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.
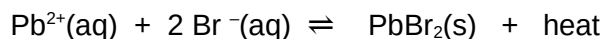
Suggested working time: 50 minutes.

_____

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) $CO_3^{2-}(aq)$ + $Ca^{2+}(aq)$ → $CaCO_3(s)$
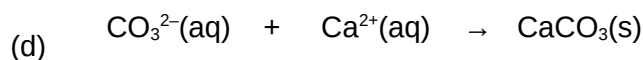
6.   Which of the following combinations will form a buffer solution?

   i. $NH_3(aq)$ / $NH_4Cl(aq)$
   ii. $NH_3(aq)$ / $HCl(aq)$
   iii. $HCl(aq)$ / $NH_4Cl(aq)$
   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 information:

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

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

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.

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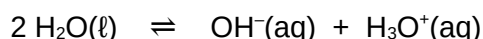
At 25 °C the concentration of H^+ is 10^{-7} mol L^{-1} and the pH of pure water is 7.0. When the temperature is increased, the pH of water reduces. Which of the following statements below is correct?

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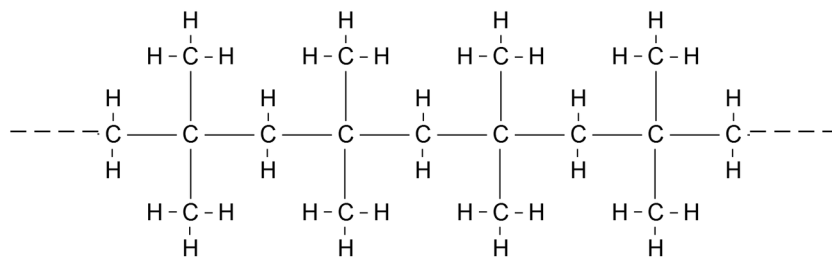
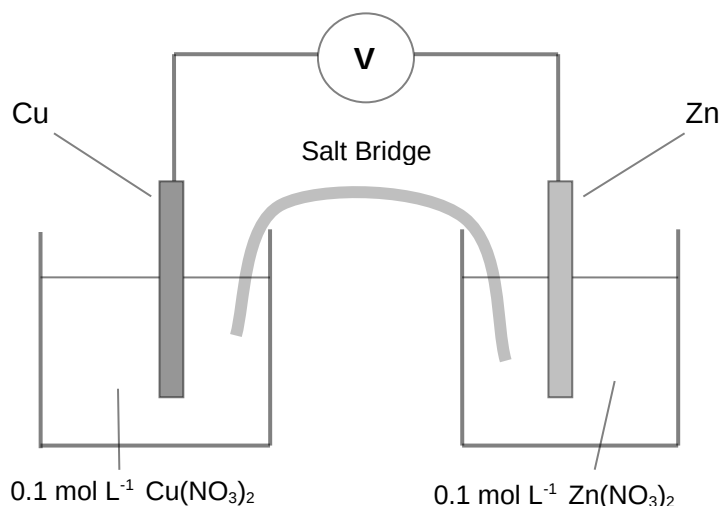Which one of the following is the correct name for the monomer used to synthesise this polymer?

(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.

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

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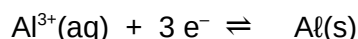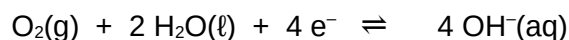
15.   This cell is described as a fuel cell because

(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) $A\ell(s) + O_2(g) + 2 H_2O(\ell) \rightarrow OH^-(aq) + Al^{3+}(aq)$
(b) $4 Al^{3+}(aq) + 3 O_2(g) + 6 H_2O(\ell) \rightarrow 12 OH^-(aq) + 4 A\ell(s)$
(c) $Al^{3+}(aq) + O_2(g) + 2 H_2O(\ell) \rightarrow 4 OH^-(aq) + A\ell(s)$
(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:
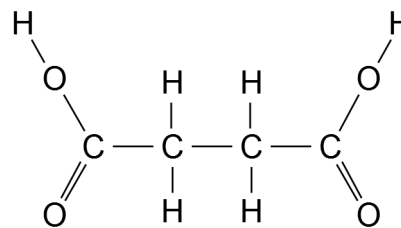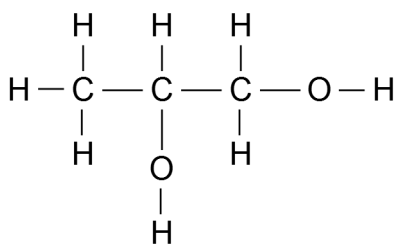
Which one of the following would be the type of product produced?

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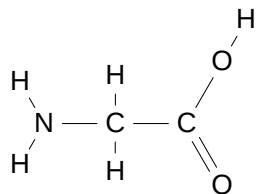
Which one of the following will this molecule **not** react with?

(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
$V_2 = C_1V_1 / C_2 = 0.05 \times 50$ mL / 0.01 $= 250$ mL	1
Required to add $250 - 50 =$ **200 mL or 2.00×10^2 mL**	1
2.45L 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
$\overset{\displaystyle O}{\underset{\displaystyle CH_3}{\overset{\|\|}{\underset{/}{C}}}} - CH_2 - CH_3$	1
Butanone	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
$CH_3 - CH_2 - CH_2 - CH_2 - OH$ or $CH_3 - CH_2 - \underset{\underset{\displaystyle CH_3}{\|}}{CH} - CH_2 - OH$	1
butan-1-ol or 2-methylbutan-1-ol	1
Total	**2**

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

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

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

$Cr_2O_7^{2-}\ +\ C_4H_9OH\ +\ 16\ H^+\ \rightarrow\ 2\ Cr^{2+}\ \ 3\ C_3H_7COOH\ +\ 7\ H_2O$
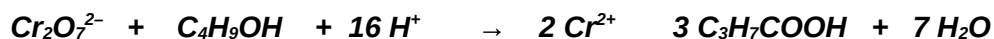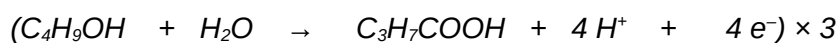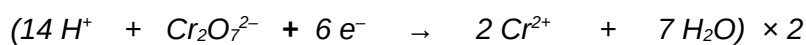
Description	Marks
Correct species	1
balanced	1
Total	**2**

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).

$$CℓO^-(aq) \ + \ H_3O^+(aq) \ \rightleftharpoons \ HCℓO(aq) \ + \ H_2O(ℓ) \ + \ HEAT$$
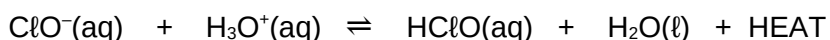
For best results, the concentration of the hypochlorous acid should be kept above 1.00 ppm.

(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	<u>endothermic</u> 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. (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
$n(NClO)_{required}$ = (100/60) × 3.43 = 5.7189 mol	1
$m(NClO)_{required}$ = 5.7189 × 74.44 = **426 g**	1
Total	**3**

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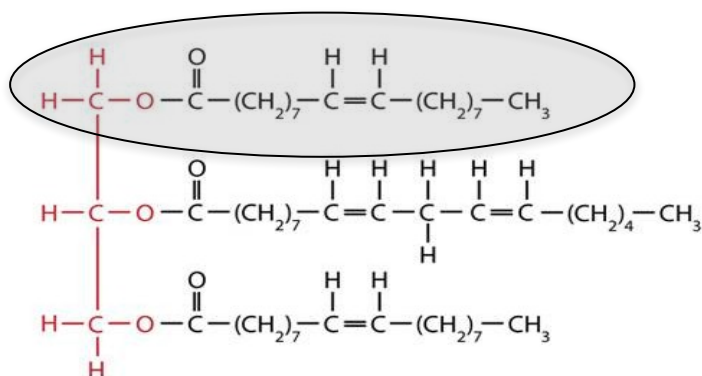
Biodiesel can be synthesised using a base-catalysed reaction with methanol. The triglyceride breaks down into fatty acids and these undergo esterification with methanol to form methyl esters. The methyl esters are the main components of biodiesel.

(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)

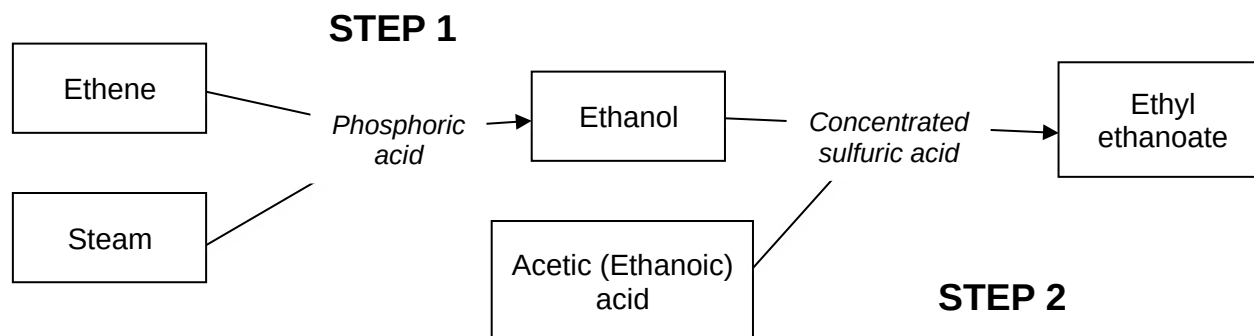| Description	Marks
sodium/potassium hydroxide	1
Total	1

(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 explain why it is described as an addition reaction.   (2 marks)

Description	Marks
C_2H_4 + H_2O → 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 → $C_2H_5OCOCH_3$ + 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 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 phosporic 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)

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 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:

$$2\ CrO_4^{2-}(aq) \quad + \quad 2\ H^+(aq) \quad \rightleftharpoons \quad Cr_2O_7^{2-}(aq) \quad + \quad H_2O(\ell)$$
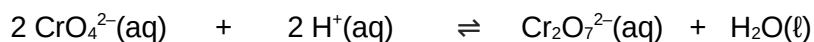
They started with 50.0 mL of a solution of 0.10 mol L^{-1} potassium chromate, and gradually added hydrochloric acid to the solution. They recorded the colour of the solution and the pH using a pH probe. Their results are shown below.

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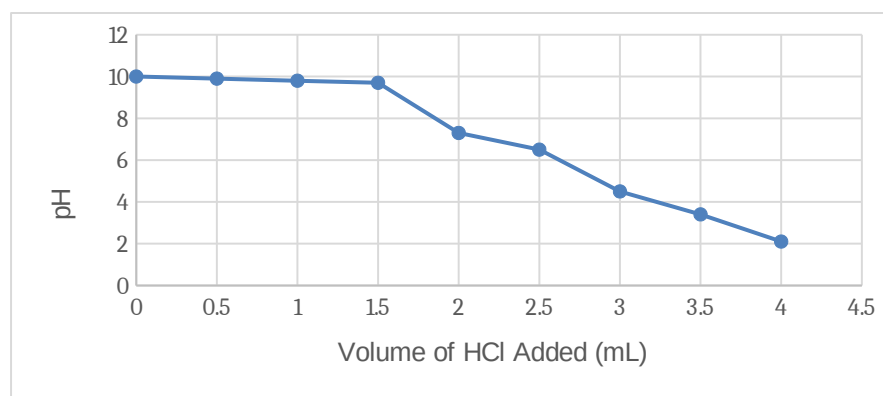
Description	Marks
appropriate scales	1
labelled axis (including units on x axis)	1
points plotted accurately	1
line drawn	1
Total	**4**

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

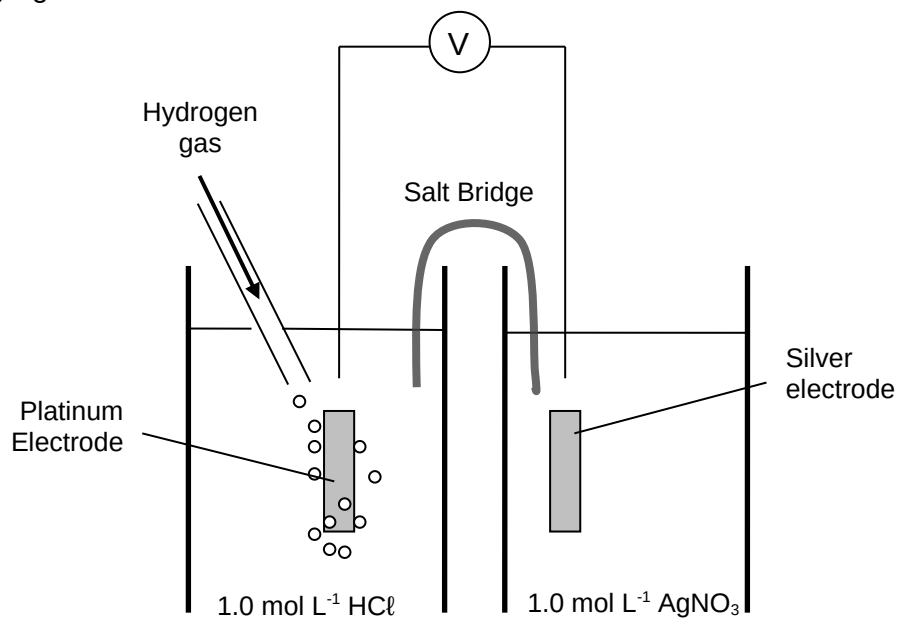| Description	Marks
the alkali / hydroxide ions are in excess so the pH doesn't change much as the acid is used up as it is added	1
Total	**1**

(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	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
or:	
only suitable for non-redox reactions	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:	$H_2 \rightarrow 2H^+ + 2e^-$	1
Cathode half-equation:	$Ag^+ + e^- \rightarrow Ag$	1
Overall equation:	$H_2 + 2Ag^+ \rightarrow 2Ag + 2H^+$	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)

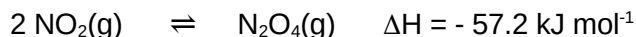| Description	Marks
sulfuric acid is a diprotic acid	1
therefore the concentration of the H^+ ions would not be 1.0 mol L^{-1}	1
Total	**2**

(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.

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

(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)
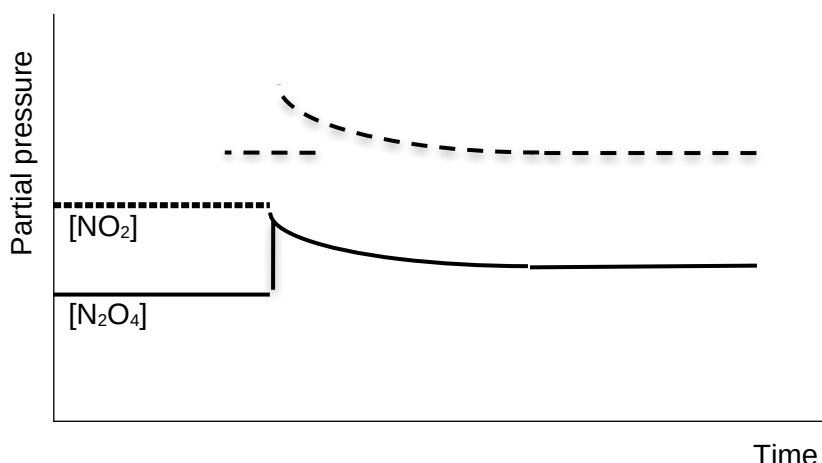
Description	Marks
sudden increase in the partial pressure of each gas with NO_2 line increasing twice as much as the N_2O_4 partial pressure	1
both lines curve down towards new equilibrium	1
curves level out <u>above</u> original values	1
Total	**3**

(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 the rates of the forward and reverse reactions are both 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 same and equilibrium is re-established	1
Total	**3**

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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 **(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.   (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
$n(Aspartic\ acid)$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
$m(Aspartic\ acid) = n \times M = 0.011257 \times 133.106$ = 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 improve the solubility	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 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
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
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 random error in this experiment. (2 marks)

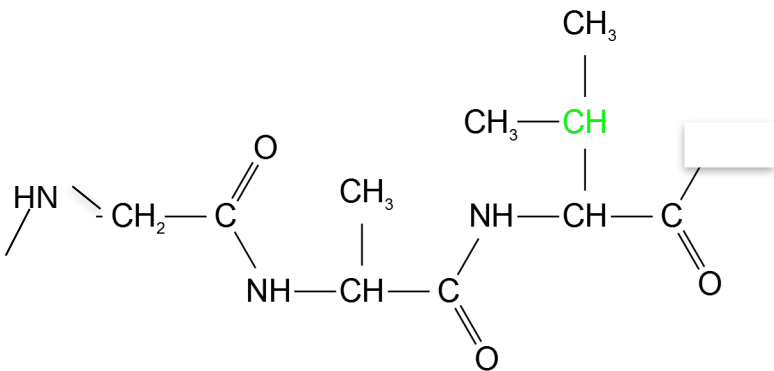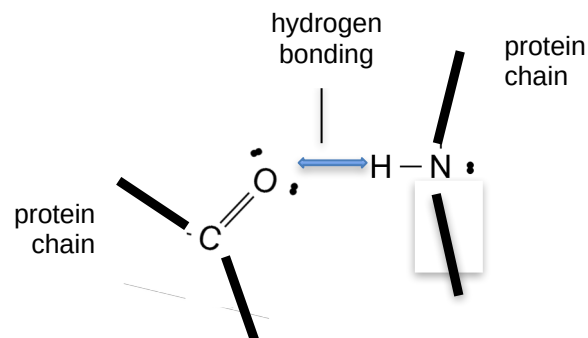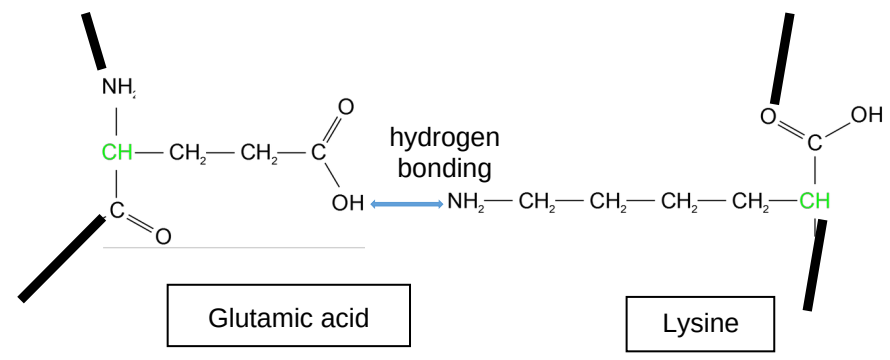| Description	Marks
the uncertainty/error when reading a burette is fixed	1
the lower the volume measured in the burette, the more significant this error/uncertainty becomes	1
Total	**2**

Question 36   **(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.

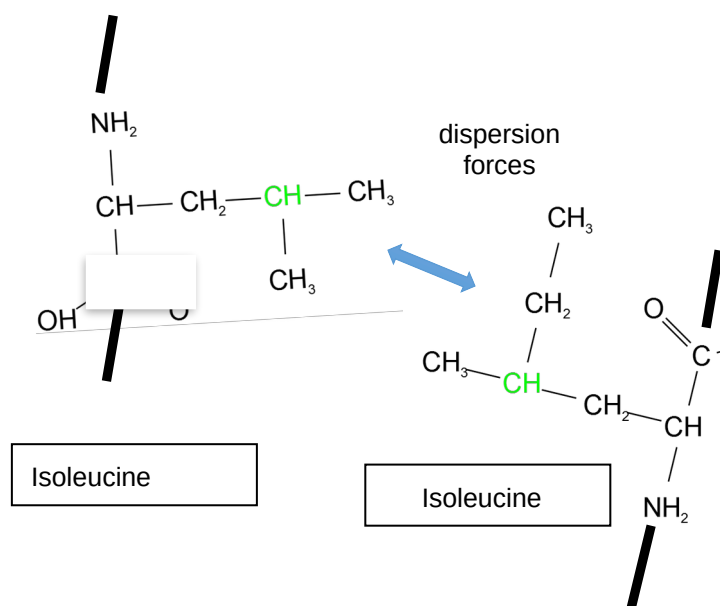Compare the primary, secondary and tertiary structure of proteins by

(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   two cysteine (Cys) molecules

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**

Description	Marks
Secondary Structure	
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	
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: 	0 – 3
Total	**3**

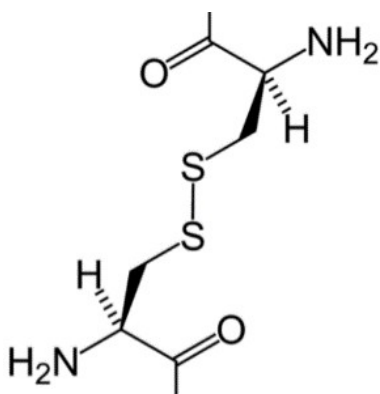| Description	Marks
Tertiary Structure	
The tertiary structure is held together dependent on the composition and the polarity of the side groups on amino acids at parts of the protein that come into close proximity. For example,	1
glutamic acid (Glu) and lysine (Lys) will form hydrogen bonding ….. Glutamic acid Lysine	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 ………. between the non-polar alkyl groups on both of the amino acids. *(Can be shown by a diagram)*	0 – 2
two cysteine (Cys) molecules will form a disulphide bond. *(Can be shown by a diagram)* 	1
Total	**6**

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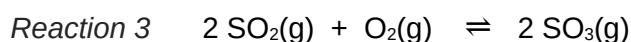
The conditions used in Reaction 3 are a moderately high temperature of 450 °C, a pressure close to normal atmospheric temperature and a catalyst of vanadium(V) oxide.

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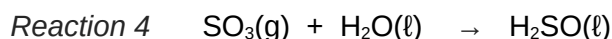
(a)   Assuming Reaction 1 and 2 are 100% efficient; calculate the mass of chalcopyrite required to produce 1.00 tonne of copper metal. (1.00 tonne = 1.00 x 10^6 g)

                                                            (3 marks)

Description	Marks
either	
%(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 x 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**

(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) × $n(Cu)$ = (4/2) × 15735.6	1
= 31471 = 3.15 × 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)

(tion	Marks
$n(SO_2)$ = 3.15 × 10^4 × 280 = 8.812 × 10^6	1
$m(SO_2)$ = 8.812 × 10^6 × 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 x 10^6 / 64.07 = 15 607 mol	1
$n(SO_3)$ = (87/100) × (2/2) × $n(SO_2)$ = 13578.9 mol	1
$m(SO_3)$ = 13578.9 × 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 x 10^6 × (98/100) = 3 626 × 10^6 g	1
$n(H_2SO_4)$ = 3 626 x 10^6 / 98.086 = 3.697 × 10^7 mol	1
$n(H_2O)$ = $n(H_2SO_4)$ = 3.697 × 10^7 mol $m(H_2O)$ = 3.697 × 10^7 × 18.016 = 6.66 × 10^8 g = 6.66 × 10^5 kg	1
$V(H_2O)$ = 6.66 × 10^5 L	1
correct significant figures and units	1
Total	5

(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 *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
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 *accept other chemically correct appropriate answers*	1
Total	**2**

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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)				
$m(CO_2) = 3.57 \times (12.01/44.01) = 0.974$ 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**

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
$n = PV / RT = 67.0 \times 0.162 / 8.315 \times 423.15$ = 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.

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

Description	Marks
	1
Total	**1**

Question 39   **(18 marks)**

Oxidation involves the loss of electrons from a chemical species. Redox reactions involve the oxidation of one species and reduction of another species. Electrochemical cells, including galvanic and electrolytic cells, consist of oxidation and reduction half-reactions connected via an external circuit.

The following situations all involve a species being oxidised.

1. An iron nail slowly dissolving in a solution of copper(II) sulfate.

2. The dissolving of a piece of impure copper at the anode of a cell used to purify copper.

3. The reaction occurring at the anode of a galvanic cell made up of zinc metal in aqueous zinc nitrate and tin metal in aqueous tin(II) nitrate.

Using the following headings and using only examples from the above situations to illustrate your explanations, and including equations and diagrams where appropriate, compare

      (i)   spontaneous and non-spontaneous reactions.   (6 marks)

      (ii)   galvanic cells and electrolytic cells.   (6 marks)

      (iii)   weak and strong oxidising agents.   (6 marks)

Marking: For each section, a maximum 5 of the exemplar marking points or other correct and relevant points of chemistry plus one mark for per section for overall quality of explanation and clarity)

Description	Marks
(i) Spontaneous and non-spontaneous reactions.	
- a spontaneous reaction is a reaction that occurs naturally - In the context of redox chemistry this will occur when a substance or species is a strong enough reducing agent to reduce (donate electrons to) another species. - For example, iron is a stronger reducing agent than copper so when an iron nail is placed in a solution of copper(II) sulfate, the following spontaneous reaction occurs: $Cu^{2+}(aq) + Fe(s) \rightarrow Cu(s) + Fe^{2+}(aq)$ - In terms of cell potentials, a spontaneous redox reaction will have a cell potential that is positive. In this example the associated cell potential can be calculated as + 0.78 Volts. - In galvanic cells, the spontaneous redox reaction determines which half-cell is the anode and which is the cathode. For example, in the galvanic cell made up of Zn/Zn^{2+} and Sn/Sn^{2+} the spontaneous reaction is $Sn^{2+}(aq) + Zn(s) \rightarrow Sn(s) + Zn^{2+}(aq)$. - A non-spontaneous redox reaction will not normally occur without the application of an external voltage reaction. The conditions described above have not been met. - For example, in the purification of copper, the overall cell potential is zero, and there will not be a spontaneous reaction. In order to make the reaction happen an external voltage is applied to make one copper electrode the anode and one electrode the cathode.	0 – 6
(ii) galvanic cells and electrolytic cells.	

• A galvanic cell is one where a spontaneous redox reaction takes place in two half-cells. Oxidation occurs at the anode and reduction takes place at the cathode. • The flow of electrons towards the cathode is caused by a spontaneous reaction. • For example, in the example 3 above, the spontaneous reaction is: $Sn^{2+}(aq) + Zn(s) \rightarrow Sn(s) + Zn^{2+}(aq)$ • The zinc is being reduced so that this electrode is the cathode, and can be considered the positive electrode. • In an electrolytic cell, oxidation also occurs at the anode but the flow of electrons is caused by an external voltage being applied to the cell. • In this case the cathode is considered the negative electrode because electrons are being 'pushed' towards this electrode by the extremal power source. • In example 2 above, an electrolysis situation is set up, so that pure copper is deposited on the cathode (positive electrode). *Marking note: A diagram could be used to compare the tin/zinc galvanic cells and the Cu electrolytic cell*	0 – 6
weak and strong oxidising agents.	
• An oxidising agent is a substance or species that will accept one or more electrons from another substance or species. • The tendency to remove electrons can be compared, with those species that readily remove electrons being described as strong oxidising agents. • For example, Cu^{2+} ions and Fe^{2+} ions can be considered as oxidising agents because they can both accept electrons when they are reduced to form the elemental metal. • However, Cu^{2+} ions are the stronger oxidising agent so Cu^{2+} ions will oxidise Zn metal to Zn^{2+} ions when the following reaction occurs: $Cu^{2+}(aq) + Fe(s) \rightarrow Cu(s) + Fe^{2+}(aq)$ • Likewise, in the Zn/Zn^{2+} and Sn/Sn^{2+} cell, the Sn^{2+} ions are a stronger oxidising agent than the Zn^{2+} ions, so they accept electrons from the circuit, in effect oxidising the Zn metal at the anode. • The relative strengths of oxidising agents can be compared by using Standard Reduction Potentials. Strong oxidising agents are the species that are involved in reduction reactions with a high reduction potential. • Weak oxidising agents are the species that are involved in reduction reactions with a low or negative reduction potential. For example the standard reduction potential for the reduction of Zn^{2+} ions, the weakest oxidising agent in the above examples has a standard reduction potential of – 0.76 Volts.	0 – 6