science

chemistry

Topic 4 – Chemical Changes

1) Reactions of metals

- Metals can react with oxygen (oxidised) to make metal oxides.
- Some metals will react with water (alkali metals) and most metals will react with dilute acids to produce hydrogen gas and a salt.
- The reactivity of a metal depends on its tendency to form positive ions.

2) The Reactivity Series

Potassium > sodium > lithium > calcium > magnesium > **carbon** > zinc > iron > **hydrogen** > copper > silver > gold are in order of most reactive to the least reactive based on their reactions with water and dilute acids.

- Metals undergo displacement reactions where a more reactive metal will displace a less reactive one from a solution containing its ions.

e.g. zinc + lead nitrate → zinc nitrate + lead

3) Ionic Equations (HT)

- Ionic equations can be used to show displacement reactions where we omit the spectator ions (ones not directly involved in the reaction)

e.g. $Zn_{(s)} + Pb^{2+}_{(aq)} \rightarrow Pb_{(s)} + Zn^{2+}_{(aq)}$

splitting into 2 half equations this becomes

$Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2e^-$ $\quad$ $Pb^{2+}_{(s)} + 2e^- \rightarrow Pb^{2+}_{(aq)}$

4) Oxidation & Reduction

Oxidation – the gain of oxygen or the loss of electrons (OIL)

Reduction – the loss of oxygen or the gain of electrons (RIG)

5) Extracting metal from ores

- An ore is a rock with enough metal in it to make it worth extracting.

Metals can be extracted by:

- Heating the ores with carbon (reduction)
- Electrolysis (expensive due to large of amounts of energy needed).
- Some metals (like gold) are found uncombined in the Earth.
- Tungsten is a special case where the ore is heated with hydrogen (this is also a reduction reaction)

6) Electrolysis

Electrolysis is the decomposition (breaking down) of an ionic substance using electricity (dc).

All ionic compounds when molten can be decomposed when electricity is passed through using electrolysis.

The liquid being electrolysed is called the electrolyte.

The electrodes are made from inert material such as graphite or platinum (so they don't produce ions & interfere with the reaction).

Metal ions or hydrogen ions always move to the negative electrode.

Non-metal ions move to the positive electrode.

Think PANIC (Positive Anode Negative Is Cathode)

7) The electrolysis of solutions

When an ionic compound is dissolved in water (aqueous), its ions become free to move. However, the products from the salt solution will be different to the molten solution because of the presence of the water, which also produces ions.

$H_2O_{(l)} \rightarrow H^+_{(aq)} + OH^-_{(aq)}$

During electrolysis, these ions compete with the metal and non-metal ions in solution, to gain or lose electrons.

So who wins?

At the cathode:

At the negative electrode, hydrogen is produced if the metal is more reactive than hydrogen.

If the metal is less reactive than hydrogen the metal will form at the negative electrode (usually copper or silver)

At the anode:

At the positive electrode, oxygen is produced unless the solution contains halide ions when the halogen is produced.

This is because if halide ions are present, **Cl^-, Br^-, I^-**, they will give up their electrons to become molecules of **Cl_2, Br_2** and **I_2**.

If no halogen is present, **OH^-** will give up electrons more readily than other non-metal ions, and oxygen forms.

8) Acids, Bases and Salts

Salts are compounds made when the hydrogen in an acid is displaced by a metal.

Soluble salts are made by reacting acids with:

- Metals (some metals are too reactive & some don't react).
- Insoluble bases (the base is added to the acid until the acid is all used up and the excess solid is removed by filtering).

Bases include: Metal oxides, metal hydroxides and metal carbonates. These will all neutralise acids.

Acid + metal → salt + hydrogen

Acid + base → salt + water

Acid + metal carbonate → salt + water + carbon dioxide

The name of the salt made depends on the name of the acid and the metal used:

- Hydrochloric acid (HCl) makes chlorides
- Sulfuric acid (H_2SO_4) makes sulfates
- Nitric acid (HNO_3) makes nitrates

e.g. hydro**chloric** acid + zinc oxide → zinc **chloride** + water

- In neutralisation reactions hydrogen ions from the acid react with hydroxide ions to produce water as shown in the equation below.

$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$

9) pH Scale

Colour	Dark Red	Red	Red	Orange Red	Orange	Orange yellow	Greenish yellow	Green	Greenish blue	Blue	Navy blue	Purple	Dark purple	Violet	Violet
pH	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14

acidic neutral alkaline

- The colours observed in the above scale are for Universal Indicator.
- Solution are acidic because they contain H^+ ions
- Solution are made alkaline by the presence of OH^- ions
- Remember a lower pH is more acidic!

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10) Strong and weak acids (HT ONLY)

- A strong acid is completely ionised in aqueous solution.

e.g. $HCl \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$

- Examples of strong acids are hydrochloric, sulfuric & nitric.

- Weak acids are only partially ionised in aqueous solution.

e.g. $CH_3COOH_{(aq)} \rightleftharpoons H^+_{(aq)} + CH_3COO^-_{(aq)}$

- Examples of weak acids are ethanoic, citric & carbonic.

- Acids provide hydrogen ions (H^+) which make solution acidic and OH^- ions make solutions alkaline.
- The degree of acidity is measured by the pH scale (power of hydrogen ions).
- **When the concentration of H^+ ions is decreased by a factor of 10, the pH goes up by one unit** (remember pH scale goes from 0 (most acidic) to 14 (most basic).
- So pH3 would have 100x more hydrogen ion concentration than pH5.

11) Extraction of aluminium

- Aluminium is manufactured by the electrolysis of a molten mixture of aluminium oxide and cryolite using carbon as the positive electrode (anode).
- The positive electrode have to continually be replaced as the oxygen that forms there react with the carbon to form carbon dioxide and the electrodes slowly disappear.

- It is also a very expensive process since the aluminium oxide has to be melted to a very high temperature (so the ions are free to move).
- The melting point is lowered by adding cryolite.
- Lots of electrical energy is also needed which is expensive.

$Al^{3+}_{(l)} + 3e^- \rightarrow Al_{(l)}$ $2O^{2-}_{(l)} \rightarrow O_{2\,(g)} + 4e^-$

Required Practical

- Preparation of a pure, dry sample of a soluble salt from an insoluble oxide or carbonate using a Bunsen burner to heat dilute acid and a water bath or electric heater to evaporate the solution.

Key steps

- Add named acid to a beaker
- Gently warm the acid
- Add named metal oxide or carbonate to the acid and stir
- Continue adding until the metal oxide is in excess (solid seen at bottom of beaker)
- Filter using a filter paper and funnel to remove excess metal oxide (or carbonate)
- Pour solution into an evaporating dish
- Heat solution until crystallisation point
- Leave for rest of water to evaporate and crystals appear.

e.g. making copper oxide

- Copper doesn't easily react with acids so we use copper oxide (or copper carbonate)
- Add excess copper oxide powder to a beaker of warm sulfuric acid to ensure all the sulfuric acid is used up.
- The excess CuO is filtered and the water can be evaporated off to obtain pure crystals of copper sulfate.

$CuO\ (s) + H_2SO_4\ (aq) \rightarrow CuSO_4\ (aq) + H_2O\ (l)$

Salt Solutions

Salt solutions can be crystallised to produce solid salts. Some of the water is evaporated by heating it until the solution becomes more concentrated. This continues until the solution becomes saturated and then crystals start to appear (think of it like the dissolved solid no longer has any solvent to hide in). The rest of the water is left to evaporate slowly and then left to dry.

Required Practical – Electrolysis of solutions

- Investigate what happens when aqueous solutions are electrolysed using inert electrodes. This should be an investigation involving developing a hypothesis.

- Use inert electrodes used (carbon) to electrolyse sodium chloride solution and copper chloride solution.
- Look for the symbols aq (solution) and l (molten liquid)

- If you electrolyse a solution of copper sulfate, copper would form at the negative electrode and oxygen would form at the positive electrode
- If you repeated with silver carbonate, you would get silver and oxygen forming.
- You might conclude from this that you always get the metal and oxygen from electrolysis.
- But then you electrolyse sodium chloride solution and you get hydrogen at the negative electrode and chlorine forming at the positive electrode.
- If you repeat with different metals solutions of differing reactivity, you would find that….

- At the negative electrode (cathode), hydrogen is produced if the metal is more reactive than hydrogen.

- At the positive electrode (anode), oxygen is produced unless the solution contains halide ions when the halogen is produced.

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Topic 6 – Rate & Extent of Chemical Change

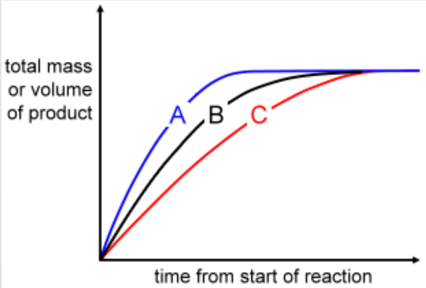
science chemistry

What is rate?
The mean rate of reaction is defined as:

$$\frac{\text{the amount of reactant used / product formed}}{\text{time}}$$

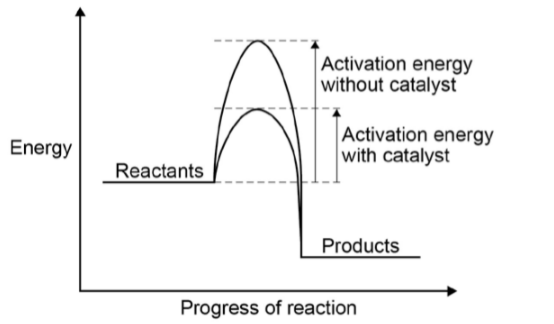
What's it measured in?
g/s (grams per seconds) or cm^3/s **(HT students also mols/s)**

How rate changes
In a graph of the reaction, the steeper the gradient the faster the reaction (in the graph below A is fastest, C is slowest). When the reaction graph levels out, the reaction has stopped.
Most reactions are fastest at the start as there are more reactant particles to react.



Factors affecting rate
Temperature
Concentration of reactants in solution (or pressure for gases)
Surface area of solid reactants
Use of a catalyst

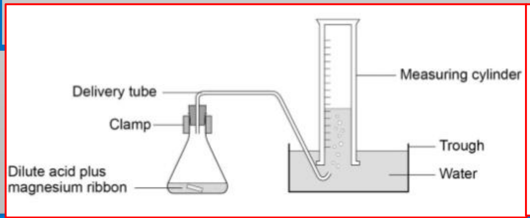
A reaction profile for a catalysed reaction can be drawn in the following form:

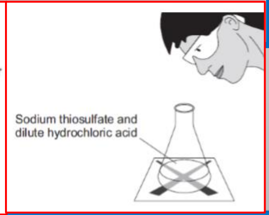


Collision Theory
Chemical reactions can occur only when reacting particles collide with each other AND with sufficient energy. So reaction rate depends on collision energy and collision frequency.
The minimum amount of energy that particles must have to react is called **the activation energy**.

- **Increasing temperature** increases rate as the particles have more kinetic energy so move around more quickly so they collide more frequently. Higher temperature means that the particles collide with more energy so more of the collisions are successful collisions (every 10ºC increase ≈ double rate).
- **Increasing concentration** of a solution increases rate as there are more particles in a given volume, so the reactant particles collide more frequently so the rate increases (double conc ≈ double rate).
- **Increasing the surface area** of a solid means that the other reactant particles collide with the solid more frequently so the reaction rate increases (powders react faster than solid lumps).
- **A catalyst** is a substance that speeds up the rate of a reaction without being used up. Catalysts increase the rate of reaction by providing a different pathway for the reaction that has a lower activation energy (see bottom left).

Required Practical 5 – measuring rate by two methods.
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 (cloudiness).
Measuring volumes of gas is more accurate in a measuring cylinder or gas syringe than a simple test tube.
When talking about control variables, keeping the volumes of reactants, temperature, concentration, mass of solid reactants volumes of liquid reactants, temperature of solutions, concentration of solutions the same.
Other control variable cold be same thickness of the cross.
Avoid saying same person doing it, or same stopwatch.





Reversible reactions and dynamic equilibrium
Reversible reactions are ones which can go forwards and backwards (i.e. products can turn back in reactants).
This symbol ⇋ is used to show a reversible reaction.
If a reversible reaction is exothermic in one direction, it is endothermic in the opposite direction.
When the forward reaction occurs at the same rate as the reverse reaction we say the reaction is in dynamic equilibrium (at this point concentrations of reactants and products do not change). There is no loss or gain of reactants or products to or from the surroundings (closed system).

When a reversible reaction has reached equilibrium, the relative amounts of all the reactants and products depend on the conditions of the reaction and these can be changed.
e.g.
Ammonium chloride ⇋ ammonia + hydrogen chloride

Heating the reaction shifts the reaction to the left, cooling it shifts it to the right

Changing Conditions and Le Chatelier's Principle (HT ONLY)

If a system is at equilibrium and a change is made to any of the conditions, then the system responds to counteract the change (Le Chatelier's Principle).
This can be used to predict the effects of changing reaction conditions.
If the temperature is raised, the amount of products from the endothermic reaction increases but the amount of products from the exothermic reaction decreases (i.e. increasing the temperature shifts the reaction towards the endothermic reaction).
In gaseous reactions, an increase in pressure causes the equilibrium position to shift towards the side with the smallest number of molecules as shown by the symbol equation for that reaction.
If the concentration of a reactant is increased, more products will be formed until equilibrium is reached again.
Factors that affect rate also need to be thought about which is why sometimes a compromise in conditions needs to be used.

Effect of catalysts on position of equilibrium (HT ONLY)
Catalysts speed up the rate of reaction of both sides of a reversible reaction so have no effect on the overall position of equilibrium.

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Topic 6 – Rate & Extent of Chemical Change

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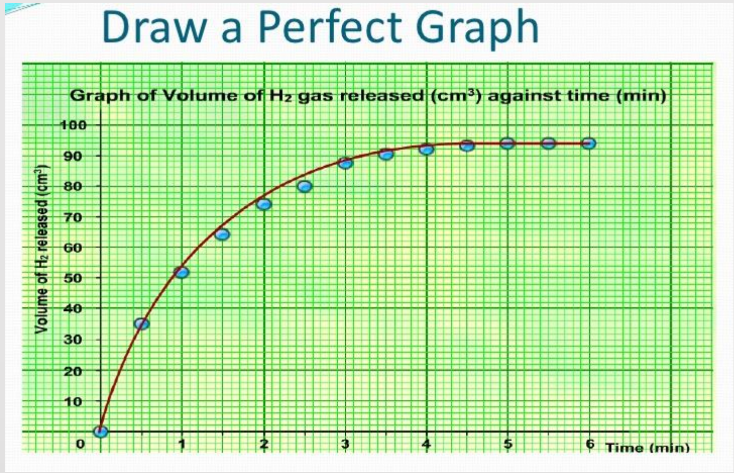
Drawing graphs

- Choose a scale that fills over half the paper and is easy to read so it will make plotting your points easier.
- Plot all your points carefully
- Draw a suitable line of best fit (this does not have to go through all the points and generally you should not join cross to cross or dot to dot).



Required Practical 5 – measuring rate by two methods.

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When talking about control variables, keeping the volumes of reactants, temperature, concentration, mass of solid reactants volumes of liquid reactants, temperature of solutions, concentration of solutions the same.

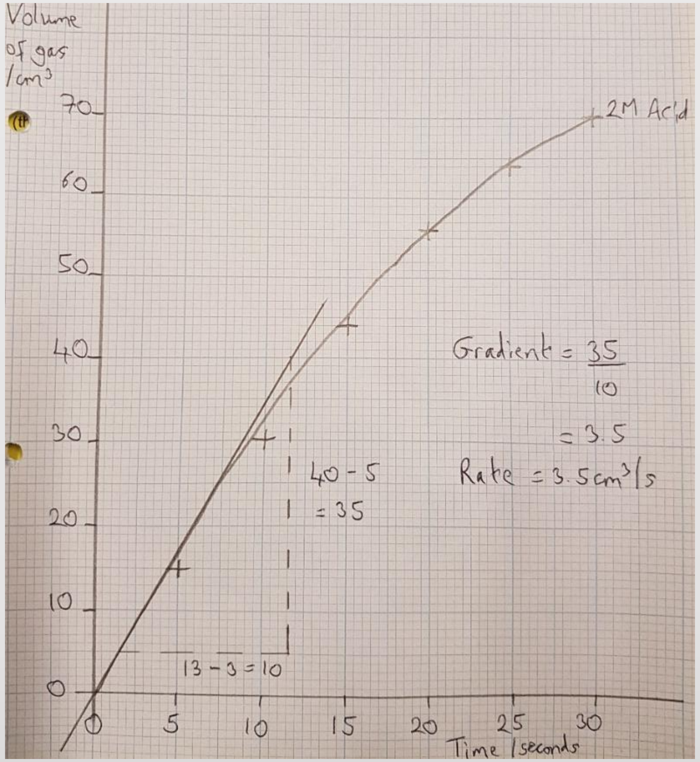
Other control variable cold be same thickness of the cross.

Avoid saying same person doing it, or same stopwatch.

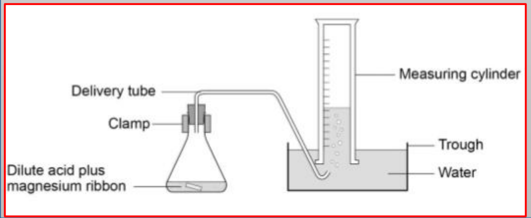
Could also use digital thermometers as easier to read / more precise.

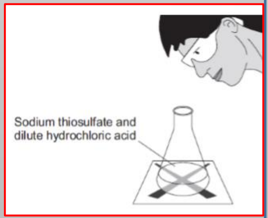
Calculating gradients / drawing tangents

We calculate gradients by measuring $\frac{dy}{dx}$



Calculating the gradient of a tangent is HT only but drawing a tangent is all students





Further examples of reversible reactions and dynamic equilibrium

A common example of a reversible reaction is the Haber process used to make ammonia (NH_3) which is used to make fertilisers.

nitrogen + hydrogen ⇋ ammonia

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

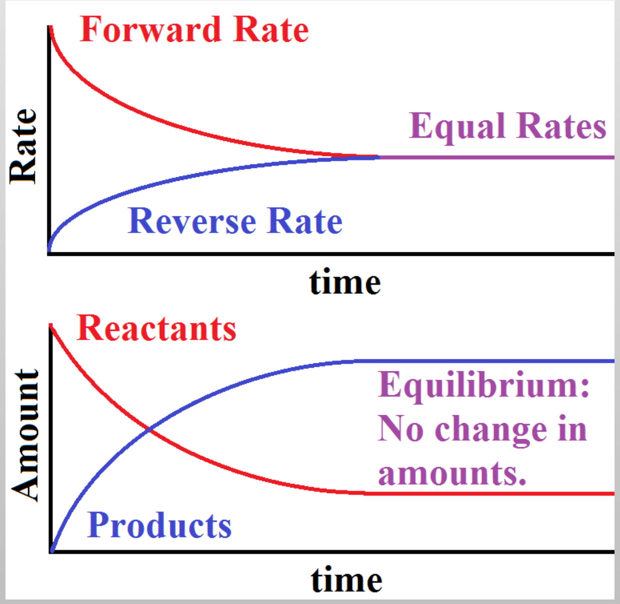
Increasing the pressure will shift the equilibrium to the side with fewest molecules of gas which in this case is towards the right (since there are 4 molecules on the left & 2 molecules on the right).

Further examples of reversible reactions and dynamic equilibrium

$$H_{2\,(g)} + I_{2\,(g)} \rightleftharpoons 2HI_{(g)}$$

If you increase the pressure in this reaction, it will have no effect on the position of equilibrium as there are an equal number of molecules of gas on either side (2 each).

However remember that increasing the pressure of reaction involving gases will speed up the reaction on both sides as you will increase the frequency of collisions.



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