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EDEXCEL INTERNATIONAL GCSE CHEMISTRY: QUESTIONS BY TOPIC

Physical Chemistry (3)

International GCSE Chemistry Topic 3

66 questions · 778 marks · Mark schemes included

Pearson Edexcel International GCSE (9–1) Chemistry 4CH1, Papers 1C, 1CR, 2C & 2CR, June 2019 - June 2025

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HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic and run from the lowest mark tariff to the highest within each one.
Click any row below to jump straight to that sub-topic or question.
On every question page, click ANSWER in the top-right corner to jump to its mark scheme.
Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

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QUESTIONS

66 questions · 778 marks · 3 sub-topics

SUB-TOPIC 3a

ENERGETICS

Sub-topic 3a · 33 questions · 385 marks · lowest tariff first

5 Oxygen can be prepared from hydrogen peroxide using a catalyst.

(a) Which is a correct statement about oxygen?

(1)

☒ **A** it burns with a squeaky pop

☒ **B** it relights a glowing splint

☒ **C** it turns blue litmus red

☒ **D** it turns limewater milky

(b) Explain how a catalyst increases the rate of a reaction.

(2)

.....

.....

.....

.....

(c) The equation for the preparation of oxygen from hydrogen peroxide is

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

This equation can also be written using displayed formulae to show all the covalent bonds in the molecules.

$$2H{-}O{-}O{-}H \rightarrow 2H{-}O{-}H + O{=}O$$

The table gives the bond energies for these bonds.

Bond	H—O	O—O	O═O
Bond energy in kJ/mol	463	143	498

(i) Use the values in the table to calculate the enthalpy change, ΔH, for the reaction.

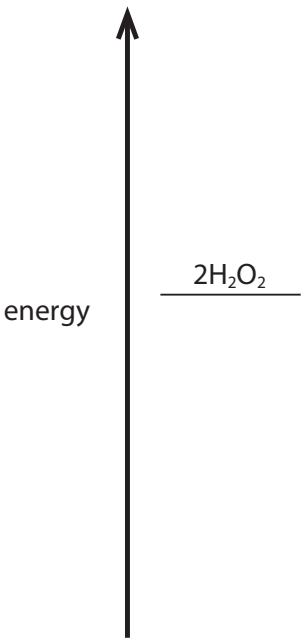
Include a sign in your answer.

(3)

ΔH = ... kJ

(ii) Complete the energy level diagram to show the position of the products and the enthalpy change, ΔH, for the reaction.

(2)



(Total for Question 5 = 8 marks)

8 This question is about reactions involving nitrogen.

(a) In a car engine, nitrogen reacts with oxygen to form nitrogen monoxide.

The equation for the reaction is

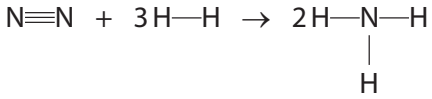
$$N_2 + O_2 \rightarrow 2NO \qquad \Delta H = +181\,kJ$$

Draw a labelled reaction profile diagram showing ΔH and the activation energy for the reaction.

(4)



(b) In the Haber process, nitrogen reacts with hydrogen to form ammonia.
This equation represents the reaction.



The table gives values of some bond energies.

Bond	Bond energy in kJ/mol
N≡N	944
H—H	436
N—H	391

(i) Calculate the total amount of energy, in kJ, needed to break the bonds in the reactants.

(1)

energy needed = ... kJ

(ii) Calculate the total amount of energy, in kJ, released in forming the bonds in the product.

(1)

energy released = ... kJ

(iii) Calculate the enthalpy change, ΔH, for the reaction.

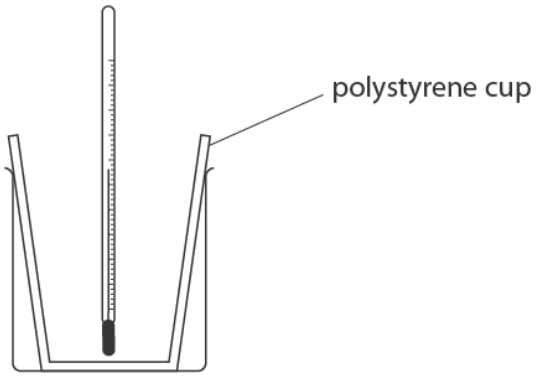
You should include a sign in your answer.

(2)

ΔH = ... kJ

(Total for Question 8 = 8 marks)

12 A student uses this apparatus to investigate the temperature change that occurs when ammonium nitrate is dissolved in water.



She uses this method.

- put 100 cm^3 of water into the polystyrene cup and measure the initial temperature of the water
- add 8.00 g of ammonium nitrate and stir
- record the lowest temperature reached by the solution

The table shows her results.

Initial temperature of water in °C	20.0
Lowest temperature of solution in °C	14.2

(a) Use the results of the experiment to explain what type of reaction is taking place when ammonium nitrate is added to water.

(2)

.....

.....

.....

.....

(b) Show that the heat energy change, Q, is about 2400 J.

[mass of 1.00 cm^3 of solution = 1.00 g]

[for the solution, c = 4.18 J/g/°C]

(3)

Q = ... J

(c) Use your answer to part (b) to calculate the enthalpy change, ΔH, in kilojoules per mole of ammonium nitrate.

[M_r of ammonium nitrate = 80.0]

Include a sign in your answer.

(4)

ΔH = ... kJ/mol

(Total for Question 12 = 9 marks)

8 A student investigates the neutralisation reaction between sodium hydroxide and nitric acid.

This is her method.

- pour 20 cm^3 of sodium hydroxide solution into a polystyrene cup
- record the temperature of the sodium hydroxide solution
- add 5 cm^3 of dilute nitric acid to the cup
- stir the mixture and record the highest temperature reached
- add further 5 cm^3 portions of dilute nitric acid, recording the highest temperature reached each time, until a total of 40 cm^3 of acid has been added

(a) (i) Give a word equation for this neutralisation reaction.

(1)

.....

(ii) Explain why a polystyrene cup is used rather than a beaker.

(2)

.....

.....

.....

.....

(iii) Give a safety precaution that the student should take when using sodium hydroxide solution.

(1)

.....

.....

(b) The table shows the student's results.

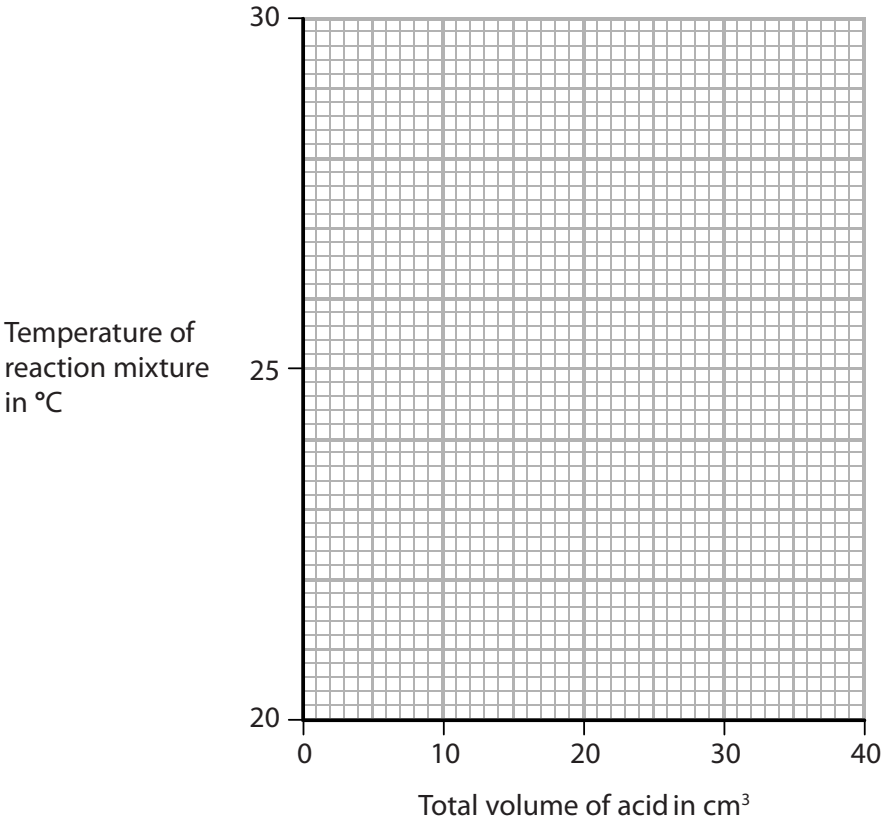
Total volume of acid in cm^3	0	5	10	15	20	25	30	35	40
Temperature of reaction mixture in °C	20.5	22.5	24.4	26.4	28.5	28.3	27.5	26.7	26.0

(i) Plot the results on the grid.

Draw a straight line of best fit through the first five points and another straight line of best fit through the last four points.

Make sure that the two lines cross.

(3)



(ii) The point where the lines cross shows

- the volume of acid needed to exactly neutralise the alkali
- the maximum temperature reached

Use your graph to determine these values.

(2)

volume of acid = ... cm^3

maximum temperature = ... °C

(Total for Question 8 = 9 marks)

7 A student investigates the reaction between magnesium and hydrochloric acid.

He uses this method.

Step 1 add 25 cm^3 of dilute hydrochloric acid to a polystyrene cup

Step 2 record the temperature of the acid

Step 3 find the mass of a 10 cm strip of magnesium ribbon

Step 4 add the magnesium ribbon to the hydrochloric acid

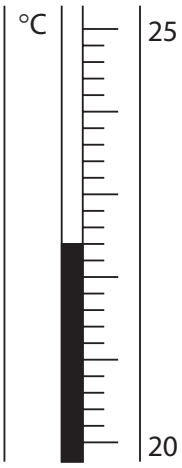
Step 5 when all the magnesium has reacted, record the highest temperature reached

(a) Complete the word equation for the reaction.

(1)

magnesium + hydrochloric acid → ..... + ...

(b) The thermometer shows the temperature of the acid at the start of the experiment.



(i) Complete the table by giving the temperatures to the nearest 0.1 °C.

(2)

temperature of the acid at the start in °C	
highest temperature reached in °C	
temperature rise in °C	20.8

(ii) Show that the heat energy change (Q) for this reaction is about 2200 J.

[mass of 1.0 cm^3 of solution = 1.0 g]

[for the solution, c = 4.2 J/g/°C]

(2)

(iii) The mass of magnesium used by the student was 0.12 g.

Calculate the value of the enthalpy change (ΔH), in kilojoules per mole of magnesium, for the reaction between magnesium and hydrochloric acid.

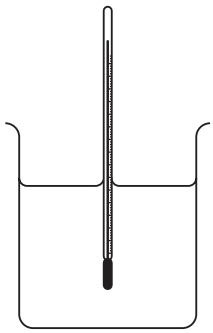
Include a sign in your answer.

(4)

ΔH = ... kJ/mol

(Total for Question 7 = 9 marks)

10 A student uses this apparatus to record the maximum temperature in the reaction between solutions of hydrochloric acid and sodium hydroxide.



This is the student's method.

- add 25 cm^3 of hydrochloric acid to the beaker
- add 25 cm^3 of sodium hydroxide solution to the beaker
- stir the mixture
- record the maximum temperature reached

(a) Name a suitable piece of apparatus to add 25 cm^3 of solution to the beaker.

(1)

.....

(b) Before the reaction, both solutions have a temperature of 21.0 °C.

The heat energy change, *Q*, for the reaction is 2880 J.

(i) Calculate the theoretical maximum temperature reached by the mixture, which has a mass of 50 g.

[specific heat capacity of mixture, c = 4.2 J / g / °C]

(4)

temperature = ... °C

(ii) Give a reason why the maximum temperature recorded by the student is lower than the theoretical maximum temperature calculated.

(1)

.....

.....

(iii) In the reaction, 0.0500 mol of hydrochloric acid completely react.

Calculate the molar enthalpy change, ΔH, in kilojoules per mole of hydrochloric acid.

Include a sign in your answer.

(3)

ΔH = ... kJ / mol

(Total for Question 10 = 9 marks)

3 When 10.0 kg of a solid fuel is burned, the heat energy produced is 3.28×10^5 kJ.

(a) Calculate the heat energy, in kJ/mol, produced by the fuel.

You should assume that the fuel is pure carbon.

Give your answer to three significant figures.

[for carbon, $A_r = 12$]

(3)

heat energy = ... kJ/mol

(b) The fuel actually contains some impurities, including sulfur.

There is 600 g of sulfur in 20 kg of fuel.

(i) Calculate the percentage of sulfur in the fuel.

(2)

percentage of sulfur = ...%

(ii) When the fuel burns, the 600 g of sulfur produces sulfur dioxide gas.

$$S + O_2 \rightarrow SO_2$$

Calculate the volume, in cm^3, of sulfur dioxide gas that would be produced at room temperature and pressure (rtp) when the fuel burns.

[for a gas, molar volume = 24 dm^3 at rtp]

(3)

volume of sulfur dioxide = ... cm^3

(iii) State the name of the environmental problem caused by sulfur dioxide in the atmosphere.

(1)

.....

(Total for Question 3 = 9 marks)

10 A student investigates the reaction between zinc and copper(II) sulfate solution.

The equation for the reaction is

$$Zn + CuSO_4 \rightarrow Cu + ZnSO_4$$

This is his method.

- add exactly 25.0 cm^3 of copper(II) sulfate solution to a polystyrene cup
- record the temperature of the solution
- add about 5 g of zinc powder (an excess) and stir the mixture
- record the highest temperature reached

(a) (i) Suggest why it is not important to add an exact mass of zinc powder.

(1)

.....

.....

(ii) State the colour change of the solution.

(2)

from ..... to .....

(b) The table shows the student's results

volume of copper(II) sulfate solution in cm^3	25.0
initial temperature of copper(II) sulfate solution in °C	19.0
final temperature of solution in °C	31.5

(i) Show that the heat energy change (Q) is about 1300 J.
[for the solution, c = 4.18 J/g/°C]

[mass of 1.00 cm^3 of solution = 1.00 g]

(3)

(ii) The mass of anhydrous copper(II) sulfate ($CuSO_4$) used to make 25.0 cm^3 of solution is 2.00 g.

Calculate the amount, in moles, of $CuSO_4$ in 2.00 g.

[M_r of $CuSO_4$ = 159.5]

(1)

amount of $CuSO_4$ = ... mol

(iii) Calculate the value of the enthalpy change (ΔH), in kilojoules per mole, for the reaction between zinc and copper(II) sulfate.

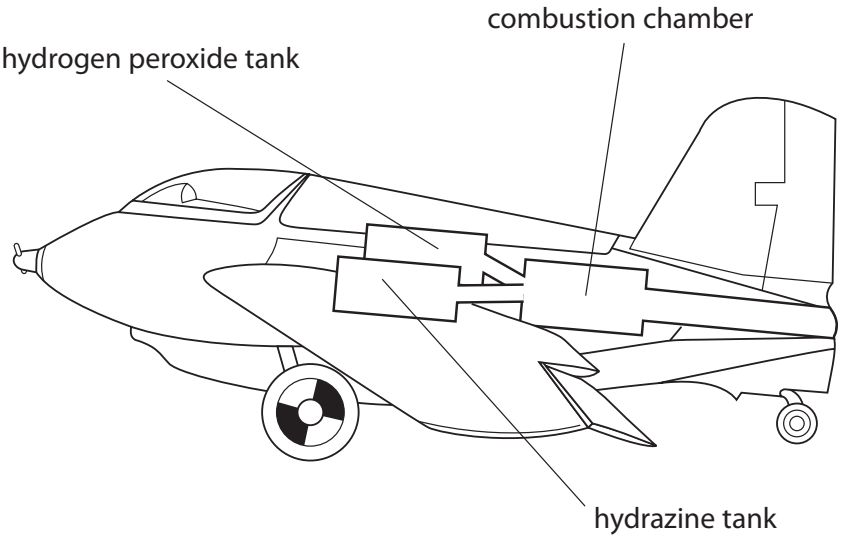
Include a sign in your answer.

(3)

ΔH = ... kJ/mol

(Total for Question 10 = 10 marks)

5 During the Second World War, engineers developed a rocket-powered aircraft.



The aircraft carried these two liquids

- hydrazine, N_2H_4
- hydrogen peroxide, H_2O_2

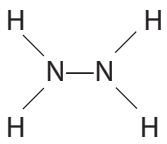
When these two liquids mix in the combustion chamber, they evaporate and then react rapidly to form nitrogen gas, N_2, and steam, H_2O

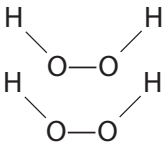
The reaction is exothermic.

The equation for the reaction is

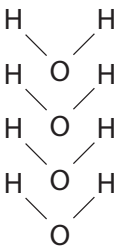
$$N_2H_4 \quad + \quad 2H_2O_2 \quad \rightarrow \quad N_2 \quad + \quad 4H_2O$$

The displayed formulae for the reactants and products are









(a) The tables give the bond energies for the bonds broken in the reactants and the bonds made in the products.

Bonds broken	
bond	bond energy in kJ/mol
N—N	159
N—H	391
O—O	143
O—H	463

Bonds made	
bond	bond energy in kJ/mol
N≡N	945
O—H	463

(i) Use the data in the tables to calculate the total amount of energy required to break all of the bonds in the reactants.

(1)

energy required = ... kJ

(ii) Use the data in the tables to calculate the total amount of energy released when all of the bonds in the products are made.

(1)

energy released = ... kJ

(iii) Calculate the enthalpy change, ΔH, in kJ/mol, for the reaction. Include a sign in your answer.

(3)

ΔH = ... kJ/mol

(b) Explain, in terms of bonds broken and bonds made, why this reaction is exothermic.

(2)

.....

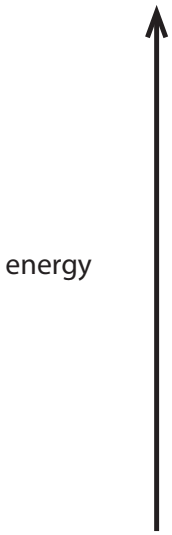
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(c) Draw an energy level diagram for the reaction between N_2H_4 and H_2O_2

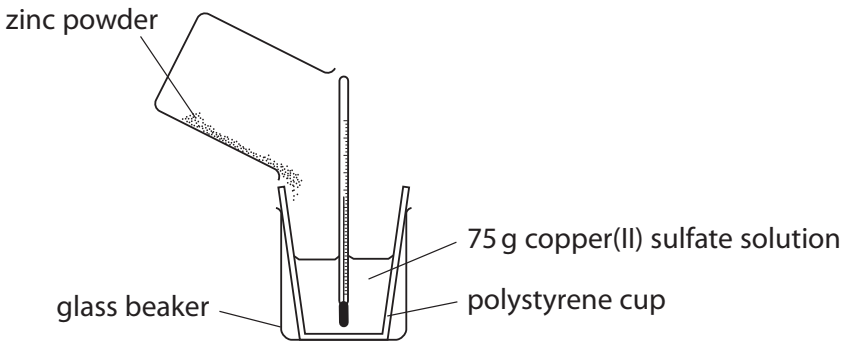
(3)



(Total for Question 5 = 10 marks)

8 This question is about exothermic reactions.

(a) A student uses this apparatus to measure the temperature increase when an excess of zinc powder is added to copper(II) sulfate solution.



(i) Complete the word equation for the reaction.

(1)

zinc + copper(II) sulfate → ..... + ...

(ii) Give a reason why the student uses a polystyrene cup inside a glass beaker.

(1)

.....

.....

(iii) State why zinc reacts with copper(II) sulfate solution.

(1)

.....

.....

(iv) The temperature at the start of the reaction is 19.7 °C.

The temperature at the end of the reaction is 48.3 °C.

Calculate the heat energy change, in joules, for the reaction.

[for the mixture, c = 4.2 J/g/°C]

(2)

heat energy change = ... J

(b) (i) The reaction between zinc and silver nitrate solution is exothermic.

A mass of 0.65 g of zinc is added to excess silver nitrate solution.

The heat energy change is 800 J.

Calculate the molar enthalpy change, ΔH, in kJ/mol.

Include a sign in your answer.

(3)

ΔH = ... kJ/mol

(ii) This is the ionic equation for the reaction between zinc and silver nitrate solution.

$$Zn(s) + 2Ag^{+}(aq) \rightarrow Zn^{2+}(aq) + 2Ag(s)$$

Explain, in terms of electrons, why this is a redox reaction.

(2)

.....

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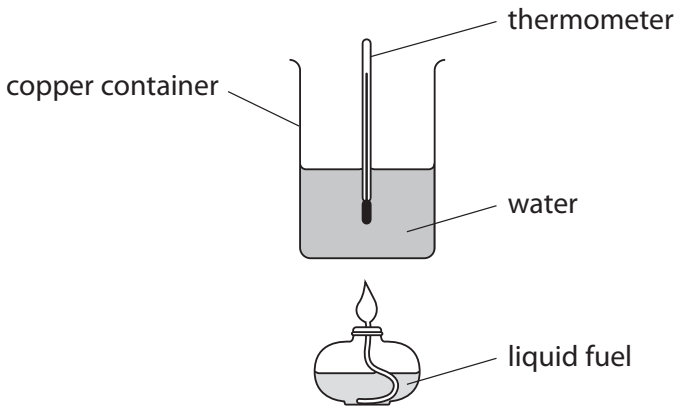
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(Total for Question 8 = 10 marks)

7 A student uses this apparatus to find the heat energy supplied by a liquid fuel.



The student burns some fuel to heat the water in the copper container and measures the change in temperature.

(a) The student notices that the bottom of the container turns black.

Give the name of the black substance that forms on the bottom of the container.

(1)

.....

(b) In one experiment, the student burns 0.92 g of ethanol.

The student calculates that the heat energy absorbed by the water is 18.2 kJ.

Show that the results of this experiment give an approximate value for the enthalpy of combustion of ethanol of $\Delta H = -900$ kJ/mol.

[M_r of ethanol = 46]

(2)

(c) The data book value of ΔH for the combustion of ethanol is –1367 kJ/mol.

Give two reasons why the student's value is much lower than the data book value.

(2)

1 .....

.....

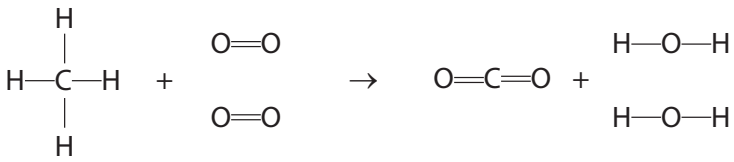
2 .....

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(d) The equation shows the combustion of methane.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O \qquad \Delta H = -890\ \text{kJ/mol}$$

This is the equation showing the displayed formulae.



The table shows the bond energies for O═O, C═O and O—H

Bond	O═O	C═O	O—H
Bond energy in kJ/mol	498	805	463

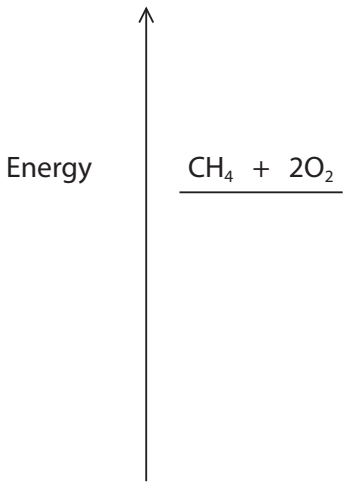
(i) Calculate the bond energy of the C—H bond, using information from the equation and the table.

(4)

C—H bond energy = ... kJ/mol

(ii) Complete the energy level diagram to show the products and ΔH.

(2)



(Total for Question 7 = 11 marks)

10 A student investigates the reaction between magnesium and nitric acid.

The student uses this method.

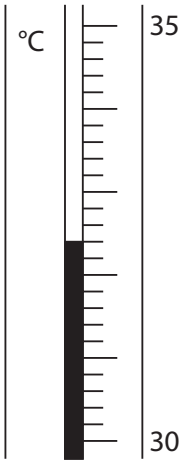
- add 40 cm^3 of dilute nitric acid to a glass beaker
- record the temperature of the acid
- find the mass of a strip of magnesium ribbon
- add the magnesium ribbon to the nitric acid
- when all the magnesium has reacted, record the highest temperature reached

(a) Complete the chemical equation for this reaction.

(1)

$$Mg + 2HNO_3 \rightarrow \text{.....} + \text{.....}$$

(b) The thermometer shows the highest temperature reached.



Complete the table by giving the temperatures to the nearest 0.1°C

(2)

starting temperature of the acid in °C	
highest temperature reached in °C	
temperature rise in °C	16.4

(c) (i) Show that the heat energy change (Q) for this reaction is about 2800 J.

[for 1.0 cm^3 of solution, mass = 1.0 g]

[for the solution, c = 4.2 J/g/°C]

(2)

(ii) The mass of magnesium used by the student was 0.12 g.

Calculate the value of the enthalpy change (ΔH), in kJ/mol, for the magnesium reacting with nitric acid.

Give your answer to two significant figures, including a sign in your answer.

(4)

ΔH = ... kJ/mol

(d) Explain why using a polystyrene cup, instead of a glass beaker, would give a more accurate result.

(2)

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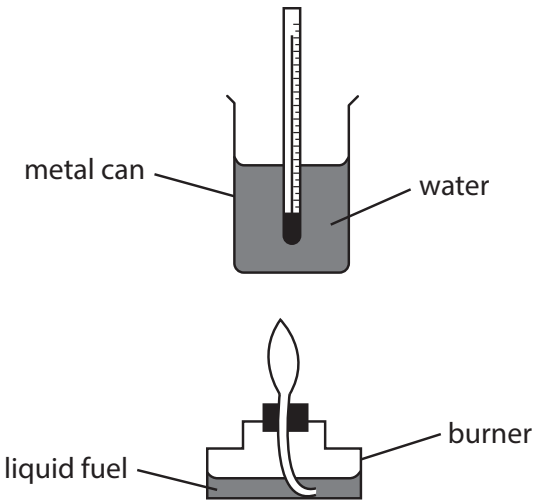
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(Total for Question 10 = 11 marks)

6 A student uses this apparatus to find the heat energy released by the combustion of liquid fuels.

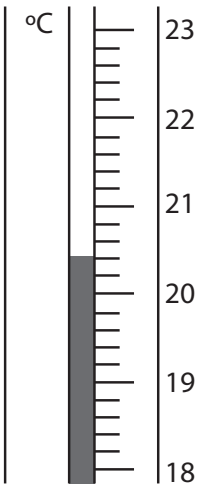


(a) Explain what is meant by the term **fuel**.

(2)

(b) (i) In one experiment, the student uses liquid ethanol as the fuel.

The thermometer shows the temperature of the water at the start of the experiment.



Complete the table by giving the temperatures to the nearest 0.1 °C.

(2)

temperature of the water at the start in °C	
highest temperature reached in °C	
temperature rise in °C	57.2

(ii) The metal can contains water of mass 150 g.

Show, by calculation, that the heat energy change (Q) for this reaction is approximately 36 000 J.

[for water, c = 4.2 J/g/°C]

(2)

Q = ... J

(iii) In the experiment, 2.3 g of ethanol (M_r = 46) is burned.

Calculate the molar enthalpy change (ΔH), in kJ/mol, for the combustion of ethanol, C_2H_5OH

Include a sign in your answer.

Give your answer to two significant figures.

(4)

ΔH = ... kJ/mol

(c) In this experiment, the calculated value of ΔH is less than the value given in a data book.

Give a possible reason for the difference in values.

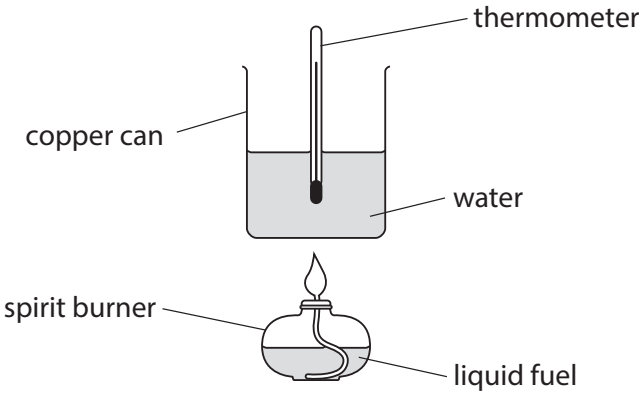
(1)

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.....

(Total for Question 6 = 11 marks)

10 A student uses this apparatus to investigate the energy content of different fuels.



(a) This is the student's method.

- pour some water into the copper can
- record the mass of the spirit burner and fuel
- measure the initial temperature of the water
- place the spirit burner under the copper can and light the burner
- stop heating the water when the temperature reaches 30°C
- record the new mass of the spirit burner and fuel

The student repeats the experiment with different fuels.

Explain two variables the student should control to make this a valid test.

(4)

1 .....

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2 .....

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(b) In one of the experiments, the student uses ethanol as the fuel.

These are the student's results for ethanol.

initial mass of spirit burner and ethanol in g	38.52
final mass of spirit burner and ethanol in g	38.29
volume of water in cm^3	100
initial temperature of water in °C	18
final temperature of water in °C	30

(i) Calculate the value of heat energy change (Q) in joules.

[for water, c = 4.2 J/g/°C 1.0 cm^3 of water has mass = 1.0 g]

(2)

Q = ... J

(ii) Calculate the enthalpy change (ΔH) in kJ/mol.

[for ethanol, M_r = 46]

Include a sign in your answer.

(5)

ΔH = ... kJ/mol

(Total for Question 10 = 11 marks)

10 A student investigates the reaction between zinc and copper(II) sulfate solution.

This is the equation for the reaction.

$$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$$

This is the student's method.

Step 1 add 25.0 cm^3 of copper(II) sulfate solution to a glass beaker
Step 2 record the temperature of the solution
Step 3 add between 5 g and 6 g of zinc powder (an excess) and stir the mixture
Step 4 record the highest temperature reached

(a) (i) Explain an improvement to step 1 to produce a more accurate temperature rise.

(2)

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(ii) Give a reason why the student does not need to know the exact mass of zinc powder added in step 3.

(1)

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.....

(iii) State the colour change in the solution.

(1)

from ..... to .....

(b) (i) The table shows the student's results.

volume of copper(II) sulfate solution in cm^3	25.0
initial temperature of the copper(II) sulfate solution in °C	18.5
final temperature of the copper(II) sulfate solution in °C	48.6

Calculate the heat energy change (Q) in joules (J).

[for the solution, c = 4.2 J / g / °C]
[mass of 1.0 cm^3 of solution = 1.0 g]

(3)

Q = ... J

(ii) The student repeats the experiment and calculates Q as 3800 J.
The solution used contains 6.38 g of copper(II) sulfate.

Calculate the molar enthalpy change, ΔH, in kJ / mol.
Include a sign in your answer.
[for $CuSO_4$, M_r = 159.5]

(4)

ΔH = ... kJ / mol

(Total for Question 10 = 11 marks)

6 A student uses this method to investigate the reaction of dilute hydrochloric acid with zinc.

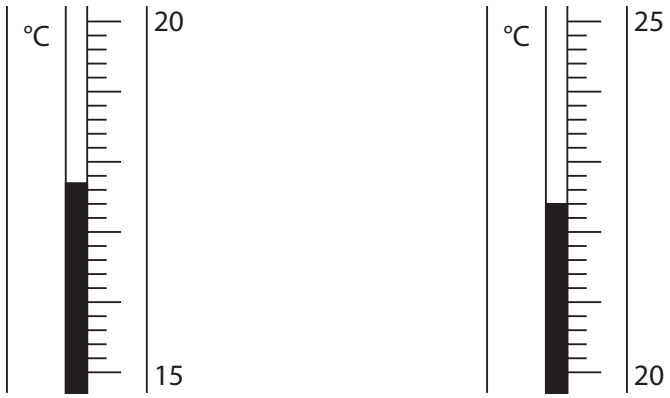
- pour some dilute hydrochloric acid into a glass beaker
- record the initial temperature of the acid
- add a piece of zinc and stir the mixture
- record the temperature of the mixture after one minute

(a) Write a word equation for the reaction of dilute hydrochloric acid with zinc.

(1)

.....

(b) The diagram shows the thermometer readings for this reaction.



before adding zinc after adding zinc

Complete the table, giving all values to the nearest 0.1°C.

(3)

temperature in °C after adding zinc	
temperature in °C before adding zinc	
temperature change in °C	

(c) Another student repeats the method using five different metals to compare their reactivity.

(i) This student uses a polystyrene cup instead of a glass beaker.

Explain why a polystyrene cup is better than a glass beaker in this investigation.

(2)

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(ii) Give three factors that the student should keep constant in this investigation.

(3)

1 .....

2 .....

3 .....

(d) The table shows some of the student's results.

Metal added	Observation	Temperature change in °C
copper	no bubbling	0.0
iron	slow bubbling	
magnesium	rapid bubbling	8.7
tin	very slow bubbling	1.4
zinc	moderate bubbling	5.1

(i) State why there is no temperature change for copper.

(1)

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.....

(ii) Predict the temperature change for iron.

(1)

temperature change = ... °C

(iii) Deduce the order of reactivity of the five metals.

(1)

most reactive .....

.....

.....

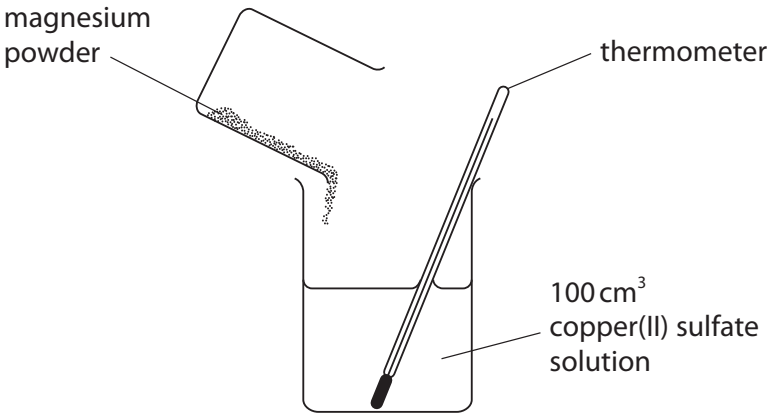
.....

least reactive .....

(Total for Question 6 = 12 marks)

6 The reaction between magnesium and copper(II) sulfate solution is exothermic.

This apparatus is used to measure the temperature increase when excess magnesium is added to 100 cm^3 of copper(II) sulfate solution.



(a) (i) State why a reaction occurs when magnesium is added to copper(II) sulfate solution.

(1)

.....

.....

(ii) Complete the word equation for this reaction.

(1)

magnesium + copper(II) sulfate → ..... + ...

(b) The temperature at the start of the reaction is 20.2 °C.

The maximum temperature recorded is 56.3 °C.

(i) Calculate the heat energy change, in joules, for the reaction.

[mass of 1.00 cm^3 of solution = 1.00 g]

[c for the solution = 4.2 J/g/°C]

(2)

heat energy change = ... J

(ii) Explain why it is better to use a polystyrene cup rather than a glass beaker in this experiment.

(2)

.....

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.....

.....

(c) The reaction between zinc and copper(II) sulfate solution is also exothermic.

(i) A mass of 0.500 g of zinc is reacted with an excess of copper(II) sulfate solution.

The heat energy change is 1.67 kJ.

Calculate the molar enthalpy change, ΔH, in kJ/mol.

Include a sign in your answer.

Give your answer to three significant figures.

(3)

ΔH = ... kJ/mol

(ii) The ionic equation for the reaction between zinc and copper(II) sulfate is

$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$$

Explain why this is a redox reaction.

(3)

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(Total for Question 6 = 12 marks)

7 The reaction between hydrogen and chlorine is exothermic.

This is the equation for the reaction.

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g) \qquad \Delta H = -184\,kJ$$

(a) State the meaning of the term **exothermic**.

(1)

.....

.....

(b) The table gives the bond energies for the H—H and H—Cl bonds.

Bond	H—H	H—Cl
Bond energy in kJ / mol	436	431

Use the equation and information from the table to calculate the bond energy of the Cl—Cl bond.

(4)

bond energy = ... kJ / mol

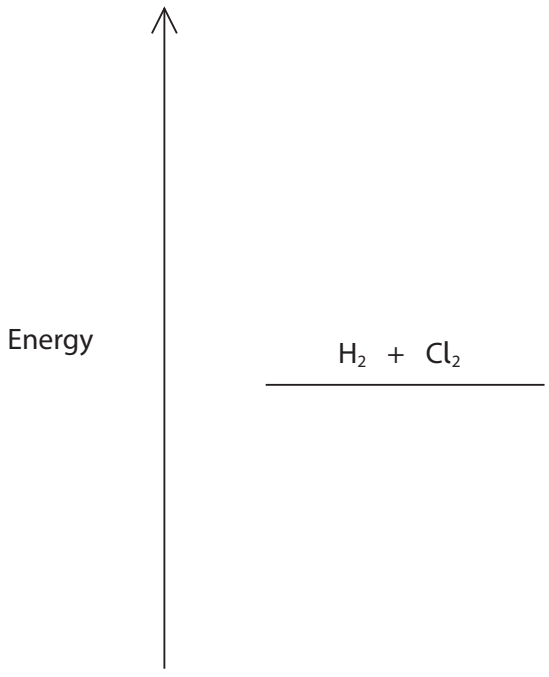
(c) Explain why this reaction is exothermic.

Refer to bond-breaking and bond-making in your answer.

(3)

(d) Complete the reaction profile diagram to show the position of the products, the enthalpy change (ΔH) and the activation energy (E_a) for the reaction.

(4)



(Total for Question 7 = 12 marks)

4 A student uses this method to investigate the reaction between sodium hydroxide solution and dilute hydrochloric acid.

- pour 25 cm^3 of dilute hydrochloric acid into a glass beaker
- measure the temperature of the acid
- add 5 cm^3 of sodium hydroxide solution and stir the mixture
- record the highest temperature reached
- continue to add further 5 cm^3 portions of sodium hydroxide solution until a total of 40 cm^3 has been added
- record the temperature after adding each 5 cm^3 portion of sodium hydroxide solution

(a) State two factors that the student must keep constant to make this a valid investigation.

(2)

1 .....

2 .....

(b) Explain how using a polystyrene cup, instead of a glass beaker, would increase the accuracy of the results.

(2)

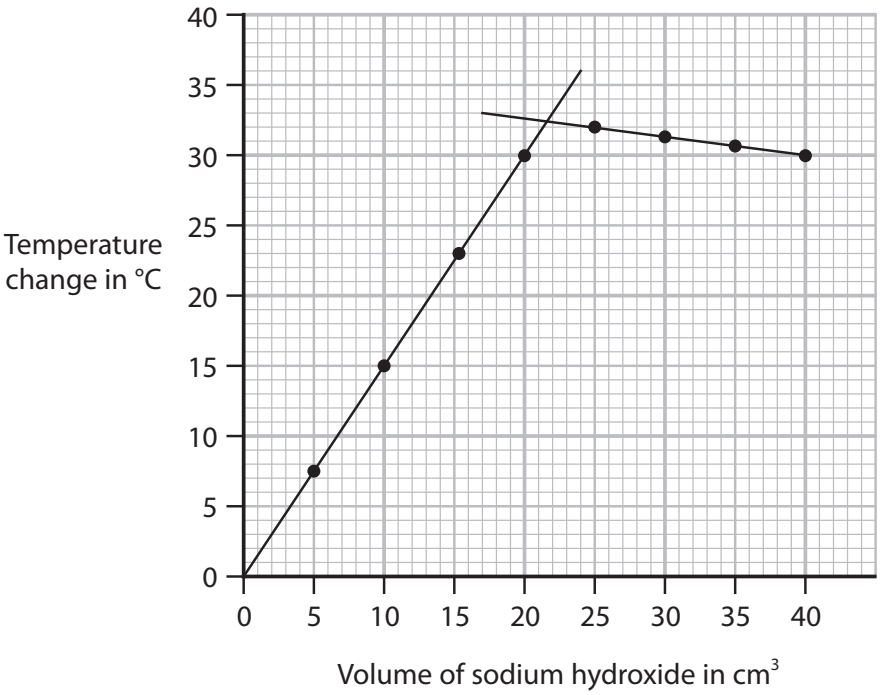
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(c) The graph shows the student's results.



(i) Use the graph to determine the maximum temperature change in °C.

(1)

maximum temperature change = ... °C

(ii) Explain the shape of the graph.

(3)

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(d) The student repeats the experiment using a polystyrene cup.

These are the student's results.

Maximum temperature change	35 °C
Volume of hydrochloric acid	25 cm^3
Volume of sodium hydroxide solution added for complete reaction	22 cm^3

Calculate the heat energy change (Q) in kJ.

[for the solution, 1.0 cm^3 has a mass of 1.0 g c = 4.2 J / g / °C]

(4)

Q = ... kJ

(Total for Question 4 = 12 marks)

7 A student does an experiment to determine the maximum temperature change when sulfuric acid reacts with sodium hydroxide.

(a) Complete the chemical equation for this neutralisation reaction.

Include the state symbols.

(2)

$2NaOH(aq) + H_2SO_4(aq) \rightarrow$ ..... + ...

(b) This is the student's method.

Step 1 add 50 cm^3 of sodium hydroxide solution to a glass beaker

Step 2 record the initial temperature of the sodium hydroxide solution

Step 3 add 5 cm^3 of dilute sulfuric acid to the beaker

Step 4 stir the mixture and record the highest temperature reached

The student repeats steps 3 and 4 until a total of 40 cm^3 of acid has been added.

Explain one way the student could improve the accuracy of the experiment.

(2)

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.....

(c) The table shows the student's results.

Total volume of acid in cm^3	0	5	10	15	20	25	30	35	40
Temperature of mixture in °C	21.0	22.3	23.8	24.4	26.5	28.0	28.5	28.2	27.9

(i) Plot the results on the grid.

(1)

(ii) Draw a circle around the anomalous result.

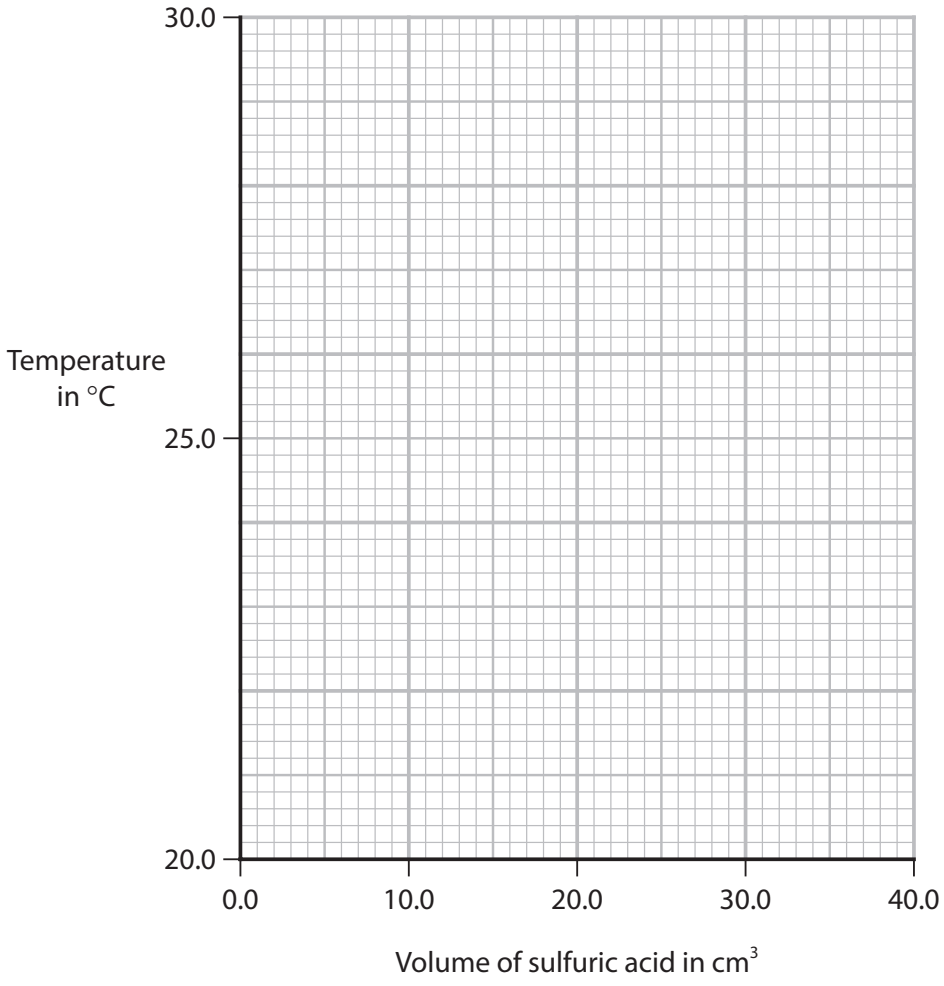
(1)

(iii) Draw a straight line of best fit through the first six points, ignoring the anomalous result.

Draw another straight line of best fit through the last three points.

Make sure that the two lines cross.

(2)



(d) The point where the lines cross shows the volume of acid needed to exactly neutralise the alkali and the maximum temperature reached.

Use your graph to determine these values.

(2)

volume of acid = ... cm^3

maximum temperature = ... °C

(e) Explain what might have caused the anomalous result.

(2)

.....

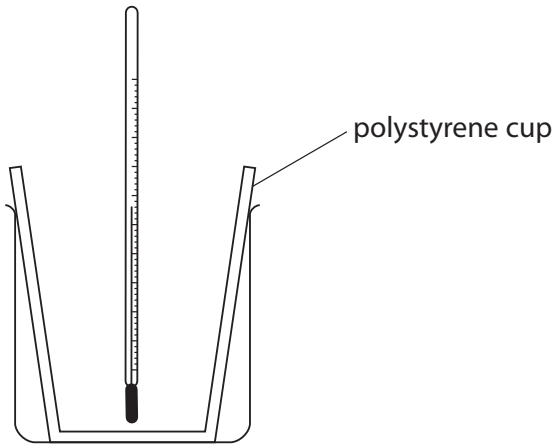
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(Total for Question 7 = 12 marks)

10 A student uses this apparatus to investigate the reaction between potassium hydroxide solution and dilute hydrochloric acid.



This is her method.

- pour 25 cm^3 of potassium hydroxide solution into a polystyrene cup and record the temperature of the solution
- pour 25 cm^3 of dilute hydrochloric acid into a measuring cylinder and record the temperature of the acid
- add the acid to the polystyrene cup and stir the mixture
- record the highest temperature reached

(a) (i) Give a word equation for the reaction between potassium hydroxide and hydrochloric acid.

(1)

.....

(ii) Explain why the student needs to stir the mixture.

(2)

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(b) The table gives the temperatures of the solutions before the student mixes them.

potassium hydroxide solution	17.8 °C
dilute hydrochloric acid	18.4 °C

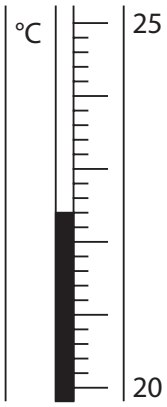
Calculate the mean (average) temperature of the two solutions.

(2)

mean temperature = ... °C

(c) The student repeats the experiment on a different day, using 25 cm^3 of potassium hydroxide solution and 25 cm^3 of dilute hydrochloric acid.

The thermometer shows the highest temperature reached at the **end** of the experiment.



(i) Complete the table by giving the missing information.

Give both temperatures to the nearest 0.1 °C.

(2)

mean temperature at start in °C	
temperature at end in °C	
temperature rise in °C	5.2

(ii) Show that the heat energy change, *Q*, in the student's experiment is about 1100 J.

[for the mixture, c = 4.2 J/g/°C]

[mass of 1.0 cm^3 of mixture = 1.0 g]

(3)

(iii) The student uses 0.020 mol of potassium hydroxide in his experiment.

Calculate the enthalpy change (ΔH) in kJ/mol, for 1.0 mol of potassium hydroxide.

Include a sign in your answer.

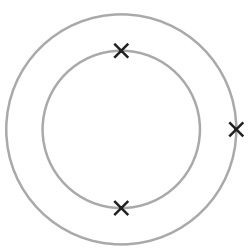
(3)

ΔH = ... kJ/mol

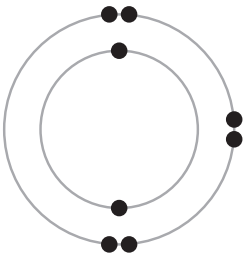
(Total for Question 10 = 13 marks)

7 This question is about lithium oxide.

(a) The diagram shows the electron configurations of an atom of lithium and an atom of oxygen.



lithium

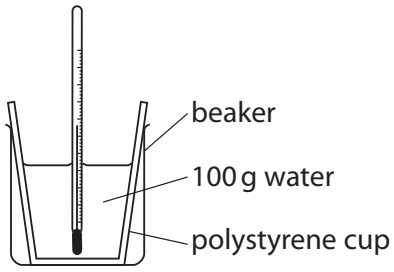


oxygen

Describe the changes in electronic configuration when lithium and oxygen react to form lithium oxide, Li_2O

(3)

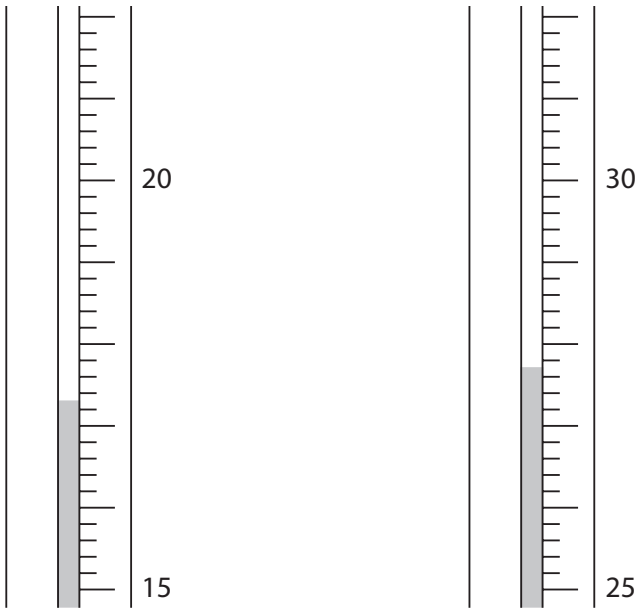
(b) Lithium oxide reacts with water to form lithium hydroxide as the only product.
A scientist uses this apparatus to measure the temperature change of the reaction.



This is the scientist's method.

- pour 100 g of water into a polystyrene cup
- record the temperature of the water
- add the lithium oxide and stir the mixture
- record the maximum temperature reached

The diagram shows the thermometer readings before and after adding the lithium oxide.



(i) Complete the table, giving all values to the nearest 0.1 °C.

(2)

temperature in °C after adding the lithium oxide	
temperature in °C before adding the lithium oxide	17.3
temperature rise in °C	

(ii) Calculate the heat energy change in the reaction.

Give your answer to two significant figures.

[c = 4.2 J / g / °C]

(4)

heat energy change = ... J

(iii) In another experiment the scientist obtains these results.

amount of lithium oxide in mol	0.0580
heat energy change in J	5210

Calculate the molar enthalpy change (ΔH) in kJ / mol.

Include a sign in your answer.

(3)

ΔH = ... kJ / mol

(iv) Give a reason why the scientist does the experiment in a polystyrene cup.

(1)

.....

.....

.....

(Total for Question 7 = 13 marks)

5 Hydrogen peroxide solution decomposes slowly at room temperature to form water and oxygen.

The equation for the reaction is

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

(a) A catalyst increases the rate of this reaction.

State one other property of a catalyst.

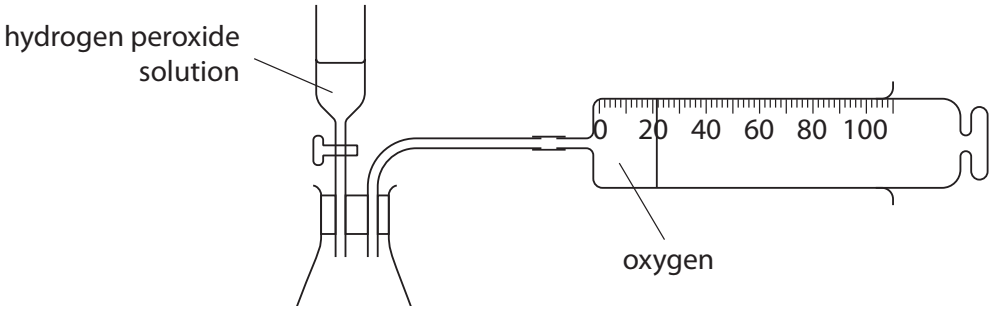
(1)

.....

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(b) A student has samples of three solids, X, Y and Z.

The student uses this apparatus to find out which solids act as catalysts in the decomposition of hydrogen peroxide solution.



Describe the method that the student should use to find out which solids act as catalysts.

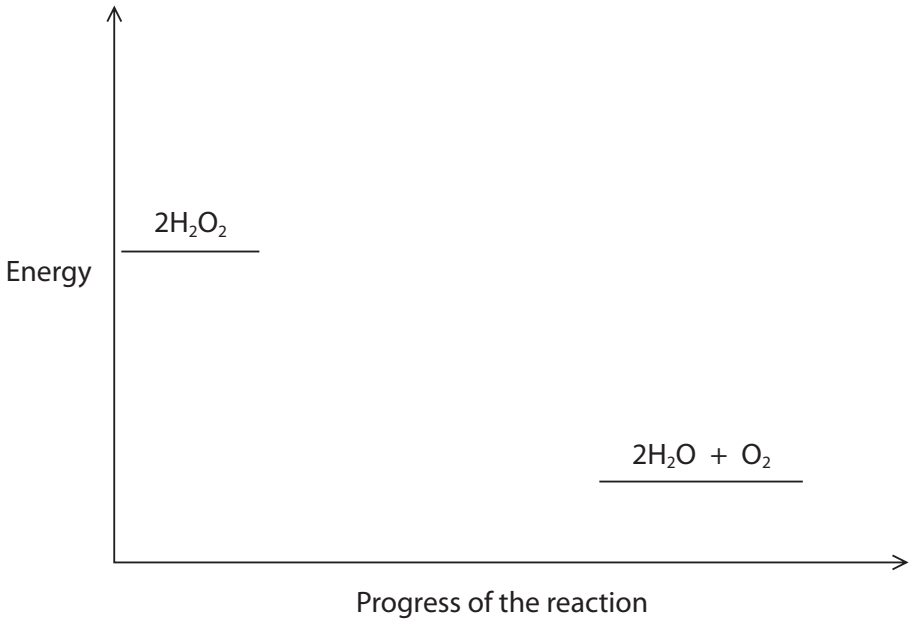
(6)

(c) The decomposition of hydrogen peroxide solution is exothermic.

On the diagram, draw and label the reaction profiles for the reaction

- without a catalyst
- with a catalyst

(2)



(d) The equation for the reaction can be shown using displayed formulae.

$$2\,H{-}O{-}O{-}H \rightarrow 2\,H{-}O{-}H + O{=}O \qquad \Delta H = -204\,kJ$$

The table gives the bond energies for two of the bonds.

Bond	Bond energy in kJ/mol
H—O	463
O—O	146

(i) Use this information to calculate the total amount of energy needed to break all the bonds in two moles of H_2O_2

(1)

energy needed = ... kJ

(ii) Use this information to calculate the total amount of energy released when all the bonds in two moles of H_2O are formed.

(1)

energy released = ... kJ

(iii) Use the value of ΔH and your answers for (i) and (ii) to calculate the bond energy, in kJ/mol, for the O═O bond.

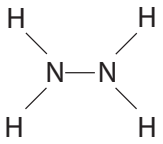
(2)

bond energy = ... kJ/mol

(Total for Question 5 = 13 marks)

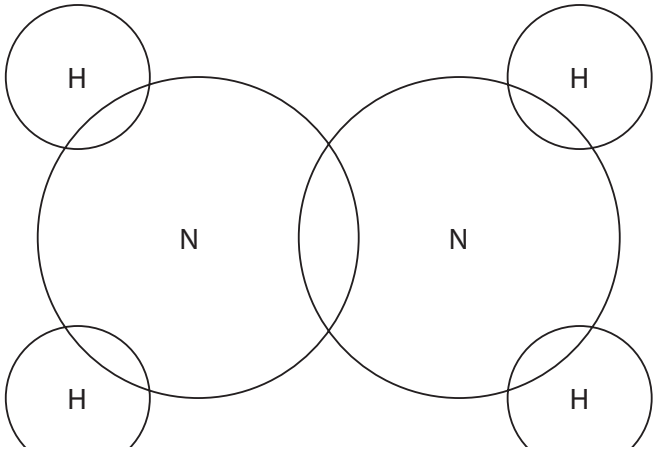
7 This question is about hydrazine, N_2H_4

(a) This is the displayed formula for a molecule of hydrazine.



Complete the dot-and-cross diagram for hydrazine.

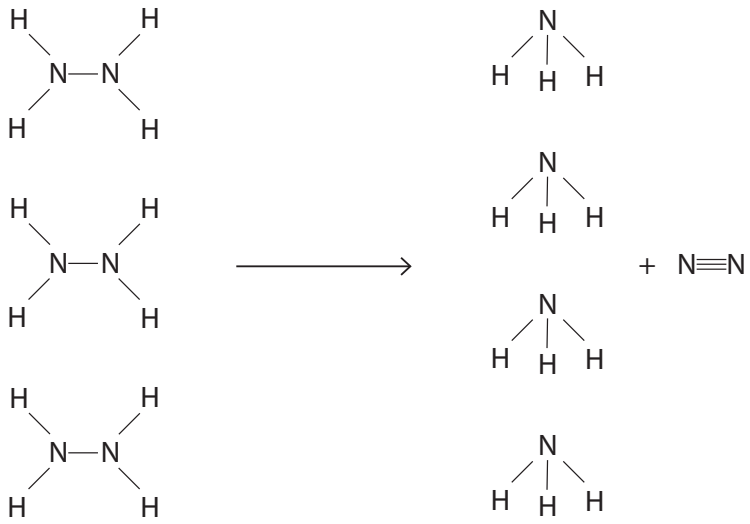
(2)



(b) This is the equation for the decomposition of hydrazine.

$$3N_2H_4(g) \rightarrow 4NH_3(g) + N_2(g)$$

The equation can be shown using displayed formulae.



The table gives the relevant bond energies.

Bond	Bond energy in kJ/mol
N—N	158
N—H	391
N≡N	945

(i) Use the data in the table to calculate the total energy needed to break all the bonds in the reactants.

(2)

energy needed = ... kJ

(ii) Use the data in the table to calculate the total energy released when all the bonds in the products are made.

(2)

energy released = ... kJ

(iii) Calculate the enthalpy change, ΔH, in kJ/mol, for the reaction.

(1)

ΔH = ... kJ/mol

(iv) Explain, in terms of bonds broken and bonds made, why this reaction is exothermic.

(2)

.....

.....

.....

.....

(c) A sample of hydrazine is completely decomposed.

This is the equation for the decomposition of hydrazine.

$$3N_2H_4(g) \rightarrow 4NH_3(g) + N_2(g)$$

The products of the decomposition are bubbled through 1100 cm^3 of water.

The ammonia completely dissolves in the water, but nitrogen is insoluble in water.

The nitrogen has a volume of 1570 cm^3 at room temperature and pressure (rtp).

Calculate the concentration, in mol/dm^3, of the ammonia solution.

Give your answer to 3 significant figures.

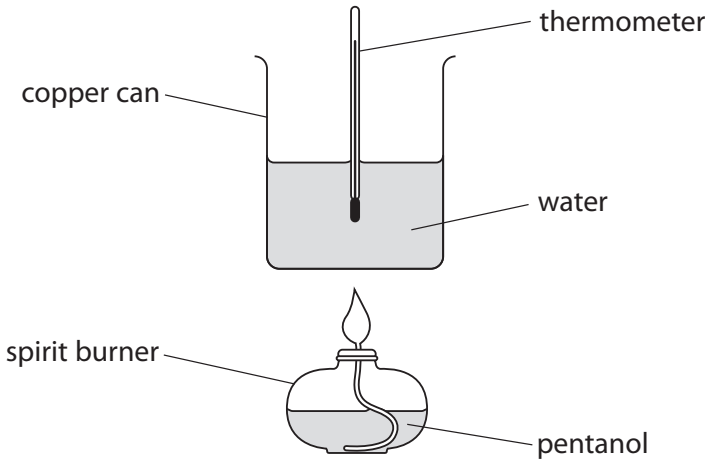
[for a gas at rtp, molar volume = 24 000 cm^3]

(4)

concentration = ... mol/dm^3

(Total for Question 7 = 13 marks)

8 A student uses this apparatus to find the molar enthalpy change (ΔH) of combustion for the liquid fuel, pentanol.



This is the student's method.

- find the initial mass of the spirit burner and pentanol
- add 100 cm^3 of water to the copper can
- record the initial temperature of the water
- light the wick of the spirit burner to heat the water
- stir the water until the temperature rises by 35.0 °C
- extinguish the flame and immediately find the final mass of the spirit burner and pentanol

(a) (i) State why the student stirs the water.

(1)

.....

.....

(ii) Suggest why it is important that the student immediately finds the final mass of the spirit burner and pentanol.

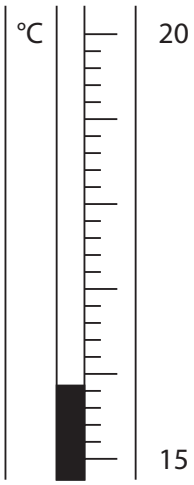
(1)

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(b) The diagram shows the initial temperature of the water.



Complete the table to show the temperature readings.

Give both values to the nearest 0.1 °C.

(2)

Initial temperature of water in °C	
Final temperature of water in °C	
Temperature change in °C	35.0

(c) (i) Show by calculation that the heat energy (*Q*) supplied by the pentanol is approximately 15 000 J.

[for water, c = 4.2 J / g / °C]

[for 1.0 cm^3 of water, mass = 1.0 g]

(2)

(ii) The table gives the initial and final mass readings.

Initial mass of spirit burner and pentanol in g	90.11
Final mass of spirit burner and pentanol in g	89.75

Use your answer to part (c)(i) and the information in the table to calculate the molar enthalpy change (ΔH) of combustion, in kJ / mol, for pentanol.

[for pentanol, $M_r = 88$]

Include a sign in your answer.

(5)

ΔH for pentanol = ... kJ / mol

(d) The formula of pentanol is $C_5H_{11}OH$

Write a chemical equation for the complete combustion of pentanol.

(2)

.....

(Total for Question 8 = 13 marks)

7 This question is about hydrogen chloride (HCl).

Hydrogen chloride is a covalent compound.

(a) State, in terms of electrostatic attraction, what is meant by a covalent bond.

(2)

(b) When hydrogen chloride gas is dissolved in an organic solvent, the hydrogen chloride remains a covalent molecule.

When hydrogen chloride gas is dissolved in water, ions are formed.

Explain what happens when dry blue litmus paper is dipped into separate samples of each solution.

(4)

(c) In the presence of ultraviolet radiation, hydrogen reacts with chlorine to form hydrogen chloride.

This is the equation for the reaction.

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$$

The table shows the bond energies.

Bond	H—H	Cl—Cl	H—Cl
Bond energy in kJ/mol	436	242	431

(i) Calculate the enthalpy change (ΔH), in kJ/mol, for the reaction.

Include a sign in your answer.

(3)

ΔH = ... kJ/mol

(ii) Draw a reaction profile for the reaction.

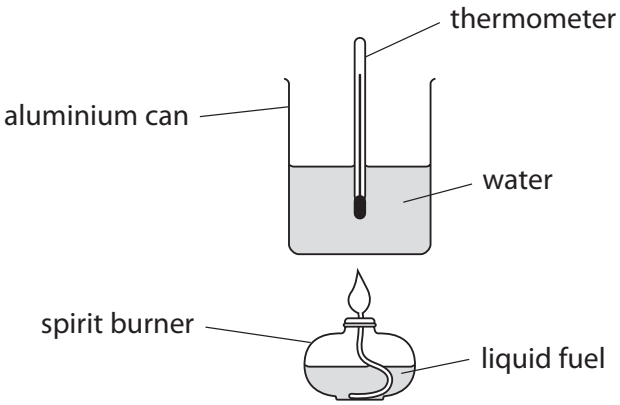
Label the reactants, the products, ΔH and the activation energy (E_a).

(4)

energy

(Total for Question 7 = 13 marks)

9 A student uses this apparatus to investigate the heat energy released when a liquid fuel burns.



This is the student's method.

- measure the mass of the spirit burner and fuel
- add 100 g of water to the aluminium can
- measure the temperature of the water
- use the spirit burner to heat the water until the temperature rises by 50 °C
- measure the new mass of the spirit burner and fuel

(a) Give a reason why the student uses an aluminium can rather than a glass beaker.

(1)

.....

.....

(b) When the fuel burns, a black solid forms on the aluminium can.

(i) Identify the black solid.

(1)

.....

(ii) Give a reason why the black solid forms.

(1)

.....

.....

(c) (i) Show that the heat energy needed to raise the temperature of 100 g of water by 50 °C is approximately 20 000 J.

[for water, c = 4.2 J/g/°C]

(2)

(ii) The student burns 1.84 g of ethanol.

Calculate the molar enthalpy change, ΔH, in kJ/mol, for the combustion of ethanol.

Include a sign in your answer.

[for ethanol, M_r = 46]

(4)

ΔH = ... kJ/mol

(d) In a different experiment, the student burns 3.7 g of butanol.

This is an equation for the incomplete combustion of butanol.

$$C_4H_9OH(l) + \ldots\ldots O_2(g) \rightarrow 2CO_2(g) + 2CO(g) + 5H_2O(g)$$

(i) Complete the equation for the incomplete combustion of butanol.

(1)

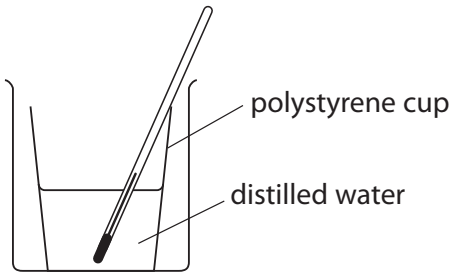
(ii) Calculate the total amount, in moles, of gas produced by the incomplete combustion of 3.7 g of butanol.

(3)

amount of gas = ... mol

(Total for Question 9 = 13 marks)

8 A student uses this apparatus to investigate the heat energy change when a salt dissolves in water to form a solution.



This is the student's method.

- add 50 cm^3 of distilled water to a polystyrene cup
- record the initial temperature of the water
- add a known mass of solid anhydrous copper(II) sulfate to the polystyrene cup and stir the solution with the thermometer until all the solid has dissolved
- record the maximum temperature of the copper(II) sulfate solution

(a) (i) Name the piece of apparatus the student should use to add the distilled water to the polystyrene cup.

(1)

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(ii) The student stirs the solution to help the solid dissolve more quickly.

Suggest another reason why the student stirs the solution.

(1)

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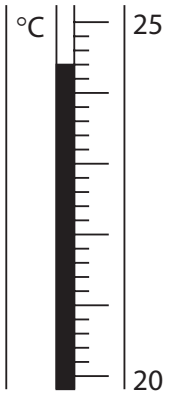
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(iii) State the colour of the copper(II) sulfate solution.

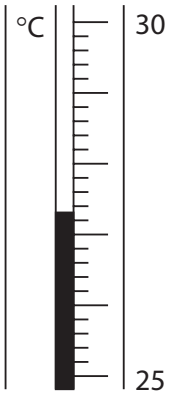
(1)

.....

(b) The diagram shows the temperatures in one experiment.



initial temperature



maximum temperature

Complete the table, giving all values to the nearest 0.1 °C.

(3)

maximum temperature in °C	
initial temperature in °C	
increase in temperature in °C	

(c) In a second experiment, when a student dissolves the anhydrous copper(II) sulfate in 50 cm^3 of distilled water, the increase in temperature is 3.3 °C.

(i) Show that the heat energy change (Q) in this second experiment is approximately 700 J.

[for water, c = 4.2 J/g/°C]

[mass of 1.0 cm^3 of water = 1.0 g]

(2)

(ii) In this experiment the student uses 1.70 g of the anhydrous copper(II) sulfate.

Calculate the molar enthalpy change (ΔH) in kJ/mol.

Include a sign in your answer.

[M_r of $CuSO_4$ = 159.5]

(4)

ΔH = ... kJ/mol

(d) Another student does a similar experiment but uses hydrated copper(II) sulfate instead of anhydrous copper(II) sulfate.

The table shows his results.

initial temperature in °C	23.8
final temperature in °C when all solid dissolves	22.7

Explain what the results show about the type of energy change that occurs when hydrated copper(II) sulfate dissolves.

(2)

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.....

.....

(Total for Question 8 = 14 marks)

9 A student investigates the reaction between solid hydrated sodium carbonate and dilute hydrochloric acid.

(a) She uses this method to investigate the temperature change during the reaction.

Step 1 pour 25.0 cm^3 of dilute hydrochloric acid into a polystyrene cup

Step 2 record the temperature of the dilute hydrochloric acid

Step 3 add 0.5 g of sodium carbonate and stir the mixture

Step 4 record the lowest temperature of the mixture

Step 5 add further 0.5 g portions of sodium carbonate, one portion at a time, stir the mixture and record the lowest temperature each time

The table shows the student's results.

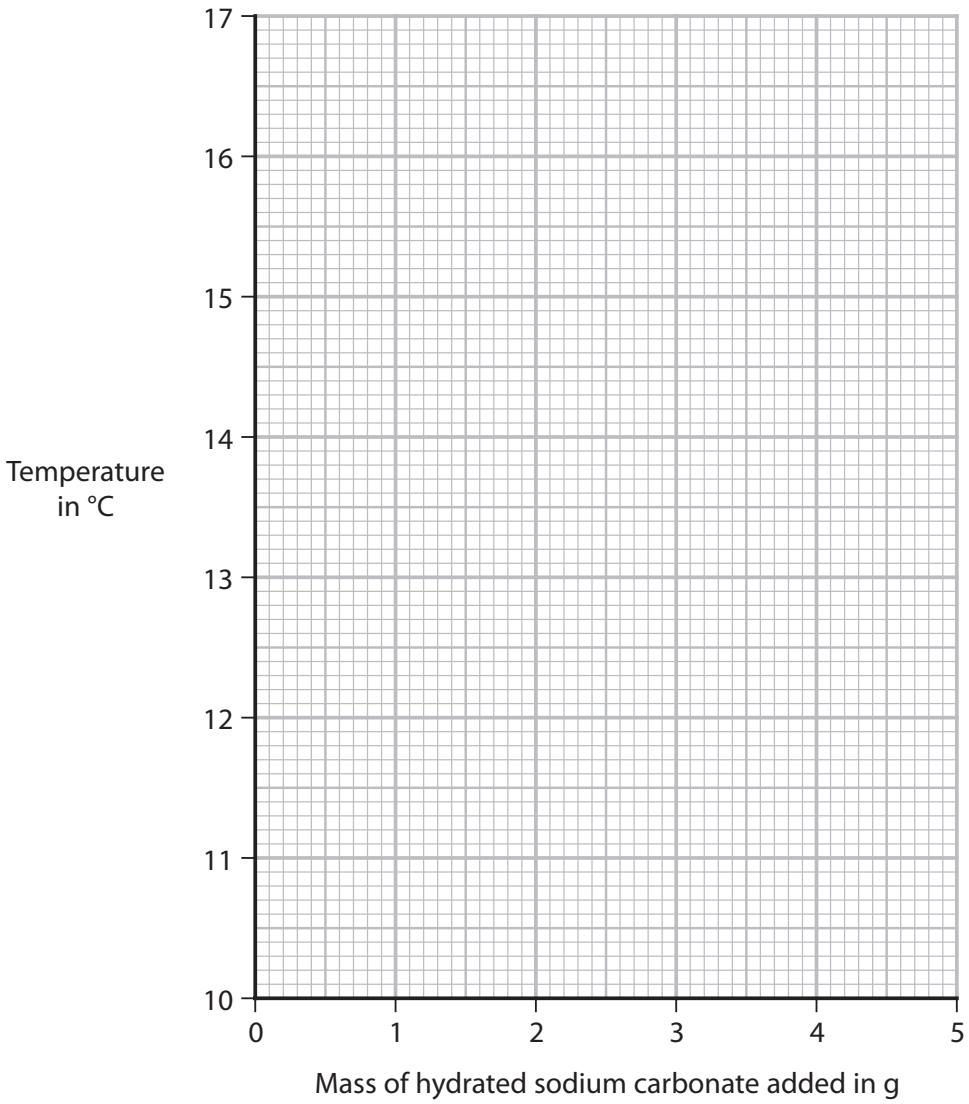
Mass of sodium carbonate added in g	Temperature in °C
0.0	17.0
0.5	15.6
1.0	14.1
1.5	13.0
2.0	12.9
2.5	12.2
3.0	11.8
3.5	11.5
4.0	11.2
4.5	11.0
5.0	11.0

(i) Plot the student's results on the grid.

(2)

(ii) Draw a curve of best fit, ignoring the anomalous result.

(1)



(iii) Explain why it is better to use a polystyrene cup instead of a glass beaker in this experiment.

(2)

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.....

.....

(iv) Suggest a reason for the anomalous result.

(1)

.....

.....

(v) State how the results show that all the dilute hydrochloric acid has reacted.

(1)

.....

.....

(vi) Use the results of the experiment to explain the type of reaction that occurs when sodium carbonate is added to dilute hydrochloric acid.

(2)

.....

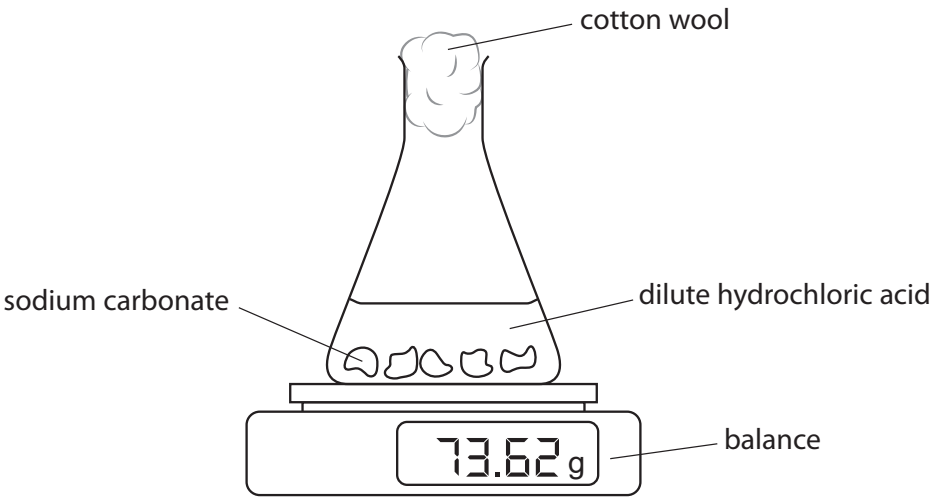
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(b) The student does another experiment using the same reaction.

The diagram shows the student's apparatus.



The mass on the balance decreases as carbon dioxide gas escapes.

(i) Give a reason for the cotton wool plug in the conical flask.

(1)

.....

.....

(ii) The student adds 2.12 g of sodium carbonate to an excess of dilute hydrochloric acid.

The chemical equation for the reaction is

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$$

Calculate the maximum mass, in g, of carbon dioxide formed in the reaction.

(3)

mass = ... g

(iii) Suggest why the mass of carbon dioxide produced is less than the calculated maximum mass.

(1)

.....

.....

(Total for Question 9 = 14 marks)

11 A student uses this method to investigate the temperature change when solid sodium hydrogencarbonate is added to ethanoic acid solution.

- pour 100 cm^3 of ethanoic acid solution into a polystyrene cup
- record the temperature of the ethanoic acid solution
- add a 1 g portion of sodium hydrogencarbonate to the ethanoic acid solution and stir
- record the new temperature
- add further 1 g portions of sodium hydrogencarbonate, stirring and recording the temperature after each portion is added

The table shows the student's results.

Mass of sodium hydrogencarbonate added in g	Temperature in °C
0	20.8
1	19.4
2	18.1
3	18.0
4	16.4
5	15.8
6	15.3
7	15.3
8	15.3

(a) (i) Plot the student's results on the grid.

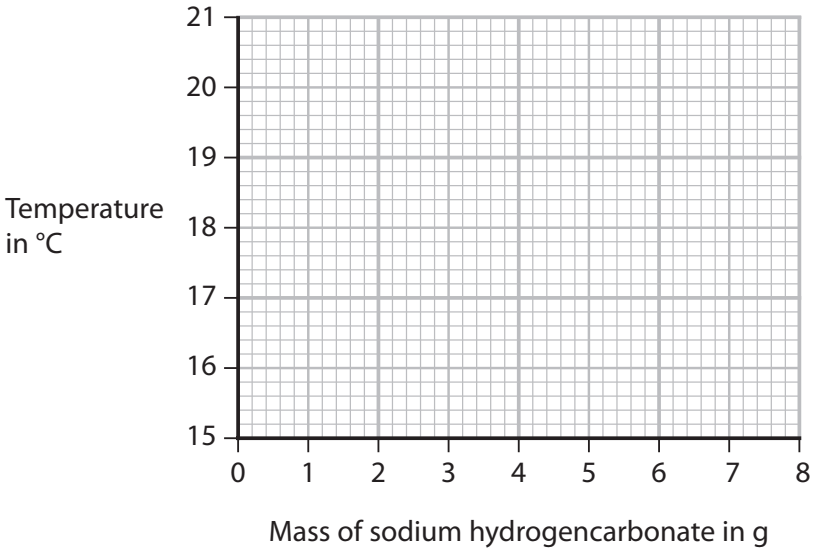
(1)

(ii) Draw a circle around the anomalous result.

(1)

(iii) Draw a curve of best fit.

(1)



(b) (i) Explain why using a polystyrene cup makes the results more accurate.

(2)

(ii) Suggest a mistake the student might have made to cause the anomalous result.

(1)

(iii) State how the results show the reaction is complete.

(1)

(iv) State how the results show that the reaction is endothermic.

(1)

(c) Use the results to calculate the heat energy change, Q, in joules.

[for 1.0 cm^3 of ethanoic acid solution, mass = 1.0 g]

[for ethanoic acid solution, c = 4.2 J / g / °C]

(2)

Q = ... J

(d) The student repeats the experiment starting with a different volume of ethanoic acid solution.

The student uses 7.0 g of sodium hydrogencarbonate to neutralise the ethanoic acid solution.

The heat energy change, Q, is 3200 J.

Calculate the molar enthalpy change, ΔH, in kJ / mol.

Include a sign with your answer.

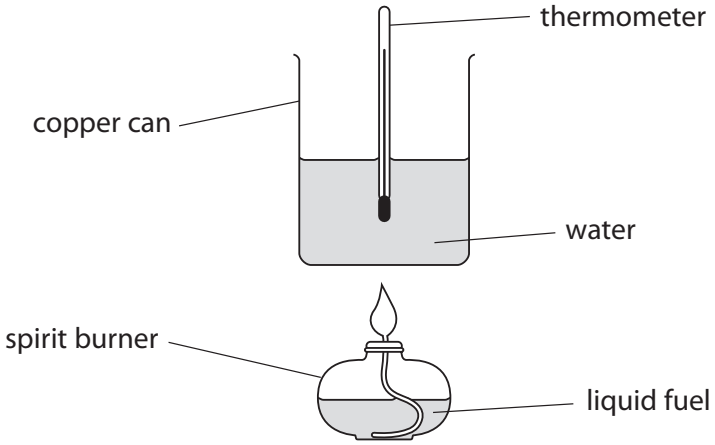
[for sodium hydrogencarbonate, M_r = 84]

(4)

ΔH = ... kJ / mol

(Total for Question 11 = 14 marks)

9 A student uses this apparatus to investigate the heat energy released when a liquid fuel is burned.



This is the student's method.

- measure the mass of the spirit burner and fuel
- add 100 cm^3 of water to the copper can
- record the temperature of the water
- use the spirit burner to heat the water until the temperature rises by 30 °C
- immediately measure the new mass of the spirit burner and fuel

(a) Suggest why the student measures the mass of the spirit burner and fuel immediately after heating the water.

(1)

(b) When the fuel is burned, the student notices that a black solid forms on the bottom of the copper can.

(i) Identify the black solid.

(1)

(ii) Explain why the black solid forms.

(2)

(c) (i) Show that the heat energy change, Q, to raise the temperature of 100 cm^3 of water by 30 °C is approximately 13 kJ.

[mass of 1.0 cm^3 of water = 1.0 g]

[c for water = 4.2 J/g/°C]

(3)

(ii) The student burns 0.96 g of methanol, CH_3OH

Calculate the molar enthalpy change, ΔH, in kJ/mol, for the combustion of methanol.

Include a sign in your answer.

[M_r of methanol = 32]

(3)

ΔH = ... kJ/mol

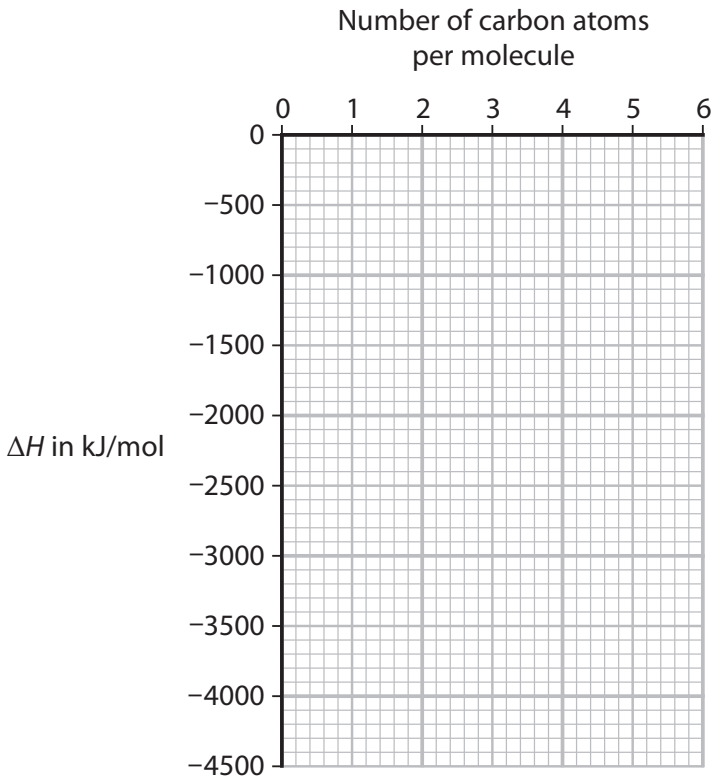
(d) The table shows data book values for the molar enthalpy change, ΔH, for the combustion of some alcohols with different numbers of carbon atoms per molecule.

Number of carbon atoms per molecule	1	2	3	4	5
Molar enthalpy change, ΔH, in kJ/mol	−730	−1370	−2020	−2680	−3320

(i) Plot the data values from the table on the grid.

Draw a straight line of best fit.

(2)



(ii) Deduce the value of ΔH for an alcohol with six carbon atoms per molecule.

Show on the graph how you obtained your answer.

(2)

$\Delta H =$ ..... kJ/mol

(iii) State the relationship between ΔH and the number of carbon atoms per molecule.

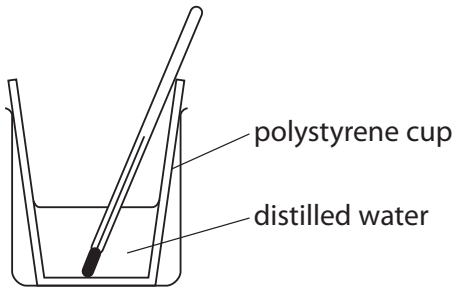
(1)

.....

.....

(Total for Question 9 = 15 marks)

10 A student uses this apparatus to find the heat energy change when ammonium nitrate dissolves in water to form a solution.



This is the student's method.

- add 50 cm^3 of distilled water to the polystyrene cup and record the initial temperature of the water
- add a known mass of ammonium nitrate to the polystyrene cup and stir the mixture until all the solid dissolves
- record the minimum temperature of the ammonium nitrate solution

(a) Give two reasons why the student stirs the mixture.

(2)

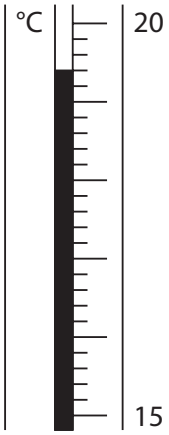
1 .....

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2 .....

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(b) The diagram shows the minimum temperature of the solution.



Complete the table by giving the missing information.

Give both values to the nearest 0.1 °C.

(2)

initial temperature of distilled water in °C	23.4
minimum temperature of solution in °C	
temperature change in °C	

(c) The student repeats the experiment, again using 50 cm^3 water, and finds that the temperature change is 3.9 °C.

(i) Show that the heat energy change, Q, in this experiment is about 800 J.

[c = 4.2 J / g / °C for the solution]

[mass = 1.0 g for 1.0 cm^3 of solution]

(2)

(ii) The student uses 2.8 g of ammonium nitrate in this experiment.

Calculate the enthalpy change, ΔH, in kJ / mol.

Include a sign in your answer.

[for NH_4NO_3, $M_r = 80$]

(4)

ΔH = ... kJ / mol

(d) Describe a test to show that the ammonium nitrate solution contains ammonium ions.

(3)

(e) In another experiment the student adds anhydrous copper(II) sulfate to distilled water.

The table shows the student's results.

initial temperature of water in °C	23.2
maximum temperature of solution in °C	28.5

Explain what the results show about the type of energy change that occurs when anhydrous copper(II) sulfate dissolves in water.

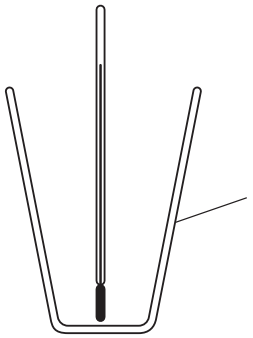
(2)

(Total for Question 10 = 15 marks)

11 A student investigates the temperature change during the reaction between zinc metal and copper(II) sulfate solution.

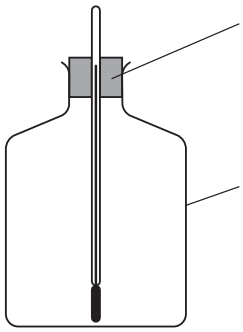
The student considers two different methods.

Method 1



- pour 50 cm^3 of copper(II) sulfate solution into the polystyrene cup
- record the temperature of the solution
- add 3 g of zinc powder
- stir using the thermometer and record the highest temperature reached

Method 2



- record the temperature of 50 cm^3 of copper(II) sulfate solution
- pour the 50 cm^3 of copper(II) sulfate solution into the glass bottle
- add 3 g of zinc powder
- push the bung and thermometer into the bottle and record the highest temperature reached

(a) Discuss the advantages and disadvantages of each method.

(6)

(b) The equation for the reaction is

$$Zn\,(s) + CuSO_4\,(aq) \rightarrow ZnSO_4\,(aq) + Cu\,(s)$$

50 cm^3 of copper(II) sulfate solution contains 0.025 mol $CuSO_4$

A mass of 3 g of zinc is used.

Show that the zinc is in excess.

[A_r of zinc = 65]

(2)

(c) The student reacts a solution containing 0.025 mol $CuSO_4$ with an excess of zinc.

These are the student's results.

temperature of 50 cm^3 of copper(II) sulfate solution = 21.1 °C

highest temperature reached = 40.6 °C

(i) Show that the energy change Q for this reaction is about 4000 J

[mass of 1 cm^3 of solution = 1.0 g]

[for the solution, c = 4.2 J / g / °C]

(3)

(ii) Calculate the molar enthalpy change (ΔH), in kJ / mol, for the reaction.

(3)

ΔH = ... kJ / mol

(d) The ionic equation for the reaction is

$$Zn\,(s) + Cu^{2+}\,(aq) \rightarrow Zn^{2+}\,(aq) + Cu\,(s)$$

Explain what is oxidised and what is reduced in this reaction.

(2)

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(Total for Question 11 = 16 marks)

SUB-TOPIC 3b

RATES OF REACTION

Sub-topic 3b · 23 questions · 282 marks · lowest tariff first

10 This is the equation for the decomposition of hydrogen peroxide.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

The rate of reaction increases when a catalyst of manganese(IV) oxide is added.

(a) Describe how a catalyst increases the rate of a reaction.

(2)

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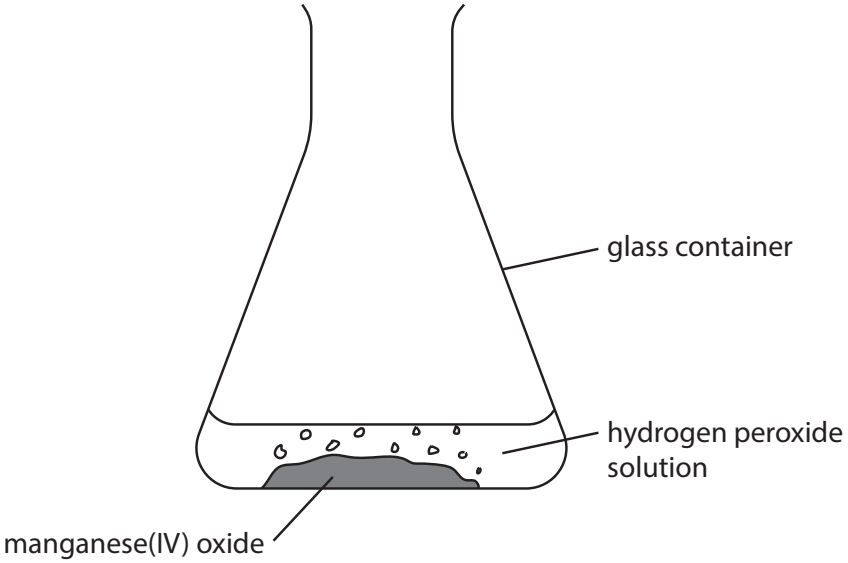
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(b) A student adds 50 cm^3 of hydrogen peroxide solution to a glass container and then adds 1.0 g of manganese(IV) oxide.

The diagram shows the apparatus the student uses.



(i) Name the glass container the student uses.

(1)

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(ii) The student waits until the hydrogen peroxide solution completely decomposes.

Describe how the student could then show that the manganese(IV) oxide was a catalyst and not a reactant.

(3)

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(Total for Question 10 = 6 marks)

5 Hydrogen peroxide solution decomposes to give water and oxygen gas.

The equation for this reaction is

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

(a) Three different solids are catalysts for the decomposition of hydrogen peroxide solution.

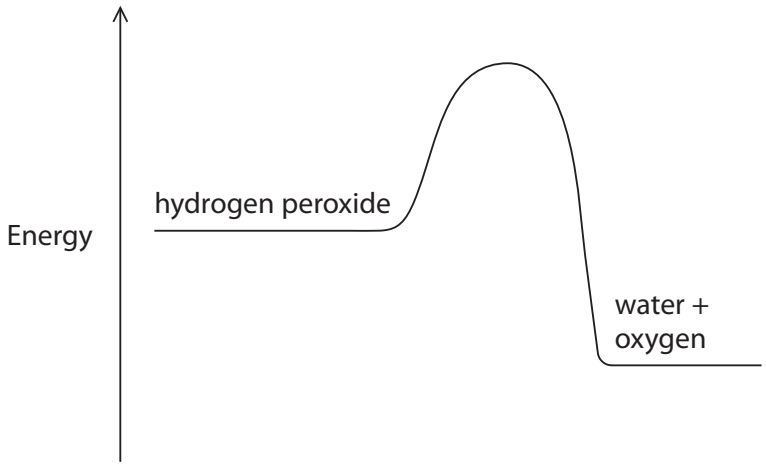
A student is given hydrogen peroxide solution and a sample of each of the solid catalysts.

The student has a timer, a measuring cylinder, a balance and the apparatus shown in the diagram.

Describe a method the student could use to find which of the three solids is the most effective catalyst for the decomposition of hydrogen peroxide solution.

(5)

(b) The diagram shows the reaction profile for the decomposition of hydrogen peroxide without a catalyst.



(i) Label the diagram to show the activation energy (E_a) and the enthalpy change (ΔH) for this reaction.

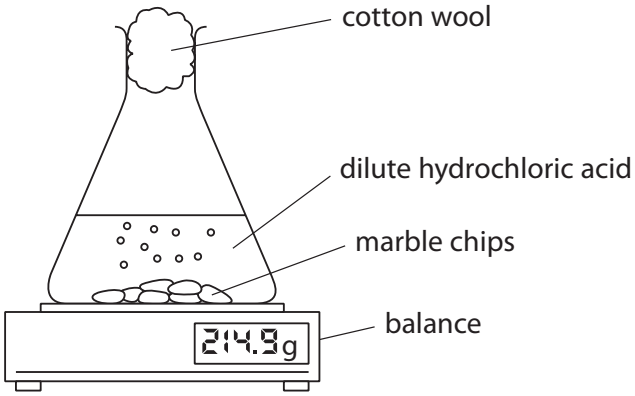
(2)

(ii) On the diagram, draw a curve to show the reaction profile for the same reaction when a catalyst is used.

(1)

(Total for Question 5 = 8 marks)

8 A student uses this apparatus to investigate the rate of reaction between marble chips and dilute hydrochloric acid.



This is the equation for the reaction.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

(a) Give a reason why the reading on the balance decreases during the reaction.

(1)

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(b) Explain why the rate of reaction is greatest at the start.

(2)

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(c) After 10 minutes, the reaction stops even though there are marble chips remaining.

Give a reason why the reaction stops.

(1)

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(d) The student repeats the experiment with hydrochloric acid at a higher temperature to investigate the effect on the rate of reaction.

(i) Give two variables that should be controlled to make sure the results are valid.

(2)

1 .....

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2 .....

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(ii) Explain the effect of increasing the temperature of hydrochloric acid on the rate of reaction.

(3)

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(Total for Question 8 = 9 marks)

9 This question is about rates of reaction.

(a) A student uses this method to investigate the rate of reaction between iron(III) nitrate solution and sodium thiosulfate solution.

- pour 50 cm^3 of iron(III) nitrate solution into a conical flask
- add one drop of catalyst solution
- add 50 cm^3 of sodium thiosulfate solution to the conical flask
- record the time for the mixture to become colourless

The student repeats the method using different catalysts and also with no catalyst.

The table shows the student's results.

Catalyst	Time for mixture to become colourless in s
no catalyst	55
cobalt(II) chloride solution	32
copper(II) sulfate solution	8
iron(II) sulfate solution	27
zinc nitrate solution	75

(i) Explain which is the best catalyst for the reaction.

(2)

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(ii) Explain how a catalyst increases the rate of a reaction.

(2)

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(b) The rate of a reaction can also be altered by changing the temperature or by changing the concentration of solutions.

(i) Explain, using the particle collision theory, how increasing the temperature affects the rate of a reaction.

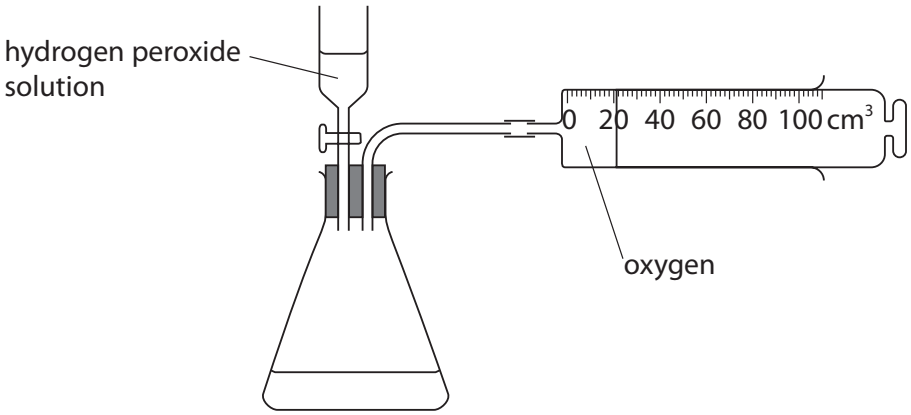
(4)

(ii) Explain why using a solution of a lower concentration decreases the rate of reaction.

(2)

(Total for Question 9 = 10 marks)

6 A student uses this apparatus to investigate the rate of reaction when hydrogen peroxide solution decomposes.



This is the equation for the reaction.

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

(a) Give a reason why the gas that collects in the gas syringe is not pure oxygen.

(1)

.....

.....

(b) The rate of reaction can be increased by adding a catalyst to the hydrogen peroxide solution.

Describe how a catalyst increases the rate of a reaction.

(2)

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(c) These solids catalyse the decomposition of hydrogen peroxide solution.

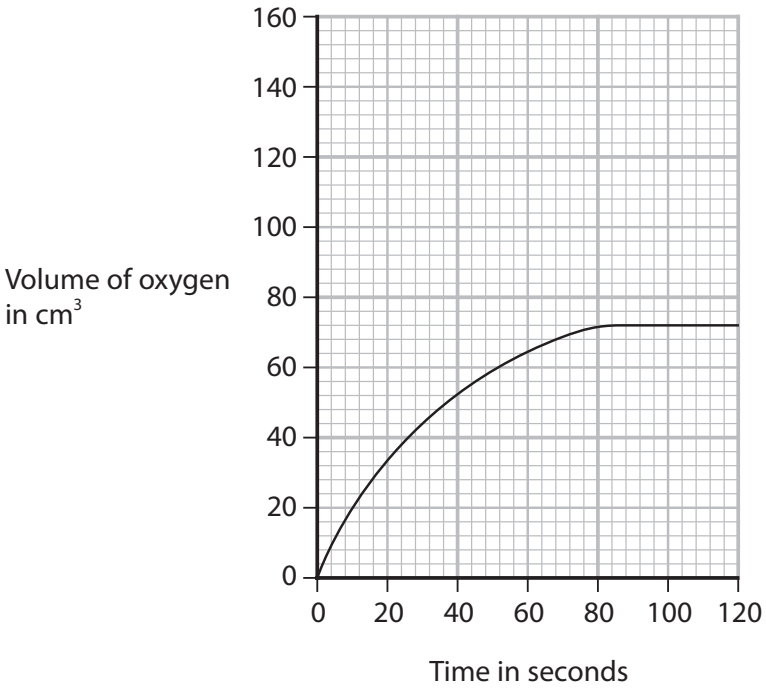
- lead(IV) oxide
- manganese(IV) oxide

Describe a method that the student could use to find out which solid is the more effective catalyst.

(5)

(d) A student investigates the decomposition of a solution of hydrogen peroxide at different temperatures.

The graph shows how the total volume of oxygen collected in the syringe changes with time when the solution is at a temperature of 20 °C.

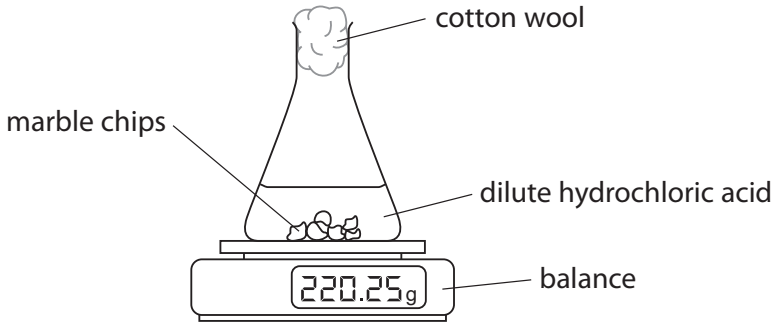


On the grid, draw the curve the student would obtain at a temperature of 40 °C when all other conditions are kept the same.

(2)

(Total for Question 6 = 10 marks)

9 A student uses this apparatus to investigate the rate of reaction between marble chips and dilute hydrochloric acid.



This is the equation for the reaction.

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$$

(a) During the reaction the reading on the balance decreases because mass is lost from the flask.

(i) State why mass is lost from the flask.

(1)

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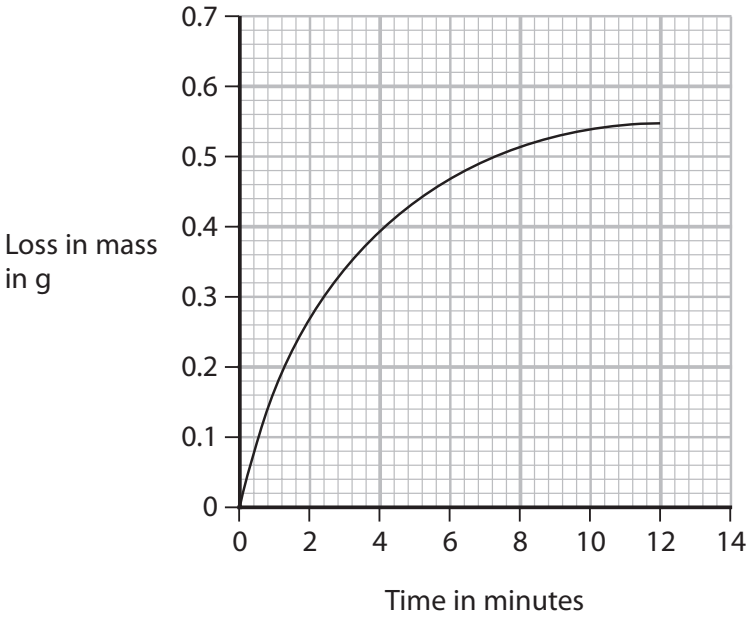
(ii) State the purpose of the cotton wool.

(1)

.....

.....

(b) This is a graph of the student's results.



(i) Explain the shape of the graph.

You should assume that the marble chips are in excess.

(4)

(ii) On the grid, draw the curve you would expect to obtain if the student uses the same volume of hydrochloric acid but with half the concentration.

Assume that all other conditions are kept the same.

(2)

(c) The student repeats the experiment using the same mass of smaller marble chips.

Explain, using particle collision theory, how using smaller marble chips would affect the rate of this reaction.

Assume that all other conditions are kept the same as in the initial experiment.

(3)

(Total for Question 9 = 11 marks)

5 Hydrogen peroxide decomposes to form water and oxygen.

This decomposition is shown in the equation.

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

(a) Give the test for oxygen gas.

(1)

.....

.....

(b) The rate of reaction is increased by adding a suitable catalyst.

Describe how a catalyst increases the rate of a reaction.

(2)

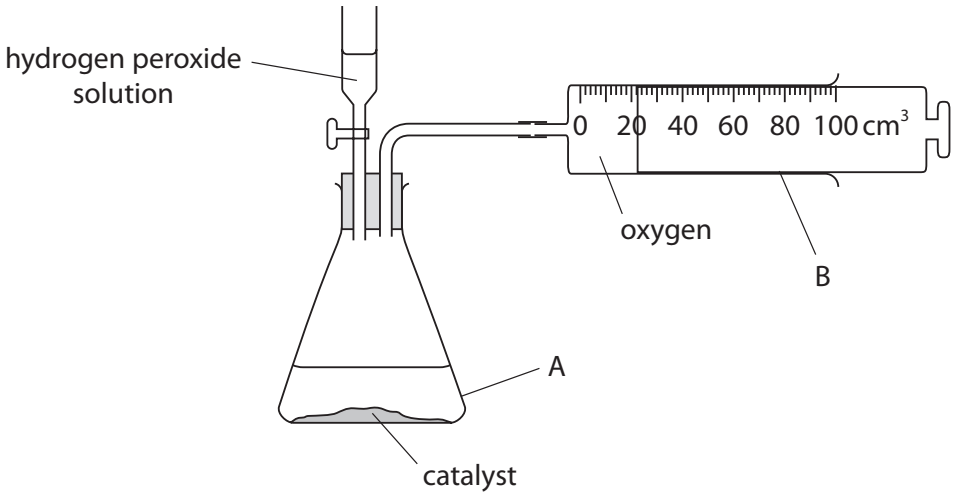
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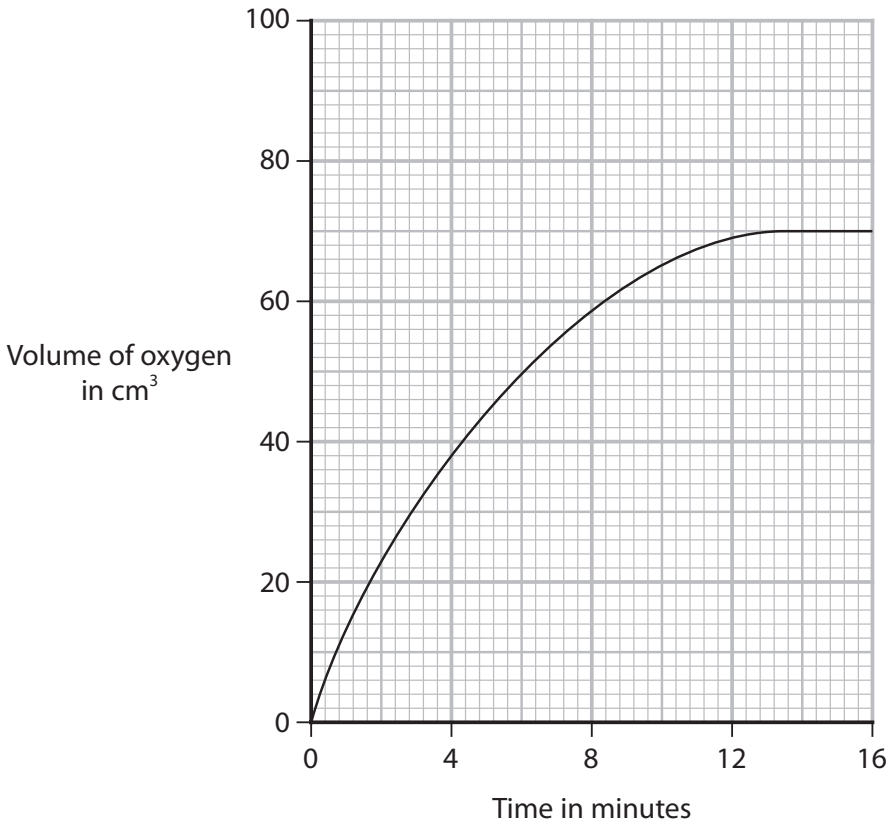
(c) A student uses this apparatus to investigate the rate of decomposition of hydrogen peroxide solution.



The student adds 100 cm^3 of hydrogen peroxide solution at 20 °C to the apparatus labelled A.

The student records the volume of oxygen gas collected every minute for 16 minutes.

The graph shows the student's results.



(i) Name the pieces of apparatus labelled A and B.

(2)

A .....

B .....

(ii) Determine the volume of oxygen gas produced in the first 4 minutes.

Show on the graph how you obtain your answer.

(2)

volume of oxygen = ... cm^3

(iii) Determine the rate of reaction at 8 minutes by drawing a suitable tangent to the curve.

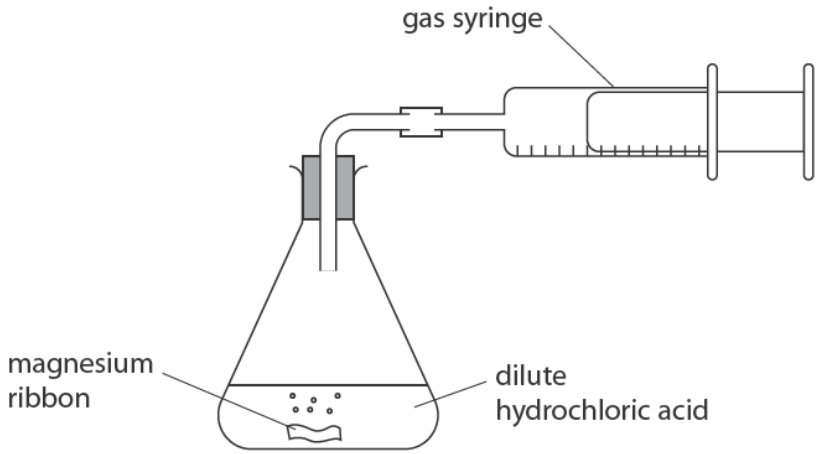
Include the units for the rate of reaction.

(4)

rate of reaction = ... units .....

(Total for Question 5 = 11 marks)

13 A student uses this apparatus to investigate the rate of reaction between magnesium and an **excess** of dilute hydrochloric acid.



She uses this method.

- use a graduated beaker to pour 50 cm^3 of dilute hydrochloric acid of concentration 2.00 mol/dm^3 into the conical flask
- add a piece of magnesium ribbon of mass 0.086 g to the acid and put the bung into the neck of the flask
- measure the total volume of gas collected every ten seconds until the reaction stops

The table shows the student's results.

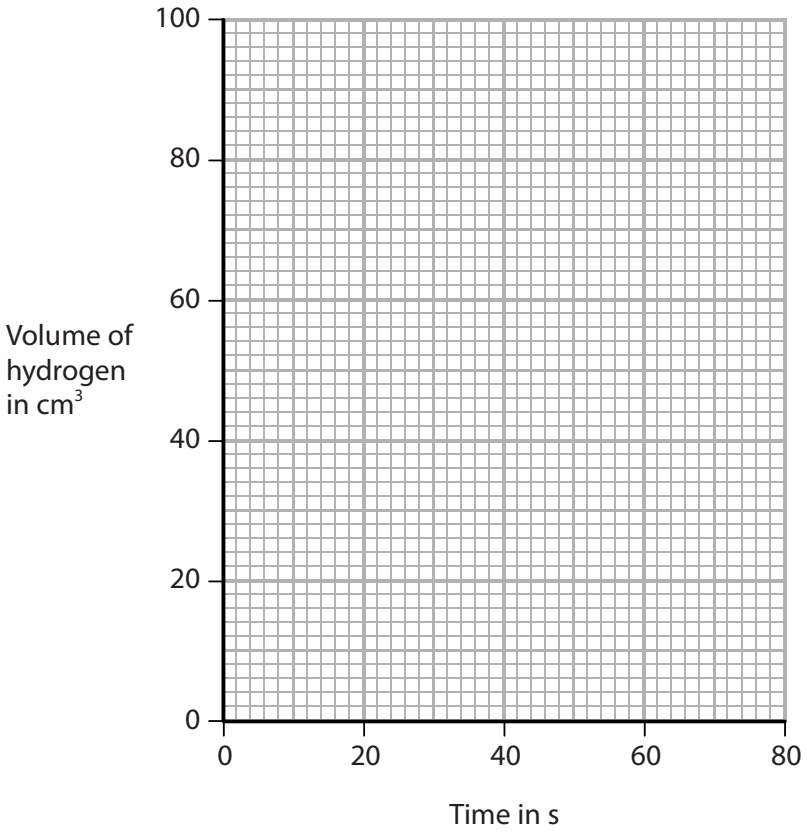
Time in s	Volume of hydrogen in cm^3
0	0
10	29
20	52
30	67
40	76
50	81
60	84
70	84
80	84

(a) (i) Plot the student's results on the grid.

(1)

(ii) Draw a curve of best fit.

(1)



(b) (i) The student repeats the experiment using

- 0.043 g of magnesium ribbon
- 50 cm^3 of 2.00 mol/dm^3 hydrochloric acid

Draw, on the grid in part (a), the curve you would expect in this experiment.

Label this curve Y.

(2)

(ii) The student repeats the experiment again, using

- 0.086 g of magnesium ribbon
- 50 cm^3 of 2.00 mol/dm^3 hydrochloric acid
- a slightly higher temperature than the first experiment

Draw, on the grid in part (a), the curve you would expect in this experiment.

Label this curve Z.

(2)

(c) The expected volume of gas produced in the first experiment is 86 cm^3.

Suggest why the volume collected is less than the expected volume.

(1)

(d) The student uses a graduated beaker to measure the volume of dilute hydrochloric acid.

Explain why it is **not** necessary to use a measuring cylinder in this experiment.

(2)

(e) The ionic equation for the reaction between magnesium and hydrochloric acid is

$$Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$$

Use the information in this equation, and the particle collision theory, to explain why the rate of reaction decreases during each of the experiments.

(3)

(Total for Question 13 = 12 marks)

6 Zinc reacts with dilute hydrochloric acid to form hydrogen.

(a) (i) Give a chemical equation for this reaction.

(2)

.....

(ii) Give a test for hydrogen gas.

(1)

.....

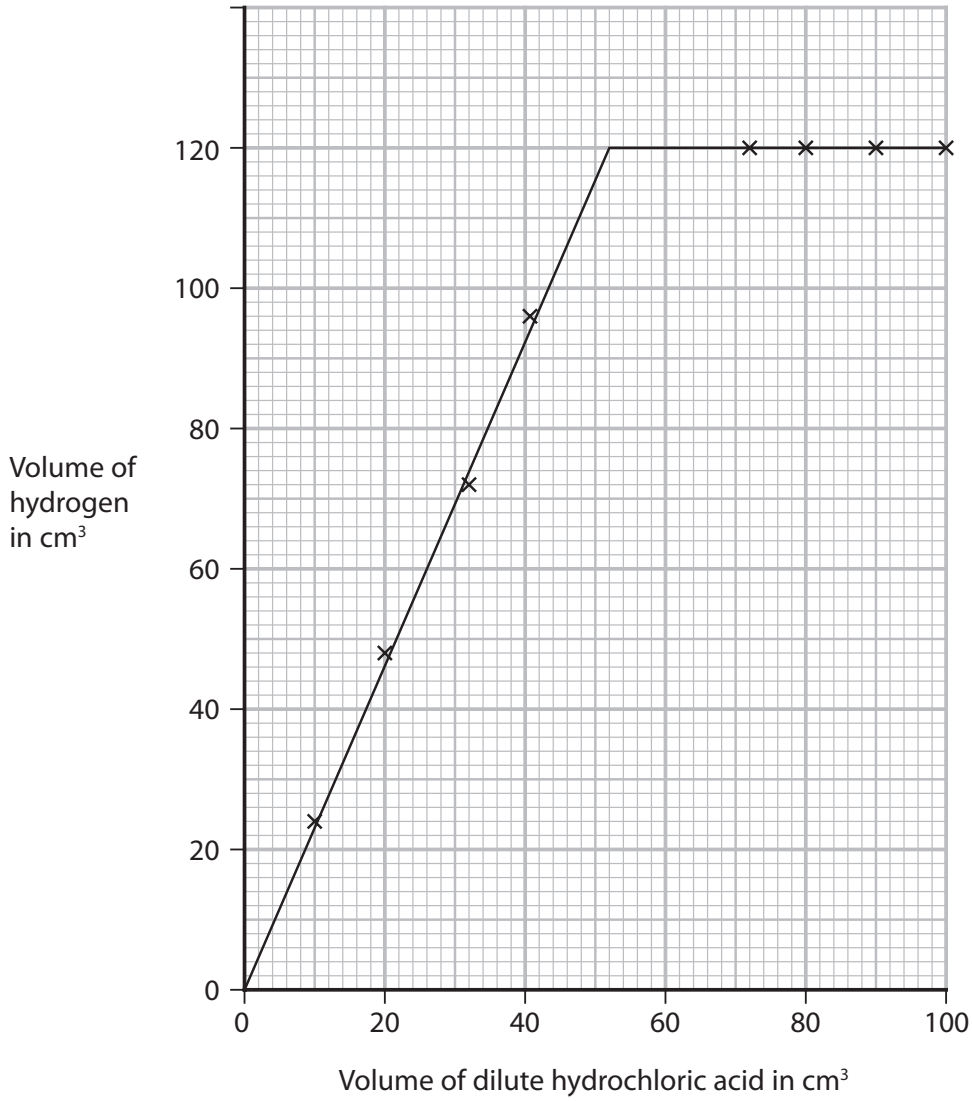
.....

(b) A student investigates the reaction between pieces of zinc and dilute hydrochloric acid.

In each experiment, he uses the same mass of zinc but a different volume of the acid.

He collects the hydrogen and measures its volume in each experiment.

The graph shows the student's results.



(i) Use the graph to find the minimum volume of acid needed to react with all of the zinc.

(1)

.....

(ii) The student repeats the investigation, using hydrochloric acid of double the original concentration.

Determine the volume of hydrogen that would be collected using 15 cm^3 of this acid.

Show your working on the graph.

(2)

volume = ... cm^3

(c) Explain how increasing the concentration of the hydrochloric acid affects the rate of reaction.

(3)

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.....

(d) The rate of reaction could also be affected by changing the temperature of the hydrochloric acid, or by using a catalyst.

Explain one other way in which the rate of reaction between zinc and hydrochloric acid can be affected.

(3)

(Total for Question 6 = 12 marks)

10 Zinc reacts with dilute hydrochloric acid to form zinc chloride and hydrogen gas.

This is the equation for the reaction.

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

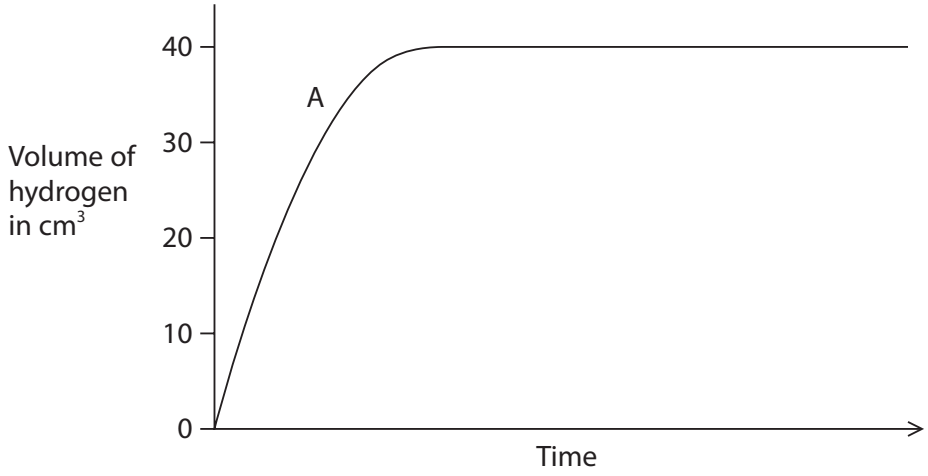
(a) In an experiment, 20 cm^3 of hydrochloric acid containing 0.0036 mol are reacted with 1.3 g of zinc granules at a temperature of 30 °C.

(i) Show by calculation that the zinc is in excess.

(2)

(ii) The volume of hydrogen collected is measured at regular time intervals.

Curve A shows the results of this experiment.



The experiment is repeated using 1.3 g of zinc powder instead of zinc granules.

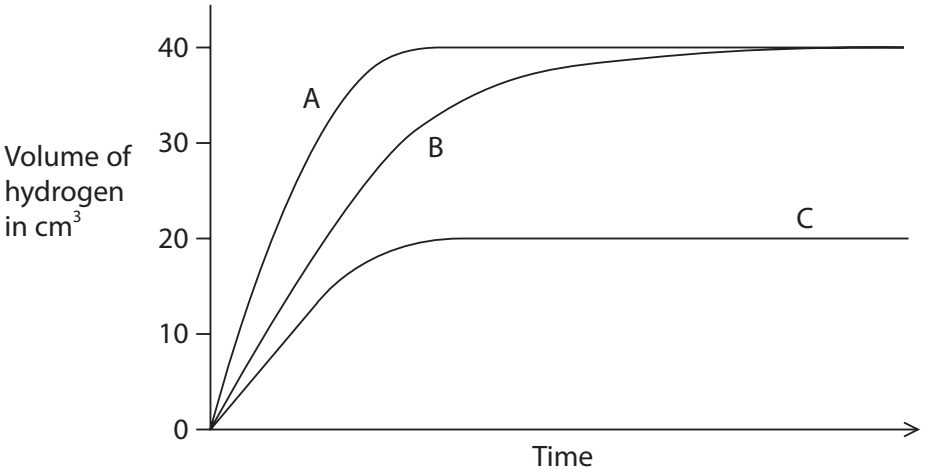
All other conditions are kept the same.

On the grid, draw the curve you would expect to obtain.

(2)

(b) In the original experiment, 20 cm^3 of hydrochloric acid containing 0.0036 mol were reacted with 1.3 g of zinc granules at a temperature of 30 °C and curve A was obtained.

The student does two more experiments and obtains curves B and C.



(i) In one of these experiments the student repeats the original method but at a temperature of 20 °C.

Explain in terms of particle collision theory why the curve obtained could be curve B.

(4)

(ii) In the other experiment the student repeats the original method but uses $20\,cm^3$ of hydrochloric acid containing 0.0018 mol.

Explain why curve C shows the results the student obtained.

(2)

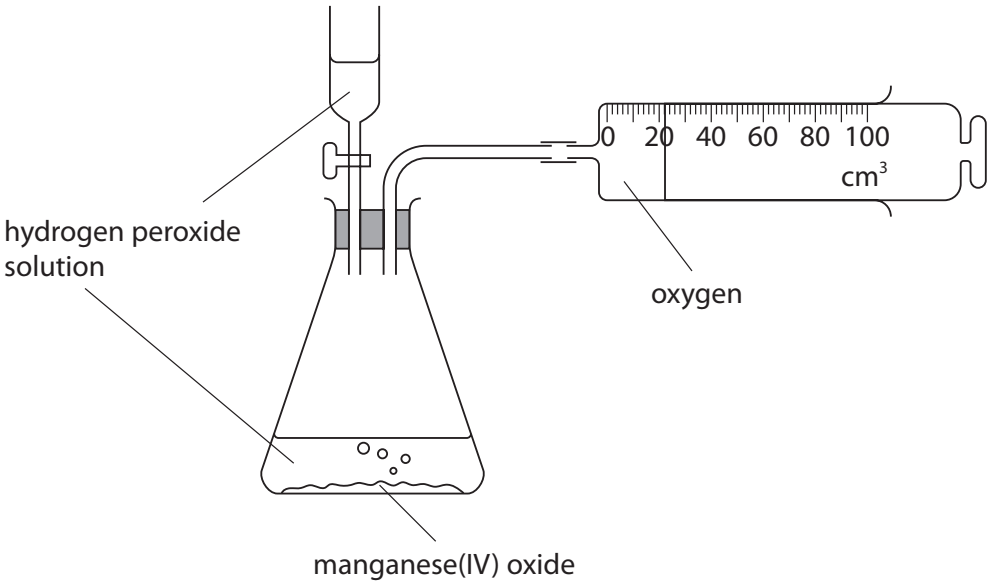
(c) Catalysts can be used to speed up reactions.

Describe how a catalyst works.

(2)

(Total for Question 10 = 12 marks)

6 A student uses this apparatus to investigate the decomposition of hydrogen peroxide solution.



This is the equation for the reaction.

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

(a) Give the test for oxygen.

(1)

.....

.....

(b) Complete the dot-and-cross diagram for a molecule of hydrogen peroxide.

Show outer electrons only.

(2)

H O O H

(c) The student measures the volume of oxygen collected at regular intervals until the reaction stops.

The table shows the student's results.

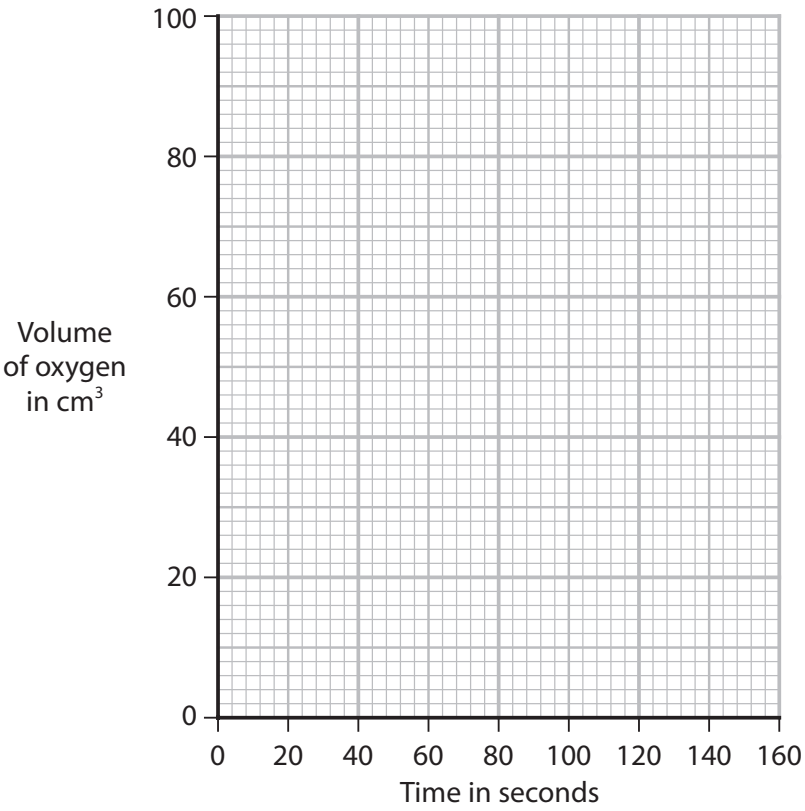
Time in seconds	0	20	40	60	80	100	120	140	160
Volume of oxygen in cm^3	0	24	44	62	78	88	94	94	94

(i) Plot the student's results on the grid.

(1)

(ii) Draw a curve of best fit.

(1)



(d) (i) Explain in terms of particle collision theory how decreasing the concentration affects the rate of a reaction.

(3)

(ii) The student repeats the experiment using the same volume of hydrogen peroxide solution but with half the original concentration.

All other conditions are kept the same.

On the grid, draw the curve you would expect the student to obtain.

(2)

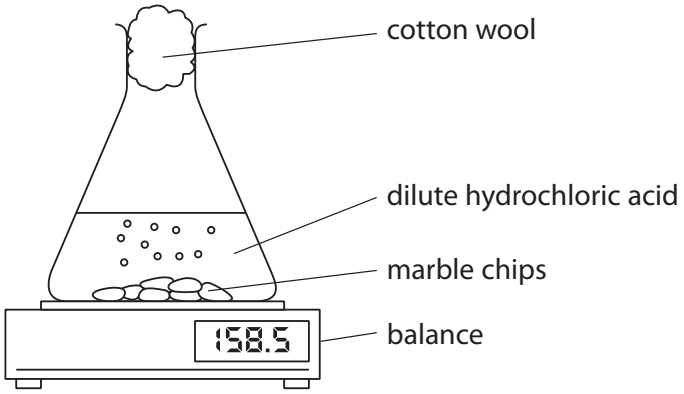
(e) In this reaction, the manganese(IV) oxide acts as a catalyst.

Explain how a catalyst works.

(2)

(Total for Question 6 = 12 marks)

5 A student uses this apparatus to investigate the rate of reaction between marble chips and dilute hydrochloric acid.



(a) During the reaction, the reading on the balance decreases because mass is lost from the flask.

(i) Explain how using the cotton wool increases the accuracy of this investigation.

(2)

.....

.....

.....

.....

(ii) Why is mass lost from the flask?

(1)

☒ **A** acid particles are moving

☒ **B** gas is given off

☒ **C** heat energy is produced

☒ **D** marble chips are dissolving

(b) This is the equation for the reaction between marble chips and dilute hydrochloric acid.

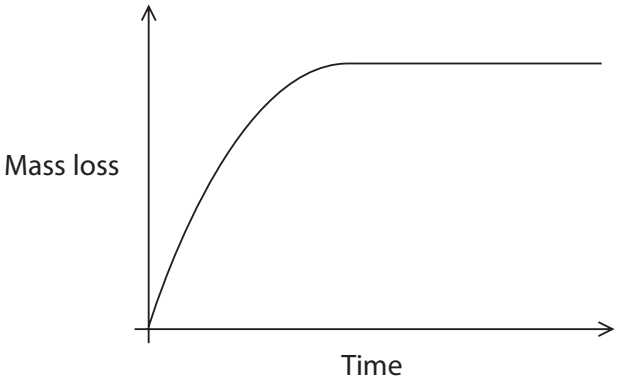
Complete the equation by adding the state symbols.

(2)

$CaCO_3$ (.....) + 2HCl (.....) → $CaCl_2$ (.....) + H_2O (.....) + CO_2 (.....)

(c) The student uses large marble chips in the investigation.

This is a graph of his results.



The student repeats the experiment using the same total mass of smaller marble chips.

On the graph, draw the curve that would be obtained.

[assume the marble chips are in excess]

(2)

(d) The rate of this reaction can be altered by increasing the temperature or by increasing the concentration of the hydrochloric acid.

(i) Explain, using the particle collision theory, how increasing the concentration of the hydrochloric acid would affect the rate of this reaction.

(3)

(ii) Explain, using the particle collision theory, how increasing the temperature would affect the rate of this reaction.

(3)

(Total for Question 5 = 13 marks)

4 A student investigates the effect of temperature on the rate of reaction between two solutions, A and B. When the reaction occurs, the mixture turns from colourless to blue.

This is the student's method.

- pour 25 cm^3 of solution A into a conical flask
- add solution B and measure the temperature of the mixture
- record the time taken for the mixture to turn blue

The student repeats this method at different temperatures.

(a) Give two variables that the student needs to keep constant in this investigation.

(2)

1 .....

2 .....

(b) The table shows the student's results.

Temperature in °C	15	20	25	35	45	65
Time taken in seconds	178	156	132	130	122	113

(i) Plot the student's results on the grid.

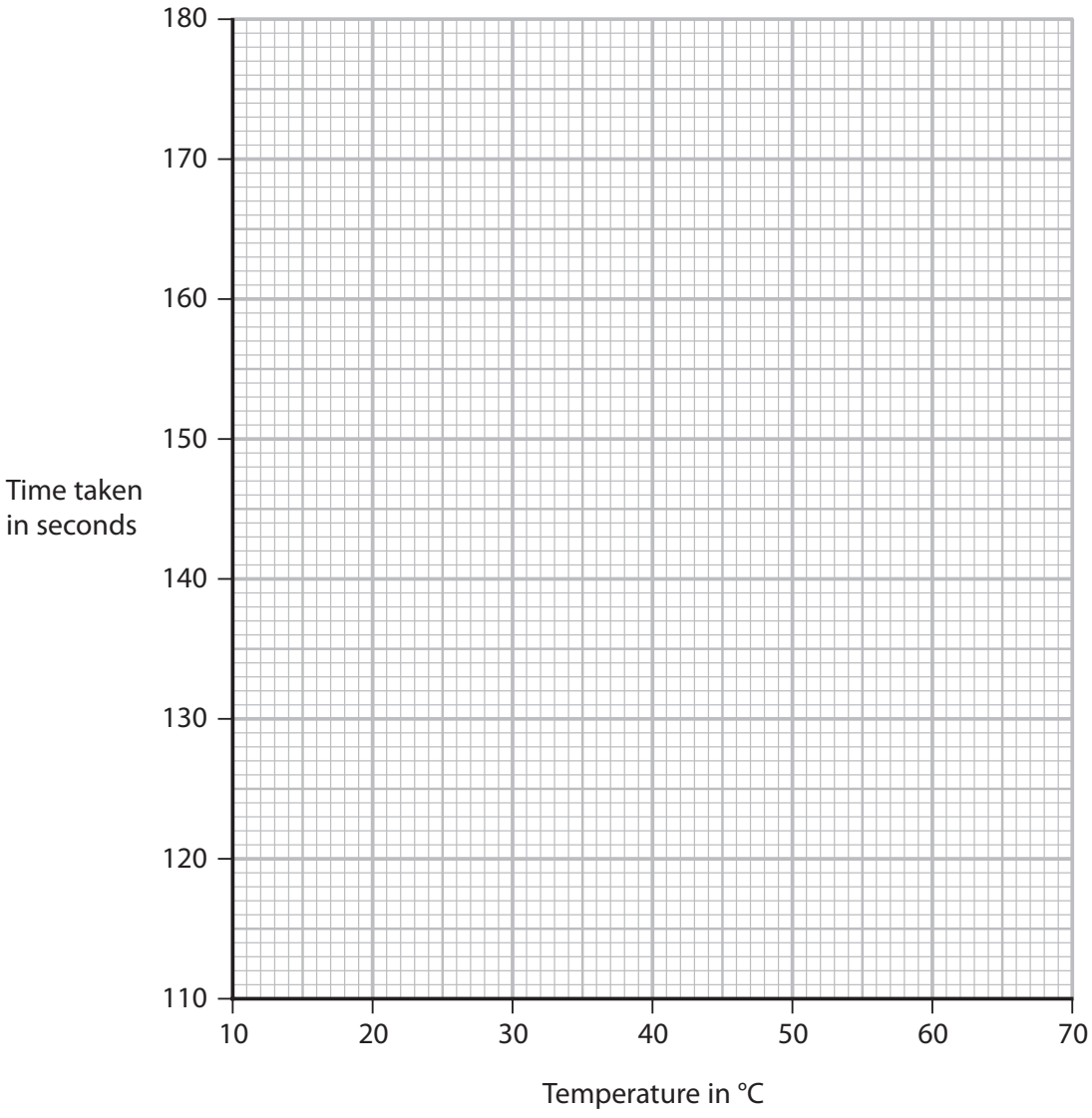
(1)

(ii) Draw a circle around the anomalous result.

(1)

(iii) Draw a curve of best fit.

(1)



(iv) Give a reason for the anomalous result.

(1)

.....

.....

(v) Use your graph to determine the time taken for the mixture to turn blue at 55 °C.

Show your working on the graph.

(2)

time taken = ... s

(c) Use information from the table to calculate the mean rate of reaction at 20 °C.

Use the expression

$$\text{mean rate} = \frac{1}{\text{time in seconds}}$$

Give your answer in standard form.

(2)

mean rate = ... s^{-1}

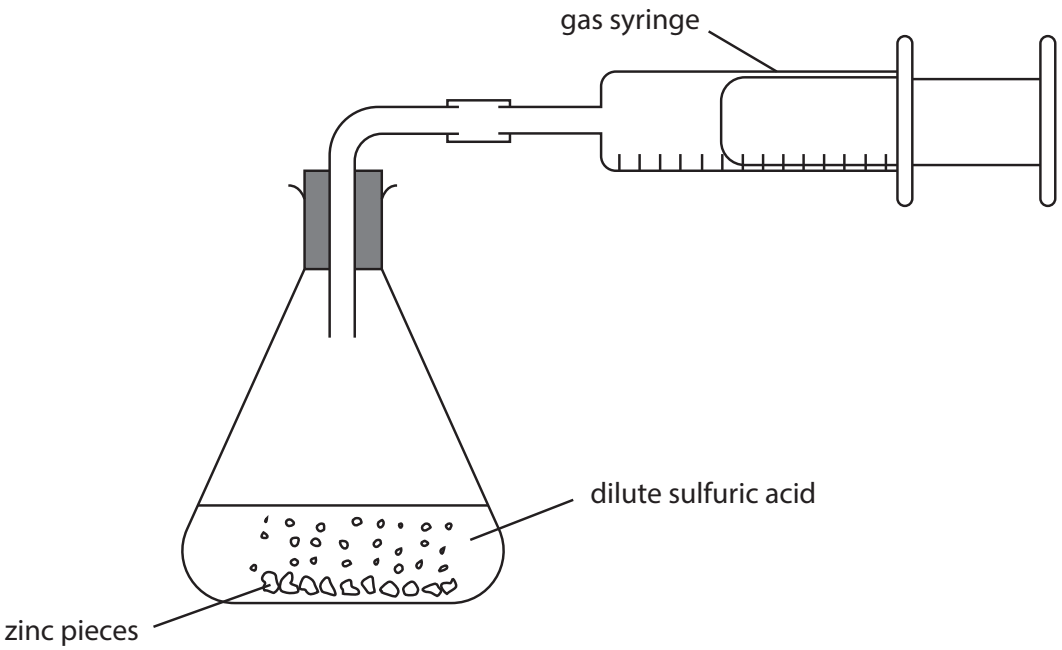
(d) Explain how increasing the temperature affects the rate of a reaction.

Refer to particle collision theory in your answer.

(3)

(Total for Question 4 = 13 marks)

7 A student uses this apparatus to investigate the rate of reaction between dilute sulfuric acid and an excess of small pieces of zinc.



This is the student's method.

Step 1 use 50 cm^3 of dilute sulfuric acid

Step 2 add approximately 5 g of small zinc pieces to the sulfuric acid

Step 3 quickly connect the gas syringe

Step 4 record the reading on the gas syringe every 30 seconds until the reaction stops

(a) (i) Name a suitable piece of apparatus to measure the volume of sulfuric acid.

(1)

.....

(ii) Give a reason why the mass of zinc pieces does not need to be measured accurately.

(1)

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(iii) Give a reason why the student quickly connects the gas syringe in step 3.

(1)

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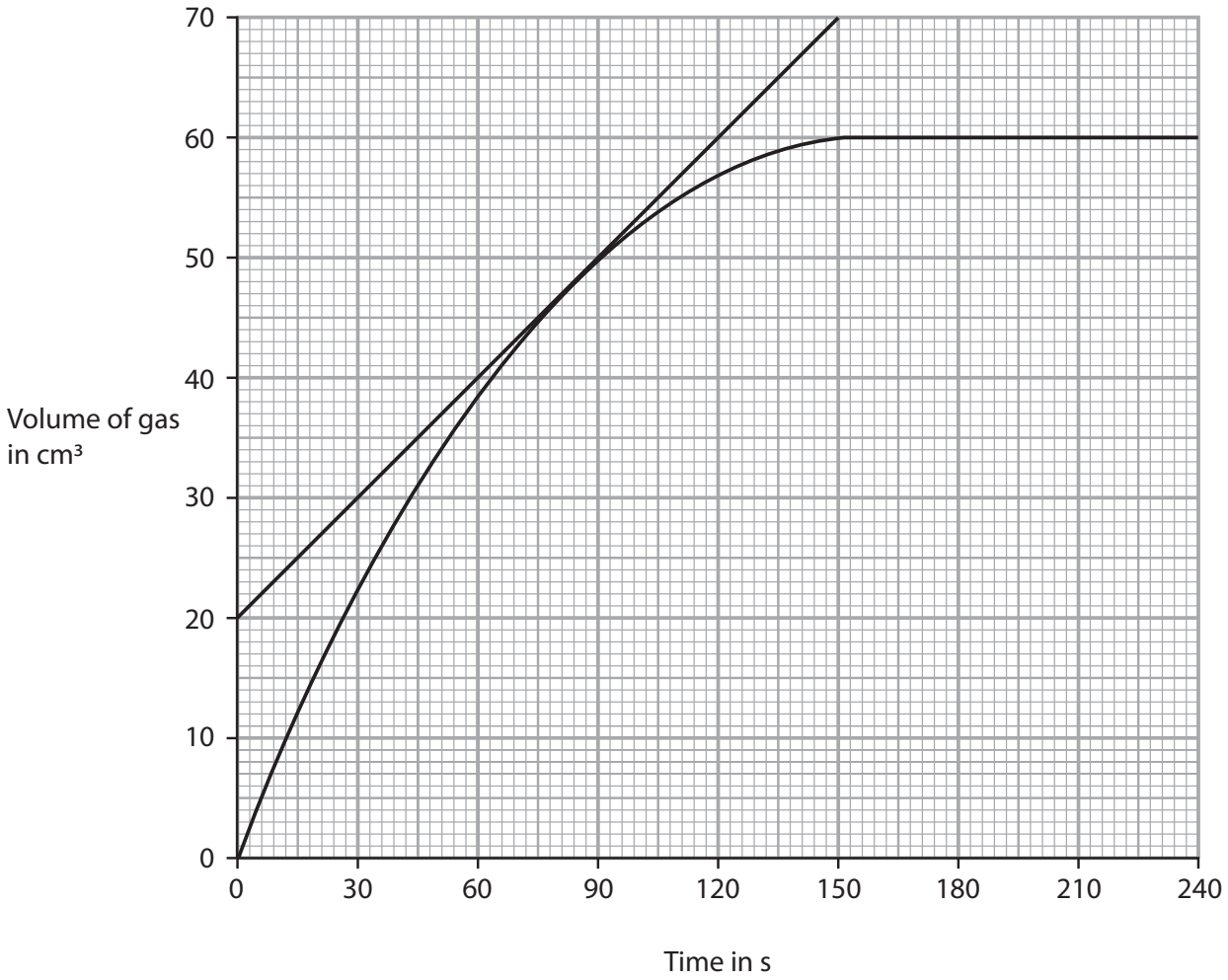
(iv) State how the student would know when the reaction stops.

(1)

.....

.....

(b) The graph shows the volume of gas collected in the syringe during the experiment.



(i) A tangent to the curve has been drawn at a time of 80 s.

Use the tangent to calculate the rate of reaction at 80 s.

Show your working on the graph.

Give the unit.

(3)

rate of reaction = ... unit .....

(ii) Explain the shape of the graph in these regions.

(6)

from 0 s to 60 s

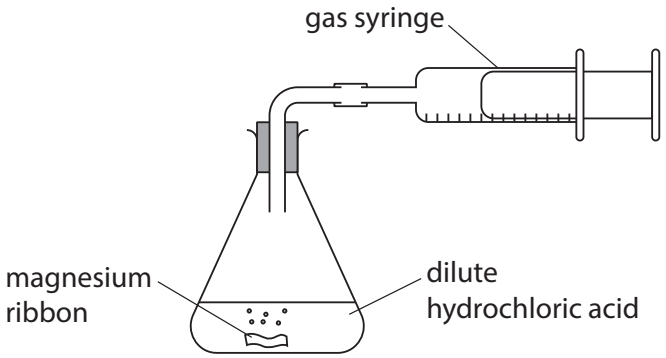
from 60 s to 150 s

from 150 s to 240 s

(Total for Question 7 = 13 marks)

2 Magnesium reacts with dilute hydrochloric acid to form magnesium chloride and hydrogen.

The hydrogen is collected in a gas syringe.



The reaction is exothermic and magnesium is in excess.

(a) State what is meant by the term **exothermic**.

(1)

.....

.....

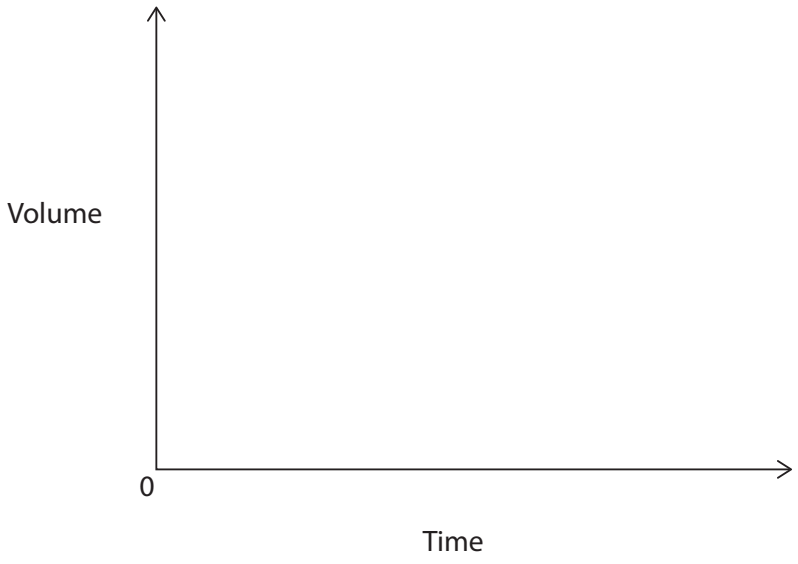
(b) Complete the chemical equation for the reaction.

(1)

Mg + 2HCl → ..... + ...

(c) Draw a sketch graph to show how the volume of hydrogen changes with time until the reaction has finished.

(2)



(d) Explain why increasing the temperature of the hydrochloric acid affects the rate of the reaction.

Refer to collision theory in your answer.

(4)

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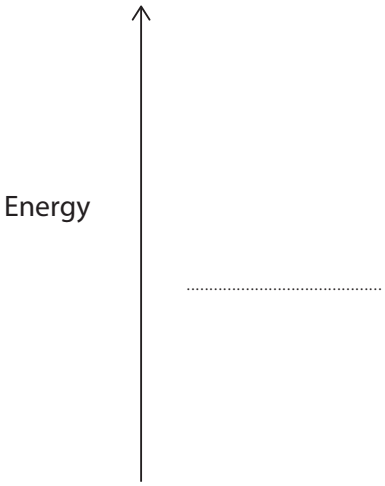
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(e) Draw a reaction profile diagram for the reaction, showing ΔH and activation energy.

Label the reactants and products.

(5)



.....

(Total for Question 2 = 13 marks)

7 Dilute hydrochloric acid reacts with a solution of sodium thiosulfate ($Na_2S_2O_3$) to form a precipitate.

The equation for the reaction is

$$Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + S(s) + H_2O(l) + SO_2(g)$$

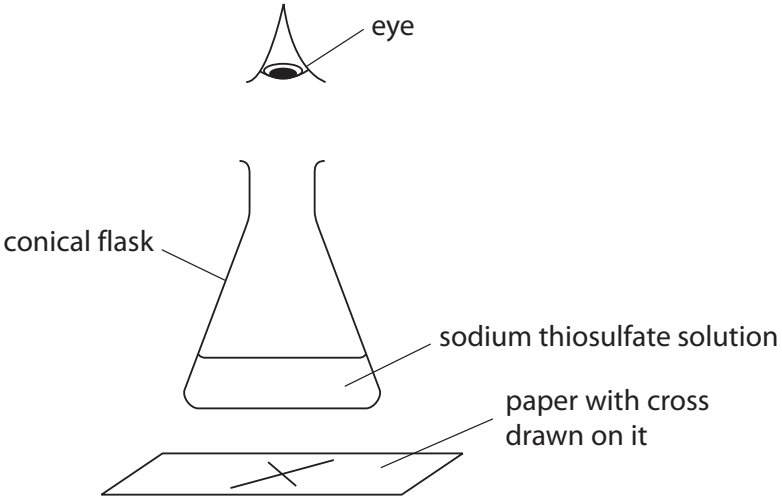
(a) State the name of the precipitate that forms.

(1)

.....

(b) The reaction is often used to investigate rates of reaction.

The diagram shows the apparatus a student uses to investigate the effect of temperature on the rate of the reaction.



This is the student's method.

- pour 50 cm^3 of cold sodium thiosulfate solution into a conical flask and heat it to 20 °C
- draw a cross (×) on a piece of paper and place it under the flask
- add 5 cm^3 of dilute hydrochloric acid to the flask
- look at the cross from above and record the time taken until the cross cannot be seen

The student repeats the experiment four times, using sodium thiosulfate solution at a different temperature each time.

He keeps the volumes of sodium thiosulfate solution and hydrochloric acid constant in each experiment.

Give two other factors that the student should keep constant.

(2)

1 .....

.....

2 .....

.....

(c) The table shows the student's results.

Temperature in °C	Time until cross cannot be seen in s
20	400
30	188
40	84
50	44
60	24

The highest temperature the student uses is 60 °C because he thinks the results might not be as accurate at temperatures higher than 60 °C.

Suggest a reason why the results might not be as accurate at temperatures higher than 60 °C.

(1)

.....

.....

.....

(d) The student wants to compare the rates of the reaction at the different temperatures.

He uses this formula to obtain a value for each rate of reaction

$$\text{rate} = \frac{1}{\text{time in s}}$$

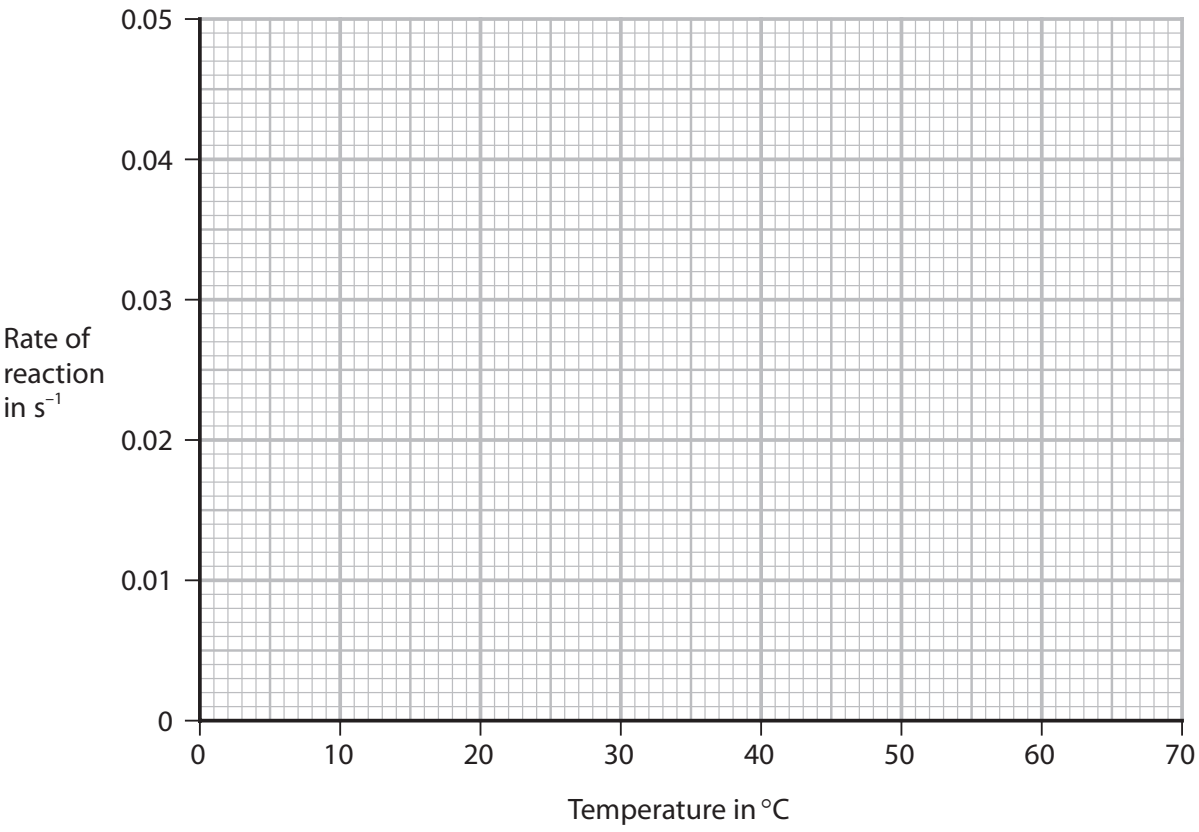
The table shows the value of the rate of reaction at each temperature.

Temperature in °C	Time until cross cannot be seen in s	Rate of reaction in s^{-1}
20	400	0.0025
30	188	0.0053
40	84	0.012
50	44	0.023
60	24	0.042

Plot the values of temperature and rate of reaction on the grid.

Draw a curve of best fit through the points.

(2)



(e) (i) Use the graph to determine a value for the rate of the reaction at 45 °C.

Show on the graph how you obtained your answer.

(2)

rate of reaction = ... s^{-1}

(ii) Calculate the time that it would take for the cross not to be seen at 45 °C.

(2)

time = ... s

(iii) Describe the relationship between rate of reaction and temperature shown by the graph.

(1)

.....

.....

(f) Explain, in terms of particle collision theory, the effect that increasing the temperature has on the rate of a reaction.

(3)

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.....

(Total for Question 7 = 14 marks)

4 A solution of hydrogen peroxide decomposes when a catalyst of manganese(IV) oxide is added.

The products of the reaction are water and oxygen.

(a) Complete the chemical equation for this reaction.

(1)

..... H_2O_2 → ..... H_2O + ... O_2

(b) Give a test for oxygen.

(1)

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(c) State the reason for adding a catalyst.

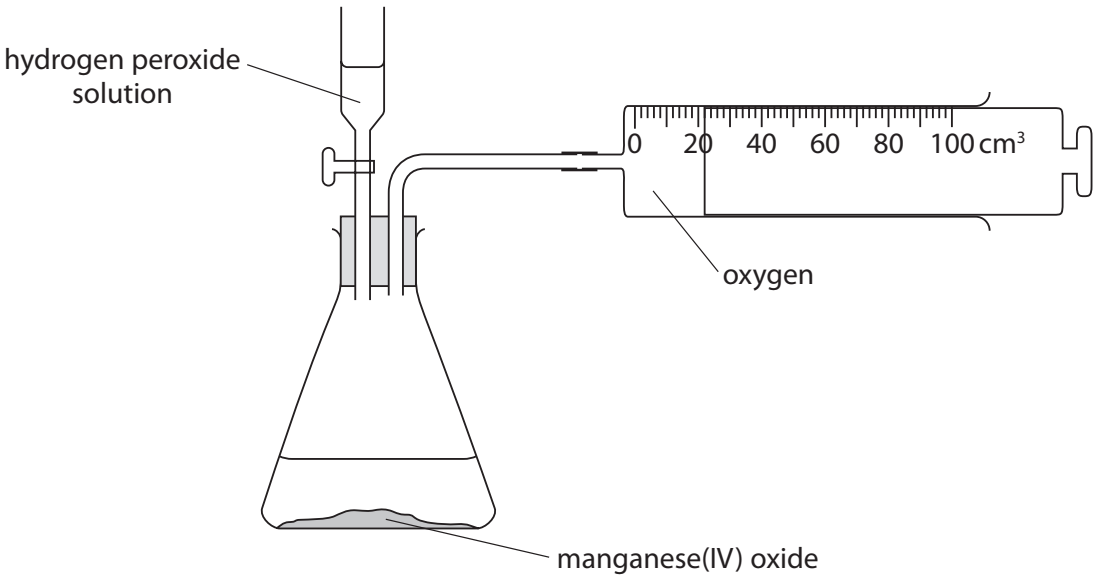
(1)

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(d) A student investigates how changing the concentration of the hydrogen peroxide solution affects the rate of this reaction.

She uses this apparatus.



The student records the volume of oxygen that collects every 2 minutes for 16 minutes.

The table shows her results.

Time in minutes	0	2	4	6	8	10	12	14	16
Volume of oxygen in cm³	0	22	38	50	55	69	76	80	80

(i) Plot the student's results on the grid.

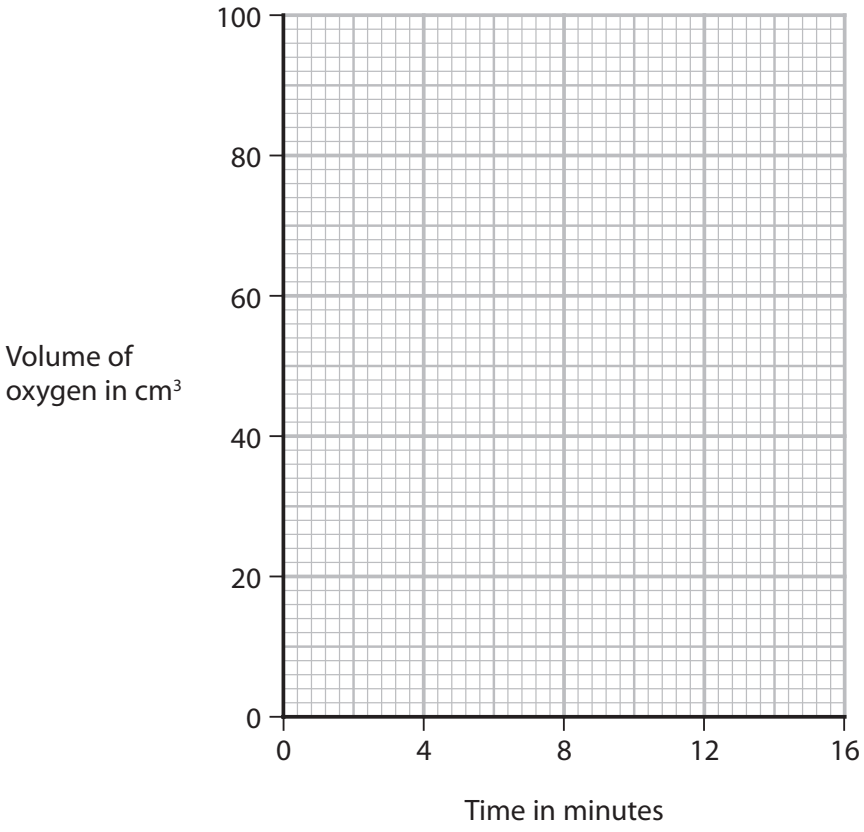
(1)

(ii) Draw a circle on the grid around the anomalous result.

(1)

(iii) Draw a curve of best fit through the points, ignoring the anomalous result.

(1)



(iv) Suggest a mistake that the student might have made to cause the anomalous result.

(1)

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(v) Determine the volume of oxygen collected during the first 3 minutes.

Show on your graph how you obtain your answer.

(2)

volume of oxygen = ... cm^3

(e) The student repeats the experiment using hydrogen peroxide solution of half the concentration of the original solution.

She keeps the volume of the hydrogen peroxide solution and all other conditions the same.

(i) Draw on the grid the curve you would expect the student to obtain.

(2)

(ii) Explain how using hydrogen peroxide solution of half the concentration affects the rate of the reaction.

Refer to particle collision theory in your answer.

(3)

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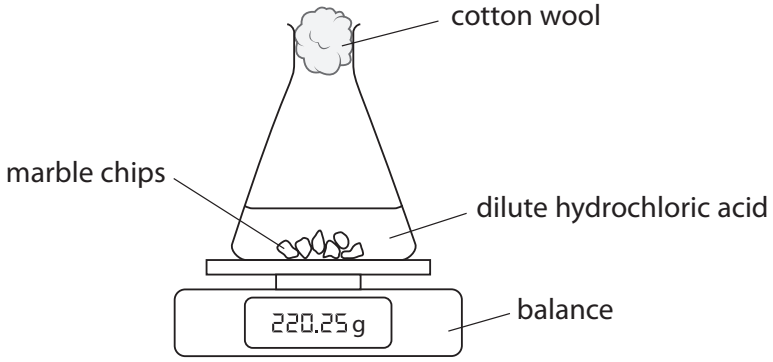
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(Total for Question 4 = 14 marks)

9 A student uses this apparatus to investigate the rate of reaction between marble chips and dilute hydrochloric acid.



The equation for the reaction is

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$$

(a) During the reaction the mass of the contents of the flask decreases.

(i) State why the mass of the contents of the flask decreases.

(1)

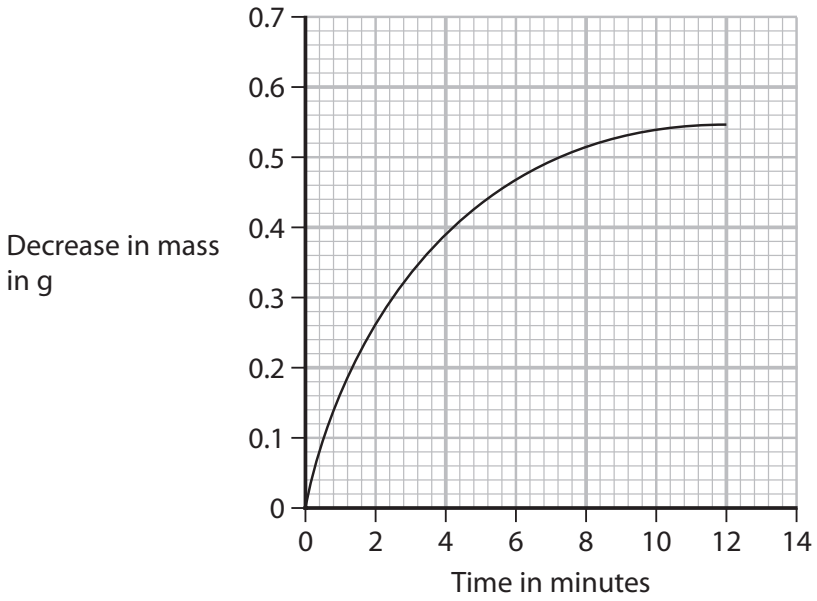
(ii) State the purpose of the cotton wool.

(1)

(iii) Explain why sulfuric acid is not a suitable acid to use in this investigation.

(2)

(b) The graph shows the student's results.



(i) In the investigation the marble chips are in excess.

Explain the shape of the graph.

(4)

(ii) The student repeats the experiment using the same volume of hydrochloric acid but of half the concentration of the original acid. All other conditions are kept the same.

On the grid, draw the curve the student would obtain.

(2)

(c) Explain, using particle collision theory, how increasing the temperature affects the rate of a reaction.

(4)

(Total for Question 9 = 14 marks)

11 This question is about reactions that form gases.

(a) Hydrogen peroxide decomposes to form water and oxygen.

The equation for the reaction is

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

25.0 cm^3 of hydrogen peroxide solution are poured into a conical flask and 1.00 g of solid manganese(IV) oxide is added.

Bubbles of oxygen gas are formed.

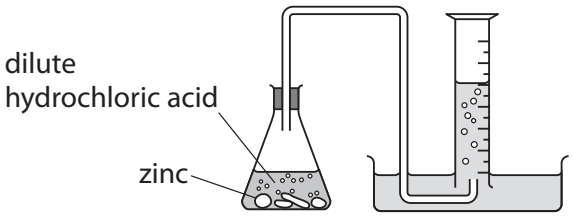
(i) Give the test for oxygen gas.

(1)

(ii) Describe a method to show that solid manganese(IV) oxide is a catalyst in this reaction and not a reactant.

(3)

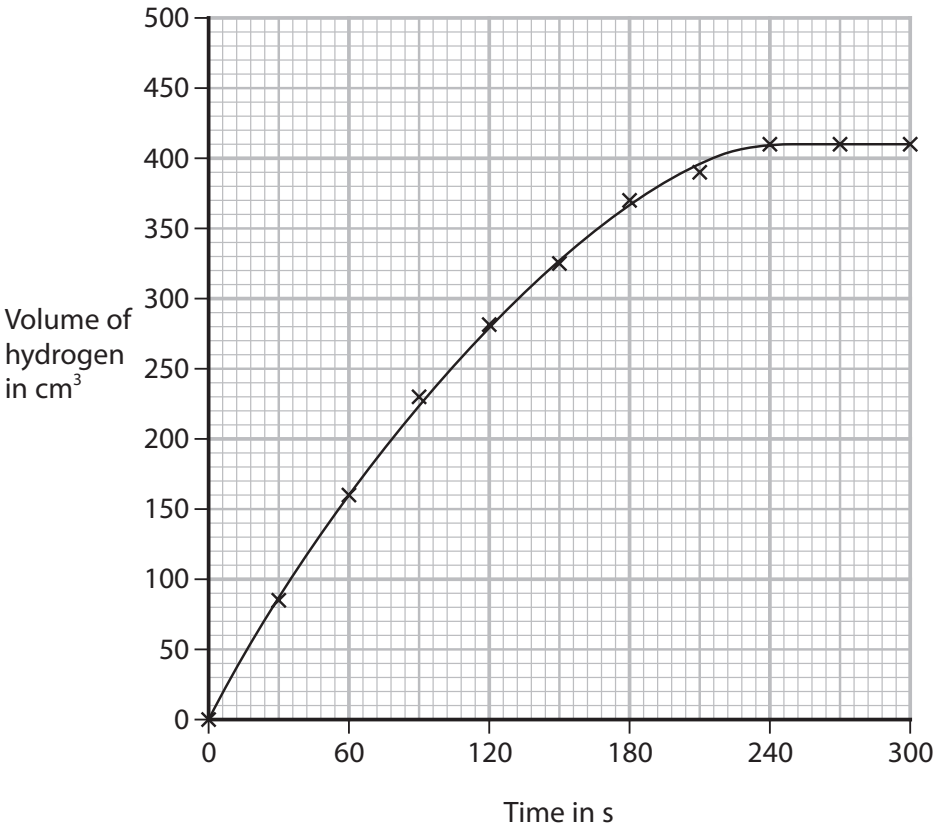
(b) A student uses this apparatus to investigate the rate of the reaction between zinc and an excess of dilute hydrochloric acid.



This is the student's method.

- pour 50 cm^3 of dilute hydrochloric acid into a conical flask
- add about 1.2 g of zinc lumps
- record the volume of hydrogen gas collected every 30 s until no more hydrogen is collected

The graph shows the student's results.



(i) Calculate the mean (average) rate of reaction, in cm^3/s, in the first 120 s.

(2)

mean rate = ... cm^3/s

(ii) The equation for the reaction between zinc and hydrochloric acid is

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

Use this equation and the particle collision theory to explain why the rate of reaction is greatest at the start of the reaction.

(3)

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(iii) The student repeats the experiment at a higher temperature but keeps all other conditions the same.

On the grid, draw the curve you would expect to see in this experiment.

(2)

Question continues on next page

(iv) Explain why the rate of reaction is greater if the same mass of zinc powder is used instead of zinc lumps. All other conditions are kept the same.

(2)

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(c) In another experiment, the student adds 0.55 g of zinc to a solution containing 2.50×10^{-2} moles of hydrochloric acid.

Use the equation to show that hydrochloric acid is in excess.

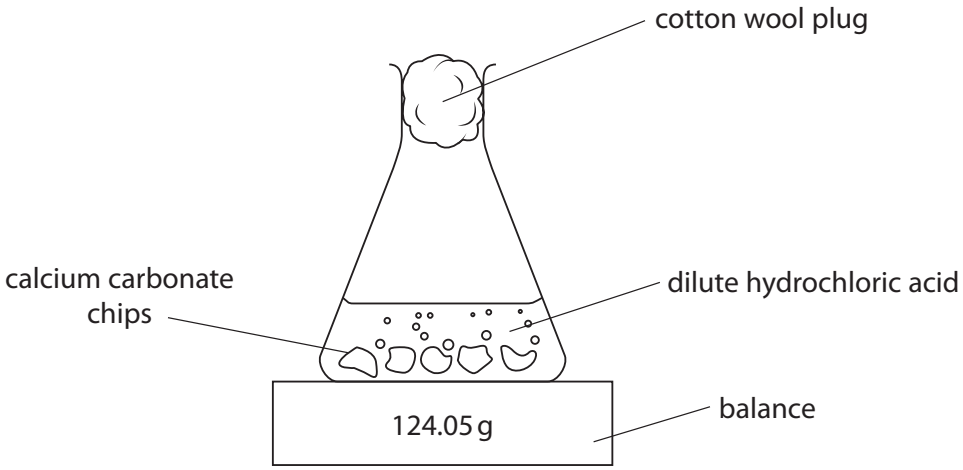
$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

[A_r of Zn = 65]

(2)

(Total for Question 11 = 15 marks)

9 A student uses this apparatus to investigate the rate of reaction between calcium carbonate chips and dilute hydrochloric acid.



Every 20 seconds the student records the reading on the balance.

(a) Explain why using a cotton wool plug increases the accuracy of the student's results.

(2)

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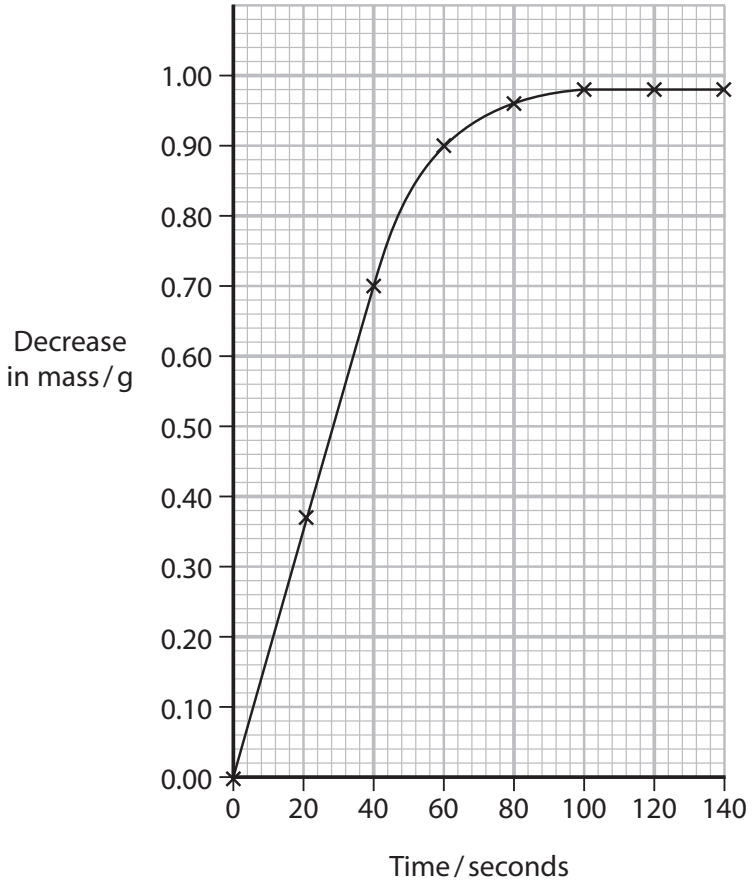
(b) Complete the equation for the reaction by adding the state symbols.

(2)

$$CaCO_3(\quad) + 2HCl(\quad) \rightarrow CaCl_2(aq) + H_2O(\quad) + CO_2(\quad)$$

(c) The student uses the balance readings to find the decrease in mass of the flask and contents.

The graph shows the student's results.



(i) Give a reason why there are some calcium carbonate chips remaining in the flask when the reaction stops.

(1)

.....

.....

(ii) State how the student would know when the reaction has stopped.

(1)

.....

.....

(iii) Use the graph to determine the amount, in moles, of carbon dioxide produced during the reaction.

[M_r of CO_2 = 44]

(2)

amount = ... mol

(iv) Use the graph to calculate the rate of reaction, in grams per second, at time 60 seconds.

Show your working on the graph.

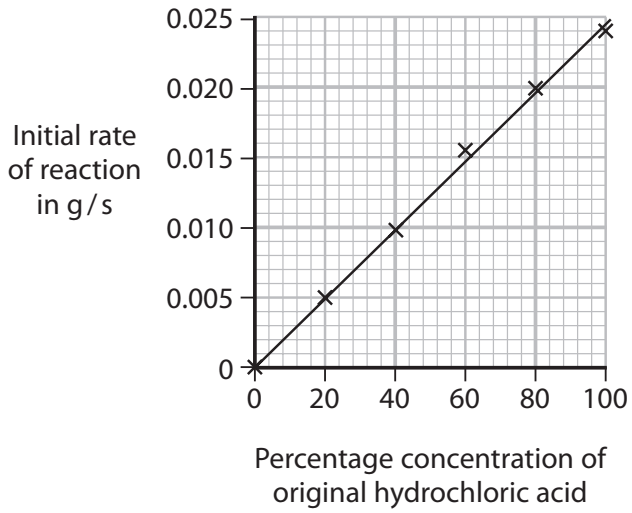
(3)

rate of reaction = ... g / s

(d) The student repeats the investigation by diluting the original hydrochloric acid.

The student then determines the initial rate of reaction at different percentage concentrations of the original hydrochloric acid.

The graph shows the student's results.



(i) Describe the relationship between the initial rate of reaction and percentage concentration of the original hydrochloric acid.

(2)

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(ii) Explain why changing the concentration of hydrochloric acid has an effect on the initial rate of reaction.

(2)

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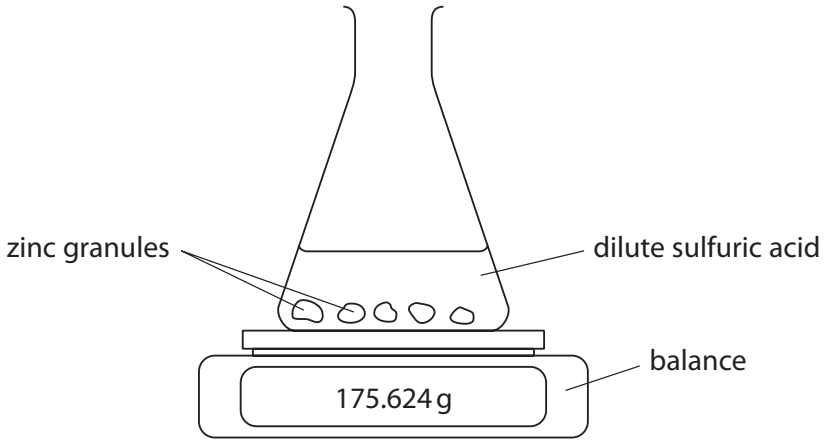
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(Total for Question 9 = 15 marks)

8 A student uses this apparatus in an experiment to study the rate of the reaction between zinc and dilute sulfuric acid.



This is the student's method.

- add a few zinc granules to a conical flask on a balance
- add 100 cm^3 of dilute sulfuric acid to the flask, start a timer and immediately record the mass of the flask and contents
- record the mass of the flask and contents every minute until the mass remains constant

The mass of the flask and contents decreases because hydrogen gas is produced and leaves the flask.

The student uses the mass readings to calculate the total mass of hydrogen produced.

(a) Complete the equation for the reaction by adding the state symbols.

(1)

$$Zn\ (\ldots\ldots) + H_2SO_4\ (\ldots\ldots) \rightarrow ZnSO_4\ (\ldots\ldots) + H_2\ (\ldots\ldots)$$

(b) The table shows the student's results.

Time in minutes	Total mass of hydrogen produced in mg
0	0
1	80
2	110
3	130
4	148
5	162
6	165
7	184
8	192
9	198
10	204
11	209
12	214
13	218
14	220
15	220

(i) Plot the student's results. The first three have been done for you.

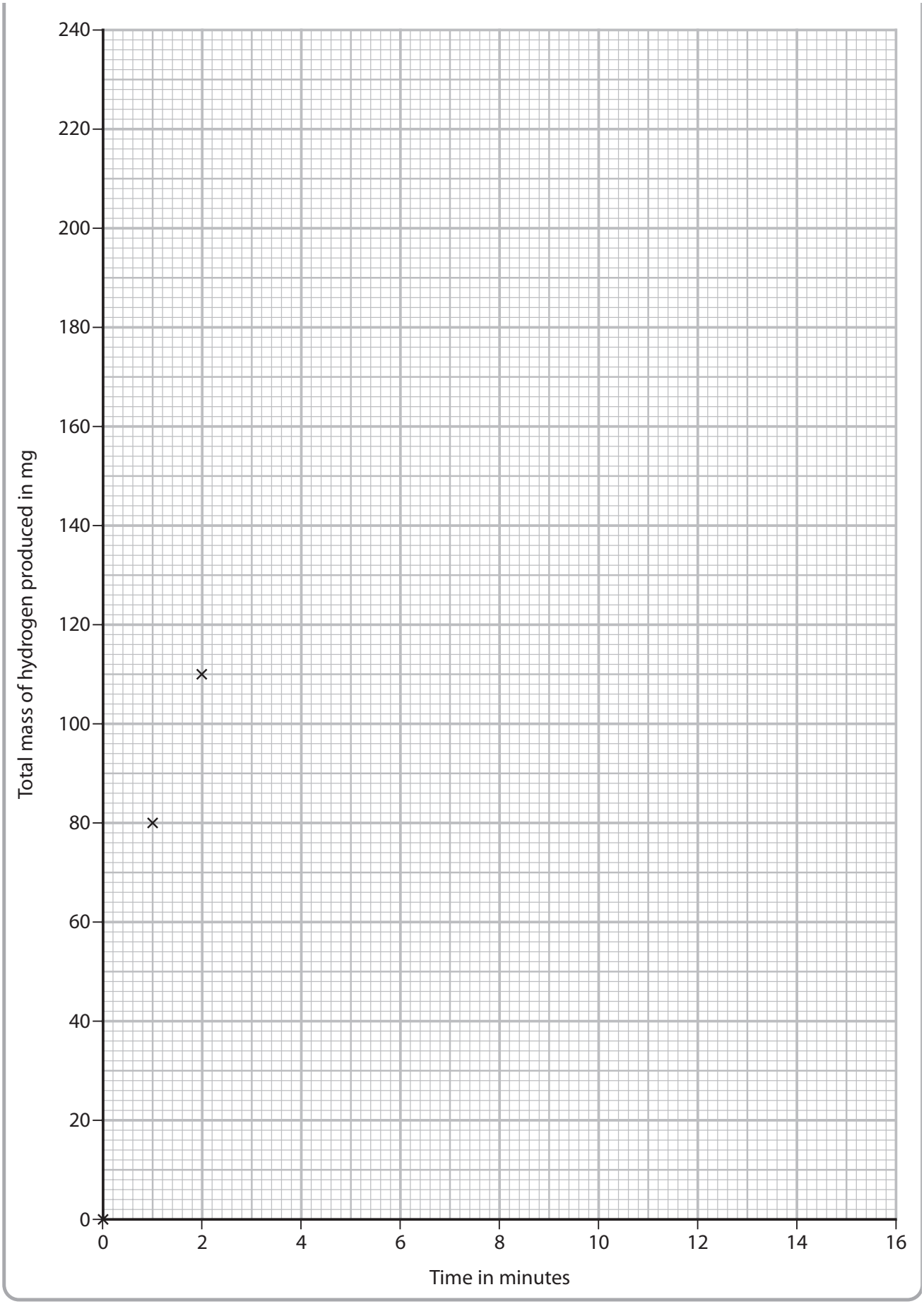
(1)

(ii) Draw a circle around the anomalous result.

(1)

(iii) Draw a curve of best fit.

(1)


Total mass of hydrogen produced in mg
240
220
200
180
160
140
120
100
80
60
40
20
0
0
2
4
6
8
10
12
14
16
Time in minutes

(iv) Give a possible reason for the anomalous result.

(1)

.....

.....

(v) Determine a more likely value for this result.

(1)

.....

(c) (i) Explain how the shape of the curve shows how the rate of the reaction changes as time increases.

(2)

.....

.....

.....

.....

(ii) At the end of the experiment there is no zinc left in the flask.

Give a conclusion the student could make from this observation.

(1)

.....

.....

(d) The student does another experiment using

- the same amount of similarly sized magnesium granules instead of zinc
- the same volume of sulfuric acid, but of a lower concentration

Explain why it is difficult to predict how the rate of reaction in this experiment compares with the rate of reaction in the first experiment.

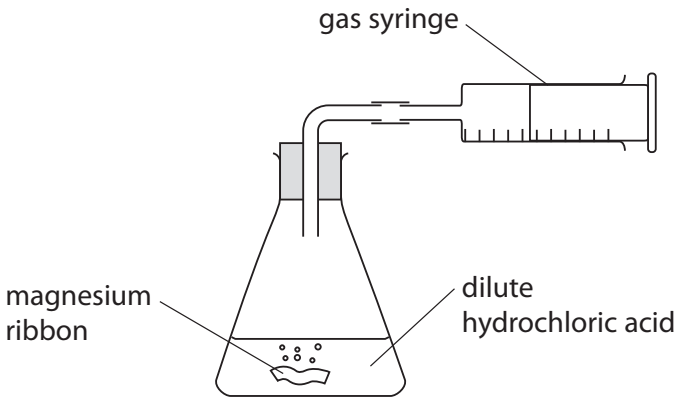
(3)

(e) Explain, in terms of particle collision theory, how increasing the temperature affects the rate of a reaction.

(3)

(Total for Question 8 = 15 marks)

6 A student uses this apparatus to investigate the reaction between magnesium and dilute hydrochloric acid.



(a) The word equation for the reaction is

magnesium + hydrochloric acid → magnesium chloride + hydrogen

(i) Complete the chemical equation for this reaction.

(1)

Mg + 2HCl → ..... + ...

(ii) Give the test for hydrogen.

(1)

.....

.....

(iii) The student uses 0.090 g of magnesium and 0.025 mol of hydrochloric acid.

Show by calculation that the hydrochloric acid is in excess.

(2)

(b) The student measures the volume of hydrogen collected at regular intervals until the reaction stops.

The table shows the student's results.

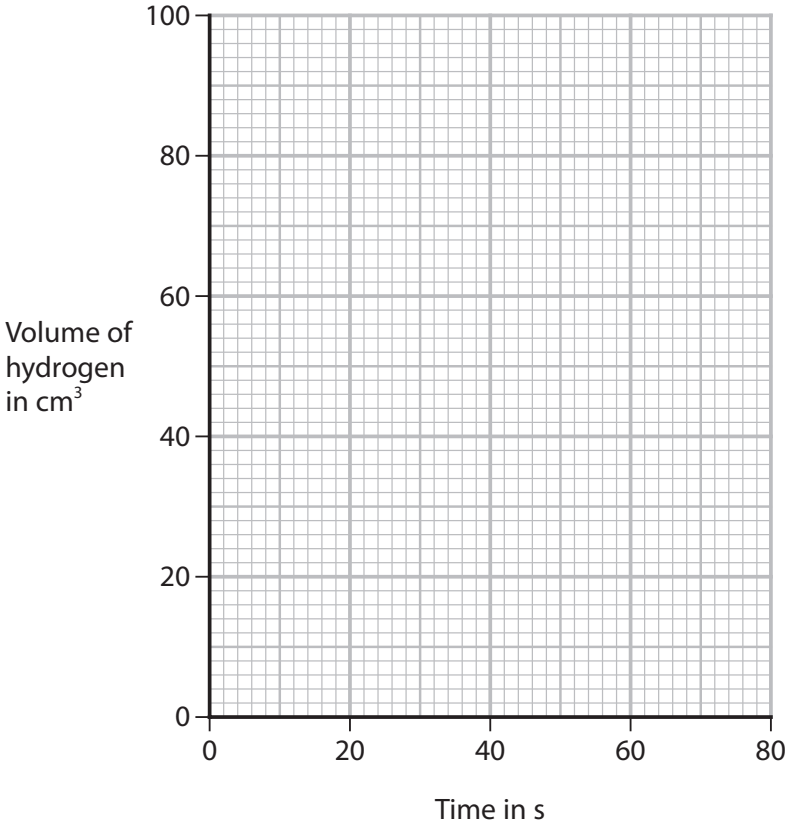
Time in s	0	15	30	45	60	75
Volume of hydrogen in cm^3	0	40	68	80	88	88

(i) Plot the student's results.

(1)

(ii) Draw a curve of best fit.

(1)



(iii) Determine the volume of hydrogen collected in the first 10 seconds.

Show on the graph how you obtained your answer.

(2)

volume of hydrogen = ... cm^3

(iv) Explain why the rate of reaction is greatest at the start of the reaction.

(2)

(c) The student repeats the experiment at a temperature 5 °C higher than the original temperature.

All other conditions are kept the same.

(i) On the grid, draw the curve you would expect the student to obtain.

(2)

(ii) Explain, in terms of particle collision theory, how increasing the temperature affects the rate of reaction.

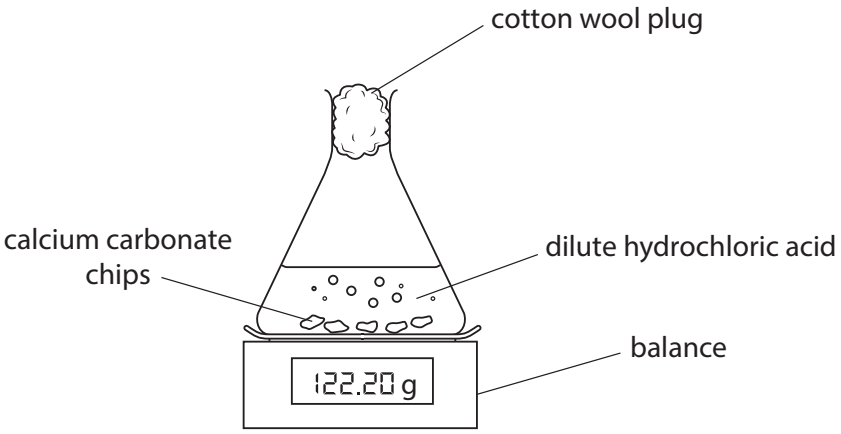
(3)

(Total for Question 6 = 15 marks)

7 A student reacts small chips of calcium carbonate with an excess of dilute hydrochloric acid.

This is the student's method.

- add 5.00 g of small calcium carbonate chips to a conical flask
- add 30 cm^3 of dilute hydrochloric acid which is in excess
- quickly add a cotton wool plug and place the conical flask on a balance



This is the equation for the reaction.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

The reading on the balance decreases as carbon dioxide gas is lost through the cotton wool plug.

(a) Calculate the mass reading on the balance when all of the calcium carbonate has reacted.
Assume that all of the carbon dioxide gas is lost through the cotton wool plug.
[for $CaCO_3$, $M_r = 100$ for CO_2, $M_r = 44$]

(3)

mass = ... g

(b) The student repeats the experiment with a different mass of calcium carbonate and a different volume of dilute hydrochloric acid.
The hydrochloric acid is in excess.
The student records the total mass of carbon dioxide produced at 1-minute intervals for 8 minutes.

The table shows the student's results.

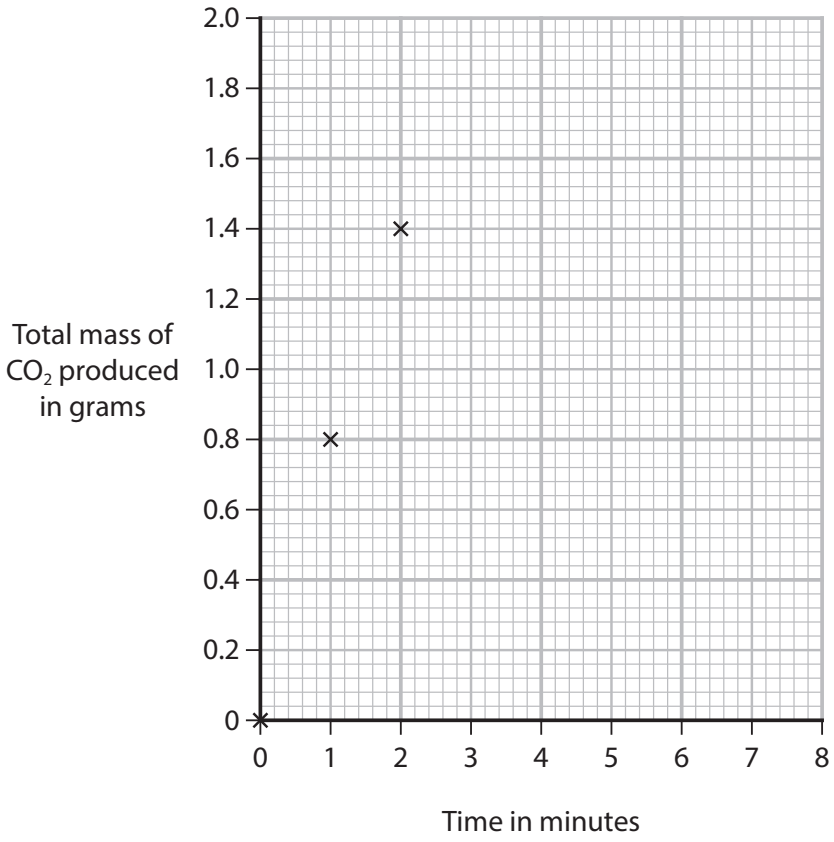
Time in minutes	Total mass of CO_2 produced in grams
0	0.00
1	0.80
2	1.40
3	1.64
4	1.72
5	1.76
6	1.80
7	1.80
8	1.80

(i) Plot the student's results.
The first three have been plotted for you.

(1)

(ii) Draw a curve of best fit through the points.

(1)



(iii) Calculate the rate of reaction at 2 minutes by drawing a tangent to the curve and calculating the gradient of the tangent.

Give the units for the rate of reaction.

(3)

rate of reaction = ...

units = ...

(iv) Explain why the shape of the graph changes during the 8 minutes.

(4)

(c) The student repeats the experiment using the same mass of calcium carbonate but as powder rather than chips, keeping all other conditions the same.

Explain the effect of this change on the rate of reaction.

(3)

(Total for Question 7 = 15 marks)

SUB-TOPIC 3c

REVERSIBLE REACTIONS AND EQUILIBRIA

Sub-topic 3c · 10 questions · 111 marks · lowest tariff first

8 This question is about ammonia gas, NH_3

(a) Ammonia can be prepared in a laboratory from the reaction between ammonium chloride, NH_4Cl, and sodium hydroxide. The other products of the reaction are sodium chloride and water.

(i) Give a chemical equation for this reaction.

(1)

.....

(ii) Give a test for ammonia gas.

(2)

.....

.....

(b) In industry, ammonia is produced from nitrogen and hydrogen.

The equation for this reaction is

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

In a sealed container, the reaction can reach a position of dynamic equilibrium.

Explain the meaning of the term **dynamic equilibrium**.

(2)

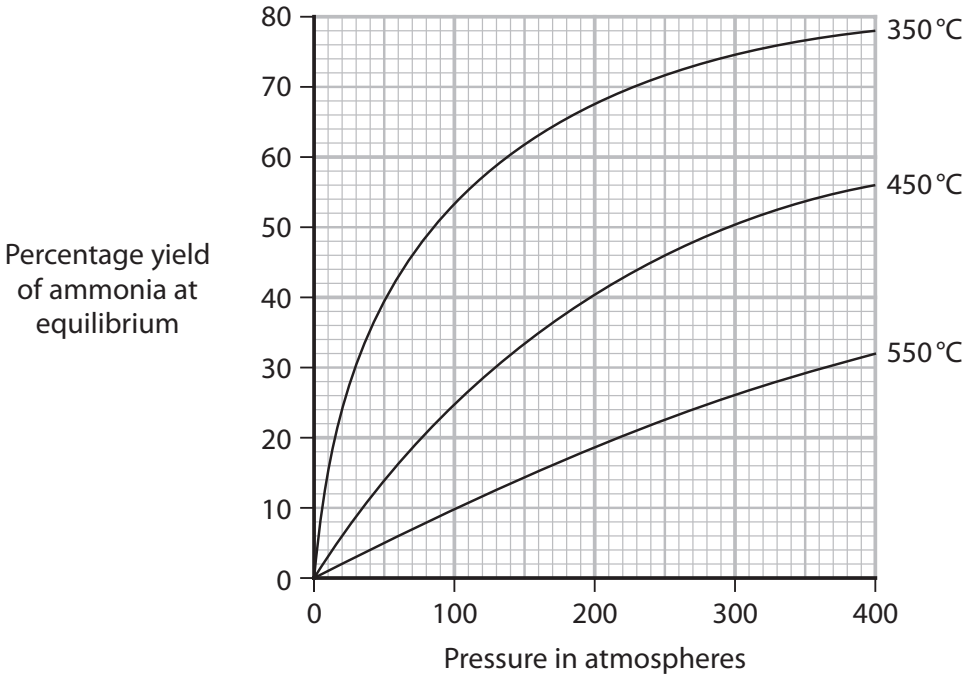
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(c) The graph shows the percentage yield of ammonia at equilibrium for different temperatures and pressures.



Using the graph, explain if the forward reaction is exothermic or endothermic.

(2)

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(Total for Question 8 = 7 marks)

7 Dinitrogen tetraoxide, N_2O_4, is a colourless gas.

Nitrogen dioxide, NO_2, is a brown gas.

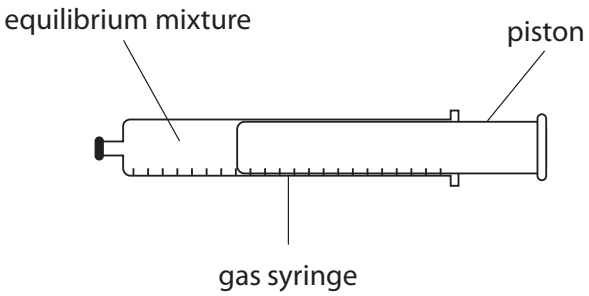
The two gases can exist together in dynamic equilibrium according to the equation

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

(a) Explain what is meant by the term **dynamic equilibrium**.

(2)

(b) Some N_2O_4 and some NO_2 are put into a sealed gas syringe and allowed to form an equilibrium mixture.



This equilibrium mixture is brown.

(i) The pressure of the gas in the syringe is increased by pushing in the piston. The mixture is then allowed to reach a new equilibrium at the same temperature as before.

Explain why the new equilibrium mixture contains less NO_2 than the original equilibrium mixture.

(2)

(ii) A student suggests that the new equilibrium mixture would be lighter in colour than the original equilibrium mixture, as there is now less NO_2 present.

Suggest why the new equilibrium mixture is actually darker than the original.

(1)

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.....

(c) Carbon monoxide, CO, and oxides of nitrogen are produced in a car engine when petrol is burned.

These oxides can be partly removed by using a catalytic converter fitted to the car's exhaust system.

(i) State how oxides of nitrogen are produced in the car engine.

(1)

.....

.....

(ii) Give a disadvantage of allowing oxides of nitrogen to escape into the atmosphere.

(1)

.....

.....

(iii) Write a chemical equation for the reaction between nitrogen monoxide, NO, and carbon monoxide to form carbon dioxide and nitrogen.

(1)

.....

(Total for Question 7 = 8 marks)

7 Hydrogen gas can be produced by reacting a mixture of methane and steam in the presence of a nickel catalyst.

The reaction conditions are a temperature of 700 °C and a pressure of 5 atmospheres.

The equation for the reaction is

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +206\,kJ/mol$$

(a) What does the symbol $\rightleftharpoons$ represent?

(1)

.....

(b) (i) The mixture of methane and steam is heated to a temperature greater than 700 °C but the pressure is kept at 5 atmospheres.

Predict the effect of this change on the yield of hydrogen at equilibrium, giving a reason for your answer.

(2)

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.....

(ii) The mixture of methane and steam is kept at the same temperature of 700 °C but the pressure is increased to more than 5 atmospheres.

Predict the effect of this change on the yield of hydrogen at equilibrium, giving a reason for your answer.

(2)

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(c) Calculate the volume, in dm^3, of hydrogen gas at rtp that is produced when 10 tonnes of methane gas completely react with steam.

[molar volume of hydrogen at rtp is 24 dm^3]

Give your answer in standard form.

(4)

volume of hydrogen = ... dm^3

(Total for Question 7 = 9 marks)

7 Hydrogen gas and iodine gas react together to form hydrogen iodide gas.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

(a) (i) The pressure of an equilibrium mixture of the three gases is increased.

Predict the effect of this change on the yield of hydrogen iodide at equilibrium, giving a reason for your answer.

(2)

(ii) A catalyst is added to an equilibrium mixture of the three gases.

Predict the effect of the catalyst on the yield of hydrogen iodide at equilibrium, giving a reason for your answer.

(2)

(b) Hydrogen gas reacts with fluorine gas to form hydrogen fluoride gas.

$$H_2(g) + F_2(g) \rightarrow 2HF(g)$$

The table gives some bond energies.

Bond	Bond energy in kJ/mol
H—H	436
F—F	158
H—F	562

Use the equation and the data in the table to calculate the enthalpy change (ΔH) in kJ/mol, for the reaction.

Include a sign in your answer.

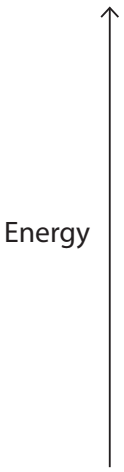
(3)

ΔH = ... kJ/mol

(c) Draw an energy level diagram for the reaction between hydrogen and fluorine.

Label the enthalpy change, ΔH.

(3)



(Total for Question 7 = 10 marks)

6 Hydrogen reacts with iodine vapour to form hydrogen iodide, HI

This is the equation for the reaction.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H = +26\,kJ/mol$$

(a) (i) Give the test for hydrogen.

(1)

(ii) State what the symbol $\rightleftharpoons$ represents.

(1)

(b) In a sealed container at equilibrium, the reaction conditions are 500°C and 2 atm.

(i) The temperature of the reaction mixture is increased to 600°C, but the pressure is kept at 2 atm.

Explain the effect, if any, on the yield of hydrogen iodide at equilibrium.

(2)

(ii) The pressure of the reaction mixture is decreased to 1 atm but the temperature is kept at 500°C.

Explain the effect, if any, on the yield of hydrogen iodide at equilibrium.

(2)

(c) An excess of hydrogen reacts with 50.8 g of iodine.

At equilibrium, the yield of hydrogen iodide is 80%.

Calculate the volume, in cm^3, of hydrogen iodide produced at rtp.

Give your answer in standard form.

[at rtp, molar volume = 24 000 cm^3]

(4)

volume of hydrogen iodide = ... cm^3

(Total for Question 6 = 10 marks)

7 Methane reacts with steam to form carbon monoxide and hydrogen.

This is the equation for the reaction.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +206\ kJ/mol$$

(a) State why carbon monoxide is poisonous to humans.

(1)

(b) Explain the effect, if any, on the yield of hydrogen at equilibrium when a nickel catalyst is used.

(2)

(c) The reaction conditions for this reaction are a temperature of 700 °C and a pressure of 5 atmospheres.

(i) The temperature of the reaction mixture is reduced to 600 °C, but the pressure is kept at 5 atmospheres.

Explain the effect on the yield of hydrogen at equilibrium.

(2)

(ii) The pressure of the reaction mixture is reduced to 4 atmospheres, but the temperature is kept at 700 °C.

Explain the effect on the yield of hydrogen at equilibrium.

(2)

.....

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.....

(d) Calculate the volume, in dm^3, of methane gas at rtp needed to produce 6.6 tonnes of hydrogen gas.

[at rtp, molar volume = 24 dm^3 1 tonne = 10^6 g]

Give your answer in standard form.

(4)

volume of methane = ... dm^3

(Total for Question 7 = 11 marks)

5 This question is about three stages in the manufacture of sulfuric acid.

(a) In stage 1, sulfur is burned in oxygen to form sulfur dioxide gas.

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

(i) State one environmental problem caused by the release of sulfur dioxide into the atmosphere.

(1)

.....

.....

(ii) A mass of 6.4 tonnes of sulfur is burned to produce sulfur dioxide gas.

Calculate the maximum volume, in dm^3, of sulfur dioxide gas that can be produced at rtp.

[molar volume of sulfur dioxide gas at rtp = 24 dm^3]

[1 tonne = 10^6 g]

Give your answer in standard form.

(3)

maximum volume = ... dm^3

(b) In stage 2, sulfur dioxide is reacted with oxygen to form sulfur trioxide gas.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

The yield of sulfur trioxide is approximately 98%.

(i) A catalyst is used in this reaction.

Explain how a catalyst increases the rate of a reaction.

(2)

.....

.....

.....

.....

(ii) The temperature is kept constant.

Give a reason why increasing the pressure would increase the yield of sulfur trioxide.

(1)

.....

.....

(iii) Suggest why it is not necessary to increase the pressure in stage 2.

(1)

.....

.....

.....

(c) In stage 3, the sulfur trioxide is reacted with concentrated sulfuric acid to form a liquid called oleum, $H_2S_2O_7$

The oleum is then added to water to form concentrated sulfuric acid.

Complete the chemical equations for these two reactions.

(2)

..... + ... → $H_2S_2O_7$

$H_2S_2O_7$ + ... → .....

(d) Sulfuric acid reacts with ammonia to form ammonium sulfate, $(NH_4)_2SO_4$

Calculate the percentage by mass of nitrogen in ammonium sulfate.

[M_r of $(NH_4)_2SO_4$ = 132]

(2)

percentage = ... %

(Total for Question 5 = 12 marks)

7 Methanol is made by the reaction between hydrogen and carbon monoxide.

This is the equation for the reaction.

$$2H_2(g) + CO(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -119\ kJ/mol$$

A mixture of hydrogen and carbon monoxide is left until dynamic equilibrium is reached.

(a) (i) Give two characteristics of a reaction at dynamic equilibrium.

(2)

1 .....

.....

2 .....

.....

(ii) Give a reason why adding a catalyst does **not** affect the yield of methanol.

(1)

.....

.....

.....

(iii) The temperature of the reaction mixture is decreased at constant pressure.

Explain the effect of this change on the yield of methanol.

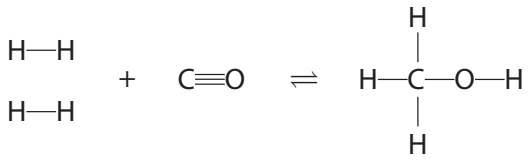
(2)

(iv) The pressure of the reaction mixture is increased at constant temperature.

Explain the effect of this change on the yield of methanol.

(2)

(b) This equation shows the displayed formulae for the reactants and product.



The table gives the bond energies for the bonds in the reactants and product.

Bond	Bond energy in kJ / mol
H—H	436
C≡O	1072
C—H	414
C—O	358
O—H	463

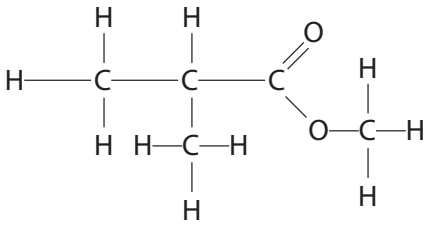
(i) Show that the molar enthalpy change, ΔH, for the reaction is −119 kJ / mol.

(3)

(ii) Explain why this reaction is exothermic.

(2)

(c) The diagram shows the displayed formula of an ester that is made from methanol and a carboxylic acid.



(i) Draw a circle around the functional group of the ester.

(1)

(ii) Give the displayed formula of the carboxylic acid used to make this ester.

(1)

(Total for Question 7 = 14 marks)

7 In the presence of an iron catalyst, nitrogen reacts with hydrogen to form ammonia.

The reaction conditions used are a temperature of 450 °C and a pressure of 200 atmospheres.

This is the equation for the reaction.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 \qquad \Delta H = -92\,kJ/mol$$

(a) (i) State what the symbol $\rightleftharpoons$ represents.

(1)

.....

.....

(ii) Give the reason for using a catalyst.

(1)

.....

.....

(b) (i) The reaction mixture is kept at a pressure of 200 atmospheres, but the temperature is increased to 550 °C.

Explain the effect of this change on the yield of ammonia at equilibrium.

(2)

.....

.....

.....

.....

(ii) The reaction mixture is kept at a temperature of 450 °C, but the pressure is increased to 300 atmospheres.

Explain the effect of this change on the yield of ammonia at equilibrium.

(2)

.....

.....

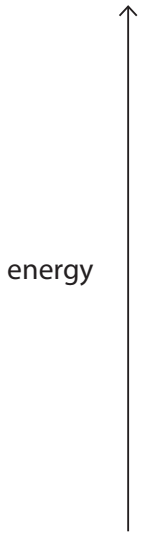
.....

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(c) Draw an energy level diagram for the reaction between nitrogen and hydrogen.

Include the reactants, products and ΔH in your diagram.

(3)



QUESTION 7 CONTINUES ON NEXT PAGE

(d) At the start of the reaction, 48 dm^3 of nitrogen is added to 120 dm^3 of hydrogen at rtp.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

[molar volume of any gas at rtp = 24 dm^3]

(i) Show by calculation that the nitrogen is in excess.

(3)

(ii) The yield of ammonia at equilibrium is 20 %.

Calculate the volume, in dm^3, of ammonia formed from 120 dm^3 of hydrogen.

(3)

volume of ammonia = ... dm^3

(Total for Question 7 = 15 marks)

7 Gaseous ethanol is manufactured by reacting ethene gas with steam.

This is the equation for the reaction.

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

(a) (i) The pressure on an equilibrium mixture of the three gases is decreased. All the other conditions are kept the same.

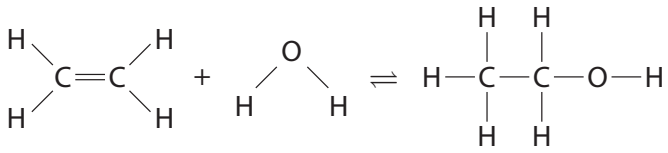
Predict the effect of this change on the yield of ethanol at equilibrium, giving a reason for your answer.

(2)

(ii) Predict the effect of adding a catalyst on the yield of ethanol at equilibrium, giving a reason for your answer.

(2)

(b) The equation shows the displayed formulae for the reactants and products.



The table gives the bond energies.

Bond	Bond energy in kJ / mol
C—H	414
C=C	614
O—H	463
C—C	346
C—O	358

(i) Using the data in the table and the equation, show that the enthalpy change, ΔH, is approximately –40 kJ / mol.

(3)

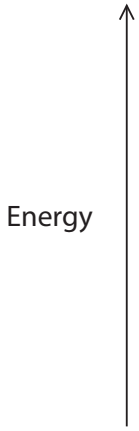
(ii) Explain, in terms of bonds broken and bonds made, why this reaction is exothermic.

(2)

(iii) Draw an energy level diagram for the reaction between ethene and steam.

Label the enthalpy change, ΔH.

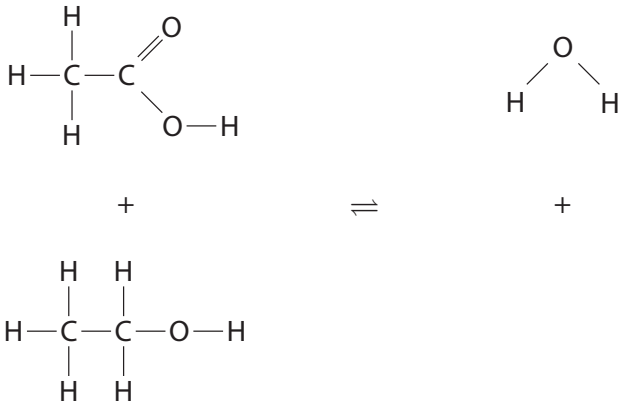
(3)



(c) Ethanoic acid reacts with ethanol to form ester A and water.

(i) Complete the equation by adding the displayed formula of ester A.

(2)



ester A

(ii) Give the name of ester A.

(1)

.....

(Total for Question 7 = 15 marks)

MARK SCHEMES

official Pearson Edexcel mark schemes

Question number	Answer	Notes	Marks
5 (a)	**B** it relights a glowing splint A is incorrect as this is the test for hydrogen C is incorrect as oxygen is not an acidic gas D is incorrect as this is the test for carbon dioxide		1
(b)	An explanation that links the following two points **M1** provides an alternative pathway OWTTE **M2** with a lower activation energy OWTTE	 **ACCEPT** more collisions with energy greater than the activation energy **ALLOW** lowers the energy needed to start the reaction	2

Question number	Answer	Notes	Marks
5 (c) (i)	• find energy needed to break bonds • find energy released when bonds form • correct subtraction to find ΔH Example calculation **M1** **(**4 x 463) + (2 x 143) **OR** 2138 (kJ) **M2** (4 x 463) + 498 **OR** 2350 (kJ) **M3** — 212 (kJ) **OR M1 – M2** correctly evaluated	 **ACCEPT** (2 x 143)/286 for **M1** and 498 for **M2** **IGNORE** any signs in **M1** and **M2** — 212 with or without working scores 3 (+) 212 with or without working scores 2	3
(ii)	Energy $2H_2O_2$ ΔH $2H_2O + O_2$ **M1** horizontal line to show products in correct position and correctly labelled **M2** vertical line in correct position and labelled ΔH	 Mark CQ on sign in (i) **ACCEPT** double headed arrow or arrow pointing from reactants level to products level **REJECT** arrow pointing from products level to reactants level **IGNORE** any attempts at including activation energy	2
			Total 8

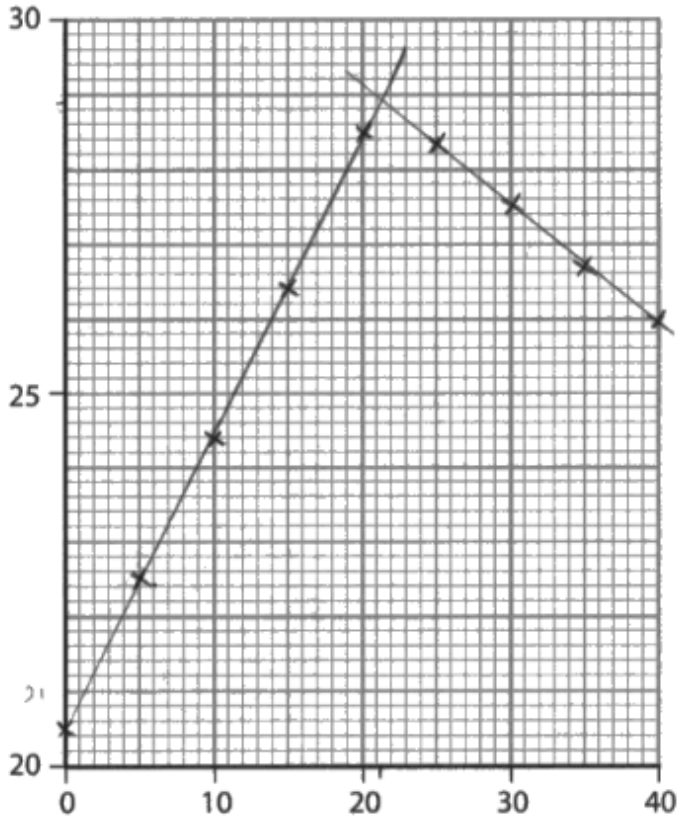
Question number	Answer	Notes	Marks
8 (a)	diagram including the following **M1** horizontal lines showing energy levels labelled $N_2 + O_2$ and 2NO **M2** level of 2NO /products above level of $N_2 + O_2$ /reactants **M3** ΔH correctly shown between reactants and products and labelled **M4** activation energy correctly shown and labelled	 ALLOW vertical line with/without arrowheads If single arrowhead must point from level of reactants to level of products Must be from level of reactants to top of "hump" ALLOW vertical line with/without arrowheads If single arrowhead must point from level of reactants to top of "hump" IGNORE any label on a horizontal axis If diagram for exothermic reaction drawn can score M1 M3 M4	4
(b) (i)	{944 + (3 × 436) =} 2252	IGNORE any sign	1
(ii)	{6 × 391 =} 2346	IGNORE any sign	1
(iii)	**M1** difference between (i) and (ii) expected value = 94 **M2** − 94	IGNORE any sign ALLOW ECF from (i) and (ii) If (ii) > (i) sign should be − If (i) > (ii) sign should be +	2

(Total for Question 8 = 8 marks)

Question number	Answer	Notes	Marks
12 a	An explanation that links together **M1** the reaction is endothermic and either of the following points: **M2** it takes in thermal energy/heat (from the surroundings) **OR** **M3** as shown by the decrease in temperature (of the reaction mixture)	**REJECT** exothermic for both marks **ALLOW** references to cooling No M2 or M3 if the statements contradict each other	**2**
b	• calculation of temperature change • substitution into $Q = mc\Delta T$ • evaluation Example calculation **M1** 14.2 – 20.0 = (-)5.8 **M2** $Q = 100 \times 4.18 \times (-)5.8$ **M3** = (–) 2420 (J)	100 x 4.18 x (20 – 14.2) scores **M1** and **M2** **ACCEPT** any number of sig figs greater than 2 Calculator answer is 2424.4 Negative sign not required If answer in kJ unit must be given. Use of 108 can score **M1** and **M3** (= 2618) 2400 alone scores 0 **ALLOW** use of 4.2 for all 3 marks (= 2436)	**3**

12 c	• calculation of moles (*n*) of ammonium nitrate • division of *Q* by *n* • conversion of J to kJ • answer given with + sign Example calculation **M1** *n*[NH_4NO_3] = 8.00 ÷ 80 **OR** 0.1(00) (mol) **M2** $\frac{Q}{n}$ **OR** $\frac{2420}{0.1(00)}$ **OR** $\frac{\text{answer to b}}{\text{answer to M1}}$ **M3** ΔH = (+)24.2 (kJ/mol) **M4** positive sign included	**ACCEPT** any number of sig figs in the numerator except 1 **ACCEPT** any number of sig figs except 1 **ALLOW** ecf from M2 correct answer with no working and no sign or incorrect sign scores 3 correct answer with no working and correct sign scores 4	**4**
		Total	**9**

Question number	Answer	Notes	Mark
8 (a) (i)	sodium hydroxide + nitric acid → sodium nitrate+ water	**ACCEPT** correct chemical equation **IGNORE** ionic equation	
(ii)	An explanation which links the following two points		
	M1 polystyrene is an insulator	**ALLOW** poor/non-conductor of heat	
	M2 less heat is lost (to the surroundings)	**ALLOW** no heat lost **ALLOW** (polystyrene) retains more heat **ALLOW** reverse arguments for glass beaker	
(iii)	Any one from		
	(she should) wear eye protection (she should) wear gloves	**ACCEPT** (safety) goggles **ALLOW** safety glasses	

(b)	(i)	**M1** all points plotted correctly to +/− half a square **M2** first best fit line drawn with a ruler **M3** second best fit line drawn with a ruler clip  	Award MAX 1 if ruler not used for both **DO NOT PENALISE HERE IF LINES DO NOT CROSS**	
	(ii)	**M1** volume reading read from graph +/- 0.5 (cm^3) **M2** temp reading read from graph to +/- 0.1 (°C)	Award 1 mark if values correct but reversed. If lines do not meet or cross or a curve is drawn between the lines 0 marks for (ii)	**Tot**

<table>
<tr><th>Question number</th><th>Answer</th><th>Notes</th><th>Marks</th></tr>
<tr><td>7 (a) (i)</td><td>→ magnesium chloride + hydrogen</td><td>ACCEPT in either order</td><td>1</td></tr>
<tr><td>(b) (i)</td><td><table>
<tr><td>temperature of the acid at the start in °C</td><td>22.4</td></tr>
<tr><td>highest temperature reached in °C</td><td>43.2</td></tr>
<tr><td>temperature rise in °C</td><td>20.8</td></tr>
</table></td><td>ALLOW ECF from incorrect starting temperature</td><td>2</td></tr>
</table>

Question number	Answer	Notes	Marks
7 (ii)	• substitute correct values into $Q = mc\Delta T$ • evaluation Example calculation **M1** Q = 25 x 4.2 x 20.8 **M2** 2184 (J)	Correct answer of 2184 or 2194 without working scores 2 **ALLOW** 25.12g for m **ACCEPT** any number of sig figs except 1 **ALLOW** ECF from M1	2
(iii)	• find the amount of magnesium in moles • divide Q by n • convert answer in J/mol to kJ/mol • answer including sign Example calculation **M1** n(Mg) = 0.12 ÷ 24 **OR** 0.005(0) **M2** $Q \div n$ **OR** 2184 ÷ 0.005(0) **OR** 436,800 (J/mol) **M3** 436,800 ÷ 1000 **OR** 436.8 (kJ/mol) **M4** – 436.8 (kJ/mol)	**ACCEPT** use of 2180 or 2200 **ALLOW** ECF on incorrect answer to (ii) and/or **M1** **ALLOW** ECF on incorrect answer to **M2** **ALLOW** ECF on incorrect answer to **M3** Correct answer with minus sign and without working scores 4 Correct answer without minus sign and without working scores 3 **ACCEPT** any number of sig figs except 1 throughout (ii) -438.8 or-438.9 also scores 4 (from 5.12g and 2194J in (ii))	4 **Total 9**

Question number	Answer	Notes	Marks
10 (a) (i)	measuring cylinder	ALLOW burette / pipette /syringe REJECT gas syringe	1
(b) (i)	M1 Q = m × c × ΔT M2 ΔT = 2880 ÷ (50 × 4.2) M3 ΔT = 13.7(1) °C M4 (maximum temp = 13.7(1) + 21.(0) =) 34.7 (°C)	 M2 subsumes M1 ALLOW ecf from M3 ALLOW any number of sig fig except 1 in M3 and M4 Correct answer without working scores 4	4
(b) (ii)	thermal energy/heat lost (to the atmosphere / surroundings)	IGNORE energy lost	1
(b) (iii)	M1 2880 ÷ 1000 OR 2.880 kJ M2 2.880 ÷ 0.05(00) M3 -57.6kJ/mol OR M1 2880 ÷ 0.05(00) OR 57 600J M2 57 600 ÷ 1000 M3 -57.6 kJ/mol	 ALLOW ecf from M1 ALLOW any number of sig fig except 1 in M3 ALLOW ecf from M1 ALLOW any number of sig fig except 1 in M3 Correct answer without working scores 3	3
			Total for question = 9

Question number	Answer	Notes	Marks
3 (a)	**M1** calculating heat energy in kJ/g = (3.28 × 10^5 ÷ 10 000) **OR** 32.8 **M2** calculating heat energy in kJ/mol = (M1 × 12) OR 393.6 **M3** = 394 OR 3.94 × 10^2 kJ/mol OR **M1** calculating amount of carbon = 10 000 ÷ 12 OR 833.3 **M2** calculating heat energy in kJ/mol = (3.28 × 10^5 ÷ M1) OR 393.6 **M3** = 394 OR 3.94 × 10^2 kJ/mol	IGNORE sign M3 subsumes M2 IGNORE sign M3 subsumes M2 correct answer with no working scores 3	3
(b) (i)	**M1** $\frac{600}{20\,000} \times 100$ OR $\frac{0.6}{20} \times 100$ **M2** = 3 (%)	ALLOW ECF from incorrect conversion of units in M1 correct answer with no working scores 2	2
(ii)	**M1** mol of sulfur = 600 ÷ 32 **OR** 18.75 **M2** vol SO_2 = M1 × 24 **OR** 450 (dm^3) **M3** = 450 000 OR 4.5 × 10^5 (cm^3)	ALLOW ECF from incorrect A_r in M1 ALLOW ECF M2 (dm^3) × 1000 M3 subsumes M2 correct answer with no working scores 3	3
(iii)	acid rain	IGNORE any effects	1

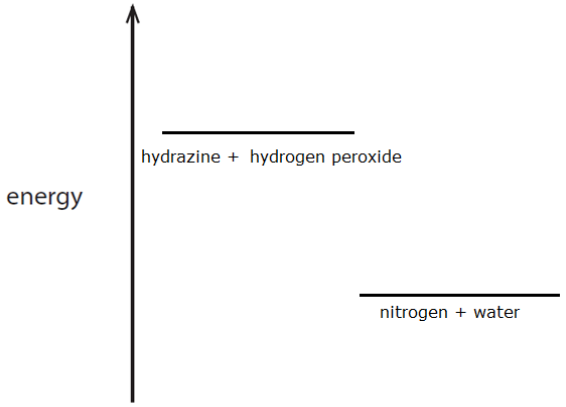
(Total for Question 3 = 9 marks)

Question number	Answer	Notes	Marks
10 (a) (i)	(because) the zinc (powder) is in excess	**ALLOW** (because) not all zinc is used up/reacts **ALLOW** (because) some zinc is left over **ALLOW** because copper sulfate is limiting reagent/all reacted/all used up	1
(ii)	**M1** blue	**ALLOW** qualifiers such as dark/light but no other colours	2
	M2 to colourless	**IGNORE** clear **ALLOW** no colour **ALLOW** decolourised **REJECT** discoloured	
(b) (i)	• Calculation of temperature increase • Substitution into Q = $mc\Delta T$ • Evaluation Example calculation **M1** (31.5 – 19.0) OR 12.5		3
	M2 Q = 25 x 4.18 x 12.5	25 x 4.18 x (31.5 – 19.0) scores **M1** and **M2**	
	M3 Q = 1310 (J)	Calculator answer is 1306.25 ACCEPT any number of sig fig greater than 1 Correct answer to 3 or more sig fig without working scores 3 1300 with no working scores 0 If answer in kJ unit must be given **ALLOW** use of 4.2 for all 3 marks (= 1312.5)	

(ii)	$n(CuSO_4) = (2.00 \div 159.5) = 0.0125$	**ACCEPT** any number of sig figs except 1	1
(iii)	• Division of *Q* by *n* • Evaluation including conversion of J to kJ • Answer given with - sign Example calculation **M1** $\frac{Q}{n}$ **OR** $\frac{1300}{0.0125}$ **OR** answer to b(i) / answer to b(ii) **M2** ΔH = (–) 104 (kJ/mol) **M3** Negative sign included	**ACCEPT** any number of sig figs in the numerator except 1 **ACCEPT** any number of sig figs **ALLOW** ECF from **M1** Correct answer with no working and no sign or incorrect sign scores 2 Correct answer with no working and correct sign scores 3 104.5(04) 104.48 104.8 105 all score 2 -104.5(04) -104.48 -104.8 -105 all score 3	3 **Total 10**

Question number	Answer	Additional guidance	Marks
5 (a) (i)	(bonds broken) 3861 (kJ)		1
(ii)	(bonds made) 4649 (kJ)		1
(iii)	**M1** subtraction of Σ(bonds made) made and Σ(bonds broken)	In (iii) ECF from (i) and (ii) must be applied Subtraction can be in any order	3
	M2 correct evaluation of the calculation shown in **M1**	**IGNORE** sign	
	M3 If Σ(bonds made) > Σ(bonds broken) final answer must be negative If Σ(bonds made) < Σ(bonds broken) final answer must be positive (and + sign given)	Expected final answer is −788 (kJ/mol)	
		-788 with no working scores 3 (+) 788 scores 2	

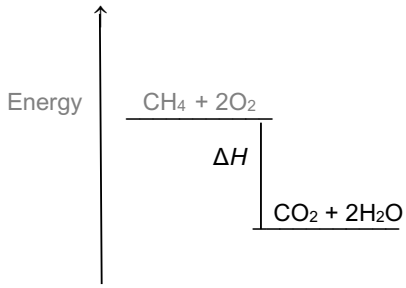
(b)	An explanation that links together the following two points: **M1** more energy is given out when the bonds are made **M2** than is taken in when the bonds are broken	If state/imply that energy required to make bonds OR If state/imply that energy released when bonds are broken scores 0/2 **ACCEPT** correct reverse argument	2

Question number	Answer	Additional guidance	Marks
5 (c)	 **M1** right hand line below left hand line **M2** correct names/formulae of both reactants **M3** correct names/formulae of both products	**IGNORE** horizontal axis drawn **IGNORE** enthalpy change shown **IGNORE** activation energy shown If only use words *reactants* (on left) and *products* (on right) award 1 mark from M2 and M3	3
		Total	**10**

Question number	Answer	Notes	Marks
8 (a) (i)	zinc + copper(II) sulfate → **zinc sulfate + copper**	**REJECT** copper(II) as a product **ACCEPT** zinc(II) sulfate	1
(ii)	polystyrene is an insulator / prevents heat loss	**ALLOW** to prevent the cup falling over	1
(iii)	zinc is more reactive / higher in the reactivity series than copper	**ALLOW** reverse argument	1
(iv)	M1 temperature rise = 28.6 °C M2 (75 × 4.2 × 28.6 =) 9009	correct answer without working scores 2 ALLOW 9010/9000 **IGNORE** any sign **ALLOW** ECF from M1	2
(b) (i)	M1 800÷1000 OR 0.8 (kJ) M2 0.65÷65 OR 0.01 (mol) M3 0.8÷0.01 = −80 (kJ/mol) OR M1 0.65÷65 OR 0.01 (mol) M2 800÷0.01 OR 80 000 (J/mol) M3 −80 (kJ/mol)	correct answer without working scores 3 **ALLOW** ECF but answer must have a − sign 80/+80 scores 2	3
(ii)	M1 zinc/Zn is oxidised because loses electrons M2 silver ion(s)/Ag^+ reduced because gain electrons OR M1 zinc/Zn is oxidised **and** silver ion(s)/Ag^+ reduced M2 zinc/Zn loses electrons **and** silver ion(s)/Ag^+ gain electrons		2

Total for question 8 = 10 marks

Question number	Answer	Notes	Marks
7 (a)	carbon	**ALLOW** soot **ALLOW** copper(II) oxide /copper oxide/CuO **REJECT** copper(I) oxide	1
(b)	**M1** (amount of ethanol) = 0.92 ÷ 46 **OR** 0.02(0) (mol) **M2** (–)18.2 ÷ 0.02(0) = (–)910 (kJ/mol)	 **ALLOW** alternative methods	2
(c)	Any 2 from **M1** heat (energy)/ thermal energy was lost (to the surroundings/apparatus) **M2** incomplete combustion (of ethanol) **M3** the ethanol was impure/ethanol evaporates		2
(d) (i)	**M1** ∑ bonds broken = 4 x C–H + 2 x 498 **M2** ∑ bonds formed = 2 x 805 + 4 x 463 **OR** 3462 **M3** 4 x C–H + 996 – 3462 = – 890 **M4** C–H = 1576 ÷ 4 = 394 (kJ/mol)	correct answer with or without working scores 4 **ALLOW** 2 x 498 **OR** 996 seen **ALLOW** ecf throughout 839 without working scores 3 616.5/617 without working scores 3	4

(ii)	 **M1** horizontal line to show products in correct position and correctly labelled **M2** vertical line in correct position and labelled ΔH/– 890 (kJ/mol)	**ACCEPT** double headed arrow or arrow pointing from reactants level to products level **REJECT** arrow pointing from products level to reactants level **IGNORE** any attempts at including activation energy If endothermic reaction shown **M2** can be awarded for correct arrow/line labelled ΔH/+890 (kJ/mol)	2
			Total 11

<table>
<tr><th>Question number</th><th>Answer</th><th>Notes</th><th>Marks</th></tr>
<tr><td>10 (a)</td><td>$Mg + 2HNO_3 \rightarrow Mg(NO_3)_2 + H_2$</td><td>IGNORE state symbols even if incorrect</td><td>1</td></tr>
<tr><td>(b)</td><td><table><tr><td>temperature of the acid at the start in °C</td><td>16.0</td></tr><tr><td>highest temperature reached in °C</td><td>32.4</td></tr><tr><td>temperature rise in °C</td><td>16.4</td></tr></table></td><td>Must be given to 1dp

ALLOW ECF from incorrect highest temperature reached

ALLOW ECF from an incorrect starting temperature</td><td>2</td></tr>
<tr><td>(c) (i)</td><td>M1 $Q = 40 \times 4.2 \times 16.4$

M2 2755 (J)</td><td>ACCEPT any number of sig figs except 1</td><td>2</td></tr>
<tr><td>(ii)</td><td>• find the amount of magnesium in moles
• divide Q by n
• convert answer in J/mol to kJ/mol
• answer including sign to 2sf

M1 n(Mg) = 0.12 ÷ 24 OR 0.005

M2 Q ÷ n OR 2755 ÷ 0.005 OR 551 000 (J/mol)

M3 551 000 ÷ 1000 OR 551 (kJ/mol)

M4 – 550 (kJ/mol)</td><td>correct answer with minus sign and without working scores 4

ACCEPT use of 2760 or 2800

ALLOW ECF on incorrect answer to (i) and/or M1

ALLOW ECF on incorrect answer to M2

ALLOW ECF on incorrect answer to M3

M4 - to score must be to 2sf and have correct sign

Use of 2800 gives an answer of
– 560 (kJ/mol)</td><td>4</td></tr>
</table>

(d)	An explanation that links the following two points **M1** polystyrene is an insulator/poor conductor OWTTE **M2** (so) there is less heat loss/more heat retained (compared to the glass beaker)	**REJECT** no heat loss	2 **Total 11**

Question number	Answer	Notes	Marks
6 (a)	M1 (a substance/a fuel that) when burned M2 releases heat (energy) / thermal energy	ALLOW burns / combusts /catches fire	2
(b) (i)	temperature at the start = 20.4 °C highest temperature reached = 77.6 °C	ALLOW ECF from incorrect temperature reading	2
(ii)	M1 150 × 4.2 × 57.2 M2 36 036 (J)	 ALLOW 36 000 if M1 is scored 36 036 with no working scores 2 ALLOW ECF from M1 as long as the 3 values are multiplied	2
(iii)	M1 36.036 kJ M2 amount of ethanol = 2.3 ÷ 46 OR 0.05 (mol) M3 36.036 ÷ 0.05 OR 720.720 (kJ) OR M3 36036 ÷ 0.05 (J) M4 −720 (kJ/mol)	ALLOW 36 kJ M3 subsumes M1 and M2 ALLOW M3 to 2 sig figs ALLOW ECF M4 with 2 sig figs and a − sign Correct answer without working scores 4 marks	4
(c)	any one from heat absorbed by the metal can incomplete combustion heat lost to the surroundings	 ALLOW heat loss	1
			total for question = 11

Question number	Answer	Notes	Marks
10 (a)	An explanation that links any two pairs **Pair 1** **M1** same volume of water **M2** so the same amount of fuel/heat is required **Pair 2** **M1** stir the water **M2** so the temperature is uniform throughout the water **Pair 3** **M1** to make sure the spirit burner is the same distance to the copper can **M2** so the same amount of heat loss occurs	 **ALLOW** same mass of water **IGNORE** references to time **ALLOW** the wick is the same height **ALLOW** any other acceptable answer	4
(b) (i)	**M1** $\Delta T = (30-18) = 12$ **M2** $Q = 100 \times 4.2 \times 12$ (= 5040 / 5000 (J))	 correct answer without working scores 2 marks **ALLOW** ecf if incorrect temperature change e.g. 7560 /7600 or 12600 /13000 scores 1	2
(ii)	**M1** (mass of ethanol =) 38.52 − 38.29 **OR** 0.23 (g) **M2** (amount =) 0.23 ÷ 46 **OR** 0.005(0) (mol) **M3** 5040 ÷ 0.005(0) **OR** 1 008 000 (J/mol) **M4** 1 008 000 ÷ 1000 **OR** 1008 (kJ/mol) **M5** − 1008 (kJ/mol)	correct answer without working scores 5 marks **ALLOW** ecf throughout **ACCEPT** 1 000 000 **ACCEPT** 1000 **ACCEPT** − 1000	5 **Total 11**

Question number	Answer	Notes	Marks
10 (a) (i)	Any two of the following M1 use a polystyrene cup M2 less **heat** will be lost M3 leave to reach a steady temperature to record it	 ALLOW use a beaker with a lid ALLOW any piece of apparatus which is better insulated	2
(ii)	the zinc/powder/it is in excess		1
(iii)	blue to colourless		1
(b) (i)	M1 $\Delta T = 30.1(^{\circ}C)$ M2 $25 \times 4.2 \times 30.1$	 ALLOW ecf from M1	3

	M3 3160.5(J)	ALLOW any number of significant figures from 2	
(ii)	M1 (moles of $CuSO_4$) 6.38÷159.5 **OR** 0.04 mol		4
	M2 3800÷0.04 **OR** 95 000	ALLOW ecf from M1	
	M3 division by 1000 = 95 (kJ)	ALLOW ecf from M2	
	M4 −95 kJ/mol	correct answer -95 scores 4 ecf -79 scores 3 (using the energy change from (b)(i)	
			Total = 11

Question number	Answer	Notes	Marks
6 (a)	zinc + hydrochloric acid → zinc chloride + hydrogen	**ACCEPT** fully correct chemical equation	1
(b)	<table><tr><td>**temperature in °C after adding zinc**</td><td>22.4</td></tr><tr><td>**temperature in °C before adding zinc**</td><td>17.7</td></tr><tr><td>**temperature change in °C**</td><td>4.7</td></tr></table>	If readings are correct but in wrong order award 1 mark for **M1** and **M2**	3
	M1 22.4		
	M2 17.7		
	M3 (+)4.7		
		ALLOW ECF for **M3** if **M1** and/or **M2** incorrect If answers not given to nearest 0.1°C penalise once only	
(c) (i)	An explanation that links any **two** of the following points		
	M1 polystyrene is an insulator	**ALLOW** is not a (good) conductor of heat **ALLOW** is a poor conductor of heat	
	M2 (so) reduces heat loss	**ALLOW** prevents heat loss **ALLOW** keeps heat in	
	M3 temperature rise/change/reading will be closer to true value OWTTE	**ALLOW** temperature rise/change/reading will be more accurate/valid	2
(ii)	Any **three** from		
	M1 amount/mass of metal	**ALLOW** size / surface area of metal	
	M2 concentration of acid		
	M3 volume of acid	**ALLOW** amount of acid	
	M4 (speed/time of) stirring		
	M5 external / room temperature	**ALLOW** initial /starting temperature	3

Question number	Answer	Notes	Marks
6 (d) (i)	no reaction (occurred between copper and hydrochloric acid)	**IGNORE** copper is unreactive **ALLOW** copper is less reactive than hydrogen	1
(ii)	Any value between 1.5 and 5.0 °C inclusive		1
(iii)	most reactive magnesium zinc iron tin copper	**ACCEPT** symbols	1
			Total 12

Question number	Answer	Notes	Marks
6 (a) (i)	magnesium is more reactive than copper	**ALLOW** magnesium can displace copper **ALLOW** magnesium is higher than copper in the reactivity series **REJECT** magnesium is more reactive than copper(II) **or** Cu^{2+} **or** copper sulfate	1
(ii)	magnesium sulfate + copper	Both are required for the mark. Either order. **REJECT** copper(II) **IGNORE** any chemical formulae given	1
(b) (i)	**M1** Temperature rise = 36.1(°C)	Correct answer with or without working scores 2	2
	M2 15 162J	**ALLOW** ecf from M1 **ALLOW** 2 or more significant figures **IGNORE** negative sign	
(ii)	An explanation that links any **two** of the following points		2
	M1 polystyrene is an insulator	**ALLOW** polystyrene is not a (good) conductor of heat **ALLOW** polystyrene is a poor conductor of heat	
	M2 (so) reduces heat loss (to the surroundings) OWTTE	**ALLOW** prevents heat loss **ALLOW** keeps heat in	
	M3 temperature rise/change/reading will be closer to true value OWTTE	**ALLOW** temperature rise/change/reading will be more accurate/valid	

(c)(i)	**M1** calculate the amount, in moles, of zinc **M2** divide Q by the amount in moles **M3** give the answer to three significant figures with a - sign Example calculation **M1** 0.500 ÷ 65 **OR** 0.00769 **M2** 1.67 ÷ 0.00769 **OR** 217 (kJ/mol) **M3** -217 (kJ/mol) **OR** **M1** 1.67 ÷ 0.5 **OR** 3.34 kJ/g) **M2** 3.34 × 65 **OR** 217 (kJ/mol) **M3** -217 (kJ/mol)	 **M2** subsumes **M1** Correct answer of -217 with or without working scores 3 marks. Allow ECF throughout	3
(c)(ii)	**M1** zinc is oxidised **and** Cu^{2+} is reduced **M2** Zinc loses electrons **M3** Cu^{2+} gains electrons	**ALLOW** zinc is oxidised and copper(sulfate) is reduced in **M1** **ALLOW** oxidation and reduction occur **ALLOW** references to changes in oxidation number for **M2** and **M3** Must mention copper ions for M3	3

Question number	Answer	Notes	Marks
7 (a)	gives out thermal energy/heat (energy)		1
(b)	• M1 expression for ∑ bond energies of reactants/bonds broken • M2 expression for ∑ bond energies of products/bonds made or evaluation • M3 correct equation linking M1, M2 and value of ΔH • M4 evaluation of Cl-Cl bond energy		4
	Example calculation	Correct answer without working scores 4	
	M1 (∑ bond energies of reactants =) 436 + X	**ACCEPT** E(Cl– Cl) or any suitable symbol or expression for X	
	M2 (∑ bond energies of products =) 2 x 431 **OR** 862(kJ)		
	M3 – 184 = 436 + X – 862 **OR** X = – 184 + 862 – 436	**ALLOW M3** ECF if 431 for **M2** If not used (-)184 in **M3** can only score M1 M2 **M3** subsumes **M1 M2**	
	M4 X = 242 (kJ/mol)	**ALLOW M4** ECF on **M3** as long as **M3** involves 436, X, 862 (or 431) and (-)184	

Question number	Answer	Notes	Marks
7 (c)	An explanation that links the following three points **M1** energy needed to break bonds / bond-breaking is endothermic **M2** energy given out when bonds are formed / bond-forming is exothermic **M3** energy given out is greater than energy needed (so exothermic) OWTTE	 **ALLOW** energy is absorbed/taken in **ALLOW** energy is released **M3 DEP M1 M2** more energy released when new bonds are formed (in products) than is needed to break the bonds (in reactants) OWTTE scores **M1 M2 M3** If any contradictory statements max 1	3
(d)	**M1** horizontal line to show products below reactants and to the right of reactants and labelled 2HCl **M2** vertical line from H_2 + Cl_2 level to 2HCl/products level and labelled enthalpy change/ΔH/ -184 **M3** curve with hump/peak shown on diagram going up from H_2 + Cl_2 line and ending at 2HCl/products line **M4** vertical line from H_2 + Cl_2 level to top of hump level and labelled activation energy/E_a	**ALLOW** products for 2HCl **ACCEPT** double headed arrow or arrow pointing from H_2 + Cl_2 level to 2HCl/products level **REJECT** arrow pointing from 2HCl/products level to H_2 + Cl_2 level **ACCEPT** double headed arrow or arrow pointing from H_2 + Cl_2 level to top of hump **REJECT** arrow pointing from top of hump to H_2 + Cl_2 level If endothermic diagram shown, can score **M2 M3** (peak/hump must be above products line) and **M4**	4 **Total 12**

Question number	Answer	Notes	Marks
4 (a)	Any two from **M1** concentration of sodium hydroxide (solution) **M2** rate of / same stirring **M3** temperature of sodium hydroxide (solution)	 **IGNORE** references to concentration of acid **IGNORE** references to volume / mass / amount of either solution **ALLOW** temperature of the room /environment	2
(b)	An explanation that links any two of the following points **M1** polystyrene/it is a better insulator than glass OWTTE **M2** less heat/thermal energy will be lost **M3** using a polystyrene cup will lead to a more accurate/a higher <u>temperature</u> (change)	 **ALLOW** polystyrene/it is an insulator **ALLOW** prevents heat loss /retains heat	2
(c) (i)	any value between 32.0 and 33.0 inclusive		1
(ii)	An explanation that links the following three points **M1** the first line shows that as more sodium hydroxide is added the temperature rises (at a steady rate) **M2** the point where the lines cross/ the highest temperature reached/ the volume of 21-22 cm^3 of sodium hydroxide shows that the sodium hydroxide has neutralised the acid/ the acid has fully reacted **M3** the second line shows that (there is no further reaction and) the cool sodium hydroxide solution decreases the temperature OWTTE	 **ACCEPT** the temperature is directly proportional to the volume added **ALLOW** there is a positive correlation between the temperature and the volume added **ALLOW** the second line shows that there is no further reaction as the mixture cools down OWTTE	3

(d)	**M1** mass of solution = 25 + 22 **OR** 47 (g) **M2** $Q = mc\Delta T$ **OR** $Q = 47 \times 4.2 \times 35$ **M3** 6909 (J) **M4** 6.9 (kJ)	correct answer without working scores 4 **ALLOW** ecf from **M1** if incorrect mass used e.g. use of 1, 22 or 25 **M2** subsumes **M1** **ALLOW** ecf from **M3** if correct conversion from J to kJ 147 /3234 /3675 (J) score 2 0.147 / 3.234 / 3.675 (kJ) score 3 **ACCEPT** any number of significant figures correctly rounded except 1	4
			Total 12

Question number	Answer	Notes	Marks
7 (a)	$2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$ **M1** equation correct and balanced **M2** state symbols correct	 If H_2 is shown as a product in the equation allow (g) for **M2**	2
(b)	An explanation that links the following points **M1** use a polystyrene cup instead of a beaker / or use a lid on the beaker **M2** as less heat is lost	**ALLOW** any other acceptable answer REJECT prevent heat loss	2
(c) (i)	all points plotted correctly to the nearest small square		1
(ii)	circle the correct anomalous point at 15 cm^3		1
(iii)	**M1** first best fit line **M2** second best fit line		2
(d)	**M1** volume of acid (approximately 27.5) **M2** maximum temperature (approximately 28.6)	values from the candidates graph to the nearest small square	2
(e)	An explanation that links the following points **M1** took the temperature too early **M2** so highest temperature was not reached **OR** **M1** did not stir the mixture **M2** so highest temperature was not reached	do not allow use too little of the acid as this would affect the rest of the graph	2
I			**Total 12**

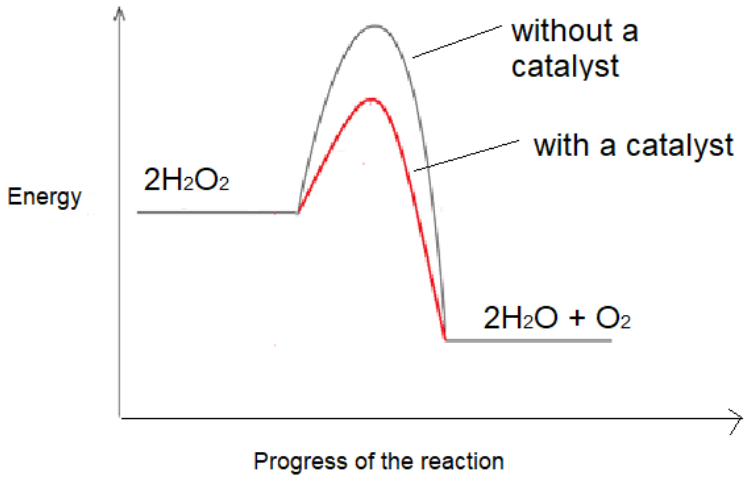
Question number	Answer	Notes	Marks
10 (a) (i)	potassium hydroxide + hydrochloric acid → potassium chloride + water	**ALLOW** correctly balanced chemical equation	1
(ii)	**M1** to mix (the two solutions more thoroughly) **M2** (so that) more reactant particles come into contact with each other OWTTE **M3** so that the heat energy is given out more quickly OWTTE **M4** so that the mixture is the same temperature throughout OWTTE	ALLOW references to increasing rate of reaction	2
(b)	Correct answer with or without working scores 2 • setting out of calculation • evaluation Example calculation **M1** $\frac{17.8 + 18.4}{2}$ **M2** 18.1		2

Question number	Answer	Notes	Marks
10 (c) (i)	Mean temperature at start in °C 17.2 Temperature at end in °C 22.4 Temperature rise in °C 5.2		2
(ii)	• calculation of volume/mass of mixture • substitution of values into $Q = mc\Delta T$ • evaluation Example calculation **M1** (volume/mass =) 25 + 25 **OR** 50 (cm^3) or (g) **M2** (Q =) 50 x 4.2 x 5.2 **M3** (Q =) 1092	 **ALLOW** ecf if 25 used in calculation 1092 without working scores 3 marks	3
(iii)	• division of Q by moles of KOH • conversion of J to kJ • answer with correct sign Example calculation **M1** $\frac{1092}{0.02}$ **OR** 54600 **M2** conversion from J to kJ OR 54.6(00) **M3** (ΔH =) − 54.6 (kJ/mol)	**ALLOW** ecf from answer to (ii) **ALLOW** any number of sig figs greater than 1 throughout **ACCEPT** 1092 or 1100 used in calculation **ALLOW** ecf from M1 Minus sign must be present **ALLOW** ecf from M2 **ACCEPT** any value between 54.5 and 55 **M3** dep on division of Q by moles	3

		Correct answer with correct sign and without working scores 3 Correct answer without sign or with incorrect sign and without working scores 2.	**Total 13**

Question number	Answer	Notes	Marks
7 (a)	M1 two lithium atoms each lose one electron /give one electron to oxygen M2 oxygen gains two electrons M3 lithium (ion) has an electron configuration of 2 and oxide (ion) is 2,8	**ALLOW** lithium loses one electron /gives one electron to oxygen **ALLOW** oxygen becomes 2,8 All 3 marks can be scored from diagrams showing the electron configurations of the ions 0 marks if reference to sharing electrons	3
(b) (i)	M1 (temperature after) = 27.7°C M2 temperature rise = 10.4 °C	 **ALLOW** ecf from M1	2
(ii)	Example calculation M1 Use of 100 in Q = m x c (x ΔT) M2 Use of 10.4 in Q = (m x) c x ΔT M3 4368J M4 4400J	Correct answer of 4400J with or without working scores 4 **ALLOW** ecf from (b)(i) 100 x 4.2 x 10.4 scores M1 and M2 **ALLOW** ecf from M1 and M2 **ALLOW** ecf from M3 **IGNORE** + or - sign in front of answer	4
(iii)	Example calculation M1 5210 ÷ 1000 or 5.21 M2 5.21 ÷ 0.0580 M3 -89.8(kJ/mol)	Correct answer of -89.8 (kJ/mol) scores 3 **ALLOW** -90 (kJ/mol) or any number of sig figs as long as correctly rounded.	3
(iv)	polystyrene is a good insulator /poor conductor (of heat) OR to minimise/reduce heat loss	**ALLOW** prevent heat loss	1
			13 marks

Question number	Answer	Notes	Marks
5 (a)	a catalyst is chemically unchanged at the end of the reaction	ALLOW (provides alternative route for reaction of) lower activation energy ALLOW not used up in reaction	1
(b)	description including six of the following points: M1 do experiment using hydrogen peroxide solution only/without X/Y/Z M2 use known volume of hydrogen peroxide solution OWTTE M3 (and) measure time for certain volume of oxygen gas to be collected OR measure volume of gas collected in a certain time period OWTTE M4 repeat using same volume of hydrogen peroxide solution M5 with known mass/amount of solid X (then Y, then Z) M6 measure time for same volume of oxygen gas to be collected OR measure volume of gas collected in same time period (with solid/X/Y/Z present) M7 after reaction (remove solid/X/Y/Z by filtration and dry) find mass of solid/X/Y/Z /check if mass unchanged M8 reference to reduced time (for certain volume of oxygen gas to be collected) OR increased volume of gas (collected in a certain time period) means X/Y/Z (possible) catalyst (1)	ALLOW measure time until no more oxygen produced ALLOW amount ALLOW reference to increased rate	6

Question number	Answer	Notes	Mark
5 (c)	M1 labelled profile curve drawn for reaction without catalyst M2 labelled profile curve drawn with lower activation energy for reaction with catalyst  	must start from reactants energy level and end at products energy level	2
(d) (i)	energy needed= [(4 x 463) + 2(146)] = 2144	Ignore sign	1
(ii)	energy released = [(4 x 463)] = 1852	ignore sign	1
(iii)	M1 for showing equation linking between (i), (ii), O=O bond energy and $\triangle H$ M2 correct calculation Example: M1 [1852+ (O=O)] - 2144 = 204 OR (O=O) = 2144 – 1852 + 204 M2 (O=O) = 496	Mark CSQ on (i) and (ii) -496 scores 1 mark	2

(Total for Question 5 = 13)

Question number	Answer	Notes	Marks
7 (a)	M1 two electrons between nitrogen and each of the four hydrogen atoms M2 two electrons between the two nitrogen atoms, and a non-bonding pair on each nitrogen	ALLOW any symbols used for electrons ALLOW each non-bonding pair shown as two separate electrons	2
(b) (i)	M1 (3×158)+(12×391) M2 5166 kJ	 5166 kJ without working scores 2 IGNORE sign of final answer	2
(ii)	M1 (12×391)+945 M2 5637kJ	 5637 kJ without working scores 2 IGNORE sign of final answer	2
(iii)	−471 (kJ/mol)	ECF on b(i) & b(ii) If final answer is +ve do not penalise lack of sign	1
(iv)	An explanation that links together the following two points: M1 bond breaking requires energy / is endothermic, bond formation releases energy / is exothermic M2 more energy released than taken in / making bonds involves more energy than breaking bonds	 “bonds” only needs mentioning once “more energy is given out when bonds are made than is taken in when bonds are broken” scores (2)	2
(c)	M1 amount of nitrogen gas = 1570÷24000 **OR** 0.06542 (mol) M2 amount of ammonia = 0.0654×4 **OR** 0.2617 (mol) M3 concentration of ammonia = 0.2617 ÷ 1100x1000 = 0.237878…. M4 0.238 (mol/dm^3) *	 ALLOW M1×4 ALLOW M3÷1.1 Must be 3 sig figs to score M4 answer of 0.238 (mol/dm^3) scores 4 marks with or without working	4
			Total for question = 13

Question number	Answer	Notes	Marks
8 (a) (i)	to allow the heat (energy) to be distributed evenly (throughout the water) OWTTE	**ACCEPT** so the temperature is the same (throughout the water)	1
(ii)	to avoid some of the liquid/fuel/pentanol evaporating OWTTE		1
(b)	<table><tr><td>Initial temperature of water in °C</td><td>15.9</td></tr><tr><td>Final temperature of water in °C</td><td>50.9</td></tr><tr><td>Temperature change in °C</td><td>35.0</td></tr></table>	PENALISE answer not to nearest 0.1 °C once only **ALLOW** ecf on initial temperature Correct values transposed scores (1)	2
(c) (i)	**M1** (Q =) 100 × 4.2 × 35 (J) **M2** 14 700 (J)	Correct answer of 14 700 without working scores 2 **ALLOW** 15 000 (J) only if **M1** is scored	2
(ii)	**M1** (mass of pentanol =) 90.11 − 89.75 **OR** 0.36 (g) **M2** (amount of pentanol =) 0.36 ÷ 88 **OR** 0.0041 (mol) **M3** 14 700 ÷ 0.0041 **OR** 3 600 000 (J/mol) **M4** 3 600 000 ÷ 1000 **OR** 3600 (kJ/mol) **M5** (ΔH =) − 3600 (kJ/mol)	Correct answer without working scores 5 **ALLOW** ecf on incorrect mass **REJECT** 0.004 (which gives final answer of −3675) **ALLOW** ecf as long as there has been an attempt to calculate moles of pentanol **ALLOW** any SF except 1 SF	5
(d)	$C_5H_{11}OH + 7.5O_2 \rightarrow 5CO_2 + 6H_2O$ **M1** all formulae correct **M2** balancing of correct formulae	**ALLOW** multiples **M2** dep on **M1** **IGNORE** state symbols even if incorrect	2
			Total 13

Question number	Answer	Notes	Marks
7 (a)	**M1** (electrostatic) attraction between nuclei (of both atoms) **M2** and a shared/bonding pair of electrons **OR** **M1** (electrostatic) attraction between a shared/bonding pair of electrons **M2** and nuclei (of both atoms)	nuclei must be plural nuclei must be plural	2
(b)	An explanation that links the following four points **M1** (in the organic solvent) litmus paper stays blue/has no change **M2** because there are no (H^+) ions/ the solution is not acidic /does not dissociate in an organic solvent **M3** (in the aqueous solution) litmus paper turns red **M4** because H^+ ions are formed/hydrochloric acid forms	 No **M1 or M2** if litmus paper turns red **REJECT M3** if litmus is bleached or turns white **M4** dep on litmus turning red initially	4
(c) (i)	**M1** reactants bond energy = 436 + 242 **OR** 678 (kJ) **M2** products bond energy = 2 x 431 **OR** 862 (kJ) **M3** – 184 (kJ/mol)	correct answer – 184 with or without working scores 3 (+)184 scores 2 **ALLOW** ecf on incorrect values on **M1** and/or **M2**	3
(ii)	**M1** show correct positions of horizontal lines and activation energy hump **M2** correct labelling of (reactants) H_2 + Cl_2 and (products) 2HCl **M3** vertical line in correct position labelled ΔH	**ALLOW** ecf if positive answer in (i) **M3 REJECT** arrow pointing down **ACCEPT** arrow pointing down or double headed arrow **REJECT** arrow pointing up	4

	M4 vertical line in correct position labelled Ea or activation energy	**ACCEPT** arrow pointing up or double headed arrow **REJECT** arrow pointing down	**Total 13**

Question number	Answer	Notes	Marks
9 (a)	aluminium is a better conductor (of heat) than glass (comparison needed)	REJECT insulation references	1
(b) (i)	carbon / soot/ C		1
(ii)	incomplete combustion occurs OR the supply of oxygen/air is limited		1
(c) (i)	M1 100×4.2×50 M2 21000(J)	 ALLOW ecf for M2 if answer close to 20000J	2
(ii)	M1 21 kJ M2 1.84÷46 OR 0.04 moles M3 21÷0.04 OR 525 (kJ/mol) M4 -525 (kJ/mol)	ALLOW 20kJ ALLOW 21÷M2 ALLOW 500 (kJ/mol) if 20kJ used M4 is for the – sign. ALLOW ecf from M3	4
(d) (i)	$5O_2$	ALLOW multiples if the rest of the balancing numbers have been multiplied	1
(ii)	M1 (M_r of butanol) 74 M2 (moles of butanol) 3.7÷74 OR 0.05 M3 0.45 moles	 ALLOW 3.7÷M1 if attempted Mr shown ALLOW M2×9 Answer of 0.45 scores 3	3
		Total = 13	

<table>
<tr><th>Question number</th><th>Answer</th><th>Notes</th><th>Marks</th></tr>
<tr><td>8 (a) (i)</td><td>measuring cylinder</td><td>ALLOW pipette/burette</td><td>1
cler</td></tr>
<tr><td>(ii)</td><td>to ensure temperature same throughout solution
OWTTE</td><td>ACCEPT to ensure heat evenly distributed throughout solution
OWTTE</td><td>1
grad</td></tr>
<tr><td>(iii)</td><td>blue</td><td>IGNORE qualifiers eg light/dark

REJECT blue-green</td><td>1
cler</td></tr>
<tr><td>8 (b)</td><td><table><tr><td>Maximum temperature in ºC</td><td>27.3</td></tr><tr><td>Initial temperature in ºC</td><td>24.4</td></tr><tr><td>Increase in temperature in ºC</td><td>2.9</td></tr></table>
M1 27.3

M2 24.4

M3 2.9</td><td>If readings are correct but in reverse order award 1 mark for M1 and M2

ALLOW ECF for M3 if M1 and/or M2 incorrect</td><td>3
grad</td></tr>
</table>

Question number	Answer	Notes	Marks
8 (c) (i)	• substitution into $Q = mc\Delta T$ • calculation of heat energy in Joules Example calculation **M1** Q = 50 x 4.2 x 3.3 **M2** 693 J	693 without working scores 2 marks	2 exp
(ii)	• calculate the amount, in moles, of $CuSO_4$ • divide Q by the amount in moles • conversion to KJ • give the correct sign Example calculation **M1** 1.70 ÷ 159.5 **OR** 0.0107 **M2** 693 ÷ 0.0107 **OR** 64766 (J/mol) **M3** 64.8 (kJ/mol) **M4** – 64.8 (kJ/mol)	ALLOW any number of SF throughout except one Mark CQ from (i) ALLOW use of 700 use of 700 gives -65.02 693 & 0.011 gives -63 700 & 0.011 gives -63.64 correct answer with correct sign and without working scores 4 correct answer without sign or incorrect sign and without working scores 3	exp 4
8 (d)	M1 temperature decreases/falls M2 (so) endothermic		2 grad

Total Q8 = 14

Question number	Answer	Notes	Marks
9 (a) (i)	**M1** and **M2** all points correctly plotted to the nearest half a square	deduct 1 mark for each error	2
(ii)	smooth curve of best fit		1
(iii)	An explanation that links any **two** of the following points **M1** polystyrene is an insulator **M2** reduces thermal energy/heat coming in from the surroundings OWTTE **M3** temperature decrease will be closer to true value OWTTE	 **ALLOW** results will be more accurate	2
(iv)	Any one from: **M1** the student recorded the temperature before adding the sodium carbonate /the temperature had not stopped decreasing OWTTE **M2** the student forgot to the stir the mixture	 **ALLOW** less than 0.5 g of/not enough sodium carbonate was added	1
(v)	(two) results at the end are the same	**ALLOW** the temperature stops decreasing	1
(vi)	An explanation that links together **M1** the reaction is endothermic and either of the following points **M2** it takes in thermal energy/heat from the surroundings **OR** **M3** as shown by the temperature decrease (of the reaction mixture)	 **REJECT** exothermic for both marks **ALLOW** references to cooling No **M2** or **M3** if the statements contradict one another	2

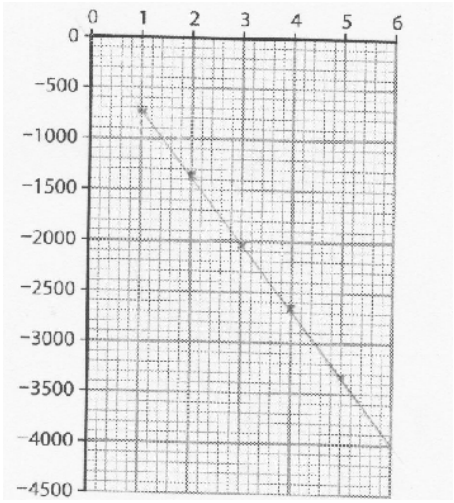
Question number	Answer	Notes	Marks
9 (b) (i)	to prevent acid / liquid / solution splashing out		1
(ii)	**M1** (M_r of sodium carbonate) = 106 **M2** (moles of sodium carbonate 2.12 ÷ 106 =) 0.02 **M3** (mass of carbon dioxide 0.02 × 44 =) 0.88 (g)	**ALLOW** ecf from **M1** **M2** subsumes **M1** **ALLOW** answer from **M2** x 44 answer of 0.88 (g) with or without working scores 3	3
(iii)	Any one from: **M1** the sodium carbonate is impure **M2** some of the carbon dioxide dissolves in the acid/solution		1
			14

Question number	Answer	Notes	Marks
11 (a) (i)	all 9 points plotted ± half a square		1
(ii)	circle around point at 3 g	ALLOW 18 or 3 circled in the table	1
(iii)	points joined by curved line of best fit		1
(b) (i)	M1 polystyrene / it is a good insulator M2 polystyrene / it reduces heat (energy) / thermal energy gain / transfer from surroundings OWTTE	ALLOW poor conductor (of heat) ALLOW polystyrene /it does not absorb heat /stops heat entering (the cup) REJECT heat loss (to surroundings)	2
(ii)	the student forgot to stir the mixture	ALLOW took the temperature reading too soon REJECT the student added too little or forgot to add the solid	1
(iii)	(the last three) results / temperatures are the same		1
(iv)	because the temperature decreases	ALLOW because heat / thermal energy is taken in	1
(c)	M1 (ΔT =) 20.8 – 15.3 **OR** 5.5 (°C) M2 (Q = 100 x 4.2 x 5.5 =) 2 310 (J)	Answer of 2310 scores 2 ALLOW ecf if incorrect temperature change IGNORE any sign given	2
(d)	M1 moles of $NaHCO_3$ = 7.0 ÷ 84 **OR** 0.0833 M2 3 200 ÷ 0.0833 **OR** 38 400 (J) M3 38 400 ÷ 1000 **OR** 38.4 (kJ/mol) M4 +38.4 (kJ/mol) OR M1 moles of $NaHCO_3$ = 7.0 ÷ 84 **OR** 0.0833 M2 3 200 ÷ 1 000 **OR** 3.20 (kJ) M3 3.20 ÷ 0.0833 **OR** 38.4 (kJ/mol) M4 +38.4 (kJ/mol)		4

		Answer of +38.4 scores 4 Answer of 38.4 scores 3 Use of 0.08 moles gives +40 which scores 4 Use of 0.083 moles gives +38.6 which scores 4 ALLOW any number of sig figs	
			Total for question = 14

Question number	Answer	Notes	Marks
9 (a)	to minimise/prevent (mass loss by) evaporation of the (liquid) fuel OWTTE	**ALLOW** to find mass of fuel used/burned	1
(b) (i)	soot/carbon	**REJECT** copper oxide	1
(ii)	An explanation that links the following two points. **M1** incomplete combustion (occurs) **M2** (because) the air/oxygen supply is limited OWTTE	**ALLOW** mark for soot/carbon if not seen in (i), unless copper oxide is mentioned in (i) If copper oxide in (i) ALLOW 1 mark for (because) copper reacts with oxygen (in air)	2
(c) (i)	• substitution into $Q = mc\Delta T$ • calculation of heat energy in Joules • conversion to kJ Example calculation **M1** Q = 100 x 4.2 x 30 **M2** = 12600 (J) **M3** = 12.6 kJ	 12600 (J) with no working scores M1 and M2 M2 ECF M1 **ALLOW** approximately = 13 kJ 12.6 kJ with no working scores 3	3

(ii)	• calculate the amount, in moles, of methanol • divide Q by the amount in moles • give the answer with the correct sign Example calculation **M1** 0.96 ÷ 32 **OR** 0.03 **M2** 12.6 ÷ 0.03 **OR** 420 (kJ/mol) **M3** – 420 (kJ/mol)	**ACCEPT** 13 ÷ 0.03 **OR** 430/433 for **M2** **AND** – 430 / – 433 for **M3**	3

Question number	Answer	Notes	Marks
9 (d) (i)	**M1** all points plotted correctly **M2** line of best fit drawn with a ruler  	does not need to start at (0,0)	2
(ii)	**M1** straight line extrapolated up to 6 carbon atoms **M2** value of ΔH read from their graph	**ALLOW** extra point shown at 6 carbon atoms negative sign needed	2
(iii)	The greater the number of carbon atoms (per molecule) the greater (the magnitude/ value of) ΔH	**ALLOW** ΔH is (directly) proportional to the number of carbon atoms per molecule **ALLOW** The greater the number of carbon atoms (per molecule) the more exothermic the ΔH value	1
			Total 15

Question number	Answer	Notes	Marks
10 (a)	**M1** so that the solid/ammonium nitrate dissolves more quickly **M2** so that the temperature is even throughout the solution OWTTE	IGNORE speed up reaction ALLOW heat transfers evenly (throughout the solution)	2
(b)	<table><tr><td>initial temperature of distilled water in °C</td><td>23.4</td></tr><tr><td>minimum temperature of solution in °C</td><td>19.4</td></tr><tr><td>temperature change in °C</td><td>4.0</td></tr></table>	must be to 1 dp **ALLOW** ecf on incorrect mimimum temperature	2
(c) (i)	**M1** (Q =) 50 x 4.2 x 3.9 (J) **M2** (Q =) 819/820 (J)	answer of 819 or 820 without working scores 2 **ALLOW** use of 4.0 giving an answer of 840	2
(ii)	• find moles of NH_4NO_3 • division of Q by moles • conversion to kJ/mol • answer with correct sign **M1** (amount of NH_4NO_3 =) 2.8 ÷ 80 **OR** 0.035 (mol) **M2** 819 ÷ 0.035 **OR** 23 400 (J/mol) **M3** 23 400 ÷ 1000 **OR** 23.4 (kJ/mol) **M4** (ΔH =) +23.4/+23 (kJ/mol)	correct answer without working scores 4 use of 820 gives 23 429 use of 800 gives 22 857 use of 840 gives 24 000 use of 820 gives 23.4 use of 800 gives 22.9 use of 840 gives 24.0	4
(d)	A description that refers to the following points **M1** add sodium hydroxide (solution to the ammonium nitrate and warm) **M2** test the gas/ammonia evolved with (damp) red litmus paper/(damp) universal indicator paper **M3** (red litmus) turns blue/ (universal indicator) turns blue/purple	 **M2** and **M3** dep on **M1** No **M2** or **M3** if solution tested with litmus/ universal indicator paper	3

(e)	An explanation that links the following points **M1** the temperature increases/rises **M2** so the reaction is exothermic		2 **Total 15**

Question number	Answer	Notes	Marks
11 (a)	Award 1 mark each for any six of the following: **Method 1** **M1** polystyrene (insulator so) reduces/prevents heat loss (to atmosphere) OWTTE **M2** no lid so heat/thermal energy will be lost (to atmosphere) **M3** stirring will ensure even temperature / more accurate (highest) temperature OWTTE **M4** no lid so possibility of spillage **OR** polystyrene cup (containing thermometer) unstable/may fall over OWTTE **Method 2** **M5** glass bottle poor insulator so heat/thermal energy loss occurs OWTTE **M6** bung helps reduce/prevent heat/thermal energy loss (to atmosphere) **M7** bung so no spillage **M8** cannot stir so cannot ensure even temperature / cannot ensure accurate (highest) temperature OWTTE	**ALLOW** references to heat/thermal energy evenly spread (throughout solution) OWTTE **IGNORE** references to increases rate of reaction **ALLOW** references to heat /thermal energy not evenly spread (throughout solution) OWTTE	6

11 (b)	**M1** 0.025 mol $CuSO_4$ reacts with 0.025 mol Zn **M2** mass Zn needed = 0.025 x 65 = 1.625 g (3g > 1.625g so having 3g Zn is excess) OR **M1** 0.025 mol $CuSO_4$ reacts with 0.025 mol Zn **M2** 3g Zn = $\frac{3}{65}$ = 0.046 mol (0.046 > 0.025 so having 3g Zn is excess)	**ALLOW** reference to 1:1 molar ratio or (only) 0.025 mol Zn needed **M2** subsumes **M1** **ALLOW** reference to 1:1 molar ratio or (only) 0.025 mol Zn needed	2

Question number	Answer	Notes	Marks
11 (c) (i)	**M1** calculation of temperature rise **M2** correct substitution into Q = m x 4.2 x temp rise **M3** correct evaluation of Q Example calculation **M1** (40.6 – 21.1) OR 19.5 **M2** Q = 50 x 4.2 x 19.5 **M3** = 4100 (J)	ALLOW 4095 IGNORE sign	3
(ii)	**M1** answer to (i) ÷ 0.025 **M2** correct evaluation in J **M3** correct conversion to kJ and minus sign Example calculation **M1** 4095 ÷ 0.025 **M2** = 163 800 (J) **M3** = −160 kJ	**ACCEPT** use of 4000 **ACCEPT** 160 000/ 164 000 **ACCEPT** −163.8/−164 160/163.8/164 scores 2	3
11 (d)	**M1** Zn/zinc is oxidised because loses electrons **M2** Cu^{2+}/copper ions reduced because gains electrons		2

Total for Question 11 = 16 marks

Question number	Answer	Notes	Marks
10 (a)	M1 a catalyst provides an alternative pathway / route M2 of lower activation energy		2
(b) (i)	conical flask	ALLOW flask	1
(ii)	M1 filter out the manganese(IV) oxide M2 allow it to dry M3 reweigh the catalyst, the same mass should be left / mass is still 1 g		3
			total for question = 6

Question number	Answer	Notes	Marks
5 (a)	A description that refers to any five of the following points M1 add hydrogen peroxide to the conical flask and add catalyst M2 start the timer M3 record volume of gas produced in a given time/ record the time for certain volume of gas to be produced M4 repeat with same mass of a different catalyst M5 and with same volume of hydrogen peroxide M6 plot the results on a graph and calculate gradient (for each catalyst) M7 the most effective catalyst gives the fastest rate of reaction OWTTE		5
(b) (i)	M1 a vertical line from the level of the hydrogen peroxide to the top of the curve labelled activation energy or E_a M2 a vertical line from the level of the hydrogen peroxide to the level of the water and oxygen labelled enthalpy change or ΔH	the line does not need an arrow head ALLOW double headed arrow REJECT arrow pointing down ALLOW double headed arrow REJECT arrow pointing up	2
(ii)	curve starting from hydrogen peroxide level, below the peak of the original curve, and ending at water and oxygen level		1
			Total for question = 8

Question number	Answer	Notes	Marks
8 (a)	carbon dioxide/a gas escapes/is lost/released (through the cotton wool)	NOT carbon dioxide/gas is given off/produced NOT wrong named gas	1
(b)	M1 the concentration (of hydrochloric acid) is highest M2 so there are more collisions per unit time	ALLOW there is a greater surface area of marble chips ALLOW greater amount of hydrochloric acid/reactants ALLOW more particles ALLOW more frequent collisions REJECT references to greater (kinetic) energy for both marks	2
(c)	the hydrochloric acid has been used up OWTTE	NOT acid is saturated IGNORE acid is a limiting factor	1
(d) (i)	any two from: (same) mass of marble chips (same) surface area of marble chips (same) concentration of hydrochloric acid (same) volume of hydrochloric acid	 ALLOW (same) amount of marble chips ALLOW (same) size marble chips NOT same amount of acid	2 3
(ii)	M1 rate of reaction increases M2 particles have more energy OR more particles have energy greater than (or equal to) the activation energy M3 so more successful collisions per unit time	 ALLOW particles move faster ALLOW more frequent successful collisions	
		Total = 9	

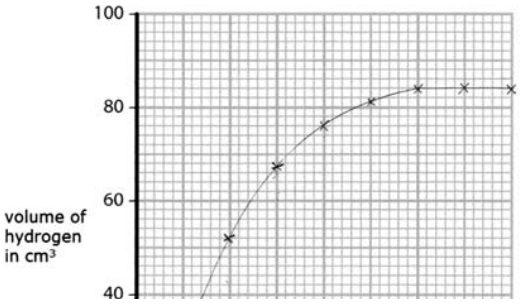
Question number	Answer	Notes	Marks
9 (a) (i)	M1 copper(II) sulfate (solution) M2 shortest time taken to turn colourless	**ALLOW** copper sulfate **ALLOW** gave greatest increase in rate OWTTE **ALLOW** made reaction happen fastest OWTTE M2 dep on M1	2
(ii)	M1 a catalyst provides an alternative pathway M2 of lower activation energy	 Any reference to increasing energy/speed of particles scores 0	2
(b) (i)	An explanation with following four points **M1** the rate of reaction increases/ the reaction is faster/ the reaction speeds up **M2** because the particles gain (kinetic) energy /move faster **M3** there are more collisions per unit time **M4** more of the collisions are successful / more collisions/particles have energy greater than the activation energy	 **ACCEPT** more frequent collisions OWTTE No M4 if refer to lower activation energy there are more frequent successful collisions scores **M3** and **M4**	4
(ii)	M1 fewer particles per unit volume M2 (hence) fewer collisions per unit time	**ALLOW** particles less tightly packed / particles further apart **ALLOW** decrease in the frequency of collisions between particles Any reference to changing energy/speed of particles scores 0	2

Total for question 9 = 10 marks

Question number	Answer	Notes	Marks
6 (a)	the gas also contains air (displaced from the conical flask)		1
(b)	M1 a catalyst provides an alternative (reaction) pathway / route M2 of lower activation energy		2
(c)	M1 add hydrogen peroxide solution (to the conical flask) and add one of the catalysts M2 record the time taken to collect a fixed volume of gas OR record the volume of gas collected in a fixed time AND any 2 from M3 repeat with the same volume / same concentration of hydrogen peroxide solution M4 (repeat at) same temperature M5 use same mass / same surface area of each catalyst AND M6 the most effective catalyst produces the greatest volume of gas per unit time OR takes the least time to produce a fixed volume of oxygen	ALLOW record the time when no more gas produced ALLOW same amount ALLOW same amount ALLOW the least time taken to complete the reaction is the most effective catalyst	5
(d)	M1 steeper curve starting at the origin M2 same volume of oxygen produced		2
			Total for question = 10

Question number			Answer	Notes	Marks
9	(a)	(i)	carbon dioxide/a gas is given off	**IGNORE** marble dissolving **IGNORE** gas formed	1
		(ii)	to prevent acid spray from leaving the flask OWTTE	**IGNORE** to stop solid from escaping	1
					4
	(b)	(i)	Any two linked pairs from the following: **M1** the curve is steep(est) at the start/the loss in mass is fastest at the start **M2** because the acid concentration is highest/maximum number of reacting particles **OR** **M3** curves becomes less steep/the loss in mass slows down **M4** acid becomes more dilute/less concentrated **OR** **M5** curve levels off/becomes flat/plateaus/the loss in mass stops **M6** acid has been used up	**IGNORE** comments linked to rate of reaction Max 2 marks for M1, M3 and M5	
		(ii)	**M1** curve drawn starting at the origin and below the original curve **M2** curve levels off at 0.27 g + or − half a small square		2
	(c)		An explanation that links the following three points **M1** the rate of reaction would increase/be faster **M2** (because) the smaller marble chips have a greater surface area **M3** (so) there will be more collisions per unit time	**IGNORE** less chance of collisions **ACCEPT** more frequent collisions MAX 1 mark if reference to particles having more energy or moving faster	3
					Total 11

Question number	Answer	Notes	Marks
5 (a)	oxygen relights a glowing splint		1
(b)	M1 a catalyst provides an alternative pathway M2 of lower activation energy	ALLOW alternative route	2
(c) (i)	A (conical) flask B (gas) syringe		2
(ii)	M1 line from 4 minutes to the curved line M2 38cm^3	 ALLOW values 37-39cm^3	2 4
(iii)	M1 tangent drawn to the graph at 8 minutes touches curve once only M2 measurements made from △ M3 use measurements to calculate rate (y2-y1/x2-x1)(1sf or more) M4 cm^3/minute If **NO** tangent drawn or drawn incorrectly(M1 not awarded) then M3 awarded for 58-60/8 or 480 calculated correctly OR numbers from a ▽ calculated correctly AND M4 for cm^3/minutes	 ALLOW ecf for tangent drawn at other than 8 minutes ALLOW cm^3/min ALLOW cm^{3}min^{-1} ALLOW cm^3/s ALLOW cm^{3}s^{-1} ALLOW cm^3/min ALLOW cm^{3}min^{-1} ALLOW cm^3/s ALLOW cm^{3}s^{-1}	
		Total = 11	

Question number	Answer	Notes	Marks
13 a (i)		all points plotted correctly to + or – half a square	**1**
(ii)		curve of best fit drawn for points plotted	**1**

Question number			Answer	Notes	Marks
13	b	i	**M1** curve Y starting at origin **and** below original curve **M2** levelling off at 42 cm^3 to + or – half a square		**2**
		ii	**M1** curve Z starting at origin **and** above original curve **M2** levelling off at 84 cm^3 to + or – half a square	**ACCEPT** curves unlabelled If curves labelled incorrectly then deduct 1 mark	**2**
	c		Any one from: **M1** some gas escapes before the bung is replaced/ before the syringe is connected **M2** the magnesium is impure/ the magnesium ribbon has an oxide coating	**IGNORE** gas escapes unqualified **IGNORE** magnesium didn't fully react /reaction didn't go to completion **ALLOW** some gas dissolves in the solution/acid/water	**1**

Question number	Answer	Notes	Marks
13 d	An explanation that links together the following two points: **M1** the acid is in excess **M2** therefore a precise/ an accurate measurement of the volume is not required	 **M2** dep on **M1**	**2**
13 e	An explanation that links the following points: **M1** the concentration of the acid/hydrogen ions/H^+ (ions) decreases **M2** therefore there are fewer (successful) collisions (between the hydrogen ions/H^+ ions and the magnesium atoms) **M3** per second/per unit time	 **ALLOW** there are fewer hydrogen ions/H^+ (ions) in the same volume **ALLOW** the surface area of the magnesium decreases less frequent collisions/ slower collision rate scores **M2** and **M3** **M3** dep on **M2** **IGNORE** less chance of collision **MAX 1** if reference to energy of particles changing	**3**
		Total	**12**

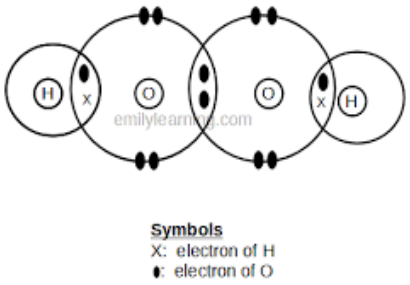
Question number	Answer	Notes	Marks
6 (a) (i)	$Zn + 2HCl \rightarrow ZnCl_2 + H_2$ M1 all symbols and formulae correct M2 correctly balanced	 M2 DEP M1	2
(ii)	lighted splint (produces squeaky) pop		1
(b) (i)	52 (cm^3)	ALLOW 51.5-52.5	1
(ii)	M1 vertical line from 15 cm^3 acid to graph line M2 volume hydrogen from graph multiplied by 2 OR M1 vertical line from 30 cm^3 acid to graph line M2 volume hydrogen from graph	ALLOW extra point drawn at 15 cm^3 ALLOW 68-70 ALLOW extra point drawn at 30 cm^3 ALLOW 68-70	2
(c)	explanation linking M1 more (acid) particles/(hydrogen) ions/H^+ in same volume M2 more (successful) collisions per second/unit time M3 rate increases	 REJECT molecules once only ALLOW particles are closer together ACCEPT more frequent collisions IGNORE more chance/probability of collision ALLOW reaction is faster /speeds up MAX 1 if refer to particles moving faster/having more energy	3

6 (d)	explanation including M1 (increase/decrease) surface area M2 increase surface area by using smaller pieces of zinc M3 more (successful) collisions per second/unit time (so rate increases)	 ACCEPT more frequent collisions IGNORE more chance/probability of collision M2 M3 ACCEPT reverse arguments	3

(Total for Question 6 = 12)

Question number	Answer	Notes	Marks
10 (a) (i)	**M1** 0.0036 moles of HCl react with 0.0018 moles of Zn **M2** mass of Zn that reacts is 0.0018 x 65 = 0.117 (g) (which is less than 1.3 g, so zinc is in excess) ***OR*** **M1** moles of zinc that can react with 0.0036 moles of HCl = 0.0036 / 2 = 0.0018 (mol) **M2** moles of Zn present = 1.3 ÷ 65 = 0.02 (mol) (which is more than 0.0018, so zinc is in excess) ***OR*** **M1** amount of zinc = 1.3 ÷ 65 = 0.02 (mol) **M2** amount of HCl that can react = 2 x 0.02 = 0.04 (mol) (which is greater than 0.0036, so zinc is in excess)	ALLOW 0.234 g is less than 1.3g, so zinc in excess for (1)	2
(ii)	**M1** curve starting at origin and steeper than curve A **M2** curve levelling off at same volume as curve A /at 40 cm^3		2
(b) (i)	An explanation that links any of the following four points **M1** curve B is less steep (than curve A) **M2** (because) the particles have less <u>kinetic</u> energy **M3** so there are fewer successful collisions per unit time/less frequent successful collisions **M4** so rate of reaction is slower / reaction takes longer to complete **M5** no change in reacting quantities, so final volume is unchanged	**ALLOW** particles move more slowly **ACCEPT** less frequent collisions that exceed activation energy **ACCEPT** reverse argument throughout	4

(ii)	An explanation that links two of the following points **M1** only half the moles (of hydrochloric acid) used / (hydrochloric acid) concentration is halved **M2** (so) only half the volume/20 cm^3 of hydrogen/gas produced **M3** hydrochloric acid is less concentrated so curve is less steep	If M1 and M2 are not scored, allow (1) mark for the idea that less HCl produces less hydrogen	2
(c)	A description that refers to the following two points **M1** (a catalyst) provides an alternative pathway/route **M2** with a lower activation energy	**IGNORE** general statements about catalysts increasing rate / not being used up	2
			Total 12

Question number			Answer	Notes	Marks
6	(a)		Relights/ignites a glowing splint/spill		1
	(b)		**M1** 3 bond pairs correct **M2** rest of molecule fully correct Eg.  	**ALLOW** any combination of dots and crosses **M2** dep on **M1**	2
	(c)	(i)	all points plotted correctly to the nearest grid line (+-1/2 small square)		1
		(ii)	best fit curve starting at 0 and levelling off at 94 cm^3	Ecf possible from misplotted point	1
	(d)	(i)	An explanation that links the following three points **M1** fewer particles (in the same volume) **M2** fewer collisions per unit time/less frequent collisions **M3** (so) rate of reaction decreases	 REJECT if reference to less/more kinetic energy/less movement IGNORE less chance of collisions REJECT if reference to less/more kinetic energy/less movement MAX 1 mark can be awarded here If kinetic energy/particle movement mentioned in answer	3
		(ii)	**M1** curve starting at 0 and less steep than original curve **M2** curve levelling off at 46-48 cm^3 inclusive		2
	(e)		An explanation that links the following two points **M1** provides an alternative pathway/route **M2** with lower activation energy		2
					Total 12

Question number	Answer	Notes	Marks
5 a (i)	An explanation linking the following two points **M1** to stop acid (spray) leaving the flask OWTTE **M2** as (without cotton wool) mass loss would be too large OWTTE	**ALLOW** so that only gas can escape (from flask) OWTTE **ALLOW** so the only cause of mass loss is gas (escaping) **REJECT** stops gas escaping **REJECT** references to substances/impurities/gases entering flask **ALLOW** as with cotton wool the mass does not decrease by more than it should OWTTE	2
a (ii)	B gas is given off A is incorrect as particles moving does not result in mass loss C is incorrect as heat energy being produced does not result in mass loss D is incorrect as marble chips dissolving does not result in mass loss		1
b	$CaCO_3$ (s) + 2HCl (aq) → $CaCl_2$ (aq) + H_2O (l) + CO_2 (g) All 5 correct scores 2 4, 3 correct scores 1	**ALLOW** upper case	2

Question number			Answer	Notes	Marks
5	c		**M1** curve steeper than the original curve **M2** levels off at the same mass loss/place as original curve		2
	d	(i)	An explanation linking the following three points **M1** (rate) increases **M2** more particles in the same volume **M3** more (successful) collisions per unit time / more frequent (successful) collisions	**ALLOW** particles closer together If reference to particles move faster/have more energy **MAX 1** **IGNORE** references to increased chance/probability of collisions	3
		(ii)	An explanation linking the following three points **M1** (rate) increases **M2** (mean kinetic) energy of particles increases **M3** more successful collisions per unit time / more frequent successful collisions OWTTE	**ALLOW** particles move faster **ALLOW** more particles have energy ≥ activation energy **ALLOW** reference to more frequent collisions between particles having ≥ activation energy	3
					Total 13

Question number	Answer	Notes	Marks
4 (a)	Any two from **M1** concentration of solution A **M2** concentration of solution B **M3** volume of solution B	 ALLOW amount of solution B Ignore apparatus	2
(b) (i)	all points plotted correctly to the nearest grid line		1
(ii)	anomalous point at 25°C circled	**ALLOW** ecf from incorrect plotting	1
(iii)	smooth curve of best fit ignoring the anomalous point	ALLOW Ecf if 35,130 circled	1
(iv)	Any one from **M1** temperature was higher than 25°C **M2** started the timer too late /stopped the timer too early/took reading too early	 **ALLOW** ecf from incorrect anomalous result circled so 35,130 gives slower as temp<35/timer stopped too late	1
(v)	**M1** vertical line on graph drawn to curve from 55°C **M2** value obtained from candidate's graph	ALLOW extra point at 55°C on curve expected value 115 to 117 s	2
(c)	**M1** $\frac{1}{156}$ **OR** 0.00641 **M2** 6.41×10^{-3}	**ALLOW** use of value from graph ALLOW 6.4×10^{-3}	2
(d)	An explanation that links the following three points **M1** rate (of reaction) increases **M2** (mean) kinetic energy of particles increases **M3** more successful collisions per second/unit time/ more frequent successful collisions	 **ALLOW** reaction is faster/ speeds up **ALLOW** particles move faster **IGNORE** vibrate more /faster **ALLOW** more frequent collisions having energy ≥ activation energy	3
			Total 13

Question number	Answer	Notes	Marks
7 (a) (i)	measuring cylinder	ALLOW burette / pipette / syringe REJECT gas syringe	1
(ii)	(the) zinc / Zn / it is in excess		1
(iii)	so as little gas as possible is lost	ACCEPT to keep as much gas as possible ALLOW to avoid loss of gas / so gas does not escape	1
(iv)	any one from no further effervescence / bubbles / fizzing no more gas collects in the syringe	 ALLOW gas syringe does not move	1
(b) (i)	M1 calculation of gradient OR 50 ÷ 150 M2 0.33 M3 units cm^3/s	triangle needs to be drawn on graph for M1 ALLOW ECF from M1 ACCEPT $cm^3\ s^{-1}$	3
(ii)	**from 0 to 60 s** M1 gradient is steepest M2 because there are most acid particles (per unit volume) / most collisions (per unit time) / most frequent collisions **from 60 to 150 s** M3 the curve becomes less steep M4 because there are fewer particles (per unit volume) / fewer collisions (per unit time) / fewer frequent collisions **from 150 to 240 s** M5 the reaction has stopped / curve levels off/becomes flat/plateaus M6 because the (sulfuric) acid has been used up	 ACCEPT because concentration is greatest / highest ACCEPT because concentration is lower ALLOW the volume of gas becomes constant	6
			total for question = 13

Question number		Answer	Notes	Marks
2	(a)	heat (energy) / thermal energy is given out /released / lost to the surroundings	not just energy, needs to be heat released or thermal energy released **ALLOW** gives out energy and raises temperature of surroundings	1
	(b)	$Mg + 2HCl \rightarrow MgCl_2 + H_2$	subscript, superscript and case must be correct IGNORE state symbols	1
	(c)	**M1** smooth curve starting at the origin **M2** levels off horizontally at constant volume	 **M2** depends on rising	2
	(d)	An explanation that links the following 4 points **M1** rate of reaction increases **M2** particles /molecules have more (kinetic) energy /KE **M3** more collisions per unit time **M4** more successful collisions /more particles have the (necessary) activation energy/E_a	 **ALLOW** particles /molecules move faster **ACCEPT** more frequent collisions **IGNORE** rate of collision increases **ALLOW** more frequent successful collisions for **M3** and **M4**	4
	(e)	**M1** label reactants and products **M2** product line below reactant line and to the right of the line **M3** showing activation hump **M4** activation energy/E_a labelled correctly	**ACCEPT** names of reactants and products **ALLOW** formulae of reactants and products even if incorrect as not given in the question **ACCEPT** with arrow pointing upwards **REJECT** arrow pointing downwards/double headed arrow /just a line	5

	M5 line showing Δ*H* from reactants to products	**ACCEPT** with arrow pointing downwards **REJECT** arrow pointing upwards/double headed arrow /just a line ecf **M1, M3, M4, M5** for endothermic reaction	**Total 13**

Question number	Answer	Notes	Marks
7 (a)	Sulfur	ALLOW sulphur	1 cler
(b)	any two from M1 concentration of hydrochloric acid M2 concentration of sodium thiosulfate M3 height of eye above flask OWTTE M4 same size of flask	ALLOW same colour/darkness /size of cross /use same cross	2 exp
(c)	any one from M1 the thiosulfate/solution would cool down/not remain at required temperature M2 larger (percentage) errors in values of times (as they become smaller)	IGNORE references to some of solution might evaporate ALLOW too short a time leads to less accurate readings OWTTE	1 exp
(d)	M1 all points plotted correctly (to the nearest grid line) M2 curve of best fit drawn	IGNORE curve below 20 and above 60	2 exp

7	(e)	(i)	M1 line on graph from 45 °C to curve M2 candidate value of rate from graph at 45 °C (expected value approx. 0.016/7)	ALLOW mark on curve at 45 °C ACCEPT value to +/– 0.0005	2 exp
		(ii)	M1 substitute answer from (i) into (time = 1 ÷ rate) M2 correct value	 ACCEPT answers to 2 or more sig figs rate = 0.016 time = 62.5 rate = 0.0165 time = 60.6 rate = 0.017 time = 58.8	2 exp
		(iii)	as temperature increases rate of reaction increases	ORA ALLOW positive correlation REJECT linear/directly proportional	1 grad
	(f)		explanation including following points (when temperature increases) M1 (mean) kinetic energy of particles increases M2 (so) more successful collisions per second/unit time / more frequent successful collisions M3 rate (of reaction) increases	 ALLOW particles move faster IGNORE vibrate more/faster ALLOW reference to more frequent collisions between particles having energy ≥ activation energy ALLOW reaction is faster /speeds up	3 exp

Total Q7 =14

Question number			Answer	Notes	Marks
4	(a)		$2\ H_2O_2 \rightarrow 2\ H_2O + (1)\ O_2$	**ALLOW** multiples and fractions	1
	(b)		Relights a glowing splint/spill		1
	(c)		Speeds up/increases rate of the reaction	**IGNORE** references to lowering activation energy	1
	(d)	(i)	All points plotted correctly	**ALLOW** ± half a square	1
		(ii)	Point at 8 minutes circled		1
		(iii)	Smooth curve of best fit		1
		(iv)	took the reading too soon/before 8 minutes	**ACCEPT** misread the volume (of oxygen)	1
		(v)	**M1** vertical line on graph drawn to curve from 3 mins		2
			M2 value obtained from candidate's graph	Expected value 29 or 30 cm^3 **ALLOW** ± half a square	

Question number	Answer	Notes	Marks
4 (e) (i)	**M1** curve drawn on graph that is less steep than curve of student's results. **M2** curve levels off at 40 cm^3	 **ALLOW** ± half a square	2
(ii)	An explanation that links the following three points **M1** reaction is slower **M2** fewer particles/molecules (in the same volume) **M3** fewer collisions per unit time	 **ACCEPT** particles are further apart / less crowded **ACCEPT** less frequent collisions **IGNORE** less chance of a collision	3 **Total 14**

Question number	Answer	Notes	Marks
9 (a) (i)	carbon dioxide/a gas is given off/escapes	**REJECT** incorrect gas	1
(ii)	to prevent acid/ liquid/ solution/ spray from leaving the flask OWTTE		1
(iii)	An explanation that links two of the following **M1** (insoluble) calcium sulfate will form **M2** which will form a coating/ layer on the marble chips **M3** slowing down/ preventing/ stopping the reaction	 M3 dep on M1 or M2	2
(b) (i)	An explanation that links the following four points **M1** the curve is steep(est) at the start **M2** because the (acid) concentration is high(est) **M3** the curve becomes less steep as the solution/ acid is becoming more dilute **M4** the curve levels off/ stops going up when the acid has all been used up **OR** **M1** the curve is steep(est) at the start **M2** because the reaction is fast(est) at the start **M3** the curve becomes less steep because the reaction slows down **M4** the curve levels off/stops going up when the acid has all been used up	 **ALLOW** there are the most (acid) particles in solution **ALLOW** the curve becomes less steep as there are fewer acid particles/particles in solution **IGNORE** references to particles of marble chips **IGNORE** references to energy	4

(ii)	M1 curve drawn starting at the origin and below the original curve M2 curve levels off at 0.27 g + or − half a small square		2

Question number	Answer	Notes	Marks
9 (c)	An explanation that links the following four points **M1** the rate of reaction increases/ the reaction is faster/ the reaction speeds up and any three from **M2** because the particles gain (kinetic) energy /move faster **M3** there are more collisions per unit time **M4** more collisions/particles have energy greater than the activation energy **M5** more collisions are successful	there are more frequent successful collisions scores **M3** and **M5**	4 **Total 14**

Question number			Answer	Notes	Marks
11	(a)	(i)	glowing splint relights	**REJECT** burning splint	1
		(ii)	A description that refers to the following three points M1 filter out manganese(IV) oxide / solid M2 leave to dry M3 same mass/ 1g of manganese(IV) oxide / solid		3
	(b)	(i)	M1 280 ÷ 120 M2 2.33	 **ALLOW** ecf from M1 **ALLOW** any number of significant figures except 1	2
		(ii)	An explanation that links the following three points M1 the concentration of hydrochloric acid is greatest M2 therefore there are more collisions M3 per unit time	 **ALLOW** the surface area of zinc is greatest **ALLOW** greatest number of/more particles (of hydrochloric acid/ zinc) More frequent collisions scores M2 and M3 Max 1 if incorrect reference to energy	3 2
		(iii)	M1 curve above original and starts at 0 M2 curve goes flat at same volume (410cm^3)		

(iv)	M1 greater surface area M2 more collisions per unit time / more frequent collisions		2
(c)	M1 8.46×10^{-3} mol of zinc M2 therefore 1.69×10^{-2} mol hydrochloric acid needed (which is less than 2.50×10^{-2} mol) **OR** M1 1.25×10^{-2} mol of zinc are needed M2 therefore 0.8(13) g of zinc is needed (and there is only 0.55g)	**ALLOW** any number of sig figs including one e.g. 0.008 moles of zinc, therefore 0.016 moles of acid needed scores M1 and M2	2
			15 marks

Question number	Answer	Notes	Marks
9 (a)	M1 to prevent acid splashing out OR so only (carbon dioxide) gas leaves the flask M2 so the decrease in mass is close to the actual value OR so that the decrease in mass is only due to the gas	IGNORE solid leaving the flask REJECT prevents gas escaping	2
(b)	M1 $CaCO_3(s) + 2HCl(aq)$ M2 $H_2O(l) + CO_2(g)$		2
(c) (i)	the hydrochloric acid has all reacted		1
(ii)	mass stays the same / stops decreasing	ALLOW effervescence / fizzing stops ALLOW the curve levels off	1
(iii)	M1 0.98 M2 (0.98÷44) = 0.022	ALLOW any number of significant figures REJECT incorrect rounding ALLOW M1÷44 Correct answer of 0.022 moles with or without working scores 2 marks	2
(iv)	M1 tangent shown on graph M2 method of calculating gradient (change in y ÷ change in x) M3 rate of reaction in g/s	ALLOW ECF from M2 Answer of 0.005 – 0.006 with a tangent shown on the graph scores 3 with or without other working.	3

		Answer of 0.015g/s (the average rate of reaction for the first 60s scores 1)	
(d) (i)	M1 the rate of reaction increases as the percentage concentration increases M2 the rate of reaction is (directly) proportional to the percentage concentration	 M2 subsumes M1	2
(ii)	M1 change in number of particles (per unit volume) M2 change in collisions per unit time	ALLOW particles are closer together or further apart ALLOW change in frequency of collisions REJECT increased / changed energy / speed	2
			Total for question = 15 marks

Question number			Answer	Notes	Marks
8	(a)		Zn (s) + H_2SO_4 (aq) → $ZnSO_4$ (aq) + H_2 (g) all state symbols correct		1
8	all clip with graph	(b) (i)	all points correctly plotted (within +/- half a square)		1
		(ii)	circle around point at 6 min		1
		(iii)	smooth curve of best fit		1
		(iv)	student took reading too soon/before 6 min		1
		(v)	mass from graph at 6 min	IGNORE UNITS	1
8	(c)	(i)	**M1** curve becomes less steep /gradient decreases (as time increases) **M2** so rate of reaction decreases	 **M2** DEP **M1**	2
		(ii)	the (sulfuric) acid was in excess OWTTE	**ALLOW** not all (sulfuric) acid reacted **ALLOW** zinc was limiting reagent **ALLOW** zinc was not in excess	1

Question number	Answer	Notes	Marks
8 (d)	**M1** magnesium (more reactive than zinc so) would make reaction faster/increase the rate **M2** less concentrated acid would make reaction slower/decrease the rate **M3** (so) difficult/impossible to know whether rate will increase or decrease overall OWTTE	**REJECT** reference to different surface area **REJECT** references to differences in energy/speed of particles **ALLOW** difficult/impossible to know which change has greater effect OWTTE **ALLOW** idea of difficult/impossible to predict (overall) effect of changing two factors at same time OWTTE **ALLOW** idea of difficult/impossible to know if changes cancel each other out OWTTE	3
8 (e)	**M1** at higher temperature particles have more (kinetic) energy **M2** more (successful) collisions per unit time **M3** rate of reaction increases	**ACCEPT** more particles have the required activation energy **ALLOW** particles move faster **ALLOW** more frequent (successful) collisions	3

Total for Question 8 = 15 marks

Question number	Answer	Notes	Marks
6 (a) (i)	$Mg + 2HCl \rightarrow MgCl_2 + H_2$	**IGNORE** state symbols even if incorrect	1
(ii)	(squeaky) pop with lighted splint		1
(iii)	**M1** amount of magnesium = 0.090 ÷ 24 **OR** 0.00375 (mol) **M2** amount of HCl needed = 2 × 0.00375 = 0.0075 (mol) (which is less than 0.025) **OR** **M1** amount of magnesium needed = 0.025÷2 **OR** 0.0125 (mol) **M2** mass of magnesium needed = 0.0125 × 24 = 0.3(g) (there is less magnesium than needed) **ALLOW** any number of significant figures		2
(b) (i)	all points plotted correctly to the nearest grid line		1
(ii)	best fit curve starting at 0 and levelling off at 88 cm^3		1
(iii)	**M1** vertical line on grid from 10 seconds to curve **M2** volume correctly read from their graph to the nearest grid line	**ALLOW** any mark at correct position on curve / either axis expected value 25 to 30 cm^3	2
(iv)	An explanation that links the following two points **M1** concentration (of HCl) is greatest (at the start) **M2** more collisions per unit time / more frequent collisions	**REJECT** incorrect references to energy **ALLOW** more particles (of HCl / more H^+ ions) **ALLOW** more HCl molecules / greater surface area of Mg **IGNORE** greater mass /more Mg **IGNORE** references to the graph	2

(c)	(i)	**M1** curve starting at 0 and steeper than original curve **M2** curve levelling off at same volume as original curve	**ALLOW** a curve starting within 1 small square of the original	2
	(ii)	An explanation that links the following three points		3
		M1 particles gain more (kinetic) energy	**ALLOW** particles move faster	
		M2 more collisions have energy greater than the activation energy	**ACCEPT** more collisions are successful	
		M3 collision frequency increases **OR** rate of reaction increases	**ACCEPT** more (successful) collisions per unit time	
				Total 15

Question number	Answer	Notes	Marks
7 (a)	M1 (moles of $CaCO_3$) = 5÷100 **OR** 0.05 mol M2 (mass of CO_2) = 0.05×44 **OR** 2.2g M3 (reading on balance) 122.2-2.2 = 120.00g	 ecf for M1 if moles attempted ecf for M2 120 g scores 2 marks	3
(b) (i)	All points plotted correctly ± half a square		1
(ii)	Curve of best fit joining all the points		1
(iii)	M1 tangent drawn at 2 minutes M2 gradient of tangent M3 g/minute/g minute^{-1}/g/min/g min^{-1}/gram/minute	If no tangent drawn 1 mark for M3 only do not allow g/m for M3	3
(iv)	An explanation that links any 2 pairs of the following points **Pair 1** M1 (the curve) is steep(est) at the start M2 because the reaction is fast(est) at the start / because the (acid) concentration is high(est) /more calcium carbonate /more chips **Pair 2** M3 (the curve) becomes less steep M4 because the reaction slows down / because the acid becomes more dilute /less calcium carbonate /less chips **Pair 3** M5 the curve levels off / the graph plateaus M6 because all the calcium carbonate /chips have reacted /used up	 ALLOW the gradient is greater at the start ALLOW the gradient decreases ALLOW the gradient becomes zero/0/flat /horizontal/constant	4
(c)	M1 the rate of reaction increases M2 because the powder has a greater surface **area** M3 so there are more collisions per unit time	If **more** energy is implied or **move** faster lose 1 mark ALLOW more frequent collisions /collide more often	3
			Total = 15

Question number	Answer	Notes	Marks
8 (a) (i)	$NH_4Cl + NaOH \rightarrow NaCl + NH_3 + H_2O$		1
(ii)	M1 moist/damp red litmus paper M2 turns blue	ALLOW moist/damp universal indicator paper	2
(b)	an explanation linking following two points: M1 forward and backward/reverse reactions are taking place at same rate M2 the concentrations of reactants and products remain constant	ACCEPT reaction is taking place in both directions at same rate REJECT concentrations of the reactants and products are equal/the same	2
(c)	an explanation linking following two points: M1 as temperature decreases yield of ammonia (formed in forward reaction) increases M2 so forward reaction is exothermic	ALLOW as temperature decreases equilibrium position shifts in forward direction/(from left) to right (producing more ammonia) IGNORE references to pressure ALLOW reverse arguments IGNORE references to Le Chatelier's Principle M2 DEP M1	2

(Total for Question 8 = 7)

Question number	Answer	Additional guidance	Marks
7 (a)	An explanation that links together the following two points: **M1** reaction is taking place in both directions (at same time) **M2** at equal rate	 **ACCEPT** both forward and backward reactions are taking place (at same time) **IGNORE** it is a reversible reaction **M2 DEP M1** rate of the forward reaction is equal to the rate of the backward reaction scores 2 marks **REJECT** both forward and backward reactions occur at constant rate for **M2** **ALLOW** the concentrations of the reactants and products remains constant scores 1 mark independently of **M1** but **REJECT** concentrations of the reactants and products are equal/the same	2

(b) (i)	An explanation that links together the following two points: **M1** (the position of) equilibrium has moved to the left	**ALLOW** (position of) equilibrium has shifted in backwards direction **ALLOW** (position of) equilibrium has shifted towards the N_2O_4 /reactants (side) **ALLOW** increasing pressure shifts (position of) equilibrium in direction that produces fewer moles (of gas) **IGNORE** references to Le Chatelier's Principle eg increasing pressure favours the side that has fewer moles of gas / increasing pressure favours the backwards reaction	2
	M2 because there are fewer moles/molecules (of gas) on the left	**ALLOW** particles **REJECT** atoms **ALLOW** because there are fewer moles of N_2O_4 (than NO_2) **ALLOW** because there are fewer moles of reactant (than product) **ACCEPT** reverse argument	
(ii)	the concentration of NO_2 has increased	**ALLOW** molecules/particles of NO_2 are closer together **ALLOW** molecules/particles of NO_2 are in a smaller volume **REJECT** more NO_2 produced	1

Question number	Answer	Additional guidance	Marks
7 (c) (i)	nitrogen/N_2 reacts with oxygen/O_2 (both from the air)	**IGNORE** nitrogen burns/combusts in oxygen **IGNORE** nitrogen is oxidised	1
(ii)	(they form) acid rain	**ACCEPT** references to respiratory problems **ALLOW** a specified harmful effect of acid rain **ALLOW** references to smog **ALLOW** references to greenhouse gases/global warming/climate change	1
(iii)	$2\,NO + 2\,CO \rightarrow N_2 + 2\,CO_2$	**ACCEPT** multiples and fractions	1
		Total	**8**

Question number	Answer	Notes	Marks
7 (a)	reversible reaction	**IGNORE** references to equilibrium **ALLOW** the reaction goes both ways **ALLOW** the reaction can go forwards and backwards	1
(b) (i)	**M1** yield increases **M2** (equilibrium shifts to the right as the forward) reaction is endothermic	**ACCEPT** more hydrogen produced **IGNORE** references to Le Chatelier e.g. an increase in temperature favours the forward reaction **M2** dep on **M1** correct or missing	2
(ii)	**M1** yield decreases **M2** (equilibrium shifts to the left as) fewer moles/molecules (of gas) on lhs / more moles/molecules (of gas) on rhs OWTTE	**ACCEPT** less hydrogen produced **ALLOW** parti es **REJECT** atoms **IGNORE** references to Le Chatelier e.g. an increase in pressure favours the side with fewer moles **M2** dep on **M1** correct or missing	2

Question number	Answer	Notes	Marks
7 (c)	• calculate the amount, in moles, of methane • use the equation to calculate the amount of hydrogen • multiply amount by 24 to find the volume of hydrogen • final answer in standard form **M1** $\frac{10{,}000{,}000}{16}$ **OR** 625,000 **M2** 625,000 x 3 **OR** 1,875,000 **M3** 1,875,000 x 24 **OR** 45,000,000 (dm^3) **M4** 4.5×10^7 (dm^3)	Mark consequentially for **M2, M3** and **M4.** 45,000,000 without working scores 3 Correct answer in standard form without working scores 4 Common answers 4.5×10^4 (3) 45,000 (2) 4.5×10^1 (3) 45 (2) 1.5×10^7 (3) 15,000,000 (2) **NOTE** even if working is incorrect e.g. division by 24 instead of multiplication **M4** can still be awarded for correct conversion to standard form	4 **Total 9**

Question number	Answer	Notes	Marks
7 (a) (i)	M1 no effect on yield	IGNORE comments about rate	2
	M2 because same number of moles (of gas) on both sides of equation	M2 dep on M1	
(ii)	M1 no effect on yield		2
	M2 because catalyst increases rate of both forward and backward reactions by same amount	M2 dep on M1	
(b)	M1 bonds broken = (436 + 158) OR 594 (ignore sign) M2 bonds made = (2 x 562) OR 1124 (ignore sign) M3 ΔH = -530 (kJ/mol)	-530 with no working scores 3 +530 or 530 with no working scores 2 +32 or 32 with no working scores 2	3
(c)	M1 right hand line below left hand line M2 correct names/formulae of reactants and products M3 enthalpy change, ΔH correctly shown and labelled with arrow pointing down	ALLOW reactants and products ACCEPT line with no arrow head / double arrow head if -ΔH or -530 is labelled REJECT arrow pointing upwards	3
	If the answer to (b) is positive M1 right hand line above left hand line M2 correct names/formulae of reactants and products M3 enthalpy change, ΔH correctly shown and labelled with arrow pointing up	ALLOW reactants and products ACCEPT line with no arrow head / double arrow head if (+)ΔH or +530 is labelled REJECT arrow pointing downwards	

Total marks for Question 7 = 10

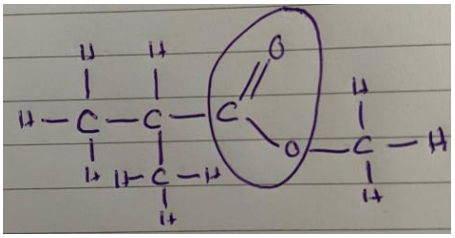
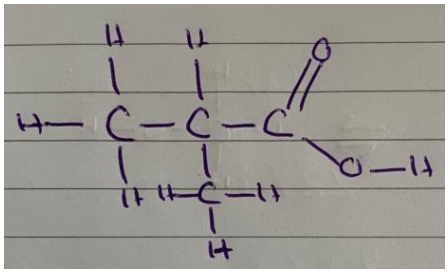
Question number	Answer	Notes	Marks
6 (a) (i)	A lighted /burning /flame splint pops	**REJECT** a glowing splint **IGNORE** squeaky pop test alone	1
(ii)	reversible (reaction)	**ALLOW** goes both ways /can go forwards and backwards at the same time **IGNORE** (dynamic) equilibrium	1
(b) (i)	An explanation that links the following two points **M1** yield increases AND reaction shifts towards the right hand side **M2** as the (forward) reaction is endothermic	 **ALLOW** yield increases AND forward reaction **M2** dep on yield increases or missing **IGNORE** references to Le Chatelier	2
(ii)	An explanation that links the following two points **M1** no effect on the yield **M2** as there are the same number of moles /molecules /2 moles /2 molecules on both sides (so no effect on the position of the equilibrium)	 **M2** dep on **M1** or missing **IGNORE** references to Le Chatelier	2
(c)	**M1** (nI_2 =) $\frac{50.8}{254}$ **OR** 0.2(0) (mol) **M2** (nHI =) $\frac{0.2(0) \times 2 \times 80}{100}$ **OR** 0.32 (mol) **M3** (volume of HI) = 0.32 × 24 000 **OR** 7 680 (cm^3) **M4** 7.68 × 10^3 / 7.7 × 10^3 (cm^3) ALTERNATIVE METHOD M1 254g gives 48000 cm^3 so M2 50.8g gives 9600 cm^3 so M3 9600 x 80/100 M4 7.68 x 10^3 cm^3	correct answer scores 4 **ALLOW** ecf throughout as long as attempt to calculate moles 3.84 × 10^3 /9.6 × 10^3 /1.92 × 10^3 scores 3 3840 / 9600 / 1920 scores 2 1.5(36) x 10^4 scores 3 15360 scores 2	4
			Total 10

Question number	Answer	Notes	Marks
7 (a)	reduces the capacity of blood to transport oxygen round the body OWTTE	**ALLOW** carbon monoxide /it binds with haemoglobin	1
(b)	An explanation that links the following two points **M1** no effect **M2** as increases rate of forward reaction and rate of backward reaction **equally**	 **M2** dep on **M1** or missing	2
(c) (i)	An explanation that links the following two points **M1** yield decreases **M2** as (forward) reaction is endothermic (so equilibrium shifts to the LHS / reactants side)	 **ALLOW** backward /reverse reaction is exothermic **M2** dep on **M1** or missing **IGNORE** references to Le Chatelier	2
(ii)	An explanation that links the following two points **M1** yield increases **M2** as there are fewer moles / molecules (of gas) on the left-hand side / there are 2 mol on LHS and 4 mol on RHS (so equilibrium shifts to the RHS / products side) ORA	 **M2** dep on **M1** or missing **IGNORE** references to Le Chatelier	2
(d)	**M1** $n(H_2) = 6.6 \times 10^6 \div 2$ **OR** 3.3×10^6 (mol) **M2** $n(CH_4) = 3.3 \times 10^6 \div 3$ **OR** 1.1×10^6 (mol) **M3** vol$(CH_4) = 1.1 \times 10^6 \times 24$ **OR** 26 400 000 (dm^3) **M4** 2.6×10^7	correct answer with or without working scores 4 **ACCEPT** 3 300 000 **ACCEPT** 1 100 000 **M2** × 24 **ACCEPT** 2.64×10^7 **ALLOW** ECF throughout common answers: $7.9(2) \times 10^7$ scores 3 5.28×10^7 scores 3 1.584×10^8 scores 2	4
			Total 11

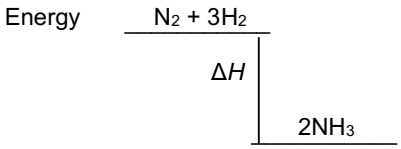
Question number	Answer	Notes	Marks
5 (a) (i)	(produces) acid rain	**ALLOW** any detrimental effect of acid rain e.g. kills fish, damages limestone buildings	1
(ii)	• M1 find moles of sulfur • M2 multiply moles by 24 • M3 answer in standard form Example calculation **M1** $6.4 \times 10^6 \div 32$ **OR** $2.0 \times 10^5 / 200\,000$ **M2** $2.0 \times 10^5 \times 24 / 200\,000 \times 24 / 4\,800\,000$ **M3** 4.8×10^6	**ALLOW** ECF as long as an attempt has been made to calculate moles Correct answer without working scores 3 4 800 000 (dm^3) without working scores 2	3
(b) (i)	An explanation that links the following two points **M1** provides an alternative (reaction) pathway/route **M2** with a lower activation energy OWTTE	**ACCEPT so** more particles/collisions have energy greater than the activation energy **ALLOW** lowers the energy needed to start the reaction	2
(ii)	fewer moles (of gas) on RHS (than on (LHS)	**ALLOW** 3 moles (of gas) on LHS and 2 moles (of) gas on RHS **ALLOW** fewer moles of product/SO_3 (gas) (than of reactants/SO_2 and O_2 (gas)) **ALLOW** molecules in place of moles **IGNORE** references to rate	1
(iii)	as yield is approximately 98% /very high (it is not necessary to increase the pressure) OWTTE	**ALLOW** reference to reaction rate (already high enough) as catalyst used OWTTE	1

Question number	Answer	Notes	Marks
5 (c)	**M1** $SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$ **M2** $H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$	**ALLOW** multiples	2
(d)	**M1** (2 x 14 ÷ 132) x 100 **M2** 21.21 (%)	**ALLOW** any number of sig figs except 1 **ALLOW** ECF from **M1** as long as 132 used correctly Correct answer without working scores 2	2
			Total 12

Question number	Answer	Notes	Marks
7 (a) (i)	**M1** the forward and reverse reactions occur at the same <u>rate</u> **M2** so the concentrations of reactants and products remain constant	 ALLOW so the moles of reactants and products remain constant REJECT so the concentrations of reactants and products are the same	2
(ii)	a catalyst increases the rate of (both) the forwards and the reverse reaction <u>equally</u>	ALLOW has the same effect on the rate of forward and reverse reaction	1
(iii)	**M1** yield increases **M2** the (forward) reaction is exothermic	 ALLOW the reverse reaction is endothermic IGNORE any references to Le Chatelier's Principle (moves / shifts) **M2** dep on **M1** correct or missing	2
(iv)	**M1** yield increases **M2** there are more moles of (gaseous) reactants than products / there are fewer (gaseous) moles on the right hand side / there are 3 moles (of gas) on the left and 1 mole (of gas) on the right ORA	 IGNORE any references to Le Chatelier's Principle (moves /shifts) **M2** dep on **M1** correct or missing	2

(b) (i)	**M1** (bonds broken) = 436 + 436 + 1072 **OR** 1944 **M2** (bonds formed) = 414 + 414 + 414 + 358 + 463 **OR** 2063 **M3** 1944 – 2063 (= – 119)		3
(ii)	an explanation that links together the following two points: **M1** more energy is given out when the bonds are made **M2** than is taken in when the bonds are broken ORA OR **M1** breaking bonds is endothermic / takes in energy AND making bonds is exothermic / releases energy **M2** the energy released is more than the energy taken in	IGNORE refs to numbers of bonds **DEP** on **M1** If state / imply that energy required to make bonds OR If state / imply that energy released when bonds are broken scores 0	2
(c) (i)			1
(ii)		REJECT -OH not displayed	1
			Total 14

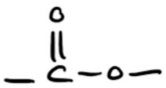
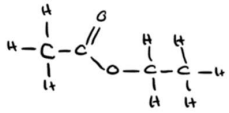
Question number	Answer	Notes	Marks
7 (a) (i)	reversible (reaction) / reaction that goes both ways OWTTE	IGNORE references to equilibrium	1
(ii)	increases the rate of reaction /speeds up the reaction	REJECT to increase yield ALLOW to reach equilibrium faster IGNORE provides an alternative pathway with lower activation energy	1
(b) (i)	**M1** yield decreases **M2** (forward) reaction is exothermic/ backward reaction is endothermic	IGNORE references to rate and Le Chatelier throughout ACCEPT (when temperature increased equilibrium shifts in) endothermic direction which is (from right) to left **M2** DEP **M1** correct or missing	2 2
(ii)	**M1** yield increases **M2** there are fewer moles (of gas) on the right-hand side/product side / there are more moles (of gas) on the left-hand side/there are 4 moles of reactants and 2 moles of product/ OWTTE	ALLOW molecules for moles **M2** DEP **M1** correct or missing	

7 (c)	 **M1** horizontal line labelled with $N_2 + 3H_2$ **M2** horizontal line showing $2NH_3$ in correct position **M3** vertical line in correct position and labelled ΔH /-92 (kJ/mol)	IGNORE any horizontal axis/labels IGNORE any attempts at including activation energy ALLOW nitrogen and hydrogen ALLOW ammonia If not balanced or words reactants and products on horizontal lines in correct position scores 1 out of 2 ACCEPT double headed arrow or arrow pointing from reactants level to products level REJECT arrow pointing from products level to reactants level If endothermic reaction can score M1 and M3	3

7	(d)	(i)	**M1** amount of nitrogen = (48 ÷ 24 =) 2 (mol) **M2** amount of hydrogen = (120 ÷ 24 =) 5 (mol) **M3** 2.5 mol of hydrogen to 1 mol of nitrogen (which is less than 3 so nitrogen is in excess) **OR** 2 mol of nitrogen needs 6 mol of hydrogen (so not enough hydrogen to react with the nitrogen)	ACCEPT alternative methods	3
		(ii)		correct answer without working scores 3 ALLOW ECF from (i)	3
			M1 5 mol of hydrogen gives 3.33 mol of ammonia **M2** volume of ammonia (if 100% conversion) = 3.33 x 24 **OR** 80 (dm^3) **M3** (volume of ammonia if 20% conversion) = $\frac{(20 \times 80)}{100}$ = 16.0 (dm^3)	ALLOW 3.3 use of 3.3 gives 79.2 use of 79.2 gives 15.84 ALLOW ECF from **M2** ACCEPT 120 dm^3 of hydrogen gives 2 x 120 ÷ 3 **OR** 80 (dm^3 of ammonia) for M1 and M2 ALLOW max 2 for use of 48 dm^3 of nitrogen giving 96 dm^3 of ammonia and final answer of 19.2 (dm^3)	
					Total 15

Question number	Answer	Notes	Marks
7 (a) (i)	M1 yield decreases AND reaction shifts towards the left hand side M2 which is the side with more moles (of gas)	ALLOW backward reaction ALLOW molecules	2
(ii)	M1 The yield (of ethanol) does not change M2 as (adding a catalyst) increases the rate of the forwards and backwards reactions equally		2
(b) (i)	M1 (bonds broken) (4 × 414) + 614 + (2 × 463) OR 3196 M2 (bonds formed) (5 × 414) + 346 + 358 + 463 OR 3237 M3 sum of bonds broken − sum of bonds formed OR −41 /mol OR M1 (bonds broken) 614 + (2 × 463) OR 1540 M2 (bonds formed) 414 + 346 + 358 + 463 OR 1581 M3 sum of bonds broken − sum of bonds formed OR −41 kJ/mol	answer of −41 with no working scores 3 answer of -40 with no working scores 0	3
(ii)	An explanation that links together the following two points: M1 more energy is given out when the bonds are made M2 than is taken in when the bonds are broken OR M1 Breaking bonds is endothermic/takes in energy and making bonds is exothermic/releases energy M2 More energy is released than taken in	 If state/imply that energy required to make bonds scores 0 If state/imply that energy released when bonds are broken scores 0 **M2 dep** on **M1**	2

(iii)	M1 right hand line below left hand line M2 correct names/formulae of both reactants and products M3 ΔH correctly shown and labelled		3

(c)	(i)	M1 displayed ester linkage  M2 rest of molecule correct 		2
	(ii)	ethyl ethanoate		1
			Total marks for question 7 = 15	