9 ACIDS AND BASES

Properties of acids and bases

TYPICAL PROPERTIES OF ACIDS AND BASES

A simple definition of an acid is that it is a substance that produces H^+ ions in aqueous solution. A base is a substance that can neutralize an acid. An alkali is a base that is soluble in water.

The typical reactions of acids are:

1. With indicators.

   Acid–base indicators can be used to determine whether or not a solution is acidic. Common indicators include:

Indicator	Colour in acidic solution	Colour in alkaline solution
litmus	red	blue
phenolphthalein	colourless	pink
methyl orange	red	yellow

2. Neutralization reactions with bases.

   (a) With hydroxides to form a salt and water,

   e.g. $CH_3COOH(aq) + NaOH(aq) \rightarrow NaCH_3COO(aq) + H_2O(l)$

   (b) With metal oxides to form a salt and water,

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

   (c) With ammonia to form a salt.

   e.g. $HCl(aq) + NH_3(aq) \rightarrow NH_4Cl(aq)$

3. With reactive metals (those above copper in the reactivity series) to form a salt and hydrogen, e.g.

   $2HCl(aq) + Mg(s) \rightarrow MgCl_2(aq) + H_2(g)$

4. With carbonates (soluble or insoluble) to form a salt, carbon dioxide, and water, e.g.

   $2HNO_3(aq) + Na_2CO_3(aq) \rightarrow 2NaNO_3(aq) + CO_2(g) + H_2O(l)$

   $2HCl(aq) + CaCO_3(s) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$

5. With hydrogencarbonates to form a salt, carbon dioxide, and water, e.g.

   $HCl(aq) + NaHCO_3(aq) \rightarrow NaCl(aq) + CO_2(g) + H_2O(aq)$

STRONG AND WEAK ACIDS AND BASES

A strong acid is completely dissociated (ionized) into its ions in aqueous solution. Similarly a strong base is completely dissociated into its ions in aqueous solution. Examples of strong acids and bases include:

Strong acids	Strong bases
hydrochloric acid, HCl	sodium hydroxide, NaOH
nitric acid, HNO_3	potassium hydroxide, KOH
sulfuric acid, H_2SO_4	barium hydroxide, $Ba(OH)_2$

Note: because one mole of HCl produces one mole of hydrogen ions it is known as a **monoprotic** acid. Sulfuric acid is known as a **diprotic** acid as one mole of sulfuric acid produces two moles of hydrogen ions.

Weak acids and bases are only slightly dissociated (ionized) into their ions in aqueous solution.

Weak acids	Weak bases
ethanoic acid, CH_3COOH	ammonia, NH_3
'carbonic acid' (CO_2 in water), H_2CO_3	aminoethane, $C_2H_5NH_2$

The difference can be seen in their reactions with water:

Strong acid: $HCl(g) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$
reaction goes to completion

Weak acid: $CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$
equilibrium lies on the left

i.e. a solution of hydrochloric acid consists only of hydrogen ions and chloride ions in water, whereas a solution of ethanoic acid contains mainly undissociated ethanoic acid with only very few hydrogen and ethanoate ions.

Strong base: $KOH(s) \xrightarrow{H_2O(l)} K^+(aq) + OH^-(aq)$

Weak base: $NH_3(g) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$
equilibrium lies on the left

Note: in aqueous solution a hydrogen ion reacts with a water molecule to form the hydronium ion $H_3O^+(aq)$. In IB chemistry both $H^+(aq)$ and $H_3O^+(aq)$ are acceptable to represent a hydrogen ion in aqueous solution.

EXPERIMENTS TO DISTINGUISH BETWEEN STRONG AND WEAK ACIDS AND BASES

1. pH measurement
   Because a strong acid produces a higher concentration of hydrogen ions in solution than a weak acid, with the same concentration, the pH of a strong acid will be lower than a weak acid. Similarly a strong base will have a higher pH in solution than a weak base, with the same concentration. The most accurate way to determine the pH of a solution is to use a pH meter.

   $0.10\ mol\ dm^{-3}\ HCl(aq)$ pH = 1.0
   $0.10\ mol\ dm^{-3}\ CH_3COOH$ pH = 2.9

2. Conductivity measurement
   Strong acids and strong bases in solution will give much higher readings on a conductivity meter than **equimolar** (equal concentration) solutions of weak acids or bases, because they contain more ions in solution.