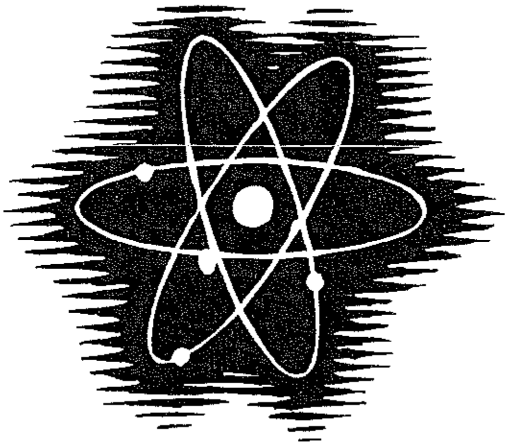
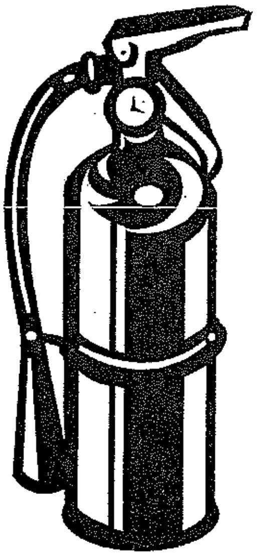
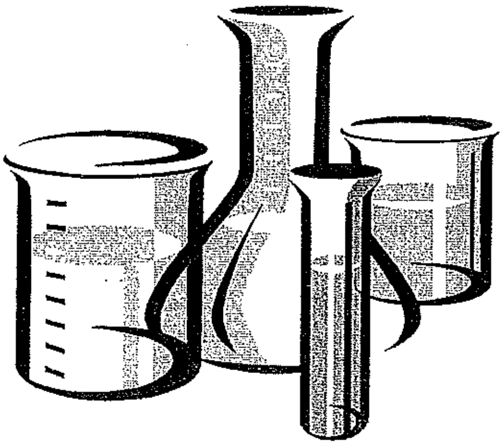




Chemical Changes and Structure
Acids and Alkalis
National 4/5



The pH Scale

The pH scale is a continuous numbered scale that indicates the acidity or alkalinity of a solution. We can use pH paper or Universal indicator and "colour match" to determine a solutions pH.

Solutions with pH **less** than 7 are **acids**.

Solutions with pH *exactly 7 are neutral.*

Solutions with pH greater than 7 are alkalis.

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14

very acidic slightly acidic slightly alkaline very alkaline

neutral

Testing pH

Results

Aim testing the pH of everyday substances

Results

Substance	Colour	pH	Acid/alkali/neutral

Metal Oxides

When a metal element burns in oxygen, the two elements combine to form an *oxide*. If they dissolve in water, these oxides form *metal hydroxides*.

e.g. potassium oxide + water → potassium hydroxide

Experiment

Aim to test the solubility of metal oxides/hydroxides

Method

Results

Substance	Formula	Soluble or Insoluble	Acid or Alkali

Metal oxides that dissolve in water form metal hydroxides, these metal hydroxides are alkalis.

Solubility of Metal Oxides

Use the data book to complete the following table

Compound	Formula	Solubility	Compound	Formula	Solubility
Sodium oxide			Copper (II) oxide		
Potassium oxide			Lead (II) oxide		
Calcium oxide			Iron (II) oxide		
Magnesium oxide			Iron (III) oxide		

The oxides of metals from Group 1, and some from Group 2 in the Periodic Table are soluble. Most other metal oxides are insoluble.

All metal oxides are called basic oxides (BASES) but only those which dissolve form alkaline solutions.

Producing OXIDES

When an element burns in air it is reacting with oxygen. The two elements combine to form an *oxide.*

e.g. carbon + oxygen → carbon dioxide

calcium + oxygen → calcium oxide

If they dissolve in water, these oxides make acidic or alkaline solutions.

Non-metal Oxides

Aim to dissolve Carbon Dioxide and Nitrogen Dioxide and determine the pH of the resulting solution.

Method

Result

Non-metal oxides, e.g. carbon dioxide, nitrogen dioxide, sulphur dioxide, dissolve in water to produce acidic solutions.

Non metal oxides

When a non metal reacts with oxygen a non metal oxide is produced. If the non metal oxide dissolves in water an **ACID** is produced.

Equations

Sulphur + oxygen → sulphur dioxide

$$S + O_2 \rightarrow SO_2$$

Sulphur dioxide + water → sulphurous acid

$$SO_2 + H_2O \rightarrow (H^+)_2SO^{2-}{}_3$$

Common Acids

Acid	Formula	Chemical Name
Sulphuric	$(H^+)_2SO^{2-}{}_4$	Hydrogen sulphate
Nitric	$H^+NO^-{}_3$	Hydrogen nitrate
Carbonic	$(H^+)_2CO^{2-}{}_3$	Hydrogen carbonate
Phosphoric	$(H^+)_3PO^{3-}{}_4$	Hydrogen phosphate
Hydrochloric	H^+Cl^-	Hydrogen chloride

Acid Rain

Rain water is often found to be acidic..........

Read pages ____________ of text book and answer the questions on the following page.

Acid Rain

1. Which two gases are mainly responsible for *increasing* the acidity of rain?

2. State the major sources of these gases in our atmosphere

a

b

3. What effect does acid rain have on:-

a growing plants and trees?

b buildings and iron bridges?

e pond and fish life?

4. Explain briefly 2 ways in which we can reduce acid rain pollution

a

b

Neutralising Acids with Alkalis

One way to neutralise an acid is to add an alkali. The general equation for this reaction is:

Acid + Alkali → Salt + Water

Neutralisation reactions always result in water being formed.

Acidic solutions contain an excess of $H^+_{(aq)}$
Alkaline solutions contain an excess of $OH^-_{(aq)}$

When an alkali is used to neutralise an acid, the $OH^-_{(aq)}$ and $H^+_{(aq)}$ react together to form water molecules.

$$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(aq)}$$

Everyday Examples of Neutralisation

- Lime is used by farmers to reduce the acidity of the soil
- When acid rain causes the pH of lakes to decrease it is often treated by adding lime to the lake
- Indigestion (caused by excess stomach acid) is treated by tablets which will neutralise the acid, e.g. Tums, Setlers
- Toothpaste is used to neutralise the acid produced in our mouths by bacteria and which could go on to cause tooth decay.

Neutralisation

Water is neutral, it contains equal concentrations of hydrogen ion and hydroxide ion.

$$[H^+_{(aq)}] \qquad = \qquad [OH^-_{(aq)}]$$

A substance that can react with an acid to produce water is called a neutraliser.

$$\text{excess } H^+_{(aq)} \xrightarrow[\text{ACID}]{} \overset{[H^+_{(aq)}] = [OH^-_{(aq)}]}{7} \xleftarrow[\text{ALKALI}]{} \text{excess } OH^-_{(aq)}$$

As the neutraliser and the acid react, the pH of the mixture moves towards 7 (neutral pH).

This is called neutralisation.

- Neutralisation moves the pH of an acid towards 7
- Neutralisation moves the pH of an alkali towards 7

A substance which neutralises an acid is called a base.
Bases which dissolve in water form alkalis.

In addition to water, a salt is always produced in a neutralisation reaction.

There are three different types of neutraliser used to produce soluble salts:

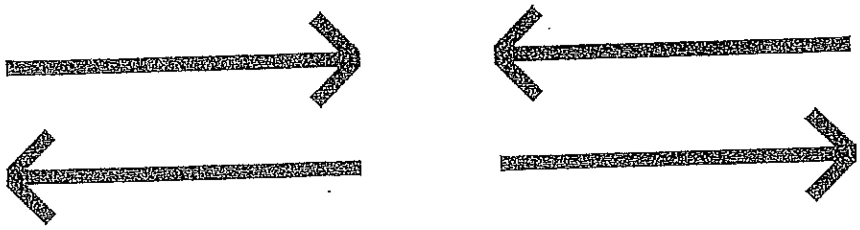
- Metal oxides
- Metal hydroxides (alkalis)
- Metal carbonates

$H^+(aq)$ and $OH^-(aq)$ ions

Place the following labels over the appropriate arrow.

decreasing concentration of $H^+(aq)$ ions   increasing acidity

decreasing concentration of $OH^-(aq)$ ions   increasing alkalinity



DARK RED   ORANGE/YELLOW   GREEN   GREEN / BLUE   DARK BLUE

pH   1   2   3   4   5   6   7   8   9   10   11   12   13   14

ACID   NEUTRAL   ALKALI

In water (and neutral solutions) there is a small number of $H^+(aq)$ and $OH^-(aq)$ ions. This is because a small number of water molecules split up as follows.

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

many water molecules   very few ions

Since each water molecule can form one $H^+(aq)$ ion and one $OH^-(aq)$ ion, the concentration of $H^+(aq)$ ions in pure water (and neutral solutions) is equal to the concentration of $OH^-(aq)$ ions.

If the concentration of $H^+(aq)$ ions, is equal to the concentration of $OH^-(aq)$ ions, then the solution is **neutral**.

In **acids**, the concentration of $H^+(aq)$ ions is greater than the concentration of $OH^-(aq)$ ions.
When an acid is diluted, the solution becomes less acid. This is because the concentration of $H^+(aq)$ decreases.

In **alkalis**, the concentration of $OH^-(aq)$ ions is greater than the concentration of $H^+(aq)$ ions.
When an alkali is diluted, the solution becomes less alkaline. This is because the concentration of $OH^-(aq)$ decreases.

It is important to remember that all solutions in water contain both hydrogen ions and hydroxide ions. **It is the relative concentrations of these ions which decides whether a solution is acid, alkali or neutral.**

Acids - a definition

Acid solutions are made by adding to water a substance which will lower the pH. The substance added can be gas, liquid or solid.

e.g. $HCl(g)$	$\xrightarrow{H_2O}$	$HCl(aq)$	$H^+(aq)$ and $Cl^-(aq)$
hydrogen chloride		hydrochloric acid	
$H_2SO_4(l)$	$\xrightarrow{H_2O}$	$H_2SO_4(aq)$	$2H^+(aq)$ and $SO_4^{2-}(aq)$
hydrogen sulphate		sulphuric acid	
$HCOOH(s)$	$\xrightarrow{H_2O}$	$HCOOH(aq)$	$H^+(aq)$ and $HCOO^-(aq)$
hydrogen formate		formic acid	

The substance added is made up of molecules - atoms of non-metal elements joined by covalent bonds.

When the substance is added to water the covalent bonds break to form ions which become attached to water molecules.

An acid solution is one which contains $H^+(aq)$ ions.

For an acid to react with an indicator compound water must be present.

Making a Soluble Salt 1: Reacting an Acid with an Alkali

1. A titration is carried out with an indicator present to indicate when the solution is exactly neutral.

2. The exact quantities used are recorded and the experiment repeated using the known volumes of acid and alkali.

3. The salt solution produced is then placed in an evaporating basin and the water is evaporated off, leaving the solid salt crystals behind.

N.B. The size of the crystals will vary depending on the rate of evaporation. Rapid evaporation will result in the production of small crystals while much larger crystals can be made by cooling the salt solution very slowly.

Ions in Acids and Alkalis

From the results of conductivity experiments we can say:

- ions are present in an acid solution
- ions are present in an alkali solution
- the concentration of ions in water is small

Water contains tiny concentrations of hydrogen ions ($H^+_{(aq)}$) and hydroxide ions ($OH^-_{(aq)}$).

$$\underset{\text{water molecules}}{H_2O_{(l)}} \quad === \quad \underset{\text{hydrogen ions}}{H^+_{(aq)}} \quad + \quad \underset{\text{hydroxide ions}}{OH^-_{(aq)}}$$

Water and neutral solutions contain *equal* concentrations of $H^+_{(aq)}$ and $OH^-_{(aq)}$ ions

An acidic solution contains *more* $H^+_{(aq)}$ *ions* than water.

An alkaline solution contains *more* $OH^-_{(aq)}$ *ions* than water

Formulae of Acids and Alkalis

Acids

Name	Formula	Ionic Formula
Hydrochloric Acid	HCl	$H^+ Cl^-$
Nitric Acid	HNO_3	$H^+ NO^-_3$
Sulphuric Acid	H_2SO_4	$(H^+)_2 SO_4^{2-}$
Carbonic Acid	H_2CO_3	$(H^+)_2 CO_3^{2-}$
Phosphoric Acid	H_3PO_4	$(H^+)_3 PO_4^{3-}$

Alkalis

Name	Formula	Ionic Formula
Sodium Hydroxide	$NaOH$	$Na^+ OH^-$
Potassium Hydroxide	KOH	$K^+ OH^-$
Calcium Hydroxide	$Ca(OH)_2$	$Ca^{2+} (OH^-)_2$
Magnesium Hydroxide	$Mg(OH)_2$	$Mg^{2+} (OH^-)_2$

The Products of Neutralisation

The products of neutralisation are always SALT + WATER.

The water is formed from the $H^{+}(aq)$ ion of the acid.

The salt is a substance in which the $H^{+}_{(aq)}$ of an acid is replaced by a metal ion or the ammonium ion.

e.g.	ACID	+	ALKALI	→	SALT	+	WATER
	hydrochloric acid	+	sodium hydroxide	→	sodium chloride	+	water
	HCl	+	NaOH	→	NaCl	+	water

Naming Salts

When naming soluble salts, the metal ion of the alkali, carbonate or oxide is always written first, followed by the negative ion of the acid.

Acid	Formula	Ions Present	Salt Formed
Sulphuric acid (hydrogen sulphate)	H_2SO_4	H^{+} SO_4^{2-}	Sulphates
Hydrochloric acid (hydrogen chloride)	HCl	H^{+} Cl^{-}	Chlorides
Nitric acid (hydrogen nitrate)	HNO_3	H^{+} NO_3^{-}	Nitrates
Carbonic acid (hydrogen carbonate)	H_2CO_3	H^{+} CO_3^{2-}	Carbonates

A reversible reaction

The splitting up of water molecules is a **reversible** reaction, i.e. at the same time as water molecules are splitting up, $H^+(aq)$ and $OH^-(aq)$ ions are reforming water molecules.

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

The reversible reaction is written:

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

The rate at which water molecules **dissociate** or **ionise** (split up) is equal to the rate at which $H^+(aq)$ ions and $OH^-(aq)$ ions react to form water molecules. Hence the concentrations of $H^+(aq)$ ions and $OH^-(aq)$ ions do not change even although the forward and the reverse reactions continue.

When the concentrations of reactants and products remain constant, the reversible reaction is said to be at **equilibrium**. However, when a reaction is at equilibrium, the concentrations of reactant's and products are **not** necessarily equal.

Since water is only a poor conductor of electricity, there must be many more ions than molecules. In fact, there are 560 000 000 water molecules for every $H^+(aq)$ ion and $OH^-(aq)$ ion.

Reaction of Acids With Metal Oxide

Aim To react acids with metal oxides

Method

Results All metal oxides react with acids to produce water and a salt. This is also an example of a neutralisation reaction.

General Equation

METAL OXIDE + ACID → SALT + WATER

Word Equation

e.g.	copper oxide	+	hydrochloric acid	→	copper chloride	+	water

Formula Equation

$$CuO + HCl \rightarrow CuCl_2 + H_2O$$

Balanced Equation

$$CuO + 2\,HCl \rightarrow CuCl_2 + H_2O$$

Further Examples

Complete the word and then balanced formula equations when the following substances reactant.

a) Iron(II)oxide + nitric acid
b) Nickel(III)oxide + sulphuric acid
c) Magnesium oxide + hydrochloric acid
d) Lithium oxide + carbonic acid

Reaction of Acids With Metal Carbonates

Aim To react acids with metal carbonates and identify the gas produced

Method

Results

All metal carbonates react with acids to produce carbon dioxide gas. This is an example of a neutralisation reaction and so the other products are a salt and water.

N.B. These reactions explain why acid rain increases the erosion of buildings made from carbonate containing minerals (such as marble and limestone).

General Equation
METAL CARBONATE + ACID → SALT + WATER + CARBON DIOXIDE

Word Equation

e.g. calcium carbonate + hydrochloric acid → calcium chloride + water + carbon dioxide

Formula Equation

Balanced Equation

Making Soluble Salts - Summary

Salts are ionic compounds containing a metal and a non-metal.
Soluble salts can be prepared using acids in three main ways.

1. *Neutralising an acid using a base or an alkali*

A ACID + METAL OXIDE → SALT + WATER

e.g. hydrochloric acid + sodium oxide →

B ACID + ALKALI → SALT + WATER

e.g. sulphuric acid + calcium hydroxide →

2. *Reacting an acid with a metal carbonate*

ACID + METAL CARBONATE → SALT + WATER + CARBON DIOXIDE

e.g. nitric acid + lithium carbonate →

3. *Reacting an acid with a reactive metal*

ACID + REACTIVE METAL → SALT + HYDROGEN

e.g. hydrochloric + magnesium →
acid

You need to know these reactions, the general equations and how to name a salt!

Writing Ionic Equations

- It is important that when you are writing ionic equations you must make sure that you only show ions for the substances that are ionic.
- If an ionic compound is present as a solid, the formula should be written in the normal way, but with the state symbol (s) placed after it.

  eg. solid sodium sulphate = $(Na^+)_2SO_4{}^{2-}{}_{(s)}$
- If an ionic compound is dissolved in water, the ions are separated and each ion is followed by the state symbol (aq)

  eg. sodium sulphate solution = $2Na^+{}_{(aq)} + SO_4{}^{2-}{}_{(aq)}$

Examples

a) Nitric acid + copper carbonate →

b) Sulphuric acid + magnesium oxide →

c) Hydrochloric acid + potassium hydroxide →

Bases

Alkalis are **solutions** which are the chemical opposites to acids, i.e. they contain negative ions which accept $H^+(aq)$ ions from an acid.
The word **base** is used to describe all substances which react in this way.

Alkalis are solutions which are a subset of the set of bases, i.e. formed from those bases which dissolve in water, increasing the pH of water due to the formation of hydroxide ions.

BASES, e.g. copper oxide, copper hydroxide,
sodium oxide, sodium hydroxide

ALKALIS, e.g. sodium hydroxide solution

Sodium oxide and sodium hydroxide are both bases which dissolve in water to form sodium hydroxide solution (an alkali).
Copper oxide and copper hydroxide are insoluble in water; they are bases since they neutralise acids but they do not form alkalis.

Explaining reactions

Spectator ions are ions which do not take part in a chemical reaction. The idea of spectator ions can best be understood by looking at a number of reactions in which they occur.

1 Reaction of a dilute acid with an alkali

e.g. the reaction of sodium hydroxide solution with dilute hydrochloric acid

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

This equation can be rewritten to show the ions present.
Since water is made up almost entirely of molecules (covalent) it is left unchanged.

$$Na^+(aq) \text{ and } OH^-(aq) \; + \; H^+(aq) \text{ and } Cl^-(aq) \; \rightarrow \; Na^+(aq) \text{ and } Cl^-(aq) \; + \; H_2O(l)$$

Both the $Na^+(aq)$ and $Cl^-(aq)$ have not changed during the reaction.

The ions are both **spectator ions** and can be cancelled out to show the actual reaction taking place.

$$\cancel{Na^+(aq)} \text{ and } OH^-(aq) \; + \; H^+(aq) \text{ and } \cancel{Cl^-(aq)} \; \rightarrow \; \cancel{Na^+(aq)} \text{ and } \cancel{Cl^-(aq)} \; + \; H_2O(l)$$

$$\text{hence} \quad OH^-(aq) \quad + \quad H^+(aq) \quad \rightarrow \quad H_2O(l)$$

This equation shows the $OH^-(aq)$ of the alkali reacting with the $H^+(aq)$ of the acid.
This reaction takes place during the **neutralisation** of **any** acid with **any** alkali.

2 Reaction of a dilute acid with a metal cabonate

e.g. the reaction of dilute sulphuric acid with sodium carbonate solution

$$H_2SO_4(aq) \quad + \quad Na_2CO_3(aq) \quad \rightarrow \quad Na_2SO_4(aq) \quad + \quad H_2O(l) \quad + \quad CO_2(g)$$

Both water and carbon dioxide are made up of molecules.

Rewriting to show the ions present gives:

$$2H^+(aq) \text{ and } SO_4^{2-}(aq) \; + \; 2Na^+(aq) \text{ and } CO_3^{2-}(aq)$$
$$\rightarrow 2Na^+(aq) \text{ and } SO_4^{2-}(aq) \; + \; H_2O(l) \; + \; CO_2(g)$$

Both the $Na^+(aq)$ and the $SO_4^{2-}(aq)$ are **spectator ions** and can be cancelled out.

$$2H^+(aq) \text{ and } \cancel{SO_4^{2-}(aq)} \; + \; \cancel{2Na^+(aq)} \text{ and } CO_3^{2-}(aq)$$
$$\rightarrow \; \cancel{2Na^+(aq)} \text{ and } \cancel{SO_4^{2-}(aq)} \; + \; H_2O(l) \; + \; CO_2(g)$$

The ion equation shows what actually happens in **any** reaction of a dilute acid with a solution of a metal carbonate.

$$2H^+(aq) \quad + \quad CO_3^{2-}(aq) \quad \rightarrow \quad H_2O(l) \quad + \quad CO_2(g)$$

Explaining reactions (continued)

3 Reaction of a dilute acid with a metal

e.g. the reaction of magnesium with dilute hydrochloric acid

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

This equation can be rewritten to show the ions present.

$$Mg(s) \quad + \quad 2H^+(aq) \text{ and } 2Cl^-(aq) \quad \rightarrow \quad Mg^{2+}(aq) \text{ and } 2Cl^-(aq) \quad + \quad H_2(g)$$

Since the chloride ion has not changed during the reaction, it is a **spectator ion** and can be cancelled out.

This leaves an equation that describes what is actually happening during the reaction of a metal with a dilute acid.

$$Mg(s) \quad + \quad 2H^+(aq) \quad \rightarrow \quad Mg^{2+}(aq) \quad + \quad H_2(g)$$

4 A precipitation reaction

e.g. the reaction of sodium chloride solution with silver nitrate solution produces a precipitate of silver chloride.

The balanced equation with state symbols is:

$$NaCl(aq) \quad + \quad AgNO_3(aq) \quad \rightarrow \quad NaNO_3(aq) \quad + \quad AgCl(s)$$

In solution, the ions in an ionic compound are free to move whereas the ions in a solid are tightly packed together.

$$Na^+(aq) \text{ and } Cl^-(aq) \quad + \quad Ag^+(aq) \text{ and } NO_3^-(aq)$$
$$\rightarrow \quad Na^+(aq) \text{ and } NO_3^-(aq) \quad + \quad Ag^+Cl^-(s)$$

The spectator ions are the $Na^+(aq)$ and $NO_3^-(aq)$ and these ions can be cancelled out.

$$\cancel{Na^+(aq)} \text{ and } Cl^-(aq) \quad + \quad Ag^+(aq) \text{ and } \cancel{NO_3^-(aq)}$$
$$\rightarrow \quad \cancel{Na^+(aq)} \text{ and } \cancel{NO_3^-(aq)} \quad + \quad Ag^+Cl^-(s)$$

$$\text{hence} \qquad Cl^-(aq) \quad + \quad Ag^+(aq) \quad \rightarrow \quad Ag^+Cl^-(s)$$

This equation shows the ions which actually react.

In any precipitation reaction,

$$A^+X^-(aq) \quad + \quad B^+Y^-(aq) \quad \rightarrow \quad A^+Y^-(s) \quad + \quad B^+X^-(aq)$$

The spectator ions can be cancelled out to leave:

$$A^+(aq) \quad + \quad Y^-(aq) \quad \rightarrow \quad A^+Y^-(s)$$

Cancelling the effect

A .... accepts $H^+(aq)$ ions from an acid forming water.

$H^+(aq)$ from acid	+	BASE	$\rightarrow$	H_2O		neutralisation

The name of this type of reaction is ....

Examples of bases are metal ...., metal .... and metal ....

There are many everyday examples of neutralisation.

Indigestion tablets contain an alkali which can neutralise excess .... in the stomach.
When you are stung by a bee, the irritation is caused by an acid solution which the bee injects under the skin. You can ease the effects of this by dabbing the skin with a solution of ammonia which is an ....
In contrast, wasp stings are .... and the irritation can be neutralised by dabbing with vinegar, an acid solution.

Concentration

It is useful when working with acid and alkali solutions to know what *quantity of acid or alkali is in the solution.*

The quantity of a solute in a certain volume of solution is called the concentration. The units are **moles per litre** and the symbol for this is **mol l^{-1}**.

A 1 mol l^{-1} solution contains 1 mole of solute per litre of solution

Making a Standard Solution

To prepare a 1 mole per litre solution of sodium hydroxide you would begin by calculating the mass of 1 mole of NaOH

$$NaOH = 23 + 16 + 1 = 40g$$

One mole is the formula mass expressed in grams, so 1 mole of sodium hydroxide will be 40 grams.

1. weigh out 40g
2. dissolve in some water
3. make up to 1 litre in a standard flask

Calculations

In arithmetic terms we describe the concentration by the equation:

$$\text{Concentration} = \frac{\text{number of moles}}{\text{volume (in litres)}}$$

If we know any two of the above quantities we can calculate the third.

$$\text{No of moles} = \text{concentration} \times \text{volume (in litres)}$$

$$\text{Volume} = \frac{\text{No of moles}}{\text{Concentration}}$$

Aim To investigate the dilution of acids and alkalis

Method

Results

		ACID		ALKALI	
Tube	Solution	Colour	pH	Colour	pH
1	10cm^{3}acid or alkali				
2	1cm^3 from tube 1 + 9cm^3 water				
3	1cm^3 from tube 2 + 9cm^3 water				
4	1cm^3 from tube 3 + 9cm^3 water				
5	1cm^3 from tube 4 + 9cm^3 water				
6	1cm^3 from tube 5 + 9cm^3 water				
7	1cm^3 from tube 6 + 9cm^3 water				
8	1cm^3 from tube 7 + 9cm^3 water				

Conclusions

As an acidic solution is diluted, the pH ______________ and the acidity ______________.

As an alkaline solution is diluted, the pH ______________ and the alkalinity ______________.

When 1 cm^3 of an acid is diluted to 100 cm^3, the $H^+_{(aq)}$ ions become more spread out. This means that the concentration of $H^+_{(aq)}$ is reduced as we dilute with water and the pH moves towards 7. The same happens when we dilute an alkali, we reduce the concentration of $OH^-_{(aq)}$ and the pH moves towards 7.

Volumetric titrations

In a neutralisation reaction, neutralisation is complete when all the $H^+(aq)$ ions from the acid have been removed by exactly the same number of $OH^-(aq)$ ions to form water,

i.e. number of moles of $H^+(aq)$ = number of moles of $OH^-(aq)$

volume in litres x conc. x number of $H^+(aq)$ in the formula = volume in litres x conc. x number of $OH^-(aq)$ in the formula

OR multiplying both sides by 1000

volume in cm^3 x conc. x number of $H^+(aq)$ in the formula = volume in cm^3 x conc. x number of $OH^-(aq)$ in the formula

Example 1:
What volume of NaOH(aq) (concentration 2 mol l^{-1}) is required to neutralise 50 cm^3 of $HNO_3(aq)$ (concentration 1 mol l^{-1})?

number of moles of $H^+(aq)$ = number of moles of $OH^-(aq)$

volume x conc. x number of $H^+(aq)$ in the formula = volume x conc. x number of $OH^-(aq)$ in the formula

$$50 \times 1 \times 1 = V \times 2 \times 1$$

$$V = \frac{50}{2}\ cm^3$$

$$= \mathbf{25\ cm^3}$$

Example 2:
If 25 cm^3 of $H_2SO_4(aq)$ is required to neutralise 25 cm^3 of KOH(aq) (concentration 0.1 mol l^{-1}), what is the concentration of the $H_2SO_4(aq)$?

number of moles of $H^+(aq)$ = number of moles of $OH^-(aq)$

$$25 \times \text{conc.} \times 2 = 25 \times 0.1 \times 1$$

$$\text{conc} = \frac{25 \times 0.1}{50}\ mol\ l^{-1}$$

$$= \mathbf{0.05\ mol\ l^{-1}}$$