Name: _____

Class: _____

Date: _____

Rates & Equilibrium part 1 AQA Triple Chemistry

Time: **83 minutes**

Marks: **77 marks**

Comments:

1. Hydrogen peroxide decomposes into water and oxygen.

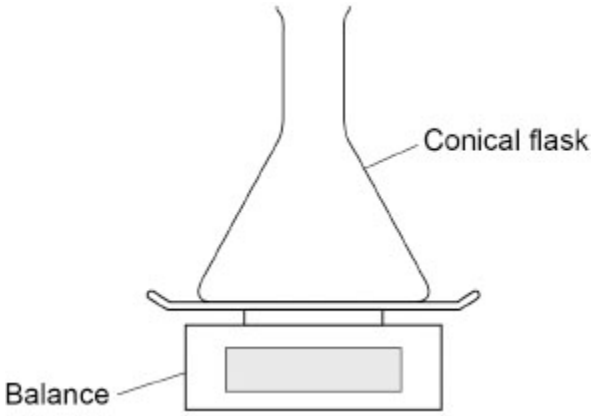
The equation for the reaction is:

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

A student investigated the effect of catalyst **A** and of catalyst **B** on the rate of this reaction.

Figure 1 shows the apparatus.

Figure 1



This is the method used.

1. Put the conical flask on the balance.
2. Add 50 cm^3 of 1.5 mol/dm^3 hydrogen peroxide solution to the conical flask.
3. Add 1.00 g of catalyst **A** to the conical flask.
4. Start a timer.
5. Record the loss in mass of the conical flask and contents every 30 seconds for 3 minutes.
6. Repeat steps 1 to 5 using catalyst **B**.

(a) Explain why the conical flask and contents lost mass.

_____

_____

_____

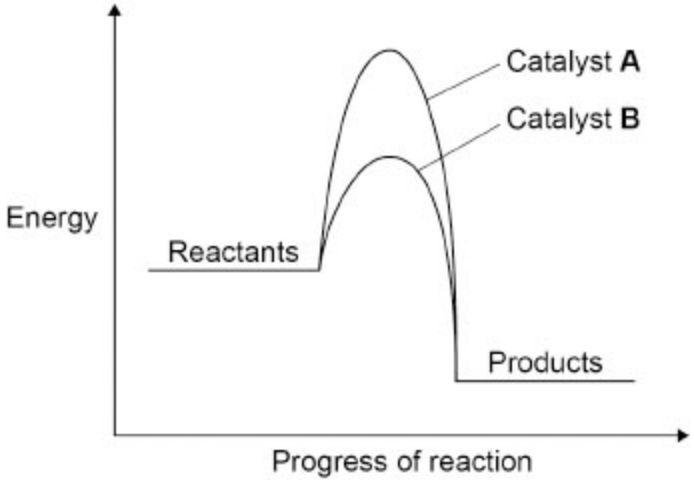
_____

(2)

(b) **Figure 2** shows the reaction profile for the decomposition of hydrogen peroxide using:

- catalyst **A**
- catalyst **B**.

Figure 2

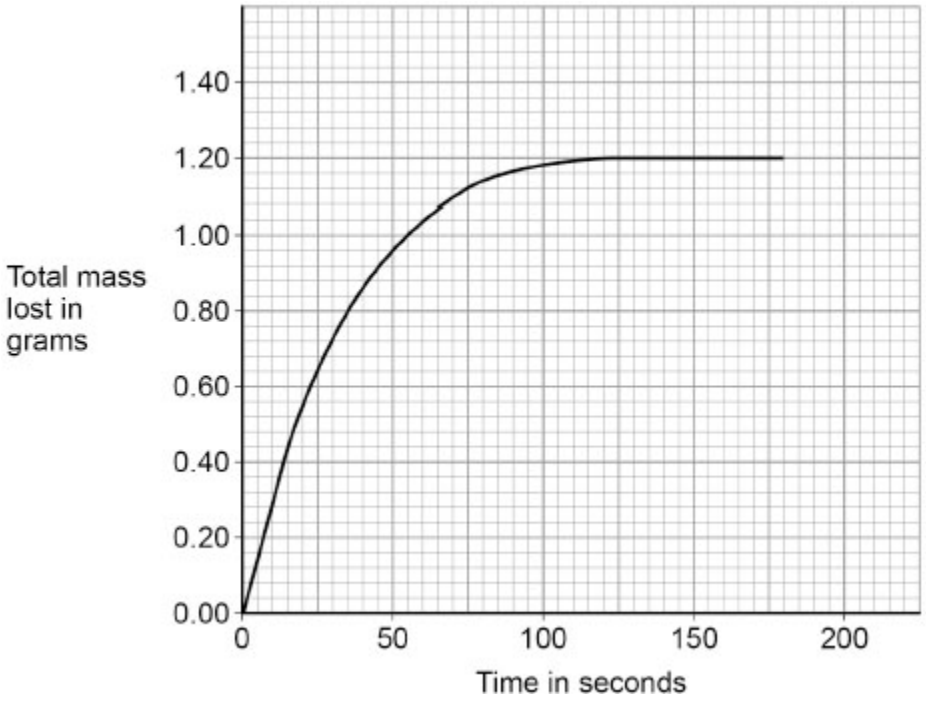


Explain why catalyst **A** and catalyst **B** give different rates of reaction for the decomposition of hydrogen peroxide.

(3)

(c) **Figure 3** shows the results for catalyst **A**.

Figure 3



Determine the rate of the reaction when the time was 60 seconds.

Give your answer in standard form.

Rate (standard form) = _____ g/s

(5)

(d) Explain how the rate of decomposition of hydrogen peroxide depends on the temperature of the solution.

_____

_____

_____

_____

_____

_____

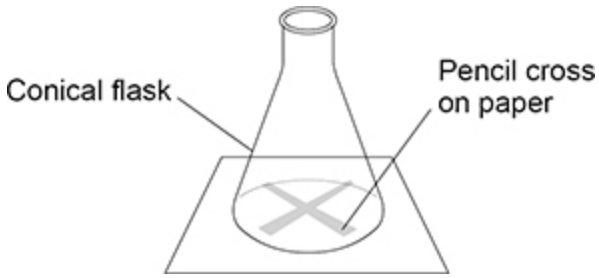
(3)

(Total 13 marks)

2. A student investigated the rate of the reaction of sodium thiosulfate solution with hydrochloric acid.

When sodium thiosulfate solution reacts with hydrochloric acid, the mixture becomes cloudy.

The figure below shows the apparatus.



This is the method used.

1. Put 75 cm^3 of sodium thiosulfate solution in a conical flask.
2. Draw a pencil cross on paper.
3. Put the conical flask on the pencil cross.
4. Add 15 cm^3 of hydrochloric acid to the contents of the conical flask.
5. Swirl the conical flask to mix the contents and immediately start a timer.
6. Stop the timer when the pencil cross is no longer visible through the reaction mixture.
7. Repeat steps 1 to 6 using different concentrations of sodium thiosulfate solution.

(a) Explain why a 50 cm^3 conical flask is unsuitable to use in this method.

_____

_____

_____

_____

(2)

(b) Name a piece of equipment suitable for measuring the volume of sodium thiosulfate solution.

_____

(1)

(c) The student measured the time taken for the pencil cross to be no longer visible for different concentrations of sodium thiosulfate solution.

Draw **one** line from each type of variable to the variable in this investigation.

Type of variable	**Variable in this investigation**
	Concentration of sodium thiosulfate solution
Dependent variable	Size of conical flask
	Temperature of sodium thiosulfate solution
Independent variable	Time for pencil cross to become no longer visible
	Volume of hydrochloric acid

(2)

(d) What effect will using a darker pencil cross have on the time taken for the cross to be no longer visible?

Tick (✓) **one** box.

The time taken will decrease. ☐

The time taken will be the same. ☐

The time taken will increase. ☐

(1)

(e) The table below shows the results.

Concentration of sodium thiosulfate solution in g/dm^3	**Time for cross to become no longer visible in seconds**
8	120
16	60
24	40
32	30

Which concentration of sodium thiosulfate solution had the highest rate of reaction?

Tick (✓) **one** box.

8 g/dm^3 ☐

16 g/dm^3 ☐

24 g/dm^3 ☐

32 g/dm^3 ☐

(1)

(f) Increasing the concentration of sodium thiosulfate solution changes the rate of the reaction with hydrochloric acid.

Which **two** statements explain the effect of increasing the concentration?

Tick (✓) **two** boxes.

The particles are closer together.	☐
The particles are further apart.	☐
The particles collide less frequently.	☐
The particles collide more frequently.	☐
The particles move faster.	☐
The particles move slower.	☐

(2)

(g) The effect on the time taken for the cross to disappear can also be investigated by:

- changing the temperature of the hydrochloric acid
- changing the concentration of the hydrochloric acid.

Complete the sentences.

Choose the answers from the box.

decreases	**stays the same**	**increases**

If the temperature of the hydrochloric acid is **increased**, the time taken for the cross to disappear _____.

If the concentration of the hydrochloric acid is **decreased**, the time taken for the cross to disappear _____.

(2)

(Total 11 marks)

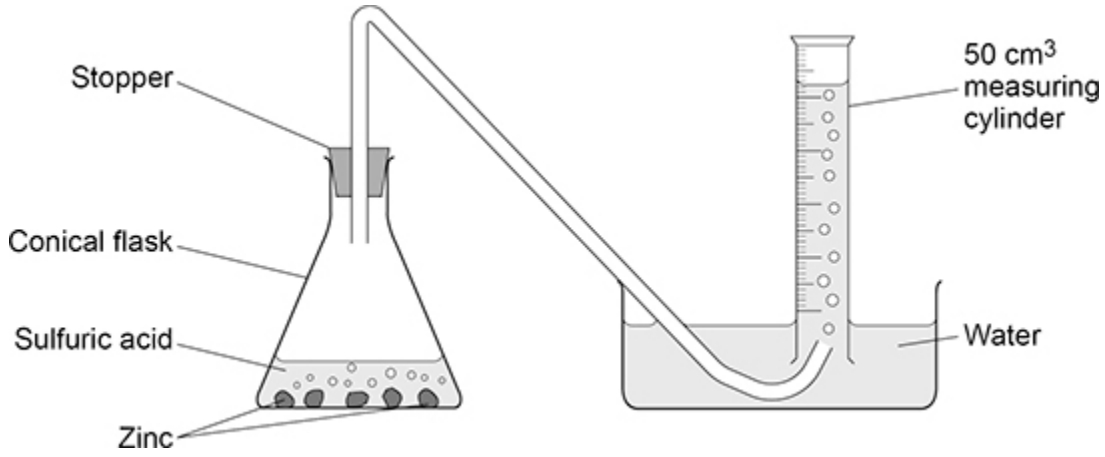
3. A student investigated the rate of the reaction between zinc and sulfuric acid.

The equation for the reaction is

$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$$

Figure 1 shows the apparatus.

Figure 1



This is the method used.

1. Pour 50 cm^3 of sulfuric acid into the conical flask.

2. Add excess zinc to the conical flask.

3. Insert the stopper and start a timer.

4. Measure the volume of hydrogen collected in the 50 cm^3 measuring cylinder every 20 seconds for 180 seconds.

(a) Explain why the volume of hydrogen collected in the 50 cm^3 measuring cylinder is less than the volume of hydrogen produced.

_____

_____

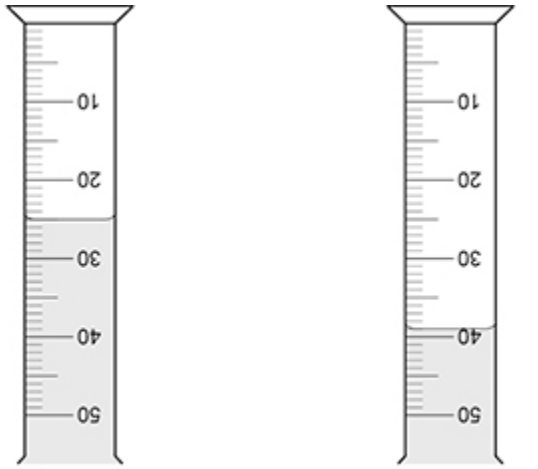
_____

_____

(2)

Figure 2 shows the volumes of hydrogen collected in the 50 cm^3 measuring cylinder after 40 seconds and after 100 seconds.

Figure 2



(b) Determine the number of moles of hydrogen collected between 40 seconds and 100 seconds.

The volume of one mole of any gas at room temperature and pressure is 24 dm^3.

Moles of hydrogen = _____

(4)

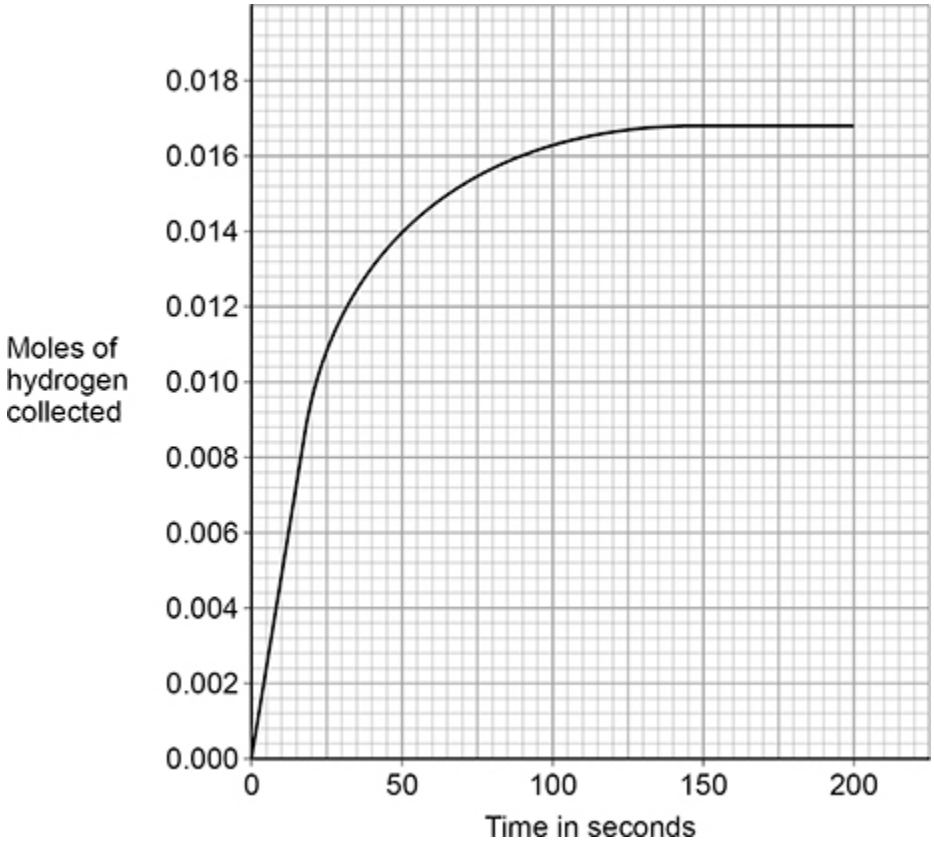
A different student investigated how the concentration of sulfuric acid affected the rate of the reaction.

(c) The student did a different experiment using sulfuric acid of concentration 0.40 mol/dm^3.

The student calculated the number of moles of hydrogen collected after every 20 seconds.

Figure 3 shows the results.

Figure 3



Determine the rate of reaction at 45 seconds.

You should draw a tangent on **Figure 3**.

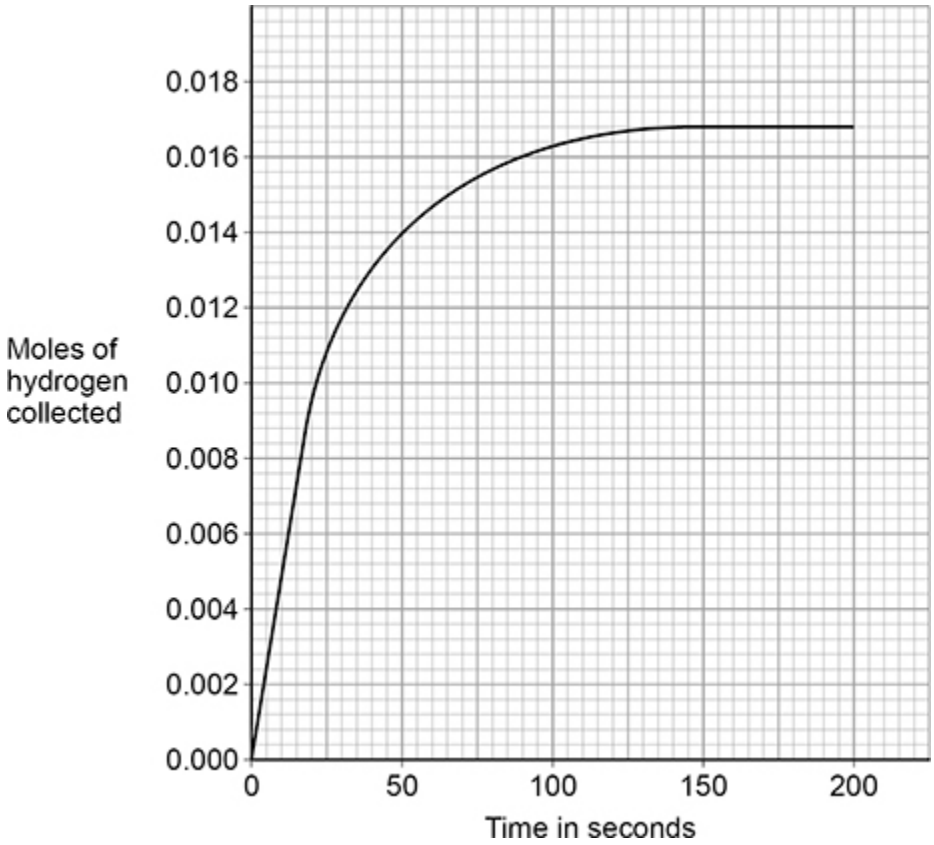
Give your answer in standard form.

Rate of reaction (in standard form) = _____ mol/s

(5)

(d) **Figure 4** shows the results for 0.40 mol/dm^3 sulfuric acid.

Figure 4



The student repeated the experiment using 0.20 mol/dm^3 sulfuric acid instead of 0.40 mol/dm^3 sulfuric acid.

Excess zinc was used in each experiment.

Sketch a line on **Figure 4** to show the results you would expect.

(2)

(e) Explain how increasing the temperature would affect the rate of reaction between zinc and sulfuric acid.

_____

_____

_____

_____

_____

_____

(3)

(Total 16 marks)

4. This question is about the rate of the reaction between hydrochloric acid and calcium carbonate.

A student investigated the effect of changing the size of calcium carbonate lumps on the rate of this reaction.

This is the method used.

1. Pour hydrochloric acid into a conical flask up to the 50 cm^3 line.
2. Add 10.0 g of small calcium carbonate lumps to the conical flask.
3. Attach a gas syringe to the conical flask.
4. Measure the volume of gas produced every 20 seconds for 100 seconds.
5. Repeat steps 1 to 4 using 10.0 g of large calcium carbonate lumps.

(a) The student used the 50 cm^3 line on the conical flask to measure the volume of hydrochloric acid.

Suggest a piece of equipment the student could use to make the measurement of volume more accurate.

_____

(1)

(b) Carbon dioxide gas is produced in the reaction between hydrochloric acid and calcium carbonate.

Which test is used to identify carbon dioxide gas?

Tick (✓) **one** box.

A burning splint pops ☐

A glowing splint relights ☐

Damp litmus paper is bleached ☐

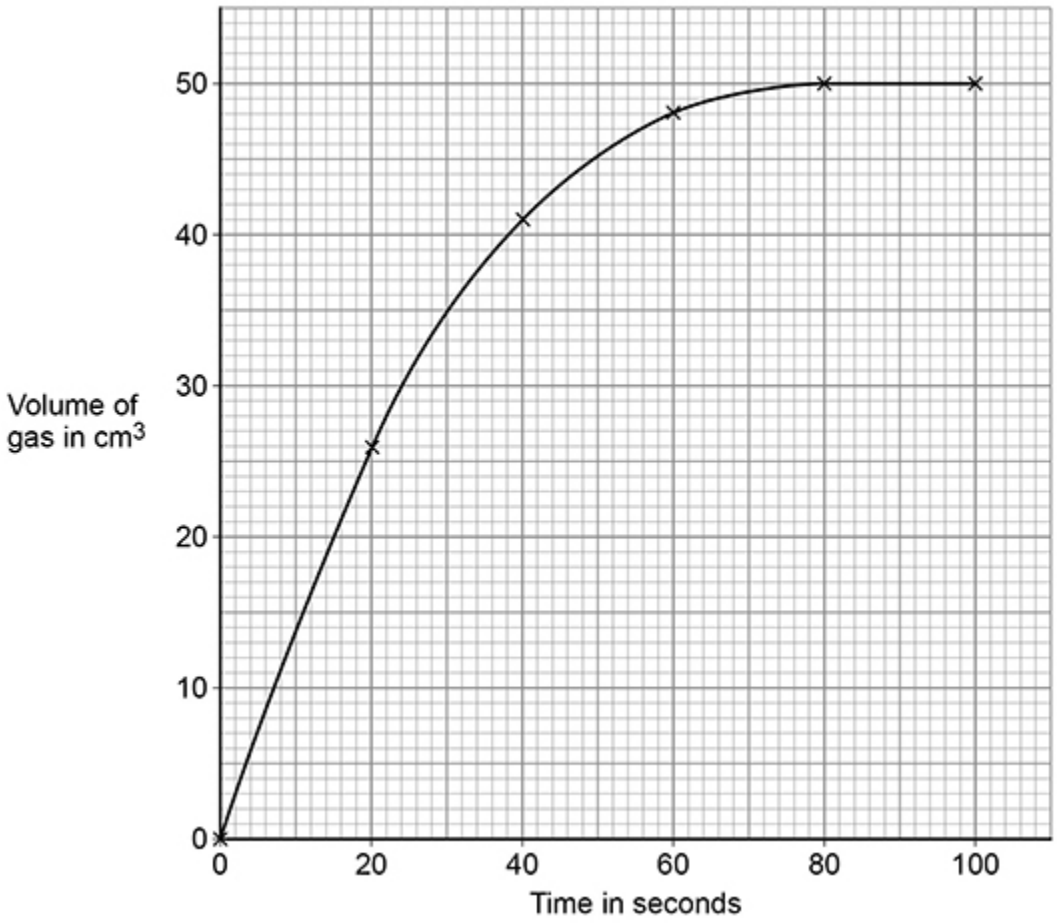
Limewater turns milky ☐

(1)

The table below shows the student's results for large calcium carbonate lumps.

Time in seconds	**Volume of gas in cm^3**
0	0
20	16
40	30
60	40
80	46
100	48

The graph below shows the student's results for small calcium carbonate lumps.



(c) Complete the graph above.

You should:

- plot the data for large calcium carbonate lumps from the table above on the graph paper
- draw a line of best fit for large calcium carbonate lumps.

(3)

(d) Determine the mean rate of reaction using **small** calcium carbonate lumps between 0 seconds and 60 seconds.

Use the equation:

$$\text{mean rate of reaction} = \frac{\text{volume of gas produced}}{\text{time taken}}$$

Use the graph above.

Mean rate of reaction = _____ cm^3/s

(3)

(e) Describe what happens to the volume of gas collected using **small** calcium carbonate lumps:

- between 0 and 20 seconds
- between 80 and 100 seconds.

Use the graph above.

Between 0 and 20 seconds

Between 80 and 100 seconds

(2)

(f) The balance used to weigh 10.0 g of calcium carbonate lumps caused an error.

The balance always read 0.2 g before being used.

What type of error was caused by the balance?

Tick (✓) **one** box.

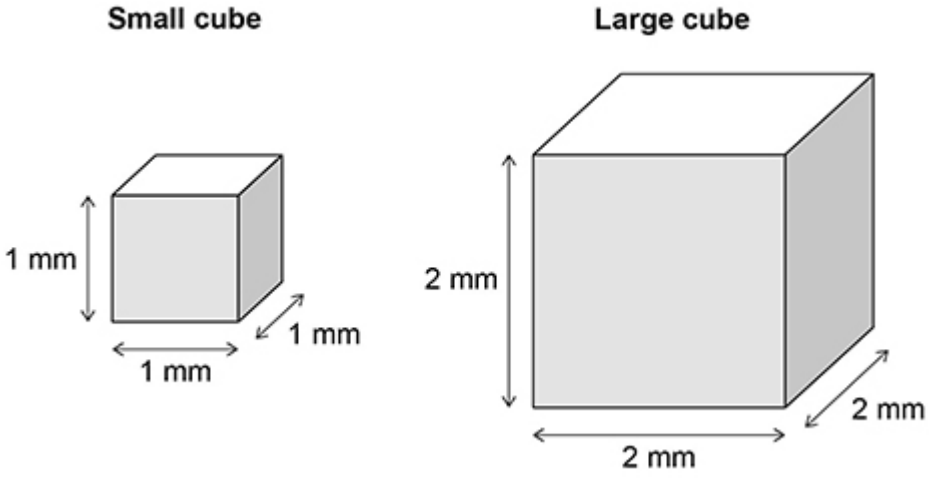
Human error ☐

Random error ☐

Systematic error ☐

(1)

The diagram shows the dimensions of two cubes of calcium carbonate.



(g) A cube of calcium carbonate has six faces.

Calculate the total surface area of the **large** cube of calcium carbonate.

Use the diagram above.

_____

_____

_____

_____

_____

_____

Total surface area = _____ mm^2

(3)

(h) The large cube of calcium carbonate was divided into eight smaller cubes.

The eight smaller cubes have a greater total surface area than the one large cube.

Compare the rate of reaction when using the eight smaller cubes with the rate of reaction when using the large cube.

Complete the sentence.

Choose the answer from the box.

faster	**slower**	**the same**

The rate of reaction of the eight smaller cubes is _____.

(1)

(Total 15 marks)

5. This question is about the rate of the reaction between hydrochloric acid and calcium carbonate.

A student investigated the effect of changing the size of calcium carbonate lumps on the rate of this reaction.

This is the method used.

1. Pour 40 cm^3 of hydrochloric acid into a conical flask.
2. Add 10.0 g of small calcium carbonate lumps to the conical flask.
3. Attach a gas syringe to the conical flask.
4. Measure the volume of gas produced every 30 seconds for 180 seconds.
5. Repeat steps 1 to 4 using 10.0 g of large calcium carbonate lumps.

The student calculated the number of moles of gas from each volume of gas measured.

The table below shows the student's results for large calcium carbonate lumps.

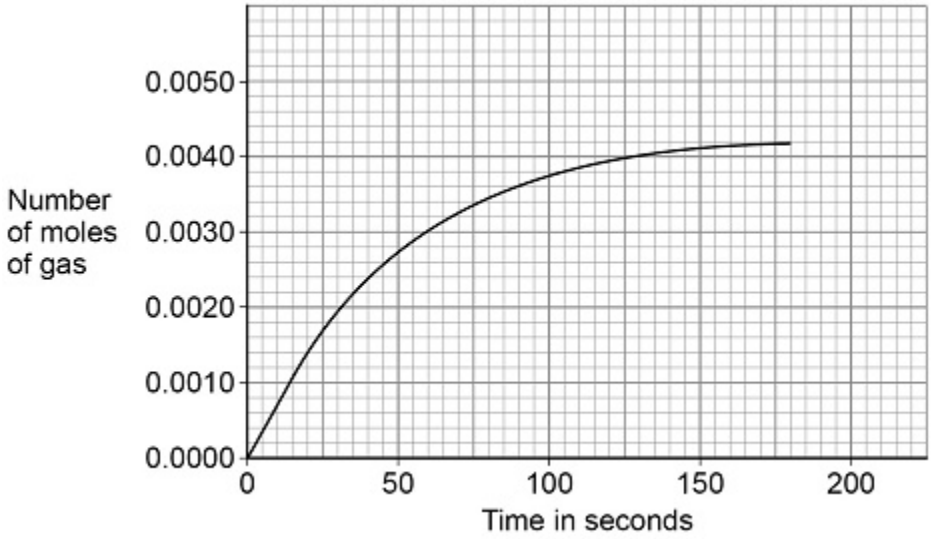
Time in seconds	Number of moles of gas
0	0.0000
30	0.0011
60	0.0020
90	0.0028
120	0.0034
150	0.0038
180	0.0040

The student plotted the results for small calcium carbonate lumps on the graph below.

(a) Complete the graph below.

You should:

- plot the data for large calcium carbonate lumps from the table above
- draw a line of best fit.



(3)

(b) Determine the mean rate of reaction for **small** calcium carbonate lumps between 20 seconds and 105 seconds.

Give the unit.

Use the graph above.

_____

_____

_____

_____

_____

_____

Mean rate of reaction = _____ Unit _____

(4)

(c) The student concluded that the large calcium carbonate lumps reacted more slowly than the small calcium carbonate lumps.

How do the student's results show that this conclusion is correct?

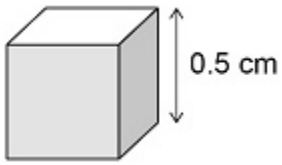
_____

_____

(1)

The difference in the rates of reaction of large lumps and of small lumps of calcium carbonate depends on the surface area to volume ratios of the lumps.

The diagram below shows a cube of calcium carbonate.



(d) Calculate the surface area to volume ratio of the cube in above diagram.

Give your answer as the simplest whole number ratio.

_____

_____

_____

_____

_____

Surface area : volume = _____ **:** _____

(3)

(e) A larger cube of calcium carbonate has sides of 5 cm

Describe how the surface area to volume ratio of this larger cube differs from that of the cube shown in the diagram above.

_____

_____

(1)

(Total 12 marks)

6. This question is about a reversible reaction.

The reaction between solutions of iron(III) ions (Fe^{3+}) and thiocyanate ions (SCN^-) is reversible.

The ionic equation for the reaction is:

	$Fe^{3+}(aq)$		$SCN^-(aq)$		$FeSCN^{2+}(aq)$
Colour of solution:	yellow	+	colourless	⇌	red

The colour of the equilibrium mixture is orange at room temperature.

(a) Give the name of the solvent used to dissolve the ions in this reaction.

_____

(1)

(b) A few drops of a colourless solution containing a high concentration of thiocyanate ions (SCN^-) are added to the orange equilibrium mixture.

Explain the colour change observed.

_____

_____

_____

_____

_____

_____

(3)

(c) A water bath is set up at a temperature above room temperature.

When a test tube containing the orange equilibrium mixture is placed in the water bath, the mixture becomes more yellow.

Explain what this shows about the energy change for the forward reaction.

_____

_____

_____

_____

_____

_____

(3)

(d) Explain why a change in pressure does **not** affect the colour of the equilibrium mixture.

_____

_____

_____

_____

(2)

(e) Other metal ions form coloured equilibrium mixtures with thiocyanate ions.

Which metal ion could form a coloured equilibrium mixture with thiocyanate ions?

Tick (✓) **one** box.

Al^{3+} ☐

Co^{2+} ☐

Mg^{2+} ☐

Na^{+} ☐

(1)

(Total 10 marks)

1.

(a) a gas was produced

allow oxygen for gas

1

(and the gas) escaped from the flask

1

(b) catalysts provide a different pathway for the reaction

1

(and) the activation energy using **B** is lower

allow converse

1

(so) the rate of reaction is higher using **B**

allow converse

*allow (so) the reaction using **B** has more particles with an energy exceeding the activation energy*

1

(c) tangent at 60 s

1

value for *x* step **and** *y* step from tangent

allow a tolerance of ± ½ a small square

allow correct use of an incorrect tangent

1

$$(\text{rate} =) \frac{\text{value for } y \text{ step}}{\text{value for } x \text{ step}}$$

allow correct use of incorrectly determined x and / or y step from a drawn tangent

1

correct calculation of rate

1

answer in standard form

allow an answer correctly given in standard form from an incorrect calculation which uses values determined from the graph

1

(d) the rate (of decomposition / reaction) increases at higher temperatures

allow converse

1

(because) particles have more energy

allow (because) particles move faster

1

(so) collide more frequently

allow (and) a greater proportion collide with sufficient energy to exceed the activation energy

1

[13]

2. (a) volume (of reactants) is 90 cm^3

allow volume (of reactants) is greater than 50 cm^3

1

(so conical) flask will overflow

allow (so) solutions will not fit (in conical flask)

1

(b) measuring cylinder

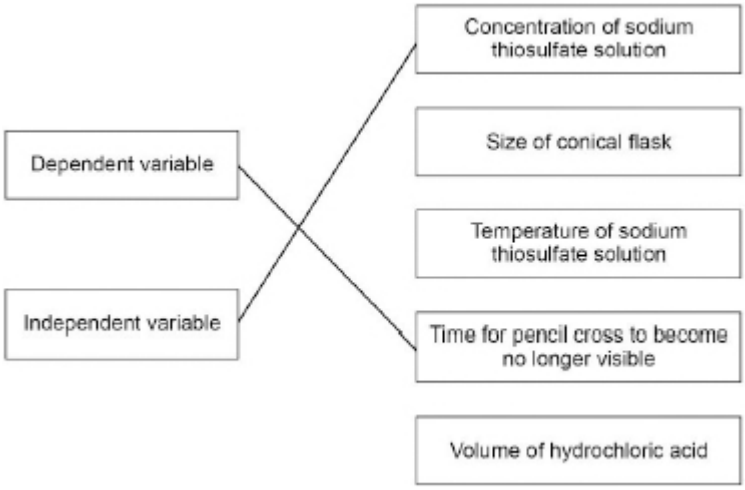
allow (volumetric / graduated)

pipette

allow burette

1

(c)



allow **1** mark if dependent variable and independent variable are identified the wrong way round

1

do **not** accept more than **one** line drawn from a box on the left

1

(d) the time taken will increase

1

(e) 32 g/dm^3

1

(f) the particles are closer together

1

the particles collide more frequently

1

(g) decreases

1

increases

1

[11]

3. (a) (some) hydrogen / gas escapes (from the flask)

1

(because the reaction starts) before the stopper is put in

allow (because) stopper cannot be inserted instantly

*allow for **1** mark some air (from the conical flask) is collected*

or

allow some hydrogen remains in the conical flask

or

allow some hydrogen remains in the delivery tube

1

(b) (volume = 39 − 25 =) 14 (cm^3)

1

(14 cm^3 =) 0.014 (dm^3)

allow correct use of an incorrectly determined volume

1

(moles of hydrogen =)

$$\frac{0.014}{24}$$

allow correct use of an incorrectly determined volume

allow correct use of an incorrect / no conversion of volume

1

= 5.8×10^{-4} (mol)

allow 5.833333 x 10^{-4} correctly rounded to at least 2 significant figures

allow 0.00058 (mol)

1

alternative approach 1:

(24 dm^3 =) 24 000 (cm^3) (1)

(volume = 39 − 25 =)
14 (cm^3) (1)

(moles of hydrogen =)
$\frac{14}{24000}$ (1)

allow correct use of an incorrectly determined volume

allow correct use of an incorrect / no conversion of volume

= 5.8 x 10^{-4} (mol) (1)

allow 5.833333 x 10^{-4} correctly rounded to at least 2 significant figures

allow 0.00058 (mol)

alternative approach 2:

(24 dm^3 =) 24 000 (cm^3) (1)

(moles of hydrogen at 100 s =

$\frac{39}{24000}$ =) 0.001625

allow correct use of an incorrect / no conversion of volume

and

(moles of hydrogen at 40 s =

$\frac{25}{24000}$ =) 0.00104 (1)

(moles 100 s – moles 40 s =)
0.001625 – 0.00104 (1)

allow correct use of an incorrectly determined number of moles

= 5.8 x 10^{-4} (mol) (1)

allow 5.833333 x 10^{-4} correctly rounded to at least 2 significant figures

allow 0.00058 (mol)

alternative approach 3:

(39 cm^3 =) 0.039 (dm^3)
and
(25 cm^3 =) 0.025 (dm^3) (1)

(moles of hydrogen at 100 s = $\frac{0.039}{24}$ =) 0.001625

allow correct use of an incorrect / no conversion of volume

and

(moles of hydrogen at 40 s = $\frac{0.025}{24}$ =) 0.00104 (1)

(moles 100 s – moles 40 s =)
0.001625 – 0.00104 (1)

allow correct use of an incorrectly determined number of moles

= 5.8 x 10^{-4} (mol) (1)

allow 5.833333 x 10^{-4} correctly rounded to at least 2 significant figures

allow 0.00058 (mol)

(c) tangent drawn at 45 s

1

correct values for *y* step **and** *x* step from tangent

allow correct use of an incorrectly drawn tangent

allow a tolerance of ± ½ a small square for each coordinate

1

(rate =) $\frac{\text{value for } y \text{ step}}{\text{value for } x \text{ step}}$

allow correct use of incorrectly determined value(s) from the tangent for y step and/or x step

1

correct calculation of rate (mol/s)

1

rate given in standard form (mol/s)

allow a correctly calculated answer in standard form from an incorrect attempt at rate determination

1

(d) line starting at 0,0.000 and less steep than existing line

1

becomes level at 0.0084 mol

allow a tolerance of ± ½ a small square

1

(e) (increasing the temperature) increases the rate of reaction

1

(because) particles have more energy

allow (because) particles move faster

1

(so) the frequency of collisions increases

allow (so) a greater proportion of collisions have enough energy to react

ignore successful

1

[16]

4. (a) measuring cylinder

allow pipette / burette

1

(b) limewater turns milky

1

(c) all six points plotted correctly

allow a tolerance of ± ½ a small square

*allow **1** mark for four or five points plotted correctly*

2

line of best fit

1

(d) (volume =) 48 (cm^3)

1

(rate=) $\frac{48}{60}$

allow correct use of an incorrectly determined value for volume

1

= 0.8 (cm^3/s)

1

(e) (between 0 and 20 seconds) (volume of gas) increases

1

(between 80 and 100 seconds) no change (in volume of gas)

allow reaction stops

1

(f) systematic error

1

(g) (area of one face = 2 x 2 =) 4 (mm^2)

1

(total surface area =) 4 x 6

allow correct use of an incorrectly calculated area of one face

1

= 24 (mm^2)

1

(h) faster

1

[15]

5. (a) all seven points plotted correctly

allow a tolerance of ±½ small square

*allow **1** mark for five or six points plotted correctly*

2

line of best fit

1

(b) 0.0038 **and** 0.0014

1

$$\frac{0.0038 - 0.0014}{105 - 20}$$

allow correct use of incorrectly determined mole value(s)

1

= 0.000028
or
= 2.8×10^{-5}

1

mol/s

allow moles per second

1

(c) (for large lumps) a smaller number of moles of gas is collected in the same time
or
(for large lumps) more time is needed to collect the same number of moles of gas
or
the line (of best fit for large lumps) is less steep

allow converse statement for small lumps

allow the line (of best fit for large lumps) takes more time to become horizontal

1

(d) (surface area = 6 x 0.5 x 0.5) = 1.5 (cm^2)

1

(volume = 0.5 x 0.5 x 0.5) = 0.125 (cm^3)

1

(surface area : volume =) 12 : 1

allow correctly calculated ratio using incorrectly calculated values for surface area and/or volume

1

(e) decreases by a factor of 10

allow 10 times smaller

allow one tenth

allow 1/10

allow 1 : 10 (large cube to small cube)

1

[12]

6. (a) water

allow H_2O

1

(b) becomes (more) red

1

(because the position of) equilibrium moves to the right

allow (because) the concentration of $FeSCN^{2+}$ (ions) increases

allow (because) the forward reaction is favoured

1

(so that) the (increase in the) concentration of thiocyanate (ions) is reduced

allow (so that) the increase in the concentration of thiocyanate (ions) is counteracted

1

(c) (the position of) equilibrium moves to the left

allow the concentration of Fe^{3+} (ions) increases

allow the reverse reaction is favoured

1

(so that) the (increase in the) temperature is reduced

allow (so that) the increase in the temperature is counteracted

1

(therefore) the forward reaction is exothermic

allow (therefore) the forward reaction releases energy (to the surroundings)

1

(d) no change in equilibrium position

1

(because) no gases are present

allow (because) only aqueous solutions are present

1

(e) Co^{2+}

1

[10]