08 Acids and Bases



1 Acids

1.1 What an acid is

DEFINITION An **acid** is a substance that produces _____, in aqueous solution.

Acid	Formula	Ions in aqueous solution
hydrochloric acid	HCl	H^+ and Cl^-
nitric acid	HNO_3	H^+ and NO_3^-
sulfuric acid	H_2SO_4	H^+ and SO_4^{2-}
ethanoic acid	CH_3COOH	H^+ and CH_3COO^-

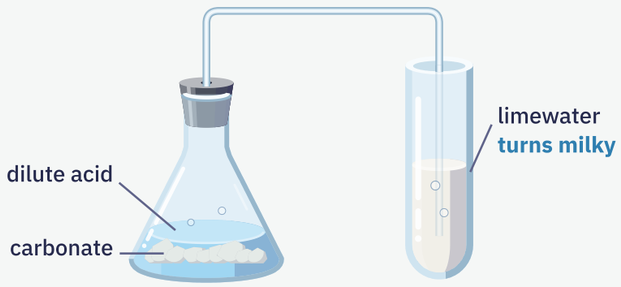
- Acids ionise only when dissolved in water. A solid acid such as citric acid does not conduct electricity, but its _____ solution does, because it contains mobile ions.
- Acids taste sour, turn blue litmus paper _____ and have a pH below 7.

1.2 Reactions of acids

Acid reacts with	Products	Example
a reactive **metal**	salt + _____	$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$
a **base**	salt + water	$MgO(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2O(l)$
a **carbonate**	salt + water + _____	$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$



hydrogen extinguishes a lighted splint with a pop



carbon dioxide turns limewater milky

- Sulfuric acid forms **sulfates**, nitric acid forms **nitrates** and hydrochloric acid forms **chlorides**.
- Unreactive metals such as copper and silver do not react with dilute acids.

NOTE Lead seems not to react with hydrochloric acid or sulfuric acid. The first reaction forms insoluble lead(II) chloride or lead(II) sulfate, which coats the lead and stops further reaction.

1 Acids (continued)

1.3 Strong and weak acids

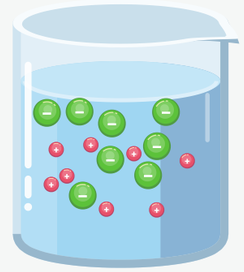
DEFINITION A **strong acid** is _____ ionised in aqueous solution, e.g. hydrochloric, nitric and sulfuric acids.

DEFINITION A **weak acid** is only _____ ionised in aqueous solution, e.g. ethanoic acid and citric acid.

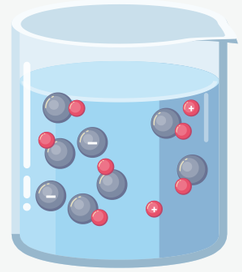
$HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$

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

- The ⇌ sign shows a reversible reaction: the ions keep re-forming molecules.
- **Strength** is how much of the acid ionises. **Concentration** is how much acid is dissolved in a given volume of water. A strong acid can be dilute, and a weak acid can be concentrated.



hydrochloric acid: all ions



ethanoic acid: mostly molecules

2 Bases and Alkalis

2.1 Bases and alkalis

DEFINITION A **base** is a metal oxide or metal hydroxide. An **alkali** is a base that is _____ in water and produces _____, in aqueous solution.

Bases that do not dissolve in water

CuO, ZnO, $Mg(OH)_2$ and most other metal oxides and hydroxides

Alkalis: bases that dissolve

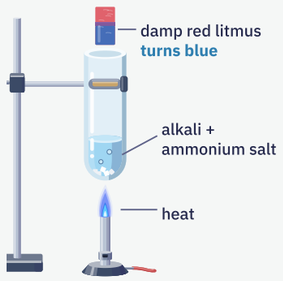
$NaOH$, KOH, $Ca(OH)_2$ and $NH_3(aq)$, clear solutions containing OH^- ions

- Alkalis taste bitter, feel soapy, turn red litmus paper _____ and have a pH above 7.
- Sodium hydroxide is a **strong** alkali: it is completely ionised. Aqueous ammonia is a **weak** alkali: $NH_3(g) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$.

2.2 Reactions of bases

Neutralisation is the reaction between hydrogen ions and hydroxide ions to produce water:
$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

Base reacts with	Products	Example
an **acid**	salt + _____	$2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$
an **ammonium salt** (alkalis, on heating)	salt + water + _____	$KOH(aq) + NH_4Cl(s) \rightarrow KCl(aq) + H_2O(l) + NH_3(g)$



- Ammonia has a pungent smell. It turns **damp red litmus paper blue**.
- An insoluble base reacts with the H^+ ions of an acid, e.g. $CuO(s) + 2H^+(aq) \rightarrow Cu^{2+}(aq) + H_2O(l)$.

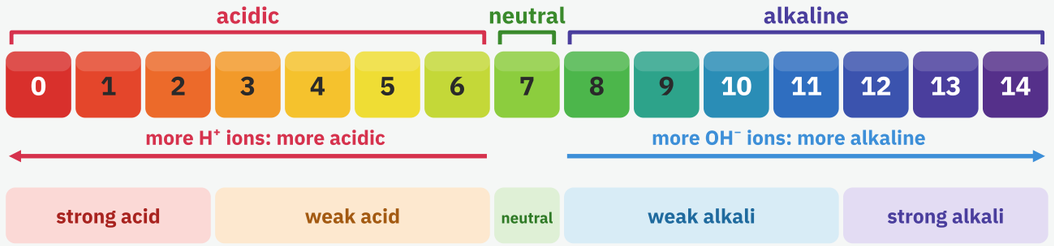
WORKED EXAMPLE Milk of magnesia contains magnesium hydroxide. Write the equation for its reaction with hydrochloric acid in the stomach.

Base + acid → salt + water. The salt is magnesium chloride, $MgCl_2$.

$Mg(OH)_2(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$

3 The pH Scale

3.1 pH and Universal Indicator



pH	Ion concentrations	Solution	Universal Indicator
below 7	more H^+ than OH^-	_____	red, orange or yellow
7	H^+ and OH^- equal	neutral	_____
above 7	more OH^- than H^+	_____	blue, then violet

- The _____ the pH, the higher the concentration of H^+ ions. A solution of pH 4 has 1000 times more H^+ ions than one of pH 7.
- pH is measured with Universal Indicator (paper or solution), a pH meter, or a pH sensor connected to a data logger.

3.2 Other indicators

Indicator	Colour in acid	Changes at pH	Colour in alkali
methyl orange	red	3 to 5	yellow
screened methyl orange	violet	3 to 5	green
litmus	red	5 to 8	blue
thymolphthalein	colourless	9 to 10.5	blue

3.3 Controlling the pH of soil

- Most plants grow best in soil that is neutral or slightly acidic. Soil that is too acidic or too alkaline reduces the nutrients a plant can absorb.
- Acid rain, fertilisers and microbes in the soil can make it too acidic.
- Farmers add **slaked lime**, calcium hydroxide, to _____ the excess acid. Too much makes the soil too alkaline.

4 Oxides

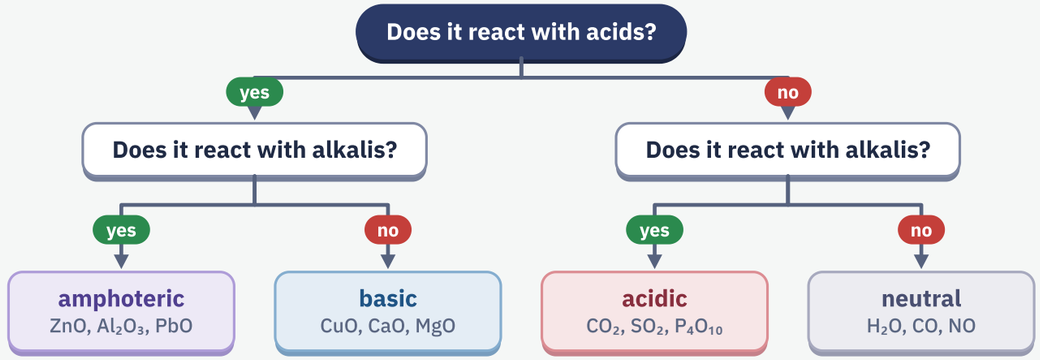
4.1 Four types of oxide

Type	Formed by	Reacts with	Examples
basic	most _____	acids, forming a salt and water	CuO, CaO, MgO, Na_2O
amphoteric	some metals	_____ acids and alkalis, forming a salt and water	ZnO, Al_2O_3, PbO
acidic	most _____	alkalis, forming a salt and water	CO_2, SO_2, SO_3, P_4O_{10}, SiO_2
neutral	some non-metals	_____ acids nor alkalis	H_2O, CO, NO

- Most basic oxides are insoluble solids. Sodium oxide and potassium oxide dissolve in water to form alkalis.
- Most acidic oxides dissolve in water to form acids: $SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$.

$ZnO(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2O(l)$
$ZnO(s) + 2NaOH(aq) \rightarrow Na_2ZnO_2(aq) + H_2O(l)$
$CO_2(g) + 2NaOH(aq) \rightarrow Na_2CO_3(aq) + H_2O(l)$

4.2 Classifying an unknown oxide



WORKED EXAMPLE Oxide X is a white solid that is insoluble in water. It reacts with dilute hydrochloric acid and with aqueous sodium hydroxide, and forms a colourless solution with each. Classify X and suggest its identity.

X reacts with both an acid and an alkali, so X is **amphoteric**.

It is a white solid oxide of a metal, so X could be **zinc oxide** or **aluminium oxide**.

EXAM TIP Classify an oxide from the element: a metal oxide is basic (or amphoteric for zinc, aluminium and lead) and a non-metal oxide is acidic (or neutral for water, carbon monoxide and nitrogen monoxide).