Topic 4 – Chemical Change

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Topic 4 – Chemical Change

Sub Topics

- Acids and Bases
- Titrations
- Strong Acids, Weak Acids and their reactions
- Metals and their reactivity
- Redox reactions
- Electrolysis

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Reactions of acids with metals

Acids react with some metals to produce a salt and hydrogen:

acid + metal → salt + hydrogen

These are redox reactions – i.e. one substance is reduced and another substance is oxidised

Need to identify which substances are which by looking at electrons gained and lost (following OIL RIG)

e.g. $2HCl + Mg \rightarrow MgCl_2 + H_2$

magnesium: $Mg \rightarrow Mg^{2+}$, ionic equation is $Mg \rightarrow Mg^{2+} + 2e^-$, Mg has lost electrons so has been oxidised

hydrogen: $2H^+ \rightarrow H_2$, ionic equation is $2H^+ + 2e^- \rightarrow H_2$, H has gained electrons, so H has been reduced

Because magnesium has been oxidised and hydrogen has been reduced in the same reaction, this is a redox reaction

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Neutralisation of acids and salt production

Acids are neutralised by alkalis (e.g soluble metal hydroxides) and bases (e.g. insoluble metal hydroxides and metal oxides) to produce salts and water

acid + alkali → salt + water

acid + base → salt + water

acids are neutralised by metal carbonates to produce salts, water and carbon dioxide

acid + metal carbonate → salt + water + carbon dioxide

The salt produced…

- In alkali and base reactions depends on the acid used…
  - Hydrochloric acid (HCl) produces chlorides (XCl)
  - Nitric acid (HNO_3) produces nitrates (XNO_3)
  - Sulfuric acid (H_2SO_4) produces sulfates (XSO_4)
- It also depends on the positive ions in the base, alkali or carbonate i.e. the metal (which is the X in the salts above).
- remember : the charges on the positive ion from the base/alkali/carbonate and the negative ion from the acid must add up to zero.
  e.g. if you have sodium hydroxide and sulfuric acid, you have Na^+ ions and SO_4^{2-} ions, so you need 2x Na^+ ions, giving you the salt: Na_2SO_4 the charges on the ions from acids are: Cl^- , NO_3^- and SO_4^{2-}

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Soluble salts

They can be made from acids by reacting them with solid insoluble substances, such as metals, metal oxides, hydroxides or carbonates:

1. Add the chosen solid insoluble substance to the acid then the solid will dissolve.
2. You know the acid has been neutralised when excess solid sinks to the bottom, so keep adding until this happens
3. Filter out excess solid leaving the salt solution, then evaporate some water, then
4. leave the rest to evaporate slowly.

This is called crystallisation

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The pH scale and neutralisation

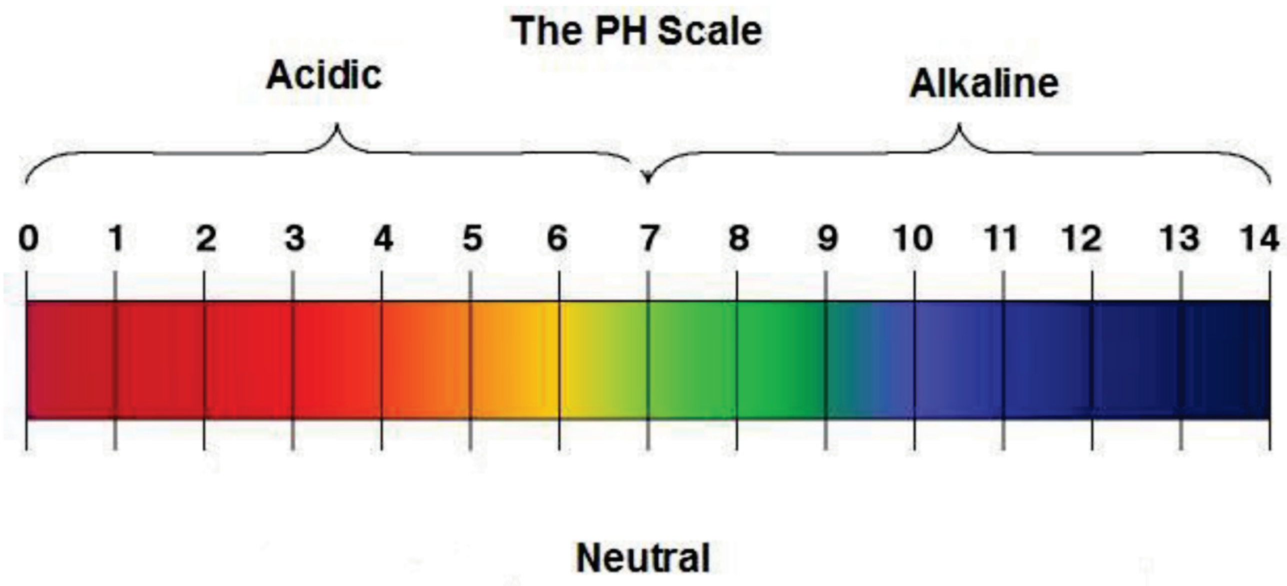
Acids produce H^+ ions in aqueous solutions

Alkalis produce OH^- ions in aqueous solutions

The pH scale (0 to 14) measures the acidity or alkalinity of a solution, and can be measured using universal indicator of a pH probe

- pH 7 is neutral
- pH < 7 is acidic
- pH > 7 is alkaline

$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$ is the ionic equation of any neutralisation reaction



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Titrations

The volumes of acid and alkali solutions that react with each other can be measured by titration using a suitable indicator.

How to carry out a titration:

1. Wash burette using dilute hydrochloric acid and then water
2. Fill burette to 100 cm^3 with acid with the meniscus' base on the 100 cm^3 line
3. Use 25 cm^3 pipette to add 25 cm^3 of alkali into a conical flask, drawing alkali into the pipette using a pipette filler
4. Add a few drops of a suitable indicator to the conical flask (e.g. : phenolphthalein which is pink when alkaline and colourless when acidic)
5. Add acid from burette to alkali until end-point is reached (as shown by indicator)
6. The titre (volume of acid needed to exactly neutralise the acid) is the difference between the first (100 cm^3) and second readings on the burette
7. Repeat the experiment to gain more precise results

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Titration Calculations

Titration calculations

1 dm^3 = 1000 cm^3

One mole of a substance in grams the same as its relative atomic mass in grams.

Working out concentrations:

E.g 25 cm^3 of dilute hydrochloric acid is neutralised by 20 cm^3 of 0.5 mol/dm^3 sodium hydroxide. What is the concentration of the hydrochloric acid?

1. Convert volumes into dm^3.

    25/1000 = 0.025dm^3 20/1000 = 0.02dm^3

2. Work out the moles of NaOH

    moles = volume x concentration

    So, 0.02 x 0.5 = 0.01 mol

3. Work out mole ratio from equation

    $HCl + NaOH \rightarrow H_2O + NaCl$

    1:1 ratio, so moles of NaOH = moles of HCl, so moles of HCl=0.01 mol

4. Work out concentration

    conc = moles / vol = 0.01 / 0.025 = 0.4 mol dm^{-3}

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Strong and weak acids

Strong acid = completely ionised in aqueous solution
e.g. hydrochloric, nitric and sulfuric acids

Weak acid = partially ionised in aqueous solution
Ethanoic, citric and carbonic acids

Stronger an acid, lower the pH (for a given conc. of aq. solutions)
As the pH decreases by one unit, the H^+ conc. of the solution increases by a factor of 10.

Strong and weak is NOT the same as concentrated and dilute – the latter refers to the amount of substance in a given volume , whereas the former refers to the H^+ ion conc in aq. solutions

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Reactivity of metals

Metal oxides

Metals + oxygen → metal oxides

Known as oxidation reactions because the metals gain oxygen

Reduction = loss of oxygen & oxidation= gain of oxygen

The reactivity series

- When metals react with other substances, metal atoms form positive ions
- Reactivity of a metal is related to its tendency to form positive ions
- Metals can be arranged in order of their reactivity in a reactivity series
  - Metals potassium, sodium, lithium, calcium, magnesium, zinc, iron and copper can be put in order of their reactivity from their reactions with water and dilute acids:

element	reaction with water
potassium	violent
sodium	very quick
lithium	quick
calcium	more slow

element	reaction with dilute acid
calcium	very quick
magnesium	quick
zinc	fairly slow
iron	more slow
copper	very slow

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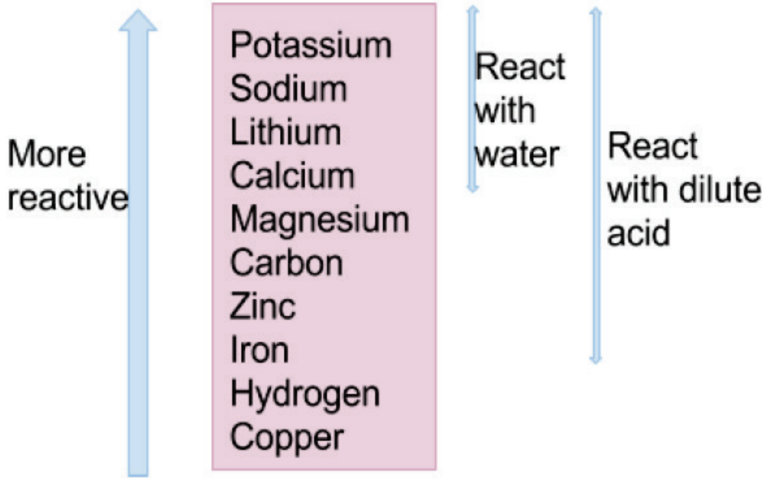
Reactivity of metals

Non-metals hydrogen and carbon are often included in the reactivity series
A more reactive metal can displace a less reactive metals from a compound
(think about how this is similar as well to halogens)

Extraction of metals and reduction

- Gold, since it is very unreactive, it is found in the Earth as the metal itself
- But, most metals are found as compounds that require chemical reactions to extract the metal
- Metals less reactive than carbon can be extracted from their oxides by reduction with carbon
  - Don't forget: reduction involves the loss of oxygen



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Oxidation and reduction in terms of electrons

Remember this phrase: OIL RIG , it stands for O xidation I s L oss and R eduction I s G ain (of electrons)

to write ionic equations:

if sodium is oxidised, it has lost an electron, leaving it with a +1 charge, so the ionic equation is: $Na \rightarrow Na^{+} + e^{-}$

if sodium +1 ion is reduced, it has gained an electron, leaving it with a charge of zero, so the ionic equation is: $Na^{+} + e^{-} \rightarrow Na$

remember: the charges on each side of the equation should add up to the same number

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Oxidation and reduction in terms of electrons

to be able to tell which element has been oxidised and which has been reduced in an equation:
e.g. $2Na + 2HCl \rightarrow 2NaCl + H_2$

HCl is made up of H^+ and Cl^- ions & NaCl is made up of Na^+ and Cl^- ions

- looking at just sodium: $2Na \rightarrow 2Na^+$, so the ionic equation must be: $2Na \rightarrow 2Na^+ + 2e^-$, meaning sodium has lost electrons & has been oxidised
- looking at just chlorine: $2Cl^- \rightarrow 2Cl^-$, meaning chlorine has not been oxidised or reduced
- looking at just hydrogen: $2H^+ \rightarrow H_2$, so the ionic equation must be:
- $2H^+ + 2e^- \rightarrow H_2$, meaning hydrogen has gained electrons so has been Reduced