4-6 Chemistry /5-6 Trilogy – Rate and extent of chemical change

1.0 A student heated hydrated cobalt chloride.
The word equation shows the reaction.

hydrated cobalt chloride (pink)	$\rightleftharpoons$	anhydrous cobalt chloride (blue)	+	water

1.1 The student recorded some observations from this experiment.
Suggest **two** observations the student may have written down.

[2 marks]

_____

_____

1.2 The student added anhydrous cobalt chloride to water and measured the temperature rise.
The student's results are shown in the table below.

	Trial 1	**Trial 2**	**Trial 3**
Temperature rise in °C	9.5	9.2	9.2

Calculate the mean temperature rise.

[1 mark]

_____

Temperature = _____°C

1.3 During the reaction in **1.2**, the temperature increased.
Name the type of reaction that causes the temperature to rise.

[1 mark]

_____

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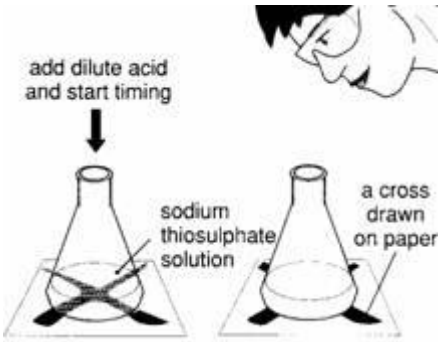
2.0 A student investigated the effect of temperature on the rate of reaction.
Figure 1 below shows the apparatus the student used.



2.1 Name a piece of apparatus which could be used to measure the volume of the acid.

[1 mark]

_____

2.2 The reaction forms a precipitate.
When should the student stop timing the reaction?

[1 mark]

_____

2.3 State the dependent and independent variables in the investigation.

[2 marks]

Dependent _____

Independent _____

2.4 The student only carried out each test once.
Explain why repeating the experiment would improve the results.

[1 mark]

_____

2.5 Describe how a preliminary investigation could be used to find an appropriate temperature range.

[2 marks]

_____

_____

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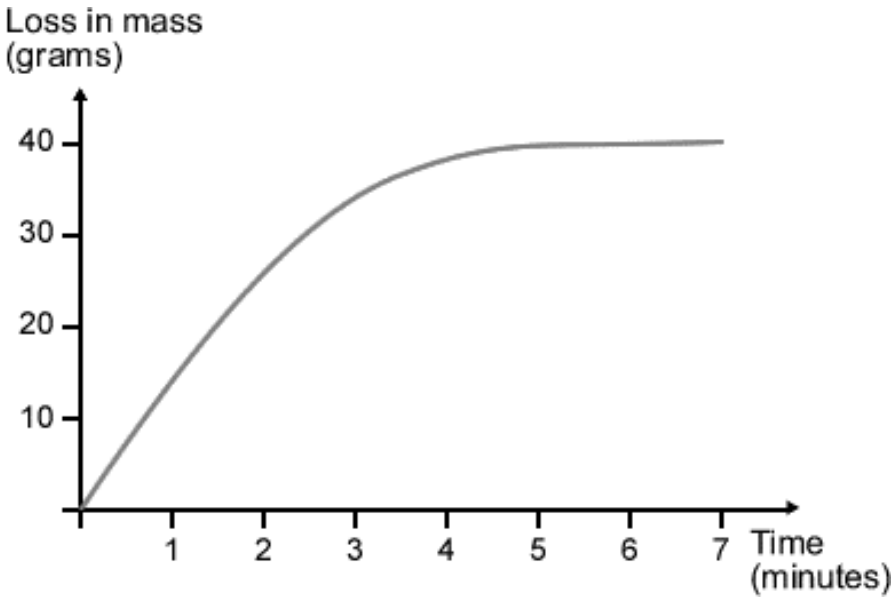
2.6 Another student used a different experiment to investigate the rate of reaction.
This student measured the loss of mass every minute.
The student's results are shown in **Graph 1** below:



Add labels to the graph to show:

- when the reaction is complete
- when the rate of reaction is fastest
- when half the reactants have been used up.

[3 marks]

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3.0 A student investigated how the concentration of hydrochloric acid affected the rate of reaction between hydrochloric acid (HCl) and magnesium ribbon to produce magnesium chloride ($MgCl_2$) and hydrogen (H_2).

3.1 Complete and balance the equation for the reaction:

[2 marks]

_____(s) + _____(aq) → _____(aq) + _____(g)

Figure 2 below shows the apparatus the student used.

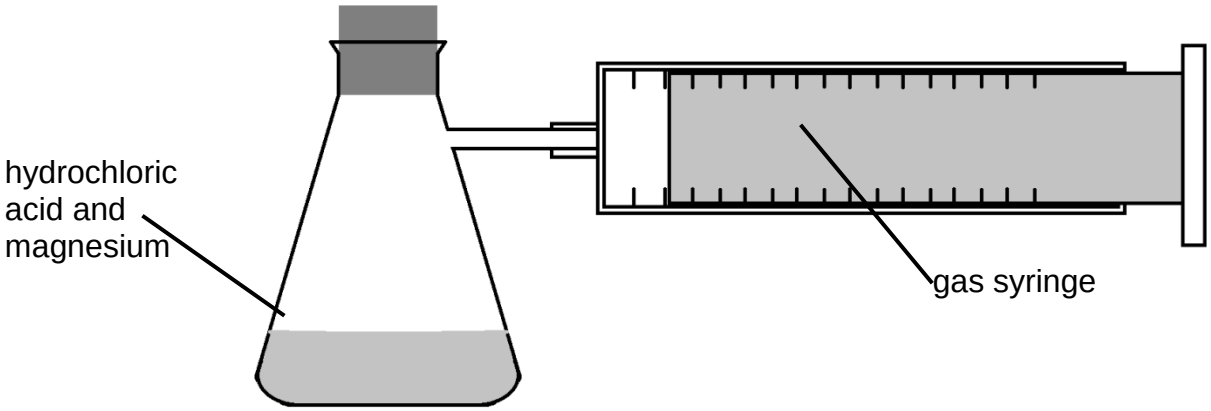

Table 1 shows the results of the experiment.

Table 1

Concentration of hydrochloric acid in mol/dm^3	Time taken for 30 cm^3 of hydrogen to be produced in s				Mean rate of reaction in cm^3/s
	Trial 1	Trial 2	Trial 3	Mean	
0.4	158	150	154	154	0.19
0.8	77	77	74	76	0.39
1.2	68	51	49		
1.6	37	39	38	38	0.79
2.0	30	29	31	30	1.00

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3.2 Calculate the rate of reaction when 1.2 mol/dm^3 hydrochloric acid is added to magnesium.

Use the equation below.

$$\text{mean rate of reaction} = \frac{\text{volume of gas in cm}^3}{\text{mean time taken in s}}$$

[3 marks]

Mean rate of reaction = _____ cm^3/s

3.3 Give **two** variables which the student should control during this investigation.

[2 marks]

_____

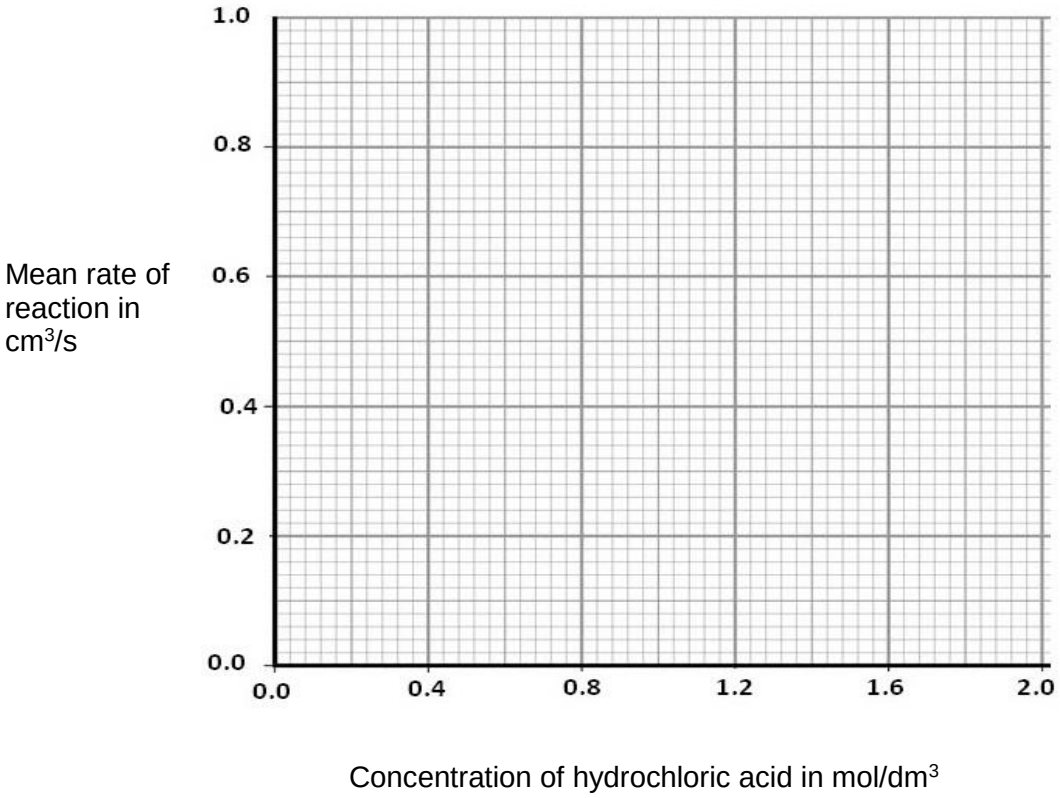
_____

3.4 On **Figure 3,** use the results from **Table 1** to

- plot a graph of rate of reaction and concentration of acid
- draw a best fit line.

[3 marks

Figure 3



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3.5 Using the idea of particle collisions, explain why the reaction rate is faster when the concentration of the acid is greater.

[2 marks]

_____

_____

3.6 The student used magnesium ribbon.
State a change that could be made to the magnesium to speed up the reaction.

[1 mark]

_____

3.7 Explain in terms of the particles why the change you gave in **3.6** would increase the speed of reaction.

[1 mark]

_____

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4.0 This question is about reversible reactions and chemical equilibrium.

4.1 Reversible reactions can reach equilibrium in a closed system.
What is meant by a **closed system**?

[1 mark]

_____

4.2 Explain why a reaction seems to have finished when a reversible reaction reaches equilibrium.

[2 marks]

_____

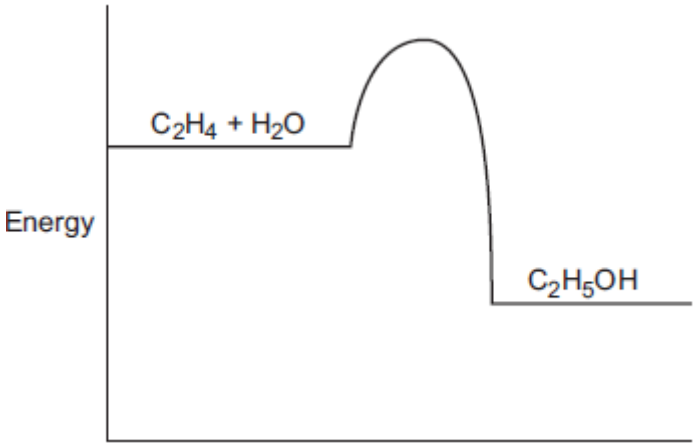
_____

Ethanol can be produced in a reversible reaction from ethene and steam.
The equation for the reaction is:

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g)$$

Figure 4 shows the reaction profile for the reaction.

Figure 4



4.3 How does the diagram show that the reaction is exothermic?

[1 mark]

_____

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4.4 A catalyst can be used for the reaction.
Indicate on **Figure 4**:

- the reaction profile for a catalysed reaction
- the activation energy for a catalysed reaction.

[2 marks]

4.5 State what is meant by **activation energy**.

[1 mark]

_____

_____

4.6 Give one similarity and one difference in the energy transfer for the back reaction to form ethene and water from ethanol.

[2 marks]

Similarity: _____

Difference: _____

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4.7 A company manufactures ethanol (C_2H_3OH).

The reaction for the process is:

$$C_2H_4\,(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \qquad \Delta H = -45 \text{ kJ per mole}$$

The temperature and pressure can be changed to increase the yield of ethanol at equilibrium.
The forward reaction is exothermic.
The conditions used in the process are:

- 60 atmospheres pressure
- 200 °C
- phosphoric acid catalyst.

Explain why these conditions are used in this process.
Use the equation and your knowledge of reversible reactions.
Consider **both** yield **and** rate of reaction in your answer.

[6 marks]

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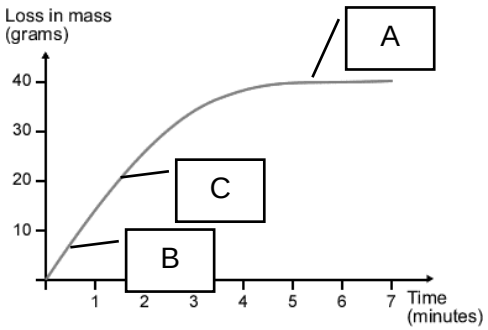
MARK SCHEME

Qu No.		Extra Information	Marks
1.1	(Solid) changes from pink to blue Droplets of water / steam		1 1
1.2	9.3 °C		1
1.3	Exothermic		1

Qu No.		Extra Information	Marks
2.1	Measuring cylinder	Allow burette/pipette	1
2.2	When the cross cannot be seen through the solution	Ignore when the solution is cloudy	1
2.3	(Dependent) Time taken for the cross to disappear (Independent) Temperature		 1 1
2.4	To check the results, So you know the readings are accurate, To eliminate/ignore anomalous results.	Allow to improve reliability.	1
2.5	Two temperatures are suggested that constitute a range Understanding demonstrated that an appropriate range will allow a pattern or trend to be seen in the results		1 1
2.6	**Graph 1**  A: Reaction is complete B: Reaction is fastest C: Half the reactants have been used up.	A: Must be after graph levels off B: Any point on straight line up before it changes gradient C: When loss of mass is 20g	1 1 1

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Qu No.		Extra Information	Marks
3.1	Formulae in correct place Correct balancing	 Allow 2 marks for $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$	1 1
3.2	(49+51)/2 (mean =) 50 (30/50 =) 0.60	 Allow 2 marks for 50 without working Allow 2 marks for 0.54 where anomaly has been included in mean	1 1 1
3.3	Any **two** from: • volume of acid • temperature (of acid) • length of magnesium (ribbon)	Do not allow concentration of acid Allow mass of magnesium ribbon	2
3.4	All points plotted correctly Best fit straight line	± ½ small square Allow 1 mark for 4 plotted correctly Allow ecf for anomalous point at (1.2,0.54) Should not be influenced by anomaly	2 1
3.5	Particles must collide in order to react Collision frequency increases as concentration increases		1 1
3.6	Cut it up **or** increase the surface area	Allow grind it up **or** make a powder Do **not** accept make it smaller **or** use a smaller piece	1
3.7	Reference to particle theory eg more collisions between acid ions/particles and atoms/particles of magnesium		1

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Qu No.		Extra Information	Marks
4.1	Nothing can enter and nothing can leave the reaction	Allow sealed reaction vessel	1
4.2	At equilibrium the forward and backward reactions have same rate So there is no (overall) change in quantities of reactants and products		1 1
4.3	The products are at a lower energy level than the reactants	Accept products have less energy or less energy at the end than the beginning	1
4.4	Pathway drawn from reactants to products, below original pathway Indication of activation energy from reactant level to highest point on catalysed reaction pathway		1 1
4.5	Minimum amount of energy needed by particles to react		1
4.6	*Similarity* Same amount of energy transferred *Difference* Endothermic reaction	 Allow 45 kJ of energy transferred (given in 4.7 below) Allow energy taken in by reaction	 1 1

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4.7			
Level 3:	A detailed and coherent explanation is given, which demonstrates a broad understanding of the key scientific ideas. The response makes logical links between the points raised and uses sufficient examples to support these links.		5-6
Level 2:	An explanation is given which demonstrates a reasonable understanding of the key scientific ideas. Links are made but may not be fully articulated and / or precise.		3-4
Level 1:	Simple statements are made which demonstrate a basic understanding of some of the relevant ideas. The response may fail to make logical links between the points raised.		1-2
	No relevant content		0
Indicative content			
60 atmospheres pressure • high pressure gives a high yield of ethanol • too high a pressure causes risk of explosion • high pressure costly to maintain • a high pressure will cause the rate to be higher • 2 moles of gas become 1 (or fewer moles of gas in products) **200 °C** • high temperature increases the rate of reaction • optimum temperature • (forward reaction is exothermic so) a high yield of ethanol requires a low temperature • but too low a temperature causes the rate of reaction to be too slow **Phosphoric acid catalyst** • a catalyst speeds up the reaction a phosphoric acid catalyst allows a lower temperature to be used (saving energy and causing a higher yield) • phosphoric acid catalyst increases the rate of reaction equally in both reactions **Others** • compromise conditions • unreacted ethene and steam is recycled			

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