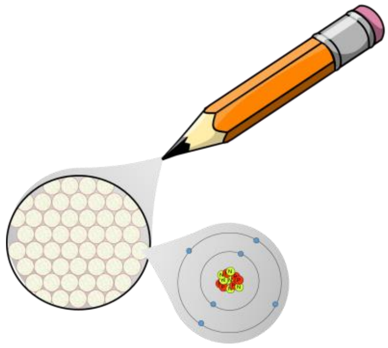
Atomic Structure and Chemical Reactions



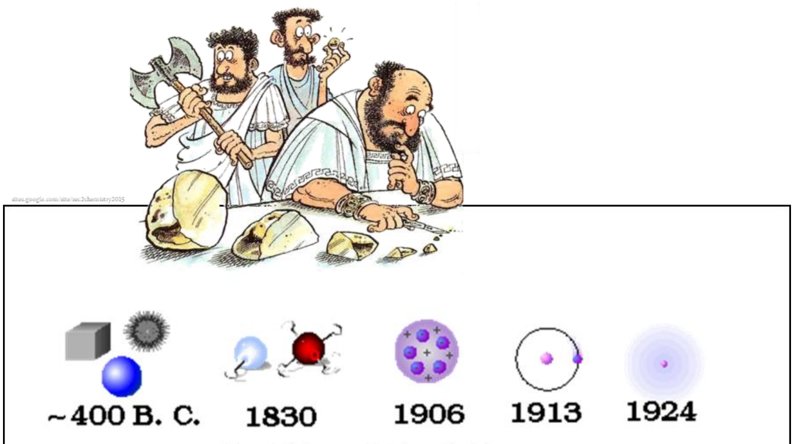
Understand that matter is made up of atoms

An atom is the smallest neutral particle that makes up matter.

The type of atom and the way these atoms are arranged and connected to each other determines the type of matter – and therefore the physical and chemical properties of the matter.

Scientists use models to show the relationship of protons, electrons and neutrons within atoms and ions

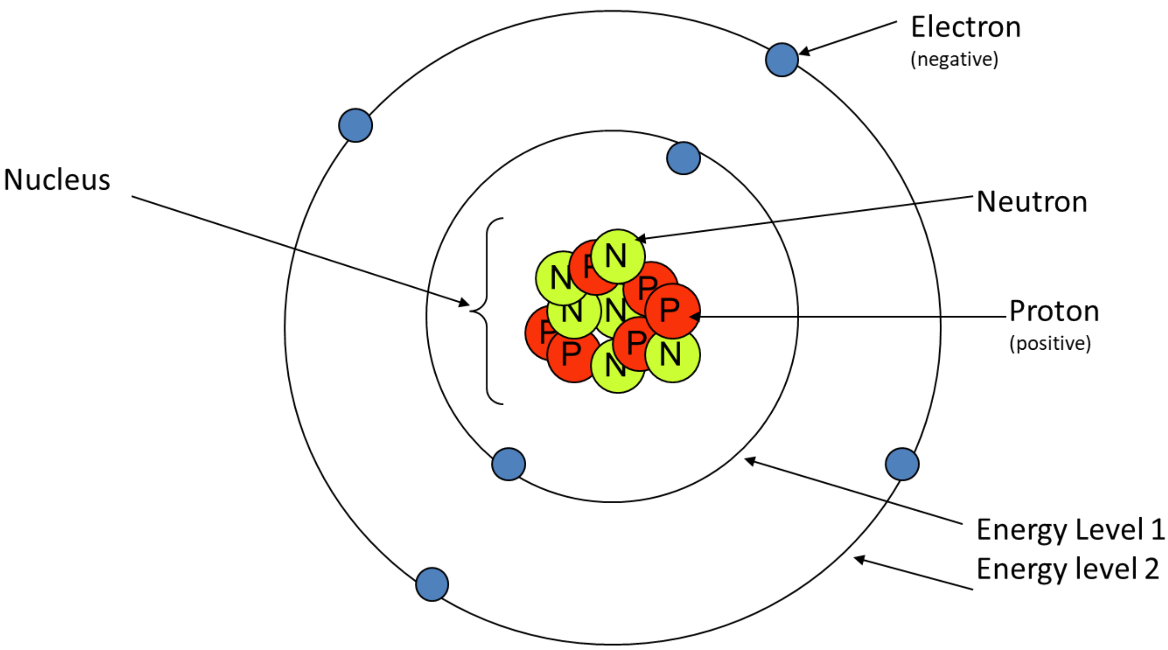
Scientists and philosophers have used models to represent their ideas of what an atom looks like. As more discoveries have been made, the model of the atom has changed.



The History of Atomic Theory

Atoms contain protons, electrons and neutrons

Atoms contain smaller particles, the number of these determine the type of atom. Atoms have a central nucleus, which contains protons (p) and neutrons (n). Electrons (e) orbit outside the nucleus, arranged in energy levels.



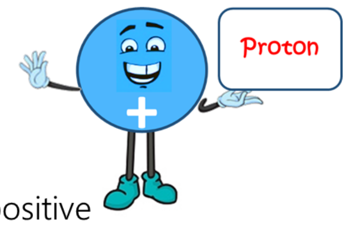
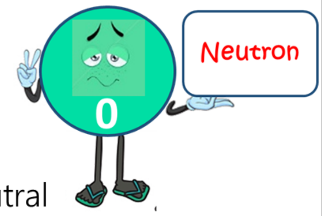
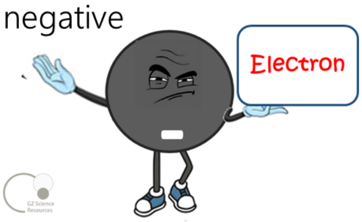
Atoms have equal number of protons and electrons

Protons are positively charged; electrons are negatively charged; neutrons have zero electrical charge.

Atoms have no overall charge because the number of protons = number of electrons.

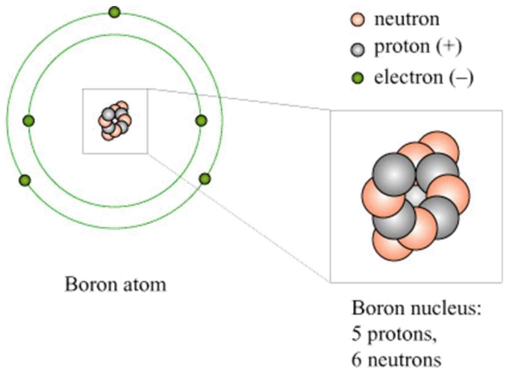
Summary

- ❑ All matter is made up of atoms. Atoms consist of protons, neutrons and electrons.
- ❑ The charges of protons and electrons are equal and opposite.

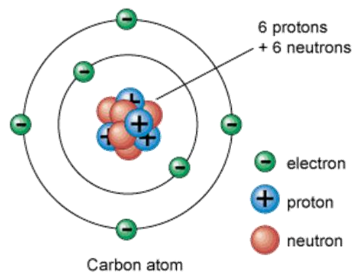
Subatomic particle	symbol	Mass compared to a proton	charge	location
 positive	p	1	+1	In the nucleus
 neutral	n	1	0	In the nucleus
negative 	e	1/1840	-1	Moving outside the nucleus

Each different type of element has a different number of protons in its atoms

Positive protons bond to each other with a special type of force in the centre of an atom, called the nucleus. Each type of atom has its specific number of protons. Neutral neutrons, in approximately the same number as protons, also join together with the protons to form the nucleus. The positive charge of the nucleus holds the same number of negative electrons in position around it.



All Boron atoms have 5 protons in their nucleus.

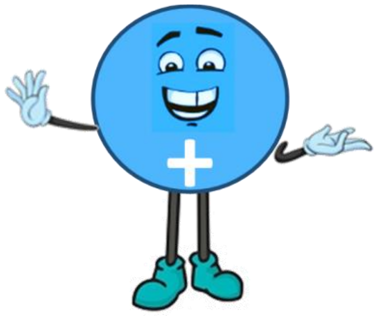


All Carbon atoms have 6 protons in their nucleus.

Atomic and Mass number

The atomic number is unique for each element. An atom has the same number of electrons as protons.
The atomic number of an atom is equal to the number of protons .
The atomic mass (mass number) of an atom is equal to the number of protons and neutrons.
Both numbers are normally found in the periodic table.

Calculating protons, neutrons and electrons



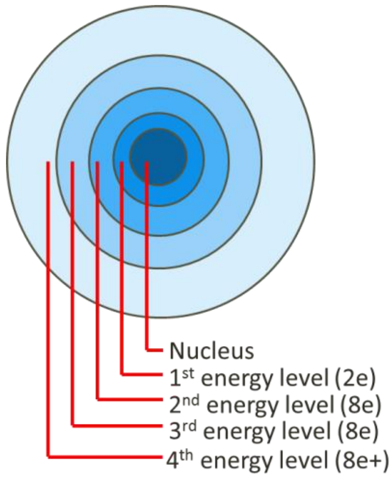
Number of protons:
For an atom = atomic number
Number of electrons:
For an atom = atomic number
Number of neutrons:
For an atom = atomic mass - atomic number

atom or ion	number of protons	Atomic number	number of electrons	number of neutrons	Mass number
carbon (C)	6	6	6	6	12
magnesium (Mg)	12	12	12	12	24
fluorine (F)	9	9	9	10	19

The electrons in an atom are arranged in a series of energy levels.

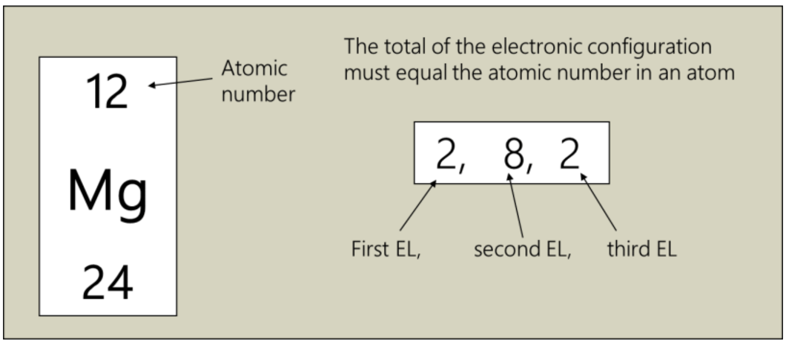
Electrons move or 'orbit' around the nucleus in energy levels or shells. The energy levels further away from the nucleus are able to fit more electrons.
The first energy level is filled first, followed by the second and so on until all the electrons (the same number of protons in an atom) have been used.
Maximum numbers of electrons in each energy level are:

- 2 in the first EL (nearest the nucleus)
- 8 in the second EL
- 8 in the third EL (before the fourth shell starts to fill)
- 8+ in the fourth EL



An atom's electron arrangement is known as its Electron configuration

A shorthand way of describing the way electrons are arranged in an atom is called the *electron configuration*. The information for the number of electrons is found by an elements Atomic Number (number of electrons = number of protons in a neutral atom). Each EL is filled to its maximum capacity, starting with the lowest EL first (EL number 1). The EL are separated by a comma. The EL are filled until all the electrons are placed.



Elements are arranged on the periodic table according to their atomic number

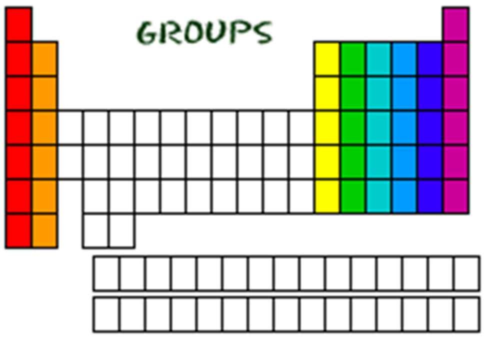
Each element has an atomic number, which tells us how many protons are contained inside each atoms nucleus. This number of protons is matched by an equal number of electrons, which move around the nucleus.

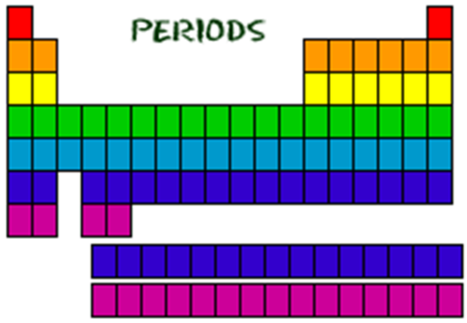
The periodic table starts with Hydrogen (H) Atomic number 1 and ends with elements that have over 100 protons such as Copernicium (Cn) Atomic number 112.

Elements can be classified as metals or non-metals. A few elements are called semi-metals or metaloids (e.g. boron and silicon), because they show some, but not all, of the properties of metals.

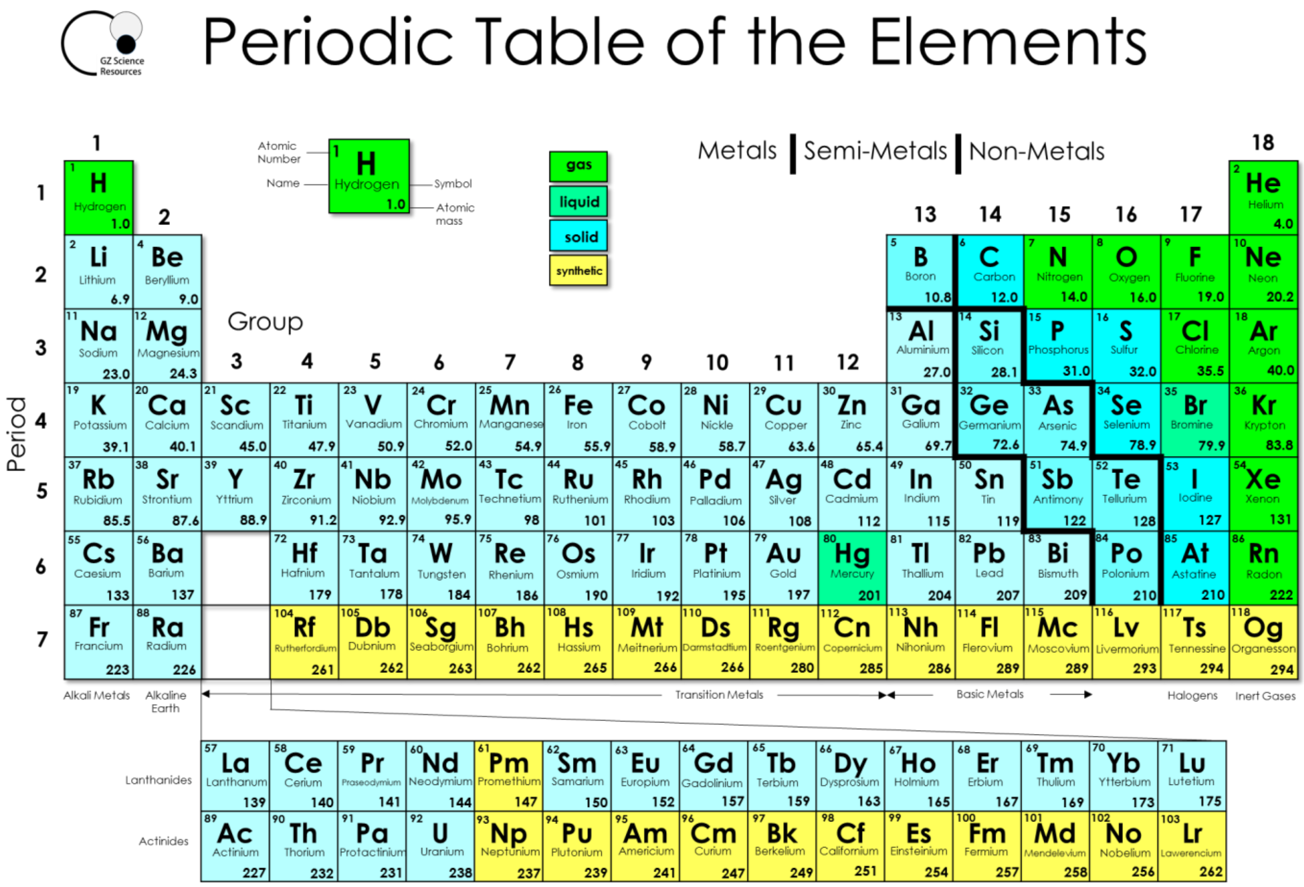
Groups are numbered vertical columns and periods are horizontal rows

The columns (downwards) of a periodic table are called groups.
The rows (across) of a periodic table are called periods.





Elements in the same group all have the same number of electrons in their outer (or valence) energy levels.	Elements in the same period all have the same number of energy levels of electrons in their atoms

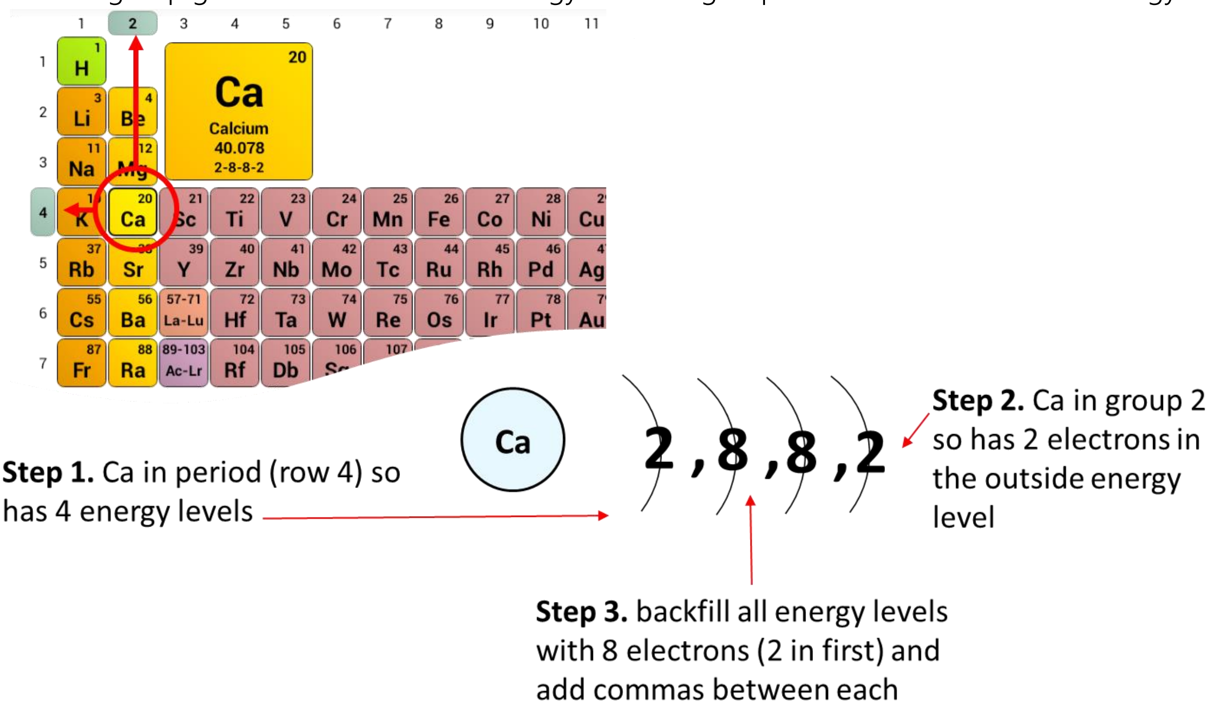


There is a relationship between the period number and the number of electron energy levels an atom has.

In the periodic table, elements have something in common if they are in the same row. All of the elements in a period have the same number of electron energy levels. Every element in the top row (the first period) has one energy level for its electrons) All of the elements in the second row (the second period) have two energy levels for their electrons. It goes down the periodic table like that.

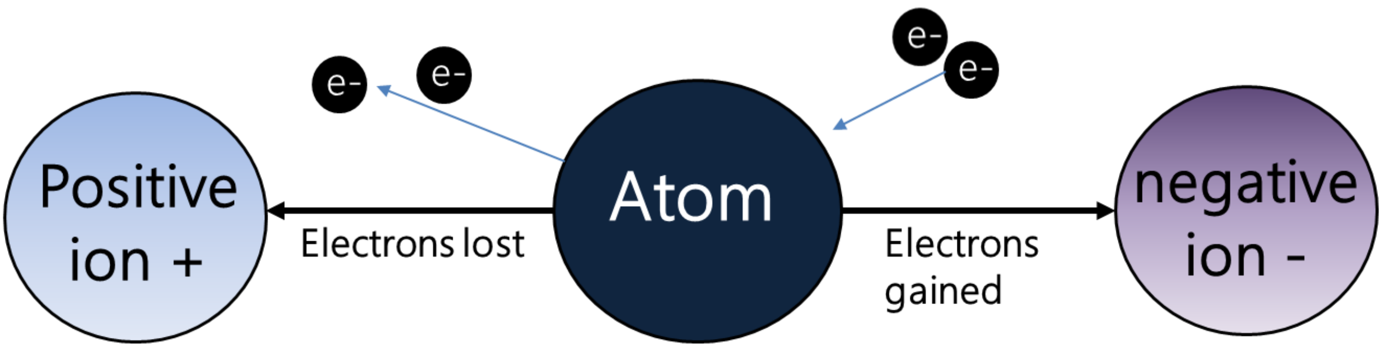
Using the Periodic table to write electron arrangements (Extension)

Period number gives number of energy levels
Last number of group gives electrons in outer energy level. i.e. group 17 - 7 electrons in outer energy level.



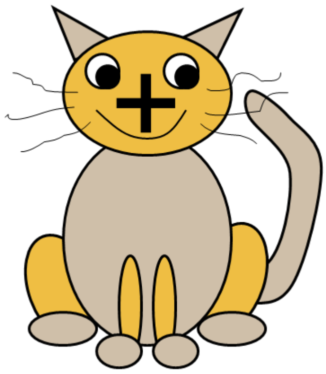
Ions

An ion is an atom or group of atoms, which has gained or lost electrons.
Elements are most stable when the outer energy level (valence shell) is full. The first energy level needs 2 electrons to be stable. The other energy levels need 8 electrons to be stable.
Elements can lose or gain electrons when they react with other chemicals to form ions and achieve stability.



Ions form when atoms gain or lose electrons.
Ions are atoms or groups of atoms with electrical charges. Ions normally form in pairs of atoms when one or more electrons are passed between them. Depending on how many electrons are present in the outside energy level or how many are "missing" determines the total number of electrons transferred.
Atoms that lose electrons form positively charged ions, or cations.
Atoms that gain electrons form negatively charged ions, or anions.

Cation (Cat)



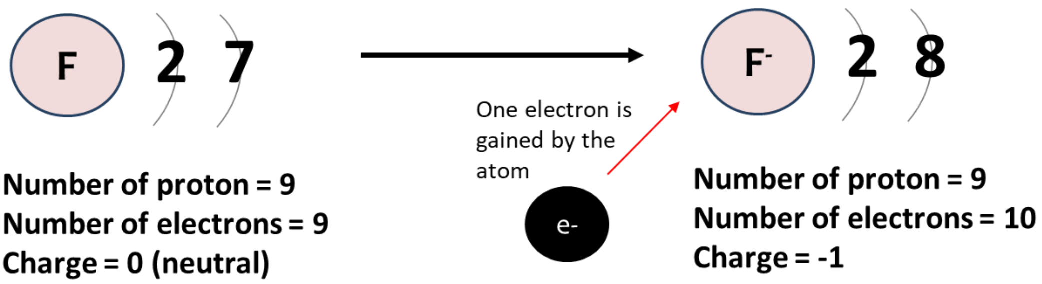
Metals lose electrons to form Cations. They have 1-3 electrons in their outside energy level

Anion (an Iron)

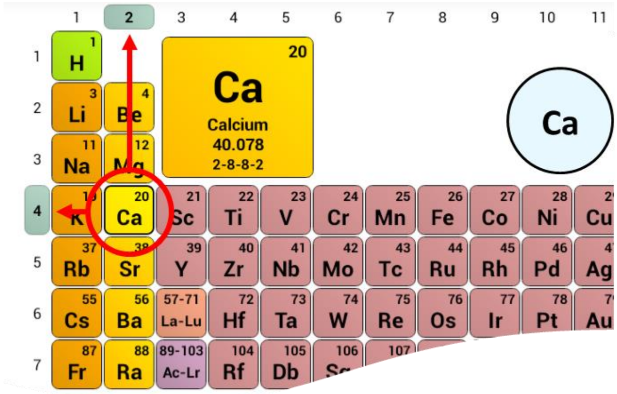
Non-Metals gain electrons to form Anions. They have 5-7 electrons in their outside energy level.

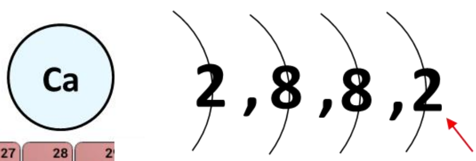
The number of protons compared to electrons determines the charge (Extension)
If an atom has the same number of electrons as it does protons then it will be neutral. A negative ion will have more electrons than protons. A positive ion will have less electrons than protons.

	Atomic Number	Number of protons	Number of electrons	Electron arrangement
F^-	9	9	10	2,8
Ne	10	10	10	2,8
Mg^{2+}	12	12	10	2,8



The (last) number of the group on a periodic table gives the number of electrons in the outside Energy Level. If there is 3 or less, in groups 1,2 or 13 then electrons will be lost to form positive ions.
If there is 5, 6 or 7, in groups 15, 16 or 17 then electrons will be gained to form negative ions



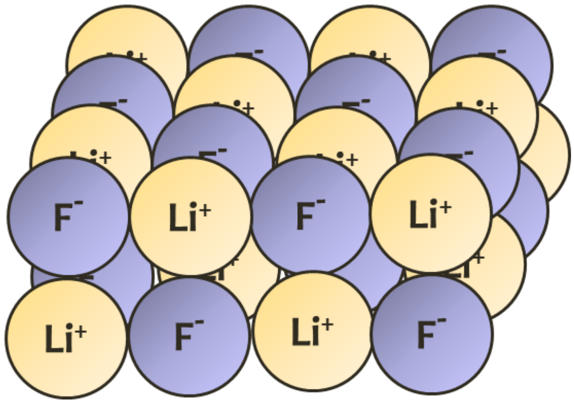


Ca in in group 2 so has 2 electrons in the outside energy level

Ca will lose 2 electrons to become a positive Ca^{2+} ion

Compounds

Compounds form from two or more different elements bonded together (in the form of atoms or ions)
Ionic compounds are the product of chemical reactions between metal and non-metal ions. Ionic compounds are made up of a fixed ratio of cations and anions. They exist in huge structures in a lattice structure. We call these structures crystals.



Compounds are neutral substances. For ionic compounds, the charges of the positive ions are balanced by the charges of the negative ions.

Ionic Bonding (Extension)

Ionic Bonding is where one atom completely takes valence (outside energy level) electrons from another to form ions and the resulting negative and positive ions hold together with electrostatic attraction. This type of bonding occurs when a metal and non-metal react and there is a transfer of electrons to form ions.

The ions then combine in a set ratio to form a neutral compound with negative and positive charges balanced out.

Ion table - Light shaded ions will be more commonly used in class

1+		2+		3+	
sodium	Na^{+}	magnesium	Mg^{2+}	aluminium	Al^{3+}
potassium	K^{+}	iron (II)	Fe^{2+}	iron (III)	Fe^{3+}
silver	Ag^{+}	copper (II)	Cu^{2+}	NOTE: while most positive ions in this group are made up from only one type of original element some ions are made up from a compound with more than one type of element – they have less total electrons than total protons.	
ammonium	NH_4^{+}	zinc	Zn^{2+}		
Hydrogen	H^{+}	barium	Ba^{2+}		
Lithium	Li^{+}	lead	Pb^{2+}		

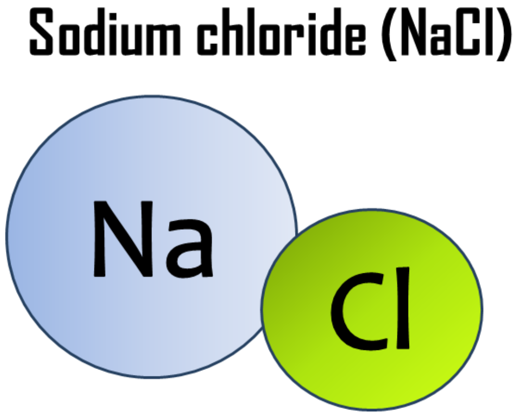
1-		2-	
chloride	Cl^{-}	carbonate	CO_3^{2-}
hydroxide	OH^{-}	sulfide	S^{2-}
hydrogen carbonate	HCO_3^{-}	sulfate	SO_4^{2-}
fluoride	F^{-}	NOTE: while many negative ions in this group are made up from only one type of original element some negative ions are made up from a compound with more than one type of element – they have more total electrons than total protons.	
bromide	Br^{-}		
nitrate	NO_3^{-}		

Naming a compound (Extension)

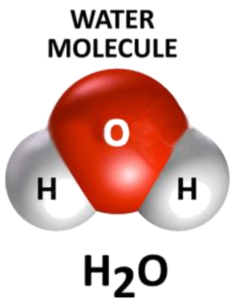
A compound is named after the atoms or ions that make it up. Many compounds are made up of ions, a positive and negative ion bonded together known as ionic compounds. Other compounds are made up of atoms bonded together.

All compounds are neutral and have the same total number of protons as the total number of electrons. Some compounds have common names such as water.

Ionic compounds (made of ions bonded) have names of two parts. The positive ion (Metal) is first then followed by the negative ion (non-metal). The compound sodium chloride is made of a sodium ion bonded to a chloride ion.



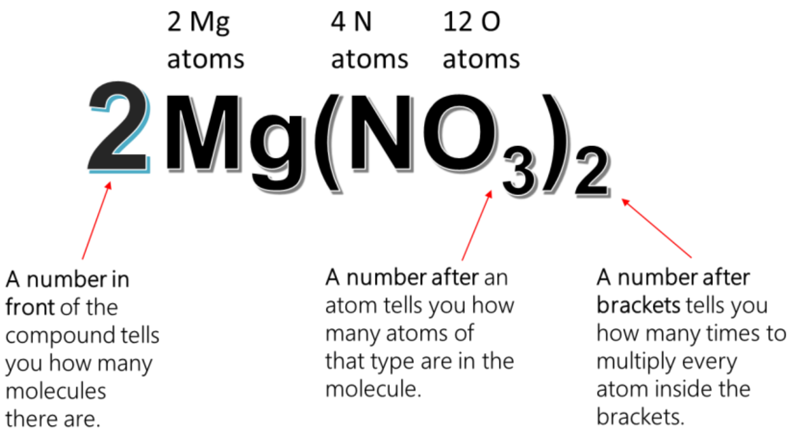
Chemical compound formula (Extension)



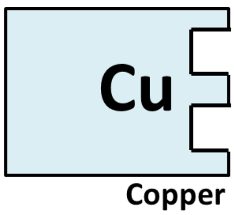
Elements in a compound combine in fixed amounts. It is possible to write a formula for a compound. Each compound has a chemical formula indicating the proportions of each combined element.

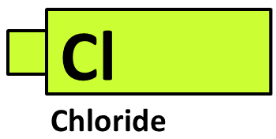
This formula for water (H_2O) tells us that there are 2 Hydrogen atoms and 1 Oxygen atom in a molecule of water

Elements in a compound combine in fixed amounts. It is possible to write a formula for a compound. A formula tells you the type of atoms that are in a compound and the number of each atom.



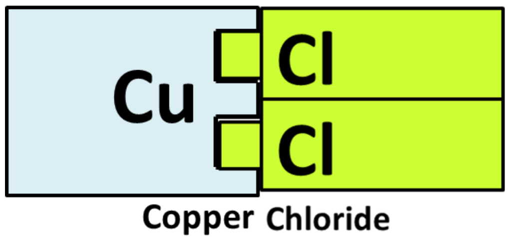
The visual method for balancing compounds (Extension)





Copper forms a positive copper ion of Cu^{2+}. It loses 2 electrons – shown by the 2 "missing spaces" in the shape

Chlorine forms a negative chloride ion of Cl^{-}. It gains 1 electron – shown by the 1 "extra tab" in the shape



Copper chloride has a formula of $CuCl_2$

If we want to form a balanced ionic compound then each space in the positive ion must be filled by a tab from the negative ion. In this case 2 chloride ions are needed for each copper ion to form copper chloride.

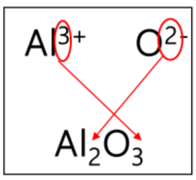
Product formula (Extension)

When products are made in a reaction the name of it is often a combination of the names of the chemicals it is formed from. For example $MgCl_2$ is called magnesium chloride

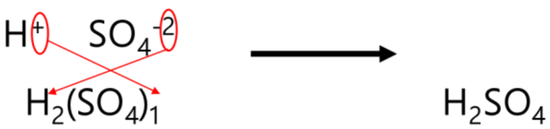
Cation			Anion	
1+	2+	3+	2-	1-
H Hydrogen	Mg Magnesium	Fe Iron (III)	O Oxide	Cl Chloride
Na Sodium	Ca Calcium		SO_4 Sulfate	OH Hydroxide
K Potassium	Cu Copper	Al Aluminium	CO_3 Carbonate	NO_3 Nitrate
NH_4 Ammonium	Pb Lead		S Sulfide	HCO_3 Hydrogen Carbonate
Ag Silver	Zn Zinc	Fe Iron (III)		F fluoride
Li Lithium	Fe Iron (II)			

Cross and Drop method for balancing ionic compounds

1. Write down the ions (with charges) that react to form the compound. Cation comes before Anion.



2. Cross and drop the charge numbers.
3. Place brackets around a compound ion.
4. If the numbers are both the same remove.
5. If any of the numbers are a 1 they are removed
6. Remove any brackets if not followed by a number

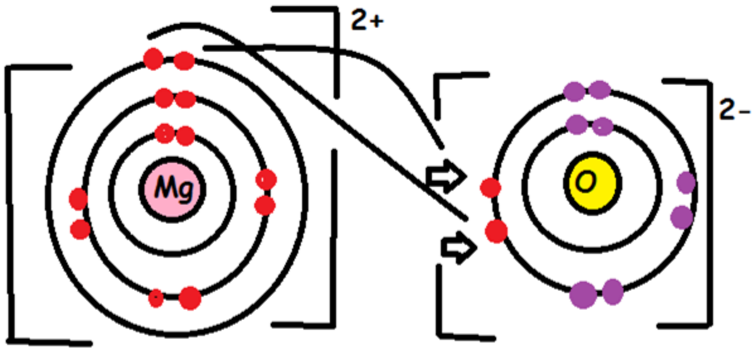


Charged ions make neutral Ionic Compounds (Extension)

The formula for magnesium oxide is MgO made of Magnesium ion has a charge of +2 and oxide ion has a charge of –2.

A compound overall has to have no charge. Therefore, the +2 charge of magnesium ion cancels out the –2 charge of oxide ion and so the ratio of ions is one to one.

The charge on the ions arises, as magnesium has to lose two electrons in order to have a full outer energy level and gets a charge of +2, and oxygen has to gain two electrons in order to have a full outer energy level and gets a charge of –2.



The formula for aluminium oxide is Al_2O_3 but the Aluminium ion has a charge of +3, and oxide ion has a charge of -2.

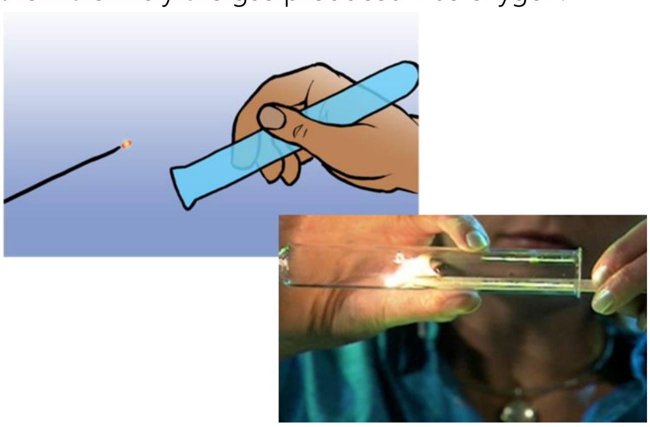
A compound overall has to have no charge. Two aluminium ions with a combined charge of +6 are required to cancel out the charge on three oxide ions with a combined charge of –6.

The charge on the ions arises as aluminium has to lose three electrons in order to have a full outer energy level and gets a charge of +3, and oxygen has to gain two electrons in order to have a full outer energy level and gets a charge of –2

Testing for Oxygen gas

How to test for Oxygen Gas

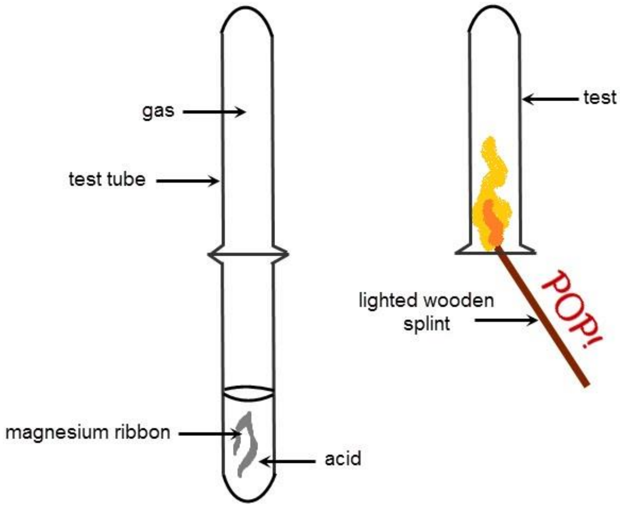
1. Put a small amount of Manganese dioxide into a boiling tube and add hydrogen peroxide.
   BE CAREFUL WITH THESE CHEMICALS and ALWAYS FOLLOW LAB SAFETY RULES
2. Put a bung with a delivery tube over the boiling tube and put the delivery tube into an upside down test tube to collect any gas.
3. Heat the tube gently with a Bunsen burner.
4. Remove delivery tube and place thumb over test tube.
5. Remove thumb quickly and place a glowing splint into the test tube.
6. If the splint re-ignites then it is likely the gas produced was oxygen.



Testing for Hydrogen gas

How to test for Hydrogen Gas

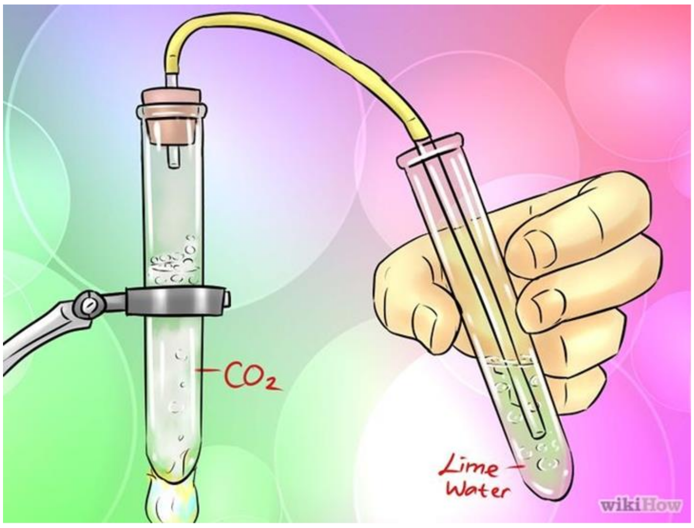
1. Put a small piece of magnesium metal into a test tube with a small amount of dilute hydrochloric acid.
2. Place another test tube upside down over top of the first test tube
3. Collect the gas in the upside down test-tube.
4. Place thumb over top of the test tube
5. Hold a lit match at the mouth of the test tube and remove thumb quickly
6. If the gas makes a loud 'pop' then it is likely that the gas produced is hydrogen.



Testing for Carbon Dioxide gas

How to test for Carbon Dioxide Gas

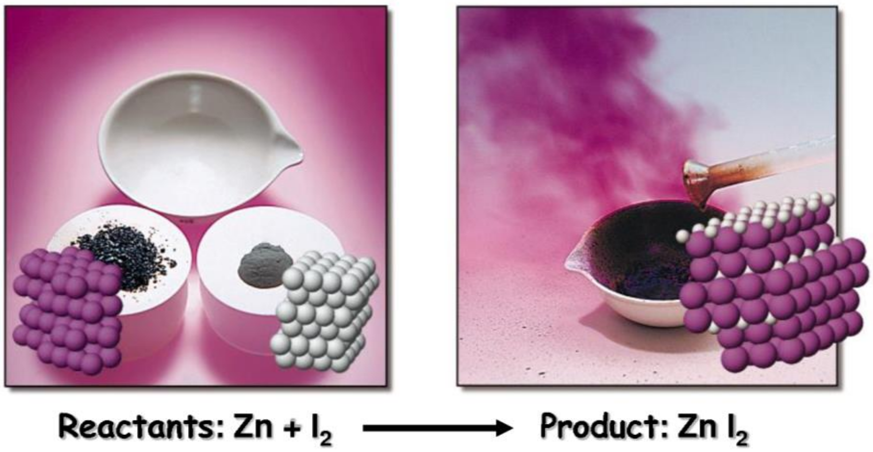
1. Put a small amount of calcium carbonate with dilute hydrochloric acid into a boiling tube.
2. Put a bung with a delivery tube over the boiling tube.
3. Place the delivery tube into a test-tube filled with clear limewater
4. Observe the gas bubbling into the limewater.
5. If the limewater turns cloudy then it is likely that the gas produced is carbon dioxide.



Carbon Dioxide is a colourless gas and limewater is a solution of calcium hydroxide in water, which is also colourless. The carbon dioxide gas reacts with the limewater and changes it into calcium carbonate which is not soluble (cannot dissolve) in water and appears as a milky white colour.

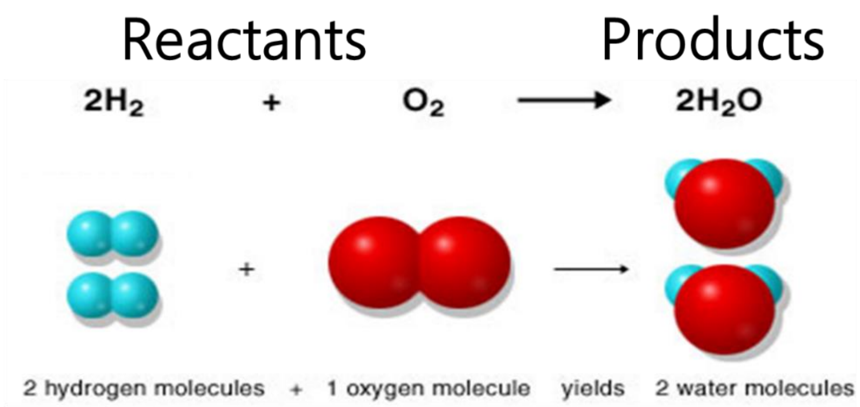
Chemical reactions - naming reactants & products

A chemical reaction is a process that produces a chemical change to one or more substances.
A chemical reaction will produce a new substance. Chemicals that are used in a chemical reaction are known as reactants. Those that are formed are known as products. Other observations of a chemical reaction may include a temperature change, a colour change or production of gas.



Reactants join together to form new products during chemical reactions

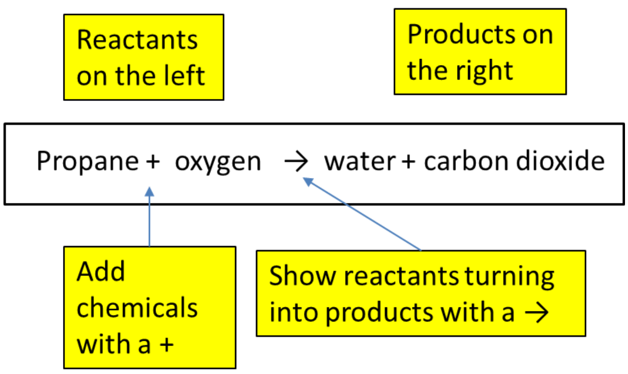
The atoms present in the reactants rearrange themselves in different combinations and form new bonds. The new combinations of atoms are called products and can either be single atoms or molecules.



Chemical reactions – word equations

When we convert descriptions of reactions into word equations there is a set way of writing it. Once we have a word equation we can write a formula equation.
For example: When we use a BBQ we cook with propane gas (C_3H_8) which needs oxygen gas in the air (O_2) to combust (or burn). The burning process creates water (H_2O) and carbon dioxide gas (CO_2)

The word equation therefore will be:

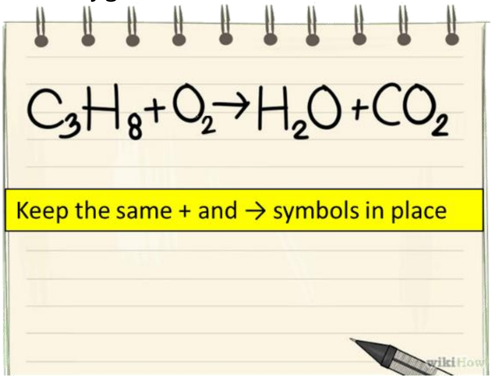


Writing and Balancing symbol equations (Extension)

In a chemical equation the total number of atoms in the reactants must equal the total number of atoms in the products as no atoms are created or destroyed just rearranged with new bonds formed or bonds broken

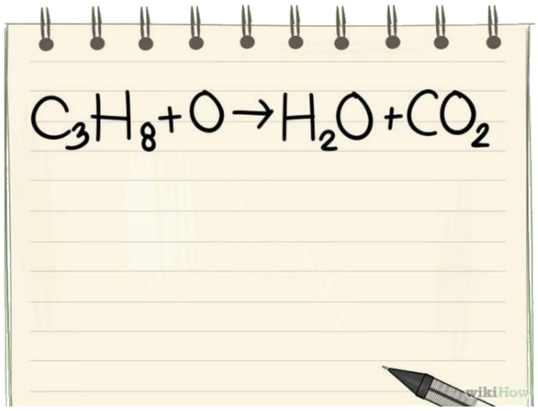
1. The word equation is:

Propane + oxygen → water + carbon dioxide



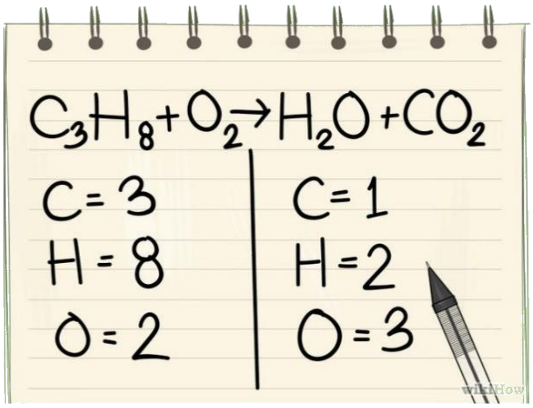
Once you can write word equations practice by writing the formula underneath

2. To balance an equation first write down the equation

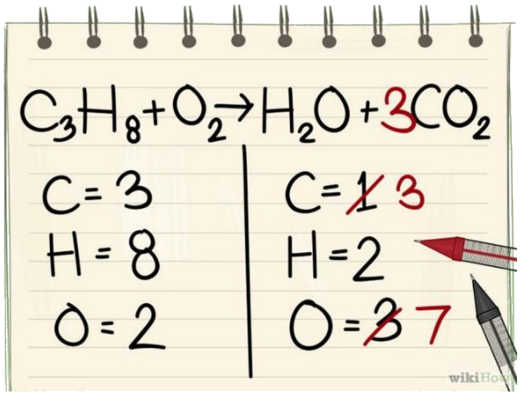


The total number of each type of atom must be the same for reactants and products if they equation is balanced

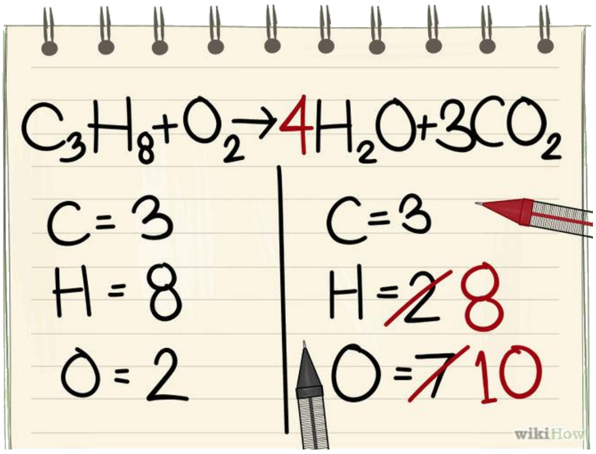
3. Count the total number of each atom for reactants and products



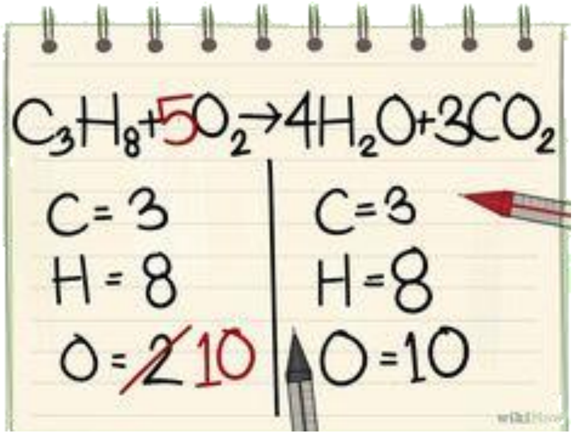
4. Starting with the first atom (C) multiply until it is the same on both sides – and place this number in front of the compound. You may change the number of another atom but you can sort this as you move down the list



5. Moving down the list to the next atom (H) multiply until both sides are the same – again you may also increase another atom but sort that out after



6. Moving to the last atom on this list (O) multiply until it is the same number on both sides



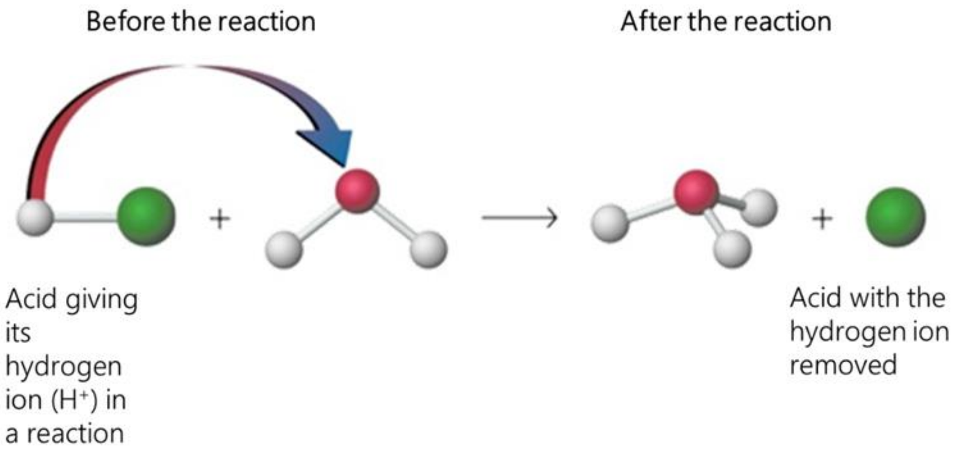
If all atoms are the same number on both sides then the equation is balanced!

Acids – their characteristics

Acids are a family of substances which all show acidic characteristics or properties. These properties relate to how the acids react with other chemicals. They have a sour taste and react with metals. Acids can be found in nature and called organic acids or manufactured in the laboratory and called mineral acids.

Name	Chemical formula
Hydrochloric Acid	HCl
Sulfuric Acid	H_2SO_4
Nitric Acid	HNO_3

All acids contain hydrogen. When an acid reacts it gives away its Hydrogen ion (H^+), which is really just a proton, and the electron remains behind.



Bases – their characteristics

Bases are a family of Chemicals that have hydroxide ions present (OH^-). They have opposite properties from acids. Common Household bases include floor clearers and antacid tablets to fix indigestion. A Base that dissolve into water is called an alkali.

Name	Chemical formula
Sodium Hydroxide	$NaOH$
Calcium carbonate	$CaCO_3$
Ammonia	NH_3
Potassium hydroxide	KOH

Bases include metal oxides (MO), metal hydroxides (MOH), metal carbonates (MCO_3) and metal hydrogen carbonates ($MHCO_3$) with M = metal

Indicators determine whether substances are acid, base or neutral.

Indicators can be used to determine the pH of a solution by the colour change. An indicator is a large organic molecule that works like a "colour dye". They respond to a change in the hydrogen ion concentration. Most of the indicators are themselves weak acids.

The most common indicator is found on litmus paper. It turns/remains red for acid and turns/remains blue for a base.

Universal Indicator, which is a solution of a mixture of indicators that provide a full range of colours for the pH scale.

Red and Blue Litmus paper works as an indicator

Added to…	Blue Litmus	Red litmus
Acid solution	Turns red	Stays red
Base solution	Stays blue	Turns blue
Neutral solution	Stays blue	Stays red

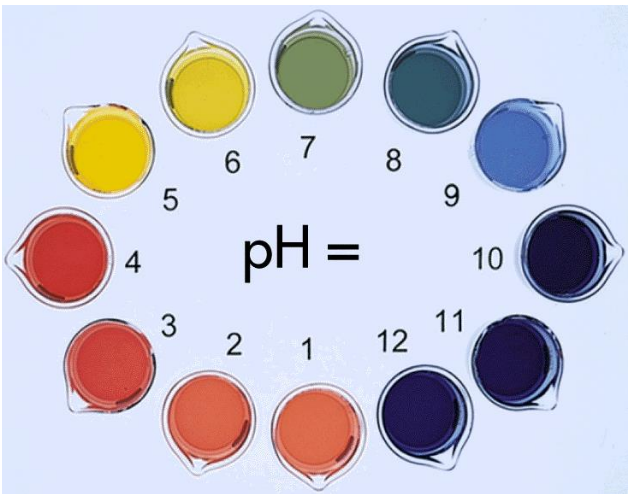
Blue litmus paper turning red in acid

Red litmus paper turning blue in base

Universal Indicator is used to give the strength of the acid or base

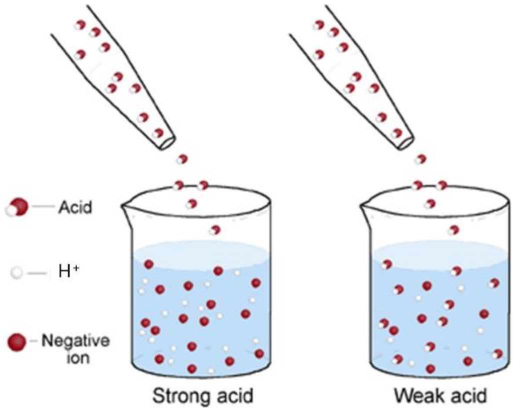
The Universal Indicator is similar to the Litmus paper in that the acids turn the indicator mostly red and the bases turn the indicator mostly blue.

It does have an advantage over the litmus paper, as it shows neutral by having a green colour and has different colours for weak acids and weak bases.



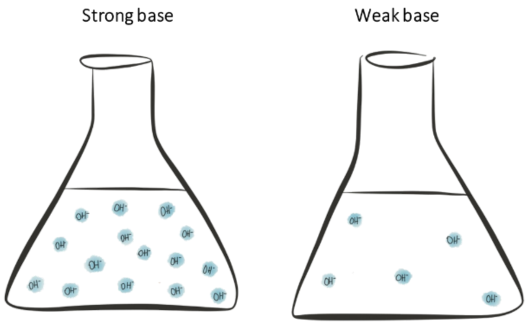
The difference between strong and weak acids and bases (Extension)

You can define acids and bases as being "strong" or "weak". Strong acids are compounds release a large amount of H^+ ions. A weak acid releases much less H^+ ions



Strong and weak bases

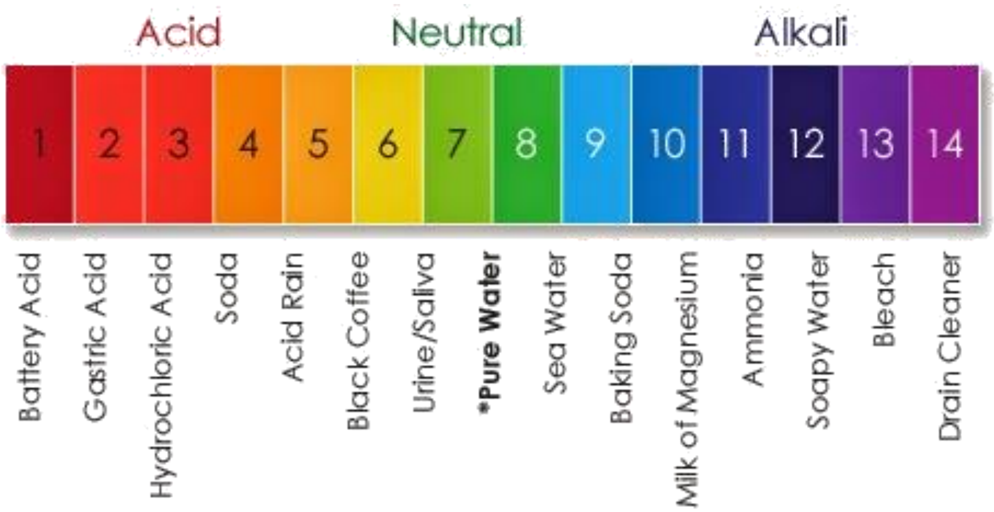
You can define bases as being "strong" or "weak". Strong bases are compounds where they release a large amount of OH^- ions. A weak base is a compound where there are much less OH^- ions released. Most weak base molecules remain unreacted.



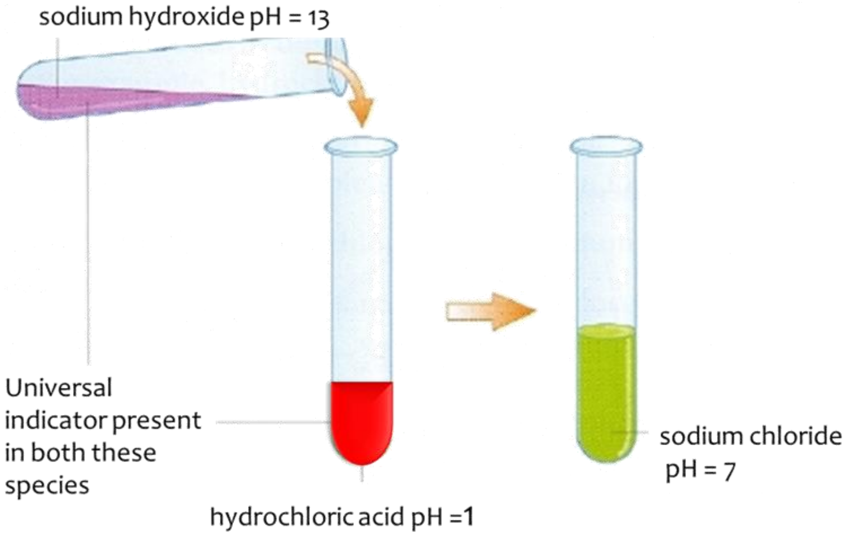
The pH scale measures level of acidity and alkalinity

The pH scale measures how acidic or alkaline a substance is. Substances with a pH of 7 are neutral, substances with a pH greater than 7 are alkaline (or 'basic') and substances with a pH lower than 7 are acidic. Remember alkalis are 'bases' that are soluble in water. (All alkalis are bases but not all bases are alkalis.)

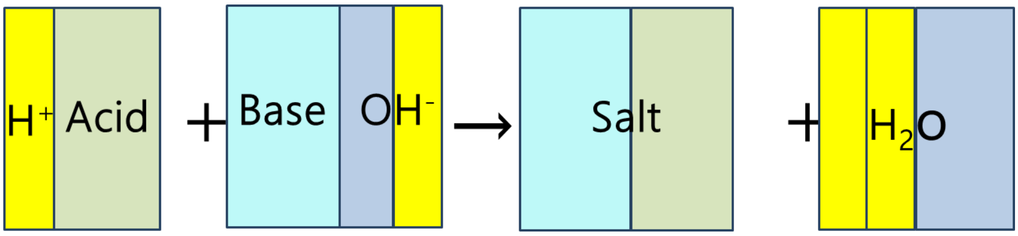
The pH of a substance is determined by the concentration of hydrogen ions. The higher the concentration of hydrogen ions the lower the pH.



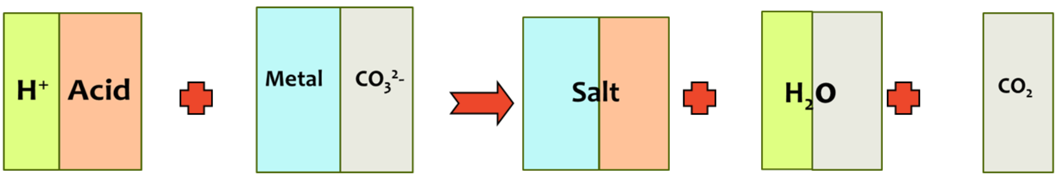
During neutralisation reactions acids combine with bases to form a salt and water



Balanced equations for salt formation (Extension)

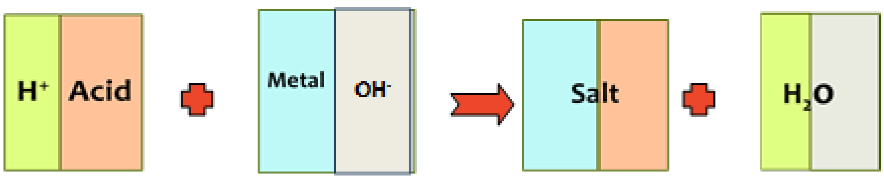


Acids react with Carbonates to give a salt and water and carbon dioxide. We can test to see if carbon dioxide has formed by bubbling the gas into another test tube filled with limewater. The limewater will turn cloudy if the gas is carbon dioxide.



H_2SO_4	+	$CaCO_3$	→	$CaSO_4$	+	H_2O	+	CO_2
sulfuric Acid		calcium carbonate		calcium sulfate		water		carbon dioxide

Acids react with hydroxides to give a salt and water. We can test to see if a solution has been neutralized (all of the acids and base has reacted to form salt and water) by testing with universal indicator which will turn green.

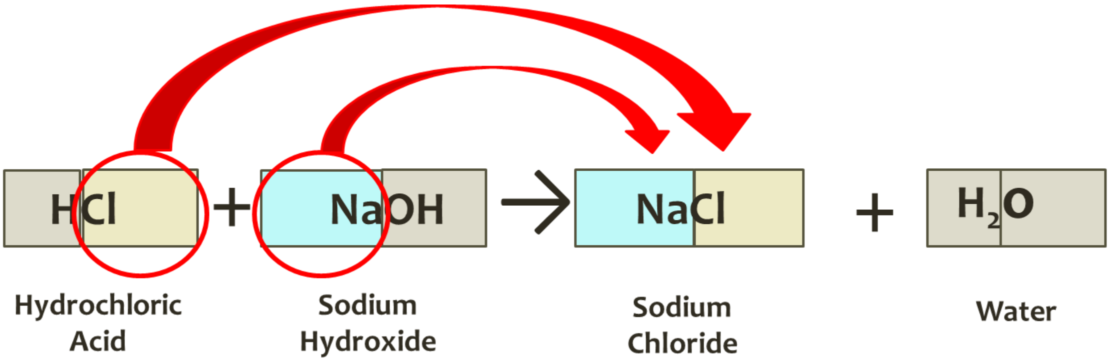


H_2SO_4	+	$CaCO_3$	→	$CaSO_4$	+	H_2O
sulfuric acid		calcium hydroxide		calcium sulfate		water

Names of salts (Extension)

When salts are formed the name depends upon the acid reacted and the metal that forms part of the base compound.

Name of acid	Name of salt formed
Hydrochloric acid	chloride
Sulfuric acid	sulfate
Nitric acid	nitrate



Acid reactions summary (Extension)

1. Acid and Base

General equation acid + base → salt + water

Word equation nitric acid + copper oxide → copper nitrate + water

Formula equation $2HNO_3 + CuO \rightarrow Cu(NO_3)_2 + H_2O$

2. Acid and Metal Carbonate

General equation acid + metal carbonate → salt + water + carbon dioxide

Word equation hydrochloric acid + magnesium carbonate → magnesium chloride + water + carbon dioxide

Formula equation $2HCl + MgCO_3 \rightarrow MgCl_2 + H_2O + CO_2$