IGCSE CHEMISTRY 0620 · CHAPTER 7 NOTES · ~14 MIN READ

Acids, bases & salts

The pH scale and indicators, what acids do to metals, bases and carbonates, how neutralisation works at ion level — and the right method for making any salt.

pH & indicators | Reactions of acids | Oxides | Making salts | Solubility rules

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No tag = **Core** (everyone) EXTENDED Extended only highlight = comes up again and again

Test yourself at the end

IN 30 SECONDS

- **Acids** produce **H^+(aq)**. **Alkalis** produce **OH^-(aq)**. The **pH scale** runs from 0 (strong acid) through 7 (neutral) to 14 (strong alkali).
- Acid + metal → **salt + hydrogen**. Acid + base → **salt + water**. Acid + carbonate → **salt + water + carbon dioxide**.
- **Neutralisation** is $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$.
- Pick the method for a salt from its **solubility**: soluble → acid + solid or titration; insoluble → **precipitation**.

BY THE END YOU CAN

- Use indicators and the pH scale, and describe the typical reactions of acids and bases.
- Write equations for neutralisation, and the ionic equation for it.
- Classify oxides as acidic, basic or amphoteric.
- Recall the solubility rules and choose a method to make a named salt.
- Explain strong and weak acids, and the idea of proton donors and acceptors. EXT

1 Acids, bases and alkalis

What they are

Acid — a substance that produces **H^+ ions** in aqueous solution. EXT An acid is a **proton donor**.

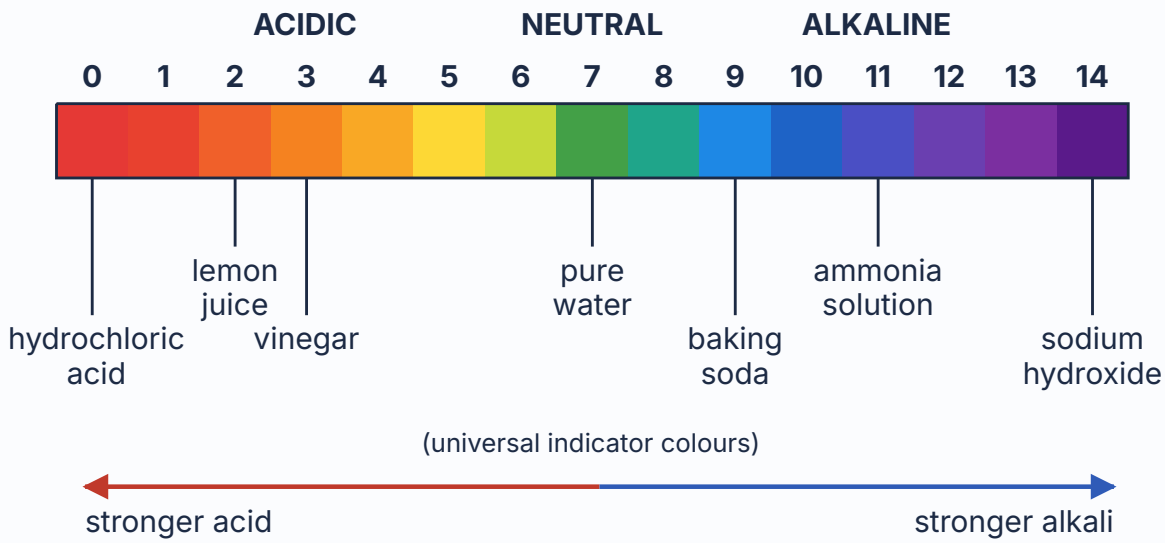
Base — a substance that reacts with an acid to form a salt and water — usually a **metal oxide or hydroxide**. EXT A base is a **proton acceptor**.

Alkali — a base that dissolves in water to produce **OH^- ions**. Every alkali is a base, but most bases are insoluble in water.

	Examples
acids	hydrochloric HCl, sulfuric H_2SO_4, nitric HNO_3, ethanoic CH_3COOH
alkalis	sodium hydroxide NaOH, potassium hydroxide KOH, calcium hydroxide $Ca(OH)_2$, ammonia solution $NH_3(aq)$
bases that are not alkalis	copper(II) oxide CuO, magnesium oxide MgO, iron(III) oxide Fe_2O_3

- EXT A proton is a hydrogen ion H^+. In $HCl + NH_3 \rightarrow NH_4^+ + Cl^-$, HCl **gives** an H^+ (donor) and NH_3 **takes** it (acceptor).

pH and indicators



The pH scale and the universal indicator colours. Lower pH = more acidic. Higher pH = more alkaline.

- **pH 0–6** acidic, **pH 7** neutral, **pH 8–14** alkaline.
- **Universal indicator** is a mixture of dyes that gives a different colour at each pH. A **pH meter** gives a more accurate reading.

Indicator	In acid	Neutral	In alkali
litmus	red	purple	blue
methyl orange	red	yellow	yellow
thymolphthalein	colourless	colourless	blue
phenolphthalein	colourless	colourless	pink
universal indicator	red, orange, yellow	green	blue, purple

MEMORY TRICK

Acids turn litmus **R**ed (A → R). **B**ases turn it **B**lue (B → B).

- Methyl orange changes colour at about pH 4, so it can tell a strong acid from everything else, but it cannot tell a neutral solution from an alkaline one.

EXAM TIP

Learn the colours of **three** indicators in acid and alkali: litmus, methyl orange and one of the "phthaleins". Say "turns **red** in acid" — not "goes red-ish".

COMMON MISTAKE

"Acids have a pH of 0 and alkalis of 14." pH 0 and pH 14 are the extremes. Any pH **below 7** is acidic and any **above 7** is alkaline.

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Reactions of acids

Acid + ...	Products	Observations
a metal	salt + hydrogen	fizzing, the metal dissolves; hydrogen gives a squeaky pop
a base (metal oxide or hydroxide)	salt + water	black CuO dissolves to give a blue solution
a carbonate	salt + water + carbon dioxide	fizzing; CO_2 turns limewater milky

- The **salt** depends on the acid: hydrochloric acid → **chlorides**, sulfuric acid → **sulfates**, nitric acid → **nitrates**, ethanoic acid → **ethanoates**.
- A base can also react with an **ammonium salt**: ammonium salt + alkali → salt + water + **ammonia gas** (pungent; turns damp red litmus blue). This releases ammonia from fertilisers.

WORKED EXAMPLE

Complete and balance: (a) $Mg + H_2SO_4$ → (b) $CuO + HNO_3$ → (c) $Na_2CO_3 + HCl$ →

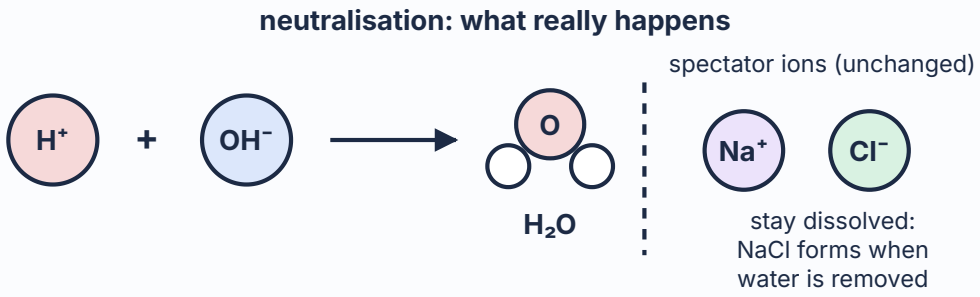
1. (a) metal + acid gives salt + hydrogen: **$Mg + H_2SO_4 \rightarrow MgSO_4 + H_2$**
2. (b) base + acid gives salt + water: **$CuO + 2HNO_3 \rightarrow Cu(NO_3)_2 + H_2O$**
3. **(c) carbonate + acid gives salt + water + CO_2: $Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$**

WORKED EXAMPLE

Write the equation for the reaction between ammonium chloride and sodium hydroxide.

1. ammonium salt + alkali → salt + water + ammonia
2. **$NH_4Cl + NaOH \rightarrow NaCl + H_2O + NH_3$**

Neutralisation



acid + alkali → salt + water

$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

ionic equation: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

it is exothermic: the temperature rises
neutral when H^+ and OH^- are in equal amounts (pH 7)

Neutralisation. H^+ from the acid and OH^- from the alkali combine to form water. The other ions (Na^+ and Cl^-) are spectator ions.

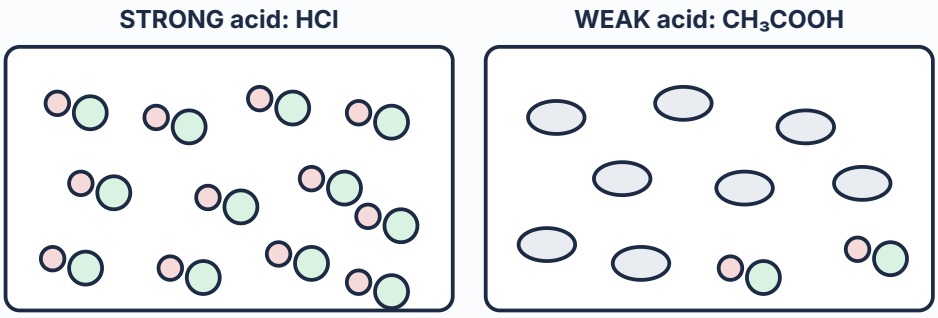
$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

ionic equation for neutralisation (acid + alkali)

- Neutralisation is **exothermic** — the temperature rises.
- The solution is exactly neutral (pH 7) when the amounts of H^+ and OH^- are equal.
- Uses: indigestion tablets (bases neutralise stomach acid), adding **lime** (calcium hydroxide) to acidic soil or lakes, treating acidic waste.

Strong and weak acids

EXTENDED



strong/weak = how much it ionises · concentrated/dilute = how much acid is dissolved

A strong acid splits up completely into ions. A weak acid splits up only a little (a reversible reaction). Strength is not the same as concentration.

- **Strong acid:** completely ionised (dissociated) in water, for example **HCl → H^+ + Cl^-**. Others: H_2SO_4, HNO_3.
- **Weak acid:** only partially ionised. A reversible reaction: **$CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$**. Others: citric acid, carbonic acid.
- For the **same concentration**, a strong acid has a **lower pH**, conducts better and reacts faster with magnesium than a weak acid.
- **Strong/weak** says how much the acid ionises. **Concentrated/dilute** says how much acid is dissolved. They are not the same thing.

WORKED EXAMPLE

EXT **25 cm^3 of 0.10 mol/dm^3 hydrochloric acid and 25 cm^3 of 0.10 mol/dm^3 ethanoic acid each react with excess magnesium. Compare (a) the starting rate and (b) the final volume of hydrogen.**

1. (a) hydrochloric acid starts faster — it is fully ionised, so it has a higher H^+ concentration
2. (b) both have the **same** number of moles of acid (0.0025 mol)
3. **each gives the same final volume of hydrogen, because the weak acid keeps ionising as H^+ is used up**

COMMON MISTAKE

"A strong acid is a concentrated acid." A **dilute** acid can still be strong. Strength is about ionisation.

2 Oxides

Acidic, basic and amphoteric oxides

Acidic oxide — an oxide of a **non-metal**. It reacts with bases and alkalis to form a salt. Examples: CO_2, SO_2, NO_2, SiO_2, P_4O_{10}.

Basic oxide — an oxide of a **metal**. It reacts with acids to form a salt and water. Examples: CuO, MgO, CaO, Na_2O.

Amphoteric oxide EXT — an oxide that reacts with **both** acids and bases. Examples: **aluminium oxide (Al_2O_3)** and **zinc oxide (ZnO)**.

- **Metal oxides are basic, non-metal oxides are acidic.** A few non-metal oxides (carbon monoxide CO, nitrogen monoxide NO and water) are **neutral**.
- Soluble acidic oxides make acids: $SO_2 + H_2O \rightarrow H_2SO_3$ (this is part of acid rain). Soluble basic oxides make alkalis: $Na_2O + H_2O \rightarrow 2NaOH$.
- $CO_2 + 2NaOH \rightarrow Na_2CO_3 + H_2O$ (an acidic oxide reacting with an alkali).
- EXT Amphoteric: $ZnO + 2HCl \rightarrow ZnCl_2 + H_2O$ (acting as a base), and it also dissolves in sodium hydroxide solution (acting as an acid). You do not need the full equation for the alkali reaction.

EXAM TIP

The idea to remember: **position in the Periodic Table decides the oxide type** — far left basic, middle amphoteric (Al), right acidic. See the Periodic Table chapter.

COMMON MISTAKE

Writing "all metal oxides are basic". Aluminium and zinc oxides are **amphoteric**.

3 Making salts

What is a salt?

Salt — a compound formed when the H^+ of an acid is replaced by a metal ion or the ammonium ion (NH_4^+).

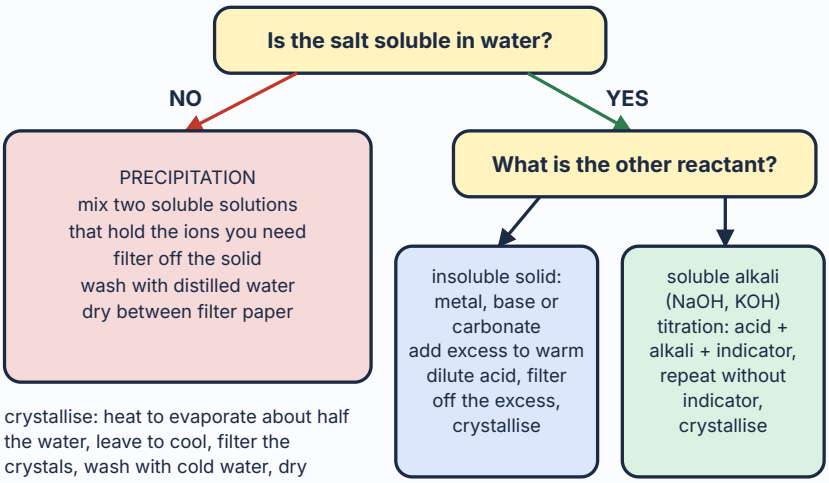
Solubility rules

Compound	Solubility in water
all sodium, potassium and ammonium salts	soluble
all nitrates	soluble
chlorides	soluble, **except** silver chloride and lead(II) chloride
sulfates	soluble, **except** barium, calcium and lead(II) sulfates
carbonates	**insoluble**, except sodium, potassium and ammonium carbonates
hydroxides	**insoluble**, except sodium, potassium (and calcium, slightly soluble)

MEMORY TRICK

SPAN — **S**odium, **P**otassium, **A**mmonium and **N**itrates: always soluble.

Which method?



always make sure the acid is fully used up or the solid is in excess

Choosing a method. First ask whether the salt is soluble. If yes, the method depends on the other reactant. If no, use precipitation.

- **Method A — a soluble salt from an insoluble solid (metal, base or carbonate):** warm some dilute acid and add the solid **in excess** until no more reacts (no more fizzing or the solid stays). **Filter** off the excess solid. **Crystallise** the filtrate (below).
- **Method B — a soluble salt from an alkali (titration):** use a pipette to put a known volume (25.0 cm^3) of alkali in a flask with an **indicator**. Add acid from a **burette** until the indicator **changes colour**. Note the volume. **Repeat without indicator** using exactly the same volumes, then crystallise.
- **Method C — an insoluble salt (precipitation)** EXT **:** mix two **soluble** salt solutions that contain the ions you need. The insoluble salt forms as a **precipitate**. **Filter**, **wash with distilled water** to remove soluble impurities and **dry** between filter papers.
- **Crystallisation:** heat the solution to **evaporate about half the water** (until a drop on a cold glass rod forms crystals), then leave it to cool slowly. Filter off the crystals, wash with a little cold water and dry.
- Metals only work if they are **moderately reactive** (Mg, Zn, Fe). Potassium and sodium are far too dangerous, and copper does not react with dilute acids.

WORKED EXAMPLE

Name the method and the chemicals you would use to make (a) copper(II) sulfate, (b) sodium nitrate, (c) barium sulfate.

1. (a) copper(II) oxide is an insoluble base, and copper(II) sulfate is soluble → **Method A**: excess CuO + warm dilute sulfuric acid, filter, crystallise. $CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$
2. (b) sodium hydroxide is a soluble alkali → **Method B**: titrate NaOH with nitric acid, repeat without indicator, crystallise. $NaOH + HNO_3 \rightarrow NaNO_3 + H_2O$
3. **(c) barium sulfate is insoluble → Method C, precipitation: barium chloride solution + sodium sulfate solution. $BaCl_2 + Na_2SO_4 \rightarrow BaSO_4 + 2NaCl$**

WORKED EXAMPLE

EXT **Write the ionic equation for the precipitation of barium sulfate.**

1. $BaCl_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaCl(aq)$
2. Cl^- and Na^+ are the same on both sides (spectator ions)
3. **$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$**

EXAM TIP

Explain why you use **excess** solid: it makes sure all of the acid is used up, so the filtrate is the pure salt solution. The excess can be filtered off because it does not dissolve.

COMMON MISTAKE

"Evaporate to dryness." If you heat until it is dry, you may lose the water of crystallisation and the crystals will be small and powdery. **Crystallise** by evaporating only part of the water.

COMMON MISTAKE

Not repeating the titration without the indicator. The indicator would contaminate the salt.

Hydrated and anhydrous salts

Hydrated — containing water of crystallisation (water bonded into the crystal in a fixed ratio). Example: $CuSO_4 \cdot 5H_2O$.

Anhydrous — containing no water of crystallisation. Example: $CuSO_4$ (white).

- Hydrated crystals lose their water of crystallisation when heated, and the colour may change: blue $CuSO_4 \cdot 5H_2O$ → white $CuSO_4$ (see reversible reactions).

WORKED EXAMPLE

EXT **2.46 g of hydrated magnesium sulfate, $MgSO_4 \cdot xH_2O$, is heated until all of the water has gone. 1.20 g of anhydrous $MgSO_4$ is left. Find x. (Mr of $MgSO_4$ = 120, Mr of H_2O = 18)**

1. mass of water lost = 2.46 − 1.20 = 1.26 g
2. moles of $MgSO_4$ = 1.20 ÷ 120 = 0.010 mol
3. moles of H_2O = 1.26 ÷ 18 = 0.070 mol
4. ratio $MgSO_4$: H_2O = 0.010 : 0.070 = 1 : 7
5. **x = 7, so $MgSO_4 \cdot 7H_2O$**

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4 Test yourself

Test yourself — cover the answers first

QUICK CHECK

1. What ion do all acids produce in water?
2. What colour does litmus turn in alkali?
3. Complete: acid + carbonate → ?
4. Give the ionic equation for neutralisation.
5. Are metal oxides acidic or basic?
6. Is silver chloride soluble or insoluble?
7. EXT Name an amphoteric oxide.
8. EXT What is the difference between a strong acid and a concentrated acid?

EXAM-STYLE

9. Describe how to make crystals of zinc sulfate from zinc oxide. [5]
10. EXT Describe how to make a pure, dry sample of lead(II) iodide. [4]
11. EXT Explain why a solution of 0.1 mol/dm³ ethanoic acid has a higher pH than 0.1 mol/dm³ hydrochloric acid. [2]
12. Magnesium reacts with dilute hydrochloric acid. Name the gas, describe the test, and write the balanced equation. [3]

Show answers

1. H^+
2. blue
3. salt + water + carbon dioxide
4. $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$
5. basic (except amphoteric ones)
6. insoluble
7. aluminium oxide / zinc oxide
8. strong = fully ionised in water; concentrated = a lot of acid dissolved per dm³
9. warm dilute sulfuric acid, and add zinc oxide until in excess
   filter off the unreacted zinc oxide
   heat the filtrate to evaporate about half the water
   leave to cool so that crystals form
   filter, wash and dry the crystals
10. mix lead(II) nitrate solution and potassium iodide solution
    lead(II) iodide forms as a yellow precipitate
    filter it off and wash with distilled water
    dry in a warm oven or between filter papers
11. ethanoic acid is a weak acid — only partly ionised, so a lower concentration of H^+ ions
    hydrochloric acid is strong and fully ionised
12. hydrogen
    lit splint gives a squeaky pop
    $Mg + 2HCl \rightarrow MgCl_2 + H_2$

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