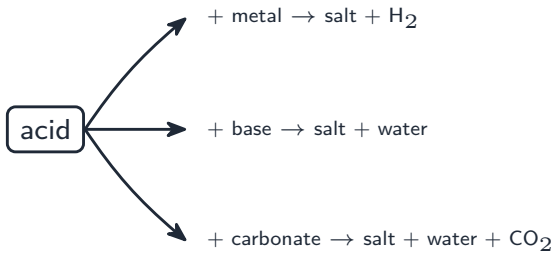
Acids, bases and salts

IGCSE Chemistry

Acids

An **acid** 酸 is a substance that forms hydrogen ions (H^+) when dissolved in water. Acids have three typical reactions:



Acids react with metals, bases and carbonates to give different products

- with **metals** 金属: acid + metal → a **salt** 盐 + **hydrogen** 氢气
- with bases: acid + **base** 碱 → a salt + water (this is **neutralisation** 中和)
- with **carbonates** 碳酸盐: acid + carbonate → a salt + water + **carbon dioxide** 二氧化碳

Describing what you see

Naming the products is only half of what the exam wants. "State the observations" asks what you would **see with your eyes**, and it carries its own marks - so learn the words:

You see	Say
bubbles of gas coming off	**effervescence** 泡腾 (also accepted: fizzing, bubbling)
the solid getting smaller and vanishing	the solid **dissolves** / **disappears**
the colour of the solution changing	name the colour, e.g. turns **blue** (copper salts)
bubbling that stops	**no more effervescence** - the acid is used up

So for magnesium added to hydrochloric acid, a full answer is: **effervescence**, and the **solid dissolves** (and the tube gets warm). For copper(II) oxide added to warm sulfuric acid: the black solid **dissolves** and the solution **turns blue**.

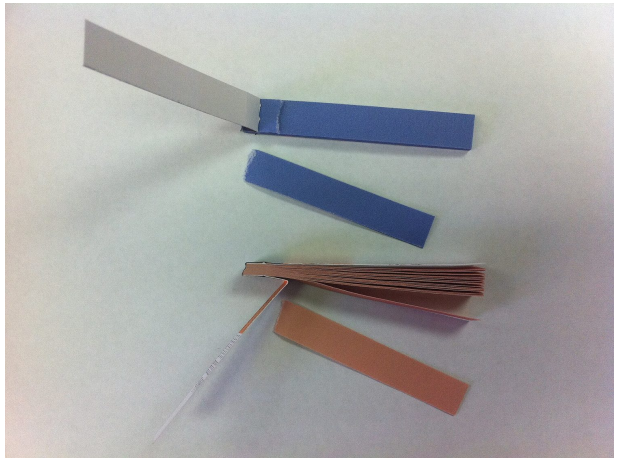
Two rules save most of the lost marks. **Never write "hydrogen is given off" as an observation** - you cannot see hydrogen, you can only see the bubbles, so write *effervescence*. And **do not write a name you cannot see**: "a salt forms" is a conclusion, not an observation.

Indicators

An **indicator** 指示剂 is a dye that changes colour to show whether a solution is acidic or alkaline.

Indicator	In acid	In alkali
litmus 石蕊	red	blue
thymolphthalein 百里酚酞	colourless	blue
methyl orange 甲基橙	red	yellow

Aqueous solutions of acids contain hydrogen **ions** 离子 (H^+). Aqueous solutions of alkalis contain hydroxide ions (OH^-).



Litmus paper: blue litmus turns red in an acid, and red litmus turns blue in an alkali

Bases and alkalis

Bases are **oxides** 氧化物 or **hydroxides** 氢氧化物 of metals. An **alkali** 可溶性碱 is a base that dissolves in water (a soluble base).

Bases have two typical reactions:

- with acids: base + acid → a salt + water (neutralisation again)

- with **ammonium salts** 铵盐: this releases ammonia gas.

pH strips: alkalis turn universal indicator purple or blue (pH > 7)

Strong and weak acids

An acid is a **proton** 质子 donor — it gives away H^+ ions (a hydrogen ion is just a proton). A base is a proton acceptor.

How strong an acid is depends on how much of it splits into ions in water:

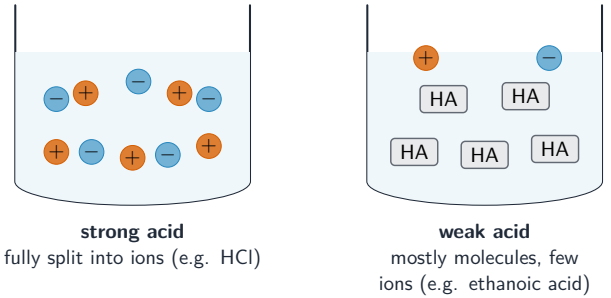
- A **strong acid** 强酸 is completely **dissociated** 电离 (fully split into ions) in water. **Hydrochloric acid** 盐酸 is strong:

$$HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$$

- A **weak acid** 弱酸 is only partly dissociated. **Ethanoic acid** 乙酸 is weak, so the equation uses the reversible arrow:

$$CH_3COOH(aq) \rightleftharpoons H^+(aq) + CH_3COO^-(aq)$$

Note: 'strong' and 'weak' are about dissociation, not about being dilute or concentrated.



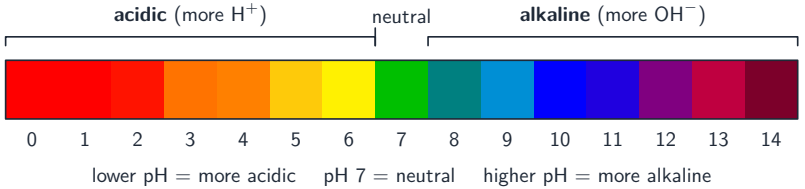
A strong acid is fully split into ions; a weak acid stays mostly as molecules (only partly dissociated)

The pH scale

The pH scale runs from 0 to 14 and tells you how acidic or alkaline a solution is. A higher hydrogen ion concentration means a lower pH.

You can find pH using **universal indicator** 通用指示剂, which turns different colours:

pH	Type	Colour of universal indicator
below 7	**acidic** 酸性	red / orange / yellow
exactly 7	**neutral** 中性	green
above 7	**alkaline** 碱性	blue / purple



Universal indicator turns red in a strong acid, green at neutral (pH 7), and purple in a strong alkali

When an acid and an alkali react, the H^+ and OH^- ions join to make water:

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

Oxides

Oxides can be sorted by how they behave:

- **Acidic oxides** are oxides of non-metals, such as SO_2 and CO_2.
- **Basic oxides** are oxides of metals, such as CuO and CaO.
- **Amphoteric** 两性 oxides react with both acids and bases to make a salt and water. Al_2O_3 and ZnO are amphoteric.

So metal oxides tend to be basic and non-metal oxides tend to be acidic.

Limestone is mostly calcium carbonate — a metal carbonate that acts as a base and neutralises acids

Preparing salts

Whether a salt can be made by a certain method depends on whether it is **soluble** 可溶 (dissolves) or **insoluble** 不溶 (does not dissolve).

Solubility rules

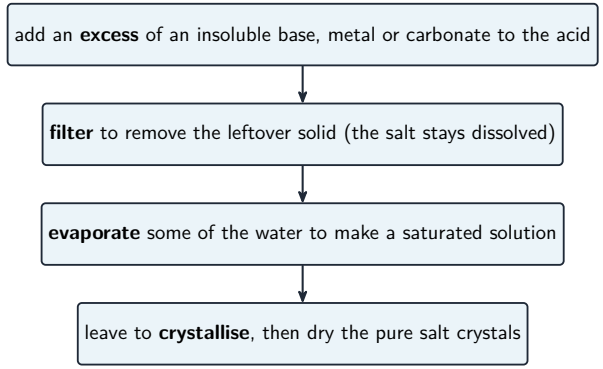
Salt type	Rule
sodium, potassium, ammonium salts	all soluble
nitrates 硝酸盐	all soluble
chlorides 氯化物	soluble, except lead and silver
sulfates 硫酸盐	soluble, except barium, calcium and lead
carbonates	insoluble, except sodium, potassium and ammonium
hydroxides	insoluble, except sodium, potassium, ammonium and (partly) calcium

Making a soluble salt

You react an acid with one of these:

- an **alkali**, using **titration** 滴定 (since both are solutions, you must measure the exact volumes);
- an **excess** 过量 of a metal, an insoluble base, or an insoluble carbonate.

When you use an excess of a solid, you then **filter** 过滤 to remove the leftover solid. Finally you **evaporate** 蒸发 some water and let the solution **crystallise** 结晶 to get the salt.



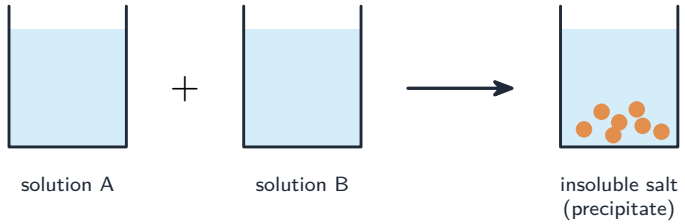
Making a soluble salt from an insoluble solid: react with excess, filter off the excess, evaporate, then crystallise

Letting the solution crystallise slowly gives well-shaped crystals — here, the blue crystals of copper(II) sulfate

Worked example. Which method would you use to prepare (a) copper(II) sulfate and (b) barium sulfate? Check the solubility rules first. (a) Copper(II) sulfate is **soluble** (only barium, calcium and lead sulfates are not), so make it from an insoluble solid and an acid: add **excess** copper(II) oxide to warm dilute sulfuric acid, **filter** off the leftover solid, then evaporate some water and crystallise. (b) Barium sulfate is **insoluble**, so make it by **precipitation**: mix two solutions that each carry one of the needed ions, then filter, wash and dry the solid. The solubility of the salt you want is what decides the method - consult the rules before you choose.

Making an insoluble salt

An insoluble salt is made by **precipitation** 沉淀: mix two solutions that each contain one of the needed ions, and the insoluble salt forms as a solid. You then filter, wash and dry it.



Mixing two solutions that each carry one of the needed ions makes the insoluble salt appear as a solid precipitate, which you then filter off

Water in salts

- A **hydrated** 水合 substance is chemically joined with water.
- An **anhydrous** 无水 substance contains no water.

The water molecules inside hydrated crystals are called the **water of crystallisation** 结晶水. For example, $CuSO_4 \bullet 5H_2O$ has five water molecules for each formula unit.

Exam tips

- Learn the three acid reactions: acid + metal → salt + hydrogen; acid + base → salt + water (neutralisation); acid + carbonate → salt + water + carbon dioxide.
- **Strong** and **weak** describe how much the acid splits into ions (dissociation), *not* how concentrated it is. A strong acid is fully dissociated; a weak acid only partly.
- A lower **pH** means a higher hydrogen-ion concentration. pH 7 is neutral, below 7 is acidic, above 7 is alkaline.
- Choose the salt method by solubility: a **soluble** salt is made from an acid + excess solid (then filter, evaporate, crystallise), or by titration with an alkali; an **insoluble** salt is made by precipitation (mix two solutions, then filter).
- Learn the solubility rules — all sodium, potassium, ammonium and nitrate salts are soluble.