Title – C6 Rates of reaction revision Monday, 25 September 2023

Do it now:

What is potable water?	What are the two methods of desalination?	What is sustainable development?
Water that is **safe to drink** (not pure water!)	1. Distillation 2. Reverse osmosis	Development that meets the needs of current generations, without compromising the needs of future generations.
What are the four main steps of sewage treatment?	What are the three methods of sterilising fresh water to obtain potable water?	Describe the practical method for determining the mass of dissolved solids in a sample of water.
1. Screening 2. Sedimentation **3. Anaerobic** digestion of sludge **4. Aerobic** digestion of effluent	1. Ozone 2. Chlorine 3. UV light	1. Measure the mass of an empty evaporating basin. 2. Fill the basin with water. 3. Evaporate all of the water using a Bunsen burner. 4. Reweigh the empty evaporating dish.

DECODE IT NOW

Word:

Rate (tier 2)

Define it:

The speed at which something happens or changes.

Write a sentence of your own that uses the word **rate.**

Digging Deeper:

Rate can also mean to judge the value or character of something e.g. He is rated as one of the best footballers in the world.

Link it (similar words):

Speed, pace, time

Write your own definition of the word **rate.**

Which subjects or topics will this word be relevant to?

Deconstruct it (root word):

From Latin word '*rata*' meaning '*proportional share*'.

Use it:

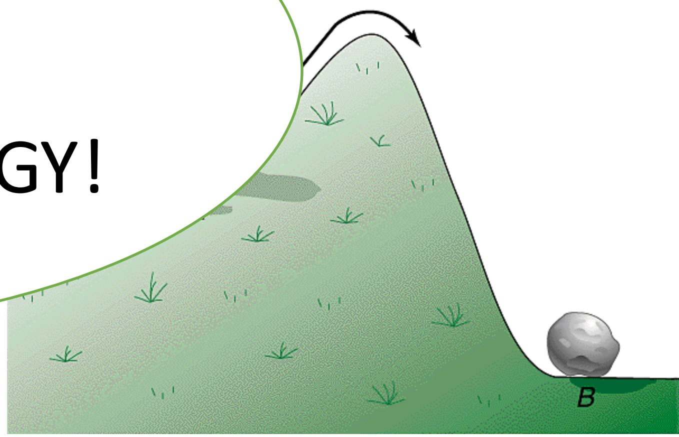
The rate of reaction increases as temperature increases

Describe what is needed for a successful reaction

LET'S RECAP...

1. Reactants

2. ACTIVATION ENERGY!



Challenge: How could you measure how quickly a reaction is happening?

Describe what is needed for a successful reaction

$$A + B \rightarrow C + D$$

Chemicals going in
= REACTANTS

Chemicals being made
= PRODUCTS

Chemical reactions can occur only when reacting particles collide with each other with sufficient energy.

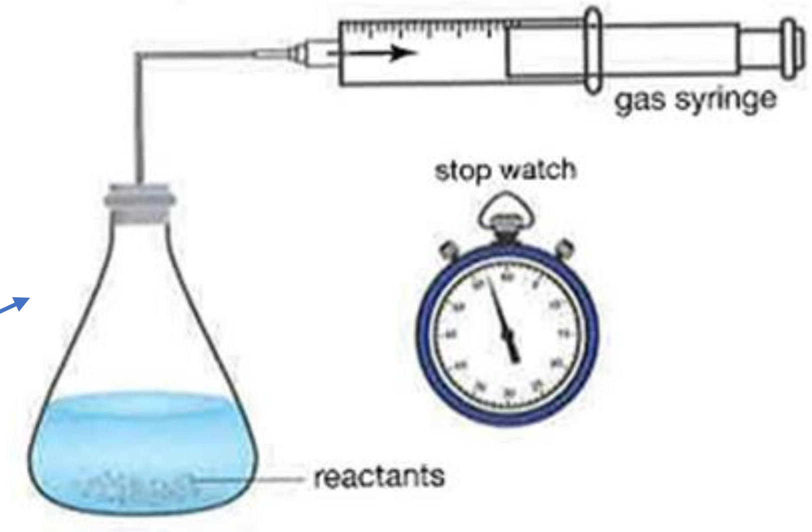
The minimum amount of energy that particles must have to react is called the **activation energy**.

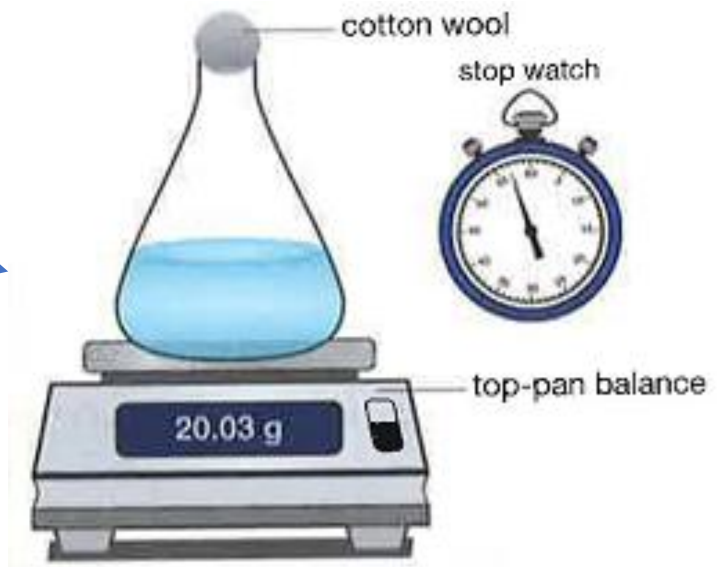
Explain how to measure the rate of a reaction.

The rate of a reaction is '*the time taken for a **product** to form*'

OR

'*the time taken for **reactants** to be used up*'





Explain how to measure the rate of a reaction.

LEARN THESE!

$$\text{Mean rate of reaction } \mathbf{(g/s)} = \frac{\text{mass of reactant used } \mathbf{(g)}}{\text{time taken } \mathbf{(s)}}$$

$$\text{Mean rate of reaction } \mathbf{(cm^3/s)} = \frac{\text{volume of product formed } \mathbf{(cm^3)}}{\text{time taken } \mathbf{(s)}}$$

Q1. A lump of magnesium is added to hydrochloric acid in a beaker. After 30 seconds, the magnesium had decreased in mass by 45g. *Calculate the mean rate of reaction and give the units.*

45 grams ÷ 30 seconds

= 1.5 g/s

Q2. 5 grams of lithium was added to 100 cm^3 of water in a beaker. After 30 seconds, 81cm^3 of gas had been produced. *Calculate the mean rate of reaction and give the units.*

81cm^3 ÷ 30 seconds

= 2.7 cm^3/s

Q3. Magnesium carbonate was added to sulphuric acid. After 3 minutes, 60cm^3 of gas had been produced. *Calculate the mean rate of reaction and give the units.*

3 minutes = 120 seconds
60cm^3 ÷ 120 seconds

= 0.5 cm^3/s

Q4. A student reacts magnesium ribbon in hydrochloric acid. 0.3kg of magnesium is used up in the first 50 seconds of the reaction. *Calculate the mean rate of reaction and give the units.*

0.3kg = 300 grams
300 g ÷ 50 seconds

= 6 g/s

Q5. The table below shows information about a chemical reaction. Calculate the <u>difference</u> in the rate of reaction between the **0-20 seconds** and **100-120 seconds**.

Time in seconds	Volume of gas in cm^2
0	0
20	24
40	44
60	59
80	70
100	76
120	79

Between 0-20:
24cm^3 ÷ 20 secs = 1.2 cm^3/s

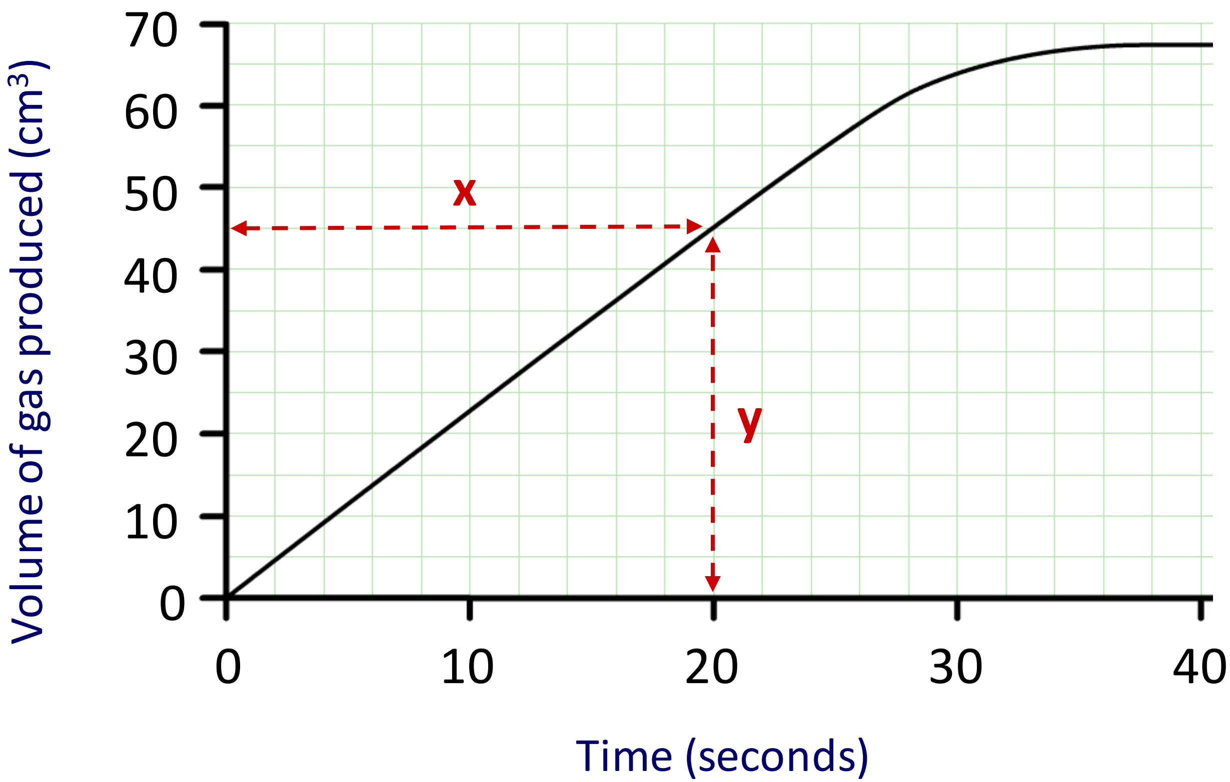
Between 100-120:
3cm^3 ÷ 20 secs = 0.15 cm^3/s

1.2 cm^3/s – 0.15 cm^3/s
Difference = 1.05 cm^3/s

Graphs can also be used to calculate rates of reaction:

This is the same as maths!

The rate of reaction = gradient of the line = $\frac{change\ in\ y}{change\ in\ x}$

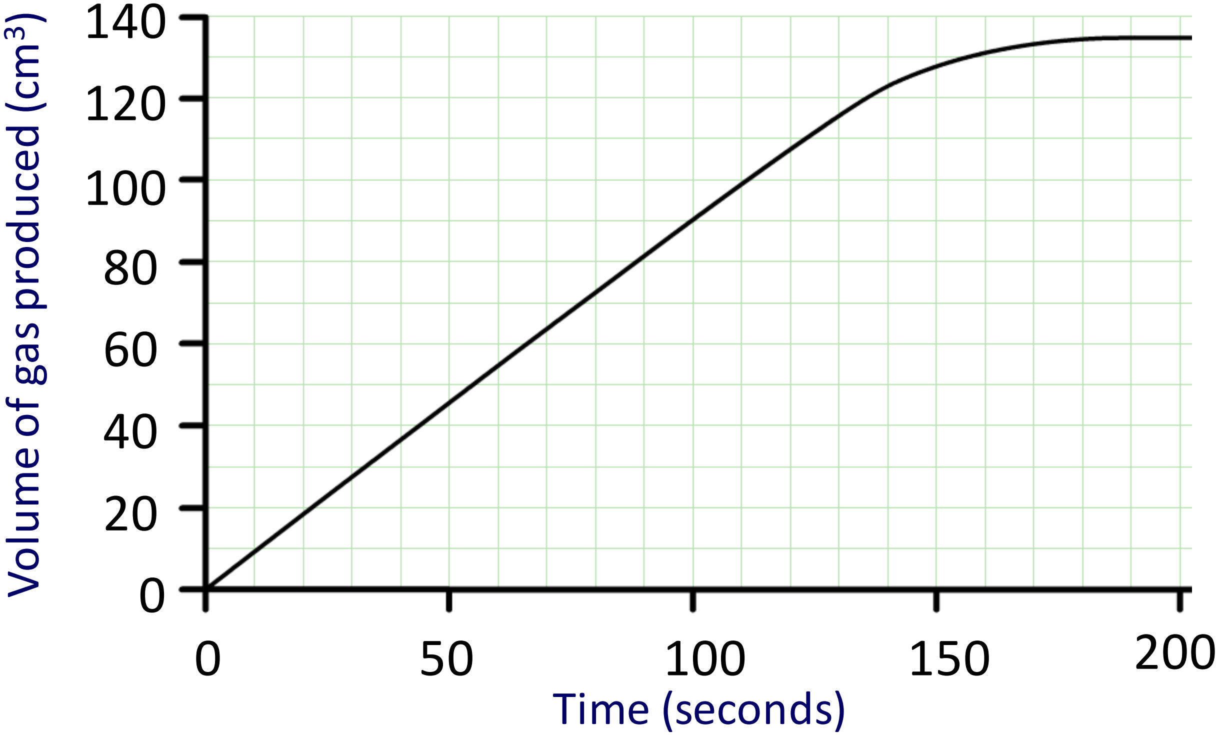


rate = gradient

= $\frac{y}{x}$

= $45cm^3$ / 20s

= **2.25 cm^3/s**



1. Calculate the mean rate of the reaction over the first 50 seconds.

rate = gradient

$= \frac{\mathbf{y}}{\mathbf{x}}$

$= 45cm^3 / 50s$

$=$ **$0.9\ cm^3/s$**

2. Calculate the mean rate of the reaction over the first 180 seconds.

rate = gradient

$= \frac{\mathbf{y}}{\mathbf{x}}$

$= 135cm^3 / 180s$

$= 0.75$ **cm^3/s**

Challenge: At what time did the reaction stop?

180 seconds

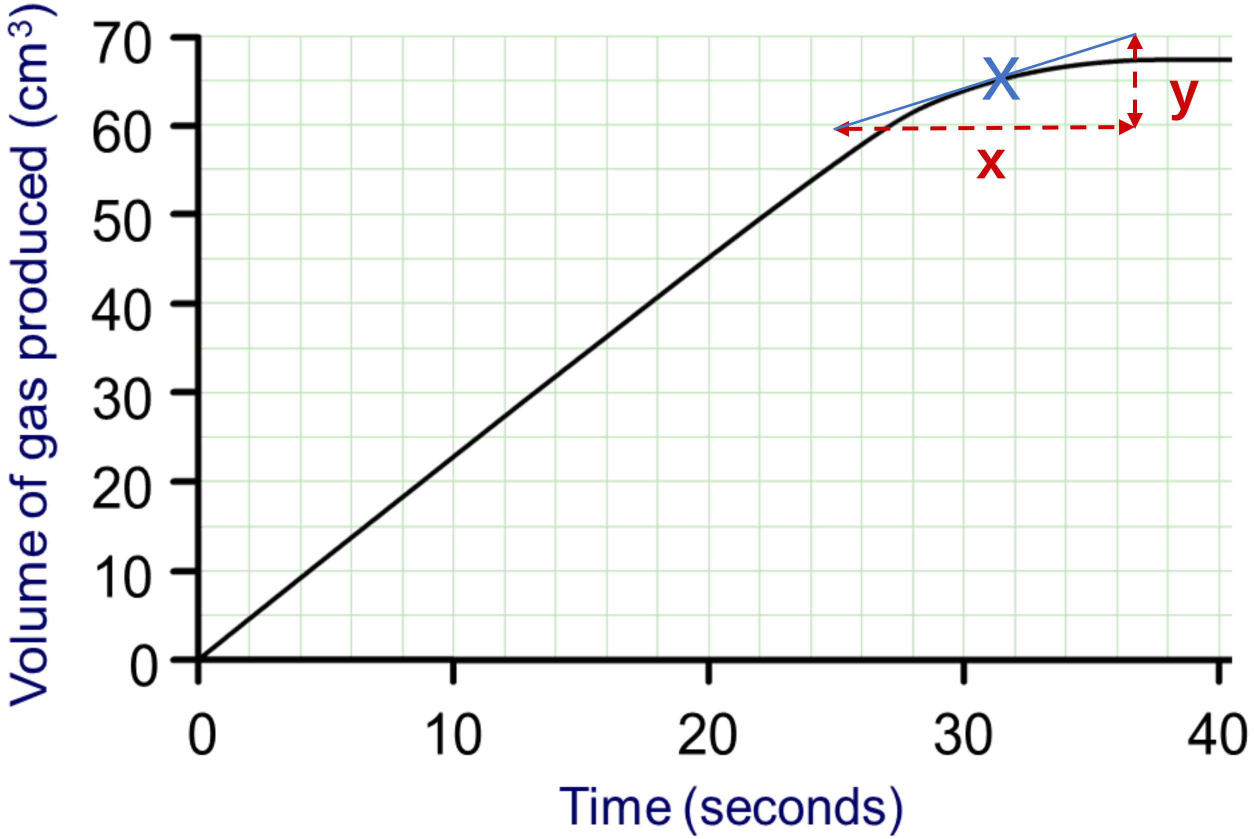
Super challenge: Why did the rate of reaction get slower as the reaction progressed?

Particles of the reactants are eventually used up

You may be asked to calculate the rate of reaction **on the curve of a graph**:

HT ONLY

1. Draw a **tangent** to the curve for the required time.
2. Construct a **right angled triangle** using the tangent.
3. Calculate the **gradient** of the tangent.



rate = gradient of tangent

$$= \frac{y}{x}$$

= $10 cm^3$ / 12s

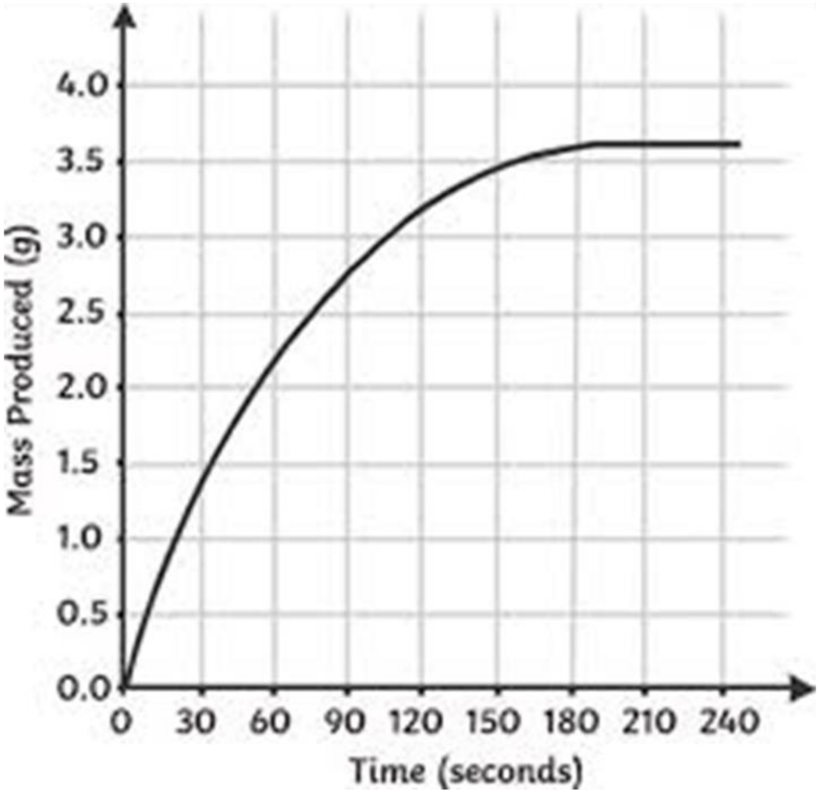
= **0.83 cm^3/s**

We are going to use the visualiser to calculate the rate of reaction at 30, 90 and 120 seconds.

We will calculate the rate at 30 seconds together, then you will attempt the other two questions by yourselves…

Get out a pencil and ruler!

HT ONLY

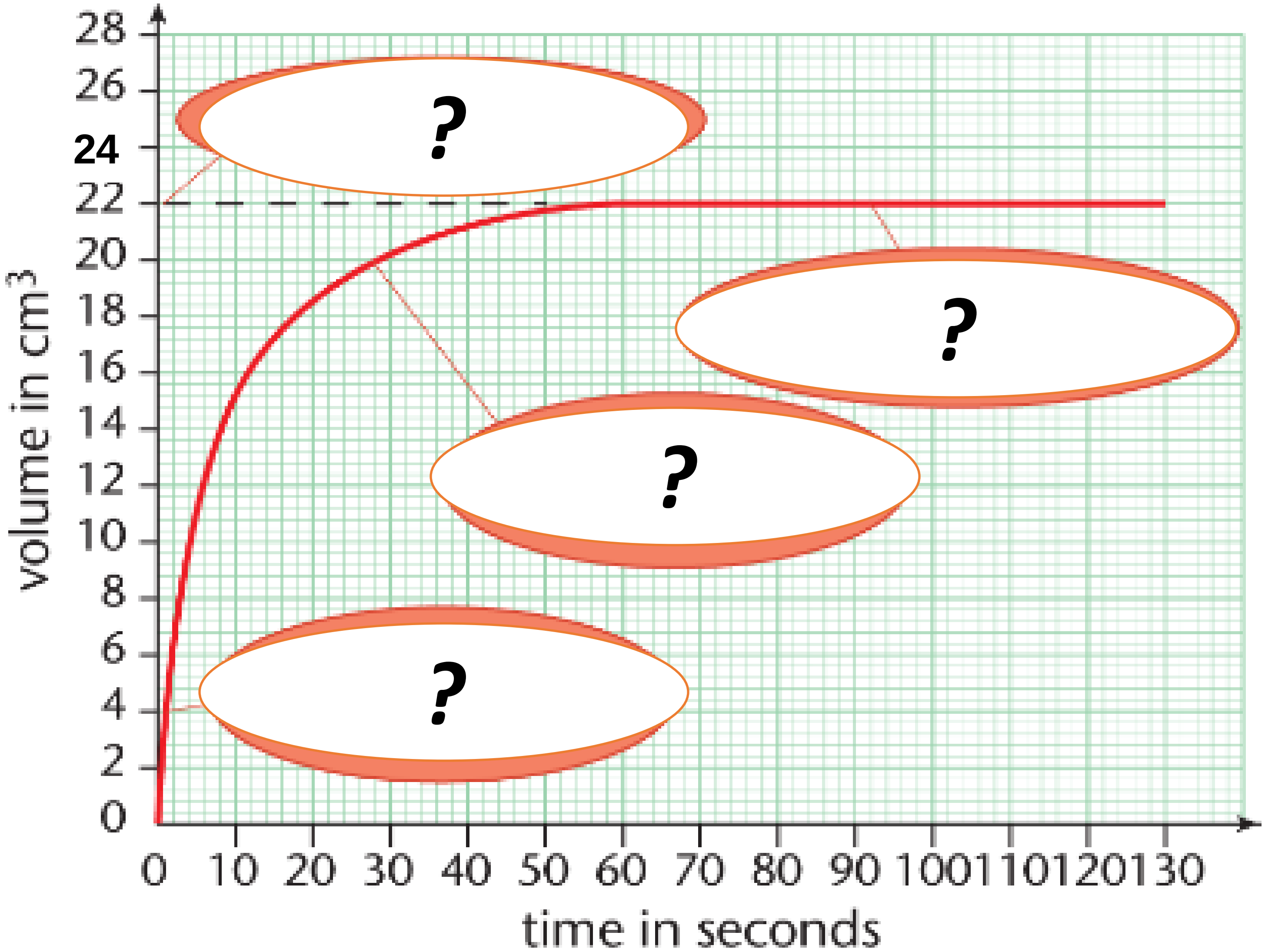


Calculate the rate of reaction at:

a. 30 seconds
b. 90 seconds
c. 120 seconds

Interpret data from graphs to describe the progress of a reaction.

What is happening at each stage of this reaction?



Identify factors which can affect the rate of reaction.

1. The **amount of energy** that the particles have when they collide.
2. **How often** the particles collide

MORE FREQUENT SUCCESSFUL COLLISIONS = A FASTER RATE OF REACTION

Challenge: Explain why sugar dissolves more quickly in a hot cup of tea compared to a cold cup of tea.

Identify factors which can affect the rate of reaction.

There are **5 factors** which affect the rates of chemical reactions:

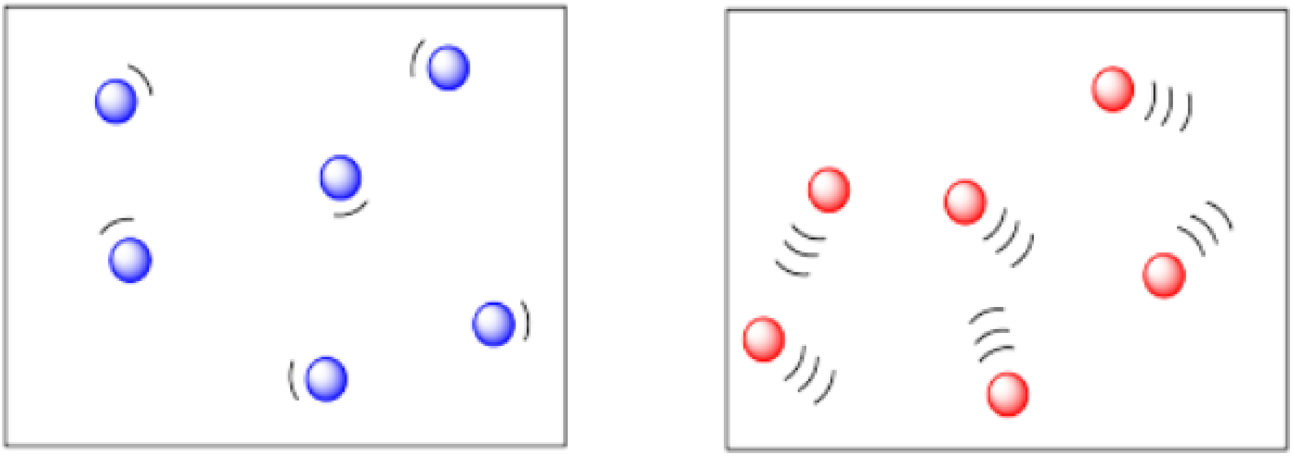
- The temperature of a reaction
- The concentrations of reactants in solution
- The pressure of reacting gases
- The surface area of solid reactants
- The presence of a catalyst

*You need to be able to **describe** and **explain** how each of these factors affects the rate of reaction.*

Describe how these factors affect the number of collisions in a reaction.

1. *Temperature*

COLD



HOT

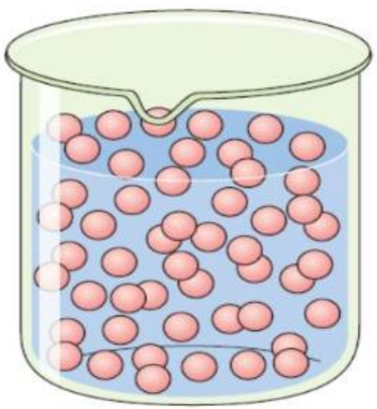
Increasing the temperature gives particles more kinetic energy, so they move around faster.

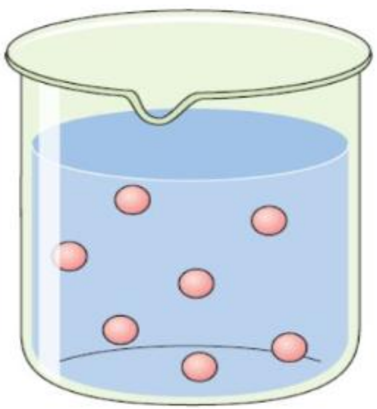
This causes more frequent successful collisions which means a faster rate of reaction.

Describe how these factors affect the number of collisions in a reaction.

2. Concentration

Which solution is the most concentrated?
What does this mean in terms of particles?





CONCENTRATED *=*
more particles in a certain volume

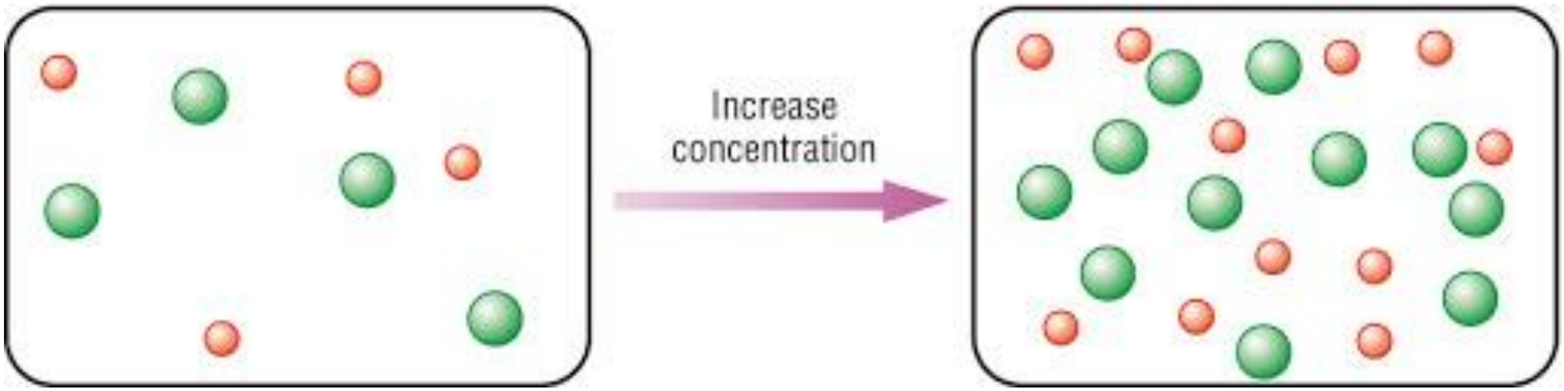
DILUTE *=*
fewer particles in a certain volume

Describe how these factors affect the number of collisions in a reaction.

2. Concentration

Increasing the concentration means there are more particles present that are closer together.

This causes more frequent successful collisions which means a faster rate of reaction.



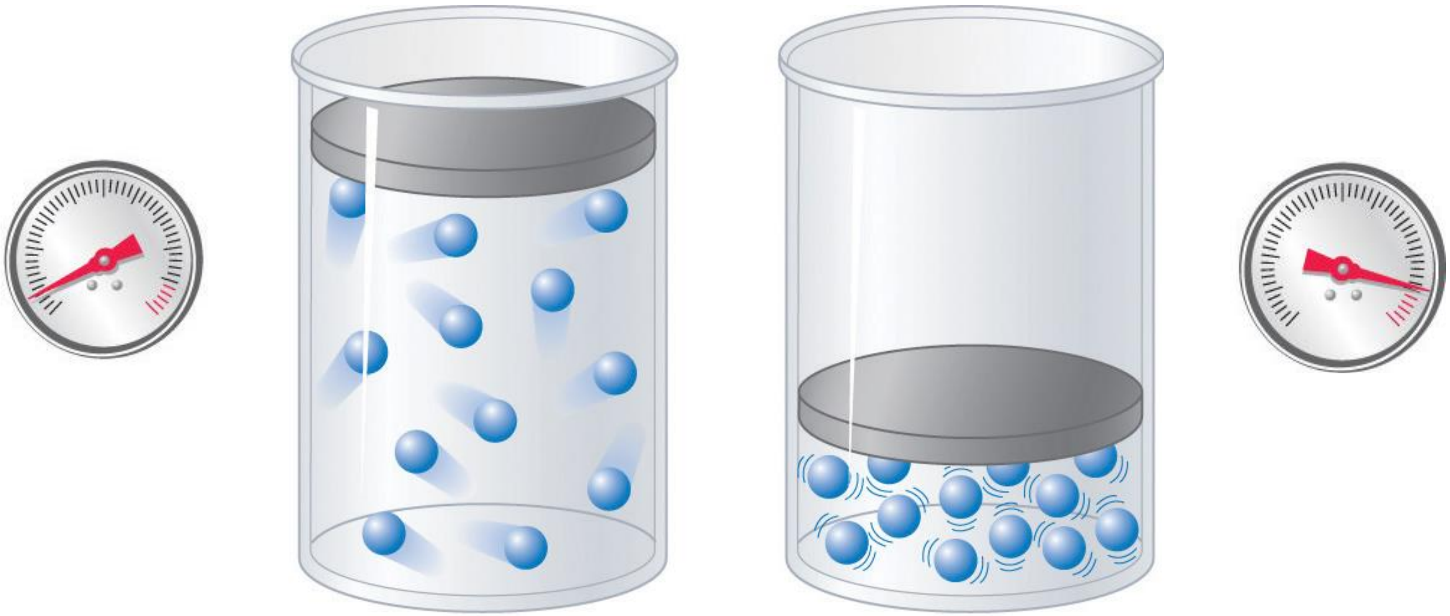
DILUTE *= fewer particles in a certain volume*

CONCENTRATED *= more particles in a certain volume*

Describe how these factors affect the number of collisions in a reaction.

3. Pressure (gases only)

Which picture shows the highest pressure?
What does this mean in terms of particles?



***LOW PRESSURE** = fewer particles per unit volume*

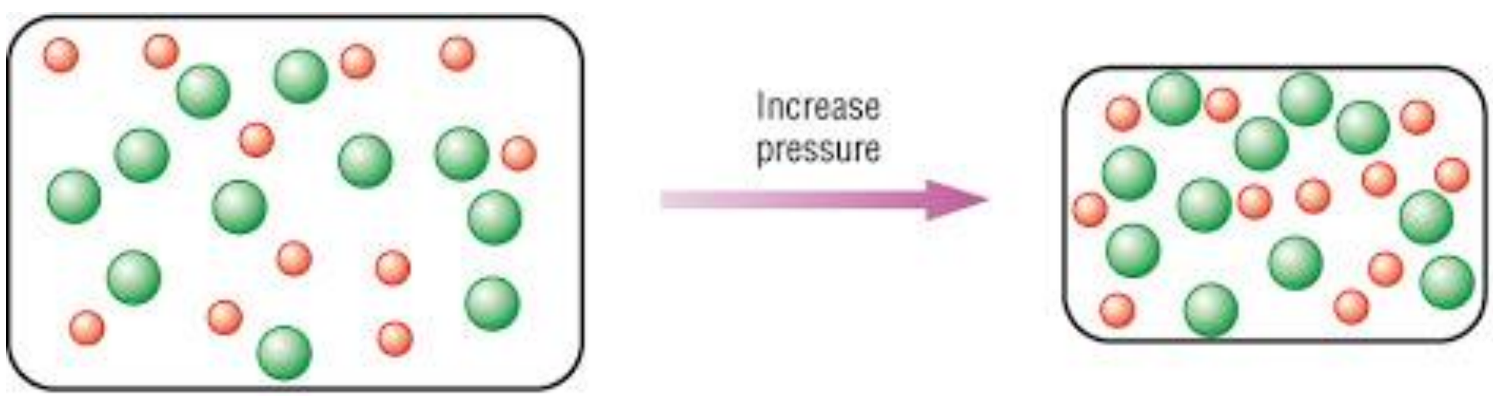
***HIGH PRESSURE** = more particles per unit volume*

Describe how these factors affect the number of collisions in a reaction.

3. Pressure (gases only)

Increasing the pressure means there are more particles in a smaller volume.

This causes more frequent successful collisions which means a faster rate of reaction.



***LOW PRESSURE** = fewer particles per unit volume*

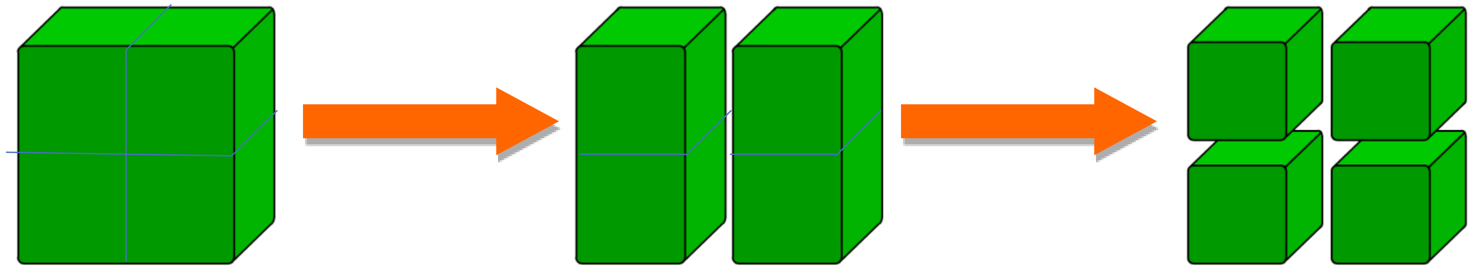
***HIGH PRESSURE** = more particles per unit volume*

Describe how these factors affect the number of collisions in a reaction.

4. Surface area

If the solid is split into pieces, the surface area increases.

LOW SURFACE AREA ***HIGH SURFACE AREA***

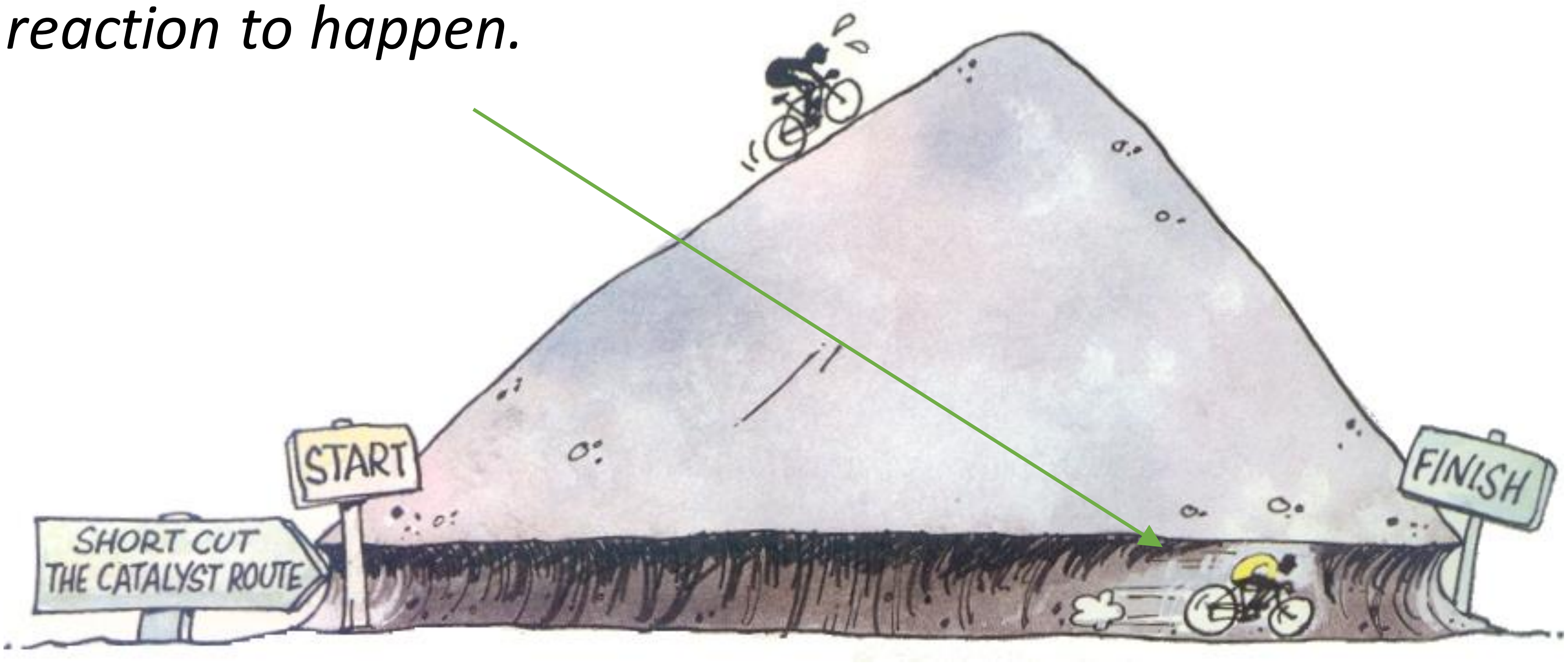


Increasing the surface area means there are more surfaces exposed to the other reactants.

This causes more frequent successful collisions which means a faster rate of reaction.

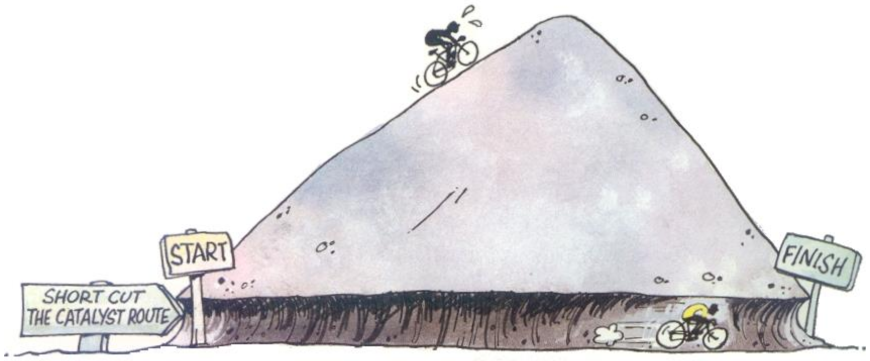
Catalysts

With a catalyst, less energy is needed for a reaction to happen.



Describe how catalysts affect the rate of reaction

Key definition!



Catalysts **speed up** the rate of a reaction.

They provide an **alternative reaction pathway** with a **lower activation energy**.

They are **not used up** in a reaction.

Catalysts; quicker, not more!

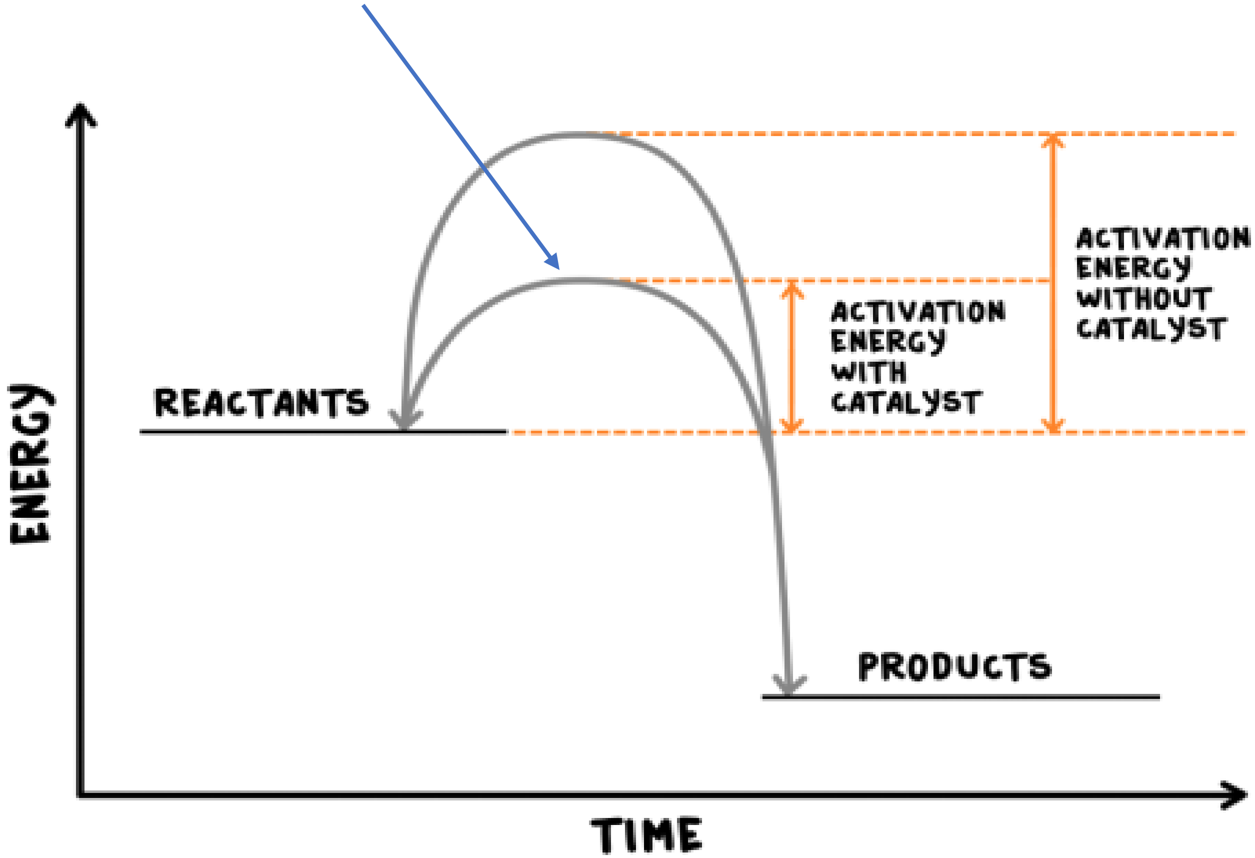
In your exams, it is very important to say that the **same amount of product** is made, but it just **takes less time** to make that product.

e.g. A reaction between magnesium and hydrochloric acid makes $24cm^3$ of hydrogen gas.

If a catalyst is added, $24cm^3$ of hydrogen gas is still made, just quicker.

Explain the new activation energy pathway a catalyst takes.

As shown on a reaction profile (from unit 5!), the ***activation energy is lower when a catalyst is used = more collisions are successful!***

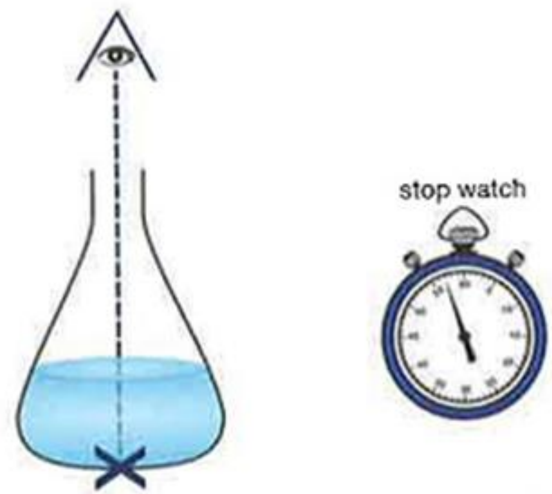


Challenge – List some examples of catalysts.

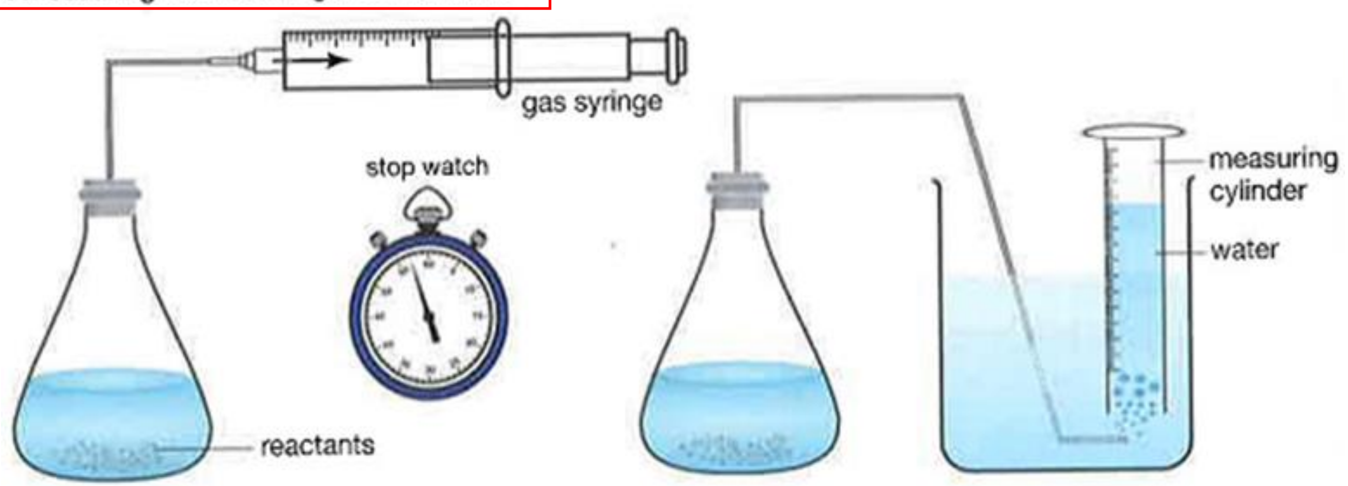
REQUIRED PRACTICAL: Investigating the effect of concentration/temperature/surface area on the rate of a reaction.

There are ***2 methods*** that you will need to know for your exams:

Timing how long it takes for cross to disappear

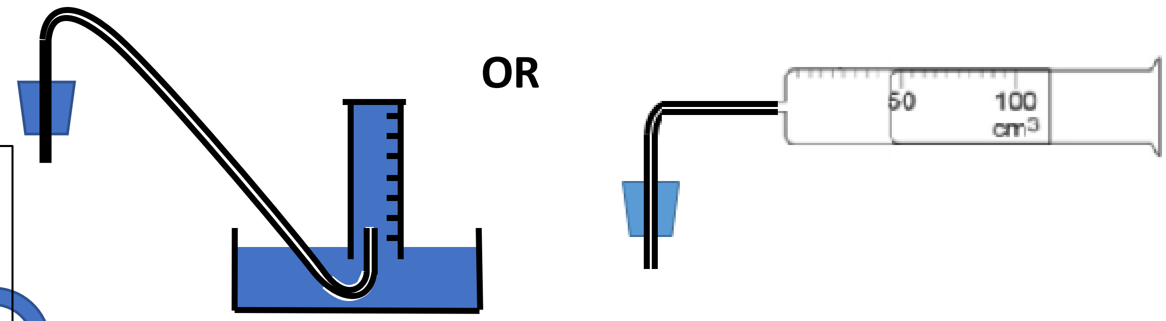


|. Measuring volumes of gases with time



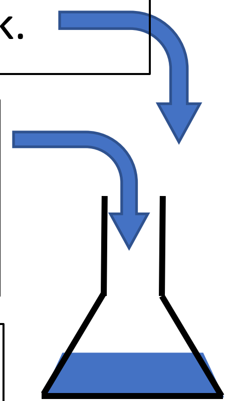
RP 1. Measuring volumes of gas over time

1. Connect the gas syringe to a bung using a delivery tube.



2. Measure 50cm^3 of 2.0M acid with a ***measuring cylinder*** and add to a conical flask.

3. Add 3cm of magnesium ribbon to the acid.

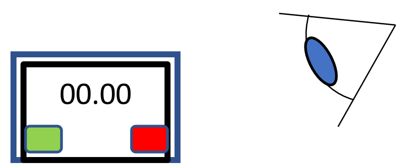


Independent variable: Concentration of acid
Dependent variable: Volume of gas produced
Control variables: Volume of acid used, size of magnesium ribbon used

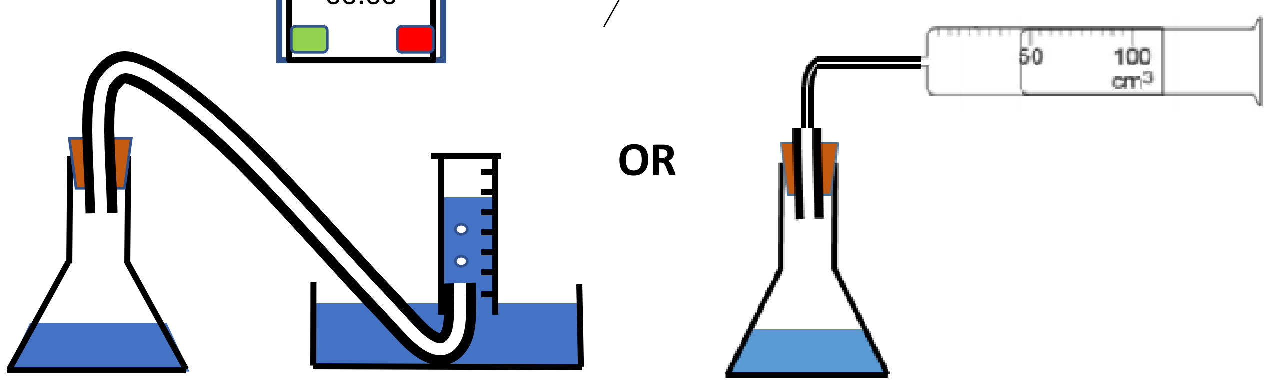
4. QUICKLY place bung into conical flask **AND** start the timer.

If this isn't done quickly enough, gas will be lost!

5. Measure and record the volume of gas produced every 10 s for 100 s.

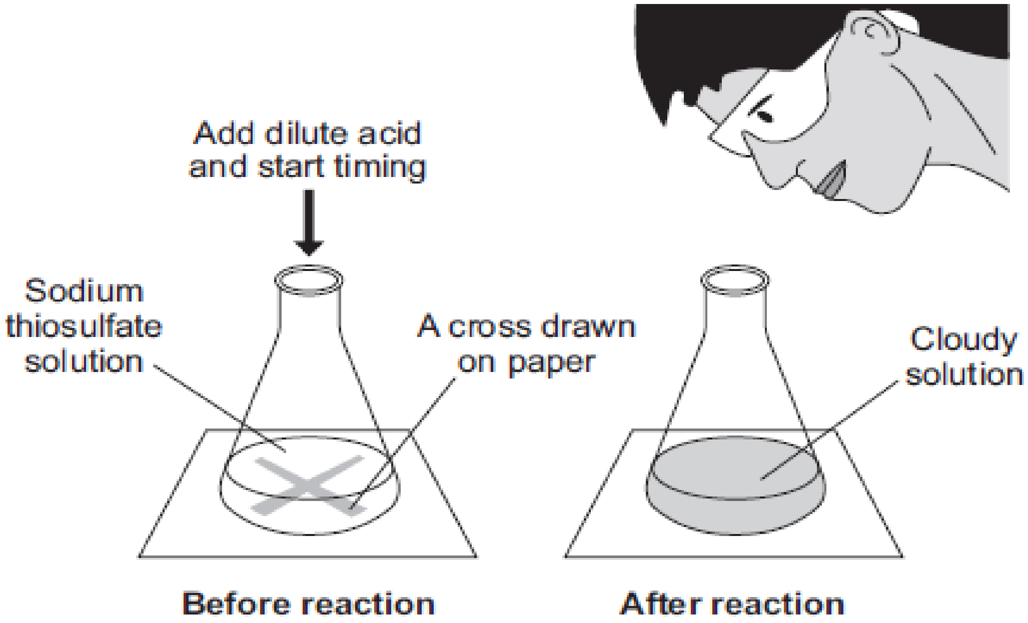


6. Repeat 1-5 for different concentrations of acid.



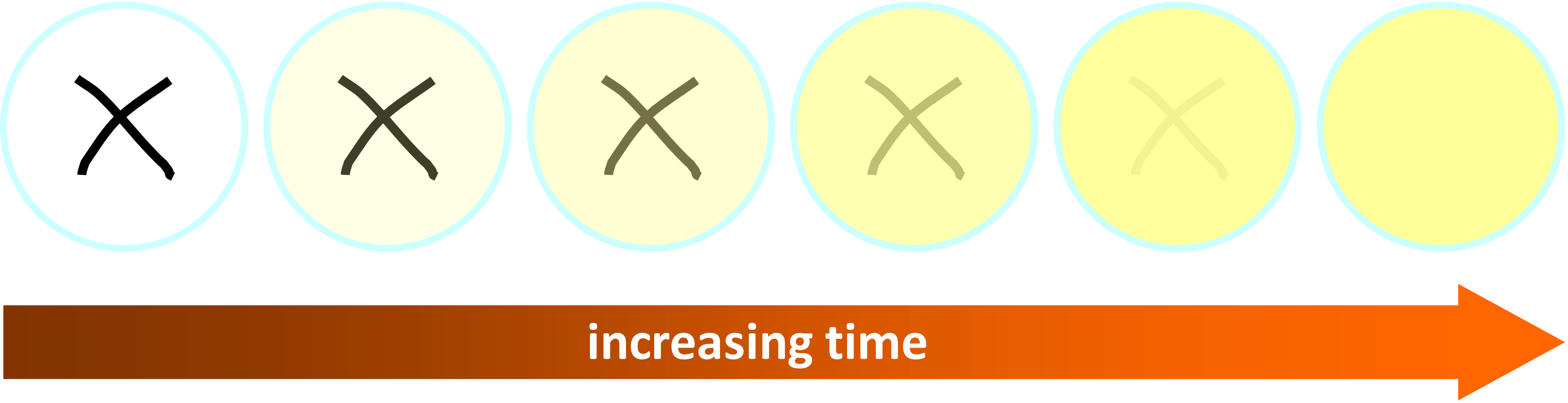
RP 2: Timing how long it takes for a cross to disappear

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



Solid formed in a solution = A PRECIPITATE

When looking down into the beaker, the cross will become fainter over time:



The time taken for the cross to disappear can be used as the time of the reaction.

Why isn't this reaction very accurate?

RP 2: Timing how long it takes for a cross to disappear

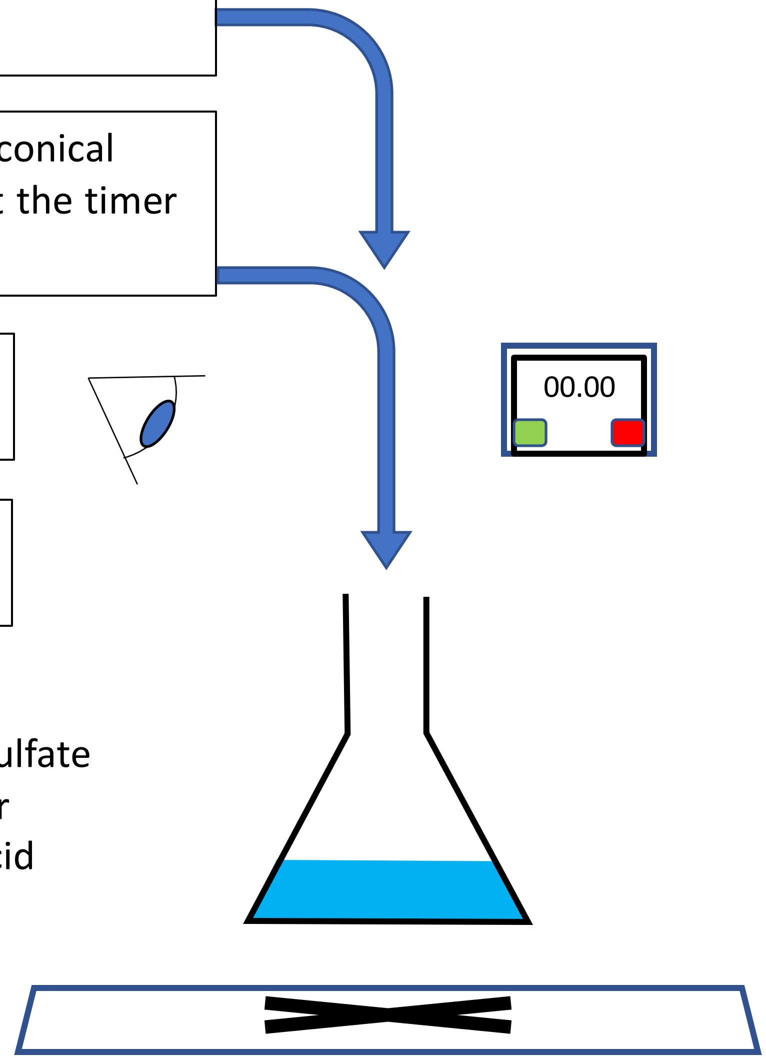
1. Draw a black cross on a white piece of paper and place a conical flask on top of the cross.

2. Add 10cm^3 of the most dilute sodium thiosulfate solution into a conical flask

3. Measure 10cm^3 of dilute hydrochloric acid into the conical flask. At the same time, swirl the flask gently and start the timer immediately.

4. Stop timer when you can no longer see the cross. Record the time taken for the cross to disappear.

5. Repeat steps 1-4 with different concentrations of sodium thiosulfate solution.



Independent variable: Concentration of sodium thiosulfate
Dependent variable: Time taken for cross to disappear
Control variables: Volume of acid, concentration of acid

Safety: Safety goggles, avoid contact with acid

4.6.1.1 Calculating rates of reactions

Content
The rate of a chemical reaction can be found by measuring the quantity of a reactant used or the quantity of product formed over time:

$$mean\ rate\ of\ reaction = \frac{quantity\ of\ reactant\ used}{time\ taken}$$

$$mean\ rate\ of\ reaction = \frac{quantity\ of\ product\ formed}{time\ taken}$$

The quantity of reactant or product can be measured by the mass in grams or by a volume in cm^3.

The units of rate of reaction may be given as g/s or cm^3/s.

For the Higher Tier, students are also required to use quantity of reactants in terms of moles and units for rate of reaction in mol/s.

Students should be able to:

- calculate the mean rate of a reaction from given information about the quantity of a reactant used or the quantity of a product formed and the time taken
- draw, and interpret, graphs showing the quantity of product formed or quantity of reactant used up against time
- draw tangents to the curves on these graphs and use the slope of the tangent as a measure of the rate of reaction
- (HT only) calculate the gradient of a tangent to the curve on these graphs as a measure of rate of reaction at a specific time.

Red	Amber	Green

4.6.1.3 Collision theory and activation energy

Content
Collision theory explains how various factors affect rates of reactions. According to this theory, chemical reactions can occur only when reacting particles collide with each other and with sufficient energy. The minimum amount of energy that particles must have to react is called the activation energy. Increasing the concentration of reactants in solution, the pressure of reacting gases, and the surface area of solid reactants increases the frequency of collisions and so increases the rate of reaction. Increasing the temperature increases the frequency of collisions and makes the collisions more energetic, and so increases the rate of reaction.
Students should be able to : • predict and explain using collision theory the effects of changing conditions of concentration, pressure and temperature on the rate of a reaction • predict and explain the effects of changes in the size of pieces of a reacting solid in terms of surface area to volume ratio • use simple ideas about proportionality when using collision theory to explain the effect of a factor on the rate of a reaction.

Red	Amber	Green

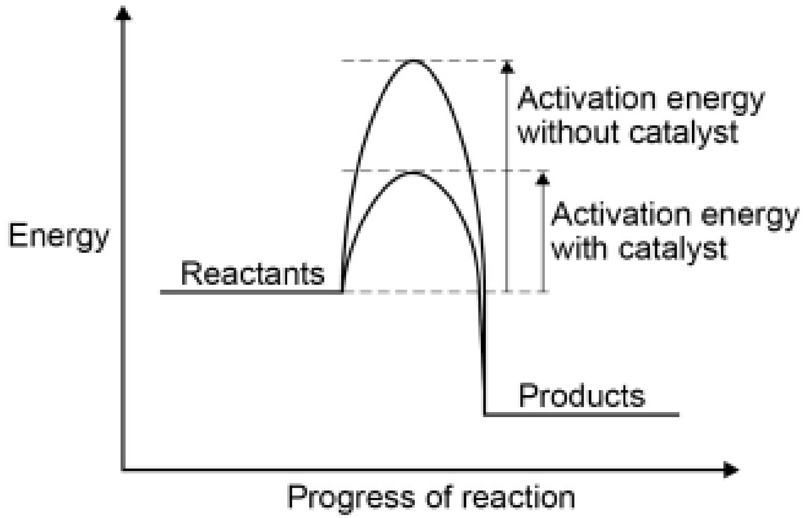
4.6.1.4 Catalysts

Content

Catalysts change the rate of chemical reactions but are not used up during the reaction. Different reactions need different catalysts. Enzymes act as catalysts in biological systems.

Catalysts increase the rate of reaction by providing a different pathway for the reaction that has a lower activation energy.

A reaction profile for a catalysed reaction can be drawn in the following form:



Students should be able to identify catalysts in reactions from their effect on the rate of reaction and because they are not included in the chemical equation for the reaction.

Students should be able to explain catalytic action in terms of activation energy.

Red	Amber	Green

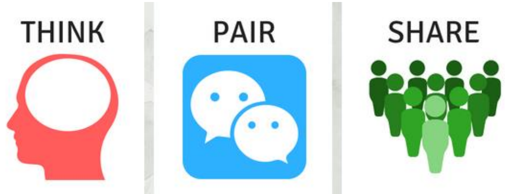
Red	Amber	Green

4.6.1.2 Factors which affect the rates of chemical reactions

Content	Key opportunities for skills development
Factors which affect the rates of chemical reactions include: the concentrations of reactants in solution, the pressure of reacting gases, the surface area of solid reactants, the temperature and the presence of catalysts.	
Students should be able to recall how changing these factors affects the rate of chemical reactions.	This topic offers opportunities for practical work and investigations in addition to required practical 5.

Required practical 5: investigate how changes in concentration affect the rates of reactions by a method involving measuring the volume of a gas produced and a method involving a change in colour or turbidity.

This should be an investigation involving developing a hypothesis.



How would we write an equation to show that A and B react to form C and D?

$$A + B \longrightarrow C + D$$

REACTANTS → PRODUCTS

Label the reactants and the products in your reaction

The heating of hydrated copper sulphate is an example of a **reversible reaction:**

ENDOTHERMIC

$$\underset{CuSO_4.5H_2O}{\text{hydrated copper sulfate}} \rightleftharpoons \underset{CuSO_4}{\text{anhydrous copper sulfate}} + \underset{5H_2O}{\text{water}}$$

EXOTHERMIC

In a reversible reaction, one direction is exothermic, which releases energy. The reverse direction is endothermic, which absorbs energy. The size of the energy change is always the same in both directions.

25J taken in

$$\text{hydrated copper sulfate(blue)} \underset{\text{exothermic}}{\overset{\text{endothermic}}{\rightleftharpoons}} \text{anhydrous copper sulfate (white)} + \text{water}$$

25J given out

The same amount of energy is absorbed as is taken out!

For example, if 25J of energy is released in one direction, 25J of energy will be taken in in the other direction.

In a reversible reaction, both products and reactants are made. The products can react together to form the original reactants:

$$A + B \rightleftharpoons C + D$$

REACTANTS **PRODUCTS**

One direction is endothermic, the other direction is exothermic. The size of the energy change is the same in both directions.

DECODE IT NOW

Word:

Dynamic

Define it:

A system that constantly changes, moves or progresses.

Write a sentence of your own that uses the word **dynamic.**

Write your own definition of the word **dynamic.**

Which subjects or topics will this word be relevant to?

Digging Deeper:

The word dynamic can also be used to describe a person that has a positive attitude and is full of energy and new ideas.

Link it (similar words):

Moving, changing, energy

Deconstruct it (Root word):

*From early 19th century Greek word **dunamis** meaning **power***

Use it:

The dynamic nature of Mr Crawford's lesson meant all students were enthusiastic!

DECODE IT NOW

Word:

Equilibrium

Define it:

A system in which opposite forces or influences are balanced.

Write a sentence of your own that uses the word **dynamic.**

Write your own definition of the word **dynamic.**

Which subjects or topics will this word be relevant to?

Link it (similar words):

Balanced, even, opposite, stable

Digging Deeper:

Equilibrium can also refer to a state of physical balance e.g. I stumbled over a rock and recovered my equilibrium.

Use it:

The forward reaction and the backward reaction were in equilibrium.

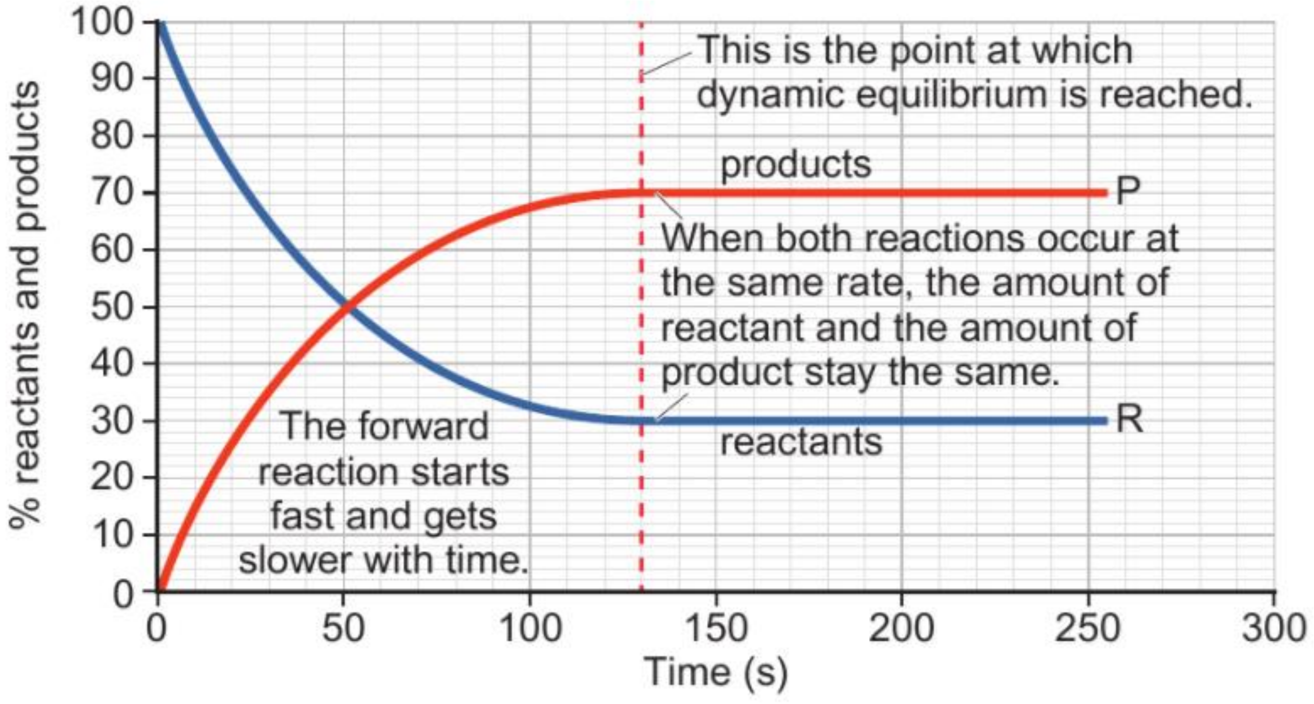
Deconstruct it (Root word):

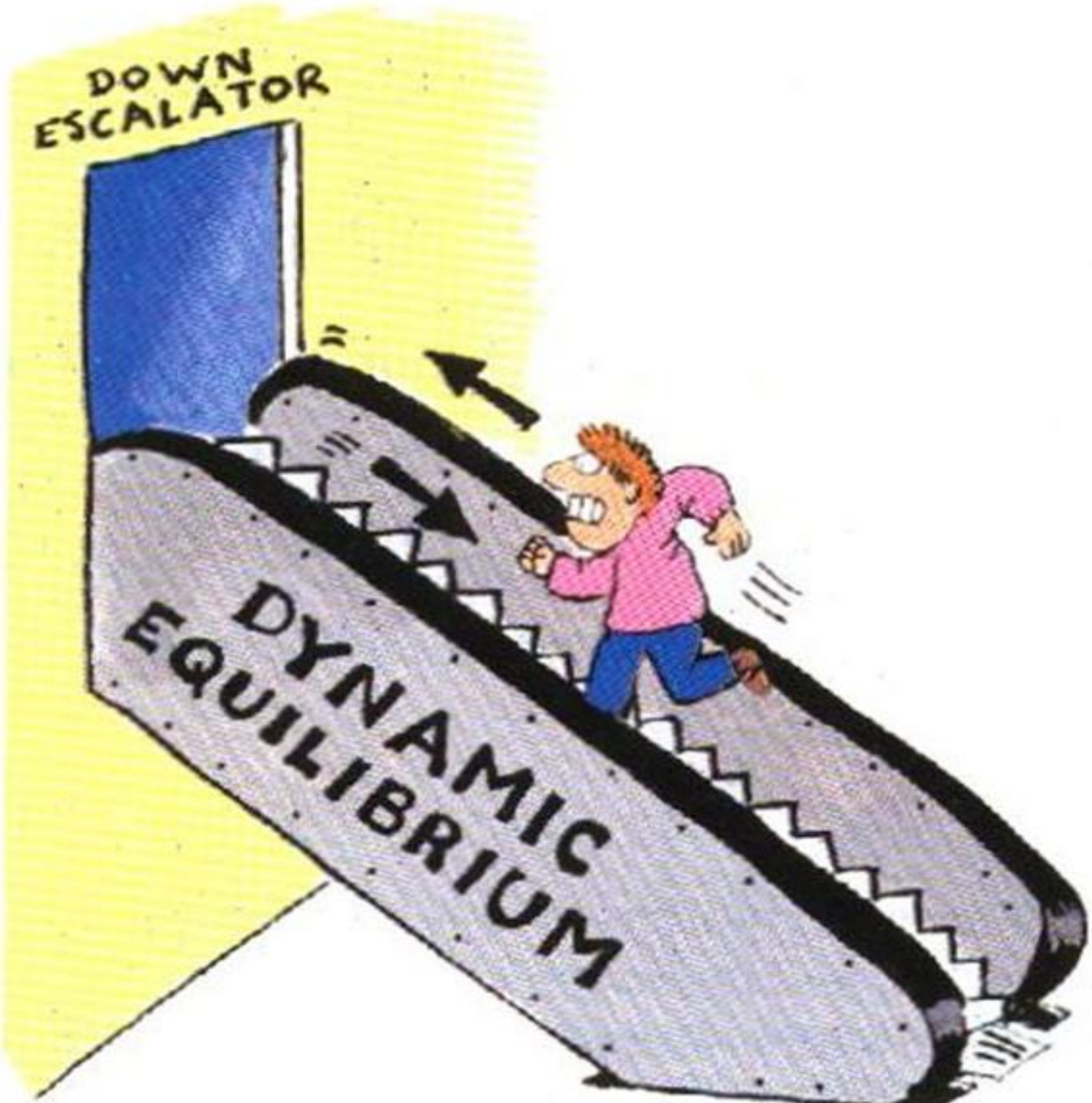
*From 17th century Latin words, **aequi** which means 'equal' and **libra** which means 'balance'.*

DYNAMIC EQUILIBRIUM is when the ***rate of the forward reaction*** is the same as the ***rate of the backward*** *reaction*.

Dynamic equilibrium can only occur in a ***closed system***, where there is ***no loss of products or reactants***.

At dynamic equilibrium, there is no change in the concentration of ***reactants or products.***




DOWN ESCALATOR
DYNAMIC EQUILIBRIUM

5.6.2.1 Reversible reactions

Content
In some chemical reactions, the products of the reaction can react to produce the original reactants. Such reactions are called reversible reactions and are represented: $A + B \rightleftharpoons C + D$ The direction of reversible reactions can be changed by changing the conditions. For example: ammonium chloride $\underset{\text{cool}}{\overset{\text{heat}}{\rightleftharpoons}}$ ammonia + hydrogen chloride

5.6.2.2 Energy changes and reversible reactions

Content
If a reversible reaction is exothermic in one direction, it is endothermic in the opposite direction. The same amount of energy is transferred in each case. For example: hydrated copper sulfate (blue) $\underset{\text{exothermic}}{\overset{\text{endothermic}}{\rightleftharpoons}}$ anhydrous copper sulfate (white) + water

5.6.2.3 Equilibrium

Content
When a reversible reaction occurs in apparatus which prevents the escape of reactants and products, equilibrium is reached when the forward and reverse reactions occur at exactly the same rate.

Red	Amber	Green

Complete the practice paper questions!

Revision lesson link:

https://www.youtube.com/watch?v=UkrBJ6-uGFA&list=PL9IouNCPbCxW8AN0t0py7LaKdKSwfL3fP

https://www.youtube.com/watch?v=SPXanyy3-hU&list=PLidqqIGKox7WeOKVGHxcd69kKqtwrKl8W&index=38

https://www.bbc.co.uk/bitesize/guides/z3nbqhv/revision/1

- Google 'BBC Bitesize Rates of reaction'.

15 Minute ILT Task:

Will come up	Revision Questions
5.6.1.1 Calculating rates of reactions	1. State the formula used to calculate rates of reaction. 2. In a reaction, 14.4 cm^3 of oxygen gas was produced in the first 8 seconds. Calculate the mean rate of this reaction. 3. What does the units of rate depend on? State the general formula for units of rate. 4. State three ways of measuring the formation of products during a reaction. 5. Describe how precipitation can be used to calculate ratees of reaction. 6. What are the advantages and disadvantages of using the formation of percipitates to calcuate rates of reaction? 7. Describe how change in mass can be used to calculate rates of reaction. 8. What are the advantages and disadvantages of using mass change to calcuate rates of reaction? 9. Describe the volume of gas given off can be used to calculate rates of reaction. 10. What are the advantages and disadvantages of using gas volume given off to calcuate rates of reaction? 11. Draw typical graphs of the amount of product formed against time and the amount of reactants left against time. 12. On a graph showing the amount of product or reactant against time, how is the rate of reaction shown? 13. Why aren't graphs showing product against time or reactant against time straight lines? What does it look like insetad and why? 14. Why do reactions start quickly and when do they stop? 15. How can you compare the rate of a reaction performed under different conditions? 16. How do you find the mean rate for a whole reaction from a graph? 17.How do you find the mean rate of reaction between two points from a graph? 18. What is a tangent and what are they used for? 19. What is the formula for calculating rates from tangents?
5.6.1.2 Factors which affect the rates of chemical reactions	1. What is the rate of reaction? 2. When do reactions only happen 3. What is the minimum amount of energy that particles require in order to react called? 4. What four main factors affect the rate of a reaction? Describe their effect.
5.6.1.3 Collision theory and activation energy	1. What does collision theory say the rate of a reaction depends on? 2. According to collision theory, what do you need to change in order to increase the rate of reaction? 3. State and describe three ways of increasing the frequency of collisions. 4. State and describe two ways of increasing the energy of collisions. 5. What is the rate of reaction directly proportional to and what does this mean?
5.6.1.4 Catalysts	1. What is a catalyst? 2. Can a catalyst be used for different reactions? 3. Draw a reaction profile showing the effect of catalysts. 4. What are biological catalysts known as?

15 Minute ILT Task:

5.6.2.1 Reversible reactions	What is a reversible reaction? How is it represented? In a reversible reaction, what effect can changing the conditions of the reaction have? In a reversible reaction, when can and equilibrium be reached? What is equilibrium? What is meant by a 'closed system'? What does it mean if the equilibrium lies to the right? What does it mean if the equilibrium lies to the left? Describe the energy transfer in reversible reactions. Describe how the thermal decomposition of hydrated copper sulfate is a good example of a reversible reaction. Describe how the thermal decomposition of CaCO3 is a good example of a reversible reaction.
5.6.2.2 Energy changes and reversible reactions 5.6.2.3 Equilibrium	1. What is a reversible reaction? How is it represented? 2. In a reversible reaction, what effect can changing the conditions of the reaction have? 3. In a reversible reaction, when can and equilibrium be reached? 4. What is equilibrium? 5. What is meant by a 'closed system'? 6. What does it mean if the equilibrium lies to the right? 7. What does it mean if the equilibrium lies to the left? 8. Describe the energy transfer in reversible reactions. 9. Describe how the thermal decomposition of hydrated copper sulfate is a good example of a reversible reaction. 10. Describe how the thermal decomposition of $CaCO_3$ is a good example of a reversible reaction.

HT ONLY

Title – C6 Reversible reactions revision HT Monday, 25 September 2023

Do it now:

Give two ways of measuring volume of gas. Using a gas syringe or an upside down measuring cylinder in water.	How is gradient calculated from a graph? Gradient = change in y ÷ change in x	Why does the reaction below appear to go cloudy? $Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow S(s) + SO_2(g) + 2NaCl(aq)$ Solid sulphur is produced as a precipitate
Describe and explain the effect of increasing temperature on rate of reaction. Increasing the temperature increases the rate of reaction as particles gain more kinetic energy, which leads to more frequent successful collisions.	Explain why using magnesium powder gives a faster rate of reaction compared to magnesium ribbon. Magnesium powder has a larger surface area than magnesium ribbon, so there are more surfaces exposed, so there are more frequent successful collisions.	Describe and explain why catalysts are added to a reaction. Catalysts increase the rate of a reaction by providing an alternative reaction pathway that has a lower activation energy. They do not get used up in a reaction.

C6 - The rate and extent of chemical change

C1 - Atomic structure and the periodic table

C2 - Bonding, structure, and the properties of matter

C3 - Quantitative chemistry

C4 - Chemical changes

C5 - Energy changes

C6 - The rate and extent of chemical change

- Rates
  - Measuring and calculating rates
  - Factors affecting rates
  - Collision theory
- Reversible reactions
  - Reversible reactions and energy
  - Equilibrium

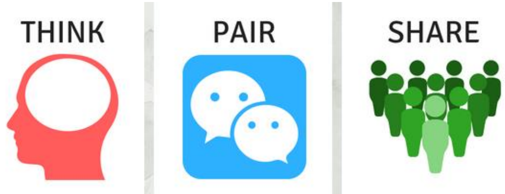
C7 - Organic chemistry

C8 - Chemical analysis

C9 - Chemistry of the atmosphere

C10 - Using resources

TRIPLE **HIGHER**



How would we write an equation to show that A and B react to form C and D?

$$A + B \longrightarrow C + D$$

REACTANTS → PRODUCTS

Label the reactants and the products in your reaction

The heating of hydrated copper sulphate is an example of a **reversible reaction:**

ENDOTHERMIC

$$\underset{CuSO_4.5H_2O}{\text{hydrated copper sulfate}} \rightleftharpoons \underset{CuSO_4}{\text{anhydrous copper sulfate}} + \underset{5H_2O}{\text{water}}$$

EXOTHERMIC

In a reversible reaction, one direction is exothermic, which releases energy. The reverse direction is endothermic, which absorbs energy. The size of the energy change is always the same in both directions.

25J taken in

$$\text{hydrated copper sulfate(blue)} \underset{\text{exothermic}}{\overset{\text{endothermic}}{\rightleftharpoons}} \text{anhydrous copper sulfate (white)} + \text{water}$$

25J given out

The same amount of energy is absorbed as is taken out!

For example, if 25J of energy is released in one direction, 25J of energy will be taken in in the other direction.

In a reversible reaction, both products and reactants are made. The products can react together to form the original reactants:

$$A + B \rightleftharpoons C + D$$

REACTANTS **PRODUCTS**

One direction is endothermic, the other direction is exothermic. The size of the energy change is the same in both directions.

DECODE IT NOW

Word:

Dynamic

Define it:

A system that constantly changes, moves or progresses.

Write a sentence of your own that uses the word **dynamic.**

Write your own definition of the word **dynamic.**

Which subjects or topics will this word be relevant to?

Link it (similar words):

Moving, changing, energy

Digging Deeper:

The word dynamic can also be used to describe a person that has a positive attitude and is full of energy and new ideas.

Use it:

The dynamic nature of Mr Crawford's lesson meant all students were enthusiastic!

Deconstruct it (Root word):

*From early 19th century Greek word **dunamis** meaning **power***

DECODE IT NOW

Word:

Equilibrium

Define it:

A system in which opposite forces or influences are balanced.

Write a sentence of your own that uses the word **dynamic.**

Link it (similar words):

Balanced, even, opposite, stable

Digging Deeper:

Equilibrium can also refer to a state of physical balance e.g. I stumbled over a rock and recovered my equilibrium.

Write your own definition of the word **dynamic.**

Which subjects or topics will this word be relevant to?

Use it:

The forward reaction and the backward reaction were in equilibrium.

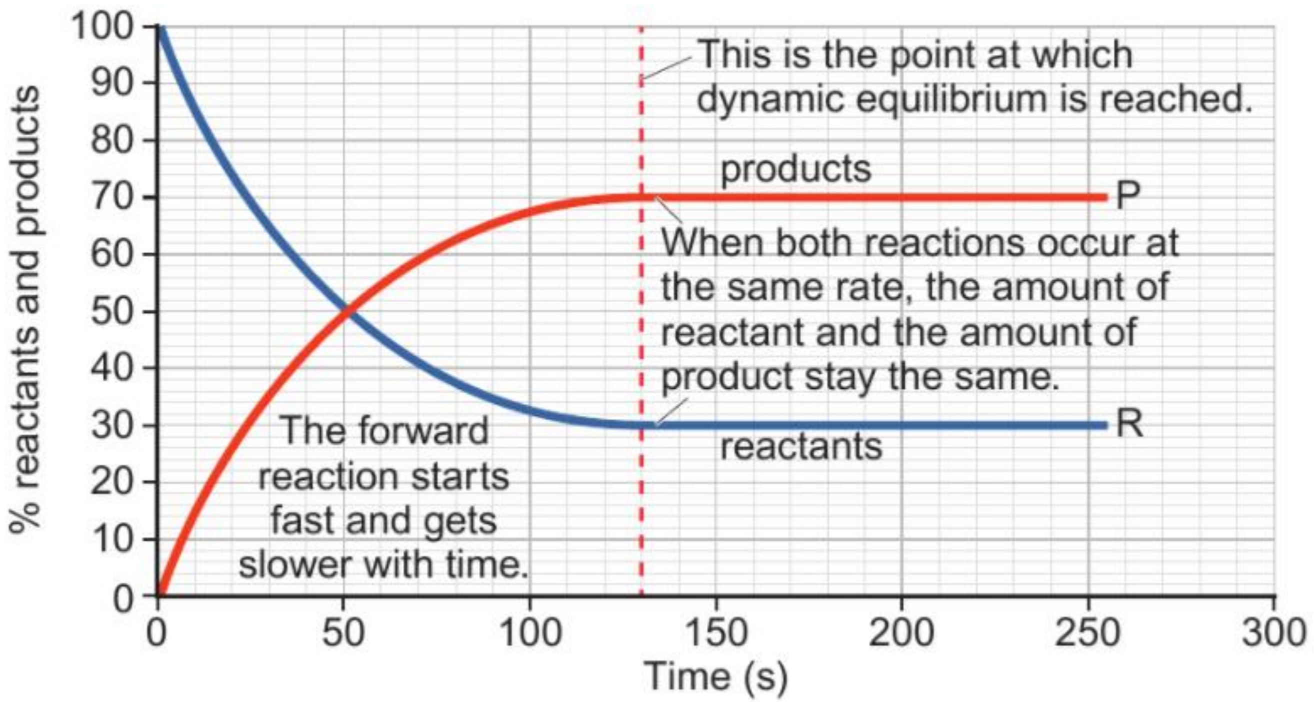
Deconstruct it (Root word):

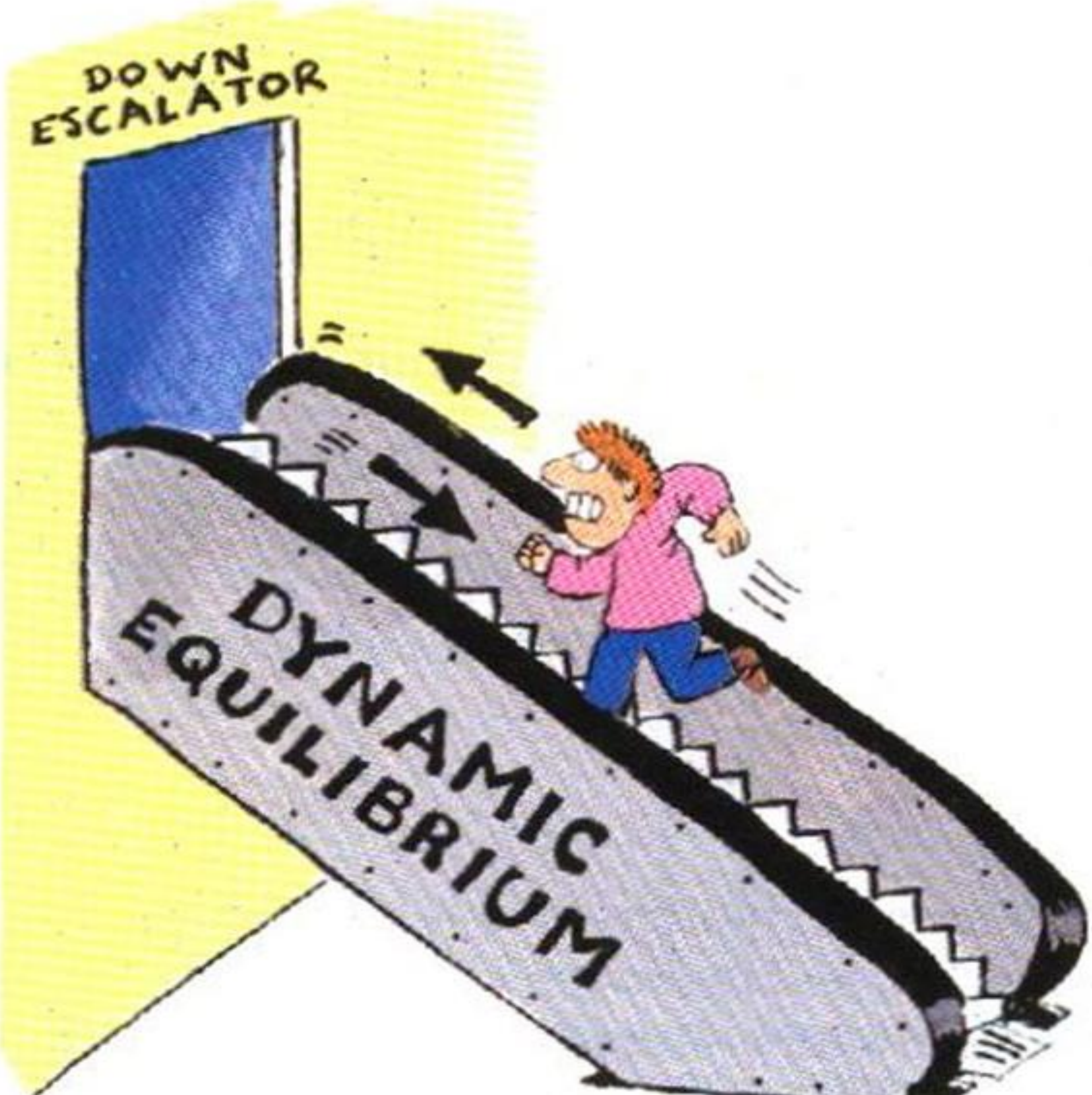
*From 17th century Latin words, **aequi** which means 'equal' and **libra** which means 'balance'.*

DYNAMIC EQUILIBRIUM is when the ***rate of the forward reaction*** is the same as the ***rate of the backward*** *reaction*.

Dynamic equilibrium can only occur in a ***closed system***, where there is ***no loss of products or reactants***.

At dynamic equilibrium, there is no change in the concentration of ***reactants or products.***




DOWN
ESCALATOR
DYNAMIC
EQUILIBRIUM

Le Chatelier's Principle

If a system is at equilibrium and a change is made to any of the conditions, then the system responds to counteract the change.

The **reaction conditions** are chosen to favour the forward reaction to make a *large amount of product as cheaply as possible*.

The three conditions which could be changed and are:

- **Concentration**
- **Temperature**
- **Pressure**

e.g. The Haber Process

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

nitrogen hydrogen ammonia

Reaction conditions:

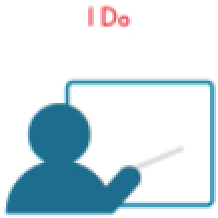
- *450°C*
- *200 atm (pressure)*
- *Iron catalyst*

Change by ...	Equilibrium position shifts ...
increasing temperature	in the direction (transferring energy from the surroundings, cooling them down)
decreasing temperature	in the direction (transferring energy to the surroundings, heating them up)
increasing gas pressure	in the direction that forms gas molecules (as this reduces pressure)
decreasing gas pressure	in the direction that forms gas molecules (as this increases pressure)
a concentration	in the direction that uses up the substance that has been added
a concentration	in the direction that forms more of the substance that has been removed

Catalysts have NO EFFECT on the POSITION OF EQUILIBRIUM – they only affect the RATE OF REACTION

TEMPERATURE INCREASE = EXOTHERMIC →

Example 1:



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

nitrogen hydrogen ammonia

← *TEMPERATURE DECREASE = ENDOTHERMIC*

Increasing temperature would shift the reaction to the **LEFT** (backwards reaction is endothermic), so the yield of ammonia would **DECREASE**.

Increasing pressure would shift the reaction to the **RIGHT** (fewer molecules on the right), so the yield of ammonia would **INCREASE**.

Increasing concentration of N_2 would shift the reaction to the **RIGHT** (to use up excess N_2), so the yield of ammonia would **INCREASE**.

Example 2:

exothermic (forward →)

$$SO_{2(g)} + 2O_{2(g)} \rightleftharpoons 2SO_{3(g)}$$

Increasing temperature would shift the reaction to the LEFT (backwards reaction is endothermic), so the yield of SO_3 would DECREASE

Increasing pressure would shift the reaction to the RIGHT (right hand side has fewer molecules), so the yield of SO_3 would INCREASE

Increasing concentration of SO_3 would shift the reaction to the LEFT (to use up excess SO_3), so the yield of SO_3 would DECREASE

Example 3:

→ ***endothermic***

$$CH_{4(g)} + H_2O_{(g)} \rightleftharpoons 3H_{2(g)} + CO_{(g)}$$

Decreasing temperature would shift the reaction to the **LEFT (backwards reaction is exothermic)**, so the yield of H_2 would **DECREASE**

Decreasing pressure would shift the reaction to the **RIGHT (right hand side has more molecules)**, so the yield of H_2 would **INCREASE**

Increasing concentration of CH_4 would shift the reaction to the **RIGHT (to use up excess CH_4)**, so the yield of H_2 would **INCREASE**

Example 4:

$$CO_{(g)} + 2H_{2(g)} \rightleftharpoons CH_3OH_{(g)}$$

You Do It Alone

→ ***exothermic***

Decreasing temperature would shift the reaction to the RIGHT (forwards reaction is exothermic), so the yield of CH_3OH would INCREASE

Increasing pressure would shift the reaction to the RIGHT (right hand side has fewer molecules), so the yield of CH_3OH would INCREASE

Decreasing concentration of CO would shift the reaction to the LEFT (to make more CO, so the yield of H_2 would DECREASE

Exam practice

In industry ethanol is produced by the reaction of ethene and steam at 300°C and 60 atmospheres pressure using a catalyst.

The equation for the reaction is:

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

The forward reaction is exothermic.

Use Le Chatelier's Principle to predict the effect of increasing temperature on the amount of ethanol produced at equilibrium.

Give a reason for your prediction.

(2)

Explain how increasing the pressure of the reactants will affect the amount of ethanol produced at equilibrium.

(2)

Exam practice

amount will decrease

1

because the equilibrium will move to the left

1

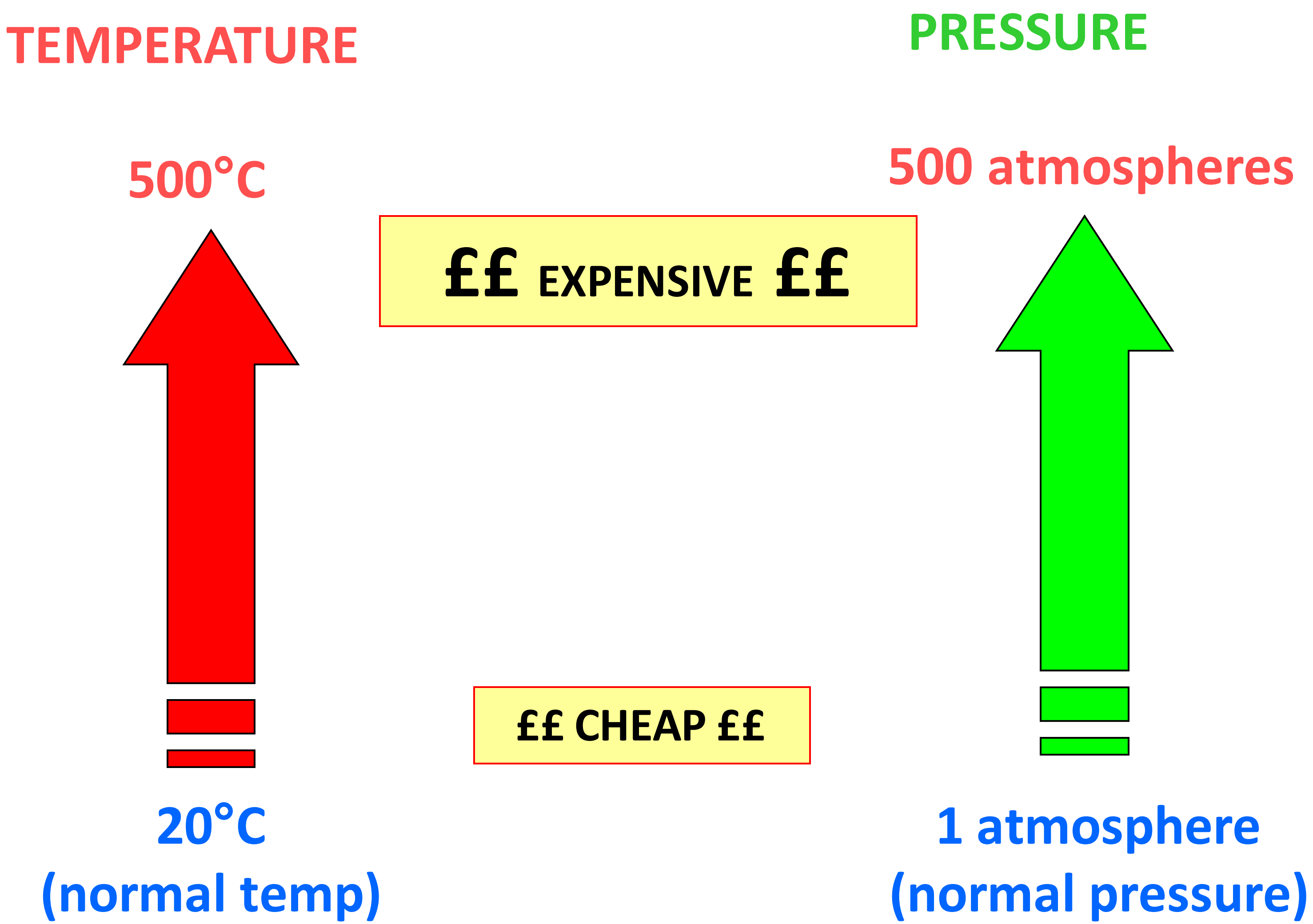
more ethanol will be produced

1

because system moves to least / fewer molecules

1

The **reaction conditions** are chosen to favour the forward reaction to make a *large amount of product as cheaply as possible*.



Reversible reactions – a compromise…

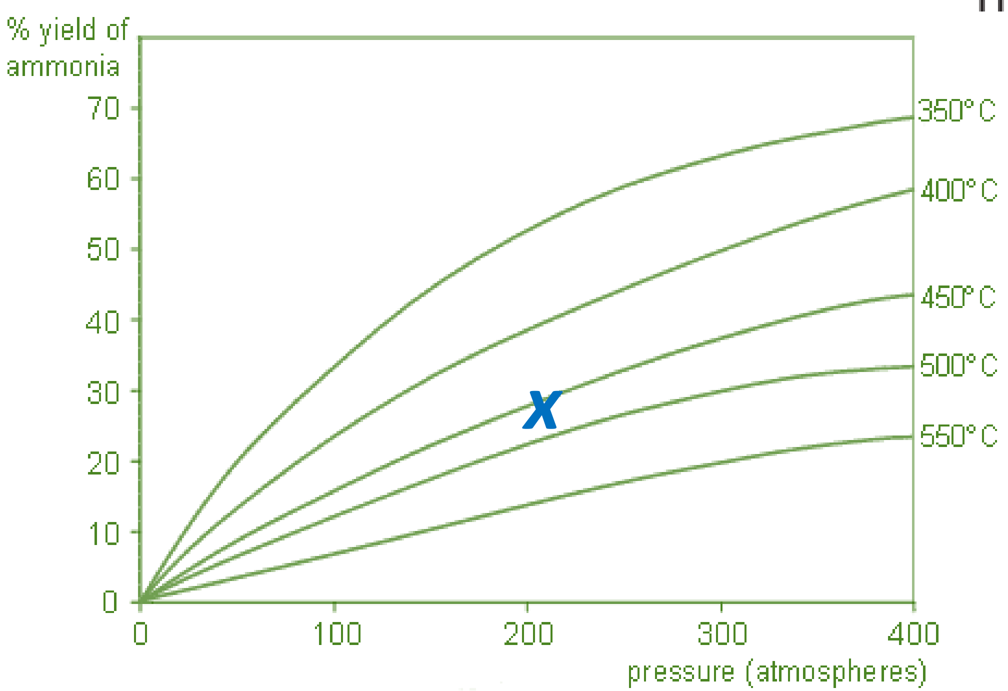
Very high pressure and temperatures will also have a **cost implication**.

A **compromise** on temperature and pressure leads to **reduced costs** and a more **economically viable product**.

e.g. The Haber Process

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

nitrogen hydrogen ammonia



Reaction conditions:

- *450°C*
- *200 atm (pressure)*
- *Iron catalyst*

Reversible reactions – a compromise…

e.g. The Haber Process

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

In theory, for maximum yield you would use a LOW TEMPERATURE and a HIGH PRESSURE.

BUT

A low temperature would give a **really slow rate of reaction**, so a temp of **450°C** is used as a COMPROMISE.

A high pressure would be **too expensive** and **could be dangerous**, so a pressure of **200 atm** is used as a COMPROMISE.

Exam practice

Ammonia is manufactured in the Haber Process, from nitrogen and hydrogen.

(a) Balance this symbol equation for the process.

$$N_2 + \mathbf{3}\ H_2 \xrightleftharpoons{\text{exothermic}} \mathbf{2}\ NH_3$$

(2)

At equilibrium, nitrogen, hydrogen and ammonia are present in the reactor.

(b) What is meant by 'equilibrium'?

Equilibrium is reached when the rate of the forwards reaction is equal to the rate of the backwards reaction (in a closed system).

(1)

Yield of NH_3 decreases as temperature increases because the reaction will favour the backwards reaction as it in endothermic.

However, at a low temperature the rate of reaction will be too slow, so a higher temperature of 450°C is used as a compromise.

Iron powder is added as a catalyst to speed up the rate of reaction (it has no effect on the position of equilibrium.

5.6.2.1 Reversible reactions

Content
In some chemical reactions, the products of the reaction can react to produce the original reactants. Such reactions are called reversible reactions and are represented: $A + B \rightleftharpoons C + D$ The direction of reversible reactions can be changed by changing the conditions. For example: ammonium chloride $\underset{\text{cool}}{\overset{\text{heat}}{\rightleftharpoons}}$ ammonia + hydrogen chloride

5.6.2.2 Energy changes and reversible reactions

Content
If a reversible reaction is exothermic in one direction, it is endothermic in the opposite direction. The same amount of energy is transferred in each case. For example: hydrated copper sulfate (blue) $\underset{\text{exothermic}}{\overset{\text{endothermic}}{\rightleftharpoons}}$ anhydrous copper sulfate (white) + water

5.6.2.3 Equilibrium

Content
When a reversible reaction occurs in apparatus which prevents the escape of reactants and products, equilibrium is reached when the forward and reverse reactions occur at exactly the same rate.

Red	Amber	Green

5.6.2.4 The effect of changing conditions on equilibrium (HT only)

Content
The relative amounts of all the reactants and products at equilibrium depend on the conditions of the reaction. If a system is at equilibrium and a change is made to any of the conditions, then the system responds to counteract the change. The effects of changing conditions on a system at equilibrium can be predicted using Le Chatelier's Principle. Students should be able to make qualitative predictions about the effect of changes on systems at equilibrium when given appropriate information.

5.6.2.5 The effect of changing concentration (HT only)

Content
If the concentration of one of the reactants or products is changed, the system is no longer at equilibrium and the concentrations of all the substances will change until equilibrium is reached again. If the concentration of a reactant is increased, more products will be formed until equilibrium is reached again. If the concentration of a product is decreased, more reactants will react until equilibrium is reached again. Students should be able to interpret appropriate given data to predict the effect of a change in concentration of a reactant or product on given reactions at equilibrium.

Red	Amber	Green

5.6.2.6 The effect of temperature changes on equilibrium (HT only)

Content
If the temperature of a system at equilibrium is increased: • the relative amount of products at equilibrium increases for an endothermic reaction • the relative amount of products at equilibrium decreases for an exothermic reaction. If the temperature of a system at equilibrium is decreased: • the relative amount of products at equilibrium decreases for an endothermic reaction • the relative amount of products at equilibrium increases for an exothermic reaction. Students should be able to interpret appropriate given data to predict the effect of a change in temperature on given reactions at equilibrium.

5.6.2.7 The effect of pressure changes on equilibrium (HT only)

Content
For gaseous reactions at equilibrium: • an increase in pressure causes the equilibrium position to shift towards the side with the smaller number of molecules as shown by the symbol equation for that reaction • a decrease in pressure causes the equilibrium position to shift towards the side with the larger number of molecules as shown by the symbol equation for that reaction. Students should be able to interpret appropriate given data to predict the effect of pressure changes on given reactions at equilibrium.

Red	Amber	Green

15 Minute ILT Task:

5.6.2.1 Reversible reactions	What is a reversible reaction? How is it represented? In a reversible reaction, what effect can changing the conditions of the reaction have? In a reversible reaction, when can and equilibrium be reached? What is equilibrium? What is meant by a 'closed system'? What does it mean if the equilibrium lies to the right? What does it mean if the equilibrium lies to the left? Describe the energy transfer in reversible reactions. Describe how the thermal decomposition of hydrated copper sulfate is a good example of a reversible reaction. Describe how the thermal decomposition of CaCO3 is a good example of a reversible reaction.
5.6.2.2 Energy changes and reversible reactions 5.6.2.3 Equilibrium	1. What is a reversible reaction? How is it represented? 2. In a reversible reaction, what effect can changing the conditions of the reaction have? 3. In a reversible reaction, when can and equilibrium be reached? 4. What is equilibrium? 5. What is meant by a 'closed system'? 6. What does it mean if the equilibrium lies to the right? 7. What does it mean if the equilibrium lies to the left? 8. Describe the energy transfer in reversible reactions. 9. Describe how the thermal decomposition of hydrated copper sulfate is a good example of a reversible reaction. 10. Describe how the thermal decomposition of $CaCO_3$ is a good example of a reversible reaction.

15 Minute ILT Task:

5.6.2.4 The effect of changing conditions on equilibrium (HT only)	1. What is Le Chatelie'rs principle? 2. Accoridg to Le Chatelie'rs principle, what three things can alter the yield of a reversible reaction? 3. Describe the effect of increasing/decreasing the temperature of a reversible reaction. 4. Describe the effect of increasing/decreasing the temperature of a the following reaction:

Exothermic →

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$$

← *Endothermic*

Which type of reversible reactions does pressure affect?

Describe the effect of increasing/decreasing the pressure of a reversible reaction.

Describe the effect of increasing/decreasing the pressure of a the following reaction:

$$CH_{4(g)} + H_2O_{(g)} \rightleftharpoons CO_{(g)} + 3H_{2(g)}$$

Describe the effect of increasing/decreasing the concentration of a reversible reaction.

Describe the effect of increasing/decreasing the concentration of a the following reaction:

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$