CHEMISTRY
ATAR

Section One: Multiple Choice

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

Section Two: Short Answer **70 marks (35% of paper)**

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

Suggested time for working for this section is 60 minutes.

Question 26 **(5 marks)**

Concentrated sulfuric acid can be used to oxidise halide ions, the sulfur atom in sulfuric acid being reduced. When doing so it can be reduced to a range of different sulfur-containing compounds, including SO_2, S and H_2S.

When reacting with chloride ions, sulfur dioxide is the dominant product. When reacting with bromide ions, sulfur (S) is the dominant product. When reacting with iodide ions, hydrogen sulfide is the dominant product.

Complete the full redox equations for the second and third of these reactions in the boxes provided below; the first one has been done for you.

| Reaction	Full redox equation
concentrated sulfuric acid and chloride ions	H_2SO_4 + **2** Cl^- + **2H$^+$** $\rightarrow$ SO_2 + Cl_2 + **2** H_2O
concentrated sulfuric acid and bromide ions	H_2SO_4 + **6**Br^- + **6H$^+$** $\rightarrow$ S + **3**Br_2 + **4** H_2O
concentrated sulfuric acid and iodide ions	H_2SO_4 + **8** I^- + **8H$^+$** $\rightarrow$ H_2S + **4**I_2 + **4** H_2O

(4 marks)

Make a statement below about the how the strength of reducing agent affects the change in oxidation number of sulfur.

As the reducing agent becomes stronger (from Cl⁻ to Br⁻ to I⁻) the decrease in the oxidation number of the sulfur becomes greater (from -2 to -6 to -8).

(1 mark)

See next page

Question 27 **(14 marks)**

The Ostwald Process is an important stage in the manufacture of sulfuric acid. The equation for the process is

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -950kJ$$
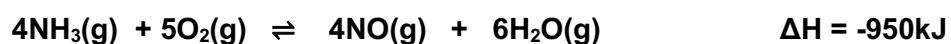
This system had reached equilibrium at 400K. The temperature of the system was then increased to 500K.

(a) Use collision theory to explain the effect of increasing the temperature on the yield of nitrogen monoxide.

> ✓ **As temp increases, rates of both the forward and backwards reactions increase**
> ✓ **Due to increased frequency of collision and proportion with E > Ea**
> ✓ **The endothermic (backwards) reaction speeds up by more than the forwards**
> ✓ **Position of equilibrium shifts to the left /** *NO is consumed at a faster rate than it is produced*
> ✓ **Yield of NO decreases.**

(5 marks)

See next page

(b) If the volume of the system is decreased at time t_1 and equilibrium is re-established at time t_2, sketch a graph of how the rates of the forwards (——) and backwards (-----) reactions vary with time.
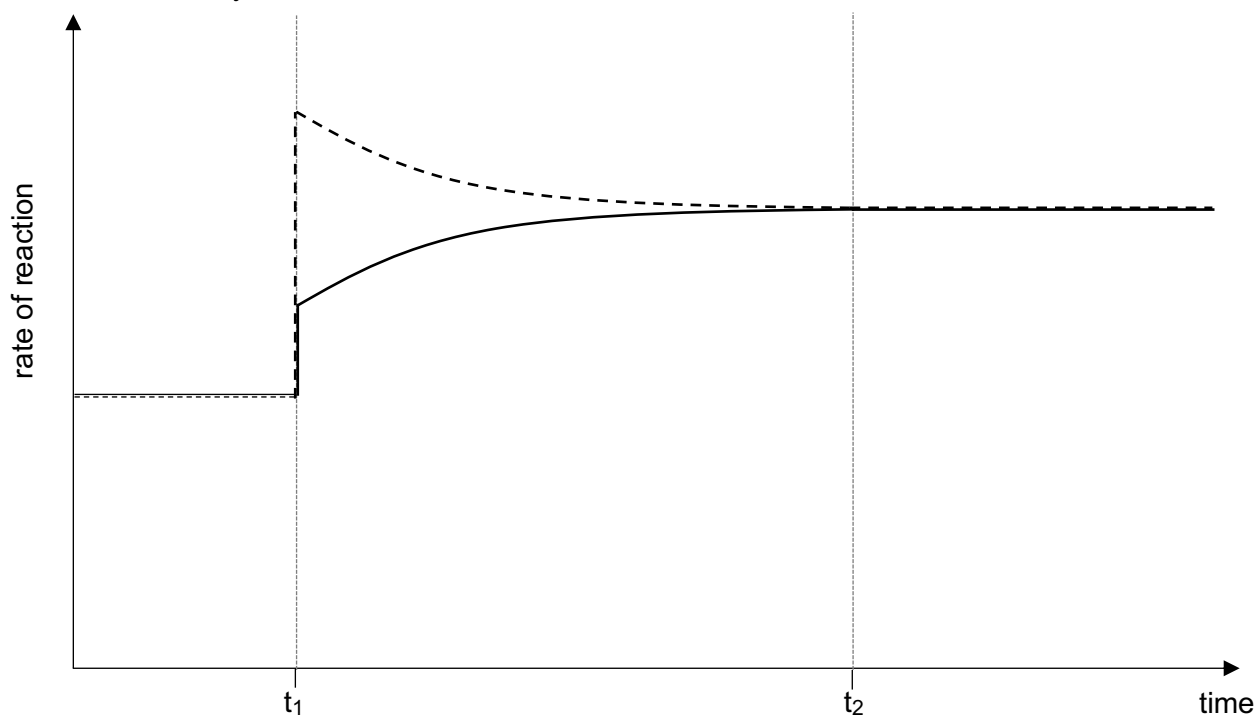
(3 marks)

In a second experiment, the volume of a system at equilibrium was suddenly doubled from 5L to 10L. The concentrations of oxygen and nitrogen monoxide were measured before the change and the concentration of oxygen was measured after the change, once equilibrium had been re-established.

(c) Use the information given to fill in the gaps in the table below:

	$[O_2]$ (molL^{-1})	$[NO]$ (molL^{-1})	amount of NO (mol)
before change	0.214	0.326	*1.63*
after change	0.092	*0.175*	*1.75*

(6 marks)

Space for working

n(O₂) before = 5 x 0.214 = 1.07 mol
n(O₂) after = 10 x 0.092 = 0.92 mol   ✓

n(NO) before = 0.326 x 5 = 1.63 mol   ✓
Δn(O₂) = 1.07 – 0.92 = 0.15 mol   ✓
Δn(NO) after = 0.15 x ⁴/₅ = 0.12 mol   ✓
n(NO) after = 1.63 + 0.12 = 1.75 mol   ✓
[NO] after = 1.75 ÷ 10 = 0.175 molL⁻¹   ✓

See next page

Question 28   **(9 marks)**

Consider the following equilibrium;

$$3MnO_4^{2-}\,(aq) \;+\; 2H_2O\,(\ell) \;\;\rightleftharpoons\;\; 2MnO_4^-\,(aq) \;+\; MnO_2\,(s) \;+\; 4OH^-\,(aq)$$

Various changes were imposed on this equilibrium mixture. Use your knowledge of equilibrium to complete the table below, showing the changes in the quantities shown once equilibrium has been re-established. Write **increase**, **decrease** or **no change** in each of the boxes.

Change imposed	Effect on rate of forward reaction	Effect on mass of solid manganese dioxide	Effect on pH
The system is diluted with water	**decrease**	**increase**	**decrease**
A small volume of concentrated nitric acid is added	**decrease**	**increase**	**decrease**
A small volume of concentrated potassium permanganate (KMnO₄) is added	**increase**	**decrease**	**decrease**

See next page

Question 29 **(8 marks)**

1.80g of indium (III) nitrate is dissolved in 20mL of distilled water and then added to 40.0mL of 0.502molL^{-1} potassium hydroxide solution. A precipitate of insoluble indium (III) hydroxide forms.

Calculate the pH of the resulting solution at 25°C.

$n(In(NO_3)_3) = 1.80 \div 300.83 = 5.98 \times 10^{-3}$ mol

$n(OH^-) = 0.502 \times \frac{40}{1000} = 0.02008$ molL^{-1}

$$In^{3+} + 3OH^- \rightarrow In(OH)_3$$

1 mol of In^{3+} is needed to react with 3 mol of OH$^-$

$\frac{0.02008}{3} = 6.69 \times 10^{-3}$ mol of In^{3+} is needed to react with 0.02008 mol of OH$^-$

Actual $n(In^{3+}) = 5.98 \times 10^{-3}$ mol so In^{3+} is limiting reagent.

$n(OH^-)_{left} = 0.02008 - (3 \times 5.98 \times 10^{-3}) = 2.14 \times 10^{-3}$ mol

$[OH^-] = \frac{2.14 \times 10^{-3}}{60/1000} = 0.0356$ molL^{-1}

*$[H^+] = \frac{1 \times 10^{-14}}{0.0356} = 2.803 \times 10^{-13}$ molL^{-1}*

pH = - log(2.803 x 10^{-13}) = 12.55

See next page

Question 30 **(4 marks)**

Sodium benzoate, $C_6H_5COO^-Na^+$ may be added to acidic food to act as a preservative. When added, it produces benzoic acid, C_6H_5COOH and an equilibrium between these two substances is established. Part of its preservative action is due to it acting as a buffer.
(K_a of benzoic acid = 6.5 x 10^{-5})

    (a)   Give an equation showing the buffer system.

$$C_6H_5COOH + H_2O \rightleftharpoons C_6H_5COO^- + H_3O^+$$
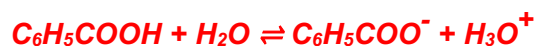
                                                                          (1 mark)

    (b)   Explain how the buffer system produced in the food would respond to the addition of an alkaline ingredient, including equations where possible.

When hydroxide ions are added, these react with benzoic acid to form benzoate ions.
$$C_6H_5COOH + OH^- \rightarrow C_6H_5COO^- + H_2O$$

The OH$^-$ concentration increases only slightly

The increase in pH is minimised as a result.

                                                                          (3 marks)

Question 31   **(5 marks)**

Citric acid is a weak, triprotic acid found in citrus fruits and is used in many processed foods as an additive. The citric acid present in fruit juice was determined using volumetric analysis. A suitable procedure is outlined below. You may assume that citric acid is the only acid present.

1. The fruit juice was diluted by taking a 25.0 mL of fruit juice, accurately pipetting this volume into a 250mL volumetric flask and making to volume with distilled water.

2. A 25.0 mL aliquot of the diluted fruit juice was placed in a conical flask.

3. A standardised, freshly prepared sodium hydroxide solution was placed into a burette.

4. A few drops of phenolphthalein, which changes colour in the pH range 8.0 to 10.0, were added to the conical flask and the titration was carried out.

5. The procedure was repeated using a clean, dry conical flask for each additional analysis until concordant results were obtained.

Complete the table below indicating what the effect would be on the titre volume and the citric acid concentration calculated for the fruit juice. Use the terms **increase**, **decrease** or **no change**.

Difference from outlined procedure	Effect on titre volume	Effect on calculated citric acid concentration
Burette was rinsed with water	**increase**	**increase**
Bromocresol green was used as an indicator (pH colour change range: 4.0 – 5.6)	**decrease**	**decrease**
The volumetric flask was overfilled	**decrease**	/////////

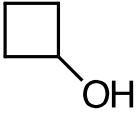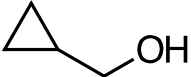**Question 32**   **(7 marks)**

Two different saturated alcohols, each with the molecular formula C_4H_8O, were reacted with acidified $K_2Cr_2O_7$. An excess of the alcohol was used in each case.

Reaction 1: $C_4H_8O \rightarrow$ **Product A**
Reaction 2: $C_4H_8O \rightarrow$ **Product B** $\rightarrow$ **Product C**

1 mark for recognising primary & secondary with correct number of C atoms.

Structure of alcohol in Reaction 1	Structure of alcohol in Reaction 2

(2 marks)

(a)   The boiling point of **Product A** is lower than the alcohol used in Reaction 1. Give an explanation for this.

Boiling requires the breaking of intermolecular forces

As the substances have a similar numbers of electrons dispersion forces are similar ✓

Product A is ketone and has a carbonyl group C=O bond and so dipole-dipole forces are the dominant intermolecular force which are weaker for molecules with similar numbers of electrons. ✓

The alcohol contains an O-H bond meaning the dominant intermolecular force is H-bonding ✓

(3 marks)

(b)   Give a chemical test that could be used to distinguish between **Products A** and **C**.

Test: *Addition of specific metal carbonate OR addition of specific alcohol with conc. H_2SO_4*

Observations for **A**	Observations for **C**
No visible reaction	**Colourless, odourless gas** **White solid dissolves** **OR** **Sweet smell produced**

(2 marks)

See next page

Question 33 **(4 marks)**

When 0.1 mol L^{-1} concentrations of two acids, nitric acid (HNO_3) and nitrous acid (HNO_2) were prepared and their pH measured. The following results were obtained:
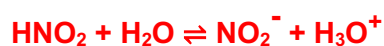
HNO_3 = 1 HNO_2 = 2.13

Explain the difference in pH using chemical equations and calculations where possible.

As concentration of HNO_3 and HNO_2 is 0.1 if acid fully ionised, a pH of 1 would be expected. $[H^+] = 10^{-pH}$

As HNO_3 has a pH of 1, it fully ionises (strong):

$$HNO_3 + H_2O \longrightarrow NO_3^- + H_3O^+$$

As HNO_2 only has a pH of 2.13 this means the acid is only partially ionised (weak):

$$HNO_2 + H_2O \rightleftharpoons NO_2^- + H_3O^+$$

(4 marks)

Question 34 **(6 marks)**

Complete the tables below, drawing full structural formulae for the substances described.

(a) (i) The reactants that produce the ester, 2-butylpropanoate.

Reactant 1	Reactant 2
 Name: *butan-2-ol*	 Name: *propanoic acid*

(4 marks)

See next page

(b)   (i) An unsaturated hydrocarbon capable of producing 2,3-dibromopentane when reacted with bromine.

Reactant 1

Name: ***trans*-pent-2-ene**   **OR**   ***cis*-pent-2-ene** |
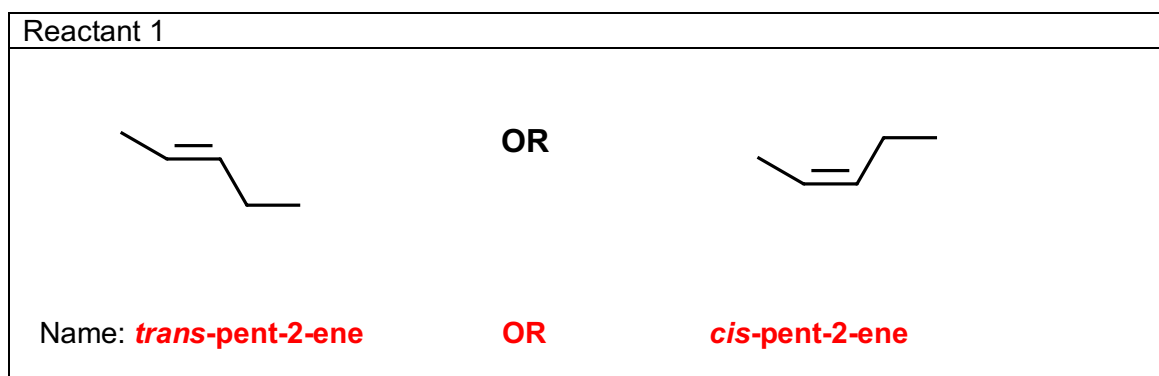
(2 marks)

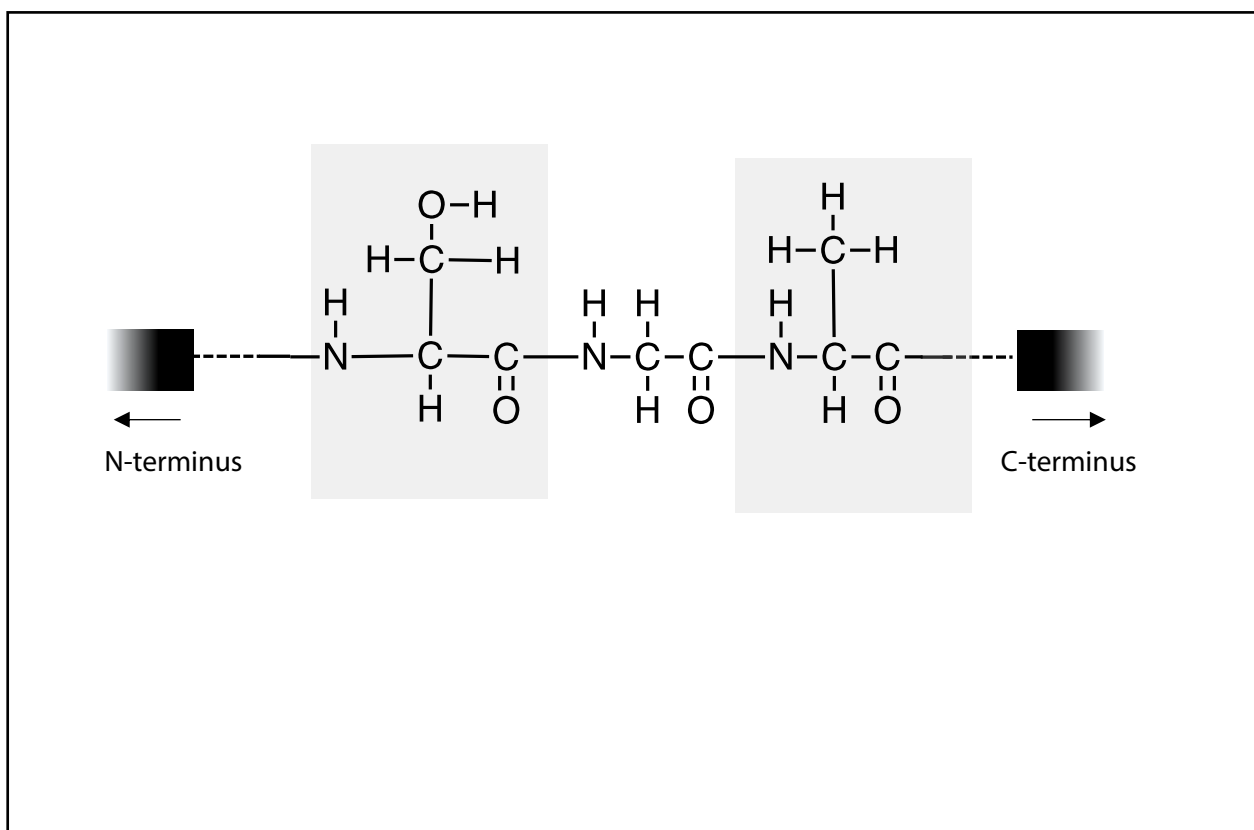## Question 35   (8 marks)

Silk is a naturally occurring fibre consisting of two main proteins. One of these called fibroin consists of the recurrent sequence shown below and provides the high strength associated with the silk fibre.

(Gly-Ser-Gly-Ala-Gly-Ala)$_n$
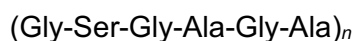
(a)   Draw a **Ser-Gly-Ala** portion of fibroin from the sequence shown in the space provided below:

(3 marks)

See next page

(b) The strength of silk is mostly due to the presence of intermolecular forces between parts of the protein chain. Name and explain the origin of the predominant intermolecular force present between sections of the peptide backbone of the fibroin.

Name of intermolecular force:

Hydrogen bonding (1 mark)

Explanation of origin of the intermolecular force:

The N-H bond is highly polarized due to the large differences in the electronegativity between these atoms.

The hydrogen atom has a partially exposed proton producing an extreme dipole

which is strongly attracted to lone pairs of electrons in neighbouring carbonyl groups, C=O.

(3 marks)

(c) The presence of glycine residues enables the protein chain to fold back on itself. This is shown in the schematic diagram below:
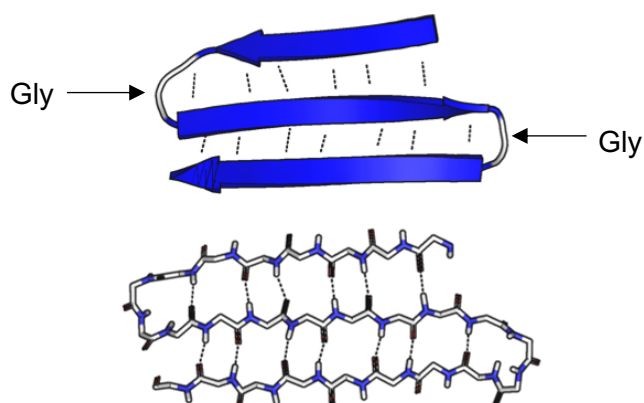
What is the name given to the structure shown above?

(anti-parallel) β-pleated sheet

(1 mark)

End of Section Two

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

This section contains **six** 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 an appropriate number of significant figures.

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Suggested working time for this section is 70 minutes.

Question 36   **(13 marks)**

Natural gas is a naturally occurring hydrocarbon gas consisting primarily of methane. Other hydrocarbons are also present, as are many other substances. One such substance is hydrogen sulfide, H_2S. Natural gas containing high levels of hydrogen sulfide (typically above about 4ppm) is often called 'sour gas'. Hydrogen sulfide is corrosive and extremely poisonous, so its presence in sour gas needs to be decreased.

There are several methods of hydrogen sulfide removal. One of these is the Claus process.

Reaction 1 $8H_2S + 4O_2 \longrightarrow S_8 + 8H_2O$

(a) In a particular process, Reaction 1 is known to be only 61.4% efficient. If the treatment of 10 tonnes of sour gas yielded 79.2g of elemental sulfur, calculate the ppm level of hydrogen sulfide in the sour gas.

$n(S_8)$ = (79.2)/(256.56)
            = 0.3087   ✔

$n(H_2S)$ = $n(S_8)$x8x(100/61.4)
            = 0.3087x8x(100/61.4)
            = 4.022   ✔

$m(H_2S)$ = (4.022)(34.086)
            = 137.1g   ✔

$ppm(H_2S)$ = (137.1g)(1x10^6)/(1x10^7)
            = 13.7ppm   ✔

   (4 marks)

See next page

In the laboratory, the hydrogen sulfide level in a sample of sour gas can be determined as follows:

1. Passing the gas through an excess of an oxidising agent such as potassium dichromate to react all of the hydrogen sulfide.

$$4Cr_2O_7^{2-} + 3H_2S + 26H^+ \longrightarrow 8Cr^{3+} + 3SO_4^{2-} + 16H_2O$$
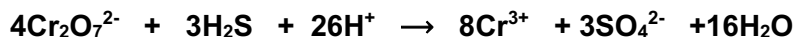
2. Reacting the excess dichromate ions with a solution of hydrogen peroxide.

$$Cr_2O_7^{2-} + 3H_2O_2 + 8H^+ \longrightarrow 2Cr^{3+} + 3O_2 + 7H_2O$$
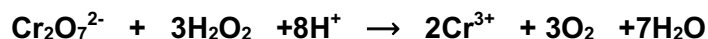
(b) In a laboratory experiment, it was found that when 987L of sour gas was analysed in this way and passed through 100mL of 0.0104molL^{-1} potassium dichromate, 23.2mL of 0.0482molL^{-1} hydrogen peroxide was required to react with the excess dichromate ions. Calculate the concentration (in molL^{-1}) of hydrogen sulfide in the sour gas sample.

$n(H_2O_2)$ = (0.0482)(0.0232)
                   = 0.001118   ✔

$n(Cr_2O_7^{2-})xs$ = $n(H_2O_2)$x1/3
                   = 0.001118x1/3
                   = 0.0003727   ✔

$n(Cr_2O_7^{2-})init$ = (0.0104)(0.100)
                   = 0.00104   ✔

$n(Cr_2O_7^{2-})react$= n(init)-n(react)
                   = 0.00104-0.0003727
                   = 0.0006673   ✔

$n(H_2S)$ = $n(Cr_2O_7^{2-})$x3/4
                   = 0.0006673x3/4
                   = 0.0005004   ✔

$c(H_2S)$ = (0.0005004)/(987)
                   = 0.000000507molL^{-1} ✔
                   (= 5.07x10^{-7}molL^{-1})

(6 marks)

(c) Given that the density of the sour gas was 0.739gL^{-1}, calculate the ppm level of the hydrogen sulfide in the laboratory sample.

$m(H_2S)$ = (0.0005004)(34.086)
                   = 0.01706   ✔

m(sour gas) = (987)(0.739)
                   = 729.4g   ✔

$ppm(H_2S)$ = (0.01706)(1x10^6)/(729.4)
                   = 23.4ppm   ✔

(3 marks)

See next page

Question 37 **(9 marks)**

There is much interest in fuel cell technology as scientists look for alternative green energy sources. One such cell is the ammonia fuel cell. A simplified diagram of such a cell is shown below:
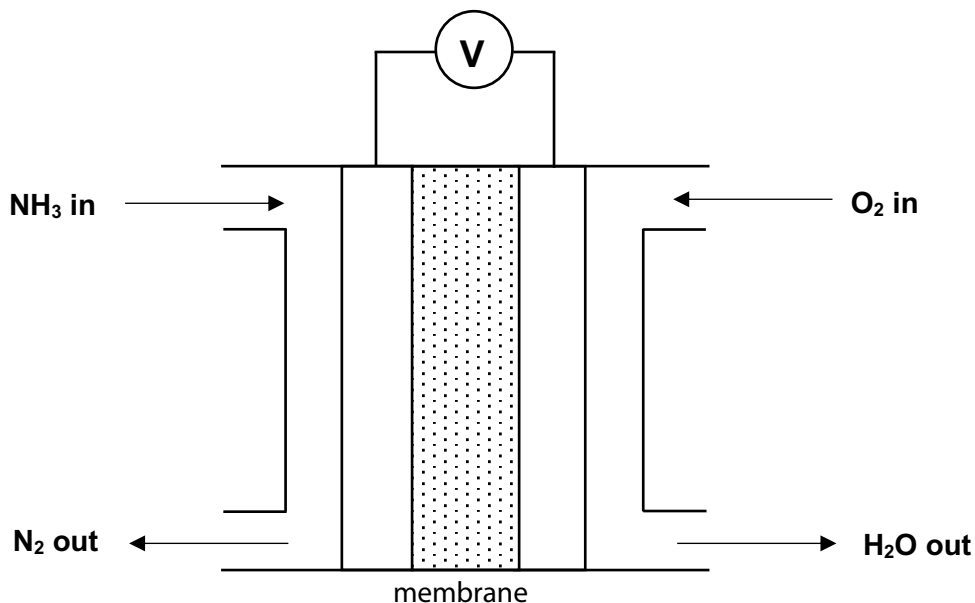
(a)   On the diagram indicate the direction of electron flow in the external circuit, and identify the direction of flow of cations across the membrane.

(2 marks)

Both flowing from left to right.

(b)   Construct half-equations for the oxidation and reduction reactions and combine them into an overall redox equation.

Oxidation half equation	$2NH_3 \rightarrow N_2 + 6H^+ + 6e^-$
Reduction half equation	$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$
Overall redox equation	$4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O$

(6 marks)

(c)   Suggest why the ammonia fuel cell is considered a clean energy source.

Nitrogen and water are the only products. They are both non-polluting / harmless / already in atmosphere.

(1 mark)

See next page

Question 38   **(15 marks)**

(a)   Western Australia has very large underground reserves of lithium, mostly in the form of lithium chloride. The lithium is extracted by electrolysis of molten lithium chloride.

(i)   At which electrode will the lithium metal be formed?

      Cathode

                                                         (1 mark)

(ii)   Write an equation for the reaction at the anode.

      $2Cl^- \rightarrow Cl_2 + 2e^-$

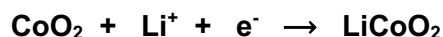   (1 mark)

(b)   One use of lithium metal is in the lithium-ion galvanic cell. The anode reaction involves the oxidation of lithium metal, which is bound on to graphite (represented by C_6)

$$LiC_6 \longrightarrow Li^+ + C_6 + e^-$$

The cathode reaction is as follows:

$$CoO_2 + Li^+ + e^- \longrightarrow LiCoO_2$$

(i)   Identify the element that is reduced at the cathode and give its change in oxidation number.

      The **Cobalt** is reduced from **+4** to **+3**

                                                         (2 marks)

(ii)   Write the combined redox reaction for the overall cell.

Overall redox equation	**$LiC_6 + CoO_2 \rightarrow LiCoO_2 + C_6$**

   (1 mark)

(c)   A useful laboratory chemical containing lithium is lithium aluminium tetrahydride, $LiAlH_4$. It is a powerful reducing agent and can be used to reduce a wide range of organic substances.

(i)   What is the oxidation number of hydrogen in $LiAlH_4$? **-1**

(1 mark)

Butanal can be reduced by reaction with lithium aluminium tetrahydride according to the following equation:

$$8C_4H_8O + 2LiAlH_4 + 8H^+ \rightarrow 8\ C_4H_{10}O + 2Al^{3+} + 2Li^+$$
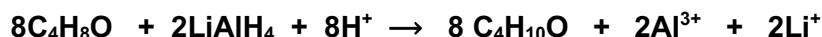
(ii) Draw the structure of butanal and the most likely structure of the organic product of the reaction.

Full structural formula for butanal	Full structural formula of the product
H H H O H–C–C–C–C H H H H	H H H H H–C–C–C–C–OH H H H H

(2 marks)

Lithium aluminium tetrahydride reacts violently in water, and so it is important that the other reactants are in excess.

(iii) What is the maximum mass of lithium aluminium tetrahydride that could be safely used to reduce 20.0mL of butanal, which has a density of $0.817gmL^{-1}$?

m(butanal)   **= (20.0)(0.817)**
               = 16.34g   ✓

n(butanal)   **= (16.34)/(72.104)**
               = 0.2266   ✓

n(LiAlH₄)   **= n(butanal)x2/8**
               = 0.2266x2/8
               = 0.05665   ✓

m(LiAlH₄)   **=(0.05665)(37.98)**
               =2.15g   ✓

(4 marks)

(iv) There is some concern about the effects of aluminium ions on health. In order to ensure that all the aluminium ions are removed by precipitation before disposing of the reaction mixture K_3PO_4 (aq) is added. Assuming that all the $LiAlH_4$ reacts, what volume of $0.12molL^{-1}$ potassium phosphate solution would need to be added?

n(Al³⁺)   **= n(butanal)x2/8 = 0.2266x2/8**
               = 0.05665   ✓

n(PO₄³⁻)   **= n(Al³⁺) = 0.05665**
v(PO₄³⁻)   **=(0.05665)/(0.12)**

               = 0.47L (470mL)   ✓   **to 2 sig figs** ✓

(3 marks)

See next page

Question 39 **(11 marks)**

Much can be learned about chemical reactions by a study of kinetics (reaction rates). One such study is the Harcourt-Essen reaction, which is the acid-catalysed iodination of propanone, the equation for which is given below

$$C_3H_6O \ + \ I_2 \ \rightarrow \ C_3H_5OI \ + \ HI$$
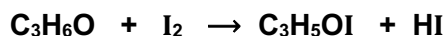
(a)   Draw the structure of iodopropanone in the box below

$$
\begin{array}{ccccc}
 & H & & H & \\
 & | & & | & \\
H- & C & - C - & C & -I \\
 & | & \| & | & \\
 & H & O & H &
\end{array}
$$

(1 mark)

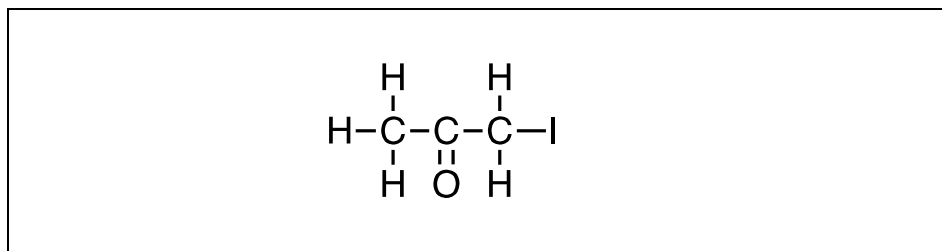A series of reactions was performed in which the concentrations of propanone, iodine and hydrogen ions were varied and the initial rate of formation of iodopropanone (CH_3COCH_2I) was monitored. A summary is given in the table below, in which eight individual experiments were performed.

For your convenience this table is also provided on a separate sheet.

Experiment	[CH₃COCH₃] ($molL^{-1}$)	[I₂] ($molL^{-1}$)	[H⁺] ($molL^{-1}$)	Initial rate of formation of iodopropanone ($molL^{-1}s^{-1}$)
1	0.0200	0.0100	0.00300	3.68×10^{-6}
2	0.0400	0.0100	0.00300	7.35×10^{-6}
3	0.0600	0.0100	0.00300	1.11×10^{-5}
4	0.0800	0.0100	0.00300	1.47×10^{-5}
5	0.0400	0.0200	0.00300	7.36×10^{-6}
6	0.0400	0.0300	0.00300	7.34×10^{-6}
7	0.0800	0.0100	0.00500	2.45×10^{-5}
8	0.0800	0.0100	0.00100	4.81×10^{-6}

(b)(i)   On the graph provided, plot how the initial rate of reaction varies with the concentration of propanone, using the results of **Experiments 1,2,3** and **4**.
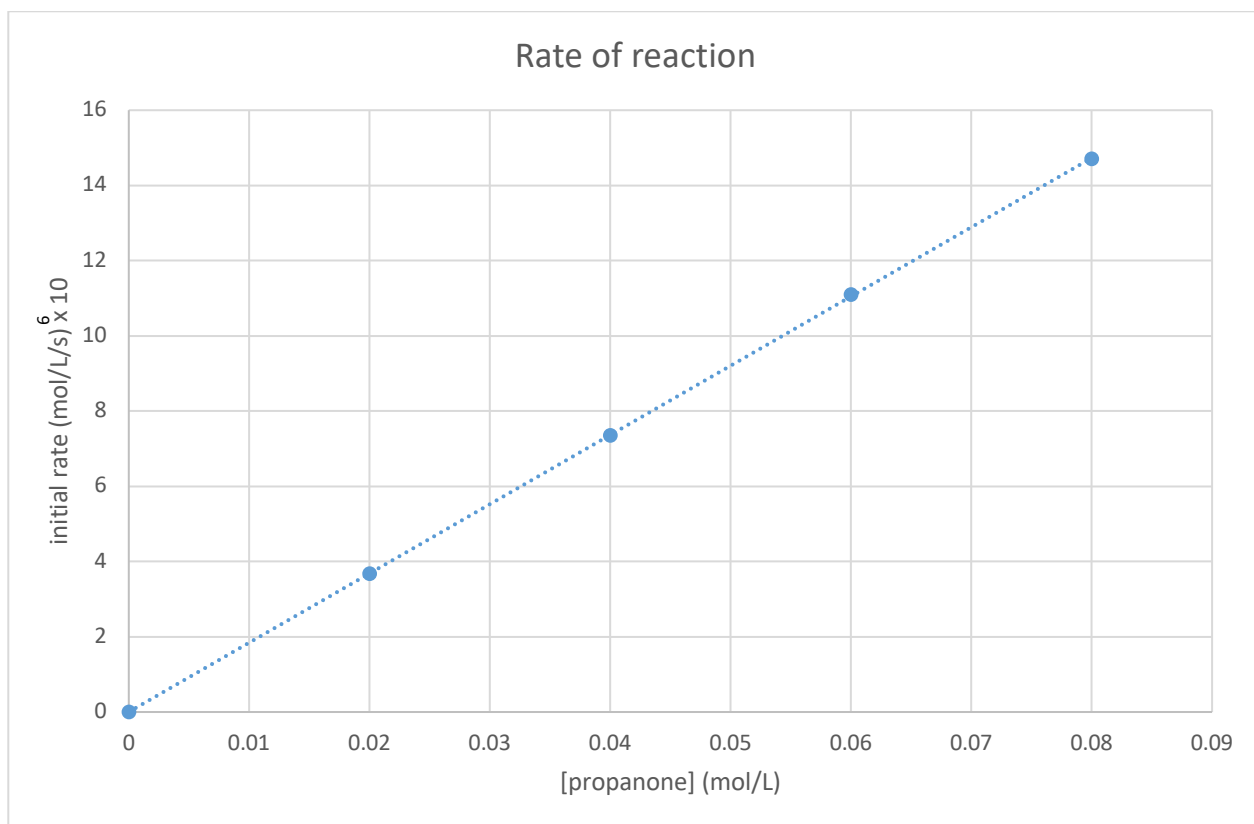
See next page

Rate of reaction

(3 marks)

(ii)   What would be a suitable conclusion to draw from these results?

As [propanone] increases, initial rate of reaction increases. (proportionality not required)

(1 mark)

(c)   Now consider experiments **4,7** and **8**.

(i)   Identify the independent variable, dependent variable and and two explicity controlled variables for these experiments

Independent variable **[H$^+$]**

Dependent variable   **(initial) rate of reaction**

Wrong way round gets zero marks

Controlled variables

1.   **[iodine]**

2.   **[propanone]**

Both required for mark

(3 marks)

(ii)   Identify one other variable that would also need to be controlled to ensure the validity of the results.

Temperature

(1 mark)

(d)   Finally, considering all the data in the table, what would you conclude about the effect of iodine on the rate of reaction?

It has no effect. Or rate is independent of [iodine] ✓✓ ('all or nothing')

(2 marks)

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Question 40   **(15 marks)**

A protein present in silk is called sericin. The structure of sericin is not fully known but it is a sticky substance which is present in large amounts in spider silk. As part of attempts to determine the structure of sericin, analyses were carried out to determine the quantities of the elements present, namely carbon, hydrogen, nitrogen and oxygen.

Complete combustion of an 800 mg sample of sericin produced 1.33 g of carbon dioxide. When a 2.41 g of sericin was combusted, 1.09 g of water were produced.

A further 1.69 g sample of the sericin was treated to produce a solution of ammonia. When this solution was titrated with 1.0 molL^{-1} hydrochloric acid, 21.1 mL of the acid was required to fully react with the ammonia present.

(a)   Determine the empirical formula for sericin.

n(C) in CO_2 $= \frac{12.01}{44.01} \times 1.33 = 0.3629 \text{ mol}$

%C in sericin $= \frac{0.3629}{0.8000} \times 100 = 45.37\%$

n(H) in H_2O $= \frac{2.016}{18.016} \times 1.09 = 0.1220 \text{ mol}$

%H in sericin $= \frac{0.1220}{2.41} \times 100 = 5.06\%$

n(NH_3) $= \frac{21.1}{1000} \times 1.0 = 0.0211 \text{ mol}$

m(N) = 0.0211 x 14.01 = 0.295611 g

%N $= \frac{0.295611}{1.69} \times 100 = 17.49\%$

%O = 100 – 45.37 – 5.06 -17.49 = 32.08%

	C	*H*	*N*	*O*	
n	$\frac{45.37}{12.01}$	$\frac{5.06}{1.008}$	$\frac{17.49}{14.01}$	$\frac{32.08}{16.00}$	
m	$\frac{3.7777}{1.2483}$	$\frac{5.0198}{1.2483}$	$\frac{1.2483}{1.2483}$	$\frac{2.005}{1.2483}$	
ratio	*3.03*	*4.02*	*1.00*	*1.600*	*x5*
	15	*20*	*5*	*8*	

$C_{15}H_{20}N_5O_8$

(11 marks)

See next page

(b) At a temperature of 600°C, a sample of 7.35 g was found to occupy a volume of 930 mL at 72 kPa. From this information determine the molecular formula of sericin.

M(EF) = 398.36

$n = PV/RT = \dfrac{72 \times 0.93}{8.314 \times 873.15} = 9.22 \times 10^{-3}$ *mol*

$M = \dfrac{7.35}{9.22 \times 10^{-3}} = 796.839$ *gmol^{-1}*

$^{MF}/_{EF}$ = 796.839 ÷ 398.36 = 2

*MF is $C_{30}H_{40}N_{10}O_{16}$*

(4 marks)

Question 41 (17 marks)

Sunflower oil is used widely in the food industry. The used oil is often sold on to make biodiesel. The process uses a suitable base but the quantity of it that is used needs to be carefully controlled and varies from batch to batch.

(a) The structure of sunflower oil is shown below. The amount of base used varies due to the free fatty acid content of the oil.
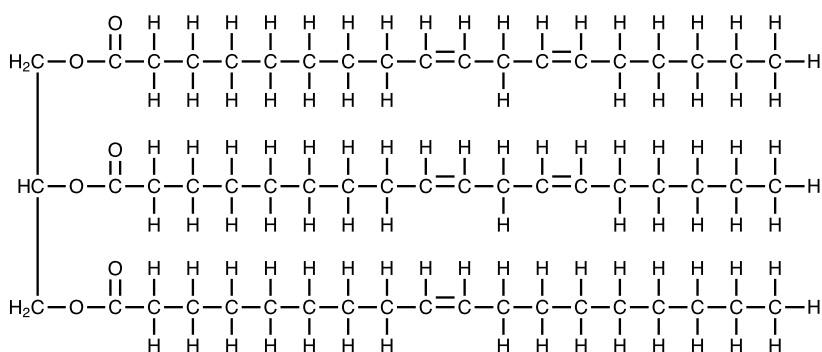
(i) Draw the structure of the monounsaturated free fatty acid that would originate from sunflower oil in the box below.

$$CH_3(CH_2)_7CHCH(CH_2)_7COOH$$

(2 marks)

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(b)   To determine the amount of base that needs to be added, a titration is carried out between a sample of the oil and potassium hydroxide to determine the free fatty acid content (FFA).

From the table below, select an appropriate indicator for the titration and justify your answer using equations where appropriate. You may refer to the free fatty acids as R-COOH.

Indicator	pH range
Bromocresol green	3.8 (yellow) – 5.4 (blue)
Phenolphthalein	8.0 (colourless) – 10.0 (pink)

Chosen indicator: *phenolphthalein*

Justification including a relevant equation:

End point near to equivalence point
Equivalence in basic range due to hydrolysis of RCOO⁻ which is conjugate base of a weak acid

$$RCOO^- + H_2O \rightarrow RCOOH + OH^-$$

(4 marks)

(c)   When 0.217 $molL^{-1}$ potassium hydroxide was titrated with a 20.0 mL sample of oil, the following titres were obtained. Complete the table below and determine the average titre.

	Rough	1	2	3	4
Initial volume / mL	0.95	4.35	2.35	2.10	3.75
Final volume / mL	19.40	21.60	19.55	20.40	20.95
Titre volume / mL	*18.45*	*17.25*	*17.20*	*18.30*	*17.20*

(i)   Average titre: *17.22 mL*

(2 marks)

See next page

(ii) From this data determine the % by mass of free fatty acid content of the oil. You may assume the free fatty acid is all linoleic acid, $C_{18}H_{32}O_2$. The average density of sunflower is 0.93 gmL^{-1}.

$n(OH^-) = \frac{17.22}{1000} \times 0.217 = 3.74 \times 10^{-3}$ *mol*

$n(OH^-) = n(RCOOH) = 3.74 \times 10^{-3}$ *mol*

m(RCOOH) = 3.74 x 10^{-3} x 280.436 = 1.05 g

mass of 20 mL of oil = 20 x 0.93 = 18.6 g

% FFA in oil = 1.05 ÷ 18.6 x 100 = 5.65%

(5 marks)

(d) Using the space below, complete and balance the reaction for producing biodiesel using a suitable catalyst. For simplicity, the structure of the oil is shown with R- groups denoting parts of the oil molecule.

(4 marks)

End of questions