 marks)

$(Cr_2O_7^{2-} + 14\ H^+ + 6\ e^- \rightarrow 2\ Cr^{2+} + 7\ H_2O) \times 2$

$(C_4H_9OH + H_2O \rightarrow C_3H_7COOH + 4\ H^+ + 4\ e\text{-}) \times 3$

$\mathbf{2Cr_2O_7^{2-} + 3C_4H_9OH + 16\ H^+ \rightarrow 4Cr^{2+} 3C_3H_7COOH + 11H_2O}$

Description	Marks
Correct species	1
balanced	1
Total	**2**

Question 28 **(10 marks)**

MARKING KEY

Swimming Pool maintenance uses sodium hypochlorite (NaClO), to control algae and bacteria. The swimming pool water can be considered as an equilibrium system as shown below, where hypochlorite ions are converted in to hypochlorous acid (HCℓO).

$$C\ell O^-(aq) + H_3O^+(aq) \rightleftharpoons HC\ell O(aq) + H_2O(\ell) + HEAT$$

For best results, the concentration of the hypochlorous acid should be kept above 1.00 ppm.

(a) Complete the table by using Le Châtelier's principle to predict, with reasoning, the effect of the following changes on the concentration of the hypochlorous acid (HCℓO) in the swimming pool. (6 marks)

	Description			Marks
Increasing the pH of the pool	decreases	1	system shifts to the left to produce $H_3O^+(aq)$	1
			to oppose the reduction in H_3O^+ (aq) caused by the increase in pH / concentration of OH^- ions	1
Increasing the temperature of the pool	decreases	1	endothermic reverse reaction favoured	1
			to oppose the increase in heat	1
	Total	**2**		**4**

(b) (i) If the concentration is 1.50 ppm, calculate the mass of hypochlorous acid in a pool that has a capacity of 120 000 litres. (density of pool water is 1.00 kg L^{-1}) (1 mark)

Description	Marks
$m(solute)_{(mg)}$ = c × mass of solution $m(HClO)_{(mg)}$ = 1.5 × 120 000 = 180 000 mg **= 180 g**	1
Total	**1**

(ii) Assuming 60% conversion of sodium hypochlorite to hypochlorous acid, calculate the mass of sodium hypochlorite that would be required provide this mass of hypochlorous acid. (3 marks)

Description	Marks
n(HClO) = 180 / 52.458 = 3.43 mol	1
$n(NClO)_{required}$ = (100/60) × 3.43 = 5.7189 mol	1
$(NClO)_{required}$ = 5.7189 × 74.44 = **426 g**	1
Total	**3**

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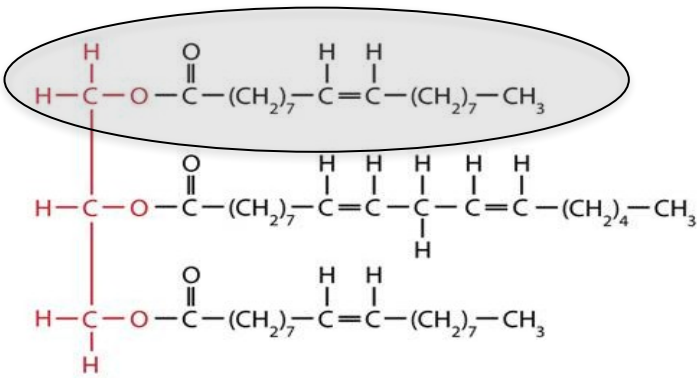
Question 29 **(5 marks)**

Biodiesel is a fuel that can be synthesised from natural oils and fats. The molecule below is a triglyceride present in vegetable oil that can be used for this process.



Biodiesel can be synthesised using a base-catalysed reaction with methanol. The triglyceride breaks down into fatty acids and these undergo esterification with methanol to form methyl esters. The methyl esters are the main components of biodiesel.

(a) State why the compound above is described as an unsaturated oil. (1 mark)

Description	Marks
contains C=C double bonds	1
Total	**1**

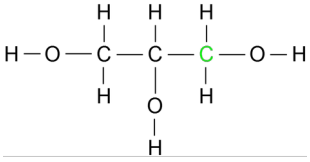
(b) Draw the structural formula of the methyl ester formed from the section of the molecule circled in the above diagram. (1 mark)

Description	Marks
$CH_3OCO–(CH_2)_7–CH=CH–(CH_2)_7–CH_3$	1
Total	**1**

(c) Name a catalyst that can be used in this process. (1 mark)

Description	Marks
sodium/potassium hydroxide or lipase	1
Total	**1**

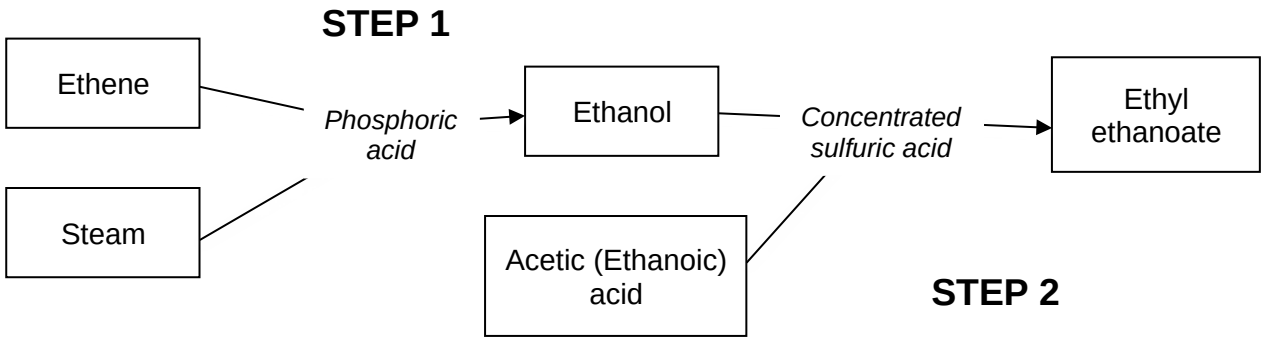
(d) As well as the methyl esters (the biodiesel), there is one other product of this reaction. Name and draw the structural formula of this product. (2 marks)

Description	Marks
	1
glycerol	1
Total	**2**

MARKING KEY

Question 30 **(13 marks)**

The following reaction sequence can be used to synthesise ethyl ethanoate.



(a) Explain, using collision theory, how phosphoric acid and sulfuric acid act as catalysts in this reaction sequence. (2 marks)

Description	Marks
provide an alternative reaction pathway with lower activation energy	1
resulting in more successful collisions	1
Total	**2**

(b) Consider Step 1 and Step 2 in this reaction sequence.

(i) Write the equation for Step 1 and explain why it is described as an addition reaction. (2 marks)

Description	Marks
$C_2H_4 + H_2O \rightarrow C_2H_5OH$	1
two reactants and only one product / the water molecule 'adds' to the molecule across the double bond.	1
Total	**2**

(ii) Write the equation for Step 2 and explain why it is described as a condensation reaction. (2 marks)

Description	Marks
$C_2H_5OH + CH_3COOH \rightarrow C_2H_5OCOCH_3 + H_2O$	1
a small molecule / water molecule is produced as a product	1
Total	**2**

(c) In Step 1, 458 kg of ethene was reacted with excess steam and 48.5 kg of ethanol was produced. Calculate the percentage yield of this reaction. (4 marks)

Description	Marks
$n(C_2H_4) = m/M = 458\,000 / 28.052 = 16\,326.8$ mol	1
expected yield $n(C_2H_5OH)_{expected} = n(C_2H_4) = 16\,326.8$ mol	1
$n(C_2H_5OH)_{produced} = 48\,500$ g $= 48\,500 / 46.068 = 1052.8$	1
% yield $= (1052.8 / 16\,326.8) \times 100$ **$= 6.45\%$**	1
Total	**4**

(d) Ethanol can also be produced via the fermentation. Biomass provides glucose ($C_6H_{12}O_6$) which is fermented.

(i) Write an equation showing the conversion of glucose to ethanol. (1 mark)

Description	Marks
$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$	1
Total	**1**

(ii) In this process, the reaction is catalysed by enzymes. Describe two characteristics of enzymes that makes them different from catalysts such as phosphoric acid and sulfuric acid. (2 marks)

Description	Marks
any two from: • They are biochemical molecules / proteins • they catalyse specific reactions • they work by having a particular shape • they are pH sensitive • they can be destroyed/denaturated at high temperatures	0 – 2
Total	**2**

Question 31 **(9 marks)**

Sodium stearate ($CH_3(CH_2)_{16}COONa$) is a soap.

(a) Using a diagram, and your knowledge of intermolecular forces, explain how the polarity of the stearate ion enables it to act as a soap. (4 marks)

Description	Marks
diagram showing the polar and non-polar regions of the stearate ion	1
the non-polar part of the molecule forms dispersion forces with non-polar dirt/ fat/oil	1
the polar head of the molecule is available to form ion-dipole bonding with water	1
therefore, the dirt/ fat/oil becomes water soluble and can be washed away	1
Total	**4**

(b) In hard water, soaps can form a precipitate of calcium stearate (scum).

(i) Write an ionic equation, including state symbols, showing this process. (3 marks)

$2\ CH_3(CH_2)_{16}COO^-(aq) + Ca^{2+}(aq) \rightarrow Ca(CH_3(CH_2)_{16}COO)_2(s)$

Description	Marks
correct species	1
balanced equation	1
correct state symbols	1
Total	**3**

(ii) Describe two problems caused by the formation of scum. (2 marks)

Description	Marks
soap is wasted as it reacts with the calcium or magnesium ions instead of acting as a soap	1
the scum can be unsightly / makes clothes look dirty/grey / can block filters	1
Total	**2**

Question 32 **(7 marks)**

A group of students was investigating the equilibrium between dichromate and chromate ions. The equation for the system is shown below:

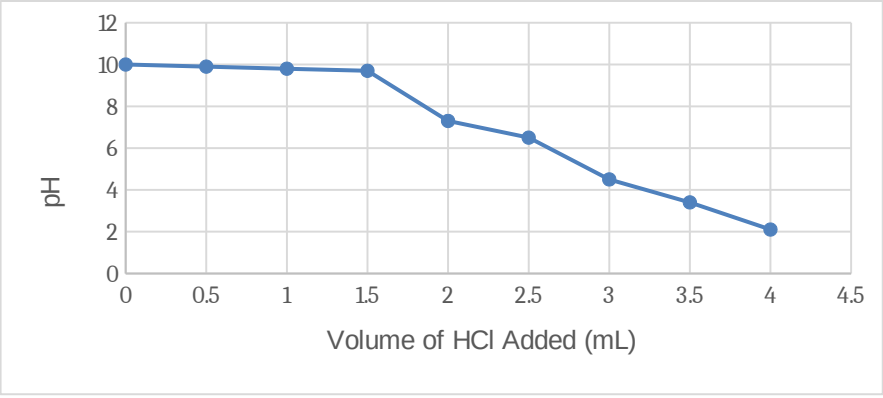
$$2\ CrO_4^{2-}(aq) + 2\ H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(\ell)$$

They started with 50.0 mL of a solution of 0.10 mol L^{-1} potassium chromate, and gradually added hydrochloric acid to the solution. They recorded the colour of the solution and the pH using a pH probe. Their results are shown below.

Table 1. Colour of a solution of potassium chromate on addition of 1.0 mol L^{-1} hydrochloric acid

Measurement	Volume of HCℓ(aq) (mL)	pH	Colour of solution
1	0.0	10	green/yellow
2	0.5	9.9	green/yellow
3	1.0	9.8	green/yellow
4	1.5	9.7	green/yellow
5	2.0	7.3	yellow
6	2.5	6.5	orange
7	3.0	4.5	orange
8	3.5	3.4	orange
9	4.0	2.1	orange

(a) Plot a graph on the grid below showing the variation of pH against volume of hydrochloric acid added. *(a spare grid is provided at the end of the questions if required)* (4 marks)



Description	Marks
appropriate scales	1
labelled axis (including units on x axis)	1
points plotted accurately	1
line drawn	1
Total	**4**

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(b) Suggest why there is no significant change in pH for the first four measurements. (1 marks)

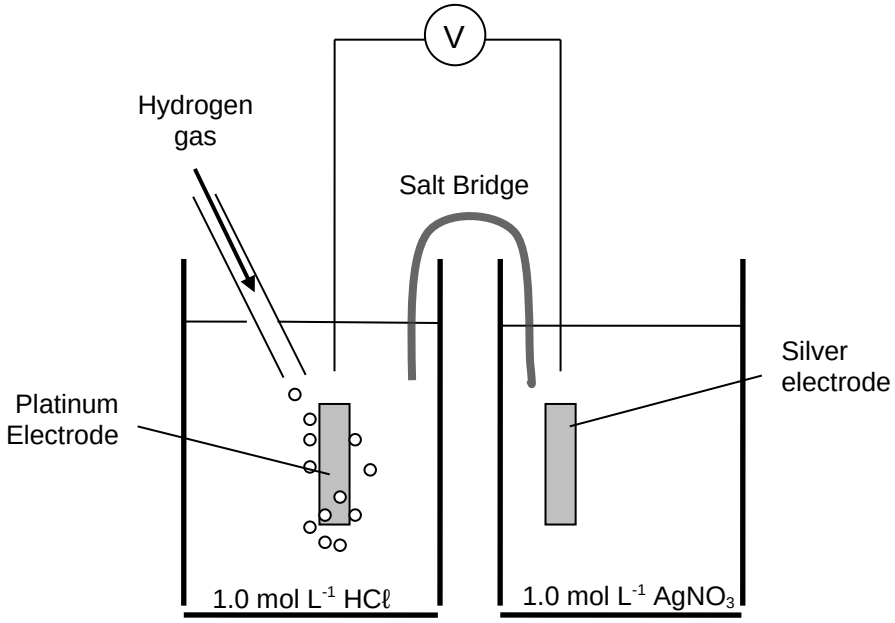
Description	Marks
The added H^+ ions are being consumed by the reaction with CrO_4^{2-}, so cannot affect the overall pH until they are in excess.	1
Total	**1**

(c) Based on these results, the students concluded that potassium chromate could be used as an indicator in an acid-base titration. Evaluate this conclusion. (2 marks)

Description	Marks
either:	
Agree (no mark for this)	
the dichromate exists in two different forms with different colours	1
dependent on the pH. (but could only be used for titrations with a strong acid and a strong base as the colour change is around pH 7–8	1
or:	
disagree (no mark for this)	
There is a pH dependent colour change, but you would have to add too much dichromate to see a colour change	1
which might affect the results of the titration	1
award correct and/or logical chemistry for this question	
Total	**2**

Question 33 **(7 marks)**

Below is a representation of an electrochemical cell used to measure the standard reduction potential for the Ag/Ag^+ half-cell.



(a) Give the half-equation for the reactions occurring at the anode and cathode and write an overall redox equation for the reaction occurring in the cell. (3 marks)

Description		Marks
Anode half-equation:	$H_2 \rightarrow 2\,H^+ + 2\,e^-$	1
Cathode half-equation:	$Ag^+ + e^- \rightarrow Ag$	1
Overall equation:	$H_2 + 2\,Ag^+ \rightarrow 2\,Ag + 2\,H^+$	1
	Total	**3**

(b) Use an arrow to show the movement of electrons on the diagram above. (1 mark)

Description	Marks
arrow showing electrons moving along the wire towards the silver electrode	1
Total	**1**

(c) Explain why 1.0 mol L^{-1} sulfuric acid is not used as the electrolyte in the hydrogen half-cell. (2 marks)

Description	Marks
sulfuric acid is a diprotic acid	1
therefore the concentration of the H^+ ions would not be 0.1 mol L^{-1}	1
Total	**2**

(d) Apart from the concentrations of the solutions, state two other conditions required to achieve an accurate measurement of the standard reduction potential for the Ag^+/Ag half-cell. (2 marks)

Description	Marks
temperature should be 25 °C	1
hydrogen should be at a pressure of 100 kPa	1

MARKING KEY

Total	**2**

Question 34 **(7 marks)**

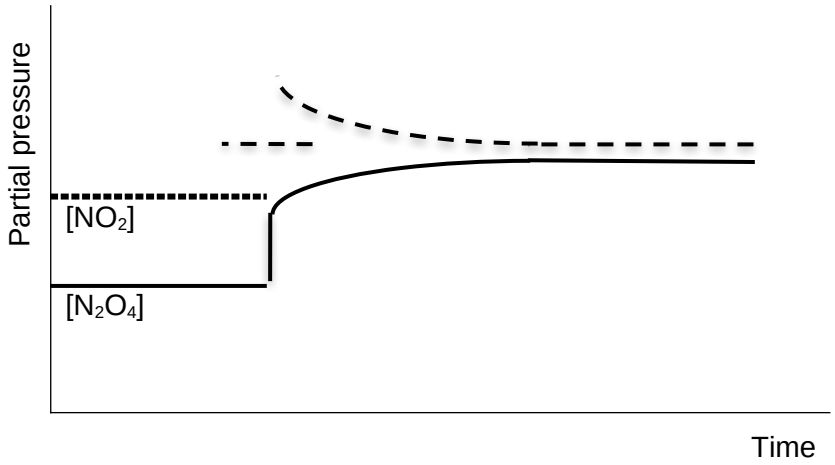
A student was investigating the equilibrium between the brown gas, nitrogen dioxide (NO_2) and the colourless gas dinitrogen tetroxide (N_2O_4). The gases were contained in a syringe. The syringe was suddenly squeezed to reduce the volume of the system. The temperature of the system was not changed. The equation for the equilibrium is shown below.

$$2\ NO_2(g) \rightleftharpoons N_2O_4(g) \quad \Delta H = -57.2\ kJ\ mol^{-1}$$

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

Description	Marks
$K = \frac{[N_2O_4]}{[NO_2]^2}$	1
Total	**1**

(b) Complete the following graph to show what happens to the partial pressures of nitrogen dioxide and dinitrogen tetroxide as the syringe is squeezed and the system responds to the change by re-establishing equilibrium. (3 marks)



Description	Marks
sudden increase in the partial pressure of each gas	1
curves down towards new equilibrium	1
curves level out above original values	1
Total	**3**

(c) Explain, with reference to reaction rates and collision theory, the shape of the graph drawn in part (b). (3 marks)

Description	Marks
more collisions so the rates of the forward and reverse reactions are increased	1
the rate of the forward reaction is increased more than the reverse reaction	1
over time, the rates of the forward and reverse reactions become the sam and equilibrium is re-established	1
Total	**3**

MARKING KEY

End of Section Two

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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 that you are continuing to answer at the top of the page.

Suggested working time: 70 minutes.

Question 35 **(21 marks)**

Aspartic acid ($C_4H_7O_4N$) is a diprotic α-amino acid. Aspartic acid has solubility of 4.5 g L^{-1} at 25 °C and a K_a value of 1.26×10^{-4}. Aspartic acid increases resistance to fatigue and is often found in food supplements, especially those used by athletes and body builders.

A chemist was asked to analyse the contents of a food supplements to check the manufacturer's claims that it contained 97.0% aspartic acid by mass. To check this claim, the following experiment was carried out. (It can be assumed that aspartic acid is the only active ingredient in the supplement)

1. 1.546 g of the supplement powder was weighed and dissolved in warmed distilled water in a beaker.
2. The solution is transferred to a 500.0 mL volumetric flask and was made up to the mark with distilled water.
3. 25.00 mL aliquots of the resulting solution were titrated, using phenolphthalein indicator, against 0.0570 mol L^{-1} sodium hydroxide solution.

The results obtained are shown below.

Burette readings (mL)	Titrations			
	1	2	3	4
Final volume	20.30	40.05	19.80	39.50
Initial volume	0.00	20.30	0.00	19.80
Titration volume (titre)				

(a) Calculate the percentage purity of the supplement. (7 marks)

Description	Marks
average titre = 19.75 mL = 0.01975 L	1
n(NaOH) = c × V = 0.0570 × 0.01975 = 1.1257 × 10-3 mol	1
n(Aspartic acid)in 25.0 mL = (½) × 1.1257 × 10-3 = 5.6287 × 10-4	1
n(Aspartic acid)in 500.0 mL = (500/25) × 5.6287 × 10-4 = 0.011257 mol	1
m(Aspartic acid) = n × M = 0.011257 × 133.106 = 1.498 g	1
% purity = (1.498 / 1.546) × 100 **= 96.9%**	1
answer to three significant figures	1
Total	**7**

(b) Consider the method used in this experiment.

(i) In Step 1, suggest why the distilled water was warmed. (1 mark)

Description	Marks
to improve the solbility	1
Total	**1**

(ii) In Step 2, the solution was transferred from a beaker into the volumetric flask. Explain why this process could be a source of systematic error. (2 marks)

Description	Marks
if some solution was left in the beaker the concentration of the solution would be weaker that it should be	1
Therefore the values for the amount of aspartic acid will <u>always</u> be less than the actual value	1
Total	**2**

(iii) Phenolphthalein changes colour at between pH 9 –10. Methyl orange changes colour at between pH 4 –5. In Step 3, predict and explain the effect on the final result if methyl orange was used as the indicator instead of phenolphthalein. (3 marks)

Description	Marks
the end point will be observed before the equivalence point	1
volume of NaOH added will be lower than the expected value	1
the amount of aspartic acid will be less than the actual value	1
Total	**3**

(c) (i) Due to the low solubility of the aspartic acid, it was suggested to the student that they use a 'back titration'. This would require the addition of a known amount of sodium hydroxide (in excess) to the aspartic acid and the titration of the unreacted hydroxide against a standard solution of acid.

Sodium hydroxide solution with a concentration of 0.978 mol L^{-1} is used and there is a standard solution of 0.100 mol L^{-1} hydrochloric acid available.

There are three pipettes to choose from (20.00 mL, 25.00 mL or 50.00 mL) for adding sodium hydroxide solution to the 1.546 g of the supplement powder.

Calculate which volume pipette the student should use to add the sodium hydroxide in order to get a titration volume (titre) of approximately 20 mL of the hydrochloric acid. (6 marks)

Description	Marks
assume sample is 97% pure m(aspartic acid) = (97/100) × 1.546 = 1.4996 g	1
n(Aspartic acid)in total = 1.4996 / 133.106 = 1.127 × 10-2 mol	1
n(NaOH)to react with this aspartic acid = (2/1) × 1.1257 × 10-3 = 0.02253 mol	1
n(NaOH)excess to react with HCl = c x V = 0.100 × 0.0200 = 0.00200 mol	1
n(NaOH)total required = 0.02253 + 0.00200 = 0.02453 mol	1
V(NaOH)total required = n/c = 0.02453 / 0.978 = 0.02508 L	1
Total	**6**

Note: full marks are not awarded if clear working is not presented

(ii) Explain why having a titre of less than 20 mL could increase the random error in this experiment. (2 marks)

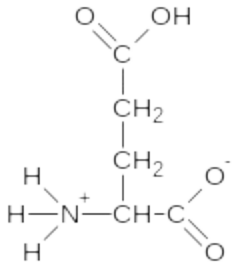
Description	Marks
The uncertainty/error when reading a burette is fixed	1
the lower the volume measured in the burette, the more significant this error/uncertainty becomes	1
Total	**2**

Question 36 **(12 marks)**

Proteins comprise of up to 2000 α-amino acid molecules joined to form a polymer. The structure of 20 commonly occurring α-amino acids are given on your data sheet.

(a) Draw a diagram of glutamic acid in zwitterion form and use this example to explain what a zwitterion is.

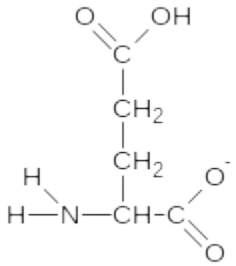
(2 marks)



Acidic COOH group loses H^+, basic NH_2 group gains the H^+, leaving a molecule with + and – charged portions, whilst still remaining an overall neutral charge overall.

(b) Draw the structure of glutamic acid in a solution that has a pH of 10.

(1 mark)

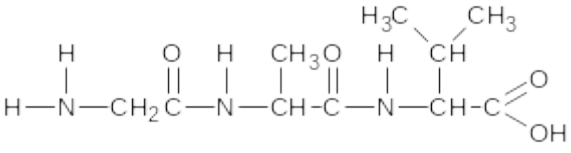


The structure of proteins can be defined on a series of levels. Compare the primary, secondary and tertiary structure of proteins by

(c) drawing the primary structure of the section of a protein represented by:

– Gly – Ala – Val –

(show all atoms in your diagram)

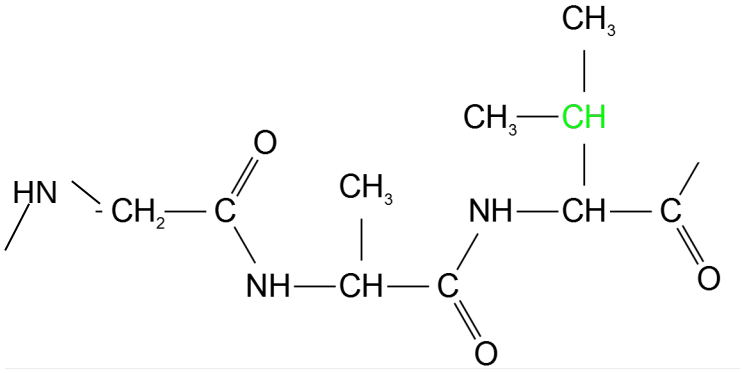


(2 marks)

MARKING KEY

(d) using a diagram to show how hydrogen bonding occurs between two parts of a protein molecule which contributes to the **secondary structure** of a protein.

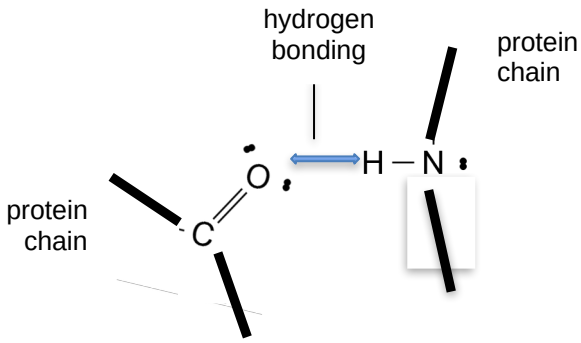
(3 marks)

Description	Marks
Primary Structure	
Overview of primary, for example 'The primary structure of a protein is the order of the amino acid in the chain of a protein'. The sequence – Gly – Ala – Val – below shows three α-amino acid molecules joined to form a section of a protein.  	0 – 2
Total	**2**

(e) using diagrams to predict and explain the type of bonding which contribute to the **tertiary structure** of the protein that would be formed between the side groups of the following pairs of amino acids in proteins.

- glutamic acid (Glu) and lysine (Lys)
- leucine (Leu) and isoleucine (Ile)
- two cysteine (Cys) molecules

(6 marks)

Description	Marks
Secondary Structure	
The hydrogen bonding that contributes to the secondary structure of the protein occurs between the C=O groip on one part of the chain	0 – 3
and the -N-H group on another part of the protein molecule	
This should be shown with a labelled diagram that shows the polarity of the two groups and the hydrogen bonding shown between the lone pairs on the oxygen atom in the C=O group and the Hydrogen atom. for example:  	
Total	**3**

Description	Marks
Tertiary Structure	
The tertiary structure is held together dependent on the composition and the polarity of the side groups on amino acids at parts of the protein that come into close proximity. For example	1
glutamic acid (Glu) and lysine (Lys) will form hydrogen bonding …..	0 – 2
…….. between the –– OH group on the glutamic acid and the $–NH_2$ group on the lysine. *(Can be shown by a diagram)*	
leucine (Leu) and isoleucine (Ile) will form dispersion forces …….	0 – 2
…….. between the non polar alkyl groups on both of the amino acids. *(Can be shown by a diagram)*	
two cysteine (Cys) molecules will form a disulphide bond. These are covalent bonds. *(Can be shown by a diagram)*	1
Total	**6**

The first mark can also be awarded if a student consistently refers to side-chains withouth the explicit statement.

MARKING KEY

Question 37 **(19 marks)**

In Mount Isa, Queensland, one of the world's most productive mines produces lead, silver, zinc and copper ore. One of the minerals extracted at Mount Isa is chalcopyrite ($CuFeS_2$), and the reaction used to smelt this compound is shown below.

Reaction 1 $2\ CuFeS_2 + 3\ O_2 \rightarrow 2\ FeO + 2\ CuS + 2\ SO_2$

The copper-containing compound is then reacted with more oxygen as shown below:

Reaction 2 $CuS + O_2 \rightarrow Cu + SO_2$

There is also a sulfuric acid plant at Mount Isa, which collects, then cleans sulphur dioxide before converting it to sulfuric acid via the Contact process.

The Contact process includes the following exothermic reaction, which has a yield of 87.0%

Reaction 3 $2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$

The conditions used in Reaction 3 are a moderately high temperature of 450 °C, a pressure close to normal atmospheric temperature and a catalyst of vanadium(V) oxide.

The sulfur trioxide produced is then added to water to produce sulfuric acid with a purity of 98%. This is a two-stage process which can be summarized as:

Reaction 4 $SO_3(g) + H_2O(\ell) \rightarrow H_2SO(\ell)$

(a) Assuming Reaction 1 and 2 are 100% efficient; calculate the mass of chalcopyrite required to produce 1.00 tonne of copper metal. (1.00 tonne = 1.00×10^6 g) (3 marks)

Description	Marks
either	
%(Cu) in $CuFeS_2$ = (63.55 / 183.54) × 100 = 34.6%	1
$m(CuFeS_2)_{required}$ = (100/34.6) × 1.00 = 2.89 tonnes	1
correct significant figures and units	1
or	
from equations $n(CuFeS_2) = n(Cu)$ $n(Cu) = m / M = 1.00 \times 10^6$ g / 63.55 = 15735.6 mol	1
$n(CuFeS_2)$ = 15735.6 $m(CuFeS_2)$ = 15735.6 × 183.54 = 2 888 119 g = 2.89 tonnes	1
correct significant figures and units	1
Total	**3**

MARKING KEY

3703.57/

(b) Calculate the total number of moles of sulfur dioxide generated in the production of 1.00 tonne of copper. (2 marks)

Description	Marks
$n(SO_2) = (4/2) \times n(Cu) = (4/2) \times 15735.6$	1
$= 31471 = 3.15 \times 10^4$ mol	1
Total	**2**

(c) In 2012 the Mount Isa mine was producing 280 tonnes of copper per day from chalcopyrite and the sulfuric acid plant had to be closed down for maintenance and repair. Sulfur dioxide that would have been processed by the sulfuric acid plant was released to the atmosphere. Calculate the mass of sulfur dioxide in tonnes, released to the atmosphere each day during this time. (2 marks)

Description	Marks
$n(SO_2) = 3.15 \times 10^4 \times 280 = 8.812 \times 10^6$	1
$m(SO_2) = 8.812 \times 10^6 \times 64.07 = 564\,584\,840$ g = 565 **tonnes !**	1
Total	**2**

(d) Calculate the mass of sulfur trioxide produced in Reaction 3 from each 1.00 tonne of sulfur dioxide. (3 marks)

Description	Marks
$n(SO_2) = 1.00 \times 10^6 / 64.07 = 15\,607$ mol	1
$n(SO_3) = (87/100) \times (2/2) \times n(SO_2) = 13578.9$ mol	1
$m(SO_3) = 13578.9 \times 80.07 = 1\,087\,262 = 1.09$ tonnes	1
Total	**3**

(e) The sulfuric acid plant at Mount Isa has the capacity to produce 3,700 tonnes of 98% sulfuric acid per day. At full capacity, calculate the volume of water required by the sulfuric acid plant each day. (1.00 kg of water has a volume of 1.00 L) (5 marks)

Description	Marks
$m(H_2SO_4) = 3\,700 \times 10^6 \times (98/100) = 3\,626 \times 10^6$ g	1
$n(H_2SO_4) = 3\,626 \times 10^6 / 98.086 = 3.697 \times 10^7$ mol	1
$n(H_2O) = n(H_2SO_4) = 3.697 \times 10^7$ mol $m(H_2O) = 3.697 \times 10^7 \times 18.016$ $= 6.66 \times 10^8$ g $= 6.66 \times 10^5$ kg	1
$V(H_2O) = 6.7 \times 10^5$ L (2SF)	1
correct significant figures and units	1
Total	**5**

MARKING KEY

(h) Explain, in terms of green chemistry,

(i) two benefits of the two plants operating together at the Mount Isa site. (2 marks)

Description	Marks
less harmful sulfur dioxide emissions from the smelting of copper / metals is reduced	1
reduction of production / transport costs (and associated emissions) for supply in the raw material for the production of sulfuric acid	1
Total	**2**

(ii) why a catalyst, and not a higher temperature, is used in Reaction 3. (2 marks)

Description	Marks
higher temperature will reduce yield and therefore waste reactant chemicals / will be expensive and increase fuel costs/environmental impact	1
a catalyst will provide a faster reaction without the associated economic and environmental consequences	1
Total	**2**

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Question 38 **(11 marks)**

Banana oil contains an ester, which gives the oil its distinctive flavour. A series of experiments were carried out to determine the formula of this ester, which was known to contain just carbon, hydrogen and oxygen.

1.51 g of the ester was combusted in excess oxygen and 3.57 g of carbon dioxide was produced.

A second sample weighing 2.11 g was combusted in excess oxygen and 2.04 g of water was produced.

(a) Calculate the empirical formula of the ester. (6 marks)

Description				Marks
Sample 1 (1.51 g)				
$m(CO_2) = 3.57 \times (12.01/44.01) = 0.974$ g $\%(CO_2) = (0.974 / 1.51) \times 100 = 64.5$ %				1
Sample 2 (2.11 g)				
$m(H) = 2.04 \times (2.016/18.016) = 0.2283$ g $\%(H) = (0.2283 / 2.11) \times 100 = 10.8$ %				1
Oxygen				
$\%(O) = 100 - 64.5 - 10.8 = 24.7\%$				1
	C	**H**	**O**	
mass (%)	64.5	10.8	24.7	
mole ratio	64.5/12.01	10.82/1.008	24.7/16.00	
	5.37	10.73	1.54	1
divide by smallest	5.37/1.54	10.73/1.54	1.54/1.54	
	3.48	*6.96*	1.00	1
round up (× 2)	7	14	2	
Empirical Formula	**$C_7H_{14}O_2$**			1
			Total	**6**

MARKING KEY

A third sample weighing 0.401 g was vaporised and the gas produced was found to occupy a volume of 162 mL at 150 °C at 67.0 kPa.

(b) From this information, prove that the empirical formula of the ester is the same as the molecular formula. (3 marks)

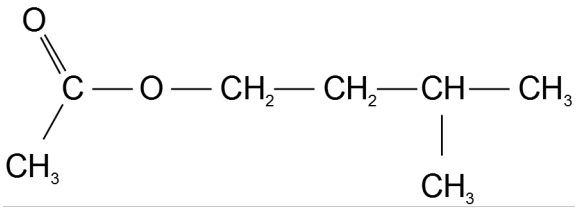
Description	Marks
n = PV / RT = 67.0 × 0.162 / 8.315 × 423.15 = 0.003085 mol	1
M = m/n M(ester) = 0.401 / 0.003085 = 129.98 = 130 g mol^{-1}	1
M(Empirical Formula) = M($C_7H_{14}O_2$) = 130.18 Therefore Empirical Formula = molecular formula	1
Total	**3**

(c) This ester can be synthesised from an alcohol and a carboxylic acid. The alcohol required is 3-methylbutan-1-ol.

(i) Name the carboxylic acid required to produce the ester. (1 mark)

Description	Marks
acetic / ethanoic acid	1
Total	**1**

(ii) Draw the structural formula of the ester present in banana oil. (1 mark)

Description	Marks
	1
Total	**1**

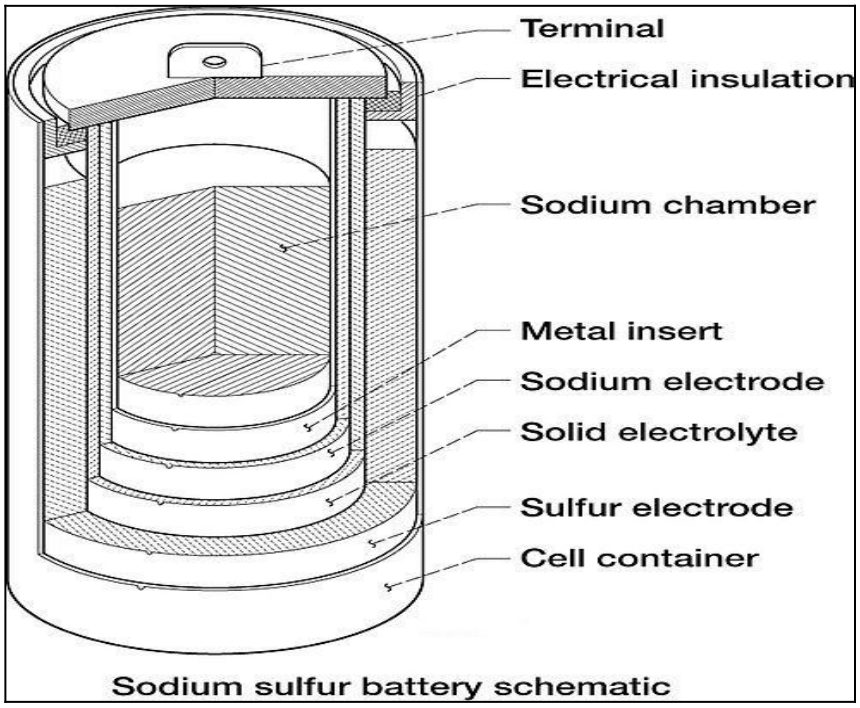
MARKING KEY

Question 39 **(15 marks)**

This question refers to the following information about a type of large scale secondary storage cell used as a backup for power grids:

Anatomy of the sodium-sulfur cell

The battery has a sodium (Na) anode and a sulfur (S) cathode. The electrolyte is the ceramic, sodium beta alumina (approx. 11 parts aluminium oxide Al_2O_3 and 1 part sodium oxide Na_2O) which has ion transmitting qualities.



Sodium sulfur battery schematic

For the cell to work, both the sodium and the sulfur must be liquid and the electrolyte must be at a temperature at which it can work as an ionic conductor. Sodium melts at 98 $^{\circ}$C and sulfur at 113 $^{\circ}$C but the electrolyte does not operate effectively until the temperature reaches around 350 $^{\circ}$C. This then is the operating temperature of the battery. The electrolyte remains solid at this temperature as its melting point is 2100 ^{0}C yet it has ***ion transmitting qualities***. The cells are commonly constructed as a pair of concentric tubes in which the inner tube made of the electrolyte contains one electrode while the outer tube made of a metal such as aluminium, contains the other electrode. The cell is completely enclosed and does not give off any gases. The cell actually has a very high electrical efficiency of the order of 85%.

The electrolyte is very brittle and thus the sodium sulfur cell does suffer from poor shock resistance. It also suffers from thermal cycling problems although this is not an issue if the temperature is maintained. The poor shock resistance is less of a problem in stationary applications but it is a serious problem in the transport market. The overall chemistry of the cell is represented below. Reduction of elemental sulfur gives polysulfides, which consist of 2 sulfur atoms in a chain terminated with S^- ionic centres. The product is known as sodium polysulfide.

$$2Na + 4S \rightarrow Na_2S_4^{*} \qquad \text{E.M.F.} = 2\ \text{V}$$

*Structure of the polysulfide ion ($^{-}S - S - S - S^{-}$)

MARKING KEY

(a) The product of the overall cell chemistry is known as sodium polysulfide (Na_2S_4). Given that **sodium** is an alkali metal with only one valence shell electron, what oxidation state **must** it exhibit in its most stable ion?

+1

(1 mark)

(b) Give a half equation for the anode chemistry in this cell.

$Na \rightarrow Na^+ + e^-$

(1 mark)

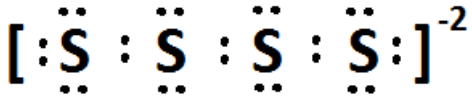
(c) Given the structure of the polysulfide ion what ***two different*** oxidation states does sulfur have in a polysulfide ion (S_4^{2-})?

i. 0

ii. -1

(2 mark)

(d) Draw a possible electron – dot structure for the polysulfide ion (S_4^{2-}).



(1 mark)

(e) Write a half equation for the cathode process.

$4S + 2e^- \rightarrow S_4^{2-}$

(1 mark)

(f) Show the addition of the anode and cathode half equations to show how the overall cell reaction (***$2Na + 4S \rightarrow Na_2S_4$***) is arrived at.

$Na \rightarrow Na^+ + e^-$

$4S + 2e^- \rightarrow S_4^{2-}$

$2Na + 4S \rightarrow 2Na^+ + S_4^{2-}$

$2Na + 4S \rightarrow Na_2S_4$

(1 mark)

MARKING KEY

(g) Given the information contained on your data chart determine the approximate reduction potential for the reaction at the cathode.

E.M.F = 2V
Ox. Pot (Na) + Red. Pot (S) = 2V
+2.71 + x = 2V
x = 2 – 2.71
Red. Pot. = -0.71V

(1 mark)

(h) The values used and determined for the electrode potentials are not completely accurate. Give the major reason for this lack of accuracy.

The Cell is not aqueous, and not at standard conditions.

(1 mark)

(i) If there is a breach in this cell and the sulfur is exposed to the air it may oxidise to form sulfur dioxide. Give a molecular equation for this reaction.

$$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$$

(1 mark)

(k) Describe a major safety hazard associated with this type of battery other than the release of sulfur dioxide into the environment.

High Operating Temperature

High reactivity of sodium (either will be awarded)

(1 mark)

(l) If this battery receives an input of 250 MJ (mega joules) of energy then how much energy, given its efficiency, can be transformed into useful output?

Useful output = input x efficiency
= 250,000,000 x 85/100
= 212,500J or 212.5kJ

(1 mark)

(m) What is meant by the term “secondary cell”?

A secondary cell is rechargable

(1 mark)

MARKING KEY

(n) Explain in a paragraph in terms of chemical bonding why the electrolyte used in this cell is very brittle and why this leads to poor shock resistance.

The electrolyte is made of a ceramic. The ceramic is made of a powdered ionic substance that is compressed or fired to become hard – much like a china plate. The bonding is a mixture of ionic and covalent, but the ionic bonding is very brittle. If dropped, the ions are displaced and may repel each other, causing the electrolyte to crack.

(2 marks)