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) ⇌ 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]

_____

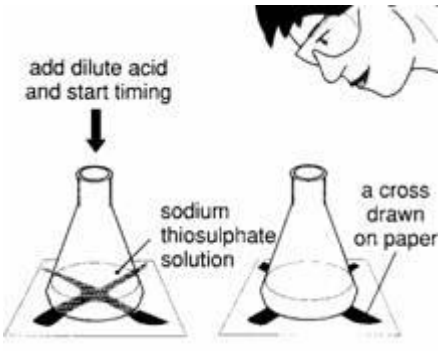
Temperature = _____ °C

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

[1 mark]

_____

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]

_____

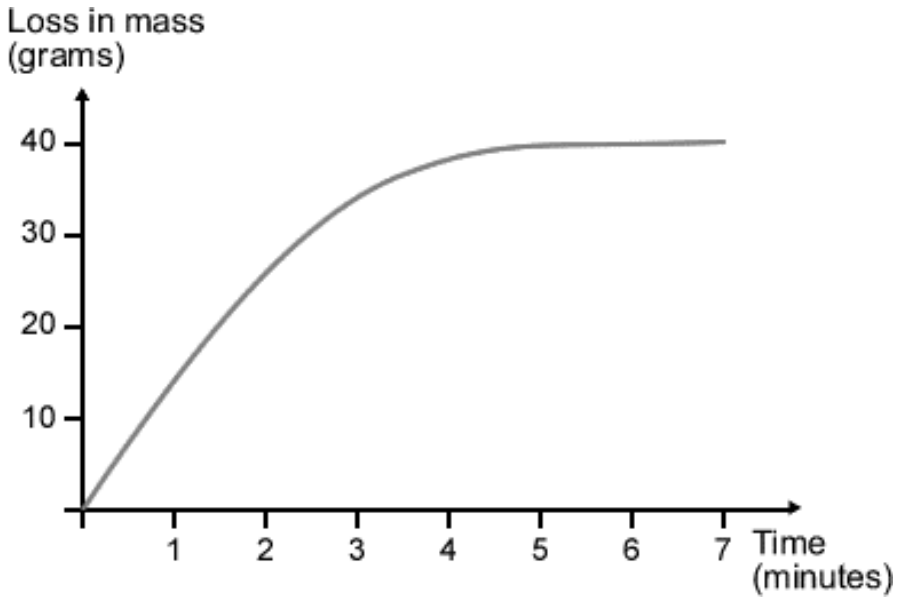
2.5 Describe how a preliminary investigation could be used to find an appropriate temperature range.

[2 marks]

_____

_____

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]

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.

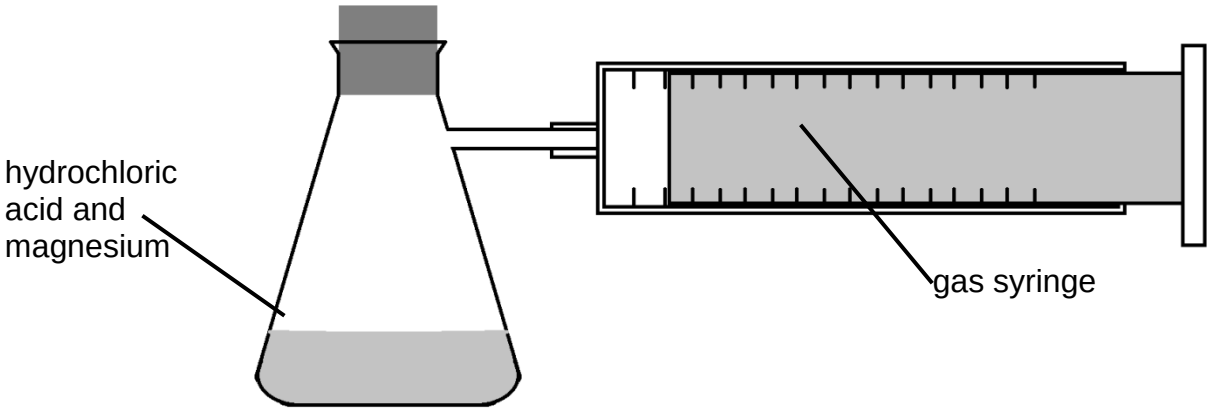


Table 1 shows the results of the experiment.

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

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]

_____

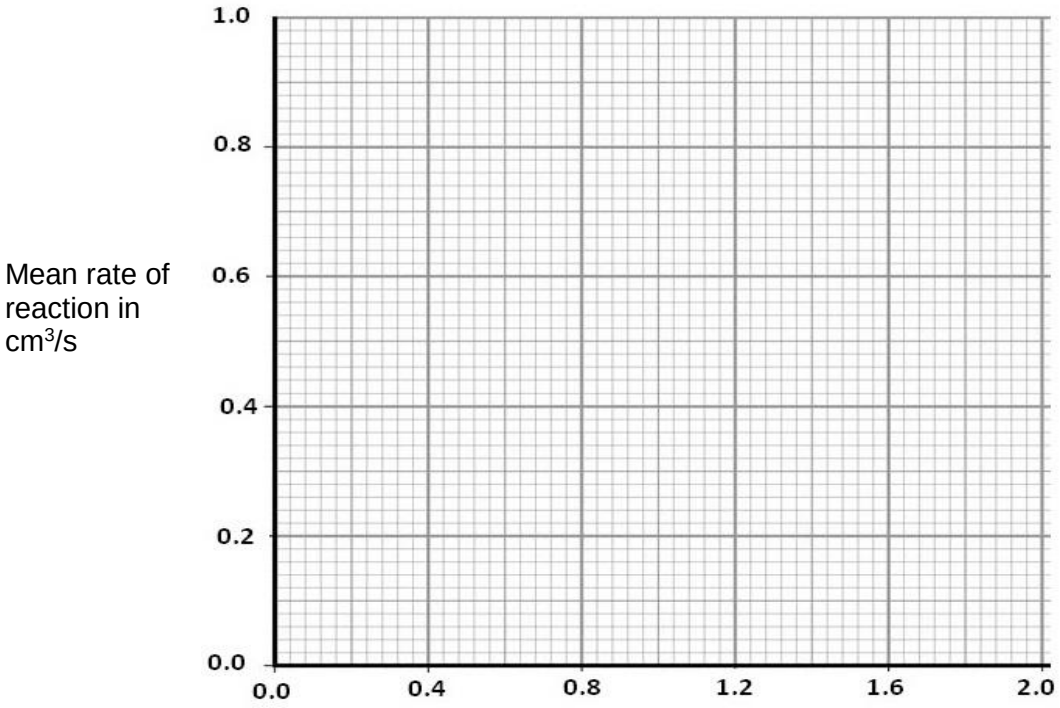
_____

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



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]

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]

_____

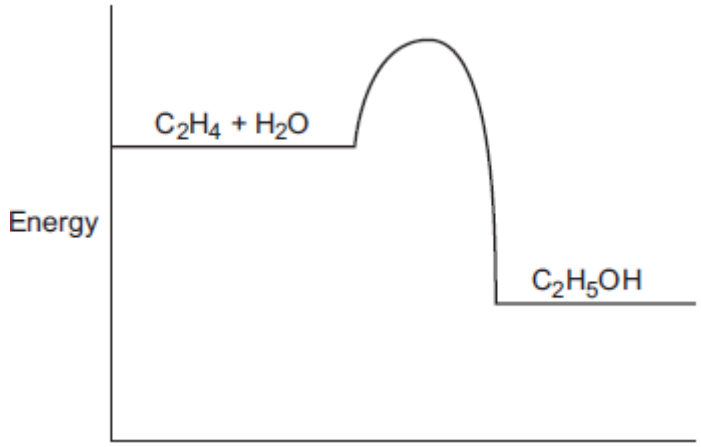
_____

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]

_____

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: _____

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:

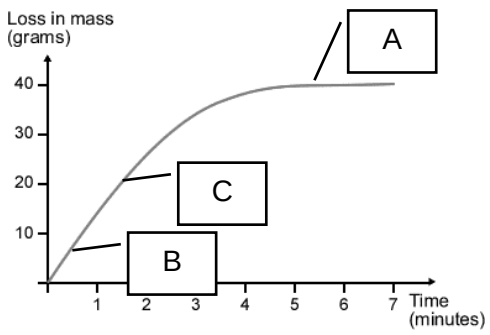
- 60 atmospheres pressure
- 200 °C
- phosphoric acid catalyst.

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]

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

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

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

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			