MARKING KEY

CHEMISTRY

Section One: Multiple-choice   SOLUTIONS

Question	Correct response
1	B
2	B
3	A
4	C
5	D
6	A
7	C
8	A
9	A
10	C
11	B
12	C
13	D
14	B
15	D
16	D
17	B
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.
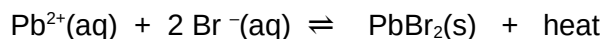
Suggested working time: 50 minutes.

_____

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. 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) $CO_3^{2-}(aq) + Ca^{2+}(aq) \rightarrow CaCO_3(s)$

5.   Use the information in the table below to determine which acid will have the lowest pH?

Name	Formula	Equilibrium constant K
Benzoic acid	C_6H_5COOH	6.3×10^{-5}
Hypochlorous acid	$HC\ell O$	2.9×10^{-8}
Hydrocyanic acid	HCN	6.2×10^{-10}
Methanoic acid	HCOOH	1.8×10^{-4}

(a)   Benzoic acid
(b)   Hypochlorous acid
(c)   Hydrocyanic acid
(d)   Methanoic acid

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. $HC\ell(aq)$ / $NH_4C\ell(aq)$
        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 information:

One of the processes involved in the acidification of the oceans caused by increasing carbon dioxide levels in the atmosphere 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.

$$2\ H_2O(\ell) \quad \rightleftharpoons \quad OH^-(aq)\ +\ H_3O^+(aq)$$
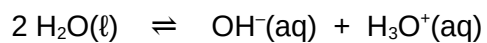
At 25 °C the concentration of H^+ is 10^{-7} mol L^{-1} and the pH of pure water is 7.0. When the temperature is increased, the pH of water reduces. Which of the following statements below is correct?

(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.

10. Consider the section of the polymer below.
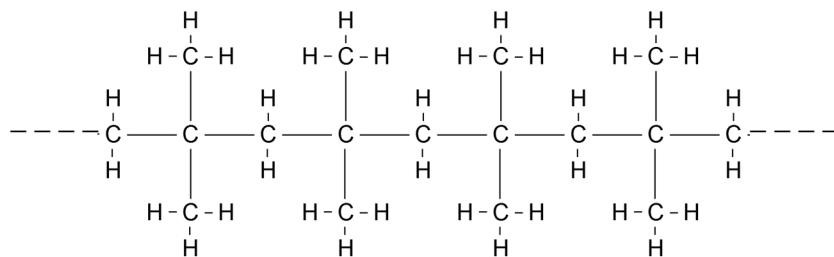
Which one of the following is the correct name for the monomer used to synthesise this polymer?
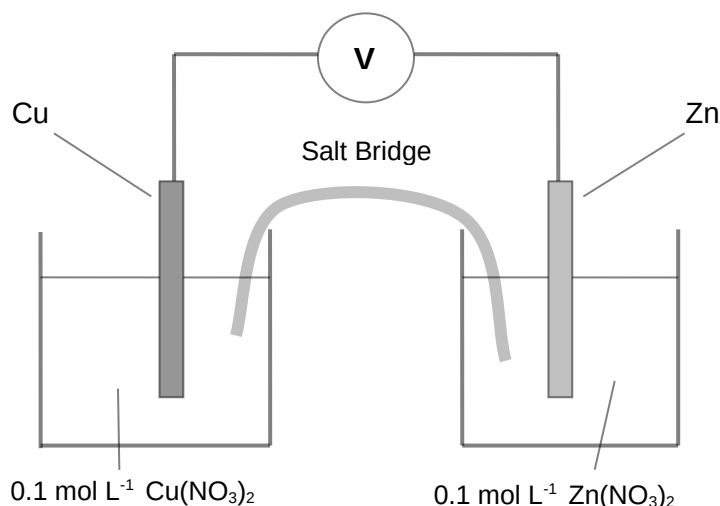
(a) but-1-ene
(b) but-2-ene
(c) 2-methylpropene
(d) 2,2-dimethylethene

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

i. $PCl_3 + Cl_2 \rightarrow PCl_5$
ii. $Cl_2 + H_2O \rightarrow Cl^- + HClO + H^+$
iii. $2\,Cl^- \rightarrow Cl_2 + 2\,e^-$
iv. $HClO_3 + H_2O_2 \rightarrow HClO_4 + H_2O$

(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 allow 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 lead 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.

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

$$Al^{3+}(aq) + 3 e^- \rightleftharpoons A\ell(s)$$
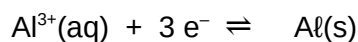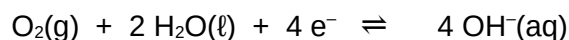
15. This cell is described as a fuel cell because

   (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) $4 A\ell(s) + 3 O_2(g) + 6 H_2O(\ell) \rightarrow 12 OH^-(aq) + 4 A\ell^{3+}(aq)$

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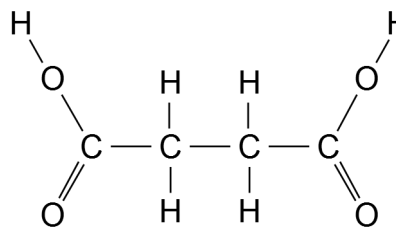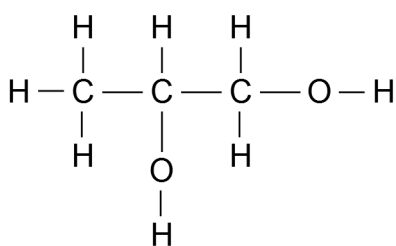
Which one of the following would be the type of product produced?

(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

23.   Consider the molecule below.
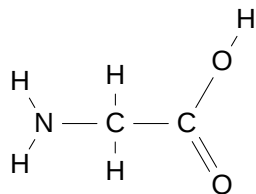
Which one of the following will this molecule **not** react with?

(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

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
$pH = -\log(H^+) = -\log(0.500)$ **= 0.301**	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)
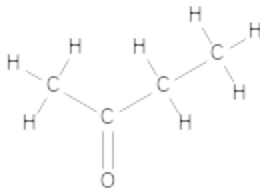
Description	Marks
$c(H^+) = 10^{-2.00} = 0.0100$ mol L^{-1}	1
$V_2 = C_1V_1 / C_2 = 0.05 \times 50 / 0.01$ = 2500 mL	1
Required to add 2500 – 50 = **2450 mL**	1
Total	3
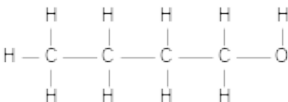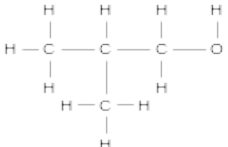
Question 27 **(6 marks)**

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 – accept butan-2-one	1
Total	**2**

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

Description	Marks
	1
butan-1-ol or 2-methypropan-1-ol – accept 1-butanol not butanol	1
Total	**2**

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

$(Cr_2O_7{}^{2-} \quad 14\, H^+ + \; + \; 6\, e^- \quad \rightarrow \quad 2\, Cr^{3+} \quad + \quad 7\, H_2O) \times 2$

$(C_4H_9OH \quad + \quad H_2O \quad \rightarrow \quad C_3H_7COOH \quad + \quad 4\, H^+ \quad + \quad 4\, e^-) \times 3$

$2\, Cr_2O_7{}^{2-} \; + \; 3\, C_4H_9OH \quad + \; 16\, H^+ \quad \rightarrow \quad 4\, Cr^{3+} \quad 3\, C_3H_7COOH \; + \; 11\, H_2O$
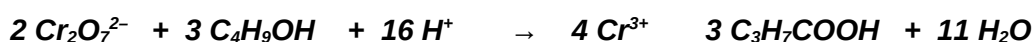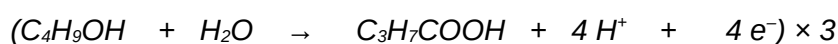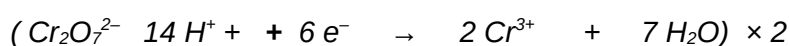
Description	Marks
Correct balanced half-equations	1
Balanced redox equation using correct ½ equations	1
Correctly balanced based on incorrect ½ equations	1
Total	**2**

Question 28 **(10 marks)**

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).

$$C\ell O^-(aq) \quad + \quad H_3O^+(aq) \quad \rightleftharpoons \quad HC\ell O(aq) \quad + \quad H_2O(\ell) \quad + \quad heat$$
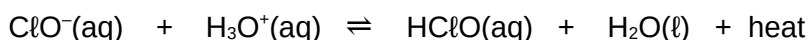
For best results, the concentration of the hypochlorous acid should be kept above 1.00 ppm.

(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)

Imposed change	Description			Marks
Increasing the pH of the pool	Decreases [HCℓO]	1	Increasing pH reduces [H_3O^+]	1
			Reducing [H_3O^+] system shifts to the left.	1
Increasing the temperature of the pool	Decreases [HCℓO]	1	Increasing temperature favours endothermic reaction	1
			Reverse reaction endothermic and position equilibrium shifts to the left	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. (Assume 1.00 L of pool water has a mass of 1.00 kg) (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(NaCℓO)$_{required}$ = (100/60) × 3.43 = 5.7189 mol	1
(NaCℓO)$_{required}$ = 5.7189 × 74.44 = **426 g**	1
Total	**3**
If incorrect formula mass is used but calc correct allocate **2 marks**	

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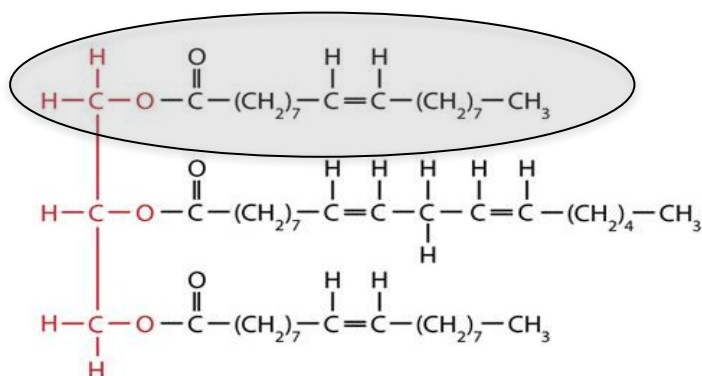
Biodiesel can be synthesised using a base-catalysed reaction with methanol. The triglyceride breaks down into fatty acids and these undergo esterification with methanol to form methyl esters. The methyl esters are the main components of biodiesel.

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

Description	Marks
contains C=C double bonds in chain	1
Just saying double bonds no marks	
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 Structural formula should be drawn to show all H's and ester linkage	1
Total	**1**

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

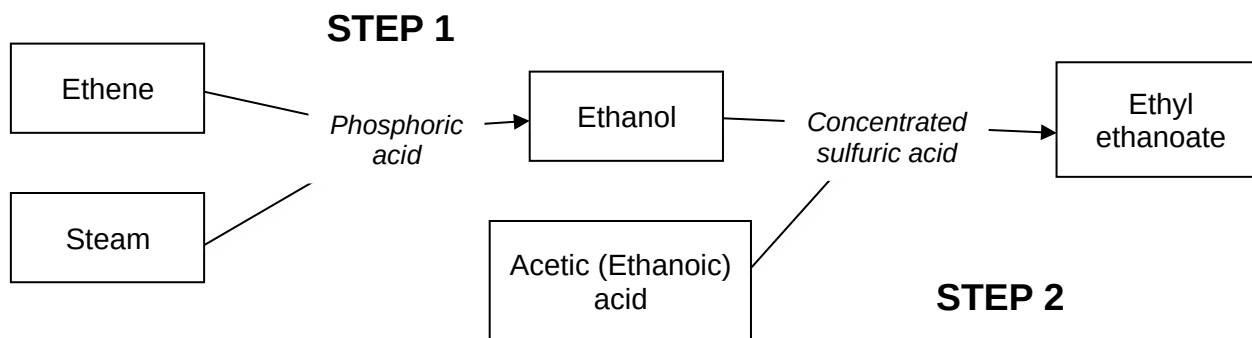| Description	Marks
sodium/potassium hydroxide	1
Total	**1**

(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**

Question 30　　　　　　　　　　　　　　　　　　　　　**(13 marks)**

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

STEP 1

| Ethene |
| Steam |

Phosphoric acid →

| Ethanol |

Concentrated sulfuric acid →

| Ethyl ethanoate |

| Acetic (Ethanoic) acid |

STEP 2

(a)　　Phosphoric acid and sulfuric acid act as catalysts in this reaction sequence. Explain, using collision theory, how a catalyst speeds up a chemical reaction.　　(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 name the type of reaction.

Description	Marks
C_2H_4 + H_2O → C_2H_5OH	1
Addition	1
Total	2

(ii)　　Write the equation for Step 2 and name the type of reaction

Description	Marks
C_2H_5OH + CH_3COOH → $C_2H_5OCOCH_3$ + H_2O	1
Condensation or esterification	1
Total	2

(c)   In the first step, 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 (1.6327 x 10^4)	1
expected yield 1 mole ethene produces 1 mole ethanol $n(C_2H_5OH)_{expected}$ = $n(C_2H_4)$ = 16 326.8 mol	1
Actual yield = 48 500 g $n(C_2H_5OH)_{produced}$ = 48 500 / 46.068 = 1052.8	1
% yield = (1052.8 / 16 326.8) × 100 **= 6.45%**	1
Total	**4**

(d)   Ethanol can also be produced using fermentation. Biomass provides glucose ($C_6H_{12}O_6$) which is fermented, producing ethanol and carbon dioxide as a by-product

    (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 make them different from catalysts such as phosphoric acid and sulfuric acid.   (2 marks)

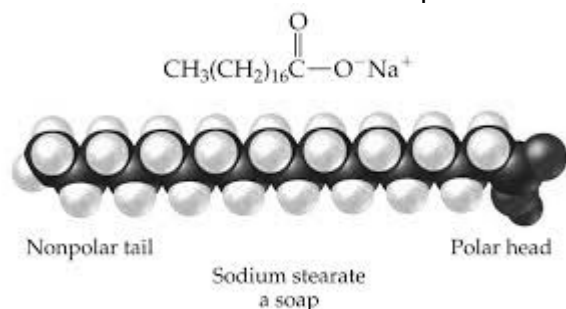| Description	Marks
any two from: • They are biochemical molecules / proteins • they catalyse specific reactions • they work by having a particular shape • they are pH sensitive • they can be destroyed/denaturated at high temperatures	0 – 2
Total	**2**

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 the soap to remove grease from a surface.   (4 marks)

$CH_3(CH_2)_{16}\overset{\overset{\displaystyle O}{\|}}{C}-O^-\ Na^+$

Nonpolar tail   Polar head

Sodium stearate
a soap

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 dipole-dipole or 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)   Explain how the problems caused by the formation of scum can be overcome by using another type of surfactant.   (2 marks)

Description	Marks
Use a detergent	1
Detergents do not form insoluble precipitates in hard water	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:

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

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)
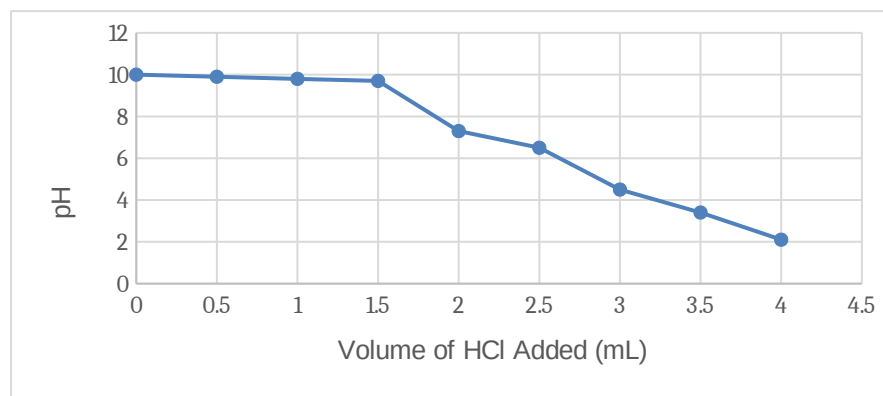
Description	Marks
appropriate scales on both axis	1
labelled axis (including units on x axis)	1
points plotted accurately	1
smooth line drawn showing tendency of the data (not dot to dot)	1
Total	**4**

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

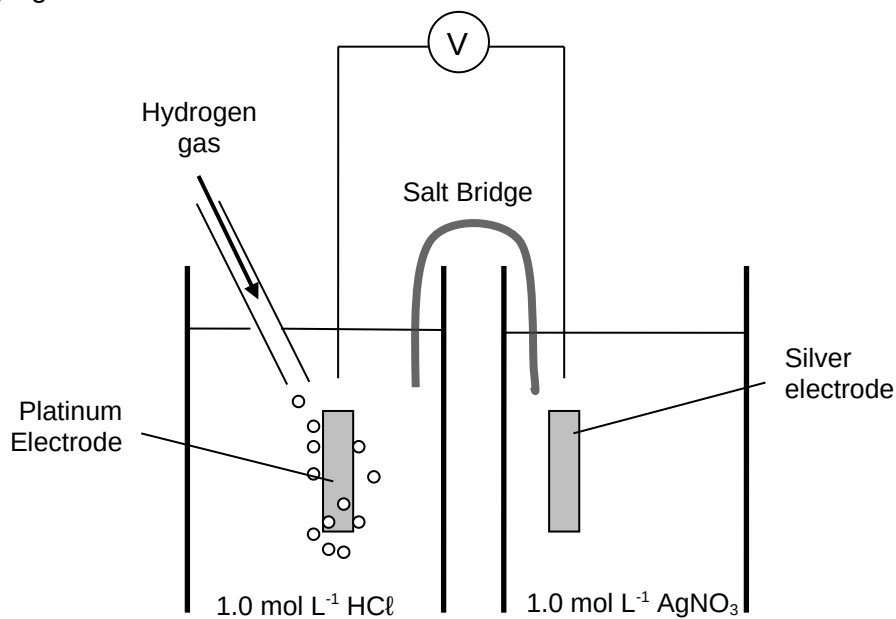| Description	Marks
The initial pH is 10 - hydroxide ions are in excess so the pH doesn't change much as the acid is used up as it is added	1
Total	**1**

(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 dependent on the pH.	1
Could only be used for titrations with a strong acid and a strong base as the colour change is around pH 5–6	1
or:	
disagree (no mark for this)	
There is a pH dependent colour change,	1
but you would have to add too much dichromate as an indicator to see a colour change which might affect the results of the titration	1
or:	
only suitable for titrations that did not involve reducing agents like oxalic acid or determining acid content of wine	1
as the chromate/dichromate would react with a reducing agent (to change to Cr^{3+}) and change colour	1
award correct and/or logical chemistry for this question	
Total	**2**

Question 33 **(8 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 in the external circuit 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)

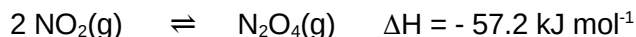| Description	Marks
sulfuric acid is a diprotic acid	1
therefore the concentration of the H^+ ions would not be 1.0 mol L^{-1}	1
Total	**2**

(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
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.

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

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

Description	Marks
$K = \dfrac{[N_2O_4]}{[NO_2]^2}$	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)
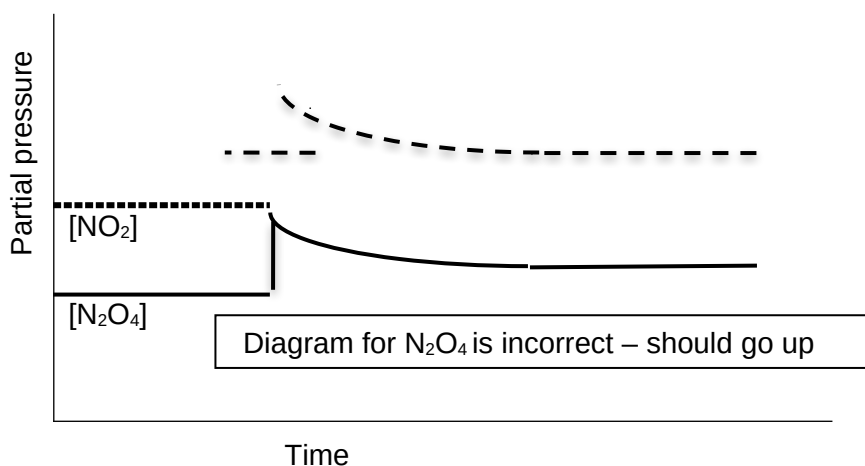
Description	Marks
sudden increase in the partial pressure of each gas with NO_2 line increasing twice as much as the N_2O_4 partial pressure	1
both lines curve down towards new equilibrium NO_2 steeper gradient	1
curves level out <u>above</u> original values	1
Total	**3**

(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 initially the partial pressures of both gases increase	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 same and equilibrium is re-established	1
Total	**3**

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 **(22 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 supplement 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)	**20.30**	**19.75**	**19.80**	**19.70**

(a) Calculate the percentage purity of the supplement **three** significant figures.

(7 marks)

Description	Marks
average-titre = 19.75 mL = 0.01975 L	1
n(NaOH) = c $\times$ V = 0.0570 $\times$ 0.01975 = 1.1257 $\times$ 10-3 mol	1
2 moles NaOH react with 1 mole Aspartic acid n(Aspartic acid)in 25.0 mL = (½) × 1.1257 $\times$ 10-3 = 5.6287 $\times$ 10-4	1
n(Aspartic acid)in 500.0 mL = (500/25) × 5.6287 $\times$ 10-4 = 0.011257 mol	1
m(Aspartic acid) = n × M = 0.011257 × 133.106 = 1.498 g	1
% purity = (1.498 / 1.546) $\times$ 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 a reason why the distilled water was warmed.   (1 mark)

Description	Marks
to increase the solubility of the aspartic acid	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 less that it should be	1
Therefore the values for the concentration 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 concentration of aspartic acid will be less than the actual value	1
The answer should be about the concentration not the amount **Total**	3

(c)   (i)   Due to the low solubility of the aspartic acid, it was suggested to the students 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 0.202 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.   (7 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
2 moles NaOH react with 1 mole Aspartic acid n(NaOH)to react with this aspartic acid = 2 × 1.1257 × 10-3 = 0.02253 mol	1
N0 moles HC⬜ in 20 mL= c x V = 0.100 × 0.0200 = 0.00200 mol n(NaOH)excess to react with HCl = 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
therefore, the 25.00 mL pipette should be used	1
Total	**7**

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

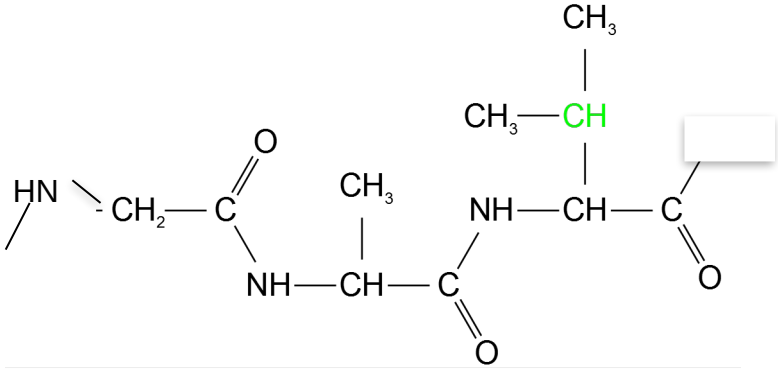| Description	Marks
the uncertainty/error when reading a burette is fixed	1
the lower the volume measured in the burette, the random error can become a higher percentage of the reading	1
Total	**2**

Question 36   **(11 marks)**
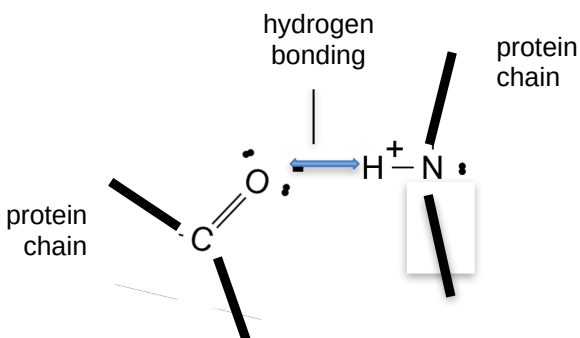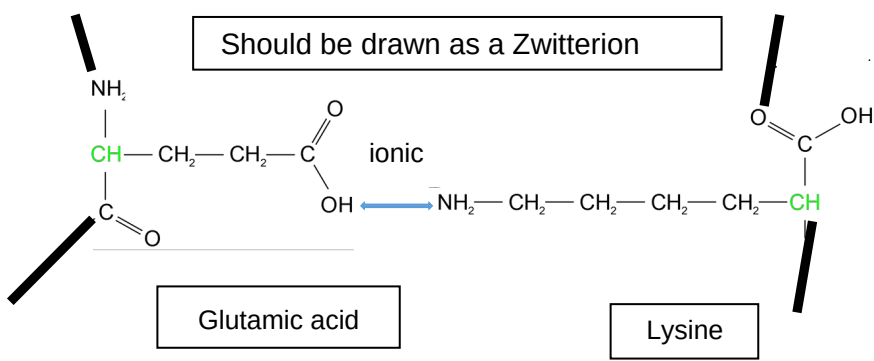
Proteins comprise up to 2000 α-amino acid molecules joined to form a polymer. The structure of 20 commonly occurring α-amino acids are given on your data sheet. The structure of proteins can be defined on a series of levels.

Compare the primary, secondary and tertiary structure of proteins by

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

         – Gly – Ala – Val –

     (show all atoms in your diagram)

(b)   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.

(c)   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.

         o   glutamic acid (Glu) and lysine (Lys)

         o   leucine (Leu) and isoleucine (Ile)

         o   cysteine (Cys) and cysteine (Cys)

Description	Marks
(a) **Primary Structure**	
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. 	
Correct sequence in diagram – can accept CH_3	1
Needs NH – and carboxylate terminals for full marks	1
Total	**2**

Description	Marks
(b) **Secondary Structure –** diagrams should show the amino acids as part of a polymer one mark deduction overall if the diagrams are between individual amino acids	
The hydrogen bonding that contributes to the secondary structure of the protein occurs between the C=O group on one part of the chain and the -N-H group on another part of the protein molecule	
Diagram showing interaction between oxygen on the carboxylate group on one chain and the H attached to a N on the other chain	1
The polarity of the two groups is shown using (+) and (-) ve signs	1
The interaction is labelled/named as H-bonding	1
Total	**3**

Description	Marks
Tertiary Structure	
Naming the intermolecular attraction between glutamic acid (Glu) and lysine as ionic bonding.	1
	1
A diagram showing ionic attraction between the O^- on the on the glutamic acid and the the $-NH_3^+$ group on the lysine.	
Total	**2**

Naming the intermolecular attraction between the alkyl groups on leucine (Leu) and isoleucine (Ile) as dispersion forces.	1
  Diagram showing the interaction between alkyl groups	1
Total	**2**
Naming the bond between the two sulfur atoms as either a disulphide bond or a covalent bond	**1**
Diagram showing the bond between the two sulfur atoms 	1
Total	**2**

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 process 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 $2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$
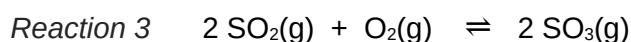
The conditions used in Reaction 3 are a moderately high temperature of 450 °C, a pressure close to normal atmospheric temperature and a catalyst of vanadium(V) oxide.

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

Reaction 4 $SO_3(g) + H_2O(\ell) \rightarrow H_2SO(\ell)$
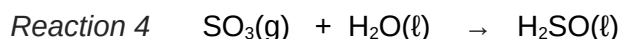
(a)   Assuming Reaction 1 and 2 are 100% efficient; calculate the mass of chalcopyrite required to produce 1.00 tonne of copper metal. (1.00 tonne = 1.00 x 10^6 g)
                 (3 marks)

Description	Marks
either	
1 mole $CuFeS_2$ produces 1 mole of Cu	1
$n(CuFeS_2) = n(Cu)$ $n(Cu) = m / M = 1.00\ x\ 10^6\ g / 63.55 = 15735.6$ mol	1
$n(CuFeS_2) = 15735.6$ $m(CuFeS_2) = 15735.6 \times 183.54 = 2\ 888\ 119$ g = 2.89 tonnes	1
or	
%(Cu) in $CuFeS_2 = (63.55 / 183.54) \times 100 = 34.6\%$	1
All of the Cu in $CuFeS_2$ is recovered	1
$m(CuFeS_2)_{required}$ to obtain 1 tonne Cu = (100/34.6) × 1.00 = 2.89 tonnes	1
Need mole /mole justification and units for full marks	
Total	**3**

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

Description	Marks
$n(SO_2) = 2 \times n(Cu) =$	1
$2 \times 15735.6 = 31471 = 3.15 \times 10^4$ 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
$n(SO_2)$ produced by 280 tonnes Cu = $3.15 \times 10^4 \times 280 = 8.812 \times 10^6$	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 1.00 tonne of sulfur dioxide.   (3 marks)

Description	Marks
$n(SO_2) = 1.00 \times 10^6 / 64.07 = 15\ 607$ mol = moles SO_3	1
Allowing for efficiency $n(SO_3) = (87/100) \times n(SO_2) = 13578.9$ 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
Mass of pure 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 Moles of H_2O needed to convert SO_3 to = moles H_2SO_4	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 $V(H_2O) = 6.66 \times 10^5$ L	1
Mass of water required to make the mass up to 3700 tonnes = 3700 – 3626 = 74 tonnes = 7.40×10^4 kg $V(H_2O) = 7.40 \times 10^4$ L	1
Volume of water required = $6.66 \times 10^5 + 7.40 \times 10^4 = 7.40 \times 10^5$	1
If the just calc mass of pure H_2SO_4 and find mass to make up 3700 tonnes max 2 marks	
Total	5

(h)   Explain, in terms of environmental chemistry,

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

(2 marks)

Description	Marks
Sulfur dioxide is not emitted into the air	1
SO_2 is the raw material for the production of sulfuric acid *accept other chemically correct appropriate answers*	1
Total	**2**

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

Description	Marks
Reaction 3 is exothermic and a higher temperature will reduce yield. Or Higher temperature increase cost - getting 97% yield	1
a catalyst will provide a faster reaction pathway with lower energy requirement giving 97% yield. *accept other chemically correct appropriate answers*	1
Total	**2**

Question 38   **(10 marks)**

Banana oil contains an ester which gives the oil its distinctive odour. 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)

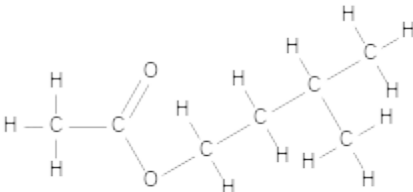| Description				Marks
Sample 1 (1.51 g)				
Moles CO2 = 3.57/44.01 = 0.08112 Moles C = 0.08112 Mass C = 0.08112 x 12.01 = 0.974 g %(CO_2) = (0.974 / 1.51) $\times$ 100 = 64.5 %				1
Sample 2 (2.11 g)				
Moles H_2O = (2.04/18.016) = 0.1132 Moles H = 011132 x 2 = 0.2264 m(H) = 0.2264 $\times$ 1.008 = 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**	
In 100 g sample	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	
Moles	*3.48*	*6.96*	1.00	1
Mole ratio (× 2)	7	14	2	
Empirical Formula	$C_7H_{14}O_2$			1
			Total	**6**

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
Moles of sample $n = PV / RT = 67.0 \times 0.162 / 8.315 \times 423.15$ $= 0.003085$ mol	1
Molar mass = m/n Molar mass(ester) = 0.401 / 0.003085 = 129.98 = 130 g mol^{-1}	1
Empirical Mass of $C_7H_{14}O_2$ = 130.18 = calculated Molar mass 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.

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

Description	Marks
	1
Total	**1**

Question 39   **(18 marks)**

Nylon is a polymer that can be made by reacting a diamine with a dicarboxylic organic acid. It is a polymers whose molecular chains are formed by regularly spaced -CONH- amide groups. Making nylon is even easier if you use a diamine and a diacid chloride instead of a dicarboxylic acid. This is because acid chlorides are much more reactive than carboxylic acids.

The reactants that can be used to make nylon are shown below.
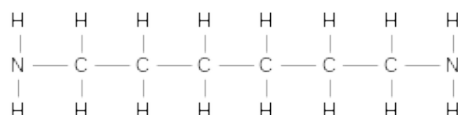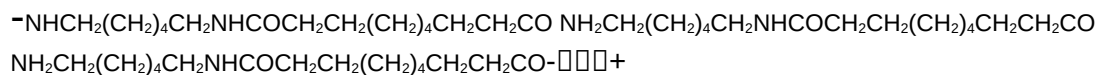

1,6 - diaminohexane

and
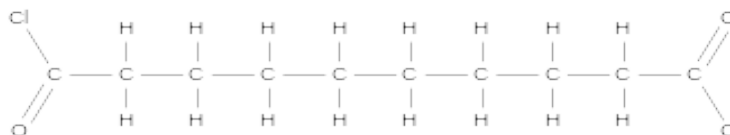
decadioyl chloride

(a)   Write an equation for the reaction that would occur when **two** of these monomers reacted. You can use the abbreviation $(CH_2)_4$ when writing out the equation.

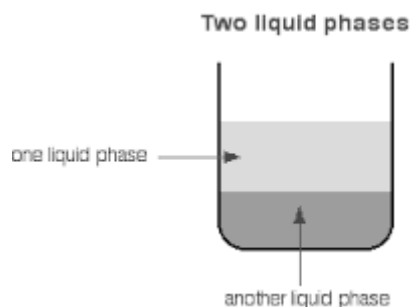| Description	Marks
$NH_2CH_2(CH_2)_4CH_2NH_2 + C\square COCH_2CH_2(CH_2)_4CH_2CH_2COC\square$ $\rightarrow \square\square NH_2CH_2(CH_2)_4CH_2NHCOCH_2CH_2(CH_2)_4CH_2CH_2COC\square\square\square\square+ HC\square$ correct number of CH_2 in each monomer	1
Equation includes $HC\square\square$ as one of the products	1
Total	**2**

(b)   Draw a section of the polymer, commencing the 1,6 - diaminohexane that has three **(3)** repeating units in its structure. You can use the abbreviation $(CH_2)_4$ when drawing the backbones of either of the monomers.

$^-NHCH_2(CH_2)_4CH_2NHCOCH_2CH_2(CH_2)_4CH_2CH_2CO\ NH_2CH_2(CH_2)_4CH_2NHCOCH_2CH_2(CH_2)_4CH_2CH_2CO$
$NH_2CH_2(CH_2)_4CH_2NHCOCH_2CH_2(CH_2)_4CH_2CH_2CO-\square\square\square+$

	Description	Marks
	Polymer drawn with NH at one end and CO- at the other end	1
(c)	Polymer drawn with correct amide linkage	1
	Total	**2**

The reaction that forms nylon occurs at the interface of two solutions made from solvents of differing polarities as shown in the diagram below. Nylon is a polymer you can make

yourself in the lab. A strand of nylon fiber can be pulled from the interface between two liquid phases.

Two liquid phases

Considering the structures of the two monomers involved in this reaction describe the nature of the two solvents used to dissolve the monomers and explain why that particular solvent would have been chosen for that monomer.

Description	Marks
1,6 – diaminohexane is polar	1
1,6 – diaminohexane would be soluble in a polar solvent	1
decadioyl chloride is non-polar	1
decadioyl chloride would be soluble in a non-polar solvent	1
Total	**4**

(d)   Nylon can be used to manufacture a high strength fibre that can be used for making fishing nets, ropes or fabrics in textile industry. The strength of the intermolecular forces between the polymer chains is the reason that nylon can make such strong fibres.

Using the same structure you have drawn in (b), draw two stands of the polymer to show the intermolecular forces that exist between the polymer chains. On your diagram name the type of intermolecular force.
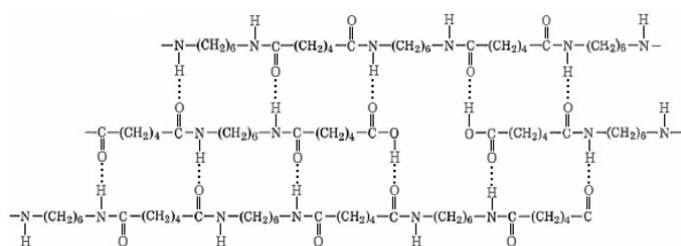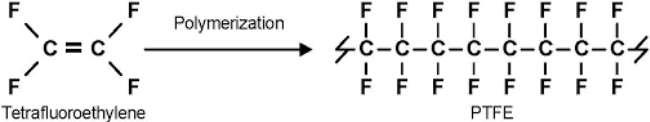

Description	Marks
Diagram showing 2 strands of polymer	1
Diagram shows C=O on one chain facing NH on a neighboring chain	1
Naming the interaction between the chains as hydrogen bonding	1
Total	**3**

(e)   Polytetrafluorethene (PTFE) is another polymer that is in common use but unlike nylon it can be used to store reactive and corrosive chemicals.

Write about 1 page addressing the following points. The answer has to be written in paragraphs and full marks will not be allocated to answers that include dot points.

- Compare the polymerisation processes used in the production of nylon and Polytetrafluorethene. Include a balanced chemical equation showing the formation of polytetrafluorethene.
- Use the structure of the polymer to explain why surfaces coated with Polytetrafluorethene slide over each other very easily. i.e. they have low coefficients of friction.
- State two properties that PTFE and polyethylene (PE) have in common.

Description	Marks
• Nylon formed condensation reaction different monomers • Polytetrafluorethene formed addition reaction same monomer	2
	1
• Weak dispersion forces between layers Or • dipoles some charge - weak dispersion forces holds layers together	1
• Small amount of force required to overcome these forces	1
Any 2 similar properties • Chemically inert • Low moisture absorption	2
Total	**7**