Unit 5 ACIDS, BASES & SALTS

See ***Chemistry for You*** Chapter 12 pg. 142 onwards.

See ***GCSE Chemistry*** Chapter 7 pg. 95 onwards

INTRODUCTION

ACIDS	ALKALIS
Acids have a pH less than 7. The **strongest acids** have a pH of 1. The **weakest acids** have a pH of 6. **Common Acids are:** • Hydrochloric Acid (HCl) • Sulphuric Acid (H_2SO_4) • Nitric Acid (HNO_3) Soluble oxides of non-metals form acidic solutions in water. *Concentrated Acids are generally corrosive, while dilute acids are harmful.* 	Alkalis have a pH more than 7. The **strongest acids** have a pH of 14. The **weakest acids** have a pH of 8. Alkalis are also **corrosive**. They are also called bases. Alkalis are soluble bases. **Common Alkalis are:** • Sodium hydroxide - NaOH • Potassium hydroxide - KOH • Calcium hydroxide - $Ca(OH)_2$ The soluble oxides and hydroxides of metals form alkaline solutions.

<u>The pH shows the concentration of hydrogen ions [H^+] in a solution</u>

- An **acid** has a large [H^+] (aq) concentration
- The stronger the acid, the higher the [H^+] (aq) concentration
- A **base** has a very low [H^+] (aq) concentration
- The stronger the base, the lower the [H^+] (aq) concentration

<u>Indicators show whether a solution is acidic, alkaline or neutral by changing colours.</u>

Indicator	**Acid**	**Neutral**	**Alkali**
Universal indicator	Red	Green	Purple
Blue litmus	Red	Blue	Blue
Red litmus	Red	Red	Blue
Phenolphtalein	Colourless	Colourless	Pink

5.1 ACIDS

Acids have a sour sharp taste.
But it is not sensible to test acids by tasting them as some are dangerous.

Acids and alkalis are chemical opposites. When added to each other, they react together and "Kill off" each other – they NEUTRALISE each other.

Acids in industry

- **Sulphuric acid** is used to make fertilizers, detergents, paints and pigments, rayons (fibers), drugs, explosives and cleaning metals.
- **Nitric acid** is used to make explosives and fertilizers.
- **Hydrochloric acid** is used to clean metal surfaces like steels before coating with zinc (galvanizing) or tin-plating.

Acids react with metals: -

Metal + Acid → Salt + Hydrogen

Reaction with HCl:

Hydrochloric acid + Zinc → Zinc chloride + hydrogen

$2\ HCl\ (aq) + Zn\ (s) \rightarrow ZnCl_2\ (s) + H_2\ (g)$

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

$2\ HCl\ (aq) + Fe\ (s) \rightarrow FeCl_2\ (s) + H_2\ (g)$

Reaction with H_2SO_4:

Sulphuric acid + Zinc → Zinc sulphate + hydrogen

$2\ H_2SO_4\ (aq) + Zn\ (s) \rightarrow ZnSO_4\ (s) + H_2\ (g)$

$2\ H_2SO_4\ (aq) + Mg\ (s) \rightarrow MgSO_4\ (s) + H_2\ (g)$

$2\ H_2SO_4\ (aq) + Fe\ (s) \rightarrow FeSO_4\ (s) + H_2\ (g)$

Reaction with insoluble bases, carbonates and sulphites:

In all cases a type of salt and water are always formed.

1. Acid + Base → Salt + Water

Hydrochloric Acid + Sodium Hydroxide → Sodium chloride + water

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

2. Acid + Carbonate → Salt + Carbon dioxide + Water

Nitric Acid + Calcium carbonate → Calcium nitrate + Carbon dioxide + Water

$2\ HNO_3\ (aq) + CaCO_3\ (s) \rightarrow Ca(NO_3)_2\ (aq) + CO_2\ (aq) + H_2O\ (l)$

3. Acid + Sulphite → Salt + Sulphur dioxide + Water

Sulphuric Acid + Sodium Hydrogen sulphite → Sodium hydrogen sulphate + Sulphur dioxide + Water

$H_2SO_4\ (aq) + NaHSO_3\ (aq) \rightarrow NaHSO_4\ (aq) + SO_2\ (g) + H_2O\ (l)$

Work each example with the different Acids :

- HCl
- H_2SO_4
- HNO_3

Vinegar and its acidity (see GCSE Biology pg. 98)

Vinegar contains a weak acid in it, that is called **ethanoic acid** – **CH_3COOH**.

This produces few hydrogen [H^+] ions when it dissolves in water compared with strong acids like HCl.

In fact it has a pH of 3.

Work out Chemistry for You pg. 157 numbers 1 – 3

5.2 Investigating the properties of alkalis.

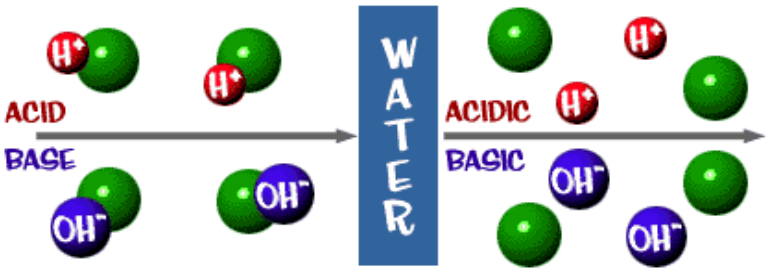
A base is a metallic oxide or hydroxide that reacts with an acid to form a salt and water only.

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

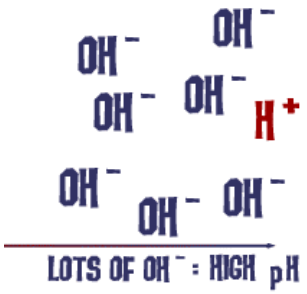
Just as acids dissolve in water to give H^+ ions, alkalis are soluble bases giving OH^- (aq) .

Propeties of alkalis

1. They feel soapy to touch
2. They turn red litmus blue
3. They have a pH larger than 7
4. They are soluble in water
5. They are electrolytes
6. All contain OH^- ions



A strong alkali releases lots of OH^- ions in solution, while weak alkalis release less OH^-. The larger the number of OH^- ions, the higher is the pH of the solution.



The higher the pH the stronger the alkali.

Strong alkalis like Sodium hydroxide NaOH are fully split into their ions Na^+ and OH^-.

Weak alkalis like Ammonium hydroxide NH_4OH are only partly split.

Reaction with ammonium salts

If an ammonium salt is warmed with an alkali in the presence of water, ammonia gas is given off. The reaction occurring is:

Ammonium salt *(NH_4^+)* + alkali → Salt + Water + **Ammonia** *(NH_3)*

$$NH_4Cl\ (aq) + NaOH\ (aq) \rightarrow NaCl\ (aq) + H_2O\ (l) + NH_3\ (g)$$

$$(NH_4)_2SO_4\ (aq) + Ca(OH)_2 \rightarrow CaSO_4\ (s) + 2H_2O\ (l) + 2\ NH_3\ (g)$$

Reaction of KOH & NaOH with amphoteric metals Al & Zn to release HYDROGEN

Aluminium + Sodium Hydroxide + water → sodium alu

$2\ Al\ (s) + 2\ NaOH\ (aq) + H_2O\ (l) \rightarrow 2NaAl(OH)_4\ (a$

Some useful bases

- Magnesium hydroxide in Milk of magnesia;
- bleaches and alkaline cleaners;

quicklime and slaked lime to counter acidity in soil.

Zinc behaves in the same way.

5.3 Neutralization

Neutralization - the formation of neutral molecules of water from H^+ (aq) and OH^- (aq), with a salt being the other product of the reaction.

Acid + Alkali → Neutral Salt + Water

Neutralization can be summarized by the ionic equation:

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

Naming Salts prepared from Acids

Neutralizing hydrochloric acid will produce chloride salts.

- Hydrochloric acid + sodium hydroxide → sodium chloride + water
- $HCl (aq) + NaOH (aq) \rightarrow NaCl (s) + H_2O (l)$

Neutralizing nitric acid will produce nitrate salts.

- Nitric acid + Calcium hydroxide → calcium nitrate + water
- $2\ HNO_3 (aq) + Ca(OH)_2 (aq) \rightarrow Ca(NO_3)_2 (s) + 2\ H_2O (l)$

Neutralizing sulphuric acid will produce sulphate salts.

- Sulphuric acid + potassium hydroxide → potassium sulphate + water
- $H_2SO_4 (aq) + 2\ KOH (aq) \rightarrow K_2SO_4 (s) + 2\ H_2O (l)$

Answer the following:

1. What is the pH of a neutral solution? _____
2. What is the pH of the strongest alkali? _____
3. What is the pH of the weakest acid? _____
4. Which ions make solutions acidic? _____
5. Which ions make solutions alkaline? _____
6. Name 3 common acids: _____ _____ _____
7. Name the salt produced when sulphuric acid neutralizes sodium hydroxide.

   _____
8. Name the salt produced when nitric acid neutralizes potassium hydroxide

   _____
9. Name the salt produced when hydrochloric acid neutralizes ammonia solution.

   _____
10. Give the ionic equation for *neutralization.* _____

(Normal) Salts and Acid Salts

- **Hydrochloric acid (HCl) can only form 1 type of salt.**

E.g. with sodium hydroxide (NaOH) it forms sodium chloride (NaCl)

Given each molecule of HCl provides 1 H^+ we call it a **monobasic acid. (***keep in mind that mono means one*)

Monobasic acids can only form 1 type of salt. This is called a normal salt.

- **Sulphuric acid can form 2 salts**.

For example with sodium hydroxide solution it can form sodium sulphate Na_2SO_4 if 2 hydrogen ions H^+ are removed – this would be the normal salt.

$$2\ NaOH\ (aq) + H_2SO_4 \rightarrow\ Na_2SO_4\ (s) + H_2O\ (l)$$

Or else it can form Sodium hydrogen sulphate $NaHSO_4$. This salt is called an acid salt as it can still provide hydrogen H^+ ions in solution.

$$2\ NaOH\ (aq) + 2\ H_2SO_4 \rightarrow\ 2\ NaHSO_4\ (s) + 2\ H_2O\ (l)$$

$$HSO_4^- \rightarrow\ H^+\ +\ SO_4^{2-}$$

So we also say that sulphuric acid is a **dibasic acid** (di meaning two) as it provides 2 H^+ ions from every molecule.

Dibasic acids can form both normal salts and acid salts.

A salt is a compound consisting of positive metal ions and negative ions derived from an acid.
If the negative ions are capable of further ionization to yield H^+ the salt is an **acid salt**.
If the negative ions are not capable of that, the salt is a **normal salt**

Acid	**Acid Salt**	**Normal Salt**
H_2SO_4	Sodium hydrogensulphate $NaHSO_4$	Sodium sulphate Na_2SO_4
H_2CO_3	Sodium hydrogencarbonate $NaHCO_3$	Sodium carbonate Na_2CO_3
H_2S	Sodium hydrogensulphide NaHS	Sodium sulphide Na_2S

5.4 Preparation of Salts

A) By precipitation from two aqueous solutions – give an insoluble salt

- A solution containing the positive ion of the salt is mixed with a solution containing the negative ion.
- Lead (II) nitrate solution can be one solution (as all nitrates are soluble in water)
- Sodium sulphate solution can be the other one (as all sulphates are soluble in water).
- These are mixed together and the insoluble salt is precipitated.
- The precipitate is then obtained by
  - filtering,
  - washing 3 times with distilled water
  - and being left to dry.

Lead (II) Nitrate (aq) + Sodium sulphate (aq) → Lead (II) sulphate (s) + Sodium nitrate (aq)

$Pb(NO_3)_2\,(aq) + Na_2SO_4\,(aq) \rightarrow PbSO_4\,(s) + 2\,NaNO_3\,(aq)$

B) By direct combination – or synthesis

When 2 elements react together to form a compound this is called a direct combination.

Iron may be reacted with chlorine. Dry chlorine gas is passed over heated iron.

Iron (s) + Chlorine (g) → Iron (III) chloride (s)

$2\,Fe\,(s) + 3\,Cl_2\,(g) \rightarrow 2\,FeCl_3\,(s)$

C) By adding excess solid (metal, insoluble base or carbonate) to a dilute acid – e.g. Zinc sulphate

- Some dilute sulphuric acid is put in a beaker.
- It is warmed.
- Small amounts of zinc are added until the reaction stops and excess zinc remains at the bottom.
- The excess zinc is filtered.
- The zinc sulphate solution is evaporated on a steam bath to the point of crystallization.
- Then it is left to cool and crystallize.
- Crystals can be obtained by filtering.

Zinc (s) + Sulphuric Acid (aq) → Zinc sulphate (aq) + Hydrogen (g)

$Zn\,(s) + H_2SO_4\,(aq) \rightarrow ZnSO_4\,(aq) + H_2\,(g)$

D) By titration of an acid with an alkali

In this method you cannot say when all the acid has reacted because the solid will dissolve even after complete neutralization occurs.

- Some dilute Hydrochloric acid (HCl) is put in a beaker and a few drops of litmus solution added. The litmus turns red.
- Then dilute sodium hydroxide (NaOH) solution is added little by little by means of a burette till the litmus turns grey (this is called the *end-point*)
- This means that the acid has been neutralized by the alkali.
- Then the litmus is removed by boiling for several minutes with activated charcoal.
- The litmus becomes adsorbed (attached to) the charcoal.
- Filtration is then carried out to remove the charcoal.
- The sodium chloride solution is evaporated to dryness on a steam bath.

Sodium hydroxide (aq) + Hydrochloric acid (aq) → Sodium chloride (s) + Water (l)

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

Some useful salts

- **Sodium hydrogencarbonate -** $NaHCO_3$ baking soda and its leavening action;
- **Sodium carbonate -** $Na_2CO_3.10H_2O$ washing soda as a water softener;
- **Calcium sulphate -** $CaSO_4.{}^1/_2\ H_2O$ plaster of Paris for 'plaster casts' and boards;
- **Magnesium sulphate -** $MgSO_4\ .7H_2O$ Epsom salts as a laxative.

Write balanced chemical equations for the following:

1. Zinc reacting with sulphuric acid
2. Magensium oxide reacting with nitric acid
3. sodium hydroxide solution reacting with hydrochloric acid
4. Potassium carbonate reacting with sulphuric acid
5. Copper (II) carbonate reacting with hydrochloric acid

Its important to give the state symbols in each case.

You can write on the back of this page.

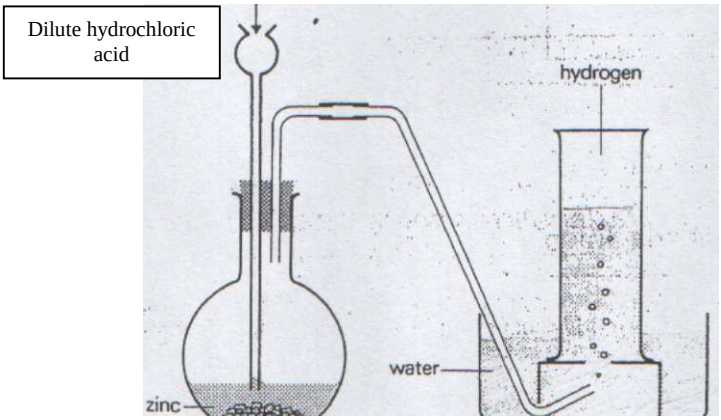
5.5 Hydrogen

Laboratory Preparation of Hydrogen

Zinc is mixed with dilute hydrochloric acid. A few drops of copper (II) sulphate solution act as a catalyst.

Zinc + Hydrochloric acid → Zinc chloride + Hydrogen

$$Zn\ (s) + 2\ HCl\ (aq) \rightarrow ZnCl_2\ (aq) + H_2\ (g)$$



Test for Hydrogen – A mixture of hydrogen and air explodes when a flame is applied. Therefore tests should only be carried out with very small volumes of gas (that burn with a 'pop')

Industrial Preparation of Hydrogen

In industry Hydrogen is made by reacting methane with steam over a Nickel catalyst at 800^{o}C and 30 atm of pressure.

$$CH_4\ (g) + H_2O\ (g) \rightarrow CO\ (g) + 3\ H_2\ (g)$$

Uses of Hydrogen

1. For filling **balloons**, but it has a disadvantage of being flammable.
2. To make **ammonia** – in a process called *The Haber Process*
3. To make **hydrochloric acid**
4. In the hardening of oils to make **margarine**
5. In the oxyhydrogen flame for cutting and **welding** steel.
6. May be used as a **fuel**.
   - Has the advantage of forming only water which is not a pollutant
   - Has the disadvantage of being dangerous as it may explode!!!

Hydrides

Compounds containing hydrogen and another element are called **hydrides**.

If the other element is a non-metal, the hydride is *covalent*. E.g. HCl, NH_3

If the other element is a metal, the hydride is *ionic*. E.g. NaH

Physical Properties of Hydrogen

1. It is an invisible gas
2. Neutral to litmus
3. If pure possesses no smell
4. It is less dense than air

Chemical properties:

a) combustion; In the presence of oxygen, hydrogen burns with a small flame and water is produced. This reaction gives out energy (exothermic) and is an example of oxidation.

hydrogen + oxygen → water (hydrogen oxide).

$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)}$

b) reaction with non- metals, e. g. Cl_2 and N_2

- Hydrogen will react with chlorine to form hydrogen chloride.

hydrogen + chlorine → hydrogen chloride.

$H_{2(g)} + Cl_{2(g)} \rightarrow 2HCl_{(g)}$

Industrial Conditions for reaction with Nitrogen

This reaction is reversible (shown by the ⇌ arrow).

nitrogen + hydrogen ⇌ ammonia (+ heat).

$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$ (+ heat)

The industrial conditions are:

1) Temperature between 450 °C and 500 °C.
2) Pressure of 200 atm (200 atmospheres).
3) An iron catalyst is used.

c) reduction of metallic oxides e. g. CuO.

Oxidation is a reaction where oxygen is added to a compound, reduction is one in which oxygen is taken away. In this case oxygen is removed from copper oxide, so hydrogen is reducing copper oxide and being itself oxidized.

$CuO\ (s) + H_2\ (g) \rightarrow Cu\ (s) + H_2O\ (l)$

d) reaction with a metal, e. g. Na

Hydrogen forms hydrides, (e.g. NaH) with a number of metals, including lithium, sodium and calcium. Sodium and hydrogen react above 200ºC (390ºF) to form sodium hydride.

$$\mathbf{H_2\,(g) + 2\,Na\,(s) \rightarrow 2\,NaH\,(s)}$$

OTHER WAYS OF PREPARING HYDROGEN

- from reactive metals and water,

The Group 1 metals, lithium, sodium, and potassium react violently with water at the ordinary temperature, yielding hydrogen.

sodium + water → sodium hydroxide + hydrogen.

$$2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2(g)}$$

potassium + water → potassium hydroxide + hydrogen.

$$2K_{(s)} + 2H_2O_{(l)} \rightarrow 2KOH_{(aq)} + H_{2(g)}$$

Calcium reacts with water more slowly unless the water is hot, when the action is more vigorous.

calcium + water → sodium hydroxide + hydrogen.

$$Ca_{(s)} + 2H_2O_{(l)} \rightarrow Ca(OH)_{2\,(aq)} + H_{2(g)}$$

- metals and steam

The manufacture of hydrogen on an industrial scale involves the reaction between steam and iron. Spongy iron from the reduction of spathic iron ore (ferrous carbonate) is heated to redness and steam passed over it.

$$3\ Fe\,(s) + 4\,H_2O\,(g) \rightleftharpoons Fe_3O_4\,(s) + 4\,H_2\,(g)$$

- an amphoteric metal and a caustic alkali.

Warm Sodium (or potassium) hydroxide solution will react with zinc, aluminium, or silicon to liberate hydrogen and leave a solution of sodium (or potassium) zincate, aluminate, or silicate.

1. a) Dilute acids and alkalis react with other substances according to a general pattern.

Some examples of these reactions are:

A. an acid on a metal

B. an acid on a sulphite

C. an alkali on an ammonium salt

D. an alkali on an amphoteric metal

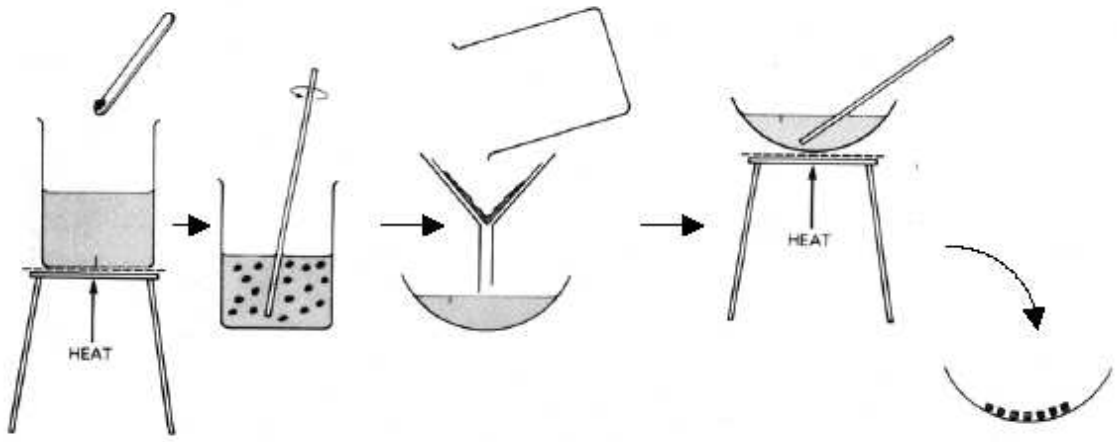
Select, from A to D

(i) the two types of reaction that would liberate hydrogen gas _____

(ii) the reaction that would liberate sulphur dioxide _____

(iii) the reaction that would liberate ammonia gas _____ (4 marks)

2. The flow chart given below shows the steps involved in preparing crystals of zinc chloride by reacting zinc metal with dilute hydrochloric acid.



a) Describe, in detail, the practical steps shown in the diagram. Emphasize what is done to ensure that:

(i) all the acid is used up, and

(ii) that pure, dry crystals are obtained.

Your description should also include names of apparatus used and observations that would be made in each step. (12 marks)

b) (i) Hydrogen gas is usually prepared by the reaction of zinc metal with dilute hydrochloric acid. Give an equation for this reaction and describe a test for the gas including the result. (4 marks)

(ii) Hydrogen is also produced when metals react with water or steam.

Write balanced equations for the reaction of sodium with water, and for the reaction of zinc with steam. (4 marks)