Rates of Reaction 4

Name: _____

Class: _____

Date: _____

Time: **71 minutes**

Marks: **69 marks**

Comments:

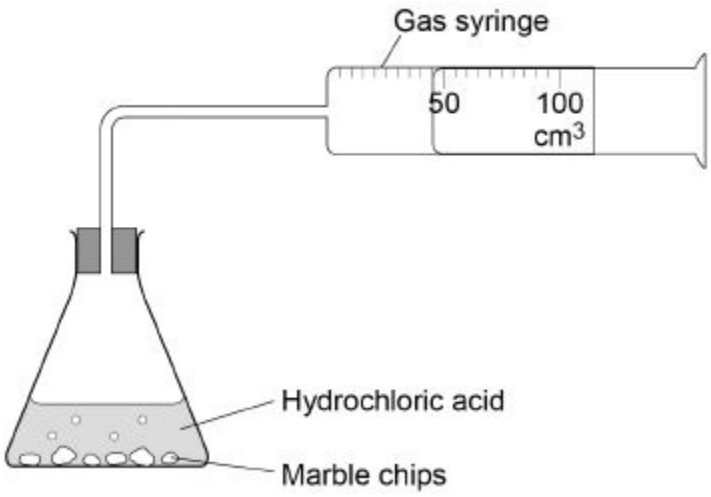
1. A student investigated the effect of the size of marble chips on the rate of the reaction between marble chips and hydrochloric acid.

This is the method used.

1. Add 10 g of marble chips into the flask.
2. Add 50 cm^3 of hydrochloric acid, connect the gas syringe and start a timer.
3. Record the volume of gas produced every 10 seconds.

Figure 1 shows the apparatus.

Figure 1



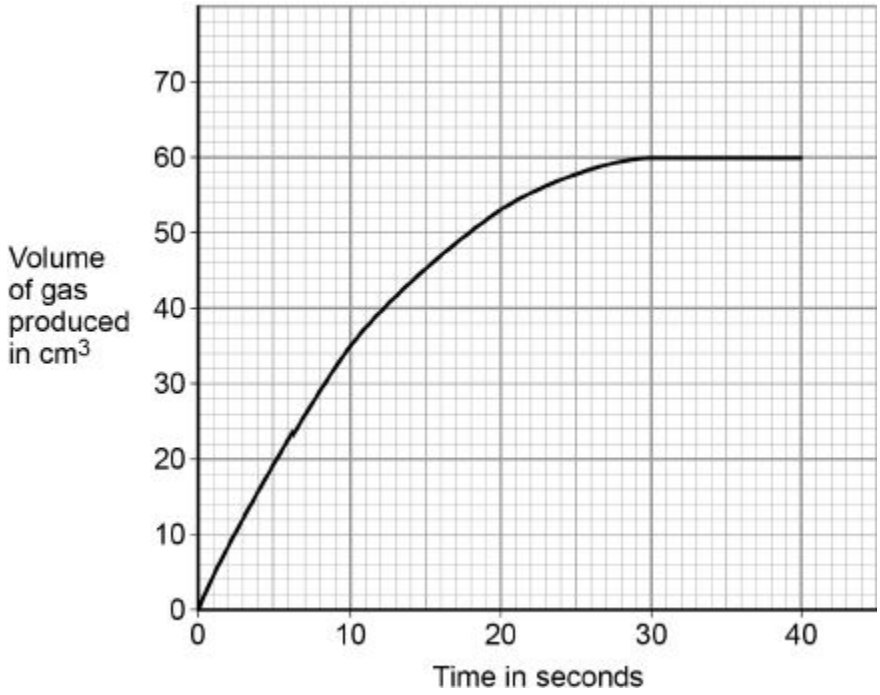
(a) Complete the equation for the reaction.

$CaCO_3$ + _____HCl ⟶ _____

(2)

Figure 2 shows the student's results.

Figure 2



(b) Describe the trend shown in **Figure 2**

Use values in your answer.

(3)

(c) Describe how you would use **Figure 2** to find the rate of the reaction at 15 seconds.

You do **not** need to do a calculation.

(2)

(d) Give the units for the rate of this reaction.

_____

(1)

The table below shows the results of the investigation.

Relative size of marble chips	**Volume of gas produced in cm^3 after given time in seconds**					
	10 s	**20 s**	**30 s**	**40 s**	**50 s**	**60 s**
Small	35	53	60	60	60	60
Medium	21	39	51	58	60	60
Large	14	29	39	48	58	60

(e) Give **one** conclusion about how the size of the marble chips affects the rate of the reaction.

_____

_____

(1)

(f) Suggest why all three sizes of marble chips produce a maximum volume of 60 cm^3 of gas.

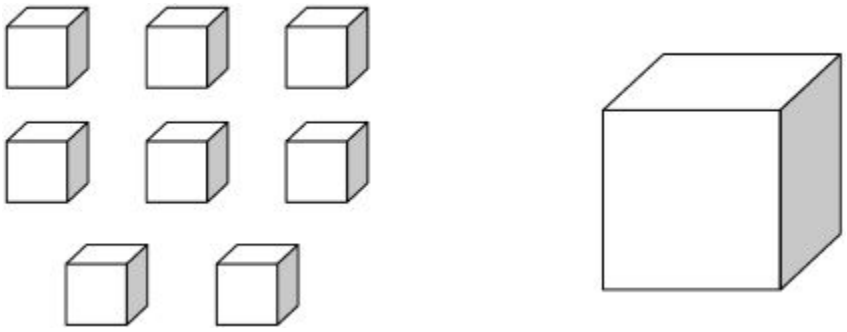
_____

_____

(1)

(g) **Figure 3** shows eight small cubes, each 1 cm × 1 cm × 1 cm, and one large cube, 2 cm × 2 cm × 2 cm

Figure 3



Total volume of small cubes = 8 cm^3

Volume of large cube = 8 cm^3

Total surface area of small cubes = 48 cm^2

Calculate the surface area of the large cube.

Surface area of the large cube = _____ cm^2

(2)

(h) Explain why the size of the marble chips affects the rate of the reaction.

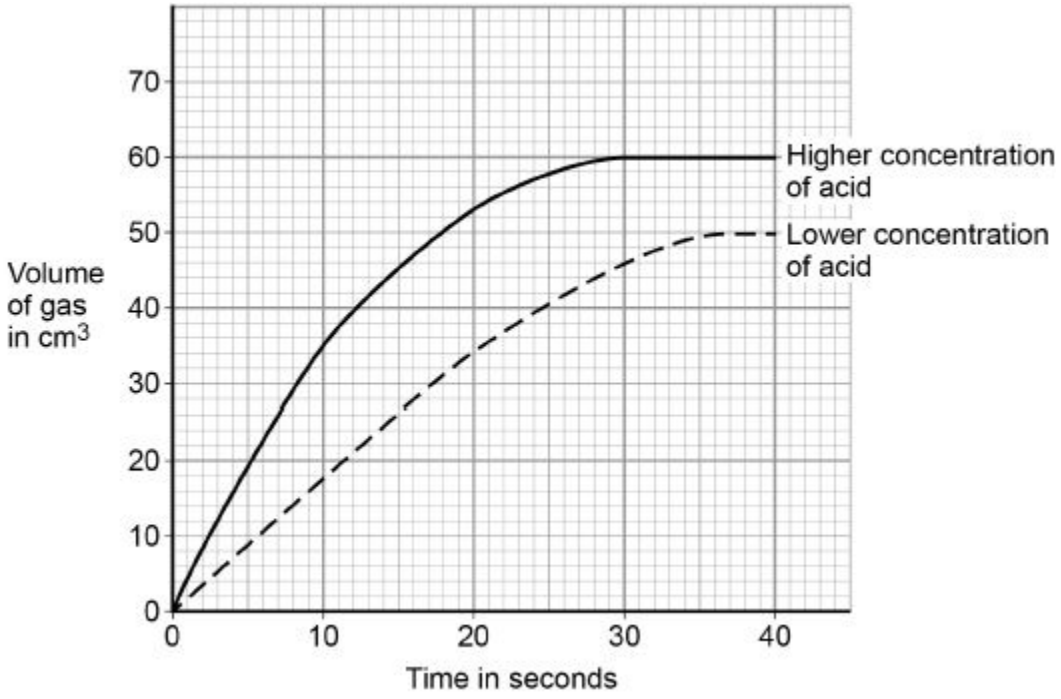
Give your answer in terms of 'collision theory'.

(2)

(i) The student repeated the investigation with small marble chips using hydrochloric acid with a lower concentration.

Figure 4 shows the volume of gas produced during the first 40 seconds.

Figure 4



Explain why the results for the lower concentration of acid are different from the results for the higher concentration of acid.

_____

_____

_____

_____

_____

_____

(3)

(Total 17 marks)

2. Bleach is a solution of sodium hypochlorite (NaClO).

Chlorine gas is produced when bleach reacts with hydrochloric acid.

$$NaClO(aq) + 2HCl\ (aq) \rightleftharpoons NaCl(aq) + H_2O(l) + Cl_2(g)$$

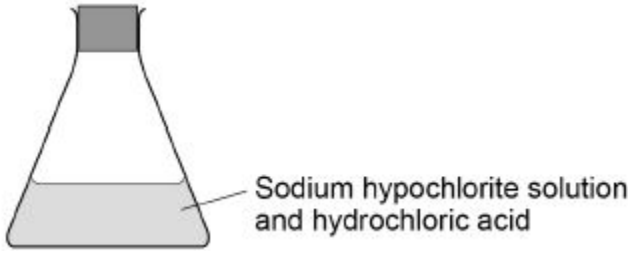
(a) Give the test and result for chlorine gas.

_____

_____

(2)

The diagram below shows a sealed flask of sodium hypochlorite and hydrochloric acid at equilibrium.



(b) Explain why equilibrium is reached in this reaction.

_____

_____

_____

_____

_____

_____

(2)

(c) The stopper in the diagram above is removed and hydrochloric acid is added.

The stopper is replaced.

Explain what happens to the equilibrium.

_____

_____

_____

_____

_____

_____

_____

_____

(4)

Chlorine gas is also produced when hydrogen chloride decomposes.

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

The forward reaction is endothermic.

(d) Predict the effect of increasing the temperature on the amount of chlorine gas produced at equilibrium.

Explain your answer using Le Chatelier's Principle.

_____

_____

_____

_____

(2)

(e) Explain the effect of increasing the pressure on this equilibrium.

_____

_____

_____

_____

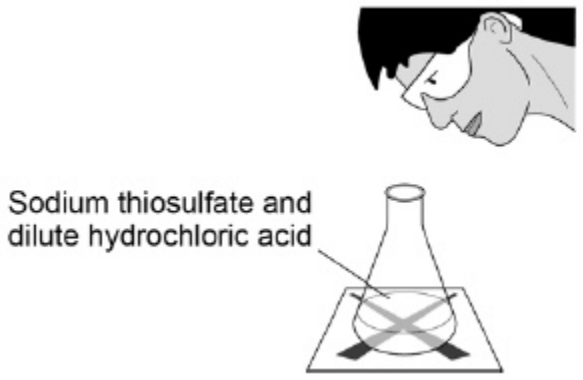
(2)

(Total 12 marks)

3. A student investigated the effect of concentration on the rate of the reaction between sodium thiosulfate and dilute hydrochloric acid.

Figure 1 shows the apparatus the student used.

Figure 1



(a) The symbol equation for the reaction is:

$$Na_2S_2O_3 + 2HCl \rightarrow 2NaCl + SO_2 + H_2O + S$$

Complete the word equation for the reaction.

sodium thiosulphate + hydrochloric acid → _____ + sulfur dioxide + water + sulfur

(1)

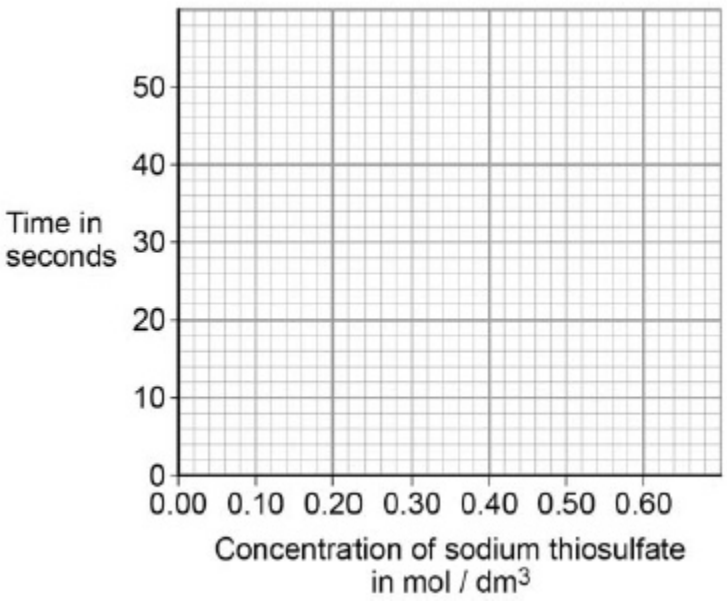
(b) The table shows the results.

Concentration of sodium thiosulfate in mol/dm^3	**Time for student to no longer see the cross in seconds**
0.10	41
0.20	21
0.30	20
0.40	10
0.50	8

Plot the data from the table on **Figure 2**.

Draw a line of best fit.

Figure 2



(3)

(c) The student determined the time for a concentration of 0.15 mol/dm^3

What is the concentration when the reaction is 20 seconds faster?

You should show your working on **Figure 2**.

Concentration = _____ mol/dm^3

(2)

(d) Estimate the time taken for the reaction when the concentration of sodium thiosulfate is 0.60 mol/dm^3

Time taken = _____ s

(1)

(Total 7 marks)

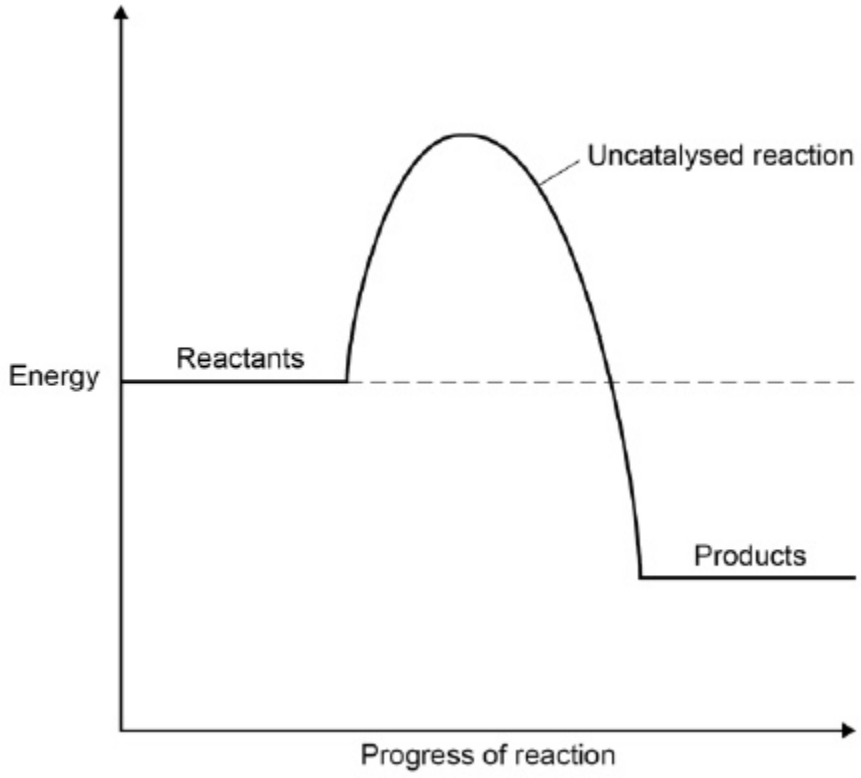
4. This question is about catalysts.

(a) Why are catalysts used in reactions?

(1)

Figure 1 shows the reaction profile for a reaction without a catalyst.

Figure 1



(b) Label the activation energy (E_A) for the reaction on **Figure 1**.

(1)

(c) Label the energy change for the reaction on **Figure 1**.

(1)

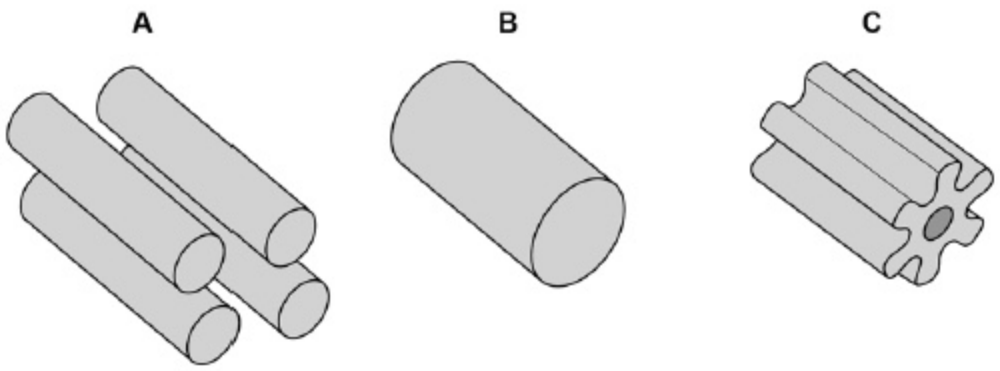
(d) Draw the reaction profile for the reaction **with a catalyst** on **Figure 1**.

(2)

(e) **Figure 2** shows three different shapes of the same catalyst.

Each catalyst has the same volume.

Figure 2



Evaluate the effectiveness of the shapes of the catalyst in **Figure 2**.

(3)

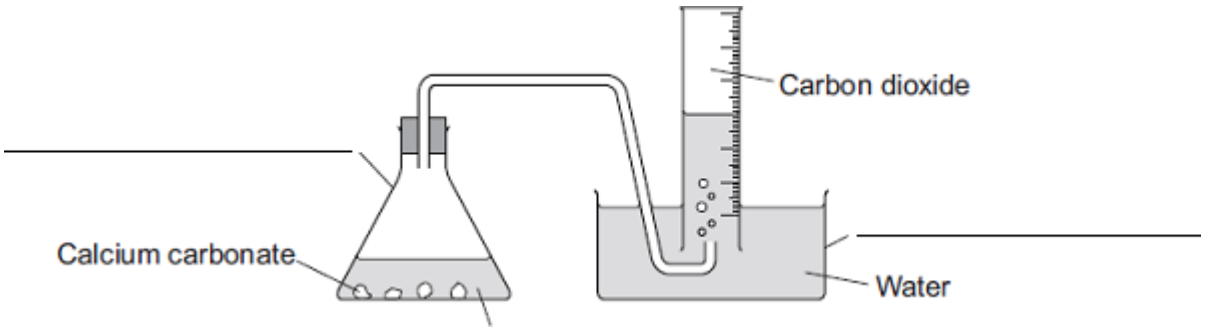
(Total 8 marks)

5. Some students were investigating the rate at which carbon dioxide gas is produced when metal carbonates react with an acid.

One student reacted 1.00 g of calcium carbonate with 50 cm^3, an excess, of dilute hydrochloric acid.

The apparatus used is shown in **Diagram 1**.

Diagram 1



(a) Complete the **two** labels for the apparatus on the diagram.

(2)

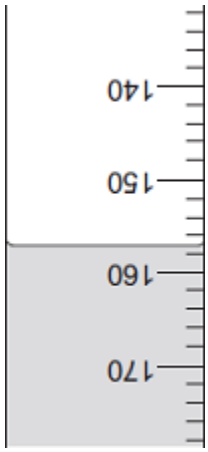
(b) The student measured the volume of gas collected every 30 seconds.

The table shows the student's results.

Time in seconds	Volume of carbon dioxide collected in cm^3
30	104
60	
90	198
120	221
150	232
180	238
210	240
240	240

(i) **Diagram 2** shows what the student saw at 60 seconds.

Diagram 2



What is the volume of gas collected?

Volume of gas = _____ cm^3

(1)

(ii) Why did the volume of gas stop changing after 210 seconds?

_____

_____

(1)

(c) Another student placed a conical flask containing 1.00 g of a Group 1 carbonate (M_2CO_3) on a balance.

He then added 50 cm^3, an excess, of dilute hydrochloric acid to the flask and measured the mass of carbon dioxide given off.

The equation for the reaction is:

$$M_2CO_3 + 2HCl \longrightarrow 2MCl + H_2O + CO_2$$

The final mass of carbon dioxide given off was 0.32 g.

(i) Calculate the amount, in moles, of carbon dioxide in 0.32 g carbon dioxide.

Relative atomic masses (A_r): C = 12; O = 16

_____

_____

_____

Moles of carbon dioxide = _____ moles

(2)

(ii) How many moles of the metal carbonate are needed to make this number of moles of carbon dioxide?

_____

_____

Moles of metal carbonate = _____ moles

(1)

(iii) The mass of metal carbonate used was 1.00 g.

Use this information, and your answer to part **(c) (ii)**, to calculate the relative formula mass (M_r) of the metal carbonate.

If you could not answer part **(c) (ii)**, use 0.00943 as the number of moles of metal carbonate. This is **not** the answer to part **(c) (ii)**.

_____

_____

Relative formula mass (M_r) of metal carbonate = _____

(1)

(iv) Use your answer to part **(c) (iii)** to calculate the relative atomic mass (A_r) of the metal in the metal carbonate (M_2CO_3) and so identify the Group 1 metal in the metal carbonate.

If you could not answer part **(c) (iii)**, use 230 as the relative formula mass of the metal carbonate. This is **not** the answer to part **(c) (iii)**.

To gain full marks, you must show your working.

_____

_____

_____

_____

Relative atomic mass of metal is _____

Identity of metal _____

(3)

(d) Two other students repeated the experiment in part **(c)**.

(i) When the first student did the experiment some acid sprayed out of the flask as the metal carbonate reacted.

Explain the effect this mistake would have on the calculated relative atomic mass of the metal.

(3)

(ii) The second student used 100 cm^3 of dilute hydrochloric acid instead of 50 cm^3.

Explain the effect, if any, this mistake would have on the calculated relative atomic mass of the metal.

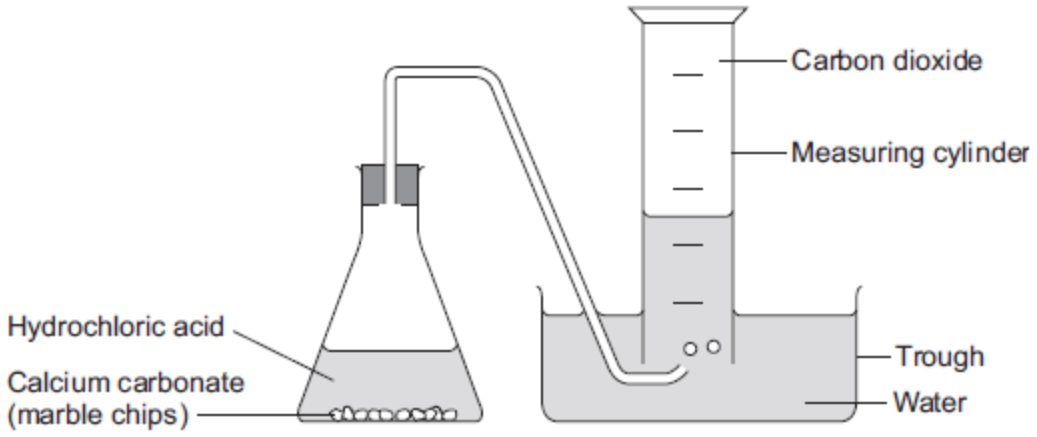
(3)

(Total 17 marks)

6. A student investigated the rate of reaction between calcium carbonate (marble chips) and hydrochloric acid.

The student used the apparatus shown in **Figure 1**.

Figure 1



The student:

- recorded the volume of gas collected every 5 seconds
- repeated the experiment using hydrochloric acid at different temperatures.

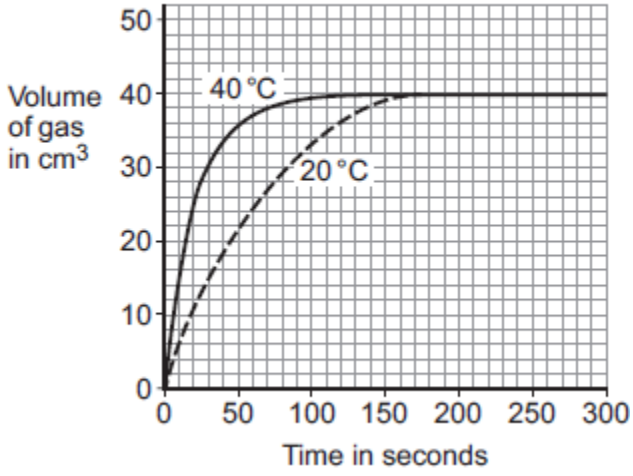
The equation for the reaction is:

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

(a) The student plotted results for the hydrochloric acid at 20 °C and 40 °C on a graph.

Figure 2 shows the student's graph.

Figure 2



Use information from **Figure 2** to answer these questions.

(i) State **one** conclusion the student could make about the effect of temperature on the rate of the reaction.

_____

_____

(1)

(ii) Give **one** reason why the student could make this conclusion.

_____

_____

(1)

(iii) For the hydrochloric acid at 60 °C the student had collected 30 cm^3 after 15 seconds.

Calculate the average rate of reaction from 0 to 15 seconds.

_____

_____

Rate of reaction = _____ cm^3 per second

(1)

(b) The student then investigated how the surface area of marble chips affected the rate of reaction.

(i) Which **two** variables should the student keep constant?

Tick (✓) **two** boxes.

Amount of water in the trough ☐

Concentration of acid ☐

Mass of marble chips ☐

Size of marble chips ☐

Volume of measuring cylinder ☐

(2)

(ii) Explain, in terms of particles and collisions, the effect that increasing the surface area of the marble chips has on the rate of reaction.

_____

_____

_____

_____

(2)

(c) Calcium carbonate is a catalyst for the industrial production of biodiesel.

Give **one** reason why using a catalyst reduces costs.

_____

_____

(1)

(Total 8 marks)

1.

(a) $CaCl_2 + CO_2 + H_2O$

products in any order

1

balancing: **2** (HCl)

dependent on correct formulae for products

1

(b) value from graph used to show volume increase

must include a time or volume value

1

values from graph used to show the volume increases less rapidly

must include time interval or volume increment

1

volume **or** time stated when graph line levels off

*allow levels off at 60 (cm^3) **or** 28 to 30 s*
allow descriptions in terms of rate of reaction

1

values must be approximately correct

(c) draw tangent at <u>15 s</u>

allow draw a straight line on the curve at <u>15 s</u>

1

calculate gradient

allow correct description of gradient calculation
ignore calculations if given

1

(d) centimetres cubed per second

*allow cm^3/s **or** $cm^3\ s^{-1}$ (all lower case)*
allow mixture of abbreviations and words, e.g. centimetres cubed/s
*do **not** accept non-SI abbreviations (e.g. sec for s)*

1

(e) (rate) increases as chips get smaller

allow converse

1

(f) same amount of acid

or

same number of moles of acid

allow same volume of acid
allow same concentration of acid
allow same mass of $CaCO_3$ / marble chips
allow one reactant is the limiting factor

1

(g) (surface area of each face = 2 × 2 =) 4

1

(6 × 4 =) 24 (cm^2)

allow 6 × student's value from step 1

1

*an answer of 24 (cm^2) scores **2** marks*

(h) small(er) chips have large(r) surface area (for the same volume)

allow converse

1

so more frequent collisions

allow more chance of collisions
allow more likely to collide

*do **not** accept reference to speed of particles or energy of collisions*

ignore more collisions
ignore more successful collisions

1

(i) (sloping part is less steep because) reaction is slower

1

due to less frequent collisions

*do **not** accept reference to speed of particles or energy of collisions*
ignore fewer collisions

1

fewer acid particles (in same volume)

ignore weaker acid

1

or
(sloping part is less steep because) reaction is slower (1)

there are fewer acid particles (in same volume) (1)

(graph levels off lower) so less gas is produced (1)

allow converse for more concentrated acid

[17]

2. (a) <u>damp / moist</u> litmus paper

ignore colour of litmus paper

1

bleaches / goes white

1

(b) forward and reverse rates equal

1

because no escape of reactants or products

allow closed system
allow particles for reactants or products

1

(c) equilibrium shifts

allow no longer in equilibrium

1

to right-hand side

allow in favour of forward reaction

1

to produce more of any products
or
to reduce any reactants

allow correct references to Le Chatelier's Principle

1

(new) equilibrium will be established

1

(d) amount of chlorine gas increases

1

(because) system shifts to counteract the change

allow (because) system shifts to take in energy
allow (because) system shifts in endothermic direction

1

(e) no change

1

because equal numbers of molecules
or
moles (of gas) on each side

1

[12]

3. (a) sodium chloride

1

(b) points correctly plotted

*allow **1** mark if 4 correct*

2

correct line of best fit

*do **not** accept straight line*

1

(c) 0.38–0.50

*allow for **1** mark for working shown on graph*

2

(d) ≥5 seconds and <8 seconds

1

[7]

4. (a) changes the rate
or
speeds up the reaction

1

(b) correct label from reactants level to top of curve

1

(c) correct label from reactants level to products level

1

(d) starts at reactant level, ends at products level

1

curves upwards underneath existing curve

1

(e) greater surface area increases catalytic effectiveness

1

plus any **two** from:
- smaller pellets give higher surface area to volume ratio
- hole increases surface area
- ridges increase surface area

2

[8]

5. (a) left hand: (conical) flask

*do **not** accept round bottomed flask or container which is not a flask*

1

right hand: beaker / trough

accept plastic box

1

(b) (i) 157

1

(ii) all calcium carbonate used up **or** reaction stopped

*do **not** accept all acid used up*

1

(c) (i) 0.007(272727…)

*correct answer with or without working gains **2** marks*

*if answer incorrect, allow (0.32 / 44) for **1** mark*

2

(ii) 0.007(272727…)

*allow ecf from **(c)(i)***

1

(iii) (M_r = mass / moles = 1 / 0.00727…) = 137.5 or 138

*allow ecf from **(c)(ii)***

if use 0.00943 moles then = 106

if use 0.007 allow 143 (142.857)

1

(iv) (138) – 60 (= 78)

23 / 85

1

(78 / 2) = 39

1

potassium

sodium / rubidium

*identity of metal ecf on A_r, but **must** be Group 1*

*If no working max **1** mark*

1

(d) (i) (relative atomic mass) would decrease

1

because the mass lost greater

1

so moles carbon dioxide larger **or** moles metal carbonate greater

1

(ii) no change

1

because the acid (already) in excess

1

so the amount carbon dioxide lost is the same

1

[17]

6.

(a) (i) the higher the temperature, the greater the rate

or

at 40 °C rate is faster than at 20 °C

accept the higher the temperature, the faster the reaction

1

(ii) 40 °C curve is steeper

accept the 40 °C line becomes horizontal sooner

accept at higher temperatures the reaction finishes sooner

accept reaction finishes sooner at 40 °C

accept at higher temperatures the gas is produced faster

or

correct comparison of data from the graph

1

(iii) 2

1

(b) (i) Concentration of acid

Mass of marble chips

2

(ii) increases rate

*incorrect reference to energy = max **1***

1

(because of) more frequent collisions (between particles)

accept particles are more likely to collide

ignore more collisions

ignore more successful collisions

1

(c) any **one** from:

- increases rate of reaction
- reduces energy required
- lower temperature can be used
- catalyst is not used up.

1

[8]