

Examiner: B Ward Moderator: K van Schoor		Form: 5 Date: 16 Sept 2024 Subject: Physical Science Assessment: Preliminary Examination: P2 Chemistry Marks: 200 Time: 3 hr
Examination number: 24112802		Teacher: SES / BWA / KVS

Q	TOTAL	MARK	MODERATED MARK	Q	TOTAL	MARK	MODERATED MARK
1	20			6	20		
2	15			7	21		
3	25			8	28		
4	24			9	17		
5	30						
TOTAL					200		

Please read the following instructions carefully:

1. This question paper consists of 30 pages and a separate Data Sheet.
2. Use the data and formulae whenever necessary.
3. Read the questions carefully.
4. Answer all the questions on the question paper.
5. Show your working in all calculations, including equations used.
6. Non-programmable calculators and appropriate mathematical instruments may be used.
7. Units need not be included in the working of calculations, but appropriate units must be shown in the final answer.
8. Answers must be expressed in decimal format, not left as proper fractions.
9. Where appropriate, express final answers correct to TWO decimal places.
10. It is in your own interest to write legibly and present your work neatly.
11. Graphs should be drawn with a sharp dark pencil.
12. One blank page is included (page 23). If you run out of space for a question, use this page. Clearly indicate the number of your answer should you use this extra space.

The use of DBE and other IEB teachers' questions, in whole or in part, is gratefully acknowledged.

QUESTION 1

MULTIPLE CHOICE QUESTIONS

[2 x 10 = 20]

Every question has only one correct answer. You may use the space provided to solve the questions BUT YOU MUST INDICATE YOUR CHOSEN ANSWER FOR EACH QUESTION IN THE GRID BELOW. Make a clear cross (X) in the box corresponding to the letter that you consider to be correct.

e.g. Here the answer C has been marked.

A	B	~~C~~	D
---	---	--------------	---

1.1	A	B	C	D
1.2	A	B	C	D
1.3	A	B	C	D
1.4	A	B	C	D
1.5	A	B	C	D
1.6	A	B	C	D
1.7	A	B	C	D
1.8	A	B	C	D
1.9	A	B	C	D
1.10	A	B	C	D

1.1 The chemical formula for manganese(II) chlorate is:

- A. MnClO_3
- B. MgClO_3
- C. $\text{Mn}(\text{ClO}_3)_2$
- D. $\text{Mg}(\text{ClO}_3)_2$

1.2 Which one of the following gives the number of carbon dioxide molecules in 22 g of $\text{CO}_2(\text{g})$?

- A. $\frac{22 \times 6,02 \times 10^{23}}{44}$
- B. $\frac{44 \times 6,02 \times 10^{23}}{22}$
- C. $\frac{44}{22 \times 6,02 \times 10^{23}}$
- D. $\frac{22}{44 \times 6,02 \times 10^{23}}$

1.3 Which one of the bonds between the atoms below has the highest polarity?

- A. H – C
- B. H – Cl
- C. H – O
- D. H – P

1.4 What is the final concentration of **nitrate ions** when 100 cm³ of 0,2 mol·dm⁻³ lead(II) nitrate is mixed with 200 cm³ of 0,5 mol·dm⁻³ sodium nitrate?

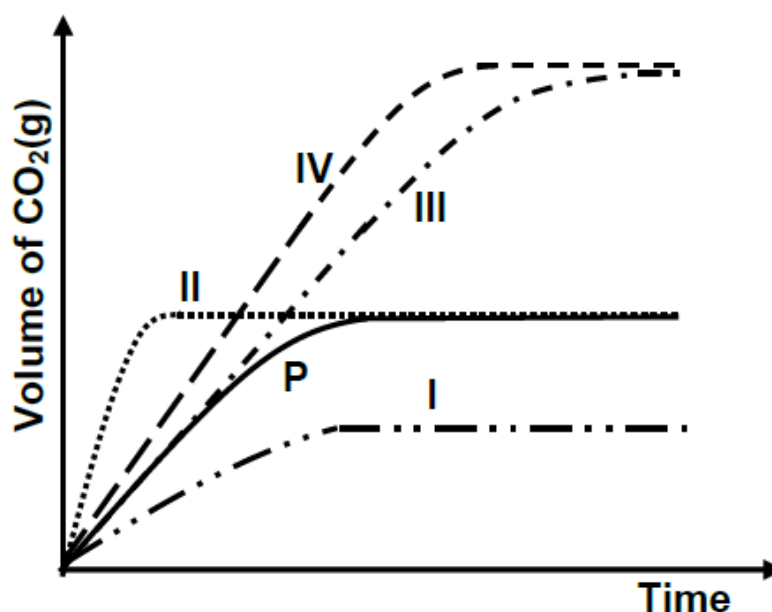
- A. 0,70 mol·dm⁻³
- B. 2,33 mol·dm⁻³
- C. 0,40 mol·dm⁻³
- D. 0,47 mol·dm⁻³

1.5 In an experiment **5 g** of calcium carbonate, CaCO₃(s), reacts with EXCESS hydrochloric acid, HCl(aq), at a temperature of **40 °C**.



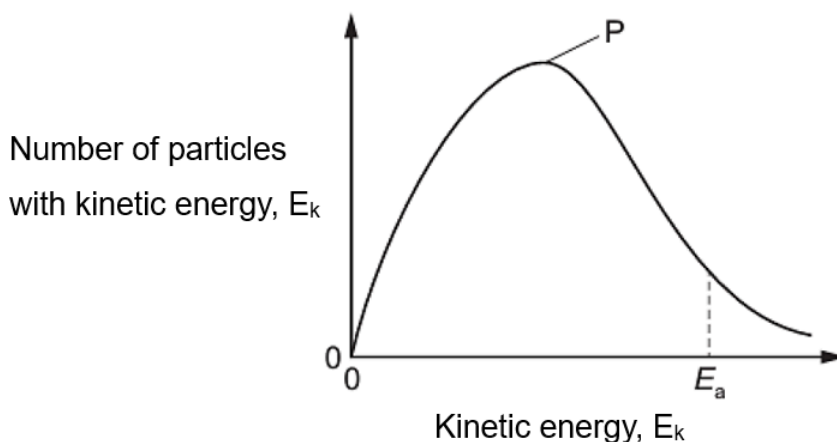
The volume of CO₂(g) produced versus time is shown by CURVE P in the graph below.

The experiment is repeated with **10 g** of the same CaCO₃(s) sample and an excess of HCl(aq) with the same concentration at **45 °C**. Which ONE of the curves will now be obtained?



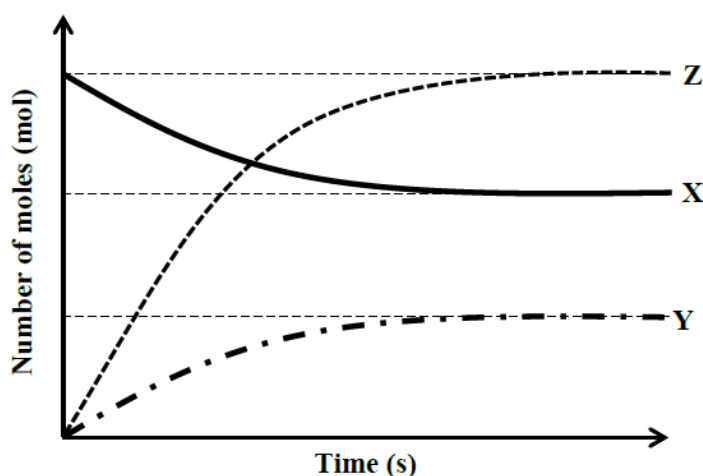
- A. Curve I
- B. Curve II
- C. Curve III
- D. Curve IV

- 1.6** The diagram shows the Maxwell-Boltzmann distribution for one mole of a gas. The gas takes part in a reaction with an activation energy, E_a .



Which statement correctly describes the effect on the diagram above of an increase in temperature?

- A. Peak P will be lower and fewer molecules will have kinetic energy $> E_a$.
- B. Peak P will be lower and more molecules will have kinetic energy $> E_a$.
- C. Peak P will be higher and fewer molecules will have kinetic energy $> E_a$.
- D. Peak P will be higher and more molecules will have kinetic energy $> E_a$.
- 1.7** Gas X is placed in a flask, which is then sealed. Gas X decomposes to produce gas Y and gas Z. The reaction reaches dynamic chemical equilibrium after a certain period of time as shown in the graph below.



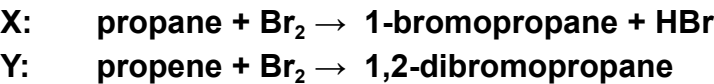
Which one of the following balanced chemical equations represents the decomposition of gas X as shown in the above graph?

- A. $X(g) \rightleftharpoons Y(g) + 3Z(g)$
- B. $2X(g) \rightleftharpoons 2Y(g) + Z(g)$
- C. $2X(g) \rightleftharpoons Y(g) + Z(g)$
- D. $X(g) \rightleftharpoons Y(g) + 2Z(g)$

- 1.8 Adding a catalyst to a reaction in equilibrium will speed up ...
- A. the forward and reverse reactions equally, and increase the yield.
 - B. the forward and reverse reactions equally, and not affect the yield.
 - C. the forward reaction more than the reverse reaction, and increase the yield.
 - D. the forward reaction more than the reverse reaction, and not affect the yield.

- 1.9 Which one of the following statements is **always** true for monoprotic acids?
- A. The lower the concentration of the acid solution, the weaker the acid.
 - B. There will be more H_3O^+ ions in 100 cm^3 of a strong acid solution than in 100 cm^3 of a weak acid solution.
 - C. The pH of a strong acid is lower than the pH of a weak acid.
 - D. One mole of a strong acid will produce more H_3O^+ ions in water than one mole of a weak acid.

- 1.10 Consider the two reactions, X and Y, below:

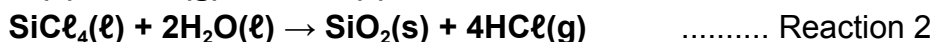


Identify the reaction that has the LOWER activation energy and the reaction that has the LOWER reaction rate under identical external conditions.

	LOWER activation energy	LOWER reaction rate
A.	X	X
B.	X	Y
C.	Y	X
D.	Y	Y

QUESTION 2 [15 marks]

Silicon is a chemical element found in group 14 of the periodic table that is a hard brittle crystalline solid with a blue lustre (shine). Below are two reactions that silicon (Si) can undergo to produce silicon dioxide (SiO_2).



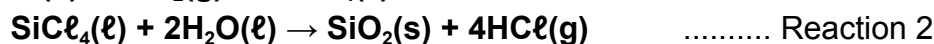
- 2.1** Silicon (Si) and silicon dioxide (SiO_2) **both** have a similar structure to **diamond**. Silicon melts at 1410°C and silicon dioxide melts at 1710°C . Comment on this bonding type and structure to explain the high melting points. (3)

- 2.2** Mpho states that SiCl_4 is an example of a non-polar molecule containing polar bonds. Explain why his statement is correct. (2)

- 2.3** The melting point of SiCl_4 is -70°C . Explain this low melting point. (2)

- 2.4** A 0,30 g **impure** sample of silicon reacts with excess chlorine gas to produce SiCl_4 . (Reaction 1). 150 cm^3 of water is then added to the reaction container and this produces solid SiO_2 and HCl gas (Reaction 2).
The HCl gas is highly soluble and completely dissolves in the 150 cm^3 of solvent producing an HCl(aq) solution of concentration $0,25 \text{ mol.dm}^{-3}$.

Using the balanced equations provided (repeated below) to answer the questions below:



- 2.4.1** Calculate the number of moles of $\text{SiCl}_4(\text{l})$ that reacts in **Reaction 2** to produce the 150 cm^3 of HCl(aq) solution of concentration $0,25 \text{ mol.dm}^{-3}$. (4)

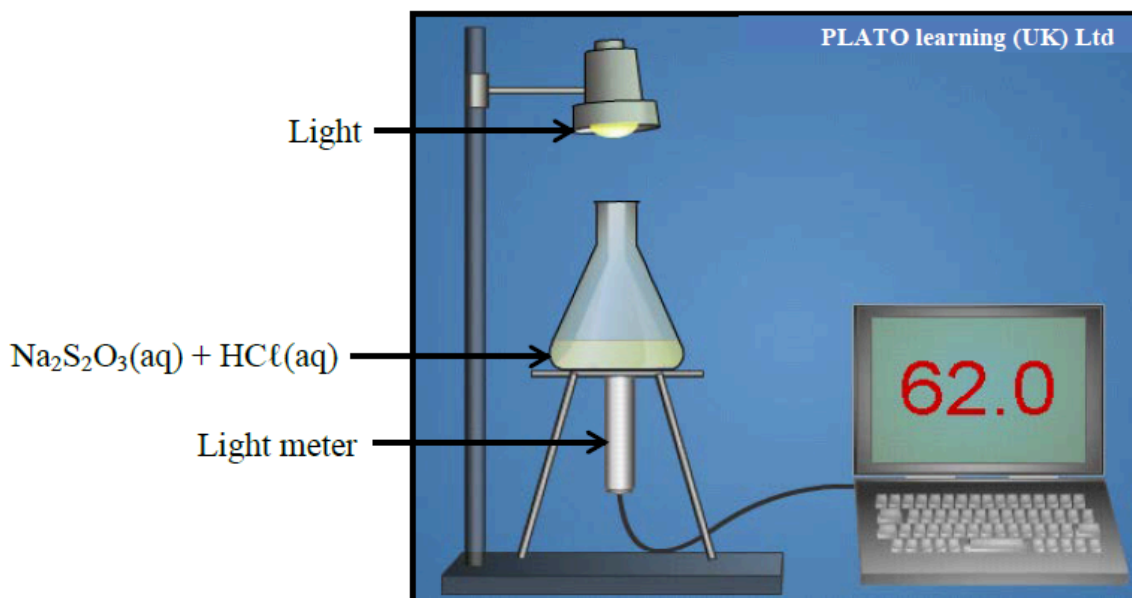
- 2.4.2** Hence, calculate the percentage purity of the initial impure sample of silicon, assuming the $\text{SiCl}_4(\text{l})$ produced in Reaction 1 reacts completely in Reaction 2. (4)

QUESTION 3 [25 marks]

Consider the reaction of $\text{Na}_2\text{S}_2\text{O}_3$ solution with dilute hydrochloric acid as given by the balanced chemical equation below.



The rate of reaction between the $\text{Na}_2\text{S}_2\text{O}_3$ solution and hydrochloric acid can be monitored using a light meter, which measures the intensity of light passing through the solution as the reaction proceeds. The apparatus is set up as shown in the diagram below.



Cameron uses the apparatus shown in the diagram to conduct a series of experiments to determine the relationship between the concentration of the $\text{Na}_2\text{S}_2\text{O}_3$ solution and the time taken for the light meter to show a reading of 62 lumens. (Lumens = unit for light intensity.)

3.1 Name the compound $\text{Na}_2\text{S}_2\text{O}_3$. (1)

3.2 Explain why the intensity of the light passing through the solution decreases as the reaction proceeds. (2)

Cameron obtains the results shown in the table below:

Experiment	Concentration of $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ ($\text{mol} \cdot \text{dm}^{-3}$)	Time (s)
1	0,2	180
2	0,4	90
3	0,6	60
4	0,8	45
5	1,0	36
6	1,2	30

3.3 Cameron plotted a graph to show the relationship between the concentration of the $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ and the time taken for the light meter to show a reading of 62 lumens. The incomplete graph is provided below. Complete the graph by providing the information requested below.

- 3.3.1

Write down a suitable label for the x-axis in the empty block provided.

(2)
- 3.3.2

Determine the scale used on the y-axis and fill in the numbers in the empty blocks provided.

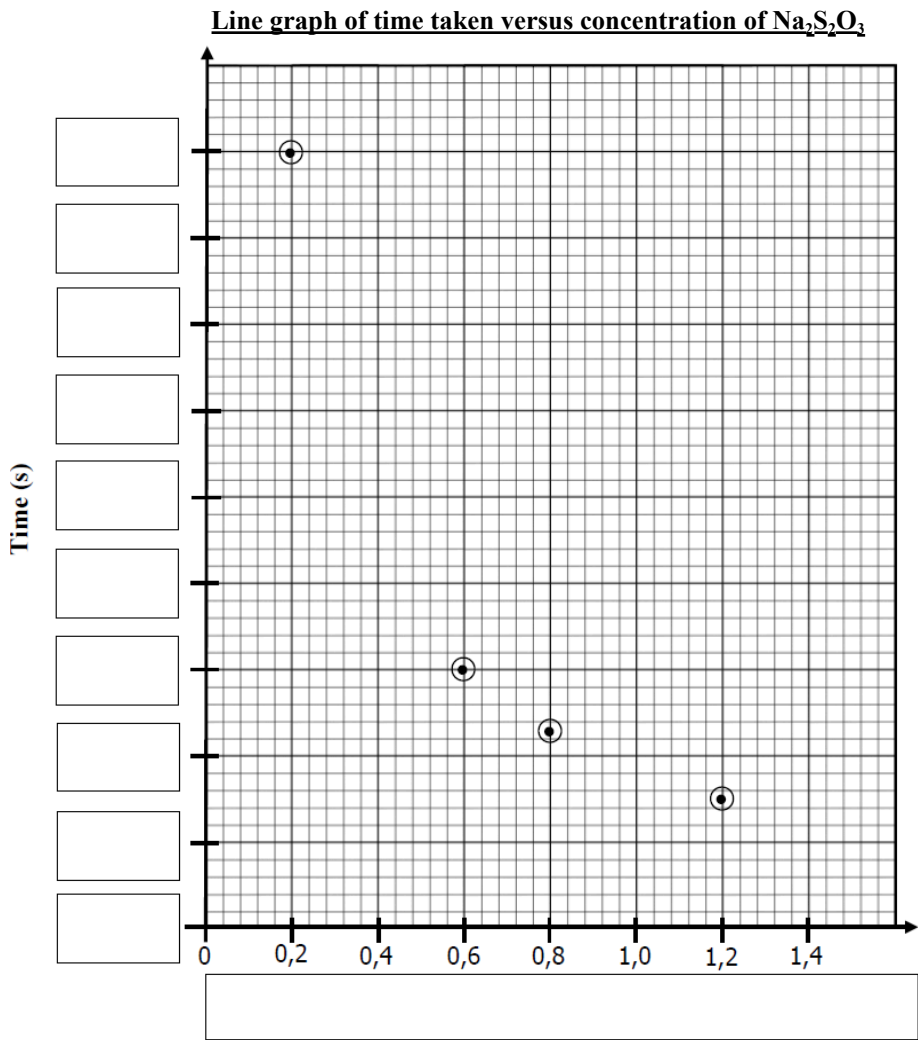
(1)
- 3.3.3

Plot the points for experiments 2 and 5.

(2)
- 3.3.4

Draw a best-fit line through the points.

(1)



3.4 State a reason why Cameron plotted time on the y-axis rather than on the x-axis. (1)

3.5 Cameron correctly states the following conclusion from his experiments:

"The time taken for the light meter to show a reading of 62 lumens is inversely proportional to the concentration of the $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$."

Cameron now plots a new graph. He plots the concentration on the x-axis and the inverse of time on the y-axis.

Describe the shape of his new graph. (2)

3.6 Explain, by referring to the collision theory, how an increase in the concentration of $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ affects the rate of the reaction with $\text{HCl}(\text{aq})$. (4)

3.7 Suggest an alternative method of monitoring the rate of this reaction if a light meter is not available. Clearly explain what **reading(s) would need to be taken**. (2)

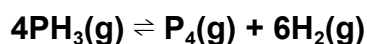
3.8 In a NEW experiment, Cameron reacts 100 cm^3 of $0,2\text{ mol} \cdot \text{dm}^{-3}$ $\text{HCl}(\text{aq})$ with a $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ solution containing $3,5\text{ g}$ of $\text{Na}_2\text{S}_2\text{O}_3$.

3.8.1 Show by calculation that $\text{HCl}(\text{aq})$ is the limiting reagent in this reaction. (3)

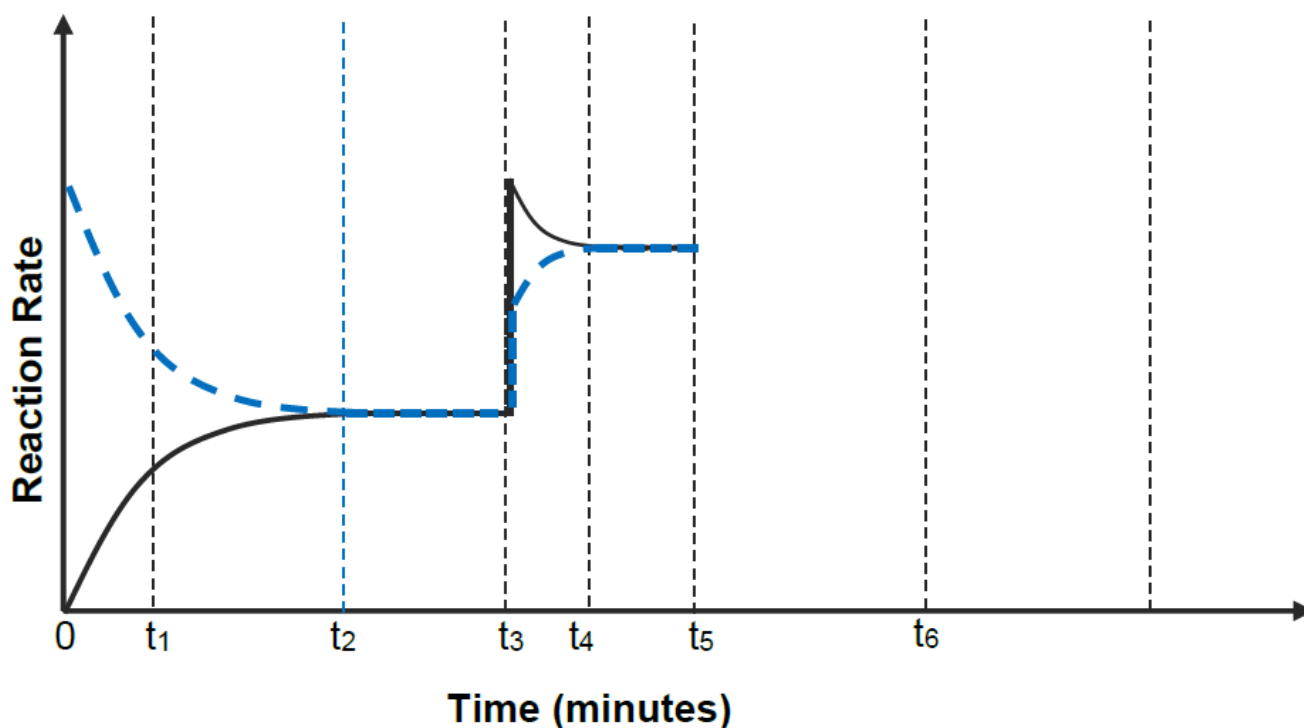
3.8.2 Cameron then filters the solution and collects $0,18\text{ g}$ of sulfur. Calculate the percentage yield of sulfur in Cameron's reaction. (4)

QUESTION 4 [24 marks]

Gas PH_3 decomposes according to the following equation:



A certain amount of PH_3 is sealed in a container and allowed to decompose. The graph of the reaction rate vs time is shown below.



4.1 Complete the statement below by circling the correct option in brackets:

At t_1 on the graph above, the rate of the forward reaction is (GREATER THAN / LESS THAN / EQUAL TO) the rate of the reverse reaction. (1)

4.2 At what time was chemical equilibrium established for the first time? (1)

4.3 Circle the correct word(s) between brackets in the statement below: (1)

Between t_2 and t_3 , the concentrations of PH_3 , P_4 and H_2 are:
(EQUAL TO EACH OTHER / CONSTANT / CHANGING).

4.4 State *Le Châtelier's Principle*. (2)

4.5 The **temperature** of the system was **increased** at time t_3 .

Is the forward reaction EXOTHERMIC or ENDOTHERMIC?

Explain by applying Le Châtelier's principle.

(4)

4.6 At t_5 , the volume of the container was increased at constant temperature, resulting in a **decrease** in the **pressure**.

4.6.1 Explain the effect of this change on the equilibrium mixture by applying Le Châtelier's principle.

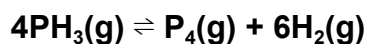
(4)

4.6.2 Complete the rate vs time graph above from t_5 until after equilibrium is re-established at t_6 .

(3)

- 4.7** Gas PH_3 was pumped into an evacuated (empty) container until the concentration was $X \text{ mol} \cdot \text{dm}^{-3}$. The container was sealed. Once equilibrium was established at 120°C , the concentration of gas H_2 was $0,32 \text{ mol} \cdot \text{dm}^{-3}$.

The reaction equation is re-written below:



- 4.7.1** Write the equilibrium constant expression, K_c , for the reaction. (2)

The value of K_c for the reaction at 120°C is 0,206.

- 4.7.2** Show that the equilibrium concentration of gas PH_3 is $0,129 \text{ mol} \cdot \text{dm}^{-3}$. (3)

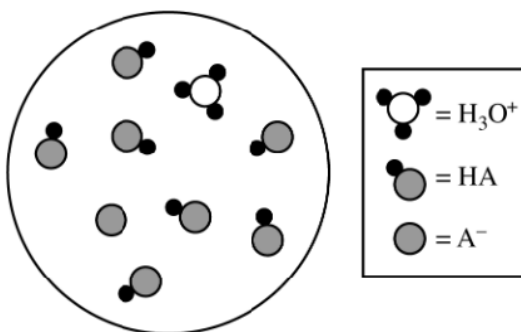
- 4.7.3** Hence, calculate X , the initial concentration of gas PH_3 in the container. (3)

QUESTION 5 [30 marks]

5.1 In humans, the acid HCl is produced in the stomach to aid digestion, and the organic acid $\text{CH}_3\text{CH}_2\text{COOH}$ is produced in the large intestine during digestion.

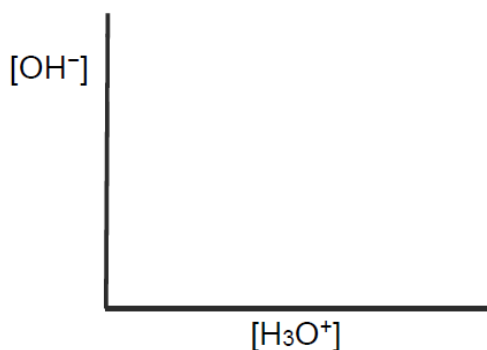
5.1.1 Define a *strong acid*. (2)

5.1.2 Does the particle diagram shown represent HCl or $\text{CH}_3\text{CH}_2\text{COOH}$? Explain your answer. (3)



5.1.3 Write an equation for the ionisation reaction of $\text{CH}_3\text{CH}_2\text{COOH}$ in water. (2)

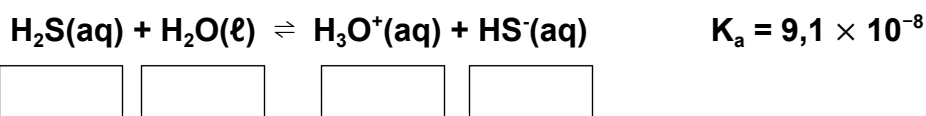
5.1.4 On the axes provided below, draw the sketch graph to show the relationship between the hydroxide and hydronium ion concentration in aqueous solutions. (2)



- 5.1.5** Determine the concentration of the **hydroxide ions** in an HCl solution of concentration $0,17 \text{ mol} \cdot \text{dm}^{-3}$ at 25°C . (3)

- 5.2** Consider the balanced equation below showing how hydrosulfuric acid (H_2S) dissolves in water.

- 5.2.1** Label each substance as either an acid or a base in the boxes below and then use lines to **link the conjugate acid-base pairs**: (2)



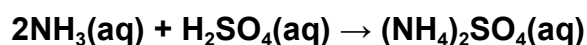
- 5.2.2** Define an *amphoteric substance*. (2)

- 5.2.3** Give the formulae of TWO amphoteric substances shown in the above equation. (2)

- 5.2.4** Explain what the size of K_a implies about the electrical conductivity of the solution. (2)

- 5.3** An experiment was carried out to determine the concentration of aqueous ammonia solution by titrating it with a $0,150 \text{ mol} \cdot \text{dm}^{-3}$ sulfuric acid solution. It was found that $25,0 \text{ cm}^3$ of the aqueous ammonia required $20,1 \text{ cm}^3$ of the sulfuric acid solution for neutralisation.

The balanced equation for the reaction is below:



- 5.3.1** Calculate the concentration of the ammonia solution. (4)

Three acid-base indicators are listed in the table below.

Indicator	Colour in lower pH	Colour in higher pH	pH range
Methyl orange	red	yellow	3,1 - 4,4
Bromothymol blue	yellow	blue	6,0 - 7,6
Phenolphthalein	colourless	pink	8,3 - 10

- 5.3.2** Define *hydrolysis of a salt*. (2)

- 5.3.3** Select the appropriate indicator from the table above. Explain your selection using a suitable equation that is directly related to the definition of hydrolysis. (4)

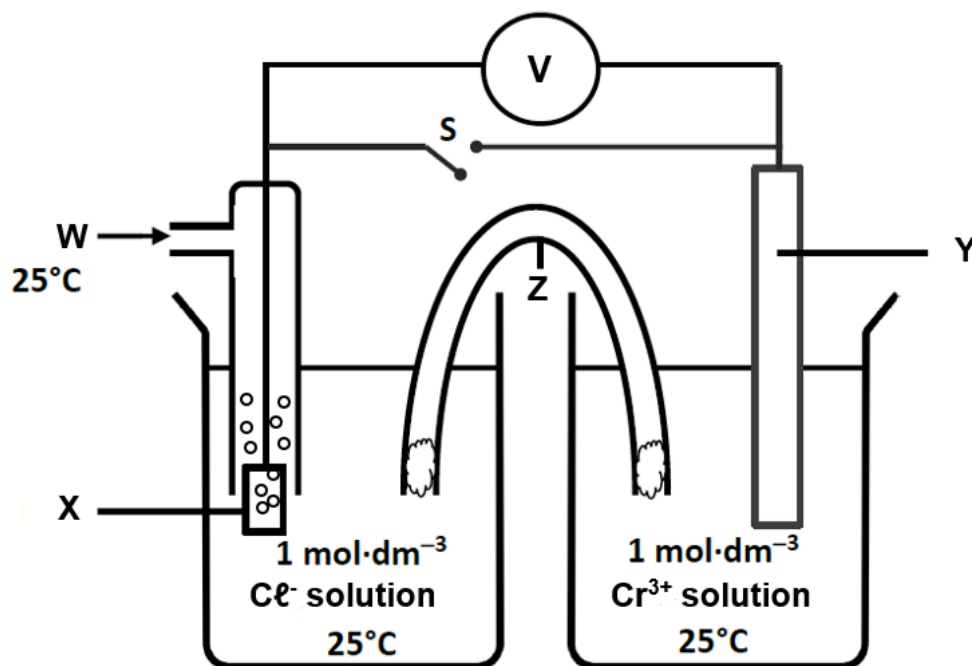
QUESTION 6 [20 marks]

Omer and Josh are given the task of setting up a galvanic cell (under standard solutions) between chlorine gas and chromium.

Chlorine gas reacts with chromium in aqueous solution as follows:



The diagram below shows a galvanic cell used to determine the cell potential ($E^\ominus_{\text{cell}}$) for the above reaction under standard conditions.



6.1 Give the chemical formulae of substances represented by the following letters: (3)

W: _____

X: _____

Y: _____

6.2 List two functions of the part of the cell labelled Z. (2)

6.3 Suggest a suitable electrolyte to use in Z. (1)

6.4 If Z is replaced by a shorter, wider version, what effect would it have on the maximum current the cell can provide? Circle the correct option from the words in brackets below: (1)
(INCREASES / DECREASES / NO EFFECT)

6.5 Write down the anode half-reaction. (2)

6.6 Identify the reducing agent in this cell. (1)

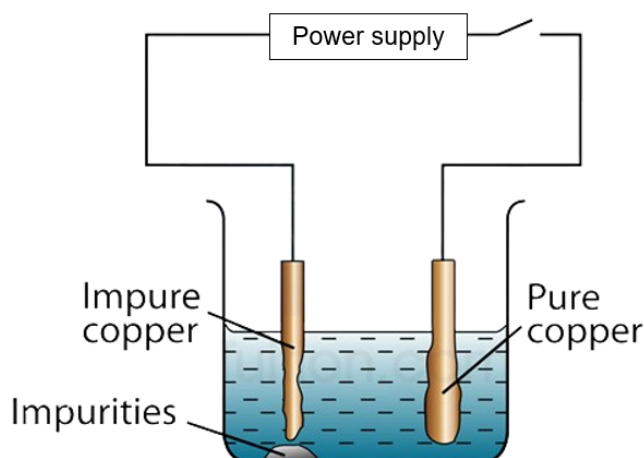
6.7 Write down the cell notation of this cell (standard conditions and state symbols are not required). (3)

6.8 Calculate the initial cell potential (E_{cell}^{θ}) for this cell under standard conditions. (3)

6.9 Omer and Josh add some silver(I) nitrate to the Cl_2/Cl^- half cell. Silver chloride (AgCl) is insoluble in aqueous solution. Make use of this fact and Le Châtelier's principle to explain how the emf of the cell will be affected. (4)

QUESTION 7 [21 marks]

- 7.1** The simplified diagram below represents an electrolytic cell used to purify copper. One of the electrodes will be made of pure copper while the other electrode will consist of the impure copper sample. The electrolyte is $\text{CuSO}_4(\text{aq})$.



- 7.1.1** Explain what is meant by the term “electrolytic cell”. (2)

- 7.1.2** Which electrode, the impure copper or the pure copper, is connected to the positive terminal of the power supply? (1)

- 7.1.3** Write down the half-reaction that takes place at the pure copper electrode. (2)

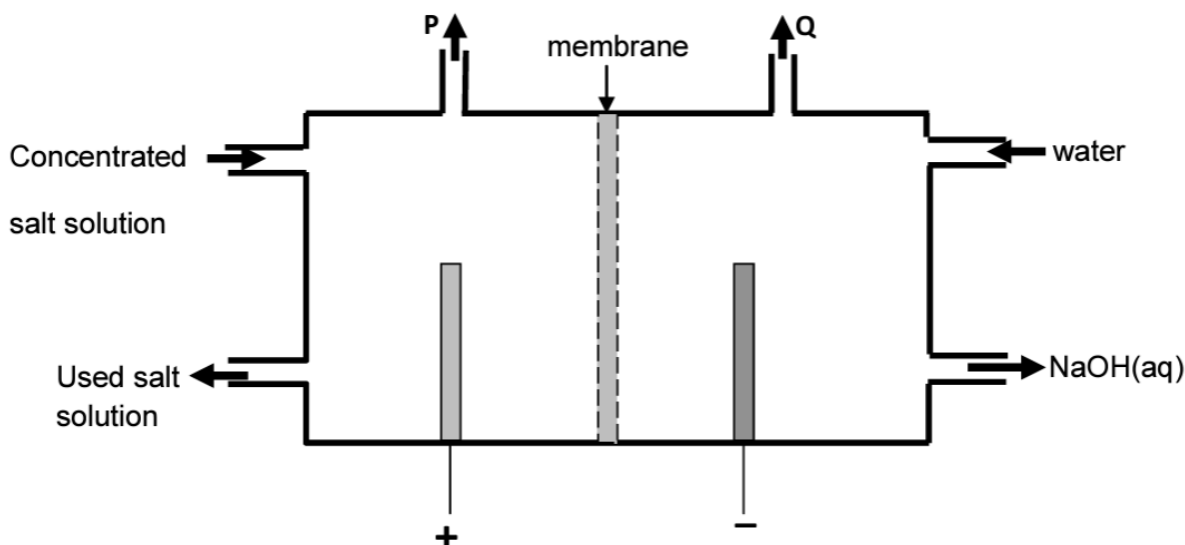
- 7.1.4** During purification, metal impurities such as silver and gold form a sludge at the bottom of the container.

- a.** Refer to the relative strengths of **reducing agents** to explain why these two metals (silver and gold) do not form ions during the purification process. (2)

- b.** Competitive reactions producing ions can take place in the cell due to the presence of certain other metal impurities. Identify one metal that would be involved in a competitive reaction. (1)
-

- 7.1.5** Calculate the current required to deposit 0,28 moles of pure copper on the electrode in 1 hour. (5)

- 7.2** The Chlor-Alkali process involves the electrolysis of a saturated aqueous solution of sodium chloride (NaCl(aq)). The diagram below illustrates a membrane cell that can be used in this process.



- 7.2.1** Give another name for a saturated solution of sodium chloride. (1)

- 7.2.2** Identify the products of the process labelled P and Q. (2)

P: _____

Q: _____

- 7.2.3** State the function and purpose of the membrane in this cell, referring to the movement of the ions in the cell. (2)

- 7.2.4** Explain why it is important for the salt solution, NaCl(aq) , to be concentrated when it enters the cell at the anode. (3)

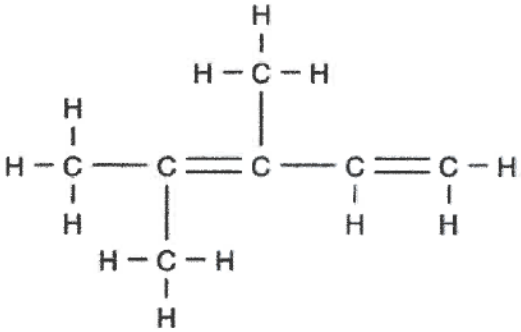
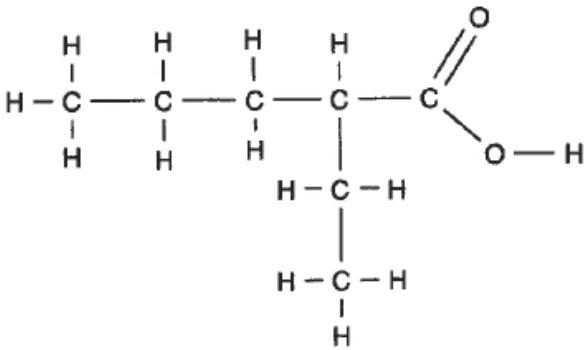
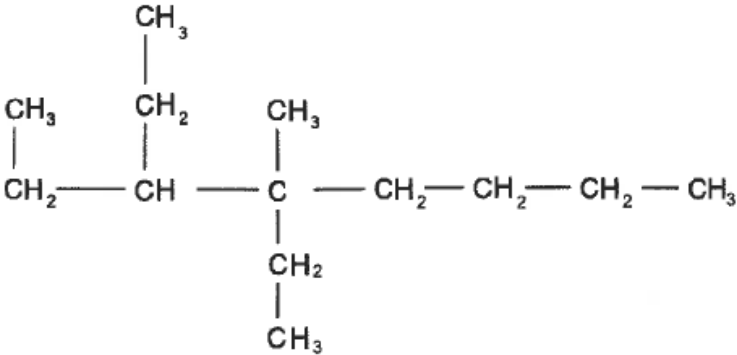
ADDITIONAL SPACE (ALL QUESTIONS)

**REMEMBER TO CLEARLY INDICATE AT THE QUESTION THAT YOU USED THE
ADDITIONAL SPACE TO ENSURE THAT ALL ANSWERS ARE MARKED.**

[illegible]

QUESTION 8 [28 marks]

Study the table below which shows organic compounds A to C and answer the questions that follow:

A. 	B. 
C. 	

8.1 Give the IUPAC name for:

8.1.1 Compound **A** (3)

8.1.2 Compound **B** (3)

8.2 Consider compound **B**.

8.2.1 Define the term *homologous series*. (2)

8.2.2 Name the homologous series to which compound **B** belongs. (1)

8.2.3 Give the IUPAC name of a **positional** isomer of compound **B**. (2)

8.2.4 Complete: Compound **C** is (SATURATED / UNSATURATED) because

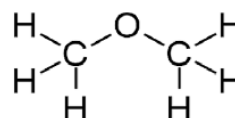
(2)

8.3 Consider compound **A**. Dienes do not have the same general formula as alkenes.

8.3.1 Write the molecular formula of compound **A**. (1)

8.3.2 Hence, deduce the general formula of hydrocarbon dienes. (1)

8.4 Dimethyl ether (shown) is a functional isomer of ethanol.



8.4.1 The dimethyl ether molecule is asymmetrical. Explain why this makes it a polar molecule. (2)

8.4.2 Predict the predominant intermolecular forces found in dimethyl ether. (1)

8.4.3 Hence, state with a reason which of dimethyl ether or ethanol would have the higher boiling point. (3)

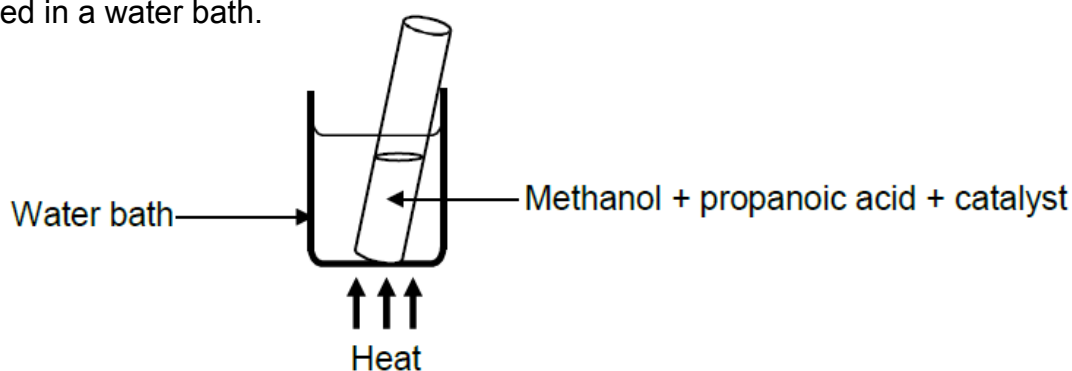
8.5 Consider Compound **C**.

8.5.1 Give the condensed structural formula for the straight chain isomer of compound **C**. (2)

8.5.2 The boiling point of compound **C** is 190°C and the boiling point of the straight chain isomer in **8.5.1** is 234°C. Explain the difference in boiling points. Refer to the relevant intermolecular forces in your answer. (5)

QUESTION 9 [17 marks]

- 9.1** In an experiment, a test tube containing methanol, propanoic acid, and a catalyst is heated in a water bath.



- 9.1.1** Identify the catalyst. (1)

- 9.1.2** State the type of reaction taking place. (1)

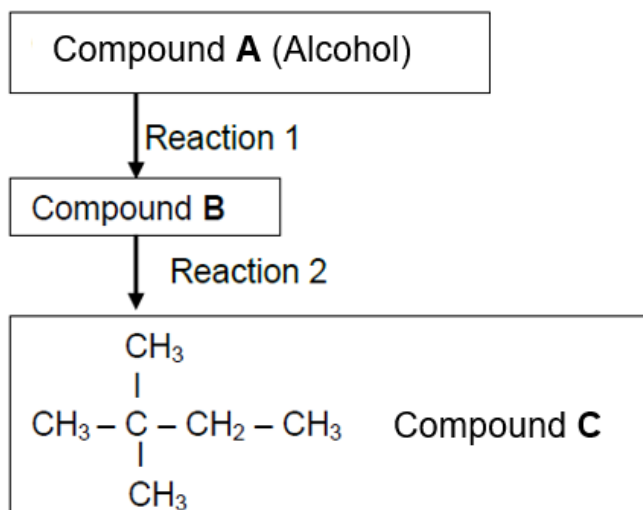
- 9.1.3** State why the use of a water bath is necessary in this experiment. (1)

- 9.1.4** Write down the balanced equation for this reaction using STRUCTURAL FORMULAE. (5)

- 9.1.5** Give the IUPAC name of the organic product of this reaction. (2)

- 9.2** Compound **A**, a **six-carbon branched-chain alcohol**, is used in a two-step reaction to prepare compound **C**.

Reaction 2 is an ADDITION reaction.



Write down:

- 9.2.1** Identify the **inorganic** reactant in **Reaction 2**. (1)

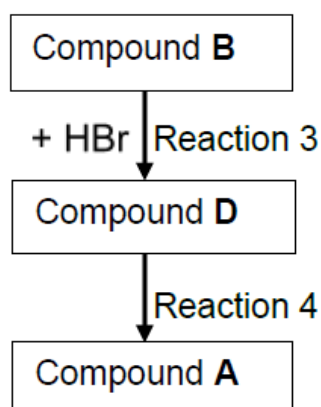
- 9.2.2** The IUPAC name of compound **B**. (2)

- 9.2.3** The general type of reaction represented by **Reaction 1**. (1)

Compound **B** is now used in a two-step reaction to prepare the original compound **A**.

In **Reaction 3**, Compound **B** reacts with **HBr** to produce Compound **D**.

Reaction 4 is a **SUBSTITUTION** reaction.

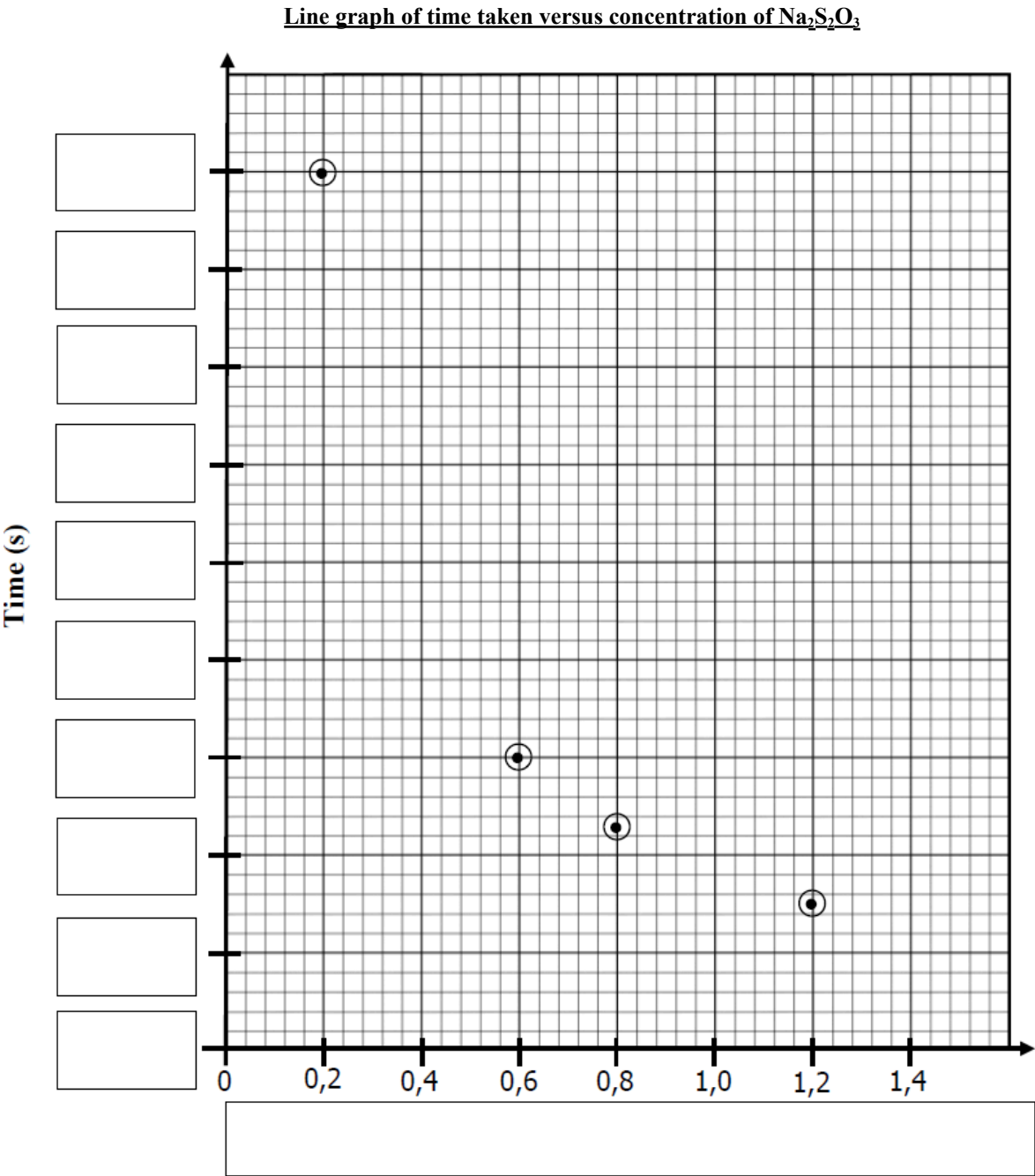


9.2.4 Give the specific type of reaction represented by **Reaction 3**. (1)

9.2.5 In **Reaction 4**, Compound D is **heated under reflux in a dilute aqueous alkali solution**. Explain why this type of heating is necessary. (1)

9.2.6 Give the specific type of reaction represented by **Reaction 4**. (1)

EXTRA GRAPH FOR QUESTION 3.3



MEMO**Question 1 (20 marks)**

- 1.1 C Mn^{2+} and ClO_3^-
- 1.2 A $N = nN_A = (m/M)(N_A) = 22/44 \times N_A$
- 1.3 C check ΔE_N
- 1.4 D $n(\text{NO}_3^-) = cV = (2 \times 0,2 \times 0,1) + (1 \times 0,5 \times 0,2) = 0,14 \text{ mol}$
 $c(\text{NO}_3^-) = n/V_{\text{tot}} = 0,14 / (0,3) = 0,47 \text{ mol} \cdot \text{dm}^{-3}$
- 1.5 D CaCO_3 is LR and Temp is higher. $\therefore$ more product and faster (steeper)
- 1.6 B In order for the AREA under the curve to remain the same, if the peak position shifts to the right, the peak height must get lower.
- 1.7 A Coefficients in balanced equation give the ratio of the CHANGE that occurs
- 1.8 B Catalysts lower E_A to get the same yield faster.
- 1.9 D pH depends on $[\text{H}_3\text{O}^+]$ which depends on acid strength AND concentration
- 1.10 C Alkenes are more reactive than alkanes (weak π bond needs less energy to break, i.e. lower E_A), $\therefore$ addition is faster than substitution (basis of Br_2 test)

Question 2 (15 marks)

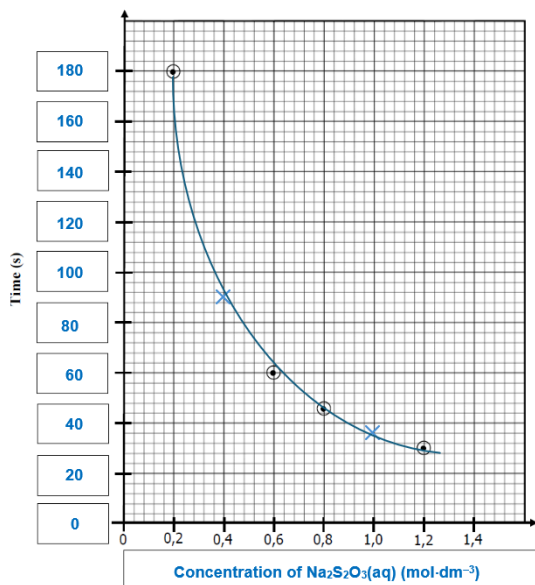
- 2.1 Both giant structures ✓
 High melting points due to large amount of energy needed ✓
 to break the many strong covalent bonds ✓ (3)
- 2.2 non-polar molecule - due to symmetry of molecule/ electron cloud is evenly distributed / no δ^+ or δ^- end ✓
 polar bond - difference in electronegativity ✓ (results in unequal sharing of electrons) (2)
- 2.3 weak London forces ✓
 small amount of energy needed to overcome forces ✓ (resulting in low M.P.) (2)
- 2.4.1 $n(\text{HCl}) = cV = (0,25)(0,15) \text{ ✓ (conversion) } = 0,0375 \text{ mol ✓}$
 $n(\text{HCl}):n(\text{SiCl}_4) = 4:1$
 $n(\text{SiCl}_4) = 0,0375 / 4 \text{ ✓} = 9,375 \times 10^{-3} \text{ mol ✓ (4)}$
- 2.4.2 $n(\text{SiCl}_4):n(\text{Si}) = 1:1$
 $n(\text{Si}) = 9,375 \times 10^{-3} \text{ mol (coe) ✓}$
 $m(\text{Si}) = nM = (9,375 \times 10^{-3})(28) = 0,2625\text{g ✓}$
- $\% \text{ purity} = \frac{0,2625}{0,30} \times 100 \text{ ✓} = 87,5\% \text{ ✓ (4)}$

Question 3 (25 marks)

3.1 sodium thiosulfate ✓ (1)

3.2 milky sulfur **precipitate/ insoluble solid** ✓ forms
less light can reach the meter / making the solution increasingly opaque ✓ (2)

3.3



3.3.1 x - axis label + unit ✓✓ (2)

3.3.2 scale ✓ (1)

3.3.3 Plotting ✓ (2)

3.3.4 Best fit line (extended) ✓ (1)
(through as many points as possible)

3.4 Time is the dependent variable ✓ (1)

3.5 Straight line ✓ through the origin ✓ (2)

3.6 More particles per unit volume ✓
More collisions (per unit time) ✓
More effective collisions per unit time ✓
Rate increases ✓ (4)

3.7 Measure time taken for black cross underneath flask to become invisible / measure change or loss in mass (as gas escapes) vs time / Measure volume of SO_2 gas produced vs time or in a set time / change in pH over certain time (at different concentrations) ✓ **suitable method** ✓ **correct variables to be measured incl TIME** (2)

3.8.1 $n(\text{HCl}) = cV = (0,2)(0,1) = 0,02 \text{ mol}$ ✓ $n(\text{Na}_2\text{S}_2\text{O}_3) = m/M = 3,5 / (2(23) + 2(32) + 3(16)) = 0,022 \text{ mol}$ ✓ $n(\text{HCl}) : n(\text{Na}_2\text{S}_2\text{O}_3) = 2:1$ 0,02 : 0,01 ✓ (**Applying ratio**) ($\text{Na}_2\text{S}_2\text{O}_3$ in excess and HCl limiting reagent) (3)3.8.2 $n(\text{HCl}):n(\text{S}) = 2:1$ $n(\text{S}) = 0,02/2 = 0,01 \text{ mol}$ ✓ $m(\text{S}) = nM = (0,01)(32) = 0,32 \text{ g}$ ✓ $\% \text{yield} = \frac{0,18}{0,32} \times 100 = 56,25\%$ ✓ (4)OR $n(\text{Na}_2\text{S}_2\text{O}_3):n(\text{S}) = 1:1$ $n(\text{S}) = 0,01 \text{ mol}$

Question 4 (24 marks)

4.1 greater than ✓ (1)

4.2 t_2 ✓ (1)

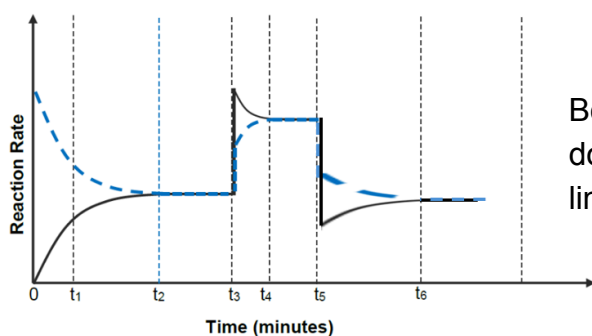
4.3 constant ✓ (1)

4.4 When an external stress (change in pressure, temperature or concentration) is applied to a system in dynamic chemical equilibrium ✓, the equilibrium point will change in such a way as to counteract the stress ✓ (2)

4.5 increase in temperature - both rates increase
 according to LCP reaction that absorbs increase in energy / reduces temp will be favoured ✓
 endothermic reaction favoured ✓
 reverse reaction increases more / is favoured ✓ therefore reverse reaction is endothermic
 forward reaction is exothermic ✓ (4)

4.6.1 decrease in pressure favours reaction producing more gas molecules ✓
 in order to increase the pressure ✓
 forward reaction is favoured ✓
 fewer reactants and more products in equilibrium mixture ✓ (4)

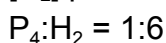
4.6.2



Both rates decrease ✓
 dotted line drops less ✓
 lines horizontal at t_6 ✓ (3)

4.7.1 $K_c = \frac{[H_2]^6 [P_4]}{[PH_3]^4}$ ✓ top ✓ bottom (-1 if no square brackets) (2)

4.7.2 $[H_2]$ produced = $0,32 \text{ mol} \cdot \text{dm}^{-3}$



OR use ICE table

$[P_4]$ produced = $0,32/6$ ✓ = $0,053 \text{ mol} \cdot \text{dm}^{-3}$

$0,206$ ✓ = $\frac{(0,32)^6 (0,053)}{[PH_3]^4}$ ✓

$[PH_3] = 0,129 \text{ mol} \cdot \text{dm}^{-3}$ (given) (3)

4.7.3 $[PH_3]$ at equilibrium = $0,129 \text{ mol} \cdot \text{dm}^{-3}$

$[PH_3]$ used = $0,32 \times \frac{2}{3} = 0,213 \text{ mol} \cdot \text{dm}^{-3}$ ✓

$[PH_3]$ initial = $0,129 + 0,213$ ✓ = $0,342 \text{ mol} \cdot \text{dm}^{-3}$ ✓ (3)

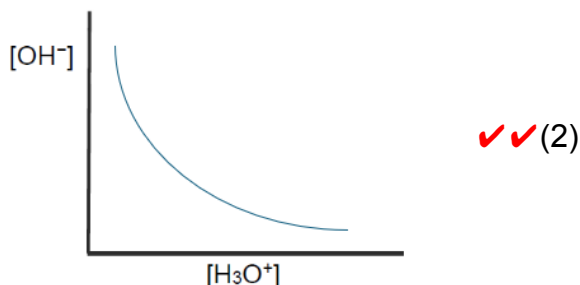
Question 5 (30 marks)

5.1.1 an acid that ionises almost completely in an aqueous solution ✓✓ (2)

5.1.2 $\text{CH}_3\text{CH}_2\text{COOH}$ ✓ - weak acid ✓ therefore only ionises partially in aqueous solution / low number of H_3O^+ ions present / high number of HA molecules ✓ (3)

5.1.3 $\text{CH}_3\text{CH}_2\text{COOH} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{CH}_2\text{COO}^- + \text{H}_3\text{O}^+$ ✓✓ (2) (single arrow -1, once in Q5)

5.1.4



5.1.5 $[\text{HCl}] : [\text{H}_3\text{O}^+] = 1:1$

$$[\text{H}_3\text{O}^+] = 0,17 \text{ mol} \cdot \text{dm}^{-3} \quad \checkmark$$

$$[\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14} \quad \checkmark$$

$$[\text{OH}^-] = 1 \times 10^{-14} / 0,17 = 5,88 \times 10^{-14} \text{ mol} \cdot \text{dm}^{-3} \quad \checkmark \quad (3)$$

5.2.1 $\text{H}_2\text{S}(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{HS}^-(\text{aq})$ ✓ A and B's correct ✓ conj ID'd (2)



5.2.2 a substance that can act as either an acid or a base ✓✓ (2)

5.2.3 H_2O ✓ and HS^- ✓ (FORMULAE) (2)

5.2.4 small K_a - few ions in solution / ionises partially ✓ - low electrical conductivity ✓ (2)

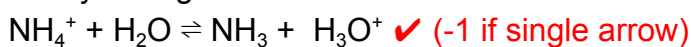
$$5.3.1 \quad \frac{c_a V_a}{c_b V_b} = \frac{n_a}{n_b} \quad \checkmark$$

$$\frac{(20,1)(0,15)}{(25,0)c_b} = \frac{1}{2} \quad \checkmark \checkmark$$

$$c_b = 0,2413 \text{ mol} \cdot \text{dm}^{-3} \quad \checkmark (4)$$

5.3.2 a reaction of an ion (from a salt) with water ✓✓ (2)

5.3.3 methyl orange ✓



$[\text{H}_3\text{O}^+]$ increases ✓

end point is acidic / pH decreases ✓ (4)

Question 6 (20 marks)

- 6.1 A Cl_2 ✓
 B Pt ✓
 C Cr ✓ FORMULAE (3)
- 6.2 Complete the circuit ✓
 Maintain electrical neutrality in the two half cells ✓ (2)
- 6.3 KNO_3 ✓ (1)
- 6.4 increases ✓ (1)
- 6.5 $\text{Cr} \rightarrow \text{Cr}^{3+} + 3\text{e}^-$ ✓✓ (2)
- 6.6 Cr OR chromium ✓ (1)
- 6.7 % $\text{Cr}/\text{Cr}^{3+}/\text{Cl}_2/\text{Cl}^-/\text{Pt}$ ✓✓✓ -1 per error (3)
- 6.8 $E^\ominus_{\text{cell}} = E^\ominus_{\text{cathode}} - E^\ominus_{\text{anode}}$ ✓
 $= 1,36 - (-0,74)$ ✓
 $= 2,1 \text{ V}$ ✓ (3)
- 6.9 $[\text{Cl}^-]$ decreases ✓
 Forward reaction is favoured ✓
 to make more Cl^- ✓
 Emf increases ✓ (4)

Question 7 (21 marks)

- 7.1.1 an electrochemical cell that uses electrical energy ✓
 to cause a non-spontaneous redox reaction to occur. ✓
 OR a cell in which electrical energy ✓ is converted into chemical energy ✓ (2)
- 7.1.2 impure copper ✓ (1)
- 7.1.3 $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$ ✓✓ (-1 if single arrow) (2)
- 7.1.4 a. silver and gold are weaker reducing agents than Cu ✓
 so cannot be oxidised ✓ (2)
 b. any metal above Cu on table ✓ (1)
- 7.1.5 $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$
 $n(\text{Cu}):n(\text{e}^-) = 1:2$ ✓ both equations
 $n(\text{e}^-) = 2(0,28) = 0,56 \text{ mol}$ ✓
 $q = nF$ (NB in this equation n = number of moles of **electrons**)
 $q = (0,56)(96500)$ ✓ = 54040 C
 $I = q/t = 54040 / 3600$ ✓ (conversion) = 15,01 A ✓ (5)
- 7.2.1 brine ✓ (1)
- 7.2.2 P: chlorine / Cl_2 ✓
 Q: hydrogen / H_2 ✓ (2)
- 7.2.3 allows cations to pass through only ✓ accepted sodium ions
 to prevent contamination of product ✓ / prevent competitive reactions (2)
- 7.2.4 under standard conditions ✓
 water is a stronger reducing agent than chloride ✓
 and will be oxidised instead ✓ / oxygen will be produced instead of chlorine (3)

Question 8 (28 marks)

8.1.1 3,4-dimethyl ✓ penta ✓ -1,3-diene ✓ (one word) (3) (-1 only for wrong numbering)

8.1.2 2-ethyl ✓ pent ✓ anoic acid (one word) (3)

8.2.1 series of similar compounds which
have the same functional group and have the same general formula ✓,
in which each member differs from the previous one by a single CH₂ unit ✓ (2)
(Note: this def may be 3 marks.)

8.2.2 carboxylic acid ✓ (1)

8.2.3 3-ethyl ✓ pentanoic acid ✓ (2) *coe from 8.1.2*

8.2.4 saturated ✓ because only C-C single bonds ✓ (2)

8.3.1 C₇H₁₂ ✓ (1)8.3.2 C_nH_{2n-2} ✓ (1)8.4.1 electron cloud unevenly distributed ✓
resulting in a δ⁺ and δ⁻ end ✓ / a dipole (2)

8.4.2 dipole-dipole ✓ (1)

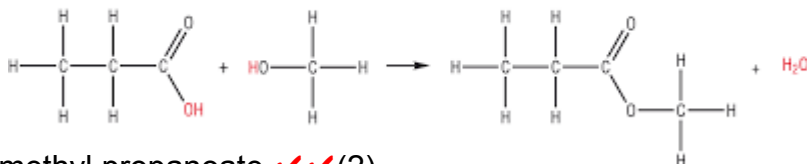
8.4.3 ethanol ✓

hydrogen bonding stronger than dipole-dipole ✓
more energy needed to overcome the forces ✓ (3)8.5.1 CH₃(CH₂)₁₁CH₃ ✓ ✓ (2)8.5.2 Both have only London IMF's ✓
Straight chain isomer has a greater contact surface area ✓
resulting in larger/greater/more temporary dipoles ✓ *accepted more IMF's*
therefore stronger London forces ✓
more energy needed to overcome them ✓ (5)**Question 9 (17 marks)**9.1.1 sulfuric acid / H₂SO₄ ✓ (1)

9.1.2 esterification ✓ (1)

9.1.3 reagents are flammable ✓ (1)

9.1.4

✓ ✓ ✓ 3 other structures
✓ ester functional group
✓ correct ester (5)

9.1.5 methyl propanoate ✓ ✓ (2)

9.2.1 hydrogen / H₂ ✓ (1)

9.2.2 3,3-dimethylbut-1-ene ✓ ✓ (2)

9.2.3 elimination ✓ (1)

9.2.4 hydrohalogenation ✓ (1)

9.2.5 To prevent loss of reactants/product (by condensation) ✓ (1)

9.2.5 Hydrolysis ✓ (1)