## Rate of Reaction

The rate of reaction is the speed at which a chemical reaction is happening. This can vary hugely from reaction to reaction.
The rate of reaction can be calculated either by measuring the quantity of reactant used or the quantity of product made in a certain length of time. The quantity can either be a volume measured in $\mathrm{cm}^{3}$ or a mass measure in grams (g).

Measuring Rate of Reaction-Higher Tier


The gradient of a volume or mass/time graph will give you the rate of reaction at a given point. However when the line is a curve you need to drawa tangent to measure the gradient. To draw a tangent follow the following steps

1. Line you ruler up across your graph, so that it touches the line on the point that you want to find out the gradient
2. Adjust the ruler until the space between the ruler and the curve is equal on both sides
3. Draw the line and pick two easy points that will allowyou to calculate the gradient of the line.

| Key Terms | Definitions |
| :--- | :--- |
| Rate of Reaction | The rate at which reactants are being turned into products |
| Reactant | What is used in a chemical reaction |
| Product | What is made ina chemical reaction |
| Catalyst | A substance which speeds up a chemical reaction without <br> being used up |
| Tangent | A straight line that touches a curve at a point |


| Equation | Meanings of terms in equation |
| :--- | :--- |
| Rate of Reaction $=\frac{\text { Reactant used }}{\text { time }}$ | Reactant used can eitherr be <br> measured in grams or $\mathrm{cm}^{3}$ |
| Rate of Reaction $=\frac{\text { Product Made }}{\text { time }}$ | Reactant used can eitherr be <br> measured in grams or $\mathrm{cm}^{3}$ |

## Measuring the Rate of Reaction

There are several experiments that can be used to measure the rate of a chemical reaction.

1. Measuring the mass lost in a chemical reaction (marble chips and acid is a good example)
2. Measuring the volume of gas produced (decomposition of hydrogen peroxide is a good example)
3. Time taken to make an X disappear (sodium thiosulphate and acid is a good example)


Calculating the Mean Rate of Reaction-Higher Tier
To calculate the mean rate of reaction from a graph you need to pick two y values on the graph and two $x$ values, subtract the largest from the smallest and the divide the value on the $y$ axis by the valued on the $x$ axis.


## Factors which affect Rate of Reaction

Being able to slow down and speed up chemical reactions is important in everyday life and in industry. We can change the rate of a reaction by:

- Changing temperature
- Changing pressure
- Changing the concentration of a solution
- Changing the surface area
- Adding a catalyst


## Collision Theory

Collision Theory: reactions occur when particles collide with a certain amount of energy.
The minimum amount of energy needed for the particles to react is called the activation energy, which is different for each reaction.
The rate of a reaction depends on two things:

- the frequency of collisions between particles. The more often particles collide, the more likely they are to react.
- the energy with which particles collide. If particles collide with less energy than the activation energy, they will not react.


## Interpreting Rate of Reaction Graphs

The results from rate of reaction experiments can be plotted on a line graph. For example how the mass changes against time or how much gas is made against time. Different lines can be plotted for different conditions, the steeper the gradient, the faster the reaction.

It is important to remember that the graphs flatten off (plateau) at the same point as the same amount of reactant is being used.



Time from start of reaction

## Collision Theory- in more detail Concentration

If the concentration of a solution is increased then there are more particles in a given volume, therefore collisions are more frequent and the chemical reaction is faster. Concentration is directly proportional to rate of reaction (if you double the concentration you double the rate).


## Collision Theory in more detail Surface Area

When you increase the surface area of a solid (you cannot increase the surface area of a liquid or gas). You increase the number of particles that are available for collision, therefore increasing the frequency of collisions therefore increase the rate of reaction.


## Collision Theory in more detail gas pressure

If the reaction is carried out in the gaseous state, then increasing the pressure will increase the rate of reaction. If there are more particles in a given volume of gas, then collisions will be more frequent and therefore the reaction will be faster.


## Collision Theory in more detail Temperature

When you increase the temperature of something the particles will move around faster, this increases the frequency of the collisions. As well as that, as the particles are moving faster the particles collide with more energy making it more likely that collisions exceed the activation energy.

## Callision Theary in more detail Catalysts

A catalyst is a substance which speeds upa chemical reaction
without heing used up. It speeds up a reaction because it lowers the
activation energy by prowiding an alternative pathway and
this means that there are more successful collisions and a faster reaction.

The effect of a catalyst is shown on the reaction profile below:

```
Catalysts are not included in a chemical equation as they are not
used up in a chemical reaction.
```



| Key Terms | Definitions |
| :--- | :--- |
| Enzymes | A biological catalyst |
| Reaction <br> Profile | A graph which show the energies of the <br> reactants and products at different stages of the <br> chemical reaction |

## Enzymes

Enzymes are biological catalysts, they speed up chemical reactions in biological systems for example in digestion in animals. Unlike catalysts enzymes have an optimum temperature where they work best, this is usually around 37 degrees Celsius.

| Key Terms | Definitions |
| :--- | :--- |
| Equilibrium | A reaction that is reversible |
| Le Chatelier's <br> principle | A principle which states, "If a system is at equilibrium and a <br> change is made to any of the conditions, then the system <br> responds to counteract the change" |
| Dynamic <br> Equilibrium | An equilibrium where the forward and backward reactions <br> are happening at the same rate |


| Key Terms | Definitions |
| :--- | :--- |
| Activation <br> Energy | The minimum energy required for a chemical reaction <br> to take place |
| Collision Theory | The theory that states for a chemical reaction to <br> happen, particles must collide with sufficient energy |
| Gradient | The measurement of how steep a line is on a graph |
| Frequency | The amount of times something happens in one second |
| Concentration | The number of particles in a given volume |

## Equilibrium

Some chemical reactions are rexersible, this means they can happen in both the forward and reverse directions. The symbol we use to represent an equilibrium reaction is shown in the equation below:

$$
\mathrm{N}_{2}+3 \mathrm{H}_{2} \rightleftharpoons 2 \mathrm{NH}_{3}
$$

In a dynamic equilibrium reaction, the forward and reverse reactions are happening at the same rate.

A dynamic equilibrium has to occur in a closed system, where no reactants and products are allowed to escape.

If the equilibrium lies to the left, it means that there is a greater concentration of reactants than products
If the equilibrium lies to the right it means there is a greater concentration of products than reactants.

Most equilibrium reactionsmace endothermic in one direction and exothermic in another direction. A gegd example is the hydration and dehydration of copper sulphate. It is exothermic when water is added to the copper sulphate, it is endothermic when water is removed.


## Lesson 1 Measuring rate: reactant lost

Q1.
A student investigated the rate of reaction between marble chips and hydrochloric acid.
Figure 1 shows the apparatus the student used.
Figure 1

(a) What is $\mathbf{A}$ ?

Tick one box.
cotton wool $\square$
limestone
poly(ethene)

rubber bung

(b) Table 1 shows the student's results for one investigation.

Table 1

| Time <br> in s | Mass lost <br> in g |
| :---: | :---: |
| 0 | 0.0 |
| 20 | 1.6 |
| 40 | 2.6 |
| 60 | 2.9 |
| 80 | 3.7 |
| 100 | 4.0 |
| 120 | 4.0 |

## On Figure 2:

- Plot these results on the grid.
- Draw a line of best fit.

Figure 2

(c) Use Figure 2 to complete Table 2.

Table 2

| Mass lost after 0.5 minutes | g |
| :--- | ---: |
| Time taken to complete the reaction | s |

(d) The equation for the reaction is:
$2 \mathrm{HCl}(\mathrm{aq})+\mathrm{CaCO}_{3}(\mathrm{~s}) \rightarrow \mathrm{CaCl}_{2}(\mathrm{aq})+\mathrm{H}_{2} \mathrm{O}(\mathrm{I})+\mathrm{CO}_{2}(\mathrm{~g})$
Explain why there is a loss in mass in this investigation.
$\qquad$
$\qquad$
$\qquad$
$\qquad$
(e) Another student investigated the rate of a different reaction.

Table 3 shows the results from the different reaction.

## Table 3

| Mass lost when the reaction was complete | 9.85 g |
| :--- | :---: |
| Time taken to complete the reaction | 2 minutes 30 <br> seconds |

Calculate the mean rate of the reaction using Table 3 and the equation:

$$
\text { mean rate of reaction }=\frac{\text { mass lost in } \mathrm{g}}{\text { time taken in } \mathrm{s}}
$$

Give your answer to two decimal places.
$\qquad$
$\qquad$
Mean rate of reaction = $\qquad$ g/s

## Lesson 2 Measuring Rate: Product formed

## Q1.

(b) A student did an experiment to see how quickly hydrogen peroxide decomposes.

The student used the apparatus shown below to measure the volume of oxygen.

(i) Draw a straight line of best fit to complete the graph.

(ii) Draw a circle around the anomalous point on the graph.
(iii) What is the volume of oxygen given off after 15 seconds?
$\qquad$ cm ${ }^{3}$
(iv) How did the volume of oxygen change between 0 and 25 seconds?

Q2.
Pieces of zinc react with dilute acid to form hydrogen gas.
The graph shows how the volume of hydrogen gas produced changes with time.

(a) Describe, as fully as you can, how the volume of gas produced changes with time.
$\qquad$
$\qquad$
$\qquad$
$\qquad$

Q3.
Lithium carbonate reacts with dilute hydrochloric acid.
A group of students investigated the volume of gas produced.
This is the method used.

1. Place a known mass of lithium carbonate in a conical flask.
2. Measure $10 \mathrm{~cm}^{3}$ of dilute hydrochloric acid using a measuring cylinder.
3. Pour the acid into the conical flask.
4. Place a bung in the flask and collect the gas as shown in Figure 1.

Figure 1

(a) Figure 2 shows the measuring cylinder.

Figure 2


What volume of gas has been collected?
Volume $=$ $\qquad$ $\mathrm{cm}^{3}$
(b) The table below shows the students' results.

| Mass of lithium carbonate in $\mathbf{g}$ | Volume of gas in $\mathbf{c m}^{\mathbf{3}}$ |
| :---: | :---: |
| 0.0 | 0 |
| 0.1 | 22 |
| 0.2 | 44 |
| 0.3 | 50 |
| 0.4 | 88 |
| 0.5 | 96 |
| 0.6 | 96 |
| 0.7 | 96 |

On Figure 3:

- Plot these results on the grid.
- Complete the graph by drawing two straight lines of best fit.

Figure 3

(c) What are two possible reasons for the anomalous result?

Tick two boxes.

Too much lithium carbonate was added.

The bung was not pushed in firmly enough.



There was too much water in the trough. $\square$

The measuring cylinder was not completely over the delivery


The conical flask was too small. $\square$
(d) Describe the pattern the graph shows up to 0.4 g of lithium carbonate added.
$\qquad$
$\qquad$
$\qquad$
$\qquad$

## Lesson 3 the Collision Theory

Q1.
Phosphoric acid is made by reacting phosphate rock with sulfuric acid.
Only three of the methods shown below will increase the rate of this reaction.
Put a tick $(\checkmark)$ next to each of the three methods that will increase the rate of this reaction.

| Method | Tick <br> $(\checkmark)$ |
| :--- | :--- |
| Use a more concentrated solution of sulfuric acid |  |
| Use larger lumps of phosphate rock |  |
| Cool the mixture of phosphate rock and sulfuric acid |  |
| Grind the phosphate rock into a powder before adding the acid |  |
| Increase the temperature of the sulfuric acid |  |
| Dilute the sulfuric acid solution with water |  |

Q2.
Draw a ring around the correct word in each box.
To make the reaction take place faster:

the temperature should be \begin{tabular}{l|l|l|}
\hline higher <br>
lower <br>

\& so that the particles have \& | less |
| :---: |
| more |

\end{tabular}

the solid calcium fluoride should be \begin{tabular}{|c|c|}
\hline powder <br>
lumps <br>

\& to give a | small |
| :---: |
| big | surface area

\end{tabular}

| the sulfuric acid solution should be | dilute | to give | less | collisions |
| :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |
|  | concentrated |  | more |  |

between the particles each second.

Q3.
(e) Lithium reacts more slowly with cold water than sodium.

State two ways the reaction can be made to go faster.
$\qquad$
$\qquad$

Q4.
(c) The student wanted to make a reaction faster.

Draw a ring around the correct answer to complete each sentence.
higher.
(i) To make the reaction faster, the temperature should be
lower.
the same.

Tick $(\checkmark)$ two reasons in the table which explain why high temperatures make reactions faster.

| Reasons | Tick <br> $\checkmark$ |
| :--- | :--- |
| Particles move faster |  |
| Particles are closer together |  |
| Particles collide more often |  |
| Particles have less energy |  |

## Q5.

(c) The student wanted to make a reaction faster.

Draw a ring around the correct answer to complete each sentence.
(ii) To make the reaction faster, the hydrogen peroxide

(b) A student wants to make the reaction take place faster.

Some suggestions are given in the table.
Put ticks $(\checkmark)$ next to the two suggestions that would make the reaction take place faster.

| Suggestions | $(\checkmark)$ |
| :--- | :--- |
| Use bigger pieces of zinc. |  |
| Use a more concentrated acid. |  |
| Use zinc powder. |  |
| Decrease the temperature of the acid. |  |

Q6.
(iv) Give two reasons why the rate of the reaction increases as the temperature increases.

Tick ( $\sqrt{ }$ ) two boxes.
The particles move faster.


The particles collide with more energy.

The number of particles increases.
(c) The student was asked why an increase in temperature changes the rate of the chemical reaction. The student listed five ideas. Only three of them are correct.

Put ticks $(\checkmark)$ next to the three correct ideas.

| Ideas | Ticks <br> $(\checkmark)$ |
| :--- | :--- |
| The particles will collide more often. |  |
| The particles will be more concentrated. |  |
| The particles will move faster. |  |
| The particles will have more energy. |  |
| The particles will get bigger. |  |

Q8.
h) The more concentrated the sodium thiosulfate solution, the less time is taken for the cross to become no longer visible.

Give two reasons why.
Tick ( $\sqrt{ }$ ) two boxes.

Particles are more spread out

Particles collide more frequently
$\square$


Particles have more energy


Particles move more quickly


There are more particles in a fixed volume


## Q9

(g) The student concludes that the rate of reaction is greater when the concentration of hydrochloric acid is higher.

Why is the rate of reaction greater when the concentration of hydrochloric acid is higher?
Tick two boxes.

The particles are moving faster


The particles have more energy $\square$

The surface area of magnesium is smaller $\square$

There are more particle collisions each second


There are more particles in the same volume


## Lesson 4 Effect of Temperature on Rate

## Q1.

A student investigated the effect of temperature on the rate of a reaction.
Figure 1 shows an experiment.
Figure 1


The student:

- put $50 \mathrm{~cm}^{3}$ sodium thiosulfate solution into a conical flask
- heated the sodium thiosulfate solution to the required temperature
- put the flask on a cross drawn on a piece of paper
- added $5 \mathrm{~cm}^{3}$ dilute hydrochloric acid and started a stopclock
- stopped the stopclock when the cross could no longer be seen
- repeated the experiment at different temperatures.

The equation for the reaction is:
$\underset{\substack{\text { sodium } \\ \text { thiosulfate }}}{\mathrm{Na}_{2} \mathrm{~S}_{2} \mathrm{O}_{3}(\mathrm{aq})}+\underset{\substack{\text { hydrochloric } \\ \text { acid }}}{2 \mathrm{HCl}(\mathrm{aq})} \longrightarrow \underset{\substack{\text { sodium } \\ \text { chloride }}}{2 \mathrm{NaCl}(\mathrm{aq})}+\underset{\mathrm{H}_{2} \mathrm{O}(\mathrm{l})}{\text { water }}+\underset{\substack{\text { sulfur } \\ \text { dioxide }}}{\mathrm{SO}_{2}(\mathrm{~g})}+\underset{\mathrm{S}(\mathrm{s})}{\text { sulfur }}$
(a) Which product is a gas?
(b) Figure 2 shows the results of this experiment at five different temperatures.

The circled result point is anomalous.
Figure 2

(i) Draw a line of best fit on Figure $\mathbf{2}$ to show how the reaction time varied with reaction temperature.
(ii) Give a possible reason for the anomalous result at $40^{\circ} \mathrm{C}$.
$\qquad$
$\qquad$
(iii) The reaction at $20^{\circ} \mathrm{C}$ produced 0.32 g of sulfur in 64 seconds.

Calculate the rate of the reaction at $20^{\circ} \mathrm{C}$ using the equation:

$$
\text { Rate of reaction }=\frac{\text { mass of sulfur }}{\text { time }}
$$

$\qquad$
$\qquad$
$\qquad$
$\qquad$
Rate of reaction = $\qquad$ grams per second
(iv) Give two reasons why the rate of the reaction increases as the temperature increases.

Tick ( $\sqrt{ }$ ) two boxes.
The particles move faster.

The particles collide less often.

All the particles have the same energy.
The particles collide with more energy.

The number of particles increases.

(v) Use the correct answer from the box to complete the sentence.

| activation | collision | exothermic |
| :---: | :---: | :---: |

The minimum amount of energy particles must have to react is called
the $\qquad$

Q2.
The picture shows three glowsticks.


Photograph supplied by iStockphoto/Thinktsock
Glow sticks contain several chemicals. When a glow stick is bent the chemicals mix. A chemical reaction takes place which causes light to be given out.

A student investigated three glow sticks. One was placed in water at $5^{\circ} \mathrm{C}$, one in water at $40^{\circ} \mathrm{C}$ and one in water at $70^{\circ} \mathrm{C}$.

The results are shown in the table.

| Temperature in ${ }^{\circ} \mathbf{C}$ | Effect on glow stick |  |
| :---: | :--- | :---: |
|  | Brightness of light |  |
| 5 | dim | 7 |
| 40 | bright | 3 |
| 70 | very bright gave out light, in hours |  |

(a) How did increasing the temperature affect the brightness of the glow stick?
$\qquad$
$\qquad$
(b) How did increasing the temperature affect the time it gave out light?
$\qquad$
$\qquad$
(c) The student was asked why an increase in temperature changes the rate of the chemical reaction. The student listed five ideas. Only three of them are correct.

Put ticks $(\checkmark)$ next to the three correct ideas.

| Ideas | Ticks <br> $(\checkmark)$ |
| :--- | :--- |
| The particles will collide more often. |  |
| The particles will be more concentrated. |  |
| The particles will move faster. |  |
| The particles will have more energy. |  |
| The particles will get bigger. |  |

(d) Suggest one way the student could improve this investigation.
$\qquad$
$\qquad$

## Lesson 5 The effect of Concentration on rate

## Q1.

A student investigates the effect of concentration on the rate of reaction.
The student reacts sodium thiosulfate solution with dilute hydrochloric acid.
This produces a cloudy mixture.
(a) The cloudiness is produced by the formation of solid sulfur.

How should sulfur be written in the chemical equation for this reaction?
Tick ( $\checkmark$ ) one box.
S(aq) $\square$
S(g) $\square$
S(I) $\square$
S(s) $\square$

The diagram shows some of the apparatus the student uses.


This is the method used.

1. Measure $40 \mathrm{~cm}^{3}$ sodium thiosulfate solution into a conical flask.
2. Stand the flask on a piece of paper with a cross drawn on it.
3. Add $10 \mathrm{~cm}^{3}$ of dilute hydrochloric acid to the flask.
4. Time how long it takes the cross to become no longer visible.
5. Repeat steps 1-4 twice more.
6. Repeat steps 1-5 with sodium thiosulfate solutions of different concentrations.
(b) Which apparatus could be used to measure $10 \mathrm{~cm}^{3}$ of dilute hydrochloric acid? Tick ( $\checkmark$ ) one box.

(c) Draw one line from each type of variable to the description of the variable.

(d) The student draws a new cross for each experiment.

Suggest why this might give inaccurate results.
$\qquad$
$\qquad$
(e) The table shows the student's results for sodium thiosulfate solution with a concentration of $12 \mathrm{~g} / \mathrm{dm}^{3}$

| Time for cross to become no longer visible in s |  |  |  |
| :---: | :---: | :---: | :---: |
| Trial 1 | Trial 2 | Trial 3 | Mean |
| 43 | 78 | 41 | $\mathbf{X}$ |

Calculate value $\mathbf{X}$ in the tabble.
Do not use any anomalous results in your calculation.
$\qquad$
$\qquad$
$\qquad$
(f) The graph shows some of the student's results.


Draw a smooth curve of best fit on the graph above.
(g) Another student does the same investigation.

Both students have a similar pattern in their results.
Which word describes investigations performed by different students, which give a similar pattern of results?

Tick ( $\checkmark$ ) one box.

Accurate


Reproducible $\square$

Valid $\square$
(h) The more concentrated the sodium thiosulfate solution, the less time is taken for the cross to become no longer visible.

Give two reasons why.
Tick ( $\sqrt{ }$ ) two boxes.

Particles are more spread out


Particles collide more frequently $\square$

Particles have more energy $\square$

Particles move more quickly


There are more particles in a fixed volume $\square$

Q2.
The student investigated how changing the concentration of the hydrochloric acid affects this reaction.

Each test tube contained a different concentration of hydrochloric acid.
The diagrams show the results of this experiment.

(b) Suggest one control variable in this investigation.
$\qquad$
$\qquad$
(c) (i) Which test tube, A, B, C or D, contained the greatest concentration of hydrochloric acid?

Test tube $\qquad$
(ii) Why did you choose this test tube?
$\qquad$
$\qquad$

## Lesson 6: Required Practical

## Q1.

A student investigated how concentration affects the rate of reaction between magnesium and hydrochloric acid.

This is the method used.

1. Place hydrochloric acid in a conical flask.
2. Add magnesium powder.
3. Collect the gas produced in a gas syringe.
4. Measure the volume of gas every 40 seconds for 160 seconds.
5. Repeat steps $1-4$ three more times.
6. Repeat steps 1-5 with hydrochloric acid of a higher concentration.
(a) Figure 1 shows a gas syringe.

Figure 1


What is the volume of gas in the syringe?

> Volume =
$\qquad$ $\mathrm{cm}^{3}$
(b) Which two variables should the student keep the same to make the investigation a fair test?

Tick two boxes.

Concentration of hydrochloric acid


Mass of magnesium powder


Temperature of hydrochloric acid


Time for reaction to end


Volume of gas collected $\square$

The table below shows the student's results for the experiment with hydrochloric acid of a lower concentration.

| Time in <br> seconds | Volume of gas collected in cm $^{\mathbf{3}}$ |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | Test 1 | Test 2 | Test 3 | Test 4 | Mean |
| 0 | 0 | 0 | 0 | 0 | 0 |
| 40 | 46 | 30 | 47 | 49 | $\mathbf{X}$ |
| 80 | 78 | 83 | 83 | 82 | 82 |
| 120 | 98 | 94 | 96 | 95 | 96 |
| 160 | 100 | 100 | 100 | 100 | 100 |

(c) Calculate mean value $\mathbf{X}$ in the table above.

Do not include the anomalous result in your calculation.
Give your answer to 2 significant figures.
$\qquad$
$\qquad$
$\qquad$

$$
\mathbf{X}=\ldots \mathrm{cm}^{3}
$$

(d) Plot the data from the table above on Figure 2.

You should include your answer to Question (c).
You do need to draw a line of best fit.

Figure 2


Figure 3 shows results of the experiment with the hydrochloric acid of a higher concentration.
Figure 3

(e) Calculate the mean rate of reaction between 0 and 50 seconds.

Use Figure 3 and the equation:

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

$\qquad$
$\qquad$
$\qquad$
Mean rate of reaction = $\qquad$ cm $3 / \mathrm{s}$
(f) Describe how the rate of reaction changes between 0 and 160 seconds.

Use Figure 3.
$\qquad$
$\qquad$
$\qquad$
$\qquad$
$\qquad$
$\qquad$
(g) The student concludes that the rate of reaction is greater when the concentration of hydrochloric acid is higher.

Why is the rate of reaction greater when the concentration of hydrochloric acid is higher?
Tick two boxes.

The particles are moving faster $\square$

The particles have more energy


The surface area of magnesium is smaller


There are more particle collisions each second


There are more particles in the same volume


## Lesson 7 The effect of Pressure on Rate

Q1.
Label the correct diagram with 'High pressure' and 'Low pressure'


Q2.
(a) Nitrogen and hydrogen are passed over iron to produce ammonia in the Haber Process.

Balance the equation for the reaction.

$$
\mathrm{N}_{2}+\mathrm{H}_{2} \quad \rightarrow \quad \mathrm{NH}_{3}
$$

(c) The figure below shows how the percentage yield of ammonia changes with pressure.


Describe the trend shown in the figure above.
$\qquad$
$\qquad$
(d) Use the figure above to determine the difference in percentage yield of ammonia at 150 atmospheres pressure and 250 atmospheres pressure.
$\qquad$ \%

Q3.
A Give an example of a reaction where high pressure is used to speed up the rate of reaction:

B Some unusual reactions happen high up in the Earth's atmosphere, such as reactions which form the ozone in the ozone layer, which happen at a height of about 40 km . The pressure of the gases in the atmosphere at this height is very low. What can you predict about the rate of the reaction which forms ozone?
C. The reaction between sulfur dioxide and oxygen to form sulfuric acid is an important industrial reaction. It happens at high pressure, which speeds up the reaction. Use ideas about collisions to explain why the high pressure speeds up the reaction:

## Lesson 8 The effect of Surface area on Rate

## Q1.

(b) A student wants to make the reaction take place faster.

Some suggestions are given in the table.
Put ticks $(\checkmark)$ next to the two suggestions that would make the reaction take place faster.

| Suggestions | $\left(\vee^{\prime}\right)$ |
| :--- | :--- |
| Use bigger pieces of zinc. |  |
| Use a more concentrated acid. |  |
| Use zinc powder. |  |
| Decrease the temperature of the acid. |  |

Q2.
(b) Very small amounts of cerium oxide nanoparticles can be added to diesel fuel.
(i) Draw a ring around the correct answer to complete the sentence.

Only a very small amount of cerium oxide nanoparticles is needed because

the nanoparticles \begin{tabular}{l|l|}

\cline { 2 - 3 } \& | are elements. |
| :--- |
| are very reactive. |
| have a high surface area to volume ratio. | <br>

\hline
\end{tabular}

(d) Modern catalytic converters contain nanosized particles of catalyst. Less catalyst is needed when nanosized catalyst particles are used.
(i) Complete the sentence.

The size of nanosized particles is $\qquad$ than normal sized particles.

Q3.
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 10.0 g of marble chips into the flask.
2. Add $50 \mathrm{~cm}^{3}$ of hydrochloric acid and start a timer.
3. Record the mass lost from the flask every 10 seconds.
4. Repeat steps 1 to 3 with different sizes of marble chips.

Figure 1 shows the apparatus.
Figure 1

(a) Draw one line from each type of variable to the correct example of the variable.

Type of variable
Example of variable

Mass lost from flask


Size of marble chips
Control

Time taken

Volume of acid
(b) The equation for the reaction is:

$$
\mathrm{CaCO}_{3}(\mathrm{~s})+2 \mathrm{HCl}(\mathrm{aq}) \mathrm{CaCl}_{2}(\mathrm{aq})+\mathrm{H}_{2} \mathrm{O}(\mathrm{I})+\mathrm{CO}_{2}(\mathrm{~g})
$$

Name the three products.

1. $\qquad$
2. $\qquad$
3. $\qquad$
(c) Another student suggests putting some cotton wool in the top of the flask.

Suggest why this improves the investigation.
$\qquad$
$\qquad$
(d) The reaction produces 1.6 g of gas in 30 seconds.

Calculate the mean rate of the reaction in the first 30 seconds.
Use the equation:

$$
\text { mean rate of reaction }=\frac{\text { mass of product produced in grams }}{\text { time in seconds }}
$$

$\qquad$
$\qquad$
Mean rate of reaction = $\qquad$
(e) What is the unit for the mean rate of reaction calculated in part (d)?

Tick one box.
g

g/s $\square$
s $\square$
s/g $\square$
(f) The table below shows the student's results.

| Time in seconds | Mass of gas produced in g |
| :--- | :---: |
| 0 | 0.0 |
| 10 | 0.8 |
| 20 | 0.6 |
| 30 | 1.6 |
| 40 | 1.8 |
| 50 | 2.0 |
| 60 | 2.0 |

Plot the data from the table above on Figure 2
Draw a line of best fit.
Figure 2

(g) Figure 3 shows a large marble chip and eight small marble chips.

Figure 3


Large marble chip


Eight small marble chips

The large marble chip has the same total volume as the eight small marble chips, but a different surface area.

Why do the eight small marble chips react faster than the large marble chip?

Tick one box.

The eight small marble chips have a larger surface area, so less frequent collisions.


The eight small marble chips have a larger surface area, so more frequent collisions.


The eight small marble chips have a smaller surface area, so less frequent collisions.


The eight small marble chips have a smaller surface area, so more frequent collisions. $\square$

Q4.
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 $50 \mathrm{~cm}^{3}$ 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.
$\mathrm{CaCO}_{3}+$ $\qquad$ $\mathrm{HCl} \rightarrow$ $\qquad$

Figure 2 shows the student's results.
Figure 2

(b) Describe the trend shown in Figure 2

Use values in your answer.
$\qquad$
$\qquad$
$\qquad$
$\qquad$
$\qquad$
$\qquad$
(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.
$\qquad$
$\qquad$
$\qquad$
$\qquad$
(d) Give the units for the rate of this reaction.
$\qquad$

The table below shows the results of the investigation.

| Relative size of <br> marble chips | Volume of gas produced in cm |  |  |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
|  | after given time in seconds |  |  |  |  |  |
|  | $\mathbf{1 0 ~ s}$ | $\mathbf{2 0} \mathbf{~ s}$ | $\mathbf{3 0} \mathbf{s}$ | $\mathbf{4 0} \mathbf{~ s}$ | $\mathbf{5 0} \mathbf{~ s}$ | $\mathbf{6 0} \mathbf{~ s}$ |
| 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.
$\qquad$
$\qquad$
(f) Suggest why all three sizes of marble chips produce a maximum volume of $60 \mathrm{~cm}^{3}$ of gas.
$\qquad$
$\qquad$
(g) Figure 3 shows eight small cubes, each $1 \mathrm{~cm} \times 1 \mathrm{~cm} \times 1 \mathrm{~cm}$, and one large cube, $2 \mathrm{~cm} \times 2 \mathrm{~cm} \times 2 \mathrm{~cm}$

Figure 3


Total volume of small cubes $=8 \mathrm{~cm}^{3}$
Total surface area of small cubes $=48 \mathrm{~cm}^{2}$
Calculate the surface area of the large cube.
$\qquad$
$\qquad$
Surface area of the large cube $=$ $\qquad$ $\mathrm{cm}^{2}$
(h) Explain why the size of the marble chips affects the rate of the reaction.

Give your answer in terms of 'collision theory'.
$\qquad$
$\qquad$
$\qquad$
$\qquad$
$\qquad$

## Lesson 9 Catalysts

## Q1.

What is the name given to substances that speed up the chemical reaction but which are not used up during the reaction?
c) The table lists some statements about catalysts. Only two statements are correct.

Tick $(\checkmark)$ the two correct statements.

| Statement | Tick $(\checkmark)$ |
| :--- | :--- |
| A catalyst can speed up a chemical reaction. |  |
| A catalyst is used up in a chemical reaction. |  |
| Different reactions need different catalysts. |  |
| A catalyst does not change the rate of a chemical <br> reaction. |  |

Q2.
Hydrogen peroxide decomposes slowly to give water and oxygen.
The reaction is exothermic.

$$
2 \mathrm{H}_{2} \mathrm{O}_{2} \rightarrow \quad 2 \mathrm{H}_{2} \mathrm{O}+\quad \mathrm{O}_{2}
$$

(a) In an exothermic reaction, energy is given out.

Draw a ring around the correct answer to complete the sentence.

In an exothermic reaction, the temperature |  | goes down. |
| :--- | :--- |
| goes up. |  |
| stays the same. |  |

(b) The energy level diagram for this reaction is shown below.


The energy changes, $\mathbf{A}, \mathbf{B}$ and $\mathbf{C}$, are shown on the diagram.
Use the diagram to help you answer these questions.
(i) Which energy change, $\mathbf{A}, \mathbf{B}$ or $\mathbf{C}$, is the activation energy?

(ii) Which energy change, $\mathbf{A}, \mathbf{B}$ or $\mathbf{C}$, shows that this reaction is exothermic? $\square$
(iii) Hydrogen peroxide decomposes quickly when a small amount of manganese(IV) oxide is added.

Draw a ring around the correct answer to complete each sentence.
Hydrogen peroxide decomposes quickly because

manganese(IV) oxide is | a catalyst. |
| :--- | :--- |
| an |
| element. |
| a solid. |.

The manganese(IV) oxide has lowered the | activation energy. |
| :--- | :--- |
| boiling point. |
| temperature. |.

Q3.
(ii) Explain how a catalyst increases the rate of a reaction.
$\qquad$
$\qquad$
$\qquad$
$\qquad$
$\qquad$

Q4.
Hydrogen peroxide $\left(\mathrm{H}_{2} \mathrm{O}_{2}\right)$ contains the same elements as water $\left(\mathrm{H}_{2} \mathrm{O}\right)$.
(a) Name the hazard symbol shown by using the correct word from the box.

| corrosive | flammable | oxidising | toxic |
| :--- | :--- | :--- | :--- |

(b) Hydrogen peroxide decomposes in the presence of a catalyst.
$2 \mathrm{H}_{2} \mathrm{O}_{2}(\mathrm{aq}) \rightarrow 2 \mathrm{H}_{2} \mathrm{O}(\mathrm{I})+\mathrm{O}_{2}(\mathrm{~g})$
(i) Complete the word equation for this chemical reaction.
hydrogen peroxide $\rightarrow$ water + $\qquad$
(ii) What does a catalyst do to a chemical reaction?
$\qquad$
$\qquad$

## Lesson 10 Reversible Reactions

Q1.
This question is about copper sulfate.
Blue copper sulfate turns white when it is heated.
The word equation for the reaction is:

$$
\begin{aligned}
& \text { hydrated copper sulfate } \rightleftharpoons \text { anhydrous copper sulfate }+ \text { water } \\
& \text { blue } \quad \text { white }
\end{aligned}
$$

(a) What name is given to hydrated copper sulfate in this reaction?

Tick one box.


Element


Product


Reactant

(b) What does the symbol $\rightleftharpoons$ mean?

Tick one box.

Endothermic $\square$

Exothermic


Reversible


Polymerisation

(c) Complete the sentence.

The colour change when the water is added to anhydrous copper sulfate is white to $\qquad$ .

A student heats 2.5 g of hydrate copper sulfate in a test tube.
0.9 g of water is given off.

The remaining solid is anhydrous copper sulfate.
(d) Calculate the mass of anhydrous copper sulfate produced.
$\qquad$
$\qquad$
Mass of anhydrous copper sulfate $=$ $\qquad$
(e) Calculate the percentage of water contained in 2.5 g of hydrated copper sulfate.
$\qquad$
$\qquad$
$\qquad$
Percentage of water $=$ $\qquad$ \%
(f) Draw one line from each compound to the formula for the compound.

Compound
Formula for the compound


Copper sulfate $\square$
$\square$


| $\mathrm{H}_{2} \mathrm{SO}_{4}$ |
| :---: |

Q2.
The Haber Process is used to produce ammonia from nitrogen and hydrogen.
The equation for the reaction is:

$$
\mathrm{N}_{2}+3 \mathrm{H}_{2} \rightleftharpoons 2 \mathrm{NH}_{3}
$$

(a) An ammonia molecule has the formula $\mathrm{NH}_{3}$

How many atoms are there in one molecule of ammonia?
Tick ( $\checkmark$ ) one box.
2

3

4

6

(b) What does the symbol $\rightleftharpoons$ mean?
$\qquad$

Q3.
The word equation shows the reaction between anhydrous cobalt chloride and water.
anhydrous cobalt chloride
$+$
water
$\rightleftharpoons$
hydrated cobalt chloride (pink)
(a) Name the type of reaction shown by the sign $\rightleftharpoons$
$\qquad$
(b) When the student added water to anhydrous cobalt chloride what happened?
$\qquad$
(c) A student measured the temperature rise when anhydrous cobalt chloride was added to water.

The student's results are shown in the table below.

|  | Trial 1 | Trial 2 | Trial 3 |
| :--- | :---: | :---: | :---: |
| Temperature <br> rise in ${ }^{\circ} \mathrm{C}$ | 8.5 | 8.2 | 8.2 |

Calculate the mean temperature rise.

$$
\text { Temperature }=\ldots
$$

(d) When water was added to anhydrous cobalt chloride an exothermic reaction took place.

Name the type of reaction when hydrated cobalt chloride reacts to form anhydrous cobalt chloride and water.
$\qquad$
$\qquad$

Q4.
Stage smoke is used for special effects at pop concerts.


By Sam Cockman [CC BY 2.0], via Flickr
Ammonium chloride can be used to make stage smoke.
Ammonium chloride is a white solid.
When heated, ammonium chloride produces white smoke which can be blown onto the stage.
The equation shows what happens when ammonium chloride is heated and cooled.

| $\mathrm{NH}_{4} \mathrm{Cl}(\mathrm{s})$ | heated $\qquad$ cooled | $\mathrm{NH}_{3}(\mathrm{~g})$ | + | $\mathrm{HCl}(\mathrm{g})$ |
| :---: | :---: | :---: | :---: | :---: |
| ammonium chloride (white) |  | ammonia (colourless) |  | hydrogen chloride (colourless) |

(a) The sentences explain how the smoke is made.

Draw a ring around the correct answer in each box to complete each sentence.
Use the information and the equation to help you.

When heated, ammonium chloride makes two colourless $\quad$| solids. |
| :--- |
| liquids. |
| gases. |

These are blown into the air where they cool and make a

| colourless <br> black <br> white | solid <br> liquid <br> gas |
| :--- | :--- |
|  |  |

which is | ammonia. |
| :--- |
| ammonium chloride. |
| hydrogen chloride. |

(b) Complete the sentence.

The symbol $\rightleftharpoons$ means that the reaction is $\qquad$

Q5.
The diagram shows how anhydrous copper sulfate can be used to test for water.


(a) What colour change will you see when water is added to the $\mathrm{CuSO}_{4}$ ?

Colour changes from $\qquad$ to $\qquad$
(b) Draw a ring around the meaning of the symbol $\rightleftharpoons$

