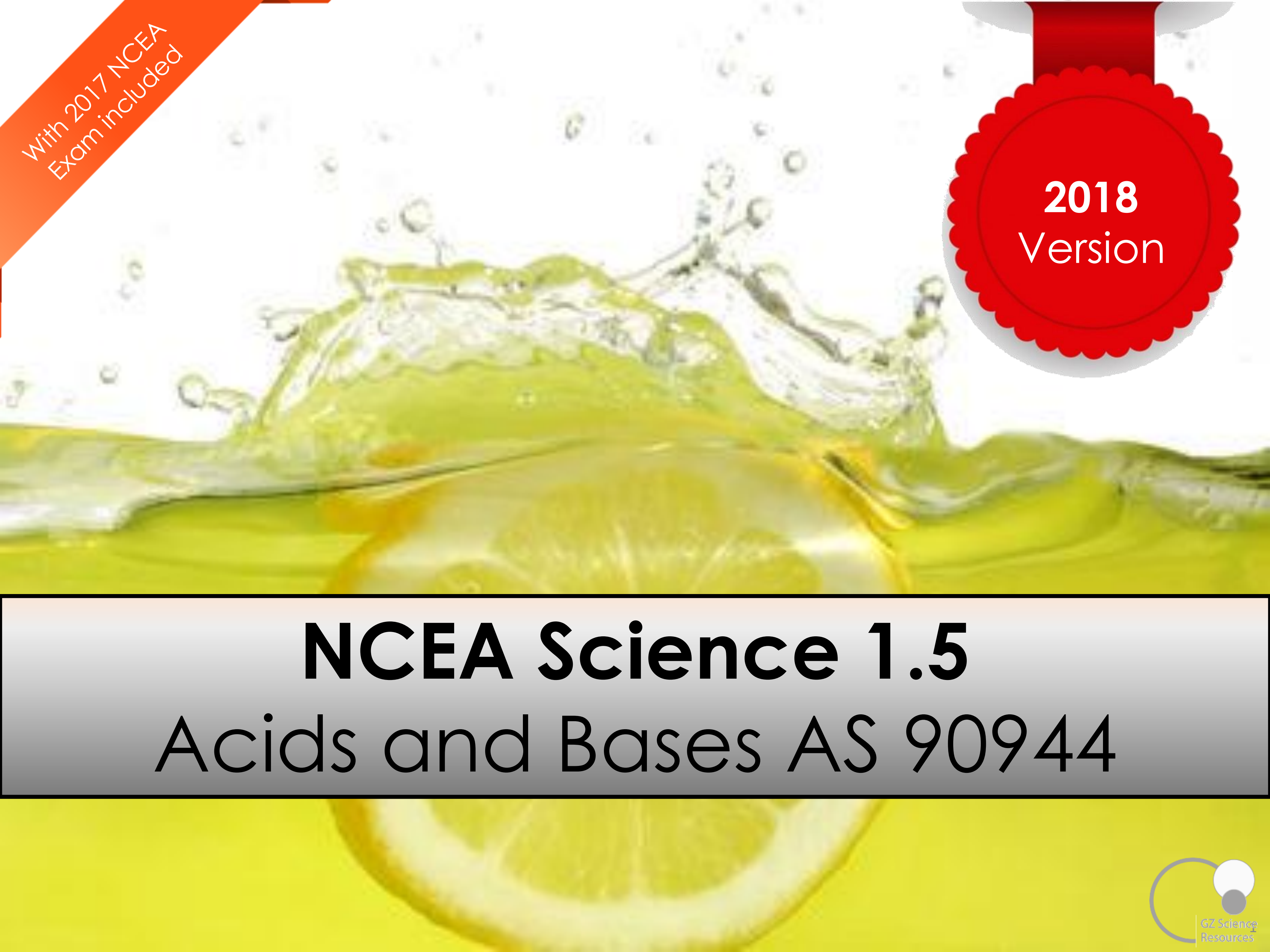

With 2017 NCEA Exam included

2018 Version

NCEA Science 1.5

Acids and Bases AS 90944

GZ Science Resources

Achievement Criteria

AS 90944
S1.5

Aspects of acids and bases **will be selected from:**

Atomic structure

- electron arrangement of atoms and monatomic ions of the first 20 elements (a periodic table will be provided)
- ionic bonding
- names and formulae of ionic compounds using a given table of ions.

Properties

- acids release hydrogen ions in water (HCl ; hydrochloric acid, H_2SO_4 : sulphuric acid, HNO_3 : nitric acid)
- reactions (of acids with bases) to form salts (Bases include metal oxides, hydroxides, carbonates and hydrogen carbonates)
- pH and effects on indicators.

Uses

- neutralisation
- carbon dioxide formation
- salt formation.

- Rates of reaction and particle theory.

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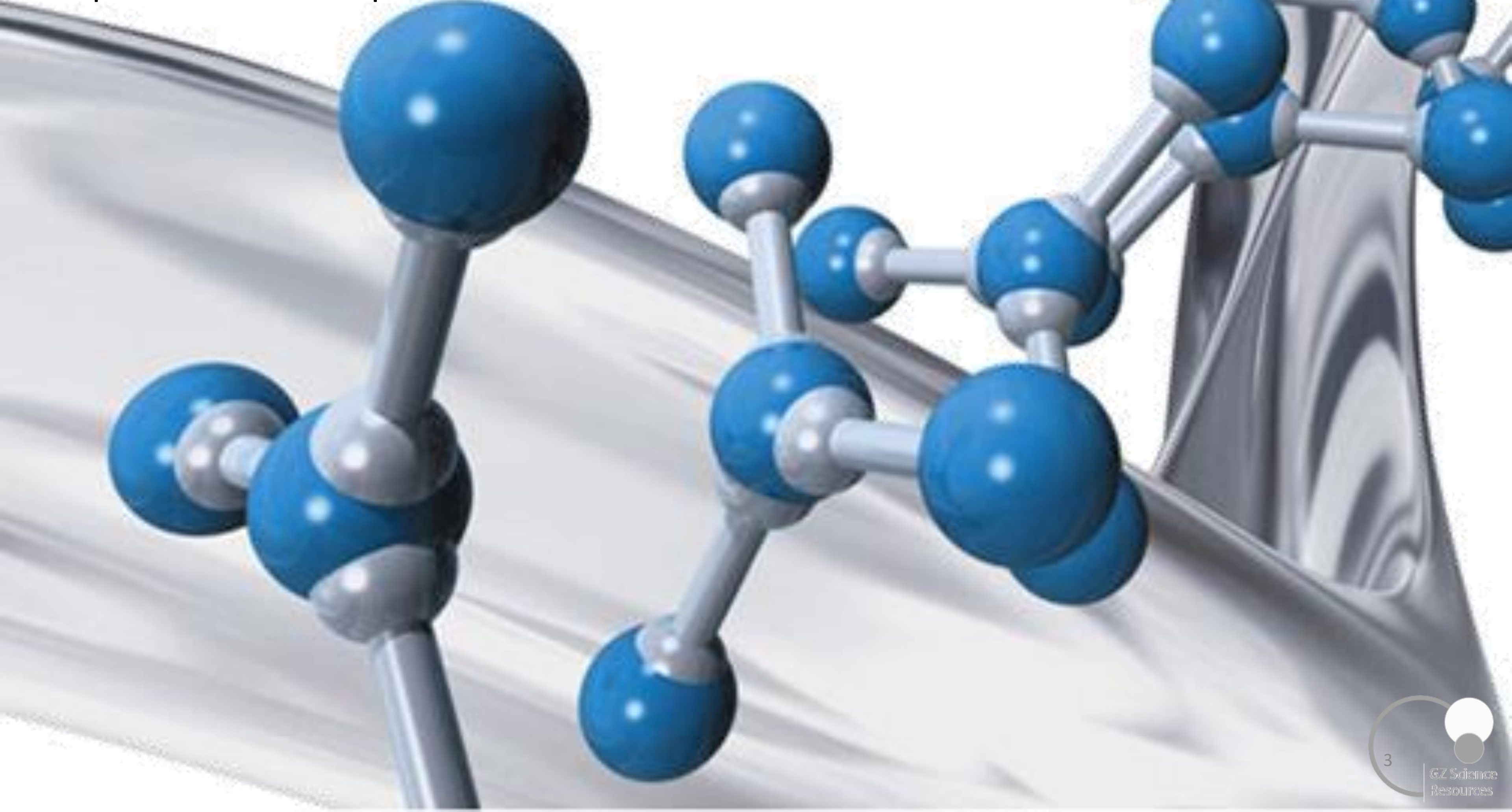
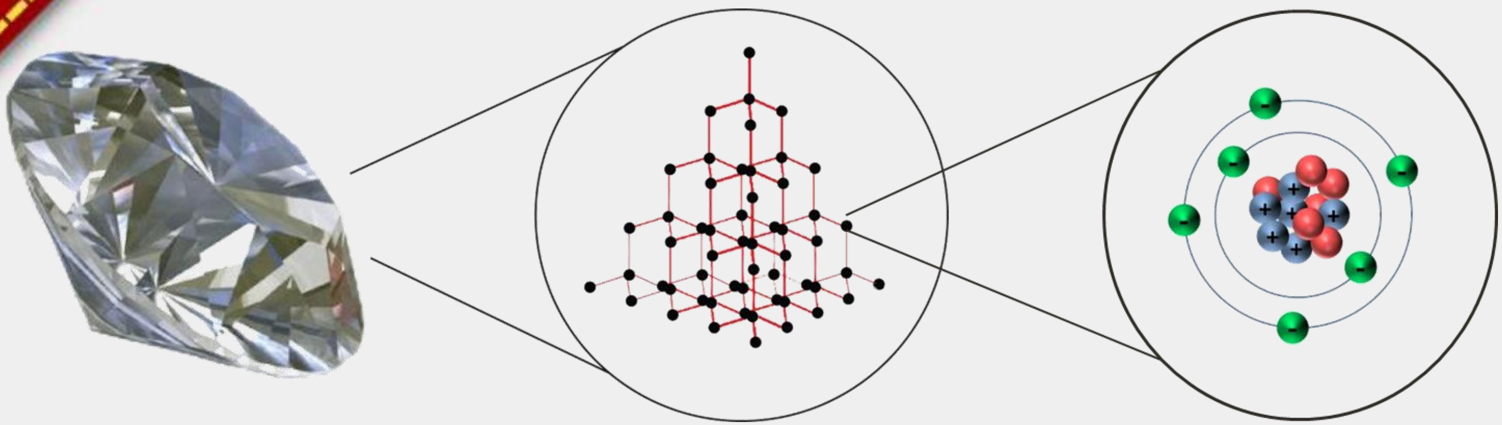
Introduction

Chemistry is the study of matter and energy and the interaction between them. The elements are the building blocks of all types of matter in the universe. Each element consists of only one type of atom, each with its specific number of protons known as its atomic number.



Background Knowledge

All Matter is made up of particles called atoms

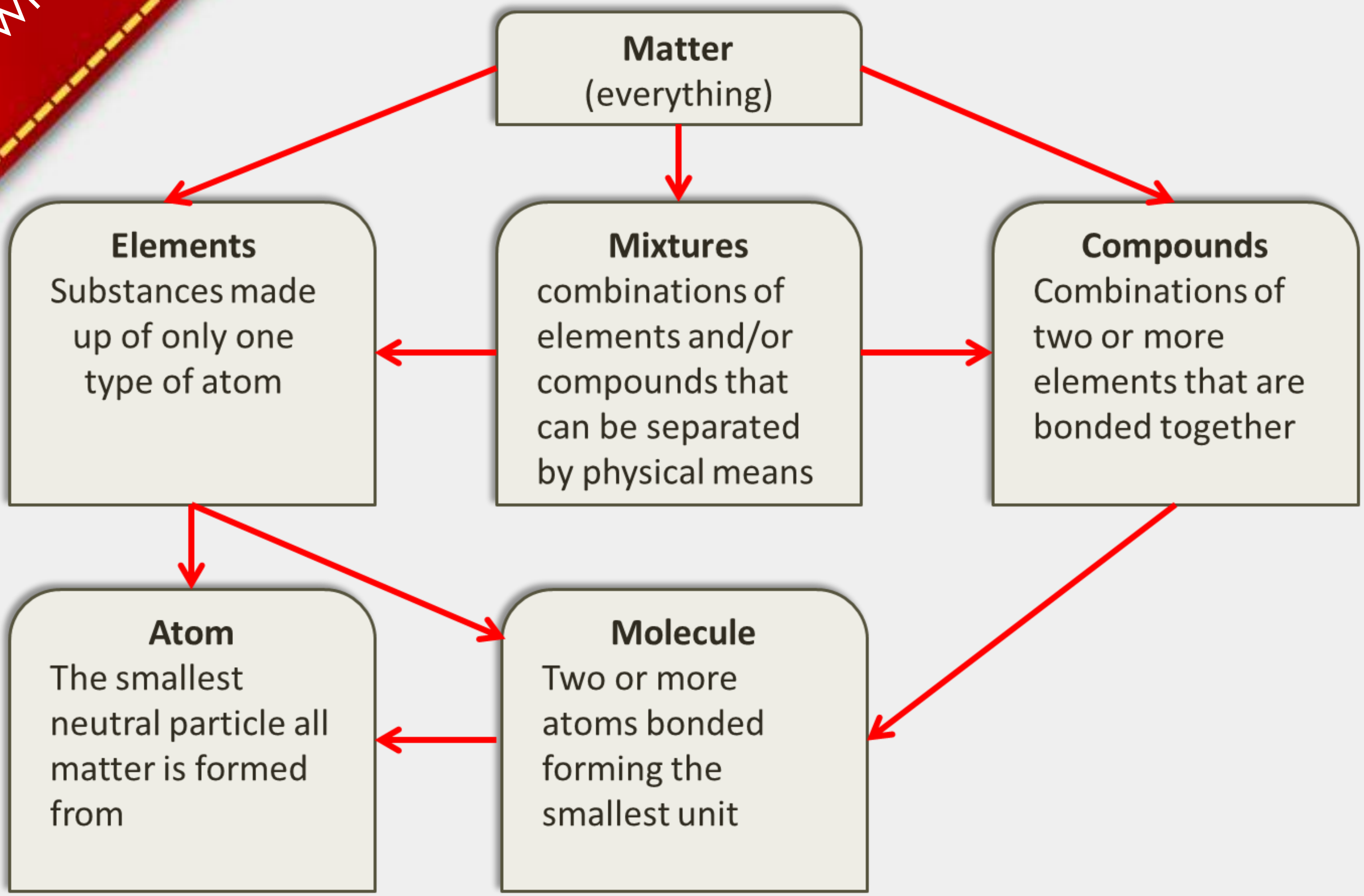


An **atom** is the smallest neutral particle that makes up matter.

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.

Background Knowledge

Matter is made up of particles /atoms



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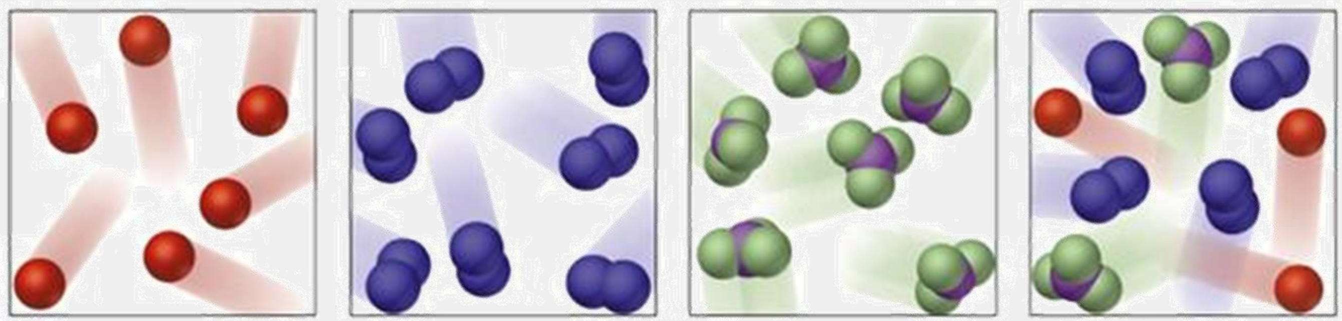
Background Knowledge

Elements are pure substances that combine to make mixtures & compounds



Atoms of an element | Molecules of an element | Molecules of a compound | Mixture of elements and a compound

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There are approximately 100 different elements but many millions of substances. Most matter around us is made up of combinations of elements.

If different elements are just jumbled up then they form a **mixture**.

If different elements have chemically reacted together and joined then they form a **compound**.

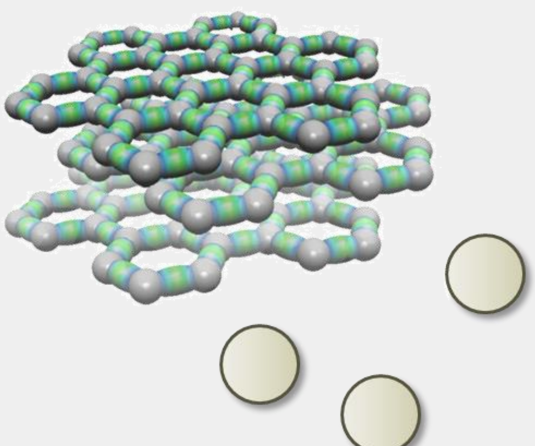
A **molecule** forms when atoms join together – either the same to form a molecule of an element or different to form a molecule of a compound.

Background Knowledge

The Particle Theory of Matter

extra info

1. All matter is made up of **very small particles** (atoms, ions or molecules)
2. Each substance has **unique particles** that are different from particles of other substances
3. There are **spaces between the particles** of matter that are very large compared to the particles themselves
4. There are **forces** holding particles together
5. The **further apart** the particles, the **weaker** the forces holding them together
6. Particles are in **constant motion**
7. At **higher temperatures** particles on average **move faster** than at lower temperatures.



Carbon in the form of graphite

Background Knowledge

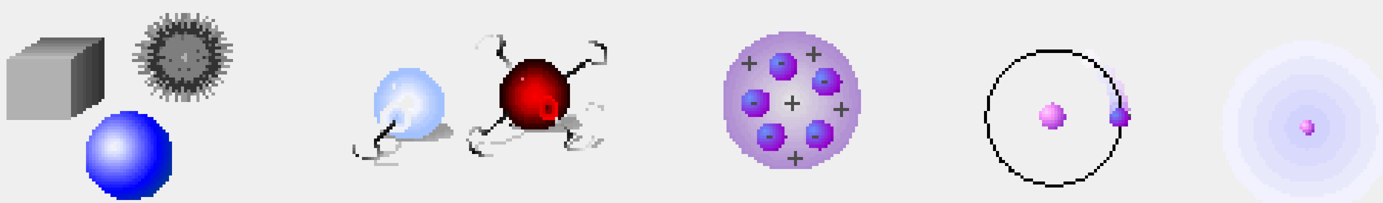
Early Atomic Theory

extra info

Atoms are the building blocks of elements.

Scientists and philosophers have guessed that all matter is made up of building blocks for a very long time. Discovery of the actual structure of the atom has only been in relatively recent times however.

Nothing exists but atoms and empty space; everything else is opinion. (*Demokritos*)



~400 B. C. 1830 1906 1913 1924

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Background Knowledge

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

extra info

John Dalton (1766–1844) was a British chemist and physicist. In 1803 he announced his atomic theory. His atom models where represented by solid spheres.

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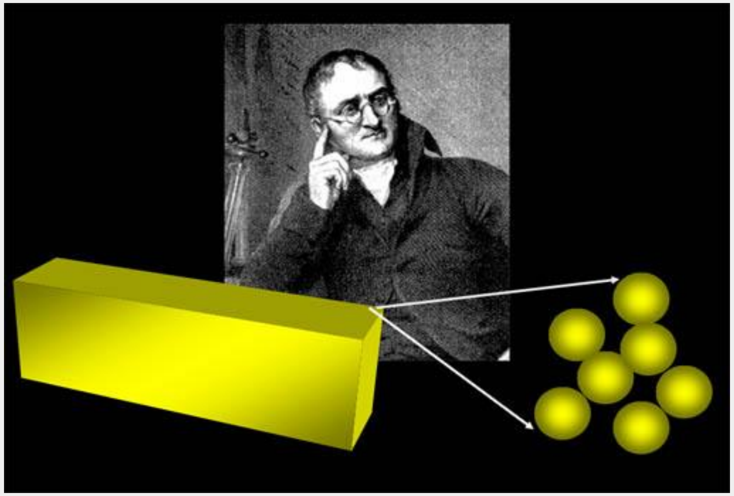


My Theory States:

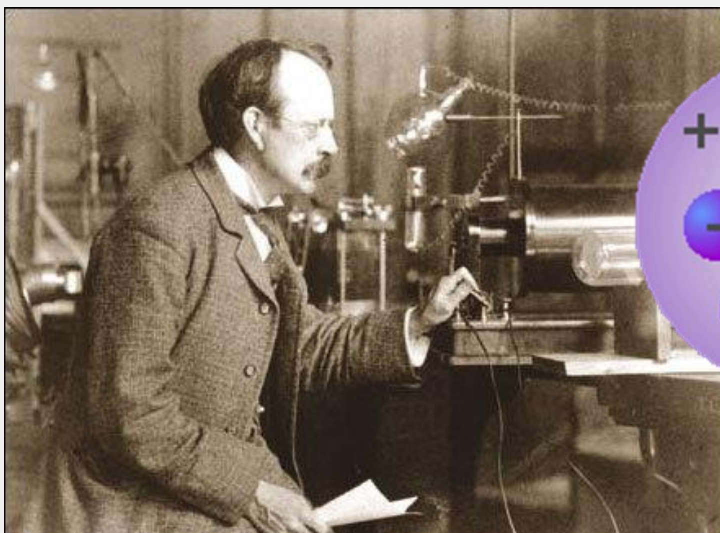
1. All Elements are made up off tiny particles called atoms.
2. Atoms of a given element are alike
3. Atoms of different elements are different
4. Chemical changes take place when atoms link up with or separate from one another
5. Atoms are not created or destroyed by chemical change

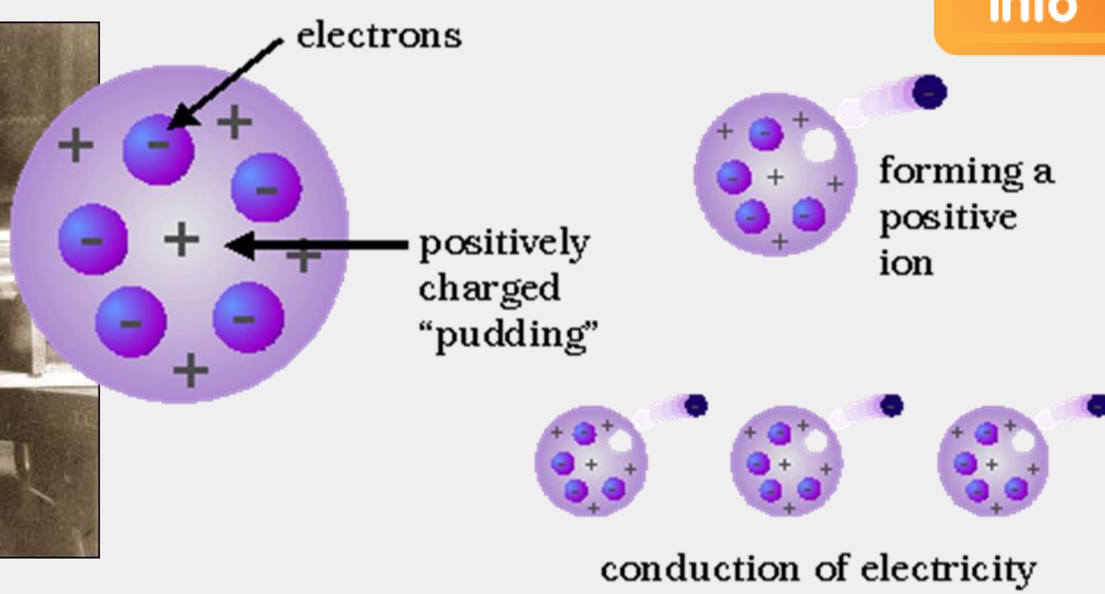
Background Knowledge

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

Sir Joseph John Thomson, who had discovered (1897) the electron, and came up with a model of the atom known as the plum-pudding model.

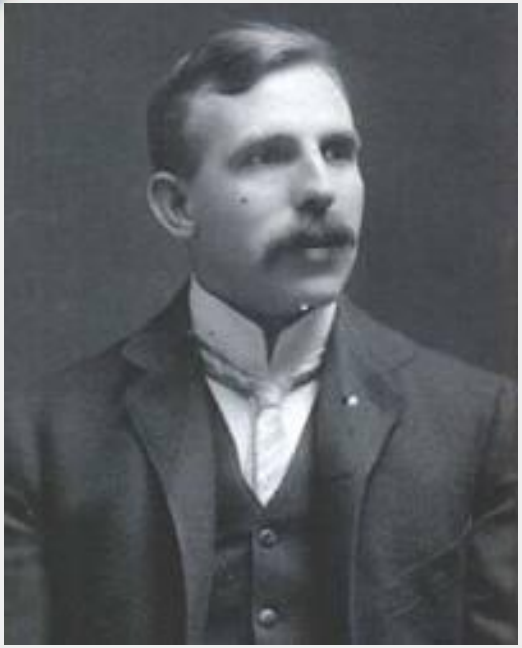
extra info



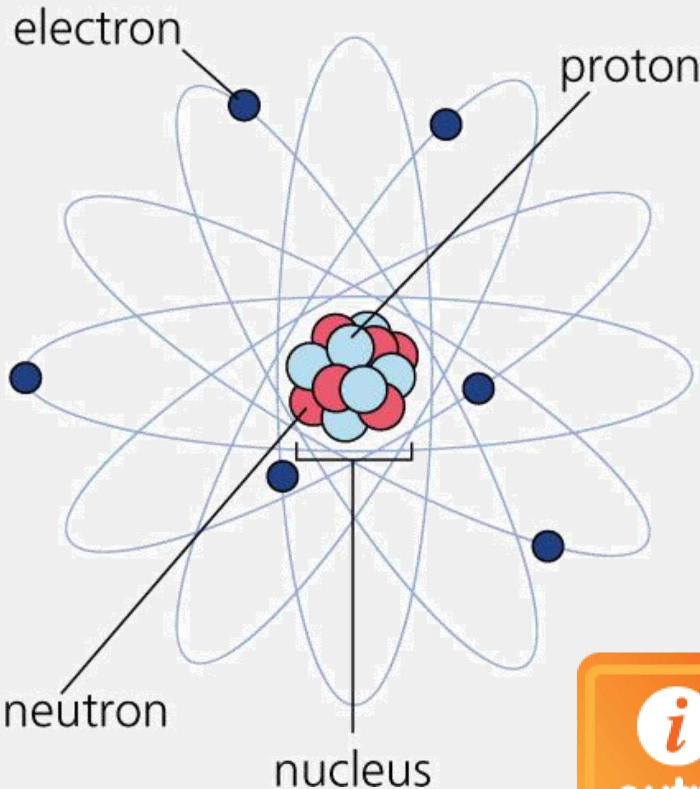


Background Knowledge

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



Ernest Rutherford was a New Zealand Scientist. In 1911 he announced his new atomic model based on what he observed from his famous 'gold foil' experiment.



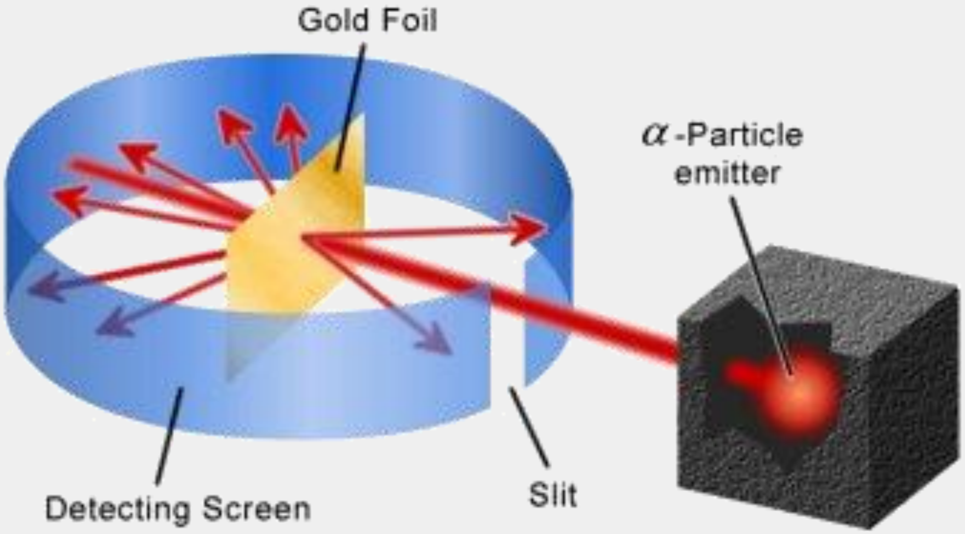
extra info

Background Knowledge

Atomic Theory

Rutherford – New Zealand Physicist 1911

Results from Rutherford's gold foil experiment could not be explained by the 'plum pudding' model of Thompson so Instead, in 1911, Rutherford proposed a new model of the atom in which all of the positive charge is condensed into a tiny, massive **nucleus** about ten thousand times smaller than the entire atom. Rutherford explained the much lighter electrons circulated outside the nucleus.



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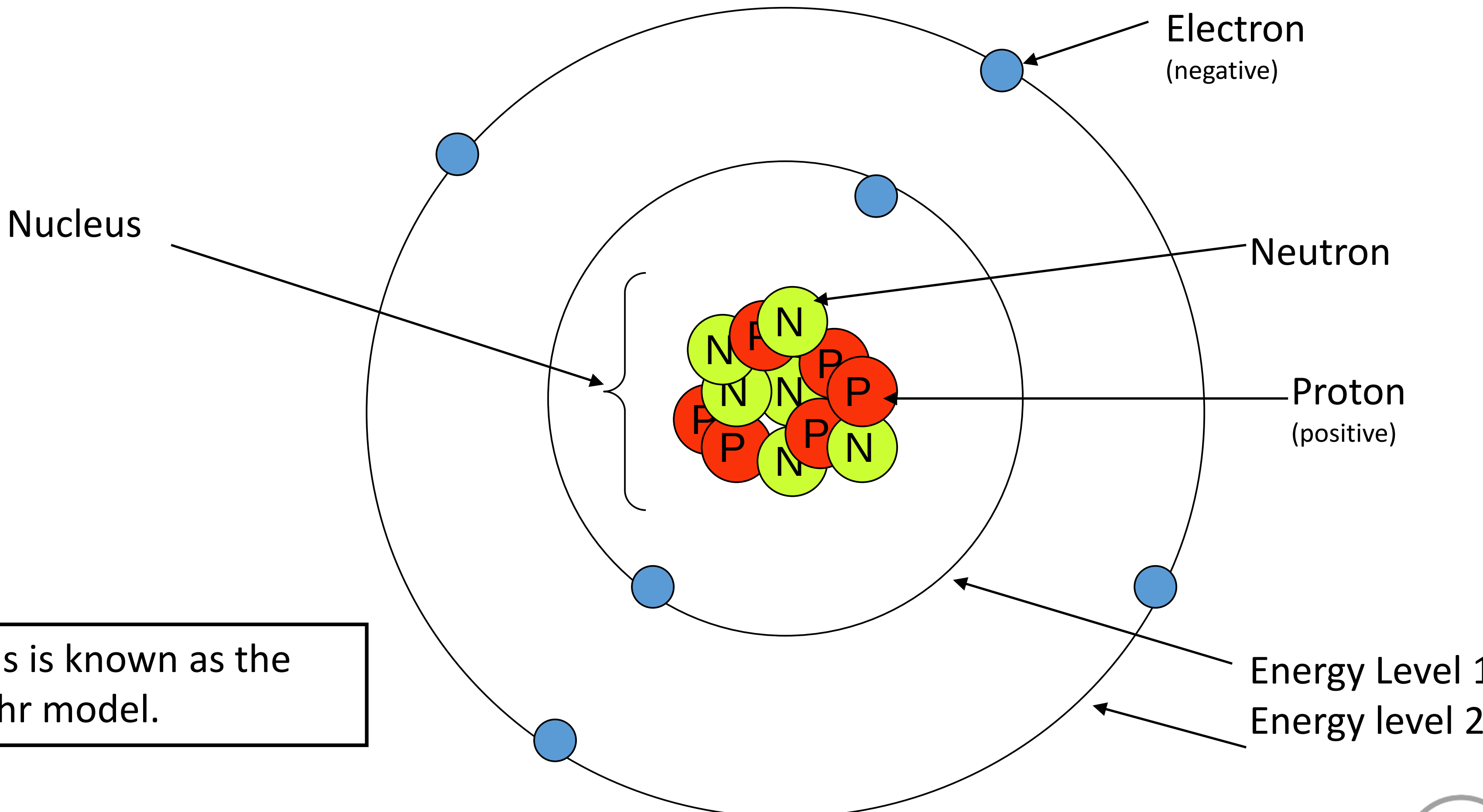
This was a revolution in the ideas of atoms as Rutherford's model implied that matter consisted almost entirely of empty space.

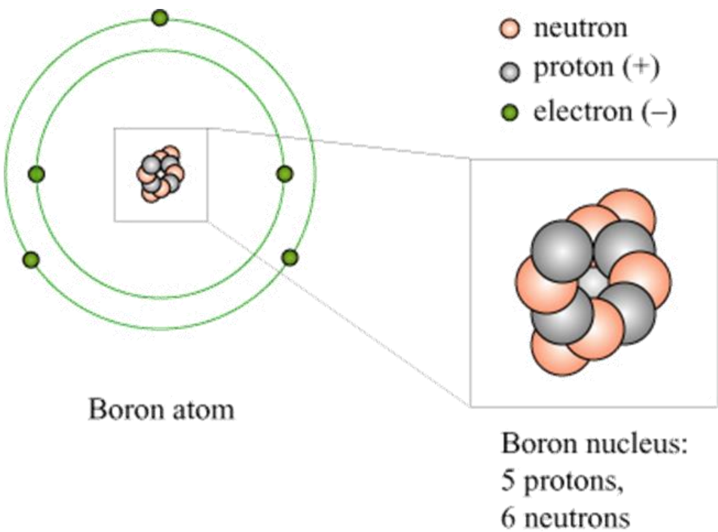
Atoms contain protons, electrons and neutrons

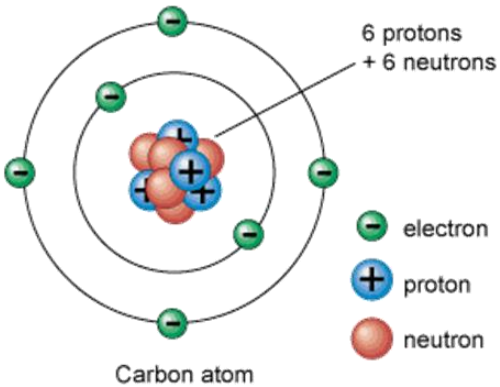
Atoms are made up of smaller particles, the number of these determine the type of atom. Atoms have a central nucleus, which contains protons (p) and neutrons (n). Electrons (e) orbit outside the nucleus, arranged in energy levels.



This is known as the Bohr model.

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





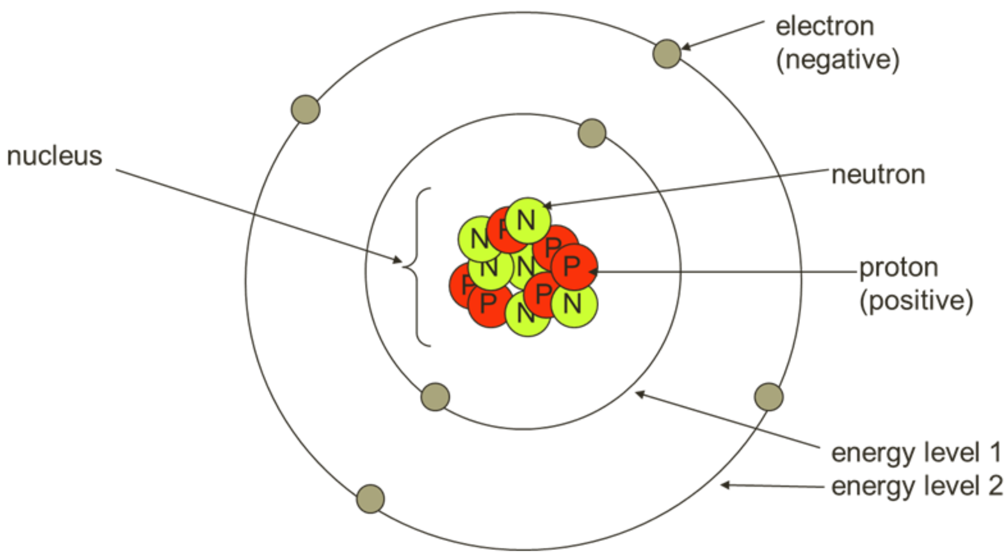
All Boron atoms have 5 protons in their nucleus.

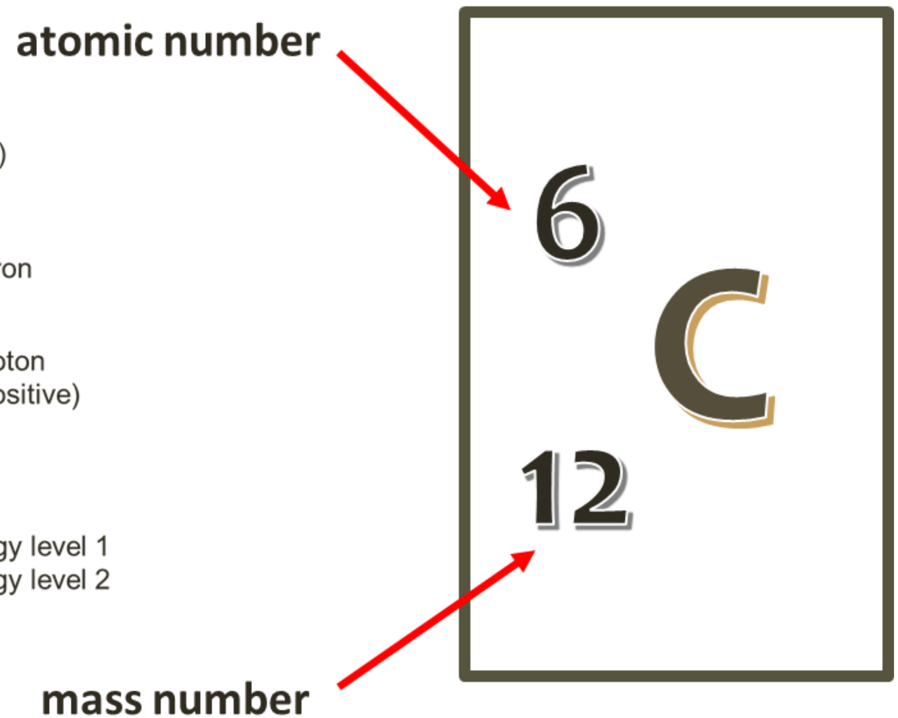
All Carbon atoms have 6 protons in their nucleus.

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 a 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.

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 mass number of an atom is equal to the number of **protons and neutrons.**
Both numbers are normally found in the periodic table.





Background Knowledge

Calculating protons, neutrons and electrons

Number of protons:
For an atom or ion = atomic number
Number of electrons:
For an atom = atomic number
For a negative ion = atomic number + charge (- =1, -2 =2 etc.)
For a positive ion = atomic number – charge (+ =1, +2 = 2 etc.)
Number of neutrons:
For an atom or ion = mass number - atomic number

atom or ion	number of protons	number of electrons	number of neutrons
Mg	12	12	12
Mg^{2+}	12	10	12
F	9	9	10
F-	9	10	10

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Background Knowledge

extra info

The Mass Number of an atom is equal to the number of protons and neutrons in an atom.

Carbon and C14 isotope

Why is the Mass Number not always a whole number?
Most elements have a proportion of their atoms that exist as isotopes – Atoms that have less or more neutrons. The Mass number is worked out by finding the Mass number of all the isotopes and averaging them by their proportions.

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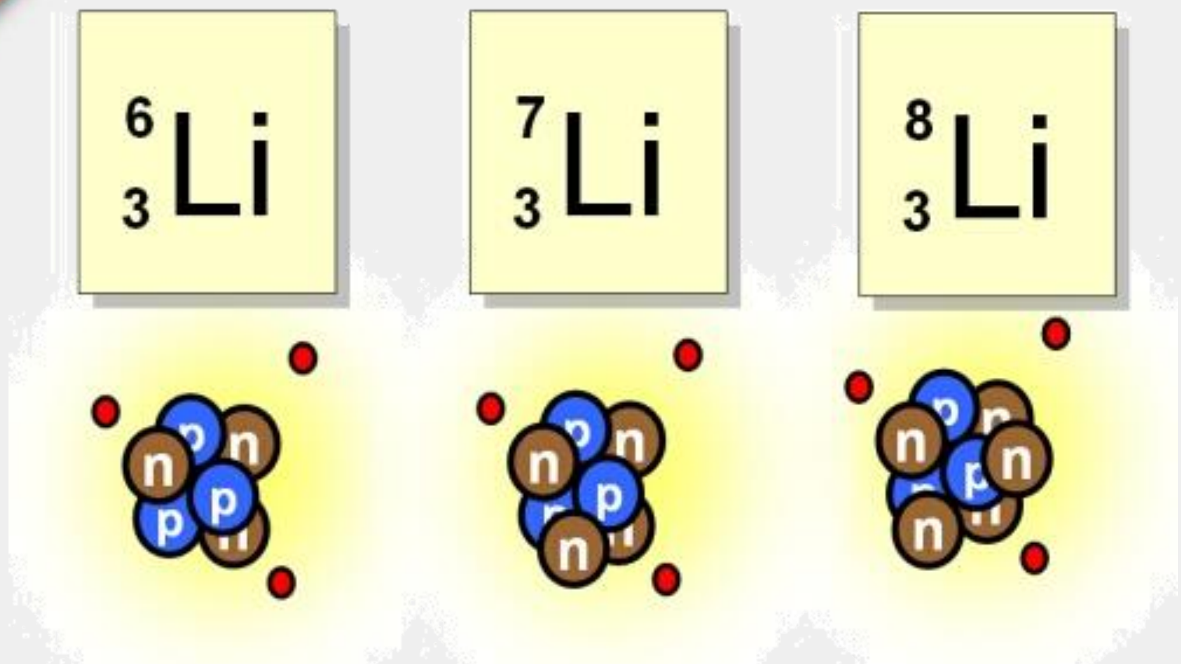
Background Knowledge

Isotopes have the same Atomic number but a different Mass number



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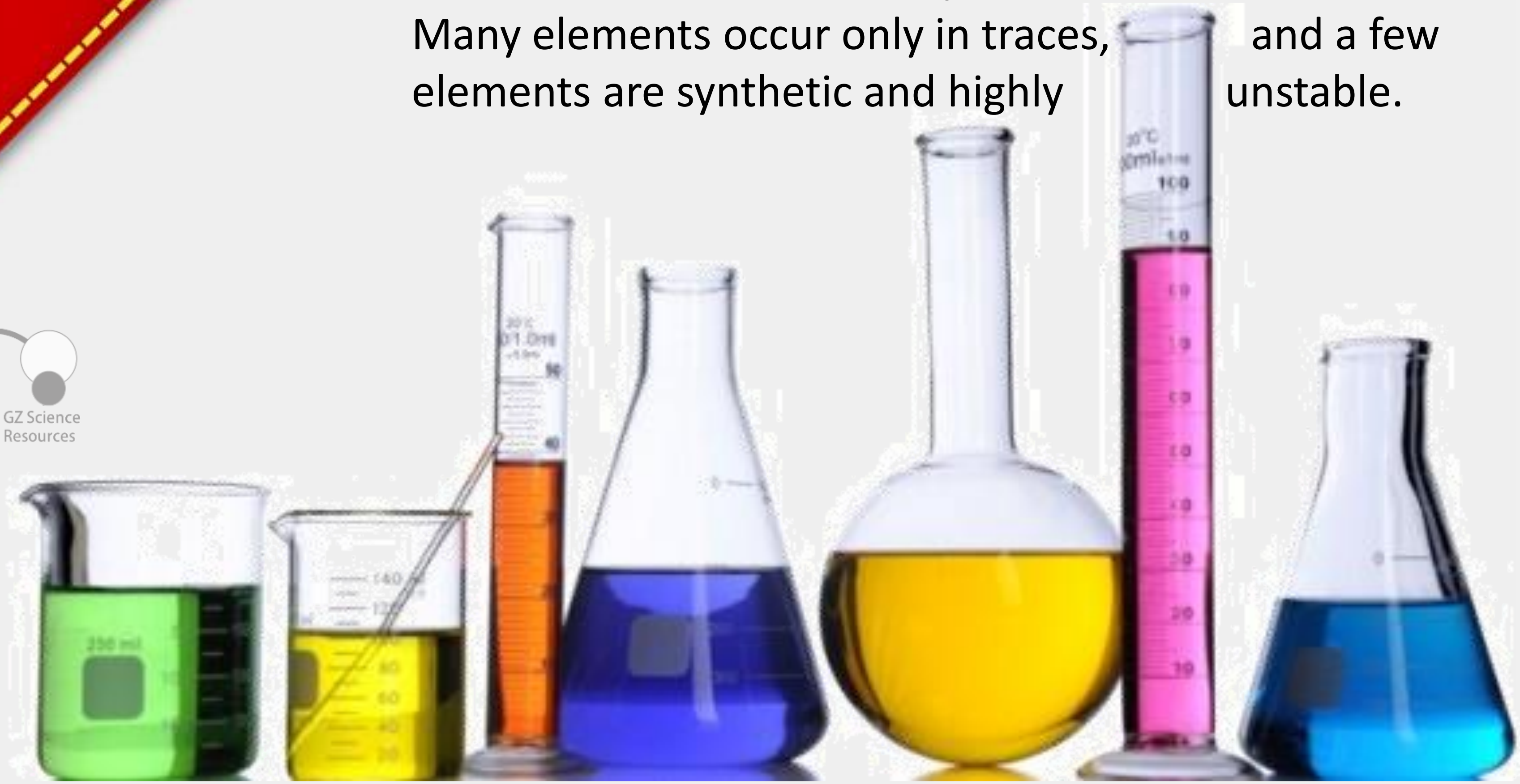
extra info

Isotopes of elements occur when atoms have the same atomic number (Z) but different numbers of neutrons in the nucleus. The numbers of neutrons in an atom does not affect the way an element behaves chemically, but it does affect the way it behaves physically.
Isotopes found in nature are generally stable, however radioactive isotopes do exist such as 238Uranium

Background Knowledge

The elements and Periodic table

A large amount of energy is required to break an atom down into smaller particles. The elements occur in widely varying quantities on earth. The ten most abundant elements make up 98% of the mass of earth. Many elements occur only in traces, and a few elements are synthetic and highly unstable.



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Background Knowledge

Periodic table Development

extra info

Mendeleev – Russian professor of Chemistry 1834 - 1907

Dimitri Mendeleev was a Chemist who created a periodic table based on elements relative atomic mass and placed the elements in groups based on the elements similar properties. Not all of the elements had been discovered at the time he created the table so he left gaps that has subsequently been filled.

Table of the Periodic Law. (Mendeléef, 1904.)

Series	Zero Group	Group I	Group II	Group III	Group IV	Group V	Group VI	Group VII	Group VIII			
0	x											
1	y	Hydrogen H—1·008										
2	Helium He—4·0	Lithium Li—7·03	Beryllium Be—9·1	Boron B—11·0	Carbon C—12·0	Nitrogen N—14·04	Oxygen O—16·00	Fluorine F—19·0				
3	Neon Ne—19·9	Sodium Na—23·05	Magnesium Mg—24·1	Aluminium Al—27·0	Silicon Si—28·4	Phosphorus P—31·0	Sulphur S—32·06	Chlorine Cl—35·45				
4	Argon Ar—38	Potassium K—39·1	Calcium Ca—40·1	Scandium Sc—44·1	Titanium Ti—48·1	Vanadium V—51·4	Chromium Cr—52·1	Manganese Mn—55·0	Iron Fe—55·9	Cobalt Co—59	Nickel Ni—59	(Cu)
5		Copper Cu—63·6	Zinc Zn—65·4	Gallium Ga—70·0	Germanium Ge—72·3	Arsenic As—75·0	Selenium Se—79	Bromine Br—79·95				
6	Krypton Kr—81·8	Rubidium Rb—85·4	Strontium Sr—87·6	Yttrium Y—89·0	Zirconium Zr—90·6	Niobium Nb—94·0	Molybdenum Mo—96·0	—	Ruthenium Ru—101·7	Rhodium Rh—103·0	Palladium Pd—106·5	(Ag)
7		Silver Ag—107·9	Cadmium Cd—112·4	Indium In—114·0	Tin Sn—119·0	Antimony Sb—120·0	Tellurium Te—127	Iodine I—127				
8	Xenon Xe—128	Caesium Cs—132·9	Barium Ba—137·4	Lanthanum La—139	Cerium Ce—140	—	—		—	—	—	(—)
9		—	—		—	—	—	—				
10	—	—	—	Ytterbium Yb—173	—	Tantalum Ta—183	Tungsten W—184	—	Osmium Os—191	Iridium Ir—193	Platinum Pt—194·9	(Au)
11		Gold Au—197·2	Mercury Hg—200·0	Thallium Tl—204·1	Lead Pb—206·9	Bismuth Bi—208	—	—				
12	—	—	Radium Rd—224	—	Thorium Th—232	—	Uranium U—239					

Groups 3 to 12 were added after Mendeleev's table – these are called the transition metals

Group 18 – the noble gases, were not discovered at that time and were also added after.

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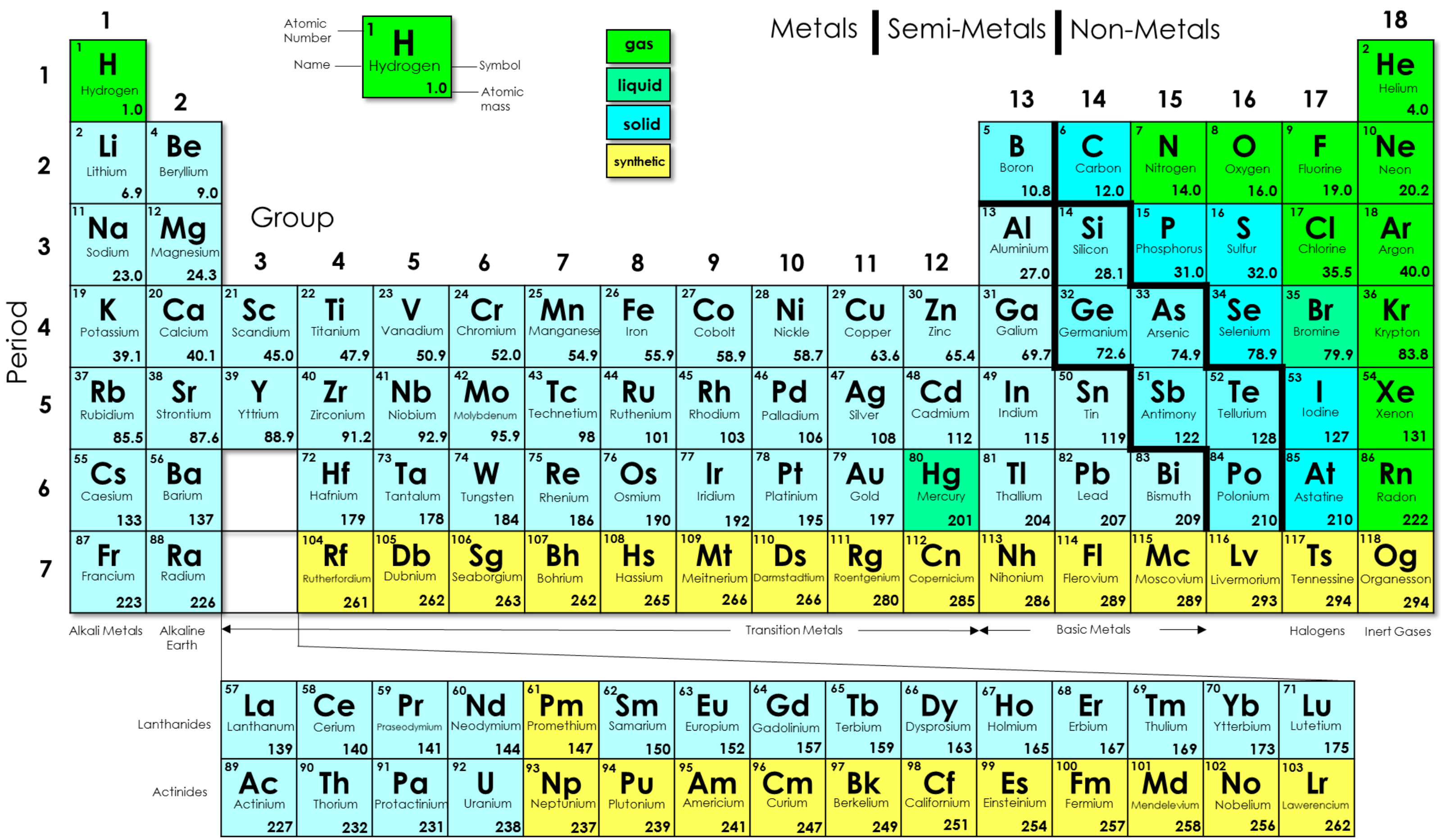
The periodic table organises elements by atomic number

The elements increase in atomic number as you move from left to right and from top to bottom of the periodic table.

Periodic Table of the Elements



Background Knowledge

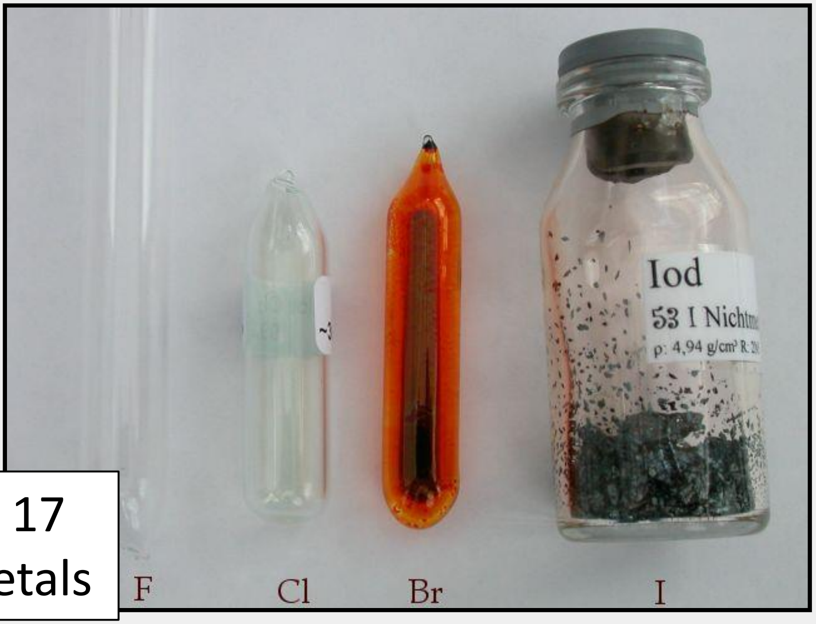
Groups of elements on the periodic table have common physical and chemical properties

extra info

Elements that are in the same group show similar types of chemical and physical properties. Their atoms chemically react the same way because their electrons in the outside energy level in the atoms are arranged the same way.

Group 1
Metals

The elements in a group also have similar physical properties because of the way the atoms join together and are arranged.



Group 17
Non-Metals

Background Knowledge

Group One Elements

extra info

These elements are called the **Alkali Metals**. They are all very reactive with air and, especially so, water. The further down the group the more reactive they are. Hydrogen is not included in this as it does not share similar properties with the rest of the elements.

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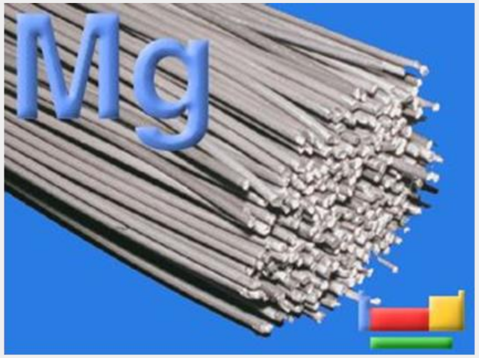
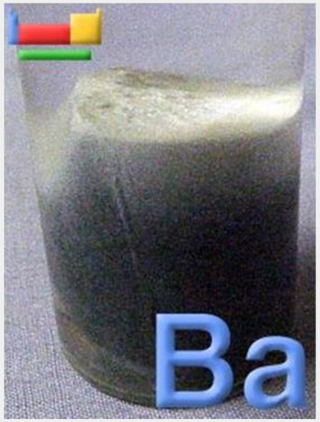
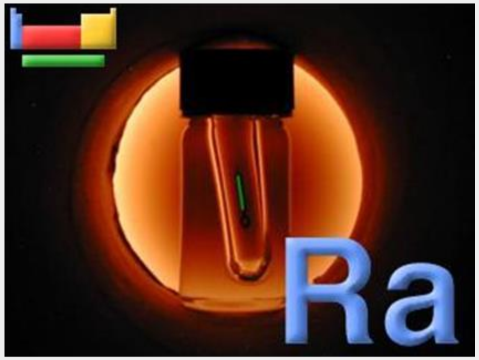
Background Knowledge

Group two elements

These elements are called the **Alkali Earth Metals**. They all react with air, but are less reactive than group 1.







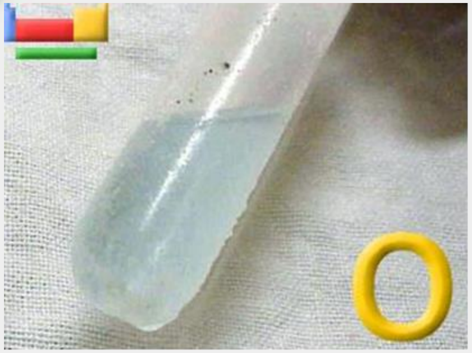
extra info

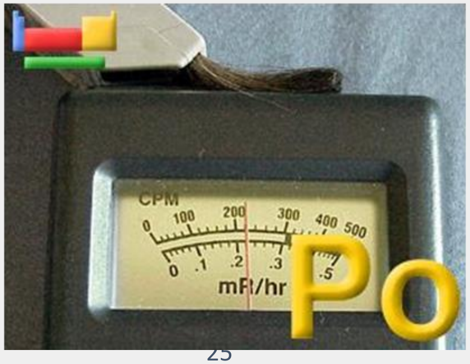
Background Knowledge

Group 16 elements

extra info

These elements are mostly Non-Metals. As we move down the group the elements show some metallic properties.





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25

Background Knowledge

Group 17 Elements

These elements are called the **Halogens**. They are very reactive an change from gas to liquid to solid as you move down the group.

extra info

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Background Knowledge

Group 18 Elements

extra info

These gases are a family of elements, and all of them are located in the far right column of the periodic table called Group Eighteen (Group XVIII). This family has the most stable elements of all.
Stable atoms have full energy levels of electrons. All of the inert gases have full outer energy levels with eight electrons (except helium (He) with a energy level that is full with two electrons). The fact that their outer energy levels are full means they do not react with other elements. In fact, they rarely combine with other elements. Their non-reactivity is why they are called inert.

These elements are called the **Inert gases**. They are very non reactive and have only just been discovered relatively recently because of that.

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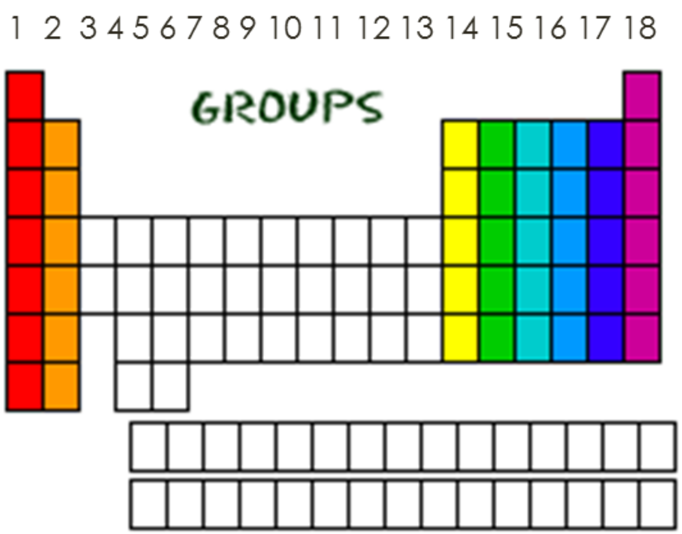
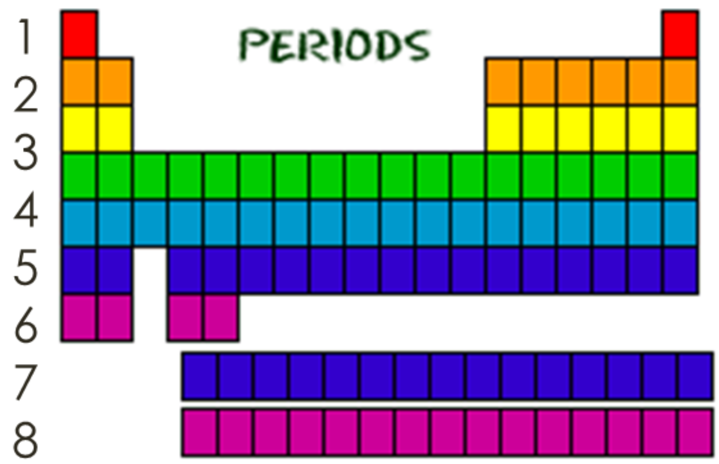
27

The periodic table organises elements by atomic number

The Periodic Table is also organised into **groups that go down a column** numbered from 1 to 18, from left to right and **Periods that go across a row numbered from 1 to 8,** from top to bottom





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

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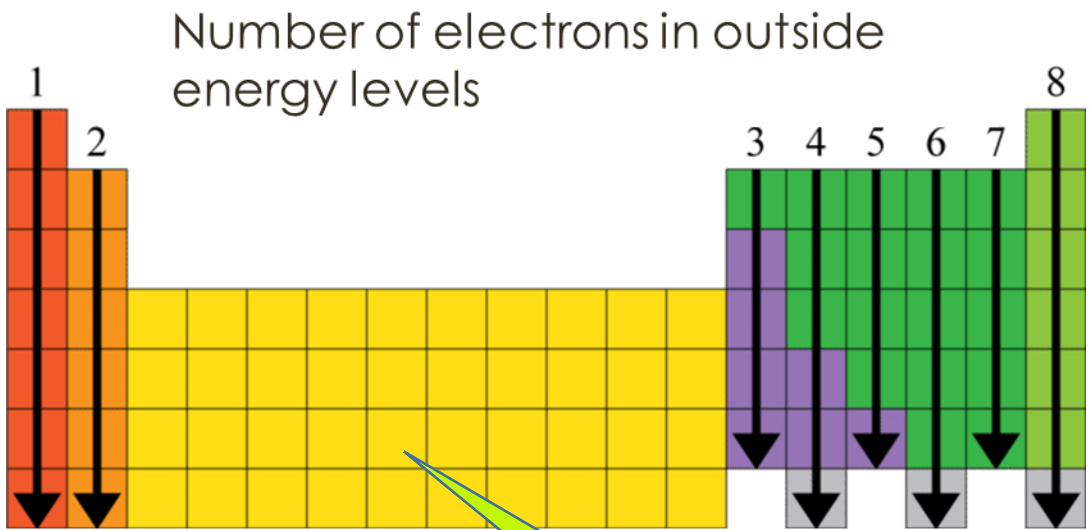
There is a relationship between the group number and the number of outer electrons.



The elements in a **group** have the **same number of electrons in their outer energy level**. Every element in the first column (group one) has one electron in its outer energy level. Every element on the second column (group two) has two electrons in the outer energy level.

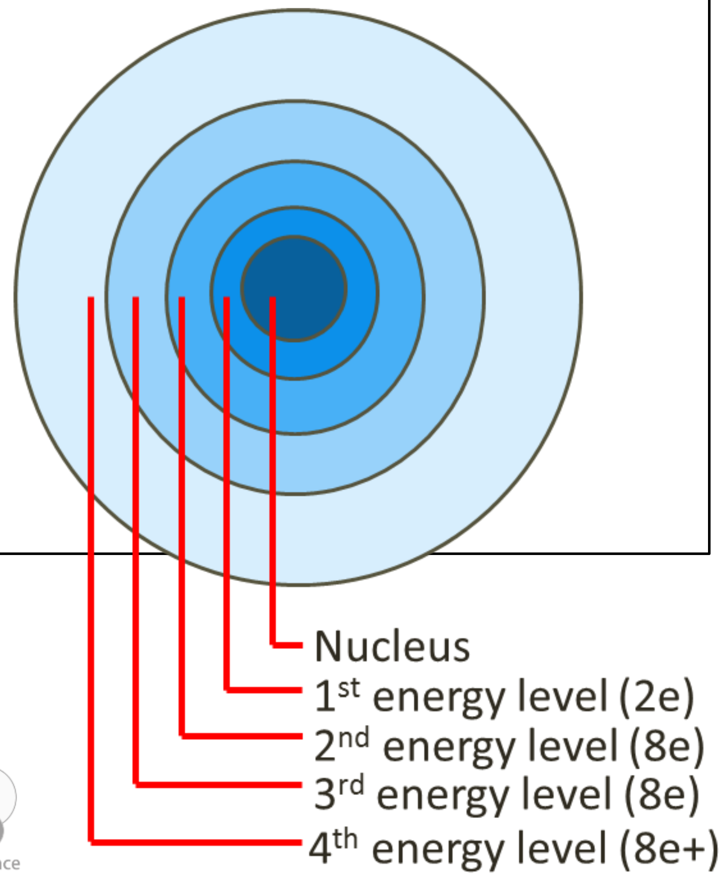
In this unit we can **leave out** the central group of elements in the yellow block

Note: for groups 13 to 18 it is only the last number that relates to number of electrons. i.e. group 13 has 3, group 14 has 4…

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



You need to draw the configurations of the first 20 elements as well as knowing their names and symbols

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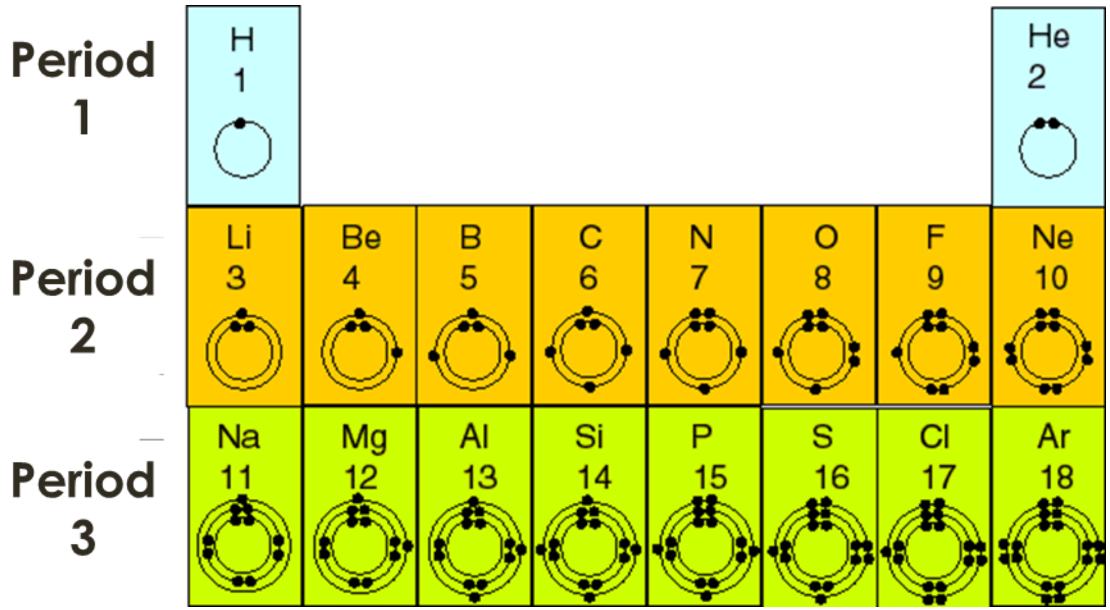
There is a relationship between the period number and the number of electron shells an atom has.



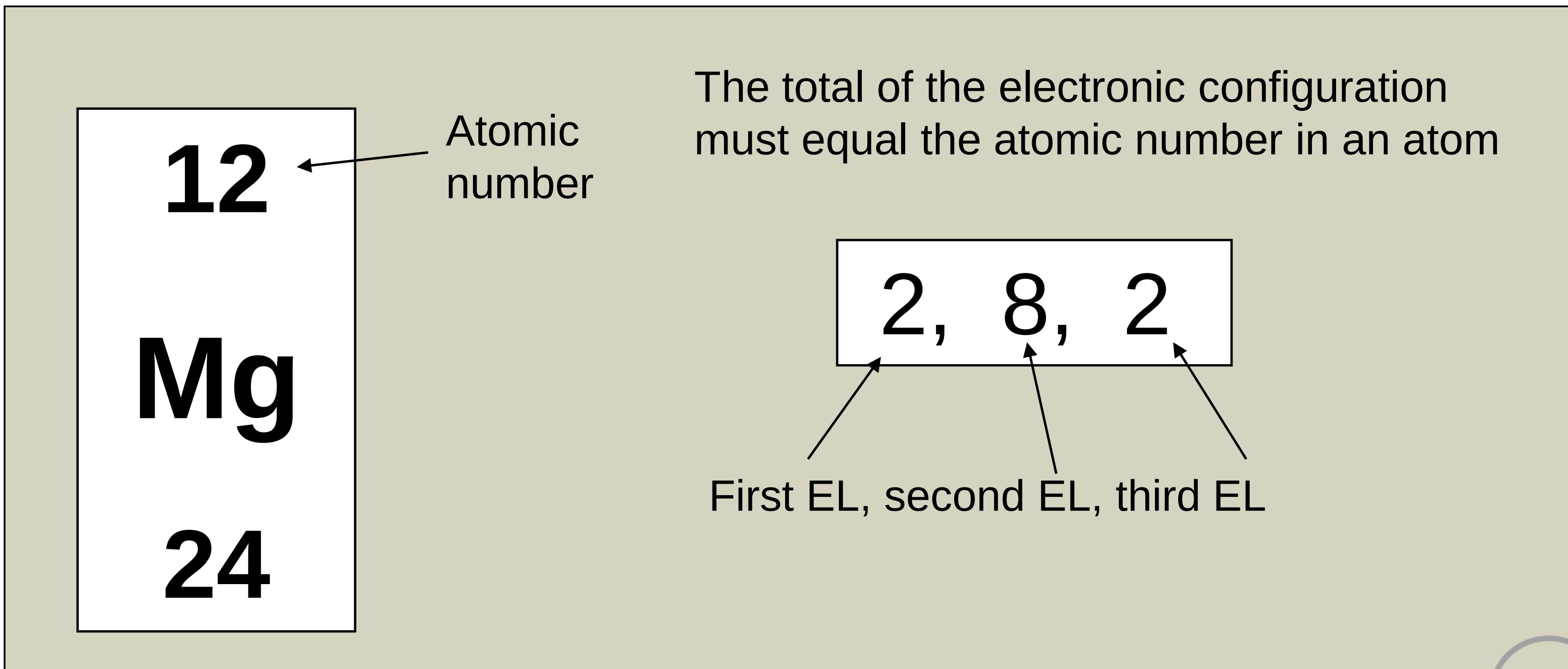
In the periodic table, elements have something in common if they are in the **same period**. All of the elements in a period have the **same number of electron energy levels**. Every element in the top row (the first period) has one energy level for its electrons) All of the elements in the second row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

At this time, the maximum number of electron energy levels for any element is seven.

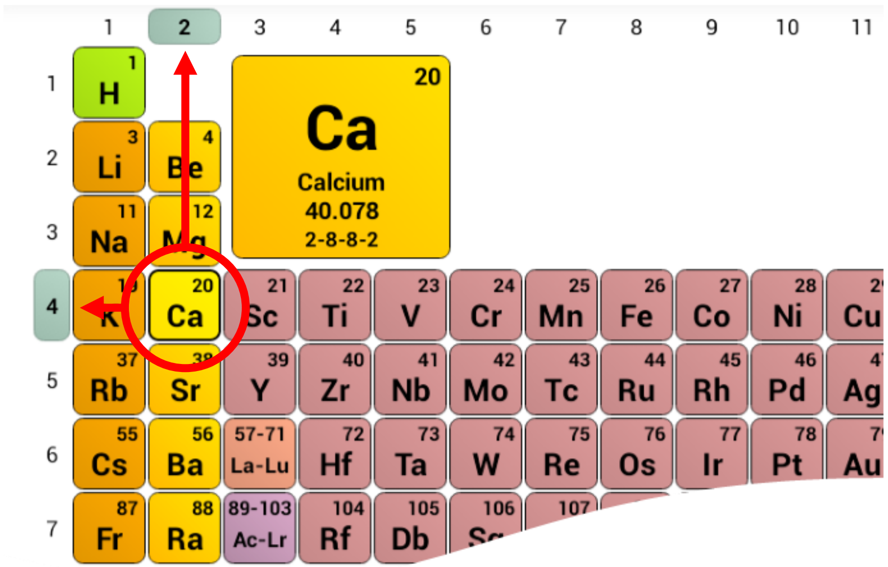
Did you know

Electron configuration

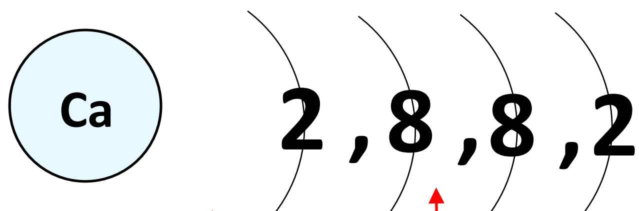
A shorthand way of describing the way electrons are arranged in an atom is called the ***electron configuration***. The information for the number of electrons is found by an elements Atomic Number (number of electrons = number of protons in a neutral atom). Each EL is filled to its maximum capacity,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



Using the Periodic table to write electron configurations



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



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

Step 1. Ca in period (row 4) so has 4 energy levels

Step 3. backfill all energy levels with 8 electrons (2 in first) and add commas between each

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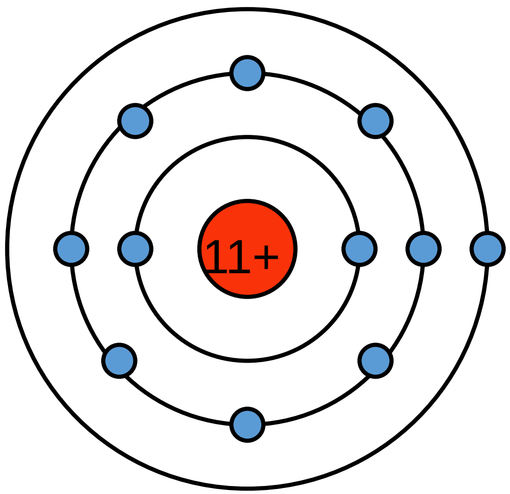
Ions are formed by gain or loss of electrons

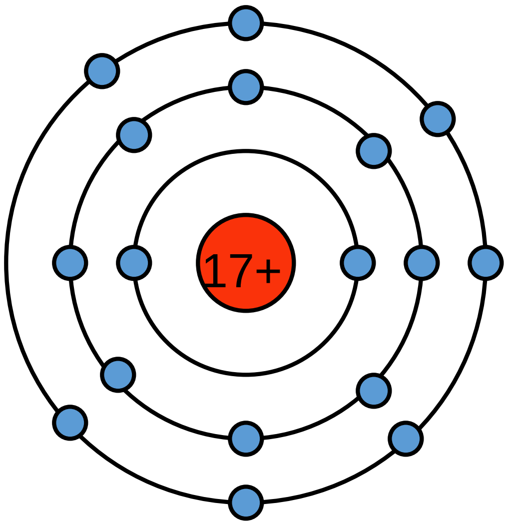
Ions are atoms or groups of atoms with electrical charge.
Elements are most stable when the outer energy level (valence shell) is full.
Elements can lose or gain electrons when they react with other chemicals to form ions.

Cation Sodium (Na)



Sodium now becomes the sodium ion Na^{+}

Anion Chlorine (Cl)

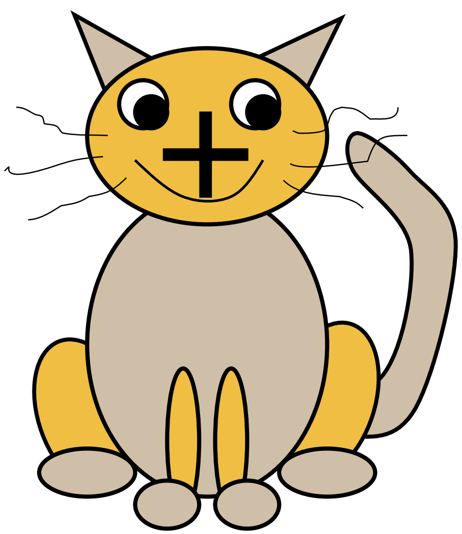


Chlorine now becomes the chloride ion Cl^{-}

Ions are formed by gain or loss of electrons

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 7-8 electrons in their outside energy level.

Ion Chart – Positive Ions (metals)

Charge on Ions					
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+}		
ammonium	NH_4^+	zinc	Zn^{2+}		
Hydrogen	H^+	barium	Ba^{2+}		
Lithium	Li^+	lead	Pb^{2+}		

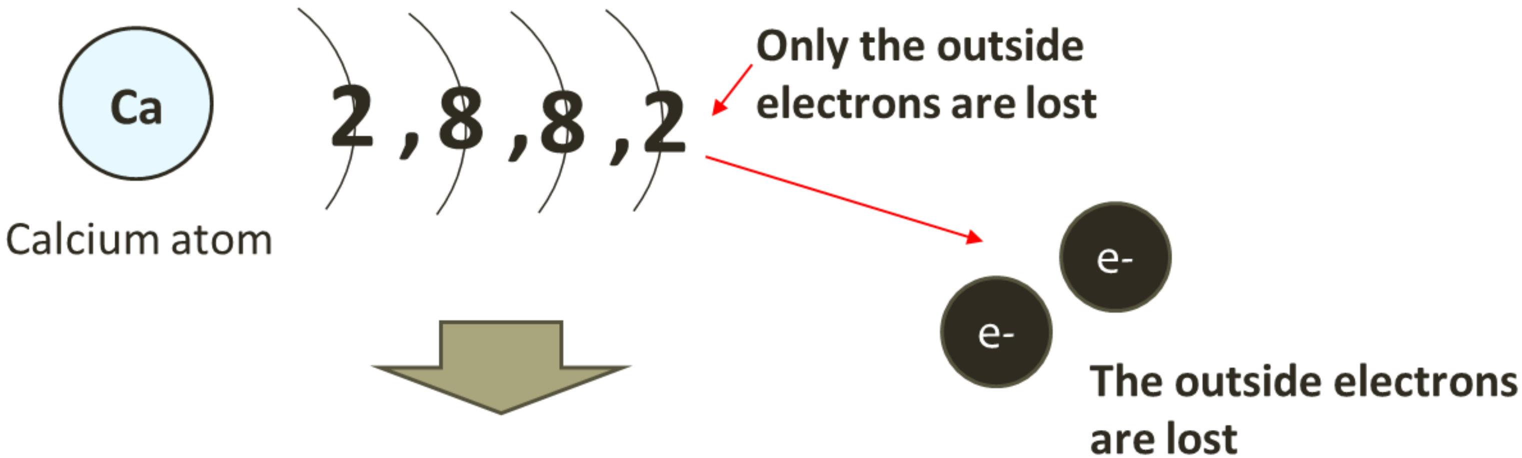
GZ Science Resources

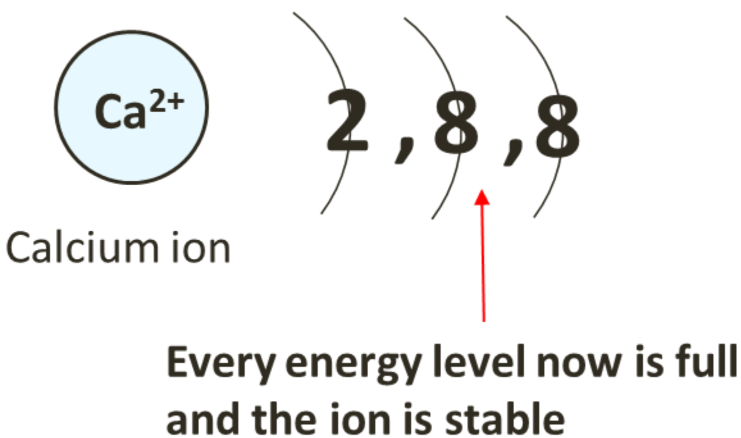
Ion chart – negative ions (non-metals)

Charge on ions			
1-		2-	
chloride	Cl^-	carbonate	CO_3^{2-}
iodide	I^-	oxide	O^{2-}
hydroxide	OH^-	sulfide	S^{2-}
hydrogen carbonate	HCO_3^-	sulfate	SO_4^{2-}
fluoride	F^-		
bromide	Br^-		
nitrate	NO_3^-		

GZ Science Resources

Electron configurations of ions – Cations (metals)

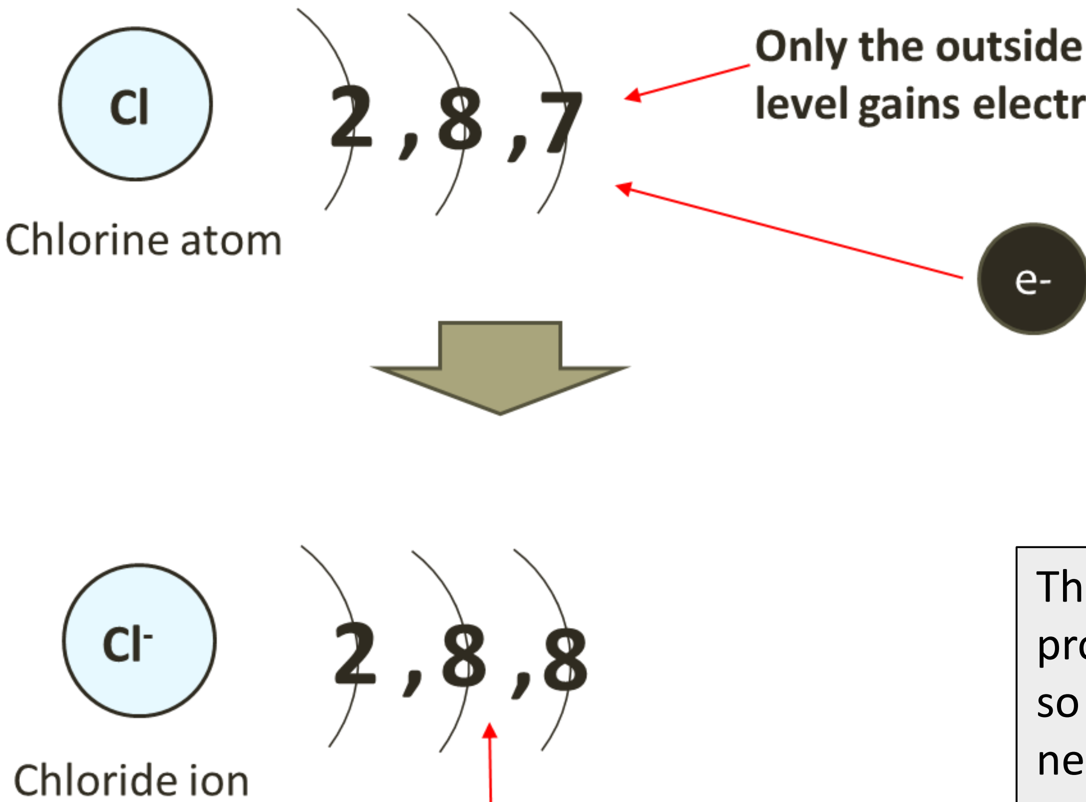




The Ca atom has 20 protons and 20 electrons so has no charge. It is neutral.

The Ca^{2+} ion has 20 protons and 18 electrons so has a 2+ charge.

Electron configurations of ions – Anions (non-metals)



Only the outside energy level gains electrons

One electrons is gained by the atom

Every energy level now is full and the ion is stable

The Cl atom has 17 protons and 17 electrons so has no charge. It is neutral.

The Cl^- ion has 17 protons and 18 electrons so has a 1- charge.

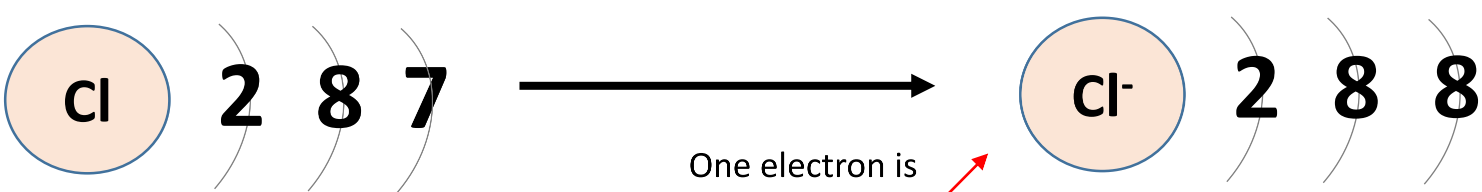
GZ Science Resources

NCEA 2012 Electron Configuration - (Part ONE)

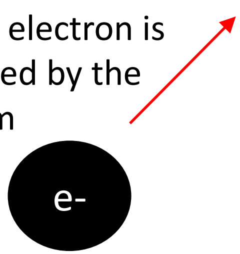
Achieved Question

Question 1a: Complete the table below for ions formed by Ca, F, and Cl.

	Atomic Number	Electron arrangement of atom	Electron arrangement of ion	Ion symbol
Ca	20	2,8,8,2	2,8,8	Ca^{2+}
F	9	2,7	2,8	F^{-}
Cl	17	2,8,7	2,8,8	Cl^{-}



One electron is gained by the atom



Number of protons = 17
Number of electrons = 17
Charge = 0 (neutral)

Number of protons = 17
Number of electrons = 18
Charge = -1

NCEA 2012 Electron Configuration - (Part TWO)

Excellence Question

Question 1b: Explain the charges on ALL three ions, in terms of electron arrangement and number of protons. Use their positions on the periodic table to explain why two of the atoms form ions with the **same charge**, AND two of the atoms form ions with the **same electron arrangement**.

	Atomic Number	Electron arrangement of atom	Electron arrangement of ion	Ion symbol
Ca	20	2,8,8,2	2,8,8	Ca^{2+}
F	9	2,7	2,8	F^{-}
Cl	17	2,8,7	2,8,8	Cl^{-}

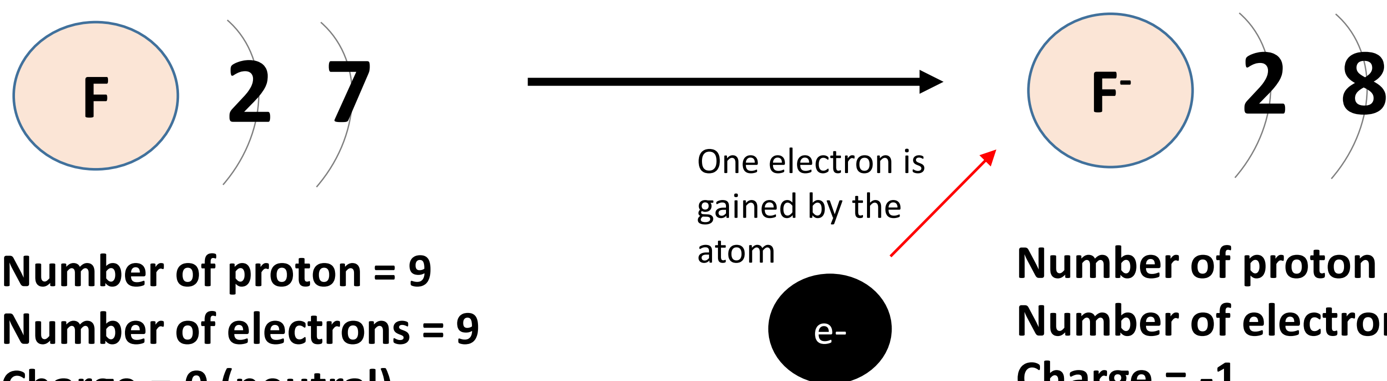
F has 9 protons and electron arrangement of 2,7. Cl has 17 protons and an electron arrangement of 2,8,7. Both atoms are in group 17 of the periodic table as they both have 7 electrons in the valence shell. Both atoms gain one electron to have a full outer shell. For F ion the electron arrangement is 2,8, and for Cl ion it is 2,8,8.
F has a charge of –1 as it now has 10 electrons (–) and 9 protons (+). Cl has a charge of –1 as it now has 18 electrons (–) and 17 protons (+).
Ca has 20 protons and electron arrangement of 2,8,8,2. Ca has two electrons in its outer shell, which it loses, so its new outer shell is full (2,8,8) and it has a charge of +2, as it still has 20 protons (+) and now has only 18 electrons (–). Therefore Ca and Cl ions now both have the same electron configuration of 2,8,8.

NCEA 2013 Electron Configuration - (Part ONE)

Achieved Question

Question 1a: F^-, Ne, and Mg^{2+} have the **same** electron arrangement.
(a) Complete the table below.

	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



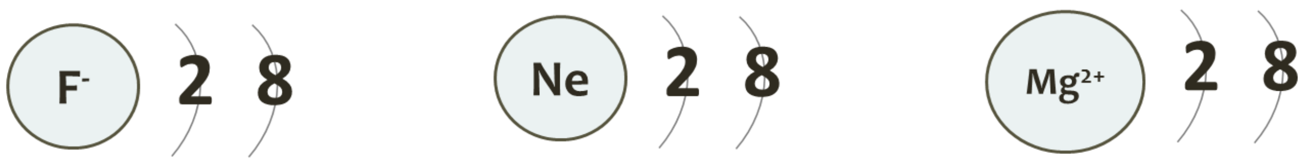
Number of proton = 9
Number of electrons = 9
Charge = 0 (neutral)

Number of proton = 9
Number of electrons = 10
Charge = -1

NCEA 2013 Electron Configuration - (Part TWO)

Excellence Question

Question 1b: Compare the atomic structure of F^-, Ne, and Mg^{2+}.
In your answer you should:
- describe the difference between an atom and an ion
- explain the charges on F^-, Ne, and Mg^{2+} in terms of electron arrangement and number of protons
- relate the position of F^-, Ne, and Mg^{2+} on the periodic table to the charges and electron arrangement
- explain why all three have the same electron arrangement.



Number of proton = 9
Number of electrons = 10
Charge = -1

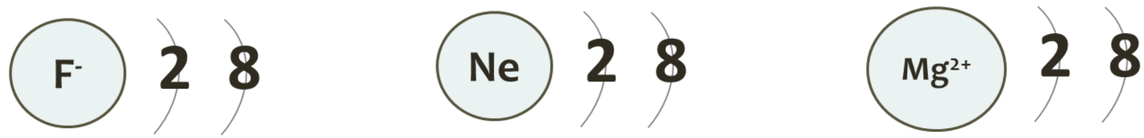
Number of proton = 10
Number of electrons = 10
Charge = 0 (neutral)

Number of proton = 12
Number of electrons = 10
Charge = +2

The difference between an ion and an atom is that an atom has a neutral charge as it has not gained or lost electrons and therefore has the same number of protons (+) and electrons (–) whereas an ion has a charge as the atom it was formed from has either gained or lost electrons to form a full outer shell and therefore has a different number of protons (+) from the number of electrons (–).

NCEA 2013 Electron Configuration - (Part TWO)

Excellence Question



Number of proton = 9
Number of electrons = 10
Charge = -1

Number of proton = 10
Number of electrons = 10
Charge = 0 (neutral)

Number of proton = 12
Number of electrons = 10
Charge = +2

Explanation of charges

Fluorine has 9 protons and electron arrangement of 2,7. Neon has 10 protons and an electron arrangement of 2,8. Magnesium has 12 protons and an electron arrangement of 2,8,2.

Fluorine gains one electron to have a full outer shell. This is because it is in group 17 and has 7 valence electrons. For fluorine ion, the electron arrangement is 2,8.

Fluorine has a charge of –1 as it now has 10 electrons (negative charges) and nine protons (positive charges).

Neon has no charge as it has the same number of protons and electrons, as it has not gained or lost electrons, as it has an electron arrangement of 2,8 because it is in group 18 of the periodic table and its valence shell is complete.

Magnesium has 12 protons and electron arrangement of 2,8,2.

Magnesium has two electrons in its outer shell as it is in group 2 of the periodic table, which it loses, so its outer shell is full (2,8) and it has a charge of +2, as it still has 12 protons (positive charges) and now has only 10 electrons (negative charges).

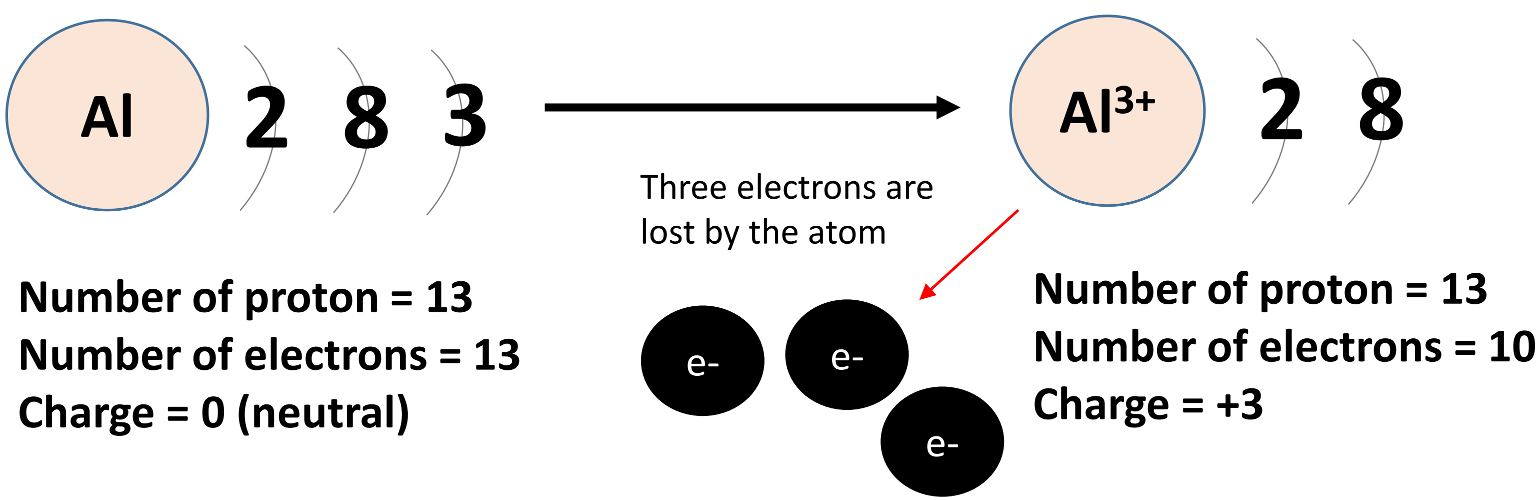
All three have the same electron arrangement as they have gained one electron, lost two electrons or have neither gained or lost electrons. The electron arrangement is 2,8 as this is the nearest possible stable electron arrangement for all three.

NCEA 2014 Electron Configuration - (Part ONE)

Achieved Question

Question 1b: Complete the table below for the ions formed by magnesium, aluminium, and oxygen.

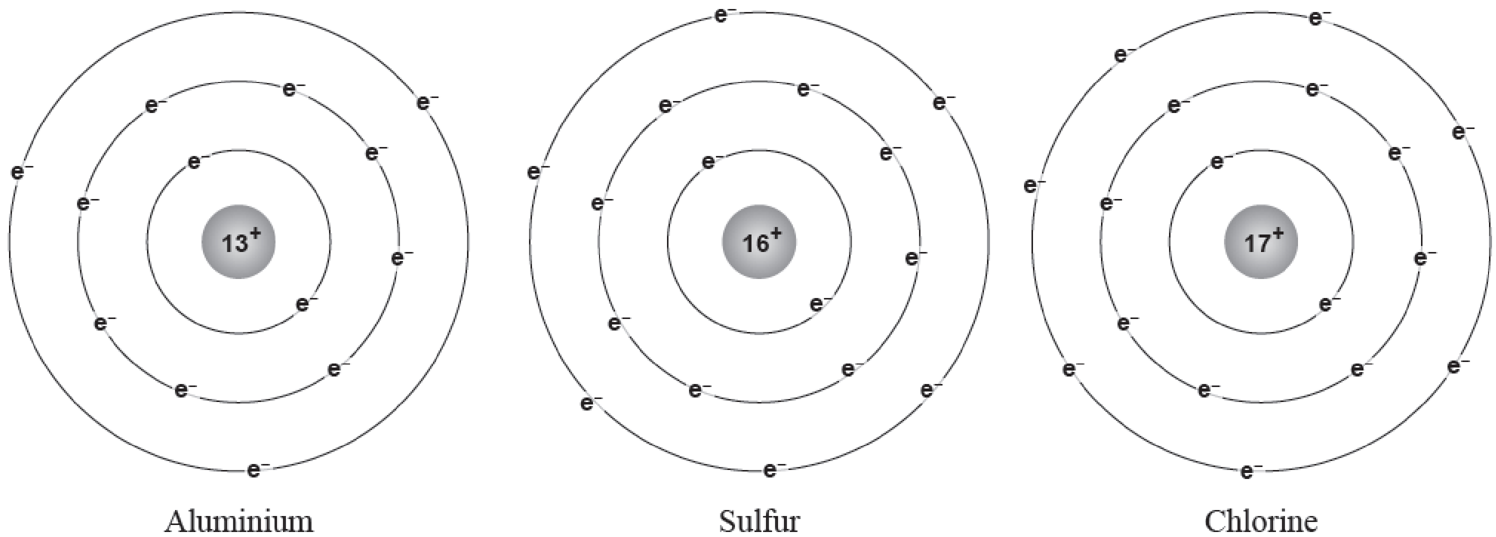
	Atomic Number	Electron arrangement of atom	Electron arrangement of ion	Charge on ion
Mg	12	2,8,2	2,8	+2
Al	13	2,8,3	2,8	+3
O	8	2,6	2,8	-2



NCEA 2015 Electron Configuration

Excellence Question

The diagrams below show models of three different atoms



Question 2a: Each of these atoms can form ions, as listed below.

• Explain why each of the **ions** has the charge it does, in terms of electron arrangement and number of protons.

• Ions are charged atoms. Explain how each of the ions below reached the charge shown. You should discuss particles gained or lost by the atoms involved, and the reasons for this.

Aluminium ion, Al^{3+}: Sulfide ion, S^{2-} : Chloride ion, Cl^{-} :

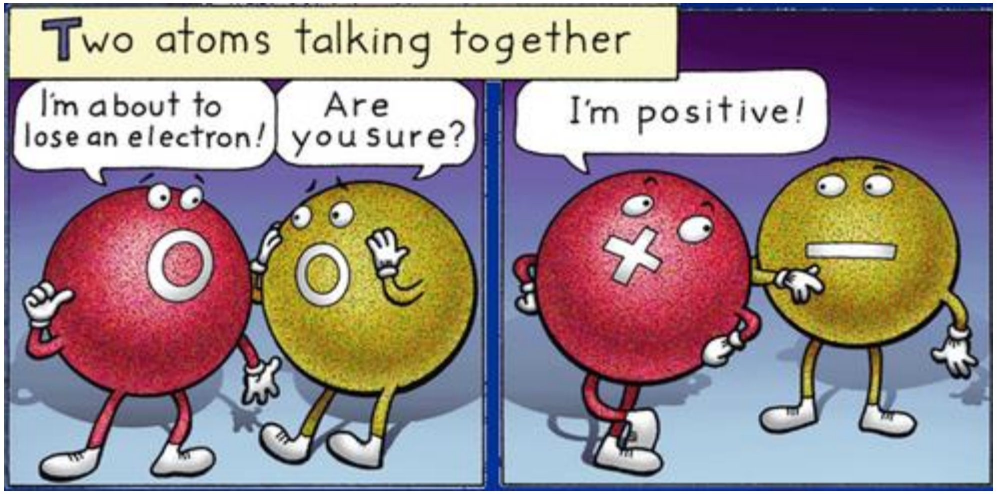
NCEA 2015 Electron Configuration

Excellence Question

Answer 2a: Al^{3+} because it has 13 protons (+ charges) and only 10 electrons (– charges). It has only 10 electrons, as its electron arrangement as an atom was 2,8,3, and when it forms an ion, it loses three electrons to form an arrangement of 2,8 to have a full outer shell, which is more stable.

S^{2-} because it has 16 protons (+ charges) and 18 electrons (– charges). It has 18 electrons, as its electron arrangement as an atom was 2,8,6, and when it forms an ion, it gains two electrons to form an arrangement of 2,8,8 to have a full outer shell, which is more stable.

Cl^{-} because it has 17 protons (+ charges) and 18 electrons (– charges). It has 18 electrons, as its electron arrangement as an atom was 2,8,7, and when it forms an ion it gains one electron to form an arrangement of 2,8,8 to have a full outer shell, which is more stable.

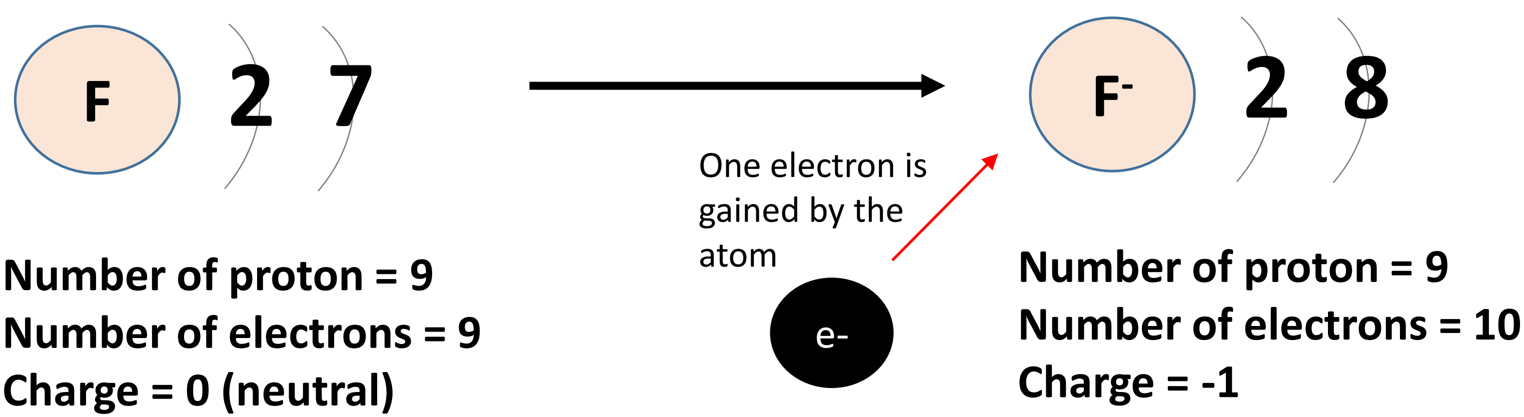


NCEA 2016 Electron Configuration

Achieved Question

Question 1a: Complete the table below.

Element	**Atomic Number**	**Electron arrangement of atom**	**Electron arrangement of ion**
F	9	2,7	2,8
S	16	2,8,6	2,8,8
Ca	20	2,8,8,2	2,8,8



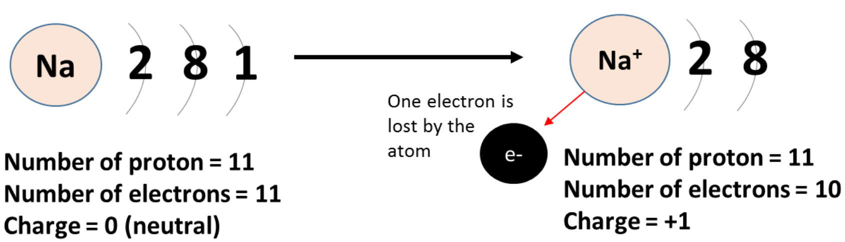
NCEA 2016 Electron Configuration

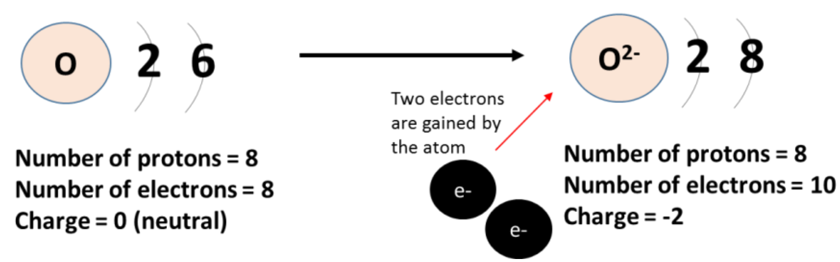
Excellence Question

Question 1c (i) : Sodium burns in oxygen gas, O_2, to form sodium oxide, Na_2O.
(i) Explain how the Na and O atoms form Na^+ and O^{2-} ions, in terms of their groups in the periodic table, electron arrangement, AND number of protons.

Answer 1c (i) : Na is a group one element, so the Na atom has one valence electron and an electron configuration of 2, 8, 1. The Na atom loses its one valence electron to gain a full outer shell – it now has 1 more proton (11) than electrons; the Na^+ ion is formed.

O is a group sixteen element, so the O atom has six valence electrons and an electron configuration of 2, 6. The O atom gains two electrons to gain a full outer shell – it now has 2 less protons (8) than electrons; the O^{2-} ion is formed.





Excellence Question

NCEA 2017 Electron Configuration (Part ONE)

Question 2a: Sodium and potassium are both highly reactive metals that react with oxygen gas. However, sodium and potassium do not react with each other.
(a) Why do sodium and potassium each react with oxygen, but not with each other?
In your answer you should:

- refer to the electron arrangements of each of the three atoms and three ions involved
- explain how the electron arrangement of each of the three atoms relates to its position in the periodic table
- explain how an ionic bond forms when sodium or potassium reacts with oxygen.

Sodium and potassium are both in Group 1 of the periodic table. This means they each have one valence electron. Their atom electron arrangements are shown below:
Na atom: 2, 8, 1
K atom: 2, 8, 8, 1
The Na and K atoms will each lose their one valence electron to gain a stable full outer shell, as shown by the ion electron arrangements below:
Na+: 2, 8
K+: 2, 8, 8

http://www.nzqa.govt.nz

Excellence Question

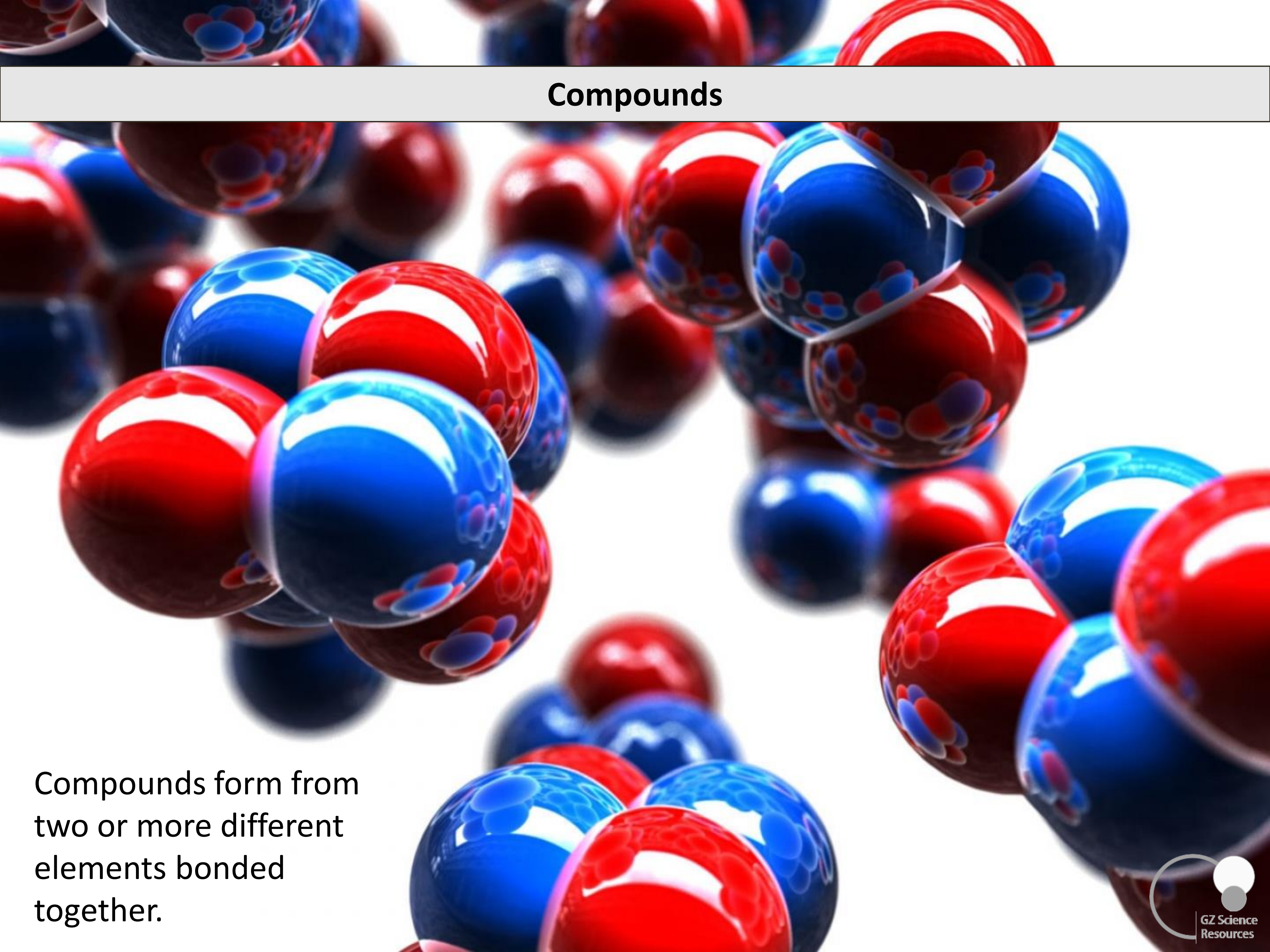
NCEA 2017 Electron Configuration (Part TWO)

Question 2a: Sodium and potassium are both highly reactive metals that react with oxygen gas. However, sodium and potassium do not react with each other.
(a) Why do sodium and potassium each react with oxygen, but not with each other?

Oxygen is in Group 16 of the Periodic Table. This means it has six valence electrons. Its atom electron arrangement is:
O atom: 2, 6
The O atom will gain two electrons to gain a stable full outer shell, as shown by the ion electron arrangement below:
O^{2-}: 2, 8

Since Na and K each lose one valence electron whereas O gains two electrons, Na and K can transfer electrons to the O atom. This transfer of electrons causes ions to form; the electrostatic attraction between the oppositely charged ions (Na^+ and O^{2-}, and K^+ and O^{2-}) is called an ionic bond. Each O atom will need to react with two K / Na atoms to get the two electrons it needs.
The Na and K atoms cannot react with each other because they each react by losing one electron. Therefore, electron transfer cannot occur between the Na and K atoms.

Compounds

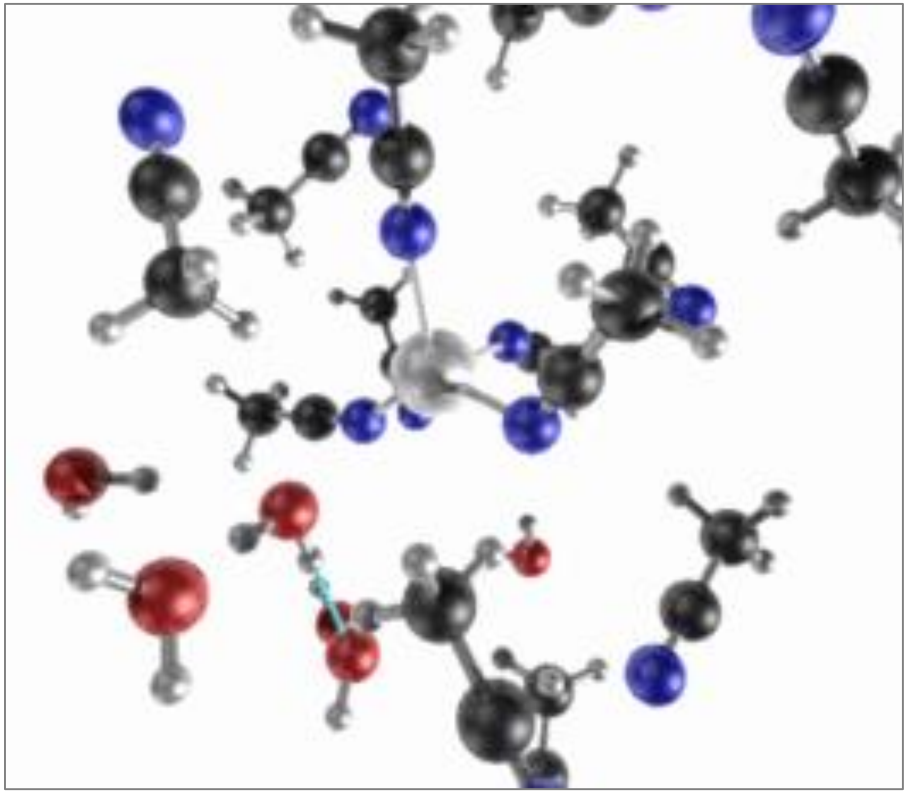


Compounds form from two or more different elements bonded together.

Compounds

The compounds are often more stable than the elements they originated from and may release this extra energy in the form of heat and/or light when bonding together.

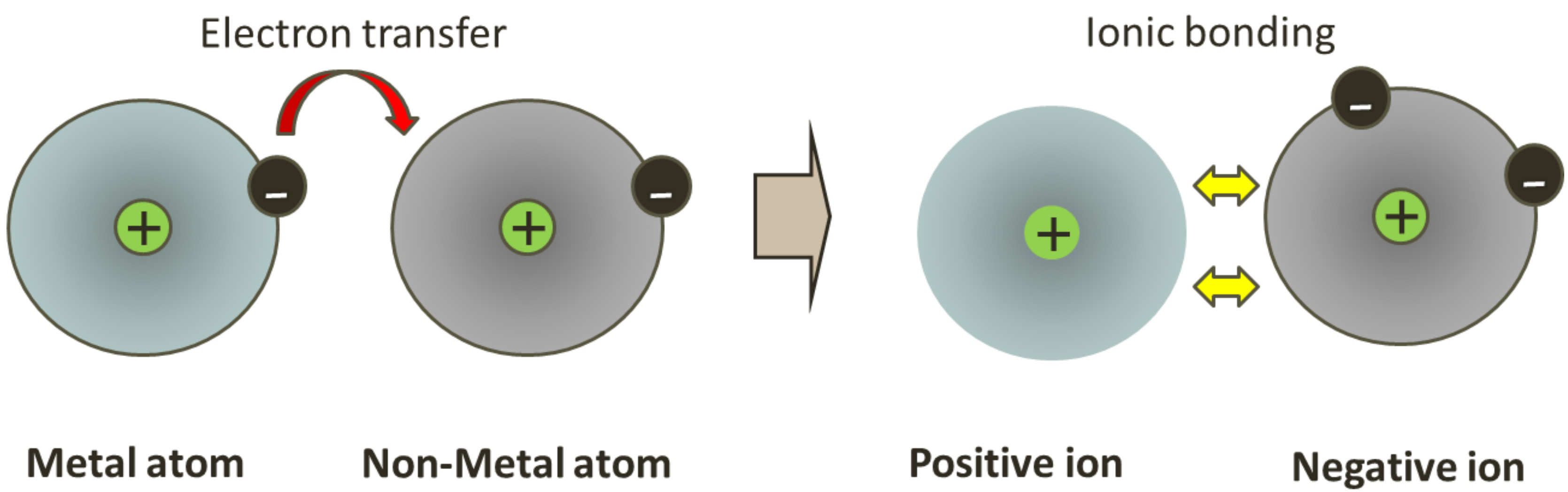
There are two main types of bonding holding atoms together in a compound; **Ionic** and **Covalent**.



Ionic Bonding

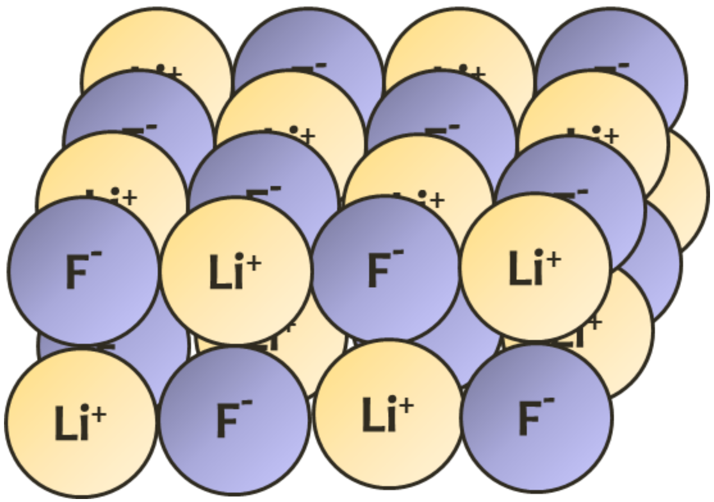
Ionic Bonding is where one atom takes valence (outside energy level) electrons from another to form ions and the resulting negative and positive ions hold together with **electrostatic attraction**. This type of bonding occurs when a **metal** and **non-metal** react and there is a **transfer of electrons**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

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



Ionic compounds are the product of chemical reactions between metal and non-metal ions

Some compounds are ionic compounds, since they are made up of cations and anions.



The Anion (F) takes the electrons off the Cation (Li) so their outer energy levels have a stable 8 electrons each.

Anions and Cations have a strong <u>electrostatic attraction</u> for each other so they bond together as a compound.

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

NCEA 2015 Ionic Bonding

Question 2b: Explain why an ionic bond would **not** form between a sulfide ion and a chloride ion.
In your answer you should:
- describe an ionic bond
- refer to charges and electron arrangements of the ions involved.

Excellence Question

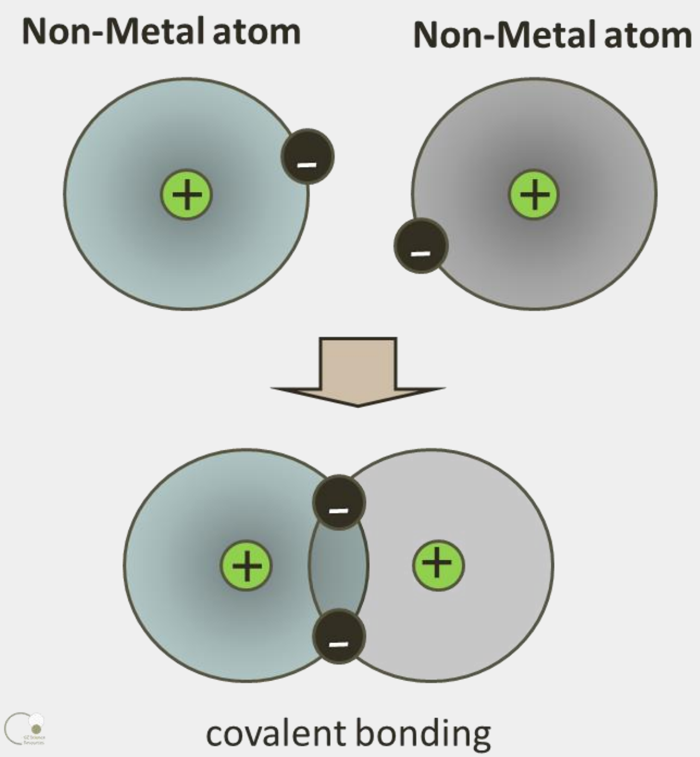
Answer 2b: An ionic bond is the attraction between a positive ion and a negative ion. It is formed because opposite charges will attract one another.

An ionic bond would not form between chloride ions and sulphide ions, as they **both have negative charges** because they have both gained negative electrons in order to form a full valence shell, and the ions with the **same charge will repel** each other.

Background Knowledge

Covalent Bonding

Covalent Bonding is where electrons are shared between neighbouring atoms. This often occurs when two or more **non-metals** react. No ions are formed and there is no transfer of electrons. The compound formed is neutral with no charge.

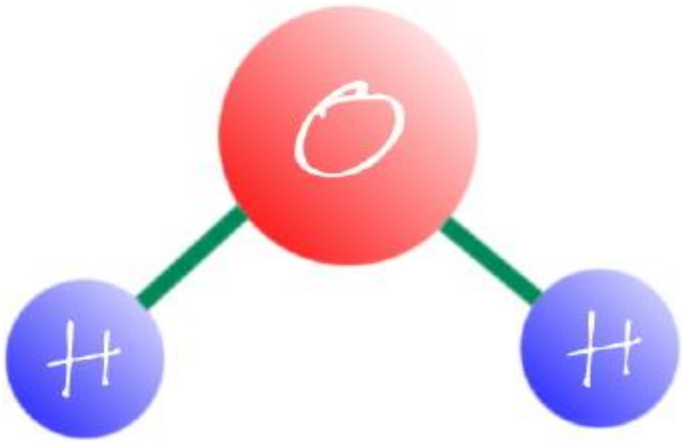


The valance electrons (electrons in outside energy level) are involved in bonding. These electrons orbit in pairs. The negative charge of the electron pair will attract the positively positive nucleus of other atoms, and this holds the atoms together in a molecule.

extra info

Chemical compound formula

Elements in a compound combine in fixed amounts. It is possible to write a **formula** for a compound.



H_2O

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

GZ Science Resources

Chemical compound formula

A formula tells you the type of atoms that are in a compound and the number of each atom.

2 Mg atoms | 4 N atoms | 12 O atoms

$$2\,Mg(NO_3)_2$$

A number in front of the compound tells you how many molecules there are.

A number after an atom tells you how many atoms of that type are in the molecule.

A number after brackets tells you how many times to multiply every atom inside the brackets.

Writing Chemical compound formula

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

Al^{3+} O^{2-}

Al_2O_3

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

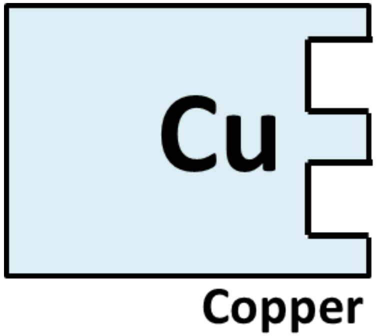
6. Remove any brackets if not followed by a number

H^{+} SO_4^{2-}

$H_2(SO_4)_1$ $\longrightarrow$ H_2SO_4

GZ Science Resources

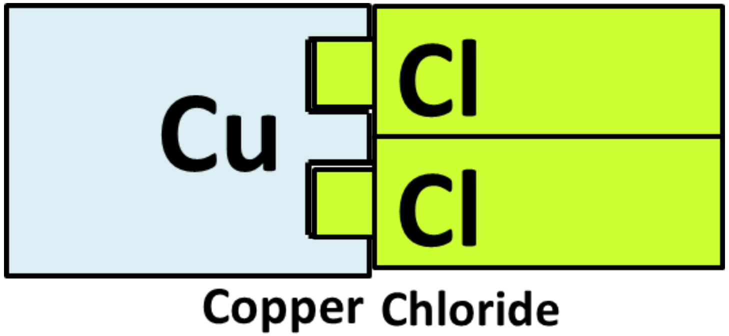
The visual method for balancing compounds



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

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.



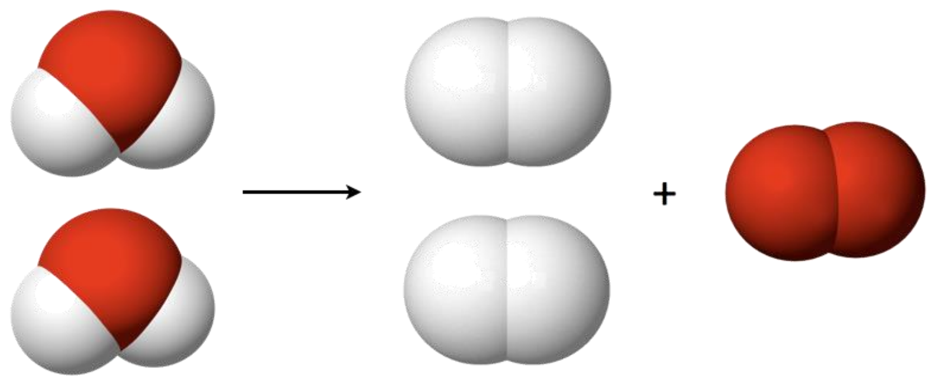
The visual ion chart

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)			

Chemical Reactions - 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.** Other observations may include a temperature change, a colour change or production of gas.
Chemicals that are used in a chemical reaction are known as **reactants**. Those that are formed are known as **products**.
Chemical reactions between particles involve breaking bonds and forming new bonds.

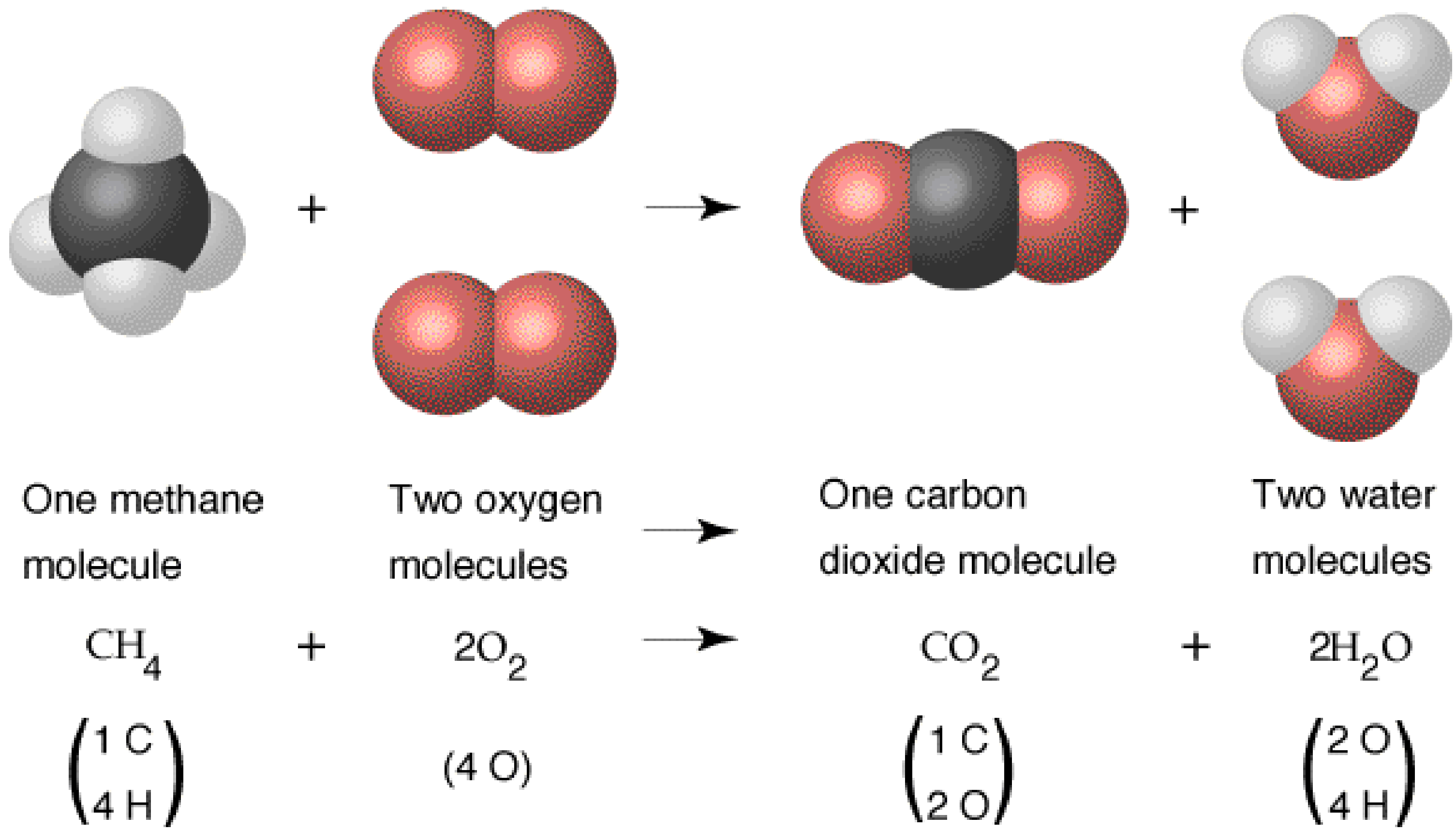
Reactants → Products



$$2H_2O \longrightarrow 2H_2 + O_2$$

Chemical equations

Compounds and elements can react together to form new substances in a **chemical reaction**. We use a **chemical equation** to show the substances we start with, called **reactants**, and the substances that are formed called **products**.



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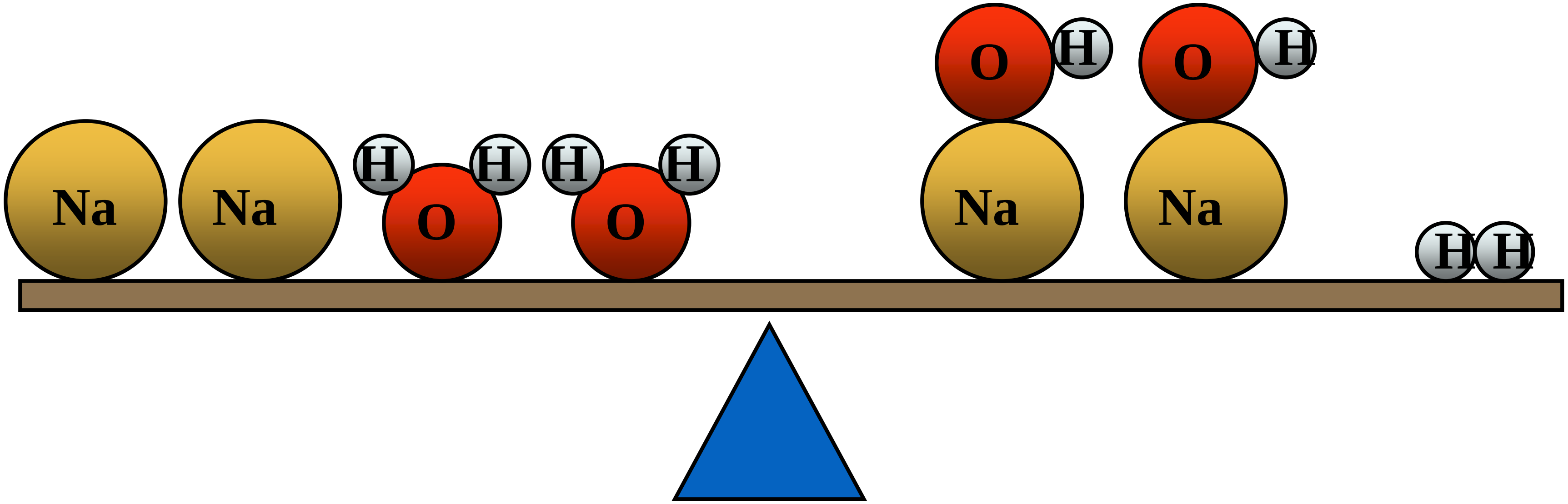
Balancing chemical equations

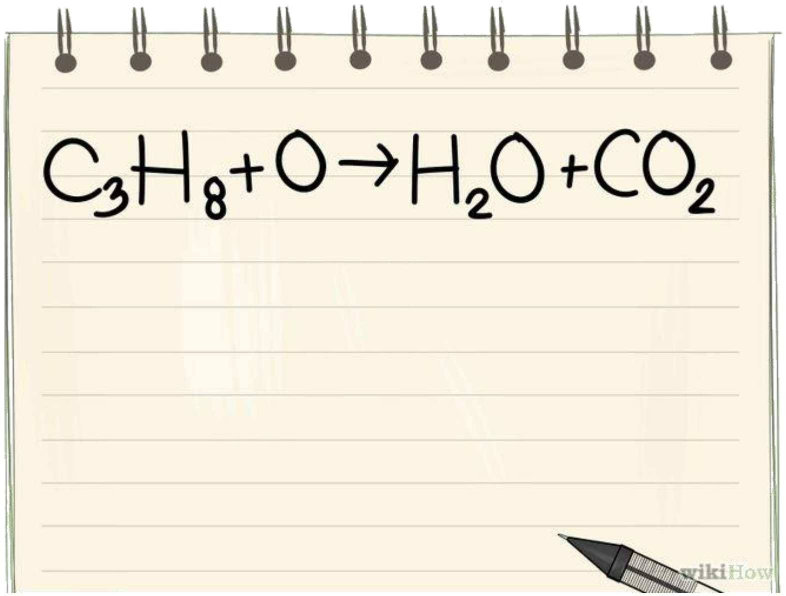
Balanced equations must have the same number of atoms on each side of the equation i.e. reactants and products.

$$2Na + 2H_2O = 2NaOH + H_2$$



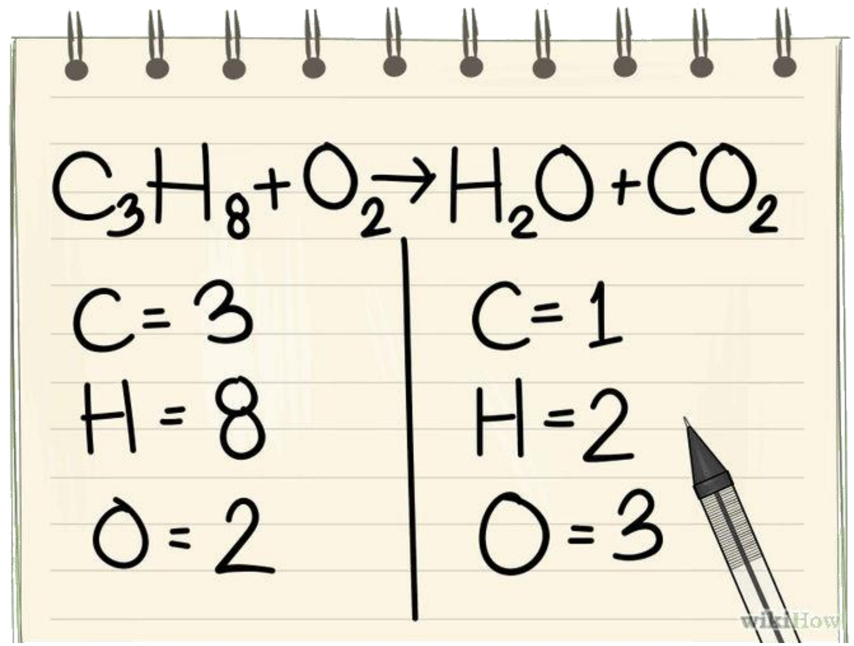
Balancing Chemical equations

1. To balance an equation first write down the equation



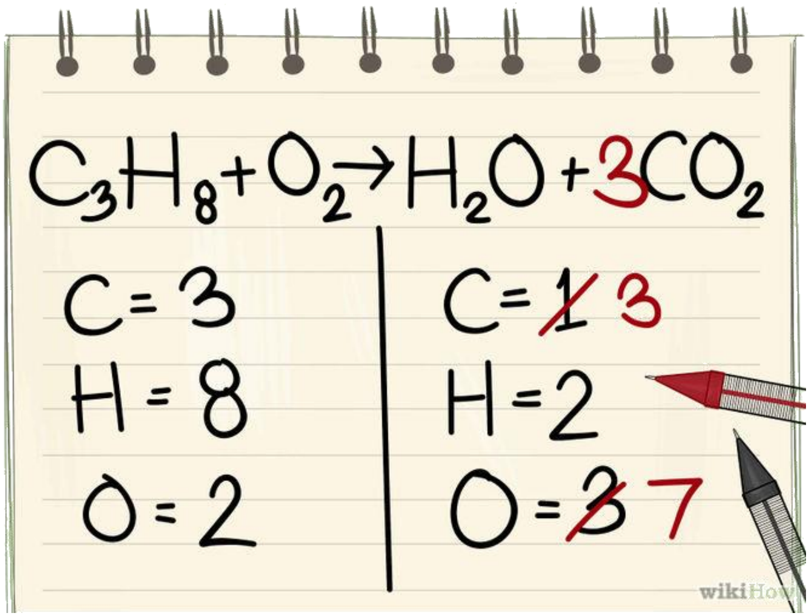
The total number of each type of atom must be the same for reactants and products if they equation is balanced

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



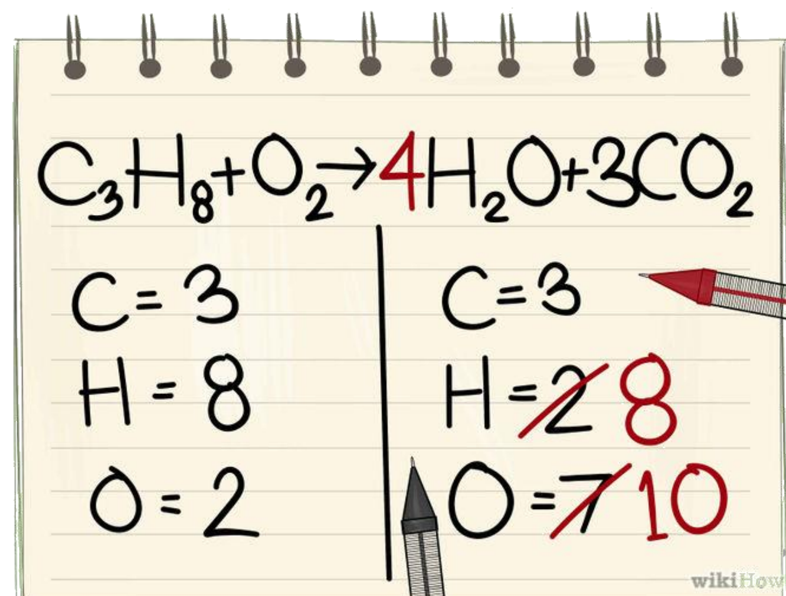
Balancing Chemical equations

3. 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



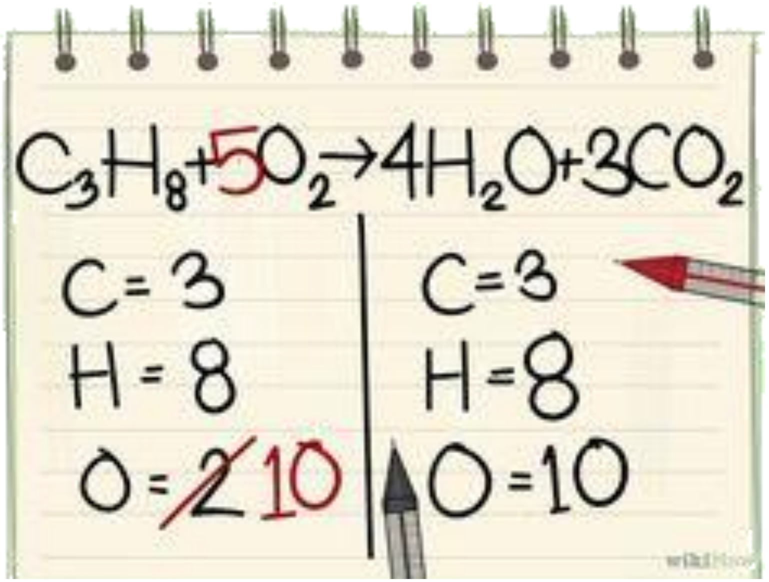
Only put numbers in front of compounds **NOT** after an atom as this changes the formula

4. 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



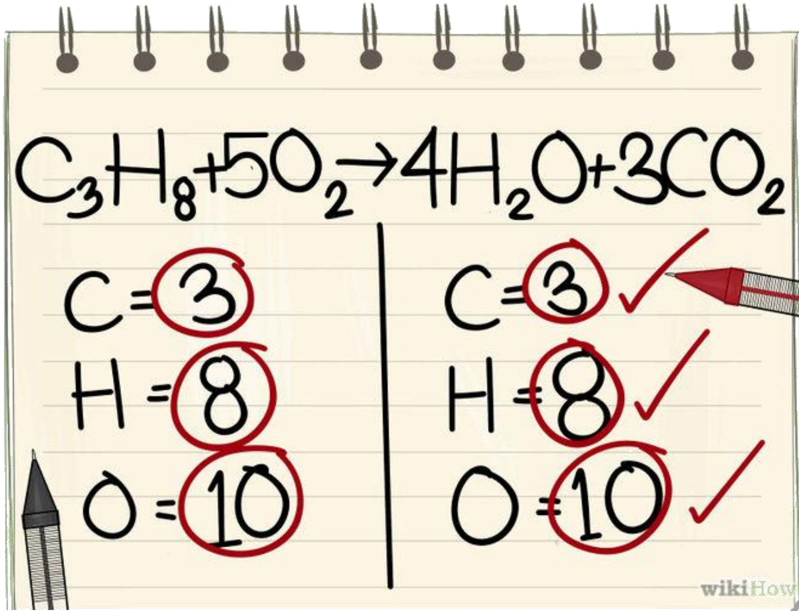
Balancing Chemical equations

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



Sometimes you may have to go back and rebalance another atom again for the second time

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



NCEA 2014 Ionic Compounds - (part one)

Excellence Question

Q: The formula for magnesium oxide is MgO. The formula for aluminium oxide is Al_2O_3.Explain why the two formulae are different.
In your answer:
• consider the ratio of ions in each formula and explain how the ratio is related to the charge on the ions
• relate the ratio of ions in the formula to the number of electrons lost or gained by each atom..

Fully explains the ratio of ions in magnesium oxide

Step one: charge of ions - Magnesium ion has a charge of +2 and oxide ion has a charge of –2.
Step two: neutral compounds - 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 therefore the ratio of ions is one to one.
Step three: movement of electrons - The charge on the ions arises as magnesium has to lose two electrons in order to have a full outer shell and gets a charge of +2, and oxygen has to gain two electrons in order to have a full outer shell and gets a charge of –2.

NCEA 2014 Ionic Compounds - (part two)

Excellence Question

Q: The formula for magnesium oxide is MgO. The formula for aluminium oxide is Al_2O_3.Explain why the two formulae are different.
In your answer:
• consider the ratio of ions in each formula and explain how the ratio is related to the charge on the ions
• relate the ratio of ions in the formula to the number of electrons lost or gained by each atom..

Fully explains the ratio of ions in aluminium oxide

Step one: charge of ions - Aluminium ion has a charge of +3, and oxide ion has a charge of -2.
Step two: neutral compounds - 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.
Step three: movement of electrons - The charge on the ions arises as aluminium has to lose three electrons in order to have a full outer shell and gets a charge of +3, and oxygen has to gain two
electrons in order to have a full outer shell and gets a charge of –2.

NCEA 2014 Ionic Compounds

Achieved Question

Question 1a: Write the formulae for the following ionic compounds.
(i) Calcium chloride
(ii) Sodium nitrate
(iii) Zinc nitrate

Answer 1a:
Calcium chloride- $CaCl_2$
Sodium nitrate - $NaNO_3$
Zinc nitrate - $Zn(NO_3)_2$

NCEA 2015 Ionic Compounds - (Part ONE)

Excellence Question

Question 2c: Determine the ionic formulae of the compound that forms when aluminium combines with chlorine, AND when aluminium combines with sulfur.
In your answer you should:
• consider the ratio of ions in each formula, and explain how the ratio is related to the charge on the ions
• relate the ratio of ions in each formula to the number of electrons lost or gained by each atom when forming ions.
Aluminium and chlorine: Aluminium and sulfur:

Answer 2c: Elements 1 and 3: $AlCl_3$
Aluminium has a charge of +3. In order to have a neutral compound overall, one aluminium ion is required to cancel out the charge on three chloride ions with a combined charge of –3. The charge on the aluminium ion arises as it gives away three electrons in order to have a full outer shell. Because it has to give 3 electrons away and each chlorine has to accept one electron, in order to have a full shell, the ratio of ions required is one to three.

NCEA 2015 Ionic Compounds - (Part TWO)

Excellence Question

Question 2c: Determine the ionic formulae of the compound that forms when aluminium combines with chlorine, AND when aluminium combines with sulfur.
In your answer you should:
• consider the ratio of ions in each formula, and explain how the ratio is related to the charge on the ions
• relate the ratio of ions in each formula to the number of electrons lost or gained by each atom when forming ions.
Aluminium and chlorine: Aluminium and sulfur:

Answer 2c: Element 1 and 2: Al_2S_3
The aluminium ion has a charge of +3. In order to have a neutral compound overall, two aluminium ions with a combined charge of +6 are required to cancel out the charge on three 2^- sulfide ions with a combined charge of –6. The charge on the aluminium ion arises as aluminium gives away three electrons in order to have a full outer shell. Because it has to give 3 electrons away and sulfur has to accept two electrons in order to have a full shell, the ratio of ions required is two to three.

NCEA 2016 Ionic Compounds

Achieved Question

Question 1b: Write the formulae for the following ionic compounds.
(i) Silver fluoride
(ii) Potassium sulfate
(iii) Calcium nitrate

Answer 1b:
Silver fluoride - AgF
Potassium sulfate - K_2SO_4
Calcium nitrate - $Ca(NO_3)_2$

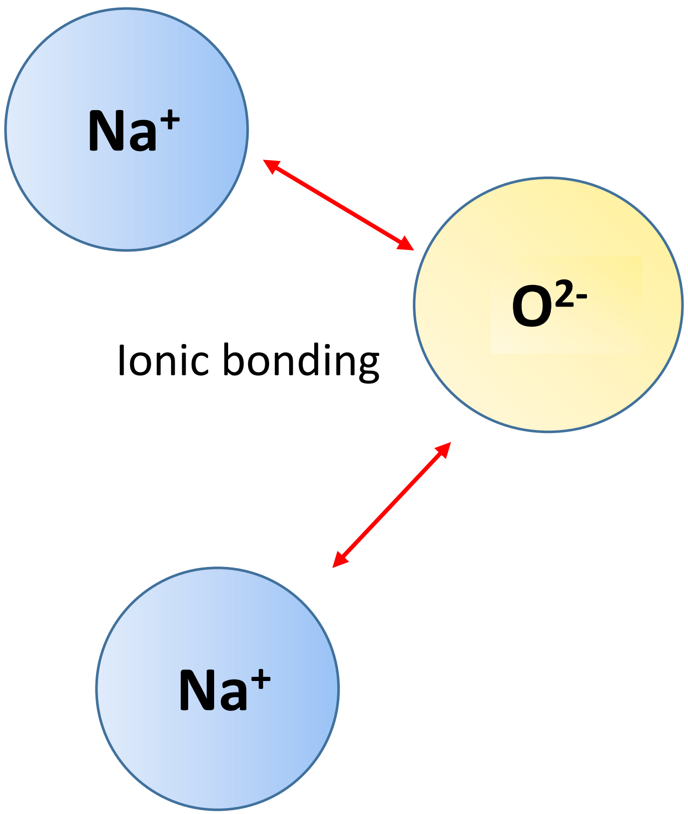
NCEA 2016 Ionic Compounds

Excellence Question

Question 1c (ii): Justify the ratio of Na^+ and O^{2-} ions in the formula Na_2O, in terms of the **electrons** lost or gained, and the **charge** on each ion.
Include an explanation of the **type of bonding** between the Na^+ and O^{2-} ions.

Answer 1c (ii):

- The Na atom **loses one electron** to form the Na^+ ion; however, the O atom requires two electrons to fill its outer shell. Therefore, **two Na atoms react for every one O atom**.
- The two Na^+ ions have a total charge of +2 to balance the –2 charge of the O^{2-} ion, i.e. an ionic compound has no overall charge.
- The bonding / attraction between the Na^+ ions and the O^{2-} ions is an **ionic bond**, formed when the electrons lost by the Na are gained by the O.



Excellence Question

NCEA 2017 Ionic Compounds

Question 3a: (i) Explain why silver oxide, Ag_2O, has a 2:1 ratio of ions.

http://www.nzqa.govt.nz

In your answer you should:

• relate the ratio of ions to the number of electrons lost or gained by each atom when forming ions

• explain how the ratio of the ions in the compound is related to the charge on the ions.

https://dir.indiamart.com/ahmedabad/silver-oxide.html

Answer 3a:

Each silver (Ag) atom loses one electron to form the Ag^+ ion;

however, each oxygen atom requires two electrons to fill its outer shell. Therefore, two Ag atoms react for every O atom,

i.e. two Ag atoms lose 2 electrons and one O atom gains 2 electrons.

The two Ag^+ ions have a total charge of +2 to balance the –2 total charge of the O^{2-} ion, i.e. an ionic compound has no overall charge.

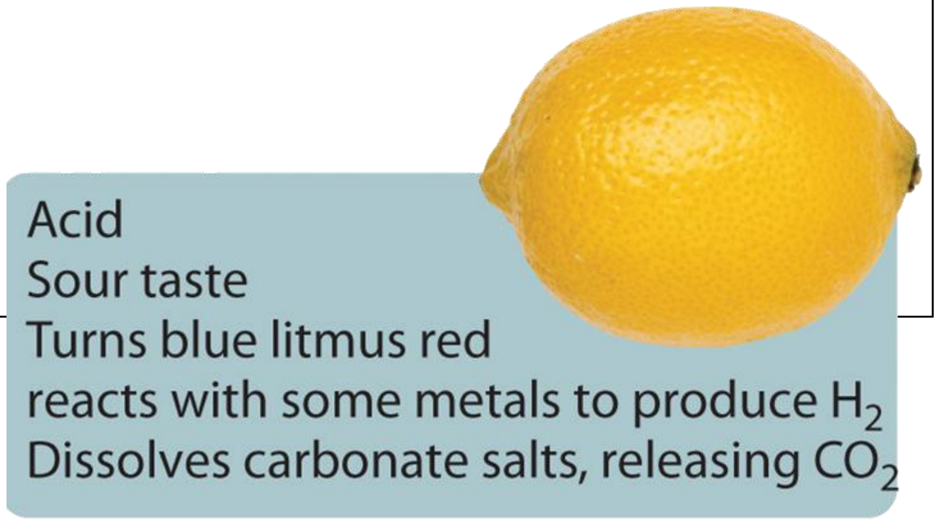
Acids– their characteristics

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**.

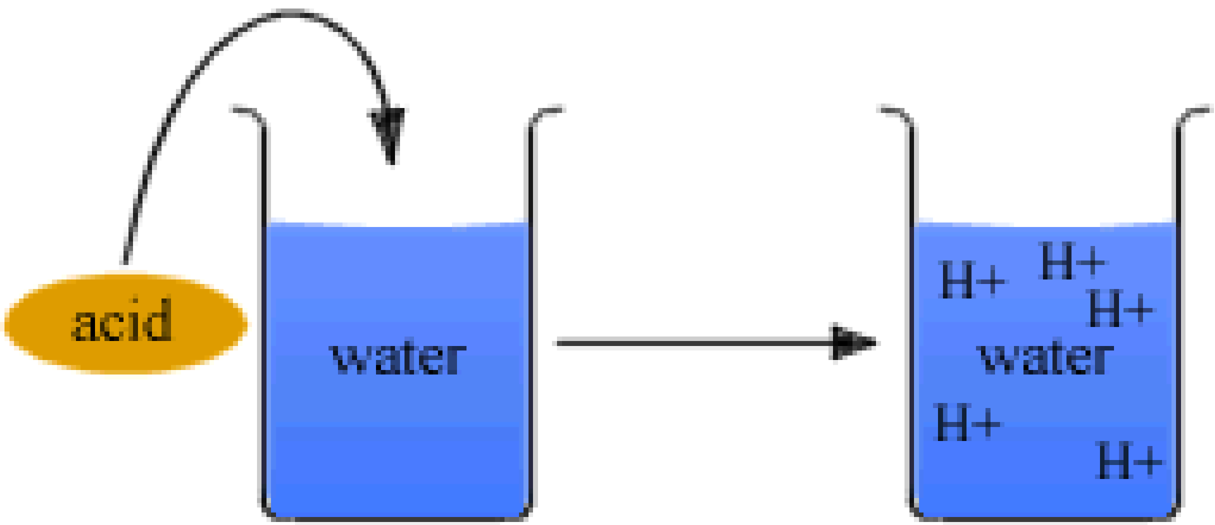
Physical and Chemical Properties of Acids

- ❑ pH < 7
- ❑ Turn blue litmus paper **red**
- ❑ Turn Universal indicator **red – yellow**
- ❑ Neutralised by bases
- ❑ React with carbonates to form a metal salt, water and carbon dioxide gas
- ❑ React with most metals to form a metal salt and hydrogen gas
- ❑ React with metal oxides to form a metal salt and water
- ❑ React with metal hydroxides to form a metal salt and water
- ❑ Have a sour taste



Acids – their characteristics

An **Acid** donates its **Hydrogen ion** (H+) , which is really just a proton - the electron remains behind.
Common acids include the strong acids HNO_3 - nitric acid, HCl - hydrochloric acid, and H_2SO_4 – sulfuric acid.



GZ Science Resources

Common acids - names and formula

Name	Chemical formula	Salts formed
hydrochloric acid	HCl	-chlorides (Cl^-)
sulfuric acid	H_2SO_4	-sulfates (SO_4^{2-})
nitric acid	HNO_3	-nitrates (NO_3^-)

GZ Science Resources

Bases – their characteristics

Bases are a family of chemicals that can remove acid particles (H^+) from a solution. They have opposite properties from acids.

Bases have a slippery feel to them and common household bases include floor clearers and antacid tablets to fix indigestion. **Bases that dissolve into water are called an alkali, and produce OH^- ions**.

Chemical and Physical Properties of Bases

- ☐ pH > 7
- ☐ Turn red litmus paper **blue**
- ☐ Turn Universal indicator **blue – purple**
- ☐ Neutralise acids
- ☐ Feel soapy
- ☐ Bases that dissolve in water are called alkalis, they form OH^- ions.

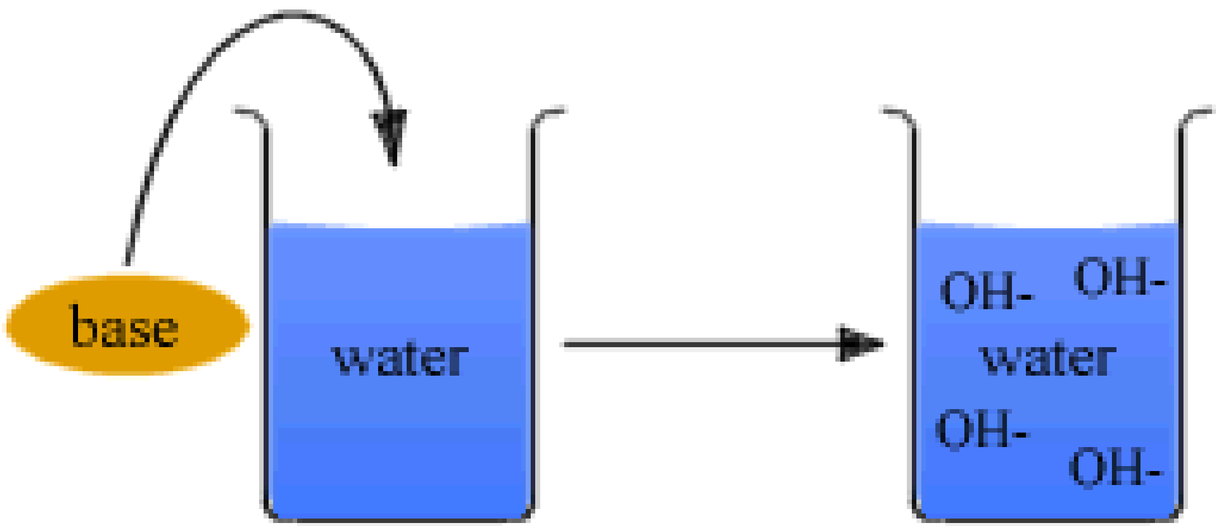
GZ Science Resources

Bases – their characteristics

A **Base** accepts a **Hydrogen ion** that have been donated from an Acid. They release hydroxide ions into solution. Common bases include the strong bases NaOH – sodium hydroxide, and other metal oxides, hydroxides, carbonates and hydrogen carbonates

Some substances such as water are **amphiprotic** and can act as both an acid or a base depending on what other substance the water is with.

extra info

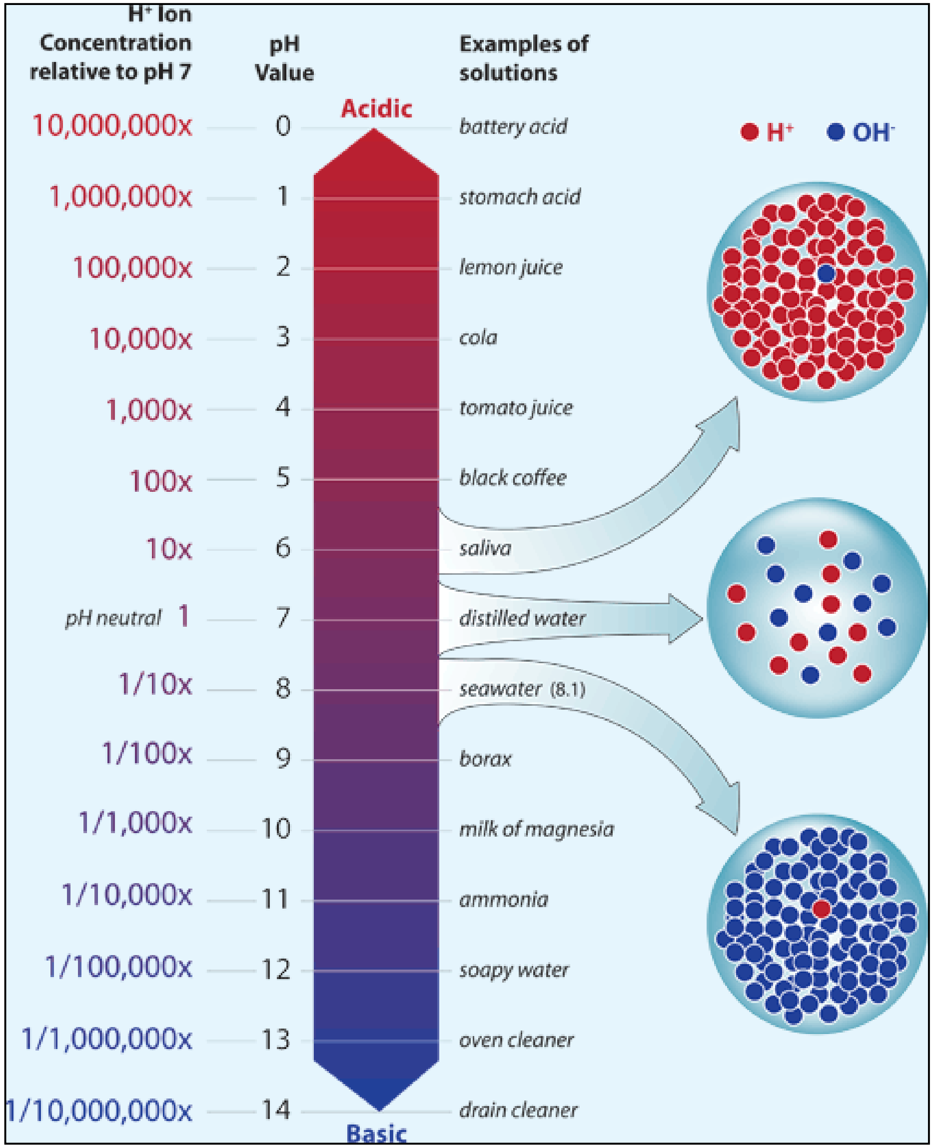


Common bases - names and formula

Name	Chemical formula
sodium hydroxide	$NaOH$
calcium hydroxide	$Ca(OH)_2$
sodium hydrogen carbonate	$NaHCO_3$
calcium carbonate	$CaCO_3$

Bases this year include **metal oxides (- O^{2-}), metal hydroxides (- OH^-), metal carbonates (- CO_3^{2-})** and **hydrogen carbonates (- HCO_3^-)**

The pH scale measures level of acidity and alkalinity



Woods Hole Oceanographic Institution

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**. 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.

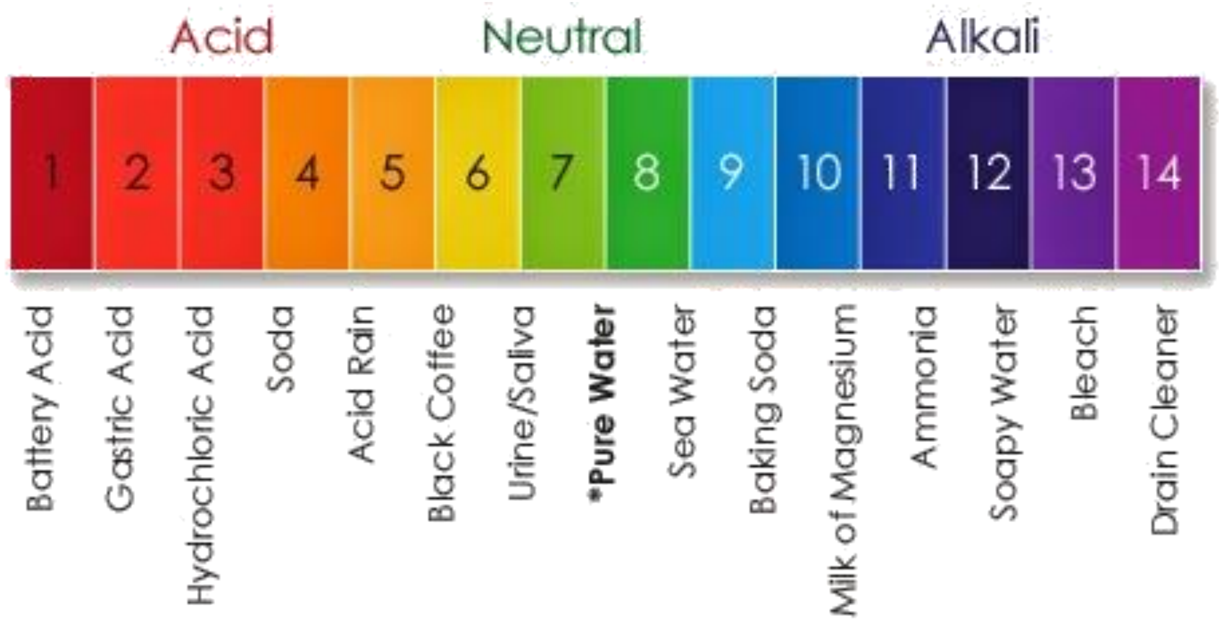
GZ Science Resources

Acidic, Alkaline or Neutral in terms of the pH scale

Acids have a pH less than 7

Neutral substances have a pH of 7

Alkalis have pH values greater than 7



The pH scale is **logarithmic** and as a result, each whole pH value below 7 is ten times more acidic than the next higher value. For example, pH 4 is ten times more acidic than pH 5 and 100 times more acidic than pH 6.

GZ Science Resources

Understand the difference between strong and weak acids and bases

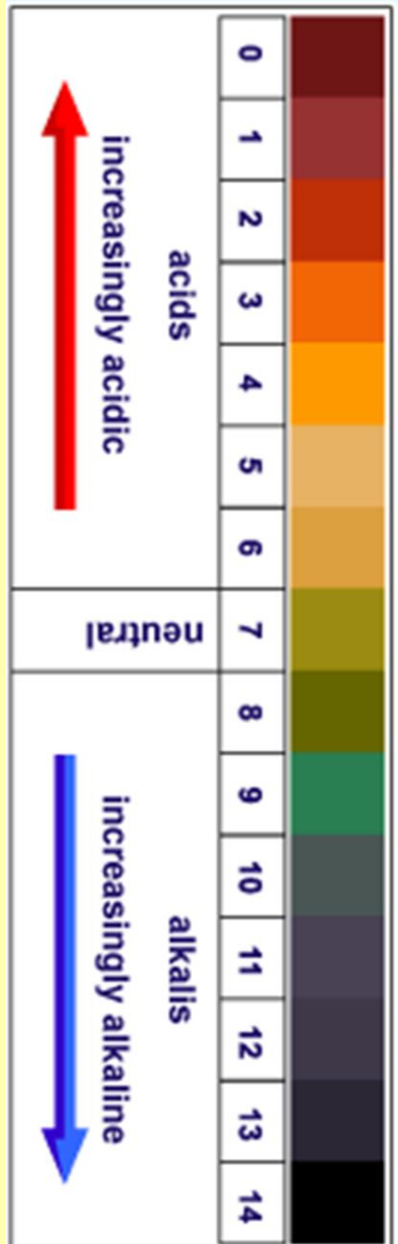
Strong Acids	Weak Acids	Neutral solution	Weak Bases	Strong Bases
Readily donate all their protons when dissolved	donate only a small proportion of protons		Accept only a small proportion of protons	Readily accept protons

Concentration of H+ ions is **greater** than that of OH- ions	Concentration of H+ ions is the **same** as that of OH- ions	Concentration of H+ ions is **less** than that of OH- ions

Increasing acidity ⟵ ⟶ Increasing alkalinity

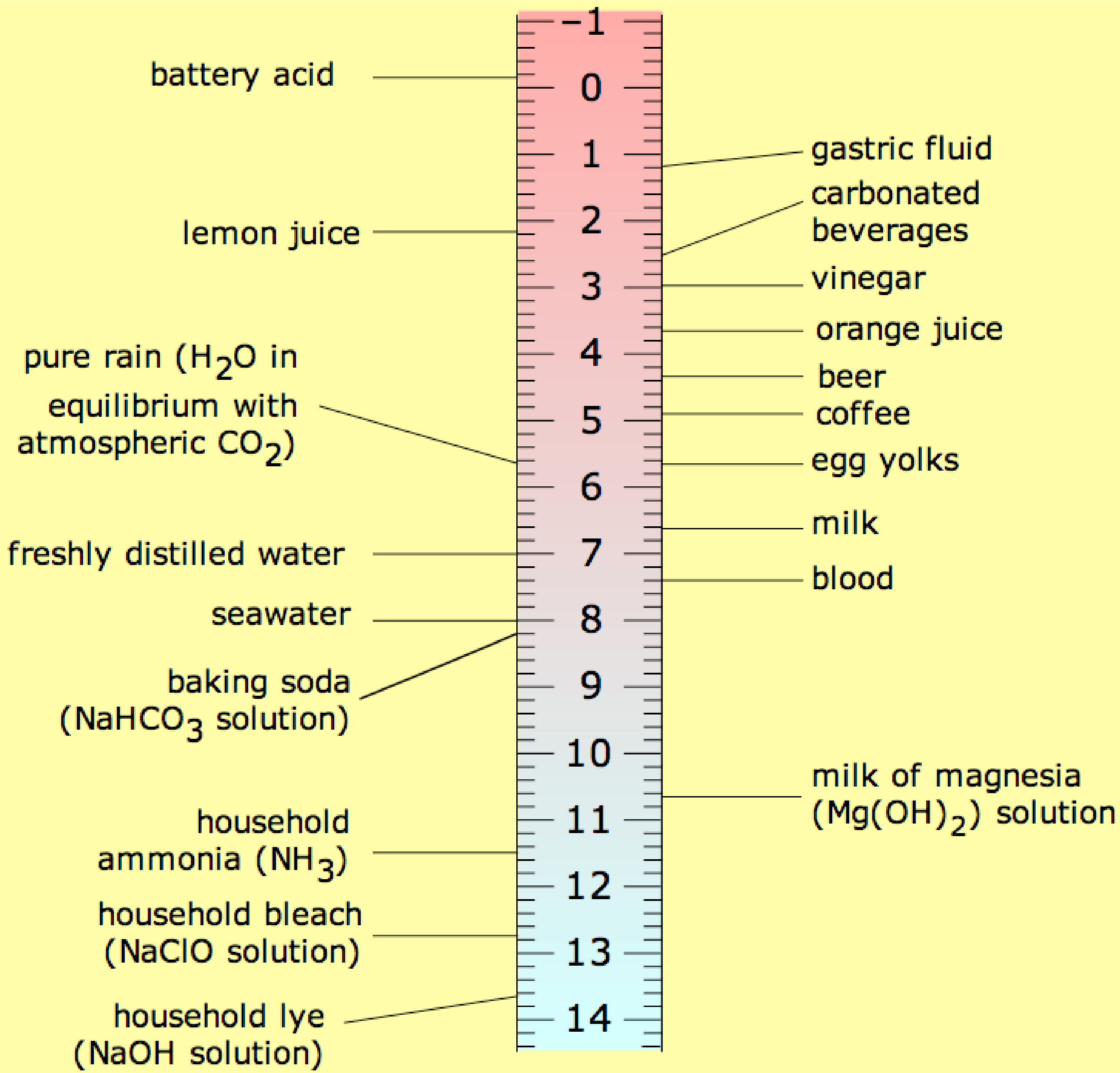
pH of Laboratory Acids and Bases

extra info



Strong Mineral Acids	HNO_3
	HCl
Weak Organic Acids	CH_3COOH
Water, Chlorides	$NaCl$ H_2O
Carbonates	$NaHCO_3$
Oxides	MgO
Most Hydroxides	$Mg(OH)_2$
Ammonia	NH_3
Sodium Hydroxide	$NaOH$

pH of common substances



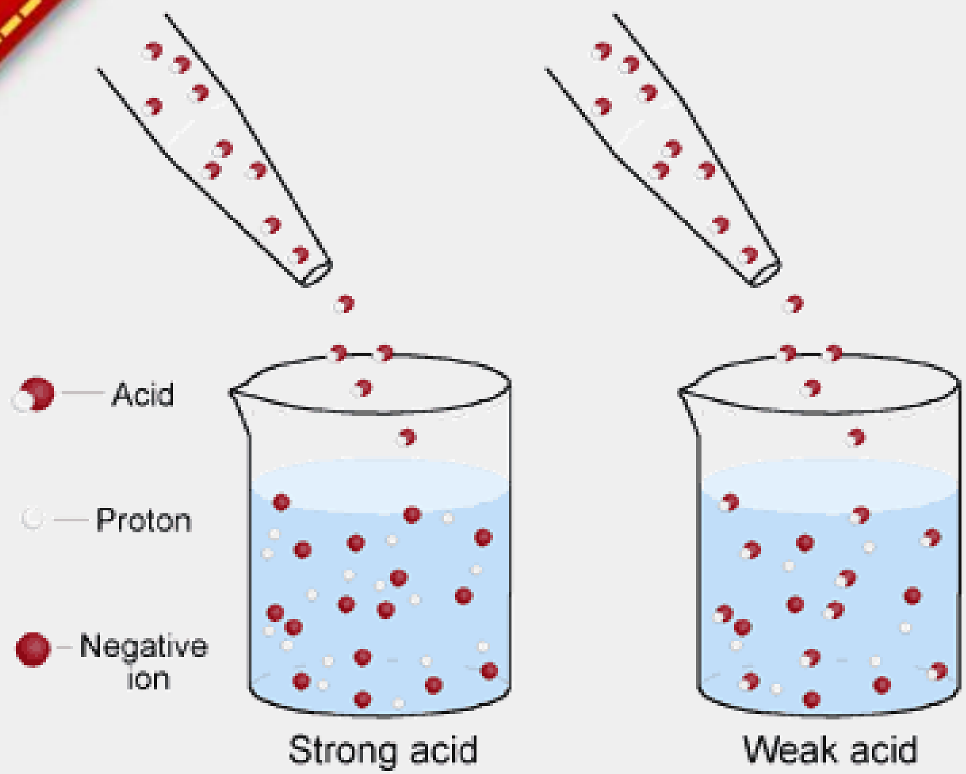
extra info

Pure water is **neutral**. But when chemicals are mixed with water, the mixture can become either acidic or basic. Examples of acidic substances are vinegar and lemon juice. Lye, milk of magnesia, and ammonia are examples of basic substances

Background Knowledge

Strong and weak acids

extra info



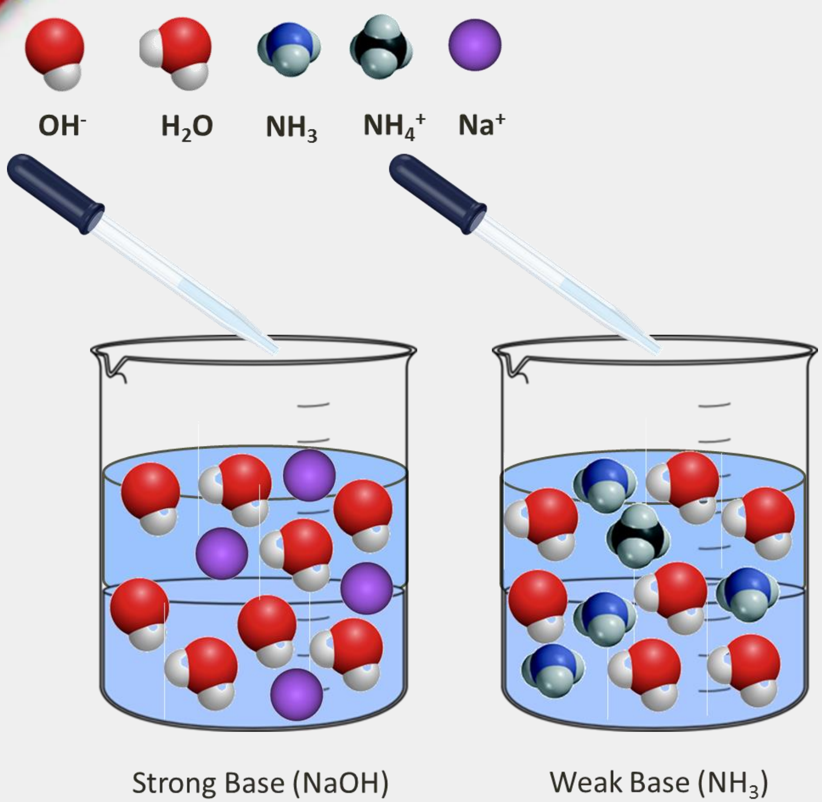
You can define acids as being "strong" or "weak". **Strong acids** are compounds that completely break up in water. All of the H^+ ions (protons) break away from the original acid molecule in water. A **weak acid** only loses some of it's H^+ ions (protons) in water.

For strong acids, after reacting there will be no intact acid molecule left. In weak acids there will be mostly unreacted acid molecules left.

Background Knowledge

extra info

Strong and weak bases



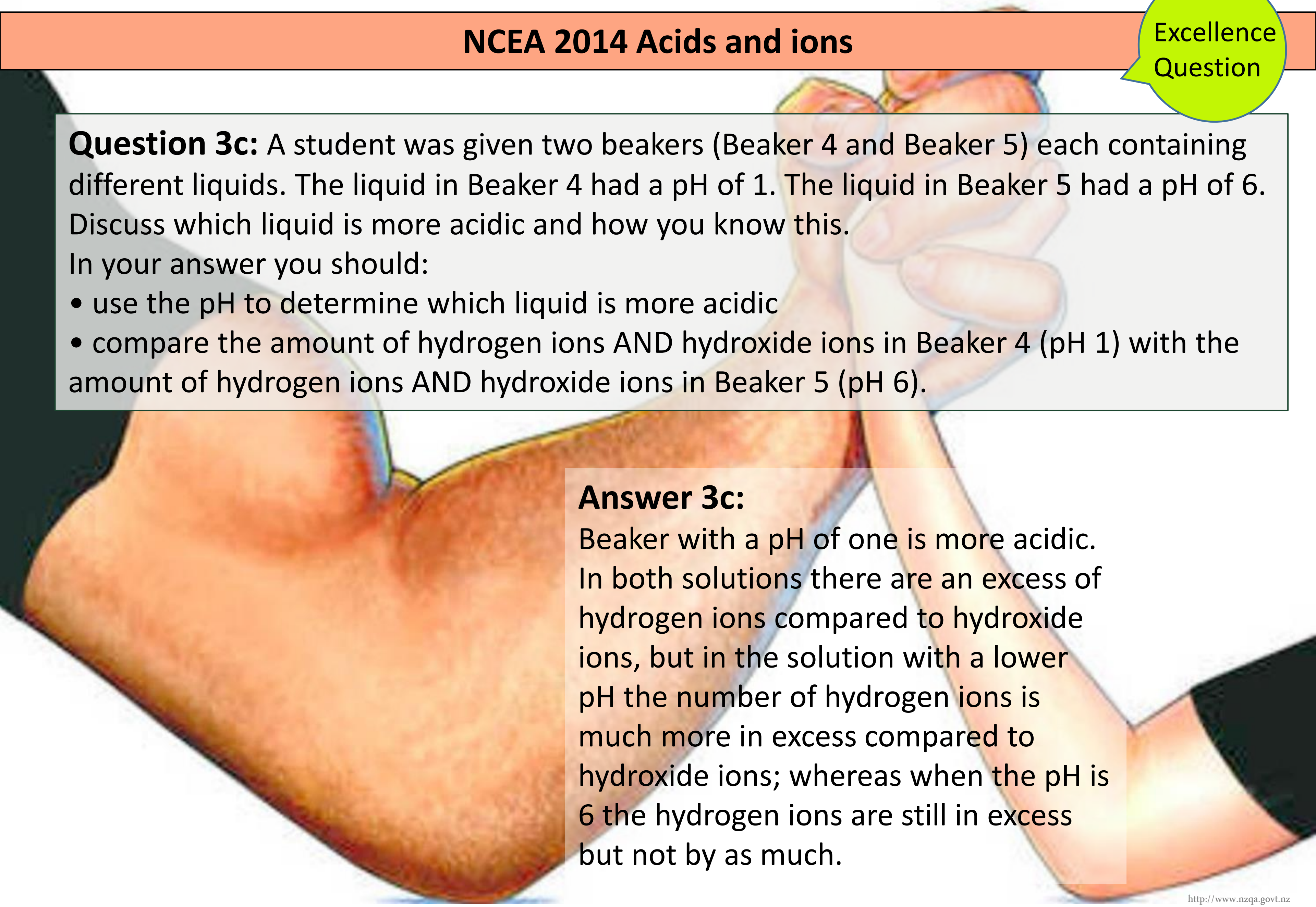
You can define bases as being "strong" or "weak". **Strong bases** are compounds where each molecule will accept an H^+ ion. A **weak base** is a compound where only some of the molecules will accept a H^+ ion. Most weak base molecules remain un reacted.

Note: For strong alkalis, all of the OH^- ions break away from the molecule in water.

GZ Science Resources

NCEA 2014 Acids and ions

Excellence Question



Question 3c: A student was given two beakers (Beaker 4 and Beaker 5) each containing different liquids. The liquid in Beaker 4 had a pH of 1. The liquid in Beaker 5 had a pH of 6. Discuss which liquid is more acidic and how you know this.

In your answer you should:

- use the pH to determine which liquid is more acidic
- compare the amount of hydrogen ions AND hydroxide ions in Beaker 4 (pH 1) with the amount of hydrogen ions AND hydroxide ions in Beaker 5 (pH 6).

Answer 3c:

Beaker with a pH of one is more acidic. In both solutions there are an excess of hydrogen ions compared to hydroxide ions, but in the solution with a lower pH the number of hydrogen ions is much more in excess compared to hydroxide ions; whereas when the pH is 6 the hydrogen ions are still in excess but not by as much.

NCEA 2015 Acids and ions

Merit Question

Question 3b: Water is formed in the reaction below.
Explain what ions form water in this reaction, and where they come from.
$HCl + NaOH \rightarrow NaCl + H_2O$

Answer 3b:
When HCl reacts it donates an H^+ and when NaOH reacts it provides OH^-, and these two ions combine to form (neutral) H_2O.

Indicators are used to determine whether substances are acid, base or neutral.

Indicators can be used to determine the pH of a solution by the colour change.

The most common indicator is found on **litmus paper**. It is red with acids and blue with bases.

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

An indicator is a large organic molecule that works like a colour dye. They react and change colour depending on the hydrogen ion concentration. Most of the indicators are weak acids.

Did you know

Red and Blue Litmus paper works as an indicator

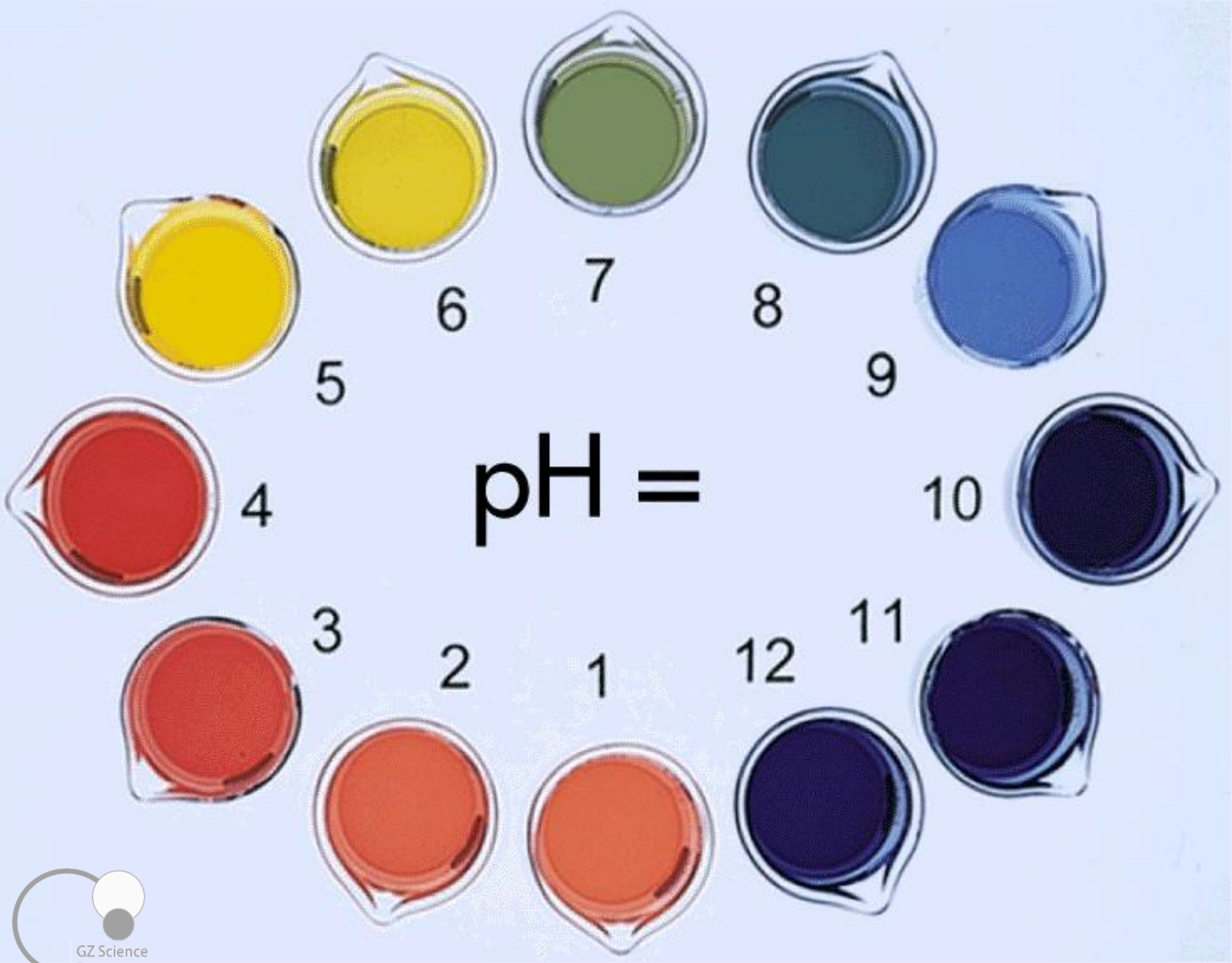
Added to…	Blue Litmus	Red litmus
Acid solution	Turns red	Stays red
Neutral solution	Stays blue	Stays red
Base solution	Stays blue	Turns blue

Blue litmus paper turning red in acid

Red litmus paper turning blue in base

GZ Science Resources

Universal Indicator is used to give the pH



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 also has different colours to **estimate the pH** of the solution not just whether it is acid or base.

Putting it all together

Blue litmus					
Red litmus					
Universal indicator					
pH	**1 - 2**	**3 - 6**	**7**	**8 - 12**	**13 - 14**
description	**Strong Acids** Readily donate all their protons when dissolved	**Weak Acids** donate only a small proportion of protons	**Neutral solution**	**Weak Bases** Accept only a small proportion of protons	**Strong Bases** Readily accept protons
H_3O^+ / OH^- concentration	Concentration of H+ ions is **greater** than that of OH- ions		Concentration of H+ ions is the **same** as that of OH- ions		Concentration of H+ ions is **less** than that of OH- ions

Increasing acidity ← → **Increasing alkalinity**

NCEA 2012 pH and Indicators - (Part ONE)

Excellence Question

Question 3:. Beaker one contains sulfuric acid solution and 5 drops of universal indicator.
Beaker two contains pure water and 5 drops of universal indicator.
Sodium hydroxide solution was added to both beakers until no more changes were observed.
(b) What is the colour of universal indicator in each solution at the **start**?
(c) Describe the colour changes as sodium hydroxide solution is added to each beaker, AND explain what this tells you about the changing pH of each solution.
(d) Explain the relationship between the pH of the solutions and the **ions** in the solutions, as the sodium hydroxide is added to each of the beakers.

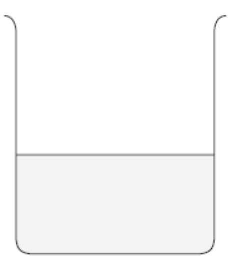
Beaker one (acid)
The solution would be red to start with as the pH would be 1–2. The ions present in solution would be H^+. The pH would be low as there is a high number of H^+ ions present.
As NaOH is added the solution would go orange, then yellow, then green. When the solution is orange and yellow the pH is still less than 7 as there are still more H^+ than $OH^–$ ions. When the solution becomes green the amount of $OH^–$ ions added (from the NaOH) cancel out the H^+ ions from the sulfuric acid and form water in a neutralisation reaction. At this stage the pH would be 7.
As more NaOH is added the solution then becomes blue and then purple. When the solution is blue the pH is 8 -11 as there are now more $OH^–$ ions present than H^+ ions. When it becomes purple the pH is 13 – 14 as there are now many more $OH^–$ ions present than H^+ ions.

NCEA 2012 pH and Indicators - (Part TWO)

Excellence Question

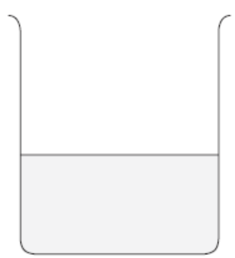
Question 3: Two beakers are shown below. Beaker one contains sulfuric acid solution and 5 drops of universal indicator.
Beaker two contains pure water and 5 drops of universal indicator.
Sodium hydroxide solution was added to both beakers until no more changes were observed.
(b) What is the colour of universal indicator in each solution at the **start**?
(c) Describe the colour changes as sodium hydroxide solution is added to each beaker, AND explain what this tells you about the changing pH of each solution.

Beaker one



Sulfuric acid + 5 drops universal indicator

Beaker two



Pure water + 5 drops universal indicator

Beaker two (water)
The solution is green initially as water contains equal numbers of H^+ and OH^- ions and is pH 7. As NaOH is added, the solution would become blue (pH 8 - 11) and then purple (pH 13 – 14). Because the water was neutral to start with, as more OH^- ions are added, the solution becomes more basic as the OH^- ions are immediately in excess.

NCEA 2013 pH and Indicators - (Part ONE)

Achieved Question

Question 2a: Potassium hydroxide (KOH) was added to a solution of sulfuric acid containing universal indicator until no further change was observed.
The experiment was repeated, but a piece of red litmus paper and a piece of blue litmus paper were each dipped into the solution after each 5 mL of potassium hydroxide was added.
The results of the experiments are shown in the table below.

Volume of KOH added (mL)	Colour of solution with universal indicator	Colour of red litmus paper	Colour of blue litmus paper
0	red	Stays red	Turns red
5	Orange-yellow	Stays red	Turns red
10	green	Stays red	Stays blue
15	blue	Turns blue	Stays blue
20	purple	Turns blue	Stays blue

Write a word equation AND a balanced symbol equation for the reaction between sulfuric acid and potassium hydroxide.

Sulfuric acid + potassium hydroxide → potassium sulfate + water

$H_2SO_4 + 2KOH \rightarrow K_2SO_4 + 2H_2O$

NCEA 2013 pH and Indicators - (Part ONE)

Achieved Question

Question 2b: Discuss what happened in this reaction as the potassium hydroxide was added to sulfuric acid.

- relate the colours of the solution observed to the acidity and pH of the solution
- explain why the different colours of the solution were produced AND link these colours to the ions present during the reaction.
- explain the advantages of using universal indicator compared to litmus paper.

As the **KOH is added, the H_2SO_4 is being neutralised until water is formed**, then after that the solution becomes more basic. When no KOH (0mL) has been added, the solution is red and has a pH of 1–2 and there is an excess of H^+ ions. As 5mL is added the solution becomes orange-yellow, the pH becomes 4–6. There is still an excess of H^+ ions but not as big an excess as when the pH was lower.

When 10 ml has been added and the solution is green, the pH is 7, which is neutral. At this point, the number of H^+ and OH^- ions is equal and they cancel each other out to form water.

After 15 mL has been added and the solution is blue, the pH is 9–12 and there is now an excess of OH^- ions. When 20 mL have been added and the solution is purple, the pH is 13–14 and there is now a greater excess of OH^- ions than when the solution was blue.

Litmus paper is useful to tell us if a solution is acidic, basic or neutral. (When blue litmus turns red and red litmus stays red, this tells us the solution is acidic. When both blue and red litmus papers stay the same, this tells us the solution is neutral. When red turns blue, this tells the solution is basic.) UI however tells us more information and tells us how acidic, basic a solution is or if it is neutral. Litmus is limited as it only tells us if it is acid, basic, or neutral whereas UI tells us how acidic or basic it is.

NCEA 2014 pH and Indicators

Achieved Question

Question 3a: A student has three unlabelled beakers each containing a colourless liquid. One contains **water**, one contains a solution of baking soda (**sodium hydrogen carbonate**), and one contains white vinegar (a solution of **ethanoic acid**).
To work out which liquid is which, the student put a drop from each beaker onto a piece of blue litmus paper and a piece of red litmus paper. She then added universal indicator to each beaker. The following results were obtained below.
Complete the last column of the table above to identify the three liquids.

	Colour of blue litmus paper	Colour of red litmus paper	Colour with universal indicator	Name of liquid
Beaker 1	stays blue	stays red	turns green	Beaker 1 = water
Beaker 2	turns red	stays red	turns orange	Beaker 2 = vinegar
Beaker 3	stays blue	turns blue	turns blue	Beaker 3 = baking soda

NCEA 2014 pH and Indicators

Excellence Question

Question 3b: Use the information in the table to show how each of the liquids can be identified.

	Colour of blue litmus paper	Colour of red litmus paper	Colour with universal indicator	Name of liquid
Beaker 1	stays blue	stays red	turns green	Beaker 1 = water
Beaker 2	turns red	stays red	turns orange	Beaker 2 = vinegar
Beaker 3	stays blue	turns blue	turns blue	Beaker 3 = baking soda

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In your answer you should:

- use all of the observations for each beaker
- state the approximate pH from the colour of the universal indicator.

Beaker 1 = water

The green colour of the universal indicator indicates that this solution has a pH of 7 and therefore is neutral. The fact that both litmus papers stay the same colour also indicates that the liquid is neutral and has a pH of seven, and therefore Beaker 1 must be water.

Beaker 2 = vinegar

The orange colour of the universal indicator indicates that the solution is acidic and has a pH of 4–5. Because the blue litmus turns red, this also indicates that the solution is acidic, and therefore Beaker 2 must be vinegar (ethanoic acid)

Beaker 3 = baking soda

The blue colour of the universal indicator indicates that the liquid is basic and has a pH of 9–10. Because the red litmus turns blue, this also indicates that the liquid is basic, and therefore Beaker 3 must be basic, as baking soda (sodium hydrogen carbonate) is basic.

NCEA 2014 pH and Indicators

Excellence Question

Question 4: A beaker contains sodium hydroxide solution and 5 drops of universal indicator. Sulfuric acid was added to the beaker until no more changes were observed.
(b) Describe how the indicator colour changes as the sulfuric acid is added to the beaker, AND explain what this tells you about the changing pH of this solution.
(c) Explain the relationship between the changing **pH** of the solution and the **ions** in the solution as the sulfuric acid is added to the beaker.

- ❑ The solution would be purple to start with, as the pH would be 13–14. The pH would be high, as there is a high number of OH^- ions present. At this stage OH^- ions are in excess when compared to H^+ ions.
- ❑ As H_2SO_4 is added, the solution would go blue. At this stage the pH would be 8–12 and OH^- ions are still in excess of H^+ ions, but not by as much as when the solution was purple.
- ❑ When the solution becomes green, the amount of H^+ ions added (from the H_2SO_4) cancel out the OH^- ions from the sodium hydroxide and form water in a neutralisation reaction. At this stage the pH would be 7.
- ❑ As more H_2SO_4 is added, the solution then turns yellow, then orange, and then red. When the solution is yellow or orange, the pH is 3–6 as there are now more H^+ ions present than OH^- ions.
- ❑ When it becomes red, the pH is 1–2, as there are now many more H^+ ions present than OH^- ions.

NCEA 2015 pH and Indicators

Question 3a: The chemical equation below represents the reaction between hydrochloric acid and sodium hydroxide:

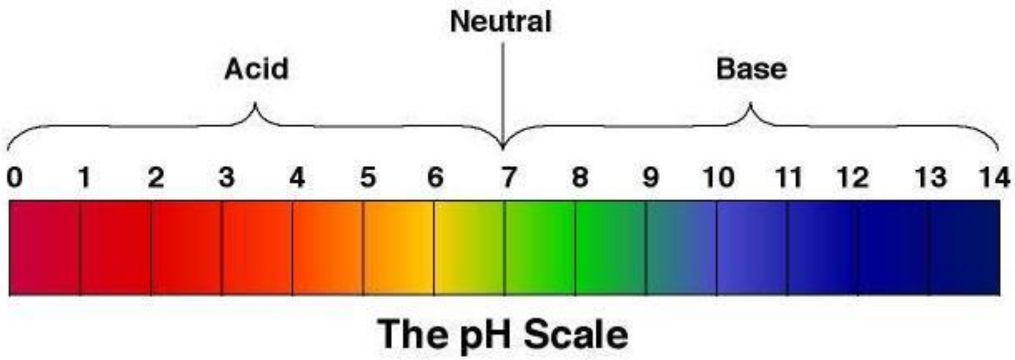
$HCl + NaOH \rightarrow NaCl + H_2O$

Complete the table below to show the approximate pH for each of the three solutions.

Answer 3a:

	Colour when UI is added	pH
HCl	red	**1 - 3**
NaOH	purple	**12 - 14**
H_2O	green	**7**

Achieved Question



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NCEA 2015 pH and Indicators - NCEA Case Study

Excellence Question

Question 3c: NaOH is gradually added to a solution of HCl with universal indicator present, until no further colour change occurs.
Discuss what is occurring in the beaker at each of the pH's shown, as the NaOH is added.
In your answer you should refer to:

- the colours that would occur at each pH
- the relative amounts of hydrogen and hydroxide present at each of the pH's shown.

pH = 1 (before any NaOH is added): pH = 4, pH = 7, pH = 10, pH = 13

NCEA 2015 pH and Indicators

Excellence Question

Question 3c: NaOH is gradually added to a solution of HCl with universal indicator present, until no further colour change occurs.
Discuss what is occurring in the beaker at each of the pH's shown, as the NaOH is added.
In your answer you should refer to:

- the colours that would occur at each pH
- the relative amounts of hydrogen and hydroxide present at each of the pH's shown.

pH = 1 (before any NaOH is added): pH = 4, pH = 7, pH = 10, pH = 13

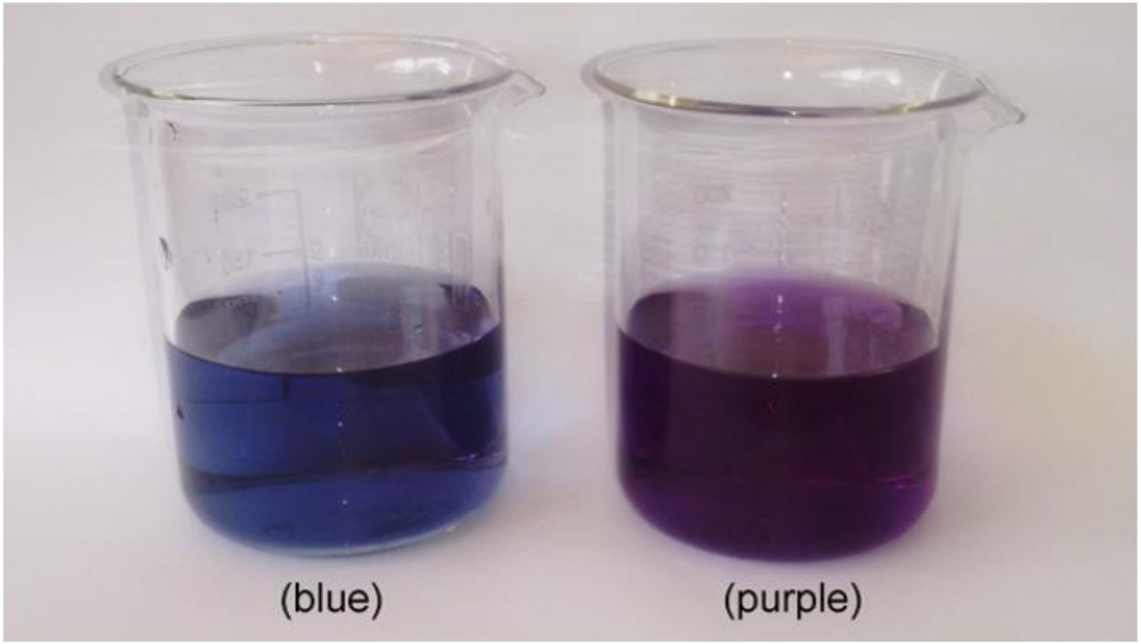
Answer 3c:
As the NaOH is added, the HCl is **being neutralised** until water is formed, then after that the solution **becomes more basic**.
When no NaOH has been added, the solution is red and has a pH of 1–2 and there is an excess of H^+ ions. The concentration of hydroxide ions is very low. At pH 4, the solution is orange–yellow and there is still an excess of H^+ ions but not as big an excess as when the pH was lower. At pH 7 the solution is green, which is neutral. At this point, the number of H^+ and OH^- ions is equal and they cancel each other out to form neutral water.
At pH 10 the solution is blue, and there is now an excess of OH^- ions. At pH 13 the solution is purple, and there is now a greater excess of OH^- ions than when the solution was blue.

NCEA 2016 pH and Indicators

Merit Question

Question 3a: A student added universal indicator to the solutions in two beakers as shown below.
Explain why the solutions are different colours.

Answer 3a:
Potassium hydroxide (KOH) has a higher hydroxide ion concentration $[OH^-]$ than potassium carbonate (K_2CO_3) and therefore has a higher pH / is more basic than K_2CO_3. Universal Indicator is purple at a pH of 12–14, whereas Universal Indicator is blue for a base with a lower pH of 8–11.



Beaker 1
Potassium carbonate

Beaker 2
Potassium hydroxide

NCEA 2016 pH and Indicators

Excellence Question

Question 3c: Explain what will happen to the indicator colour in **Beaker 2 (potassium hydroxide)** as the hydrochloric acid is added.
Relate this to the changing pH, the ions present in the beaker, and the type of reaction occurring.

Answer 3c:

- Beaker 2 is initially purple since $[OH^-]$ is much greater than [H+]; the pH is 12–14.
- As HCl is added, the H^+ start to neutralise some of the OH^-.
- As the pH decreases to 8–11, the solution turns blue and $[OH^-] > [H^+]$.
- Once enough HCl has been added such that $[OH^-] = [H^+]$, the UI turns green since all the OH^- have been neutralised by H^+ ions to form water, and the pH equals 7.
- As more HCl is added, the pH decreases to pH 3–6 since $[H^+] > [OH^-]$, so the UI turns yellow / orange.
- As more HCl is added, the pH decreases to 1–2 since $[H^+]$ becomes much greater than $[OH^-]$, so UI turns red.

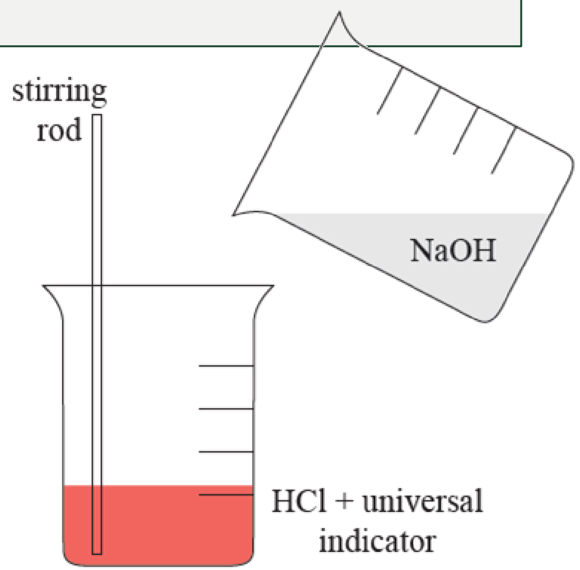
Beaker 2
Potassium hydroxide

http://www.nzqa.govt.nz

Excellence Question

NCEA 2017 pH and Indicators (Part ONE)

Question 3b: A solution of sodium hydroxide (NaOH) is slowly stirred into a beaker of hydrochloric acid (HCl) with universal indicator added. The HCl and universal indicator solution **starts out red**.
Explain the changes in the colour of the universal indicator as the sodium hydroxide solution is slowly added until no further colour changes occur.
In your answer, you should:
• relate the changes in the colour of the universal indicator to the approximate pH of the solution
• link the pH to the relative concentrations of hydrogen ions and hydroxide ions in solution
• explain the neutralisation reaction occurring.



The HCl is initially red since [H^+] is much greater than [OH^-]; the pH is 1–2. As NaOH is added, the OH^- start to neutralise some of the H+. As the pH increases to 3–6, the solution turns orange / yellow and [H^+] > [OH^-]. Once enough NaOH has been added such that [OH^-] = [H^+], the UI turns green since **all** the H^+ have been **neutralised** by the added OH^- ions to form water, and the pH equals 7.

$H^+ + OH^- \rightarrow H_2O$

Excellence Question

NCEA 2017 pH and Indicators (Part TWO)

Question 3b: A solution of sodium hydroxide (NaOH) is slowly stirred into a beaker of hydrochloric acid (HCl) with universal indicator added. The HCl and universal indicator solution **starts out red**.

Explain the changes in the colour of the universal indicator as the sodium hydroxide solution is slowly added until no further colour changes occur.

In your answer, you should:

- relate the changes in the colour of the universal indicator to the approximate pH of the solution
- link the pH to the relative concentrations of hydrogen ions and hydroxide ions in solution
- explain the neutralisation reaction occurring.

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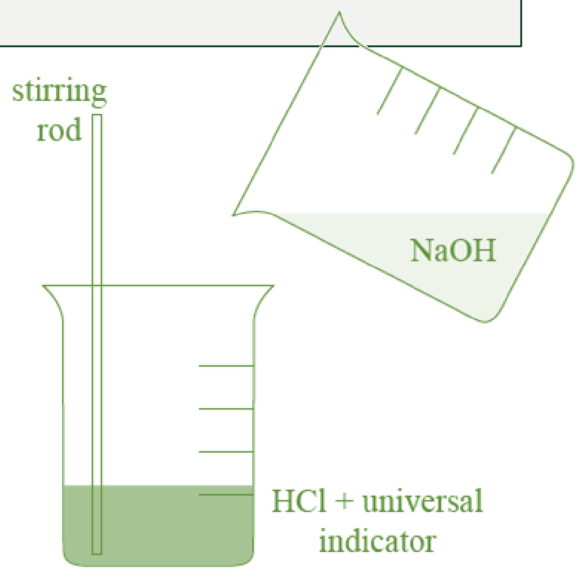
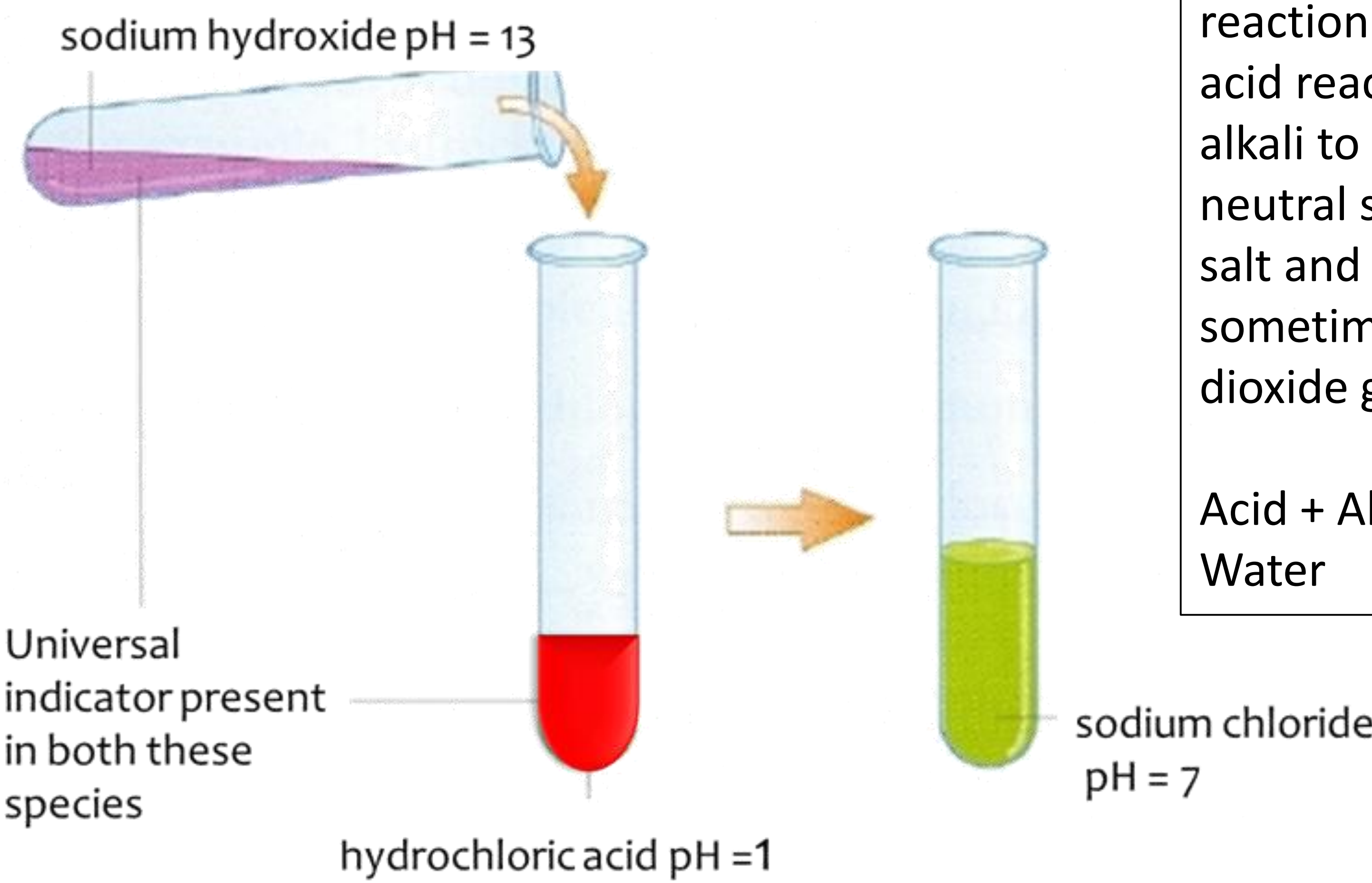
As more NaOH is added, the pH increases to pH 8–11 since $[OH^-] > [H^+]$, so the UI turns blue. As yet more NaOH is added, the pH increases to 12–14 since $[OH^-]$ becomes much greater than $[H^+]$, so UI turns purple.
[Information may be given in a table.]



During neutralisation reactions, hydrogen ions combine with hydroxide ions to form water molecules.



Neutralisation is a reaction where an acid reacts with an alkali to form a neutral solution of a salt and water. (and sometimes carbon dioxide gas)

Acid + Alkali → Salt + Water

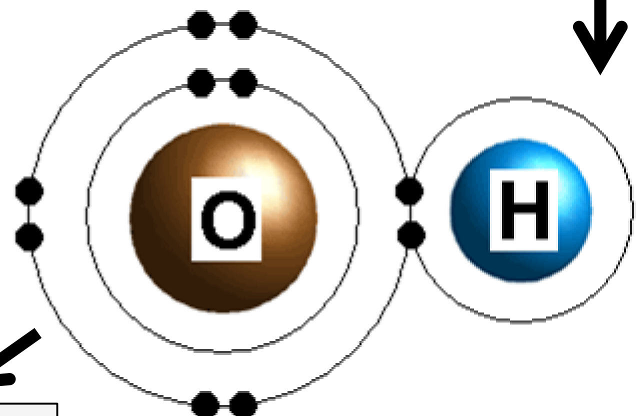
GZ Science Resources

During neutralisation reactions hydrogen ions combine with hydroxide ions to form water molecules

From an acid

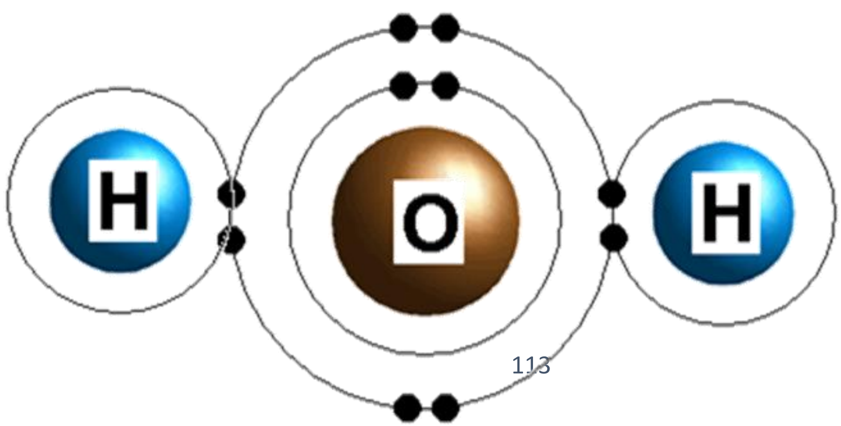
Hydrogen ion
1 proton
0 electrons
= +1 charge

From a base



Hydroxide:
9 protons
10 electrons
= -1 charge

Neutralisation



Water
10 protons
10 electrons
= 0 charge

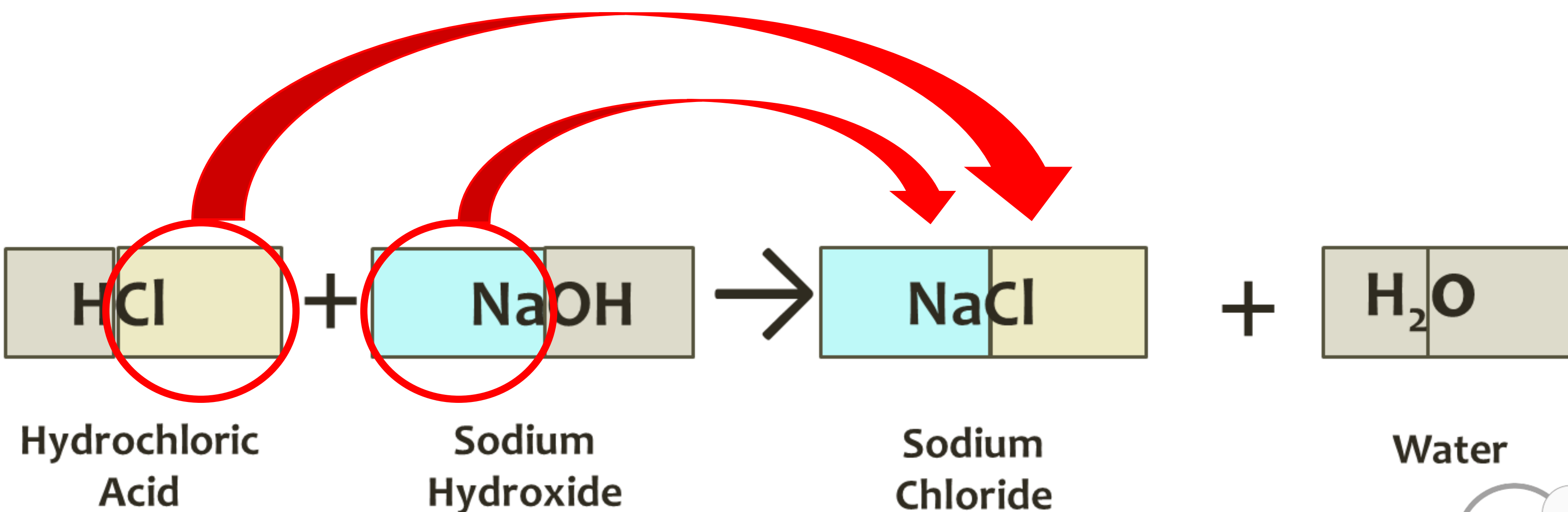
extra info

113

Names of salts

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	Formula of ion
hydrochloric acid	chloride	Cl^-
sulfuric acid	sulfate	SO_4^{2-}
nitric acid	nitrate	NO_3^-



Balanced equations for salt formation - Hydroxides

Hydroxides **neutralise** acids and a salt and water are formed

$$H^{+}\ \text{Acid} + \text{Base}\ OH^{-} \rightarrow \text{Salt} + H_2O$$

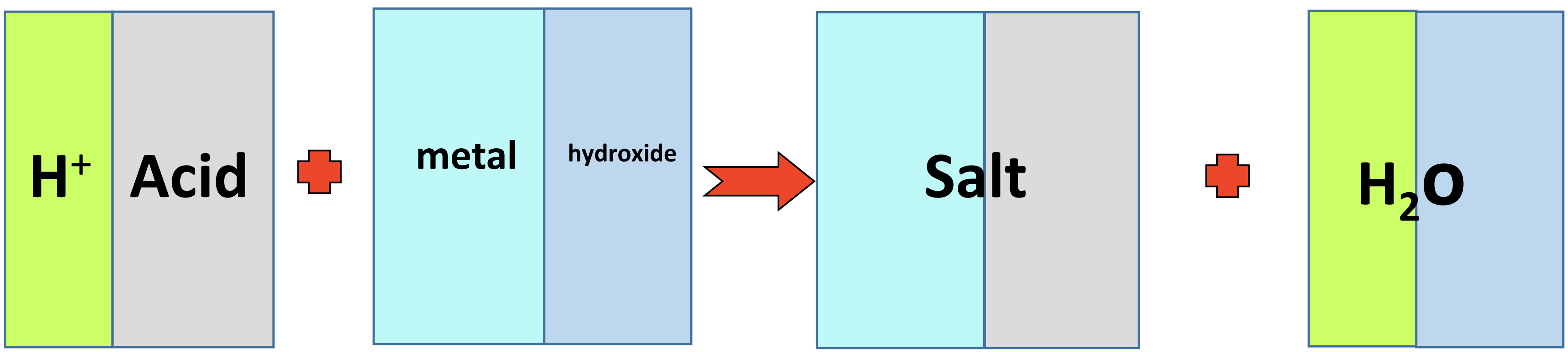
Example

$$HCl + NaOH \rightarrow NaCl + H_2O$$

Hydrochloric Acid + **Sodium Hydroxide** → **Sodium Chloride** + **Water**

Acid and Hydroxides reaction

Hydroxides **neutralise** acids and a salt and water are formed



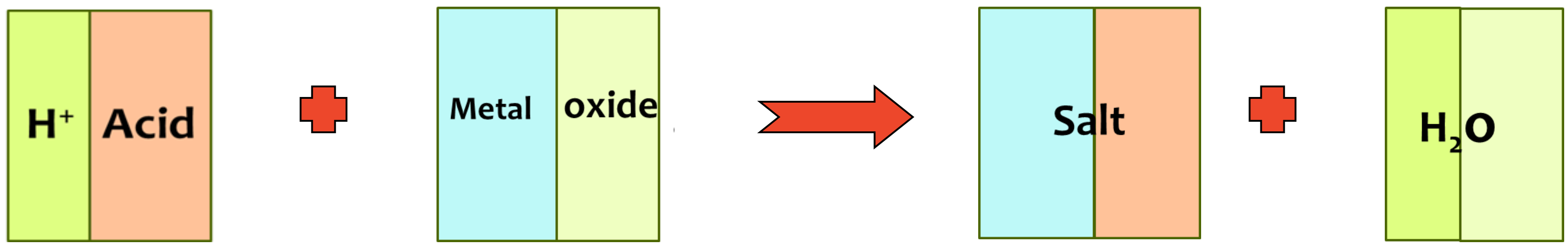
$2HCl$	+	$Cu(OH)_2$	$\rightarrow$	$CuCl_2$	+	$2H_2O$
Hydrochloric acid		copper hydroxide		copper chloride		water

Bases used in S1.5 are limited to: metal **hydroxides (MOH)** , metal **oxides (MO)**, metal **carbonates (MCO_3)** and metal **hydrogen carbonates ($MHCO_3$)**.

(M – metal)

Acid and Oxide reactions

Acids react with metals oxides in a neutralisation reaction to give a metal salt and water.



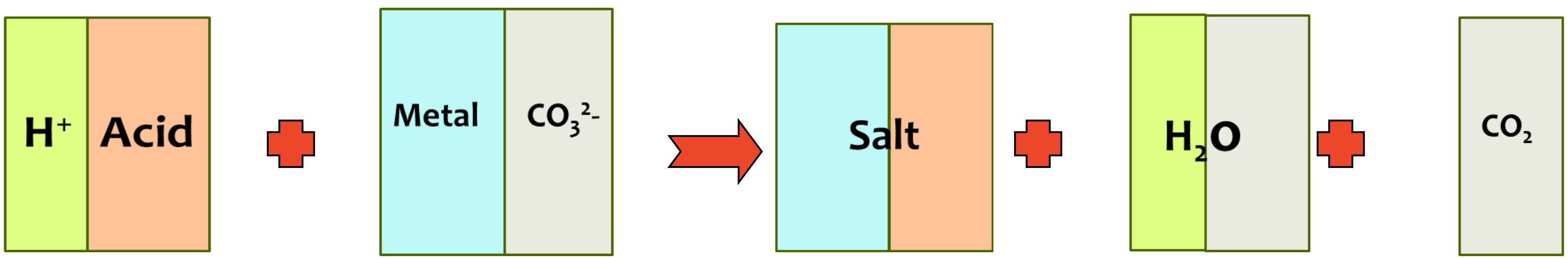
$2HCl$	+	CuO	$\rightarrow$	$CuCl_2$	+	H_2O
Hydrochloric acid		copper oxide		copper chloride		water

Note: When the above reaction takes place in a water solution the copper and the chloride ions are dissolved and exist separately in the water. Only when the water is removed by evaporation does the copper chloride salt form.

Did you know

Acid and Carbonate reactions

Acids react with Carbonates to give a salt and water and carbon dioxide.

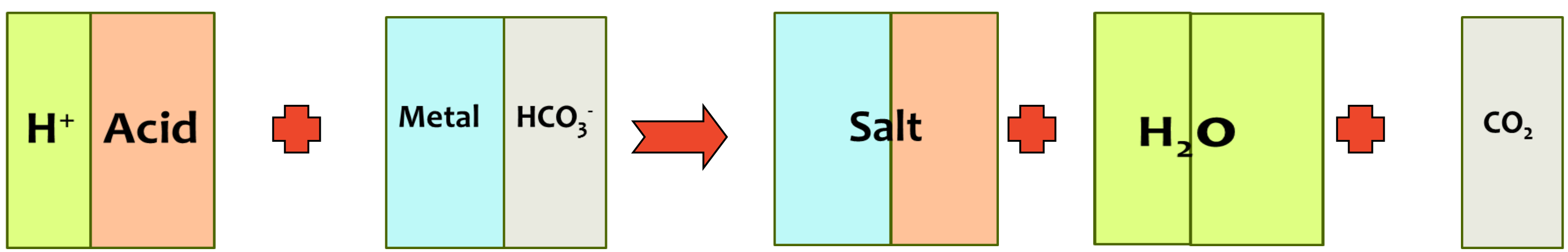


H_2SO_4	+	$CaCO_3$	$\rightarrow$	$CaSO_4$	+	H_2O	+	CO_2
sulfuric acid		calcium carbonate		calcium sulfate		water		carbon dioxide

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.

Acid and Hydrogen Carbonate reactions

Acids react with Hydrogen Carbonates to give a salt and water and carbon dioxide.



$$H_2SO_4 + 2NaHCO_3 \rightarrow Na_2SO_4 + 2H_2O + 2CO_2$$

Sulfuric Acid	sodium hydrogen carbonate	sodium sulfate	water	carbon dioxide

Hydrogen carbonate and acid also produce carbon dioxide gas that can be tested with limewater.

Acid reactions summary

1. Acid and Metal Oxide

General equation acid + metal oxide → salt + water

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

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

2. Acid and Metal Hydroxide

General equation acid + metal hydroxide → salt + water

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

Formula equation $\mathbf{2}HNO_3 + Cu(OH)_2 \rightarrow Cu(NO_3)_2 + \mathbf{2}H_2O$

3. Acid and Metal Hydrogen Carbonates

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

Word equation sulfuric acid + sodium hydrogen carbonate → sodium sulfate + water +carbon dioxide

Formula equation $H_2SO_4 + 2NaHCO_3 \rightarrow Na_2SO_4 + 2H_2O + 2CO_2$

4. 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 $\mathbf{2}HCl + MgCO_3 \rightarrow MgCl_2 + H_2O + CO_2$

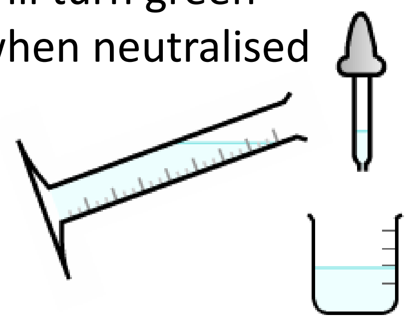
NCEA 2012 Neutralisation

Excellence Question

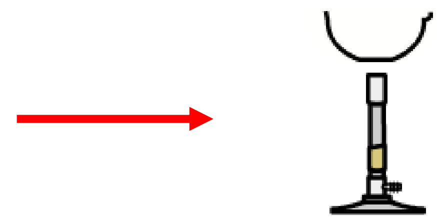
Question 2a: A student wanted to make the neutral salt, sodium nitrate. Explain how to make sodium nitrate by mixing sodium carbonate and nitric acid solutions using school laboratory equipment. Explain how litmus paper could be used during the process described to show the salt being produced is **neutral**.

How to make it
Mix the two solutions together, then take the resulting solution and put it in an evaporating dish. It could be heated using a Bunsen burner or left somewhere warm for a few days. The water would evaporate off leaving behind the neutral salt sodium nitrate.

Add universal indicator to acid and add base. UI will turn green when neutralised



Heat to remove water. The sodium nitrate will remain



Litmus paper: The solution will be neutral when red and blue litmus papers both stay the same colour. When blue paper changes to red the solution is acidic. When red paper changes to blue the solution is basic.

NCEA 2012 Acid Reactions

Question 2c: Write a word equation AND a balanced symbol equation for the reaction between sodium carbonate and nitric acid.

Achieved Question

Word equation:

nitric acid + sodium carbonate → sodium nitrate + water + carbon dioxide.

Excellence Question

Balanced symbol equation:

$$2HNO_3 + Na_2CO_3 \rightarrow 2NaNO_3 + H_2O + CO_2$$

NCEA 2012 Acid Reactions

Question 3a: Write a word equation AND a balanced symbol equation for the reaction between sulfuric acid and sodium hydroxide.

Achieved Question

Word equation:

Sulfuric acid + sodium hydroxide → sodium sulfate + water

Balanced symbol equation:

Excellence Question

$$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$$

NCEA 2013 Neutralisation- (Part ONE)

Excellence Question

Question 4b: Experiment One

A student carried out an experiment in the lab using the following method:

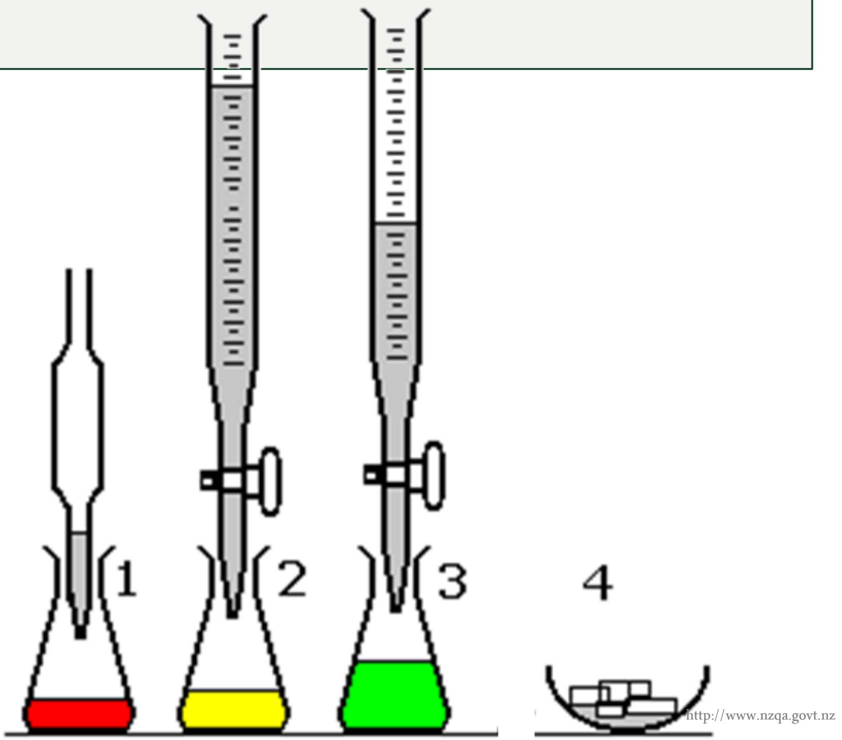
Step one: Universal indicator was added to a solution of hydrochloric acid in a beaker.

Step two/three: Calcium hydroxide was added slowly until the solution turned yellow then green.

Step four: The contents of the beaker were then poured into an evaporating dish and left in a sunny place for several days.

Explain the purpose of each step in the method and how the equipment and chemicals used achieve that purpose.

UI is used to check the pH of the solution. Calcium hydroxide is added so that it reacts with HCl to form calcium chloride. It is added until the solution is green so that the solution formed is neutral. The contents are put into an evaporating dish so that the water can evaporate to leave the salt calcium chloride. It is left for a few days to ensure that all the water has evaporated as this process takes time.



NCEA 2013 Neutralisation - (Part TWO)

Excellence Question

Experiment Two

In another experiment the following method was used:

Step one: A beaker was placed on a balance as shown in the diagram below.

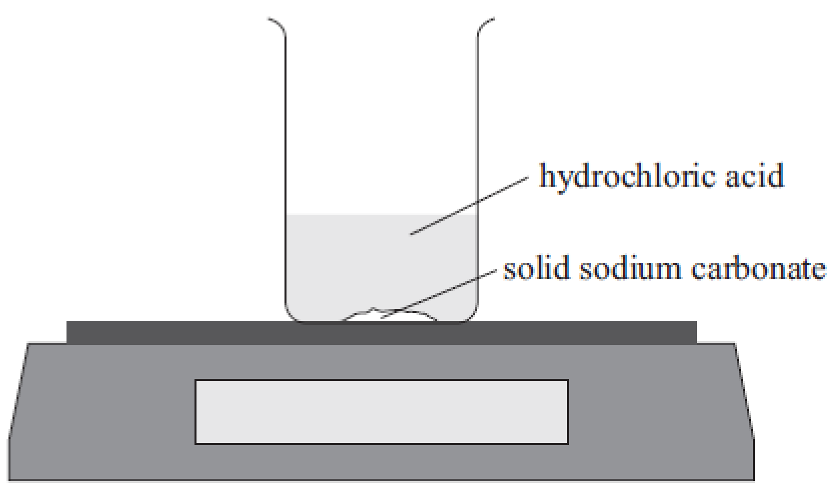
Step two: Hydrochloric acid was added to solid sodium carbonate in the beaker.

Step three: The mass was recorded over time.

Write a word equation AND a balanced symbol equation for the reaction between hydrochloric acid and sodium carbonate.

hydrochloric acid + sodium carbonate → sodium chloride + water + carbon dioxide

$$2HCl + Na_2CO_3 \rightarrow 2NaCl + H_2O + CO_2$$



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NCEA 2013 Neutralisation- (Part TWO)

Excellence Question

Experiment Two

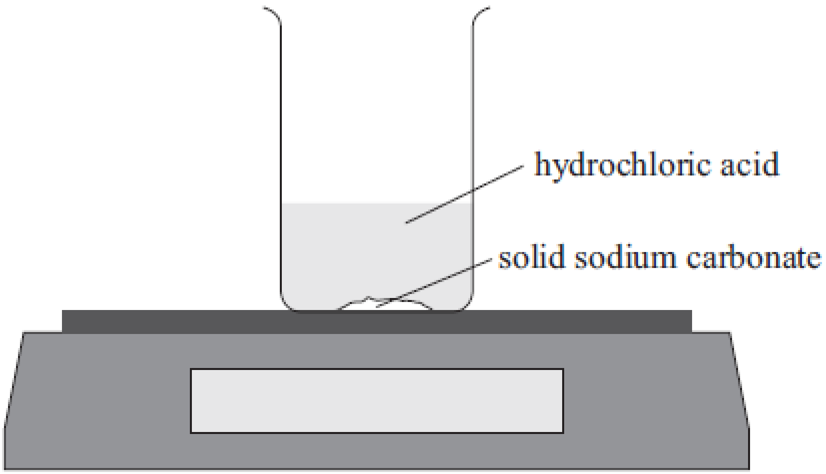
(d) Explain why the mass of the beaker and contents would decrease over time.

In your answer you should:

• state any other observations that would be made as hydrochloric acid reacts with the sodium carbonate

• explain how the products formed by the reaction lead to the decrease in mass of the beaker and contents.

Observations: Fizzing would be observed. The fizzing observed is due to carbon dioxide gas being released, and therefore because the carbon dioxide gas is leaving the beaker, there is less mass remaining in the beaker and therefore the balance measures less weight.



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NCEA 2013 Acid Reactions

Question 2a: Write a word equation AND a balanced symbol equation for the reaction between sulfuric acid and potassium hydroxide.

Achieved Question

Word equation:

Sulfuric acid + potassium hydroxide → potassium sulfate + water

Balanced symbol equation:

Excellence Question

$$H_2SO_4 + 2KOH \rightarrow K_2SO_4 + 2H_2O$$

NCEA 2014 Acid Reactions

Question 2c: Write a word equation AND a balanced symbol equation for the reaction between calcium carbonate and hydrochloric acid.

Achieved Question

Word equation:

Hydrochloric acid + calcium carbonate → calcium chloride + carbon dioxide + water.

Balanced symbol equation:

Excellence Question

$$2HCl + CaCO_3 \rightarrow CaCl_2 + CO_2 + H_2O$$

NCEA 2014 Acid Reactions

Question 4a: A beaker contains sodium hydroxide solution and 5 drops of universal indicator.
Sulfuric acid was added to the beaker until no more changes were observed.
(a) Write a word equation AND a balanced symbol equation for the reaction between sulphuric acid and sodium hydroxide.

Word equation:

Sulfuric acid + sodium hydroxide → sodium sulfate + water

Balanced symbol equation:

Excellence Question

$$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$$

NCEA 2015 Acid Reactions

Question 1c: Write a word equation AND a balanced symbol equation for the reaction between nitric acid and calcium carbonate.

Achieved Question

Word equation:

nitric acid + calcium carbonate → calcium nitrate + carbon dioxide + water

Balanced symbol equation:

Excellence Question

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

NCEA 2015 Acid Reactions

Question 3d: In a different chemical reaction, hydrochloric acid reacts with magnesium hydroxide.
Write a word equation and a balanced chemical equation for this reaction in the boxes below.

Achieved Question

Word equation:

Hydrochloric acid + magnesium hydroxide → magnesium chloride + water

Excellence Question

Balanced symbol equation:

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

NCEA 2016 Acid Reactions

Question 1d: Write a word equation AND a balanced symbol equation for the reaction between **sodium hydroxide** and **sulfuric acid**.

Achieved Question

Word equation:

sodium hydroxide + sulfuric acid → sodium sulfate + water

Excellence Question

Balanced symbol equation:

$$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$$

NCEA 2016 Acid Reactions

Question 3b: Write a word equation AND a balanced symbol equation for the reaction between **hydrochloric acid** and **potassium carbonate** in Beaker 1.

Achieved Question

Word equation:

hydrochloric acid + potassium carbonate → potassium chloride + water + carbon dioxide

Excellence Question

Balanced symbol equation:

$$2HCl + K_2CO_3 \rightarrow 2KCl + H_2O + CO_2$$

NCEA 2017 Acid Reactions

Question 1d: Write a word equation AND a balanced symbol equation for the reaction between sodium hydrogen carbonate ($NaHCO_3$) and sulfuric acid (H_2SO_4).

Achieved Question

Word equation:

sodium hydrogen carbonate + sulfuric acid → sodium sulfate + water + carbon dioxide

Balanced symbol equation:

Excellence Question

$$2NaHCO_3 + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O + 2CO_2$$

Excellence Question

NCEA 2017 Acid Reaction – identify unknowns (Part ONE)

Question 2b: Three unlabelled colourless solutions are known to be:

- nitric acid (HNO_3)
- sodium chloride ($NaCl$)
- sodium hydrogen carbonate ($NaHCO_3$).

How could each of these unlabelled solutions be identified using only **potassium carbonate (K_2CO_3)** solution, and **red litmus paper**?

In your answer you should:

- complete the table
- explain how the observations allow you to identify each solution
- include balanced symbol equation(s) for any reactions.

Unlabelled solution	Observation (if any) with red litmus paper	Observation (if any) with potassium carbonate (K_2CO_3)
Nitric acid (HNO_3)	Remain red	Bubbles of gas form/fizzes/heat
Sodium chloride ($NaCl$)	Remain red	No reaction
Sodium hydrogen carbonate ($NaHCO_3$)	Turn blue	No reaction

Excellence Question

NCEA 2017 Acid Reaction – identify unknowns (Part TWO)

Question 2b: Three unlabelled colourless solutions are known to be:

- nitric acid (HNO_3)
- sodium chloride (NaCl)
- sodium hydrogen carbonate ($NaHCO_3$).

How could each of these unlabelled solutions be identified using only **potassium carbonate (K_2CO_3)** solution, and **red litmus paper**?

In your answer you should:

- complete the table
- explain how the observations allow you to identify each solution
- include balanced symbol equation(s) for any reactions.

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Prepare a test tube each filled with a sample (5mL) of the unknown substance.
Test each sample with dampened red litmus paper.
Observations of 2 samples will be for the red litmus paper to remain red – place those 2 samples to one side.
1 of the samples will turn the red litmus paper blue. This solution can be identified as sodium hydrogen carbonate as it is a base.
With the remaining 2 samples add a small amount of potassium carbonate to both.
The sample that bubbles are observed to form will be nitric acid – as this is a neutralisation reaction between and acid and a base (the potassium carbonate) and the bubbles of gas will be carbon dioxide. (see equation below) The third test tube that does not react will be sodium chloride solution as this is neutral.

Balanced symbol equation(s):

$$2HNO_3 + K_2CO_3 \rightarrow 2KNO_3 + H_2O + CO_2$$

NCEA 2017 Acid Reactions

Question 3a: (ii) Silver oxide is a base and will react with hydrochloric acid. Write a word equation AND a balanced symbol equation for the reaction between silver oxide and hydrochloric acid.

Achieved Question

Word equation:

Silver oxide + hydrochloric acid → silver chloride + water

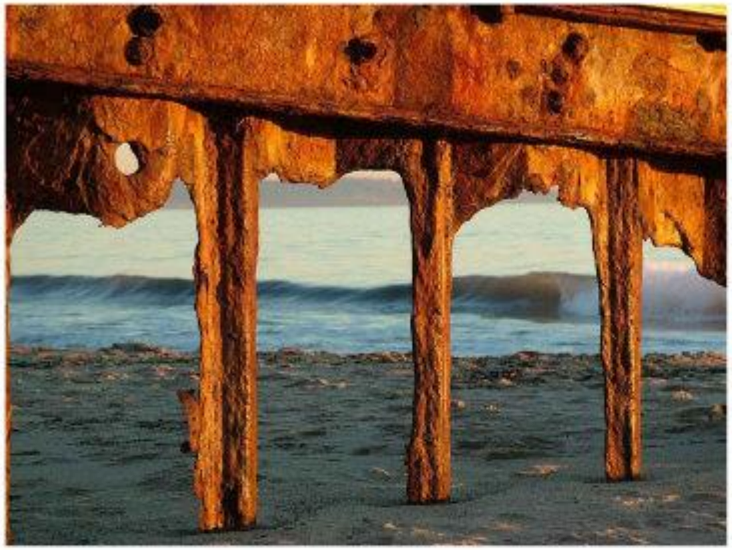
Balanced symbol equation:

Excellence Question

$$Ag_2O + 2HCl \rightarrow 2AgCl + H_2O$$

Reaction Rate

The reaction rate is the speed at which a chemical reaction occurs.
This is measured by how quickly the reactants change into products or how quickly one of the reactants disappears.
Reactions can vary in their reaction rate



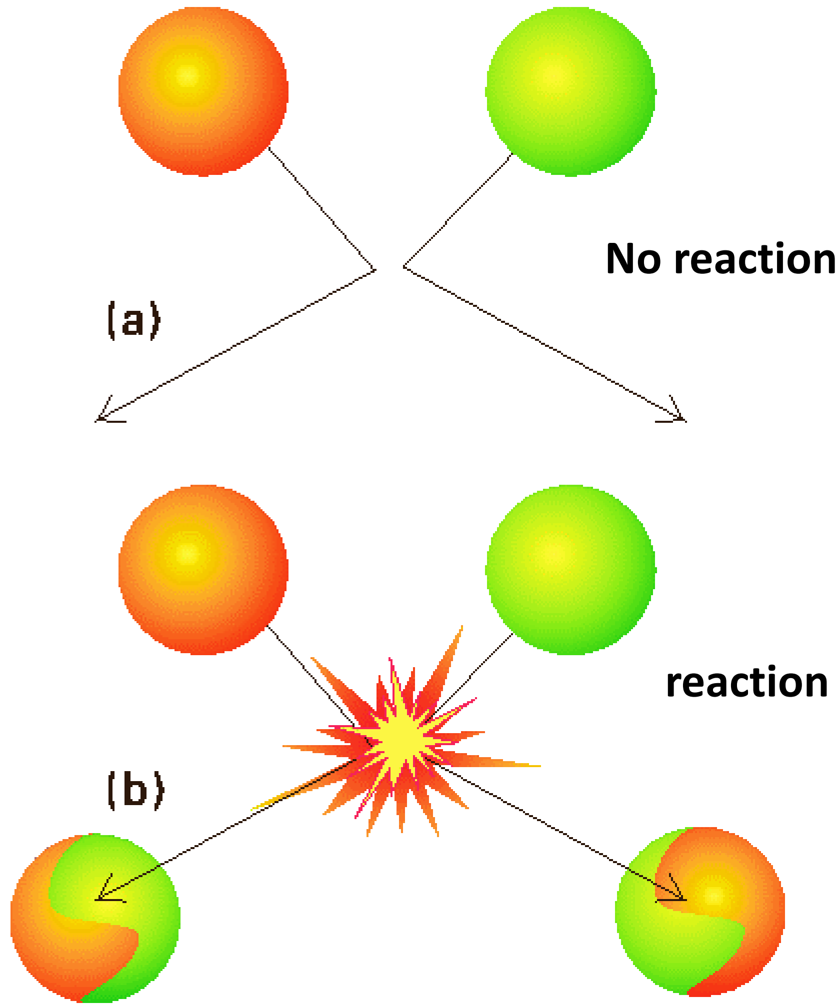
Iron oxidising

oxygen and hydrogen combusting

Collision Theory

Chemical reactions between particles of substances only occur when the following conditions have been met:

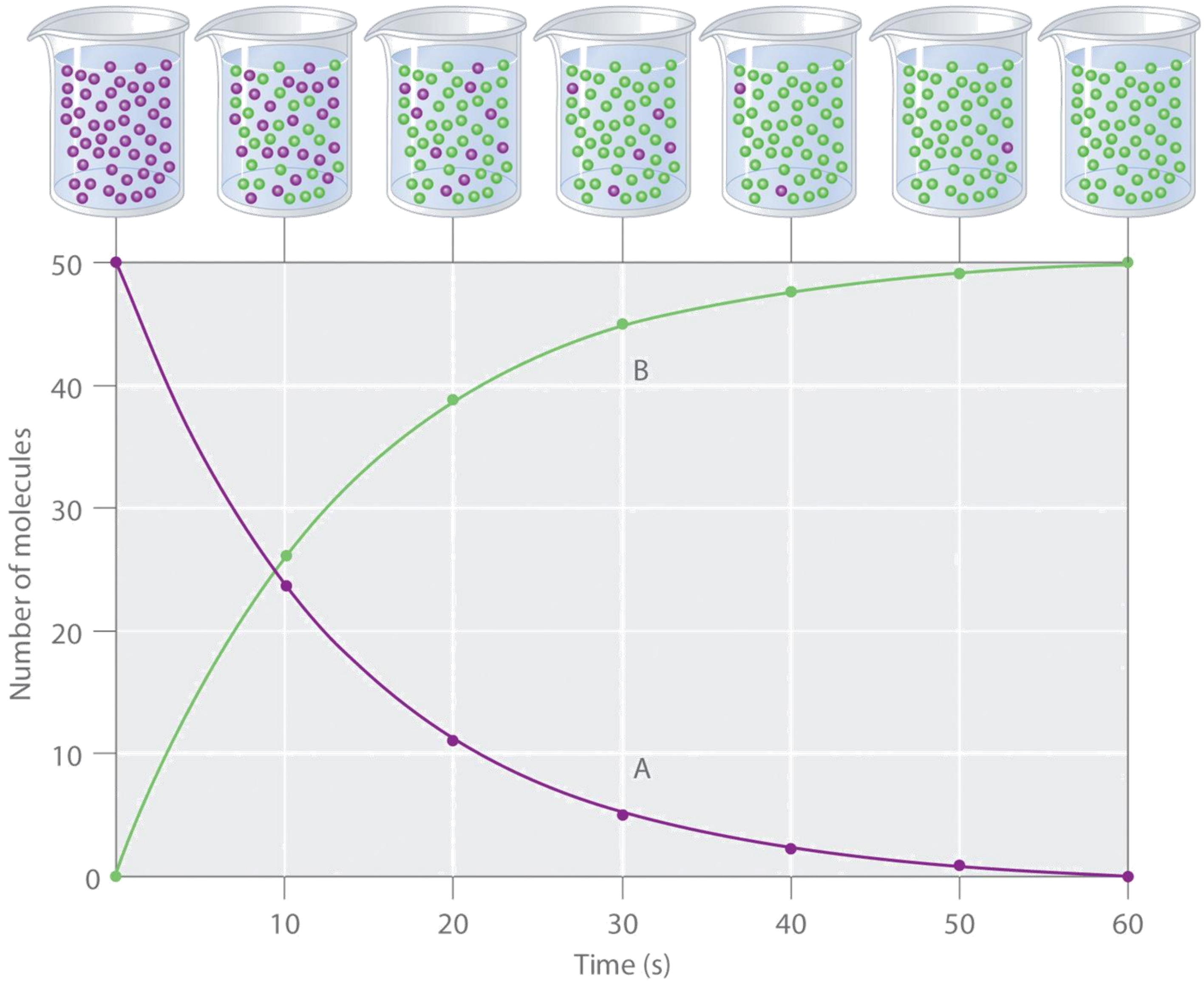
- **Particles must collide.**
- **With enough energy (called activation energy EA)**
- **And with the correct orientation**



If these conditions are met the collision will be considered **successful**. (effective)

Reactions over time

Reactions take place over time. As the amount of reactants decrease the amount of products increase. The reaction rate is shown as a curve because the amount of reactants at the start is greater and the reaction rate slows as they decrease



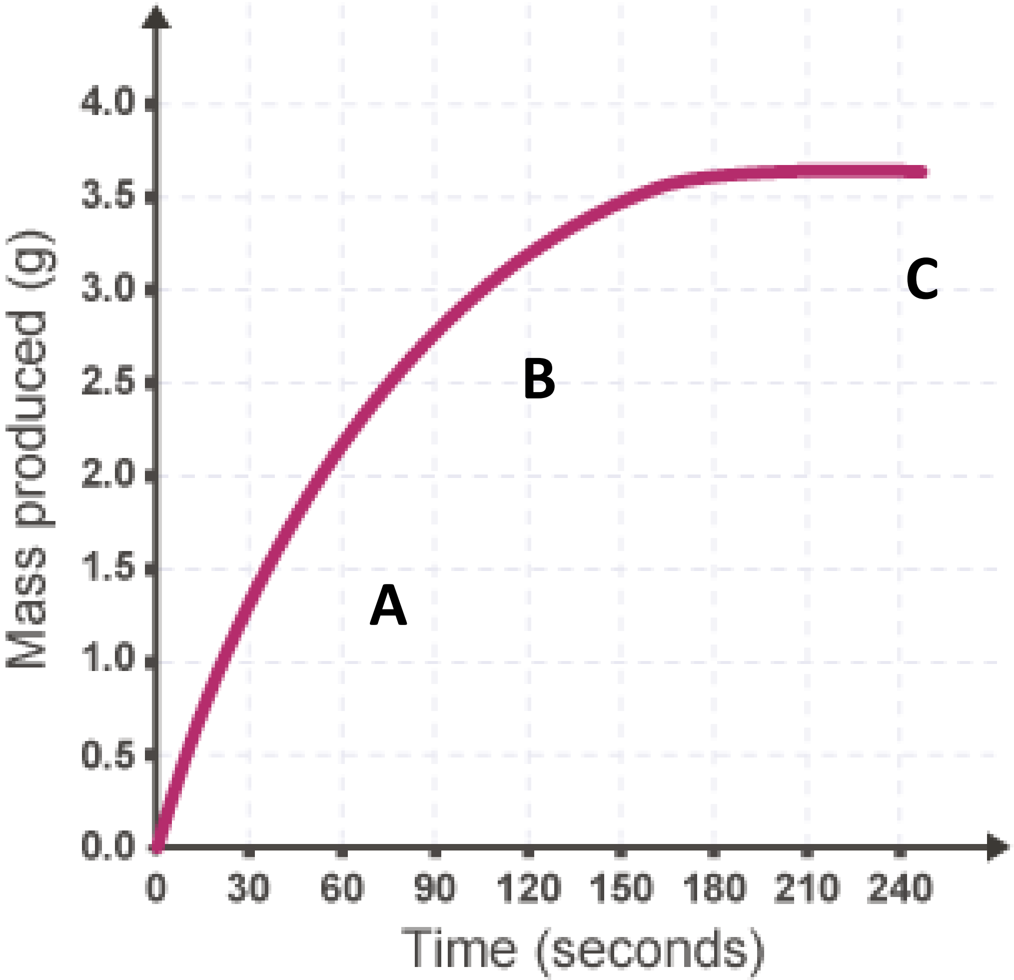
GZ Science Resources

Reaction rate is the speed at which a chemical reaction occurs

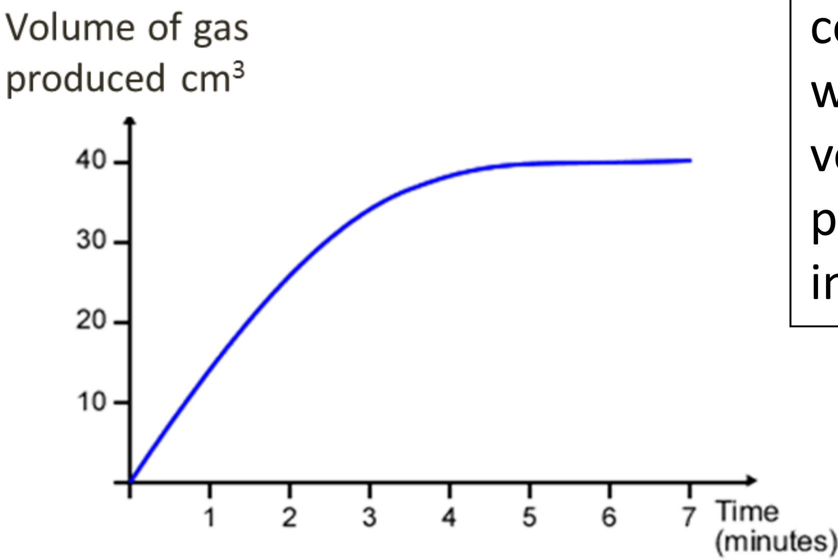
A. Reactions start out **relatively fast** because there is a much **higher concentration of reactant particles** available to collide and therefore the frequency of collisions will be high. The **gradient of the line** on the graph for products formed will be **high**.

B. As the reaction proceeds there will be **less reactant particles** available to collide as many have **already reacted to form products**. The **gradient of the line** will be **lower**.

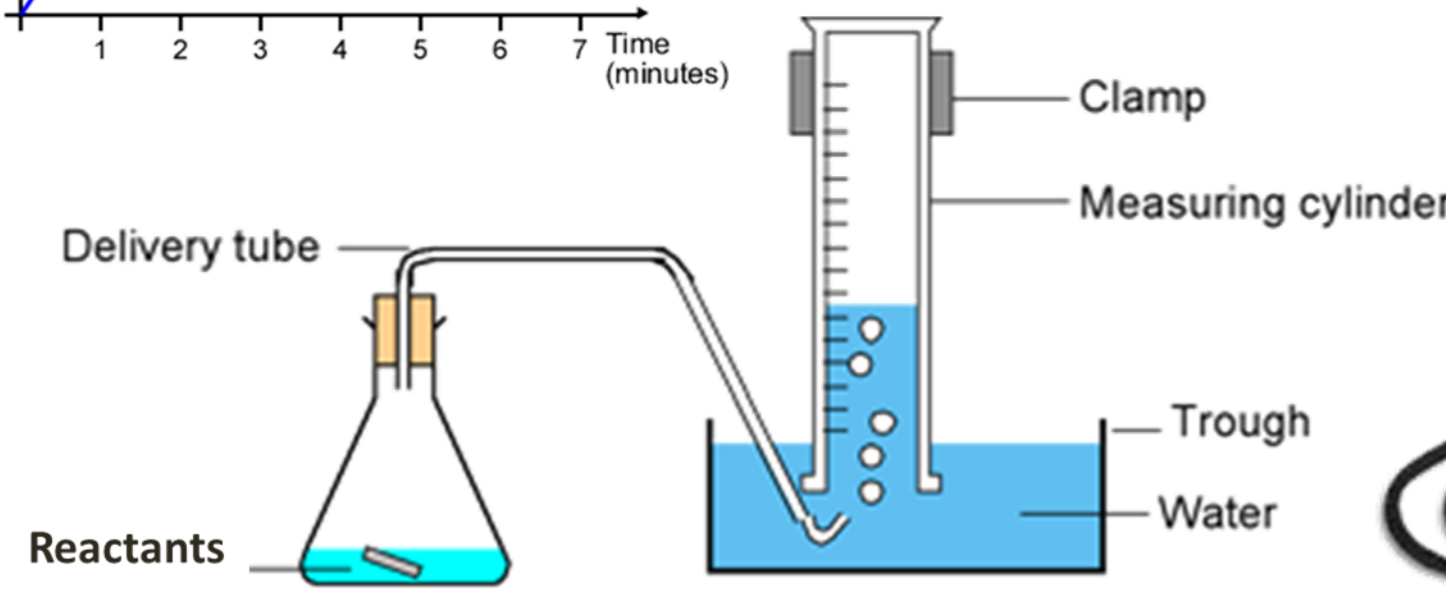
C. When the reaction has come to **completion**, when **all of the reactants have reacted** to form particles, then there will be **no further collisions** and the **gradient of the line** will be **zero**.



Measuring the rate of reaction



When gas is one of the products it can be collected in an upside down cylinder. The water displacement is a measure of the volume of gas produced. The amount produced needs to be recorded at set time intervals and then graphed.

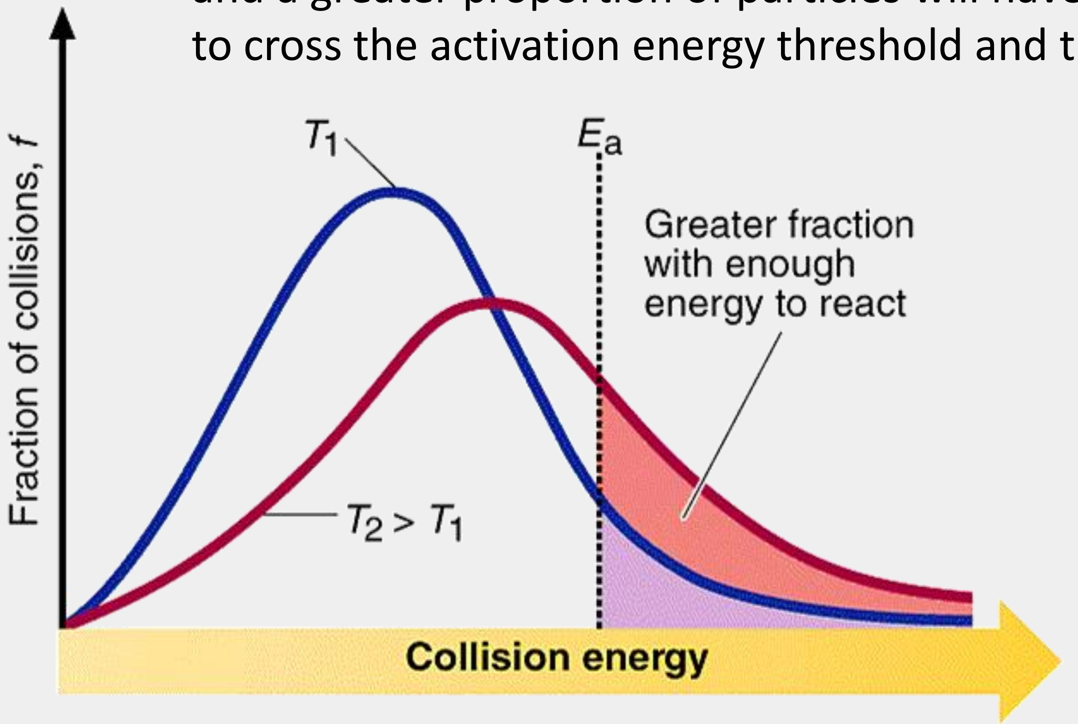


Background Knowledge

Activation Energy (E_A)

Activation energy is the initial energy required for a reaction to occur. It could be provided in the form of heat or kinetic energy.

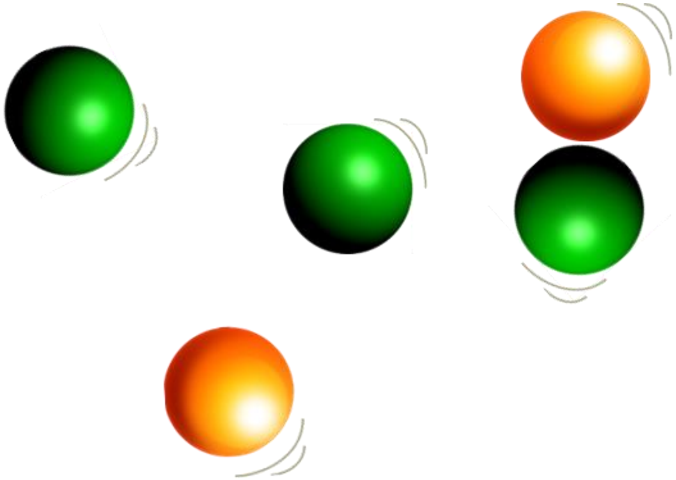
At lower temperatures (T1) most particles will have the same collision energy when they collide. As the temperature is increased (T2) the range of collision energy is more spread out and a greater proportion of particles will have enough energy to cross the activation energy threshold and therefore react.



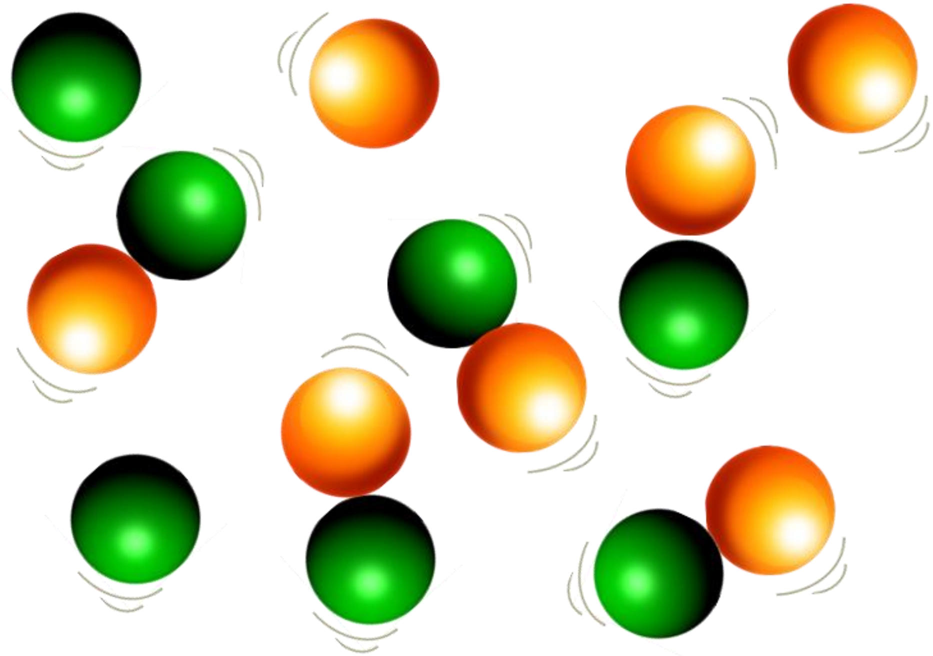
extra info

GZ Science Resources

Reaction rate can be increased by increasing the concentration



Low concentration = few collisions

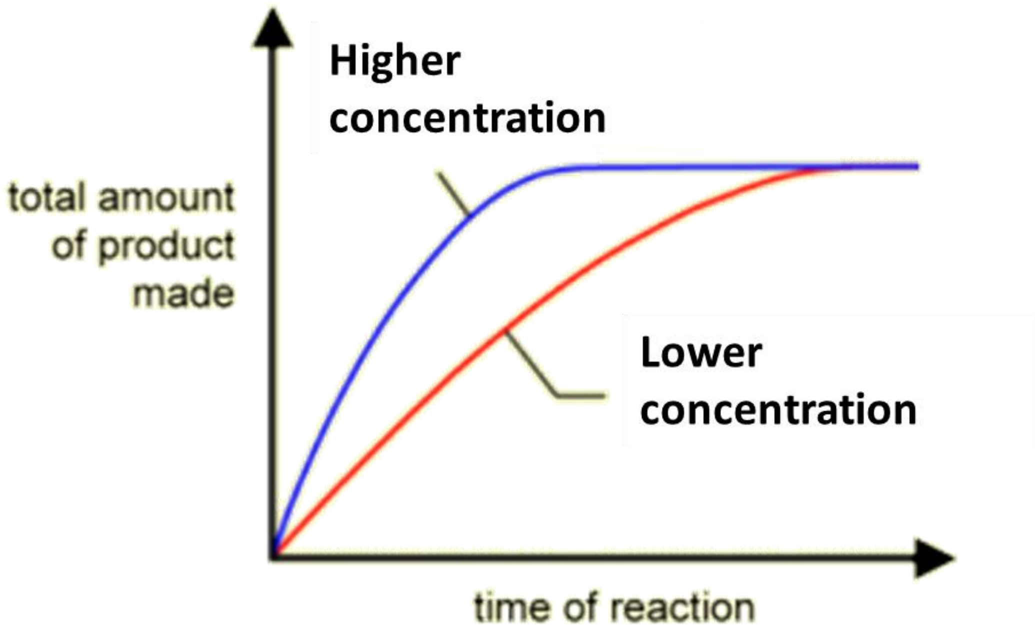


High concentration = more collisions

If there is a **higher concentration of a reactant**, there is a greater chance that particles will collide because there is less space between particles. There are **more particles per unit volume**. The **higher frequency of collisions** means there are more **successful collisions** per unit of time and this will **increase the rate of the reaction**.

If there is a lower concentration, there will be fewer collisions and the reaction rate will decrease.

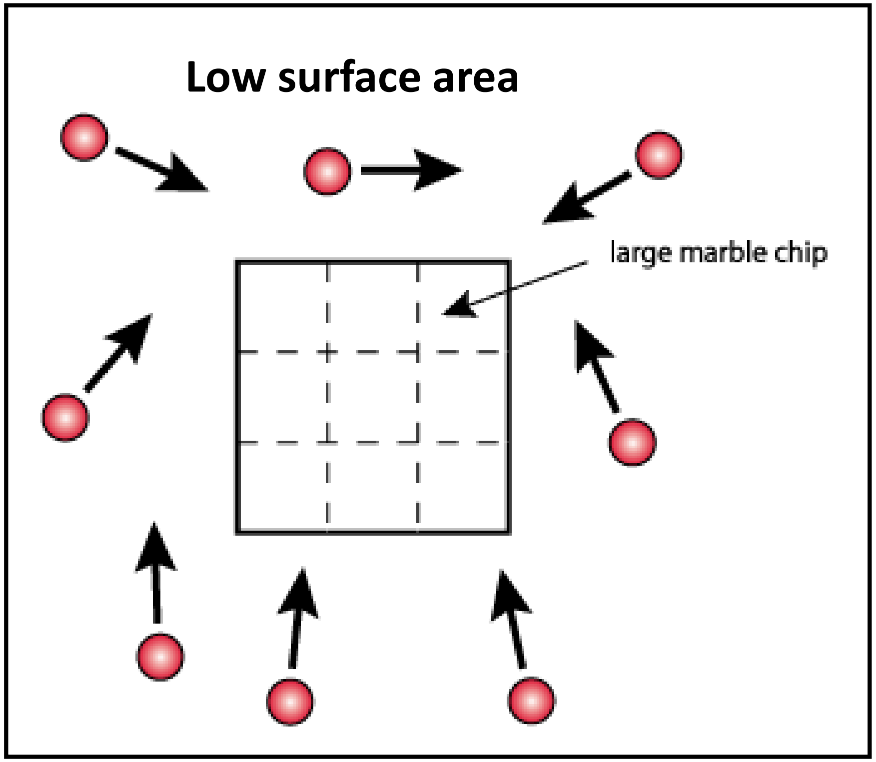
Reaction rate can be increased by increasing the concentration

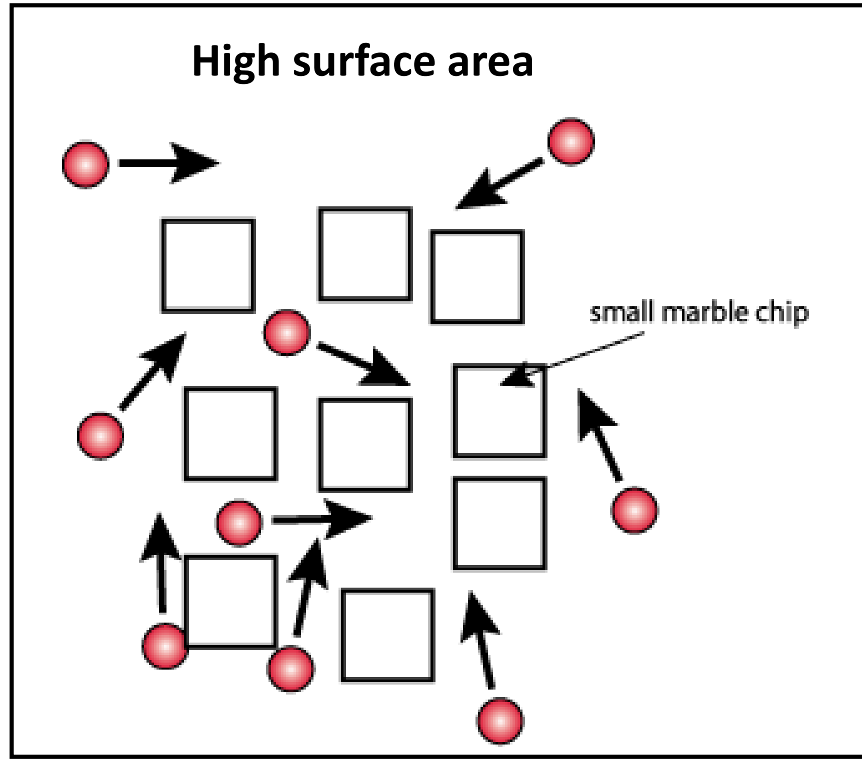


It is important to note that the total amount of product made depends upon the total amount of reactants at the start. A solution that contains only half the particles of another will require twice the volume to produce the same quantity of product.

Also, note that the **proportion of successful collisions does not change** by increasing the concentration only the frequency (amount of collisions per unit of time) of collisions is increased.

Reaction rate can be increased by increasing the Surface Area

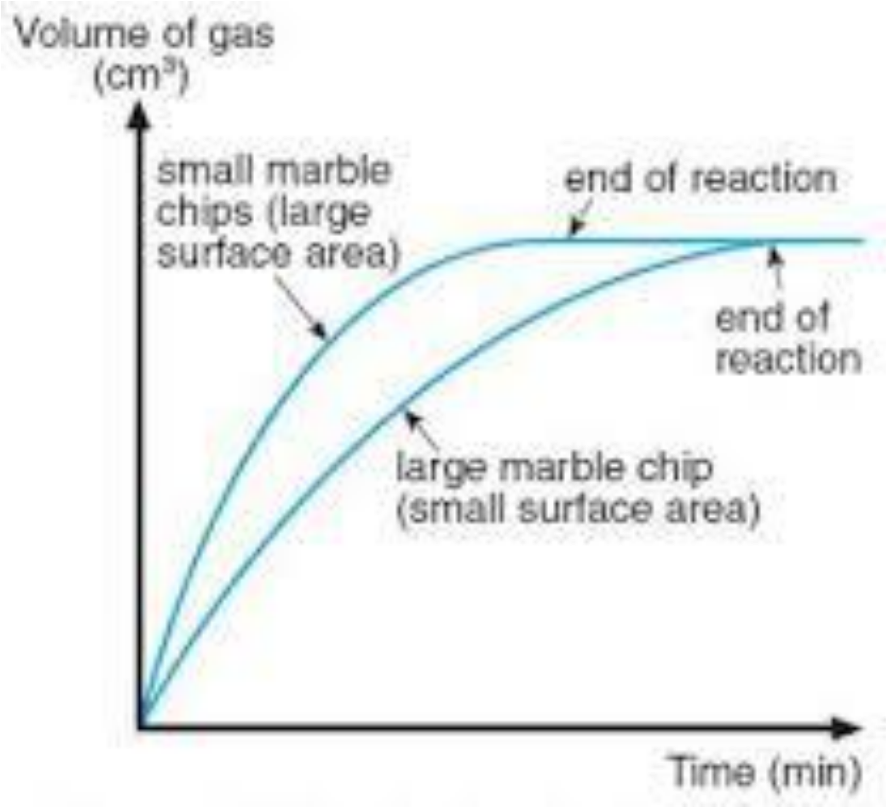




Surface area can be increased by grinding and crushing large lumps into a finer powder. The smaller the pieces the greater the surface area.

Reaction rate can be increased by increasing the surface area

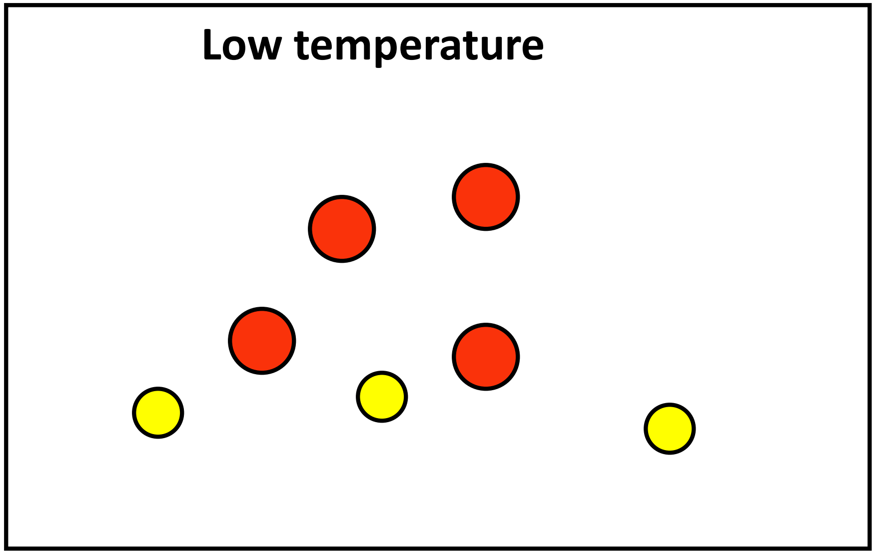
By increasing surface area, a greater number of reactant particles are exposed and therefore able to collide. The frequency of collisions (number of collisions per unit of time) will increase and therefore the number of successful collisions so the reaction rate will also increase.

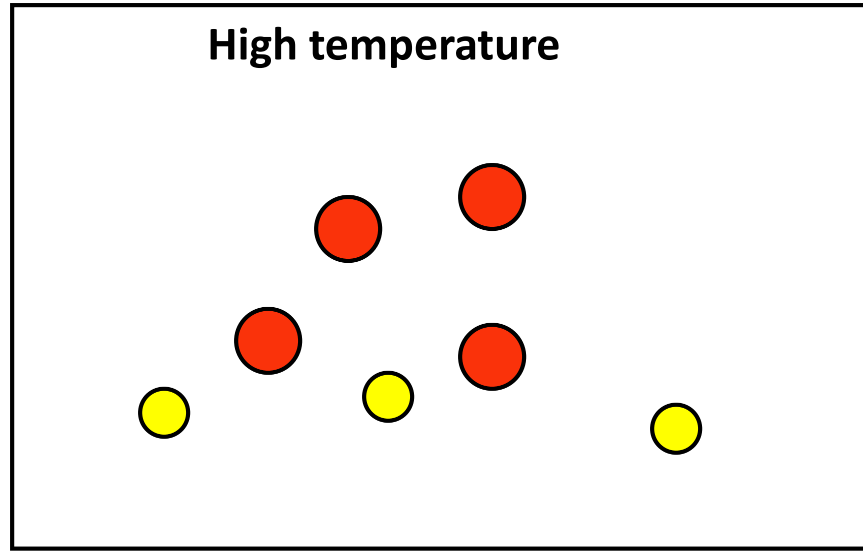


An example is comparing the reaction between marble (calcium carbonate) and hydrochloric acid to produce carbon dioxide gas.

Note: although the reaction rate is higher for the smaller marble chips the total amount of gas (CO_2) produced is the same for both reactions as they both started off with the same amount of reactants.

Reaction rate can be increased by increasing the Temperature





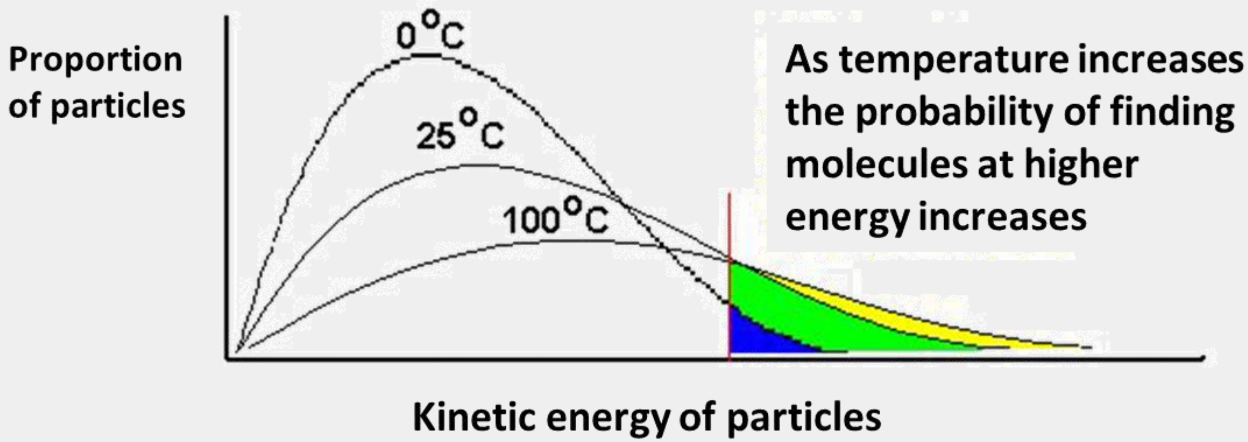
Increasing temperature effects the reaction rate in <u>two ways</u>.

Firstly when you raise the temperature of a system, the particles move around a lot more (because they have more kinetic energy). When they move around more, they are **more likely to collide and the frequency of collisions increases**, therefore the number of successful collisions increase and so reaction rate increases as well. When you lower the temperature, the molecules are slower and collide less frequently therefore the reaction rate decreases.

Secondly at a higher temperature a **larger proportion of particles have sufficient (kinetic) energy to have the energy required during a collision for it to be successful** and therefore a reaction to occur. This increases the proportion of successful collisions and therefore the reaction rate.

Background Knowledge

Reaction rate can be increased by increasing the Temperature



At any given temperature there will be a range in the kinetic energy of particles. At a lower temperature a greater proportion of particles are likely to have insufficient kinetic energy during a collision in order for a successful collision, and therefore a reaction, to take place.

Increasing the temperature also increases the probability of a successful collision.

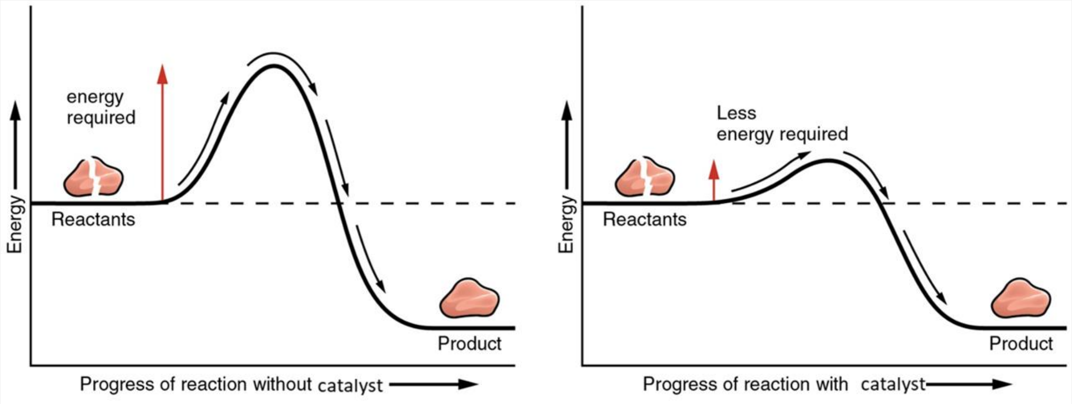
Background Knowledge

extra info

Reaction rate can be increased by using a catalyst.

A catalyst is a substance that increases the reaction rate without being used up or forming part of the products. Only some reactions have catalysts that are effective, but for many reactions there is no catalyst that works.

A catalyst lowers the minimum amount of energy required for a reaction to take place. This means that the particles can successfully collide with less energy than they required before the catalyst was added. **A greater proportion of particles will successfully collide**, and therefore the reaction rate will be increased.

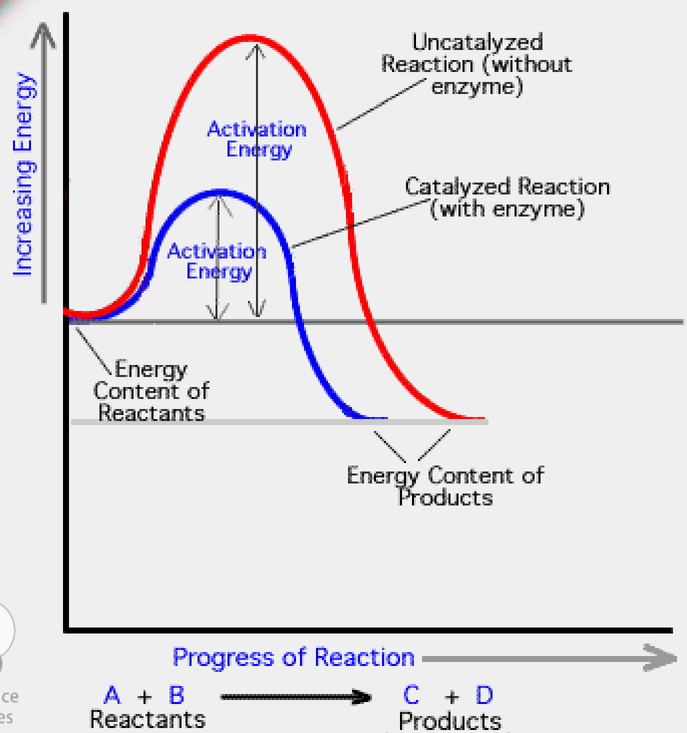


GZ Science Resources

Background Knowledge

extra info

Reaction rate can be increased by using a catalyst.



Cell metabolism consists of reactions between chemicals. Chemical reactions require an amount of energy in order for them to be successful. This energy is called activation energy.

Catalysts are substances that lower the amount of activation energy required – less energy is needed for a reaction to be successful. They are not used up in the reaction and do not form part of the product. They can be reused over and over.

Enzymes are biological catalysts.

Factors affecting Reaction Rate

extra info

<u>Increase the frequency of collisions</u>

- By **increasing surface area**: smaller pieces of reactant expose more reactant particles to collisions. Stirring will also in crease the reaction rate

- By **increasing the concentrations**: more reactant particles exist in a given volume so more collisions occur (per unit volume)

<u>Increase the energy of collisions</u>

>by **increasing temperature**: particles move faster so have more kinetic energy. More collisions will be effective (successful)

Note: increasing temp also increases frequency of collisions (collisions per unit time)

<u>Make it easier for reaction to occur</u>

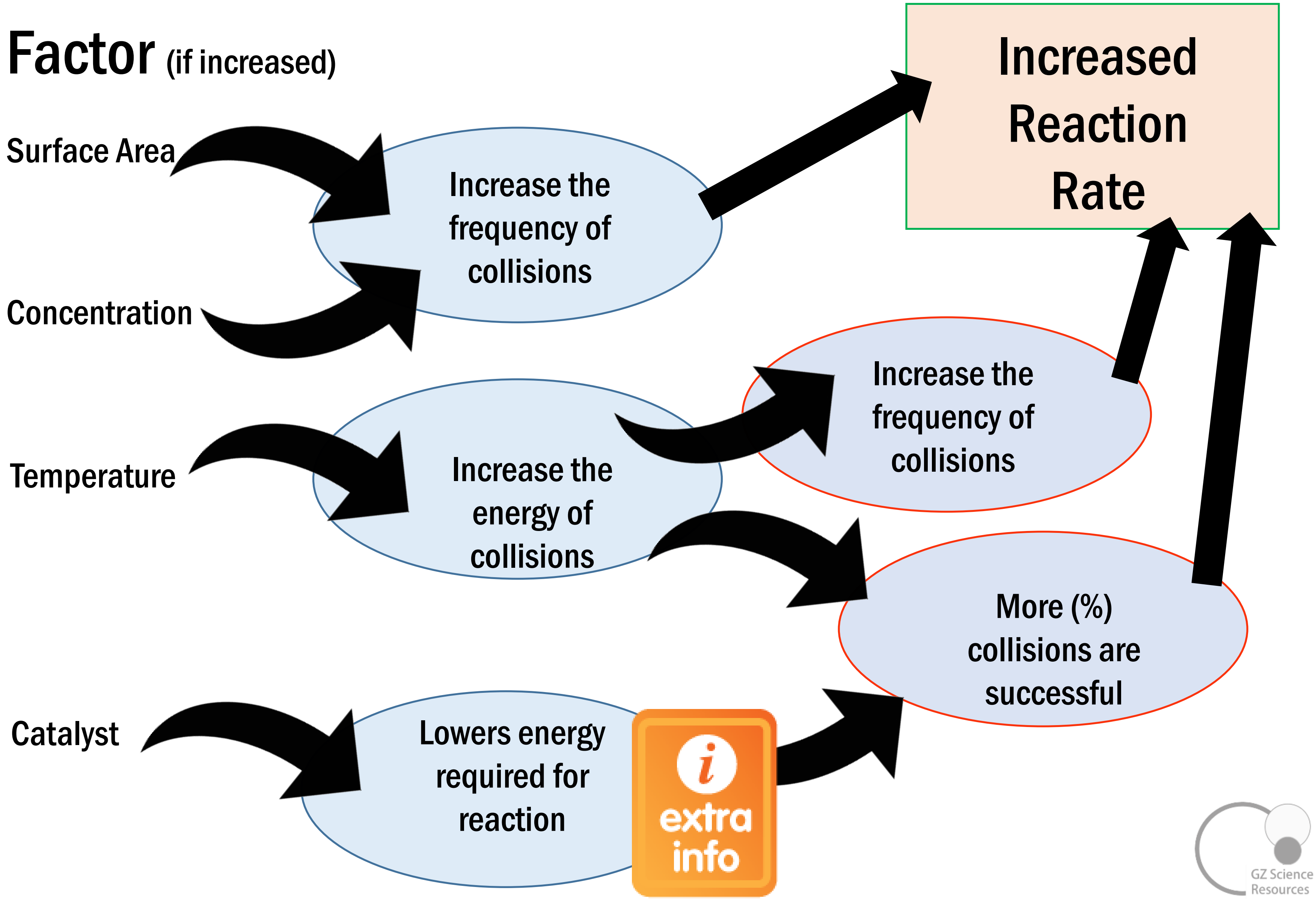
>by **using a catalyst**: allows reaction to occur with less energy so more collisions are effective (successful)

Reaction rate can also be slowed down by decreasing these

Writing Reaction rate Answers

1. Always **identify the factor involved**, ideally at the beginning of the answer: surface area, temperature, concentration or catalyst. If you are unsure look at the remaining questions as the same factor is rarely used twice.
2. Particles need to **collide** with **sufficient kinetic energy** and in the **correct orientation** in order for an effective/successful collision to occur.
3. Increasing surface area and concentration of reactants increases the **number of collisions per unit of time** (frequency) and particles per unit volume available to react.
4. Increasing temperature increases **both** the number of collisions per unit of time **and** the average amount of kinetic energy the particles have, so more particles have sufficient energy to obtain the activation energy requirements. Discuss both effects.
5. **Link** the **increase in effective/successful collisions** to an **increase in reaction rate**.

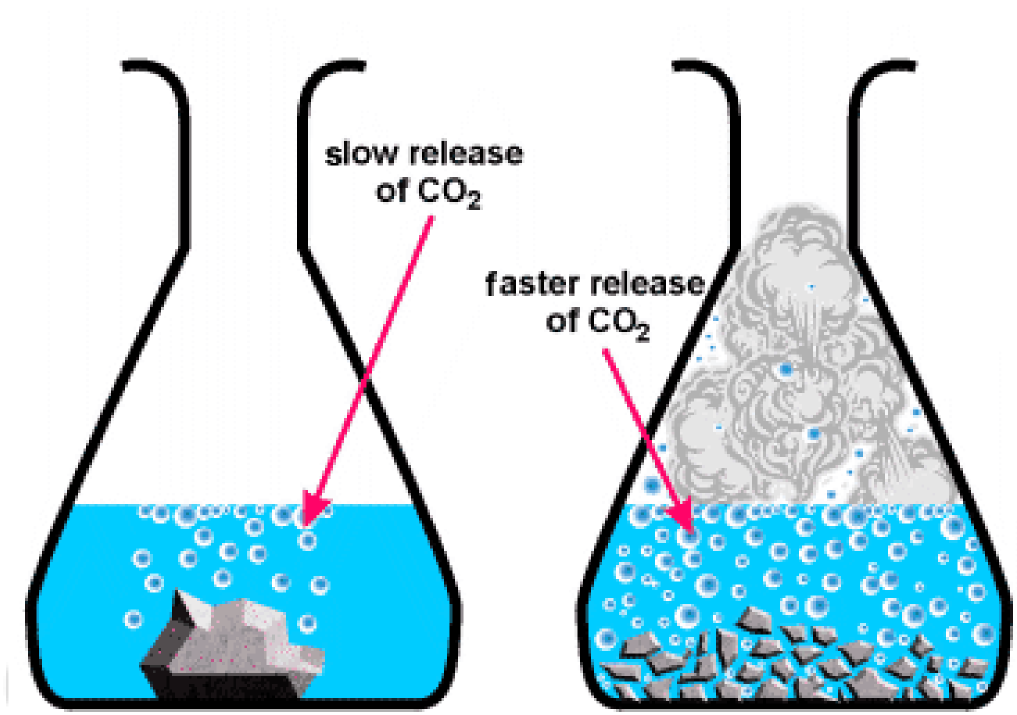
Summary of Reaction rates



NCEA Reaction rate

Hydrochloric acid was reacted with calcium carbonate in the form of marble chips (lumps) and powder (crushed marble chips) in an experiment to investigate factors affecting the rate of a chemical reaction..
Explain why the hydrochloric acid would react faster with the powder.

When the marble chips are crushed there is a **greater surface area**. This means there are now **more particles for collisions** to occur between the acid and the calcium carbonate. Because more collisions can now occur **more frequently** the **reaction rate is faster**.



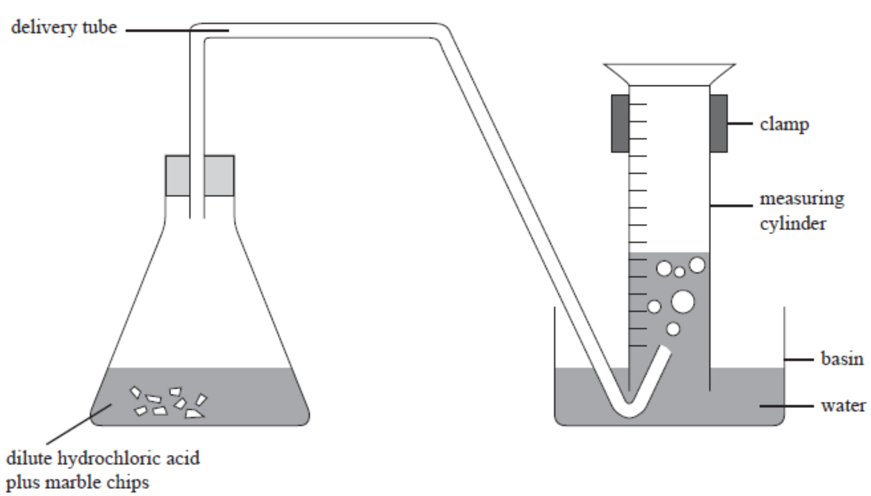
NCEA 2012 Reaction Rates – (Part One)

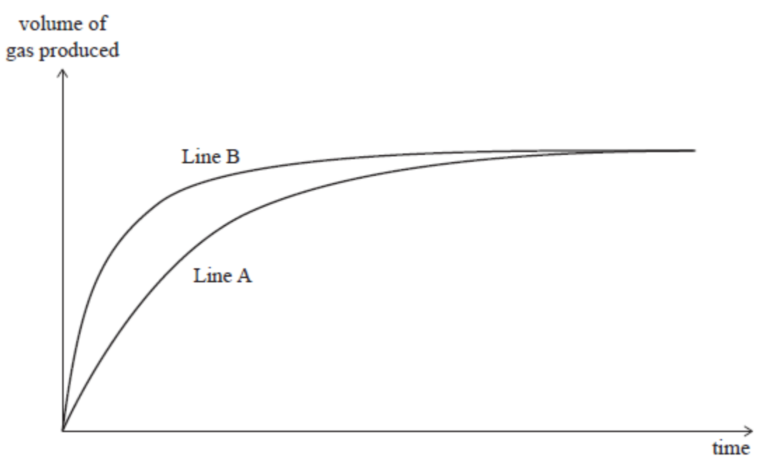
Excellence Question

Question 4a : The following experiment was carried out at **20°C** and then repeated at **40°C**.

Marble chips (calcium carbonate) were added to hydrochloric acid in a conical flask. The mass and size of marble chips, and the concentration and volume of hydrochloric acid used, were the **same** for both experiments. The flask was connected to an inverted measuring cylinder in a basin of water, as shown in the diagram below.

The volume of gas produced at the two different temperatures was measured for a few minutes and the results were used to sketch the graph shown below.





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NCEA 2012 Reaction Rates – (Part One)

Excellence Question

Question 4a : State which line on the graph represents the reaction at **40ºC** and explain how you worked this out.
In your answer you should:
- identify which line represents the reaction at 40°C
- explain why the line you have identified is the reaction at 40°C
- give reasons for the different rates of reaction in terms of particles
- explain why both lines end up horizontal.

The reaction is faster at the higher temperature, because the H^+ ions have more kinetic energy, and therefore are moving faster. When they are moving faster, there will be more collisions per unit time (higher frequency), and more of these collisions will be effective, as the particles will collide with more energy.
Line B represents the faster reaction, as it is steeper at the start. This represents the reaction carried out at 40°C.
Both lines become horizontal at the same point on the Y-axis, as this is when both reactions have finished, ie one of the reactants has been completely used up and therefore no more gas is produced. Both finished with same amount of gas produced, as both reactions had the same amount of reactants to start with.

NCEA 2013 Reaction Rates – (Part One)

Excellence Question

Question 3a : The table below shows the size of marble chips (calcium carbonate) used in a chemical investigation into factors affecting rate of reaction.

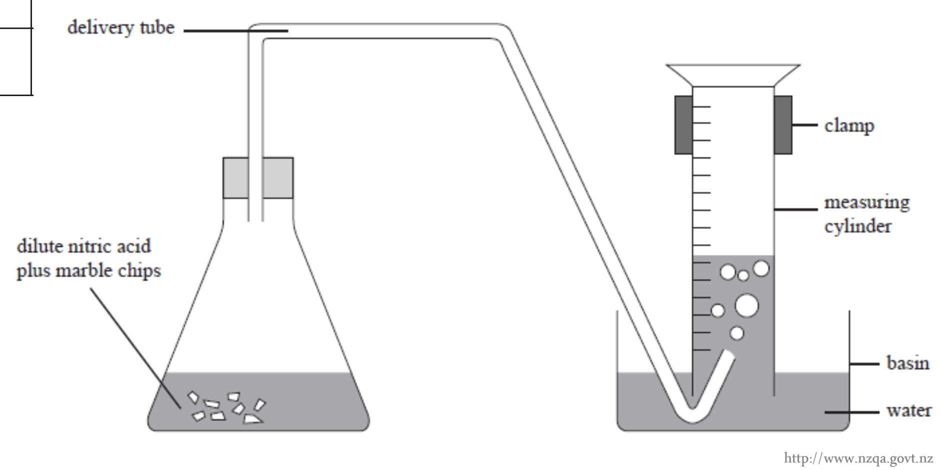
Experiment 1: 10 mL of hydrochloric acid was added to a boiling tube containing small marble chips.

Experiment 2: 10 mL of hydrochloric acid of the same concentration as in Experiment 1 was added to another boiling tube containing large marble chips.

In both experiments the total mass of the marble chips was the same.

The boiling tubes were connected to an inverted measuring cylinder in a basin of water, as shown in the diagram below.

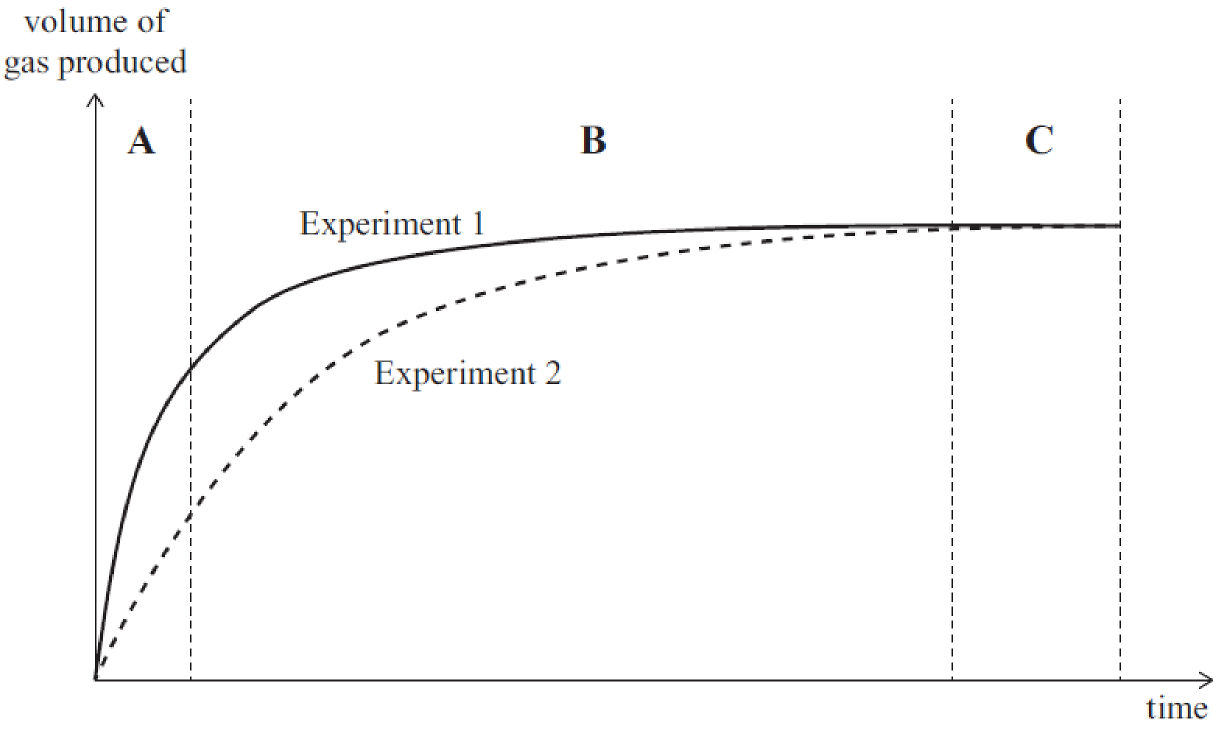
Experiment	Size of marble chips (calcium carbonate)
Experiment 1	small marble chips
Experiment 2	large marble chips



NCEA 2013 Reaction Rates – (Part One)

Achieved Question

Question 3a : The graph below shows the results for the volume of gas produced over a period of time.
State what factor affecting the rate of reaction is being investigated in this experiment.

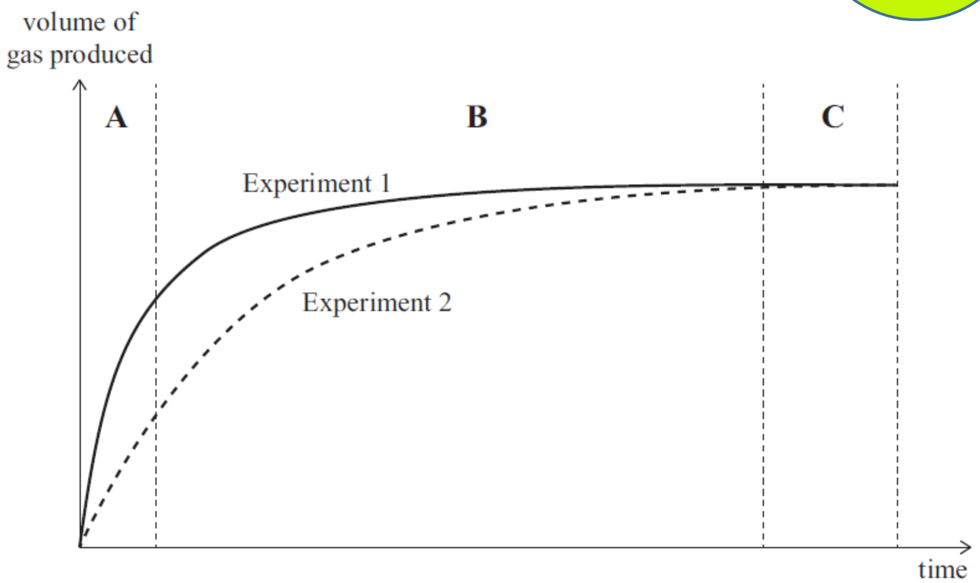


The factor being investigated is surface area of the calcium carbonate / marble chips.

NCEA 2013 Reaction Rates – (Part Two)

Excellence Question

Question 3b : Explain what is happening in **Experiment 1** in sections A, B, and C of the graph in terms of reaction rate.
In your answer you should refer to particle collisions.

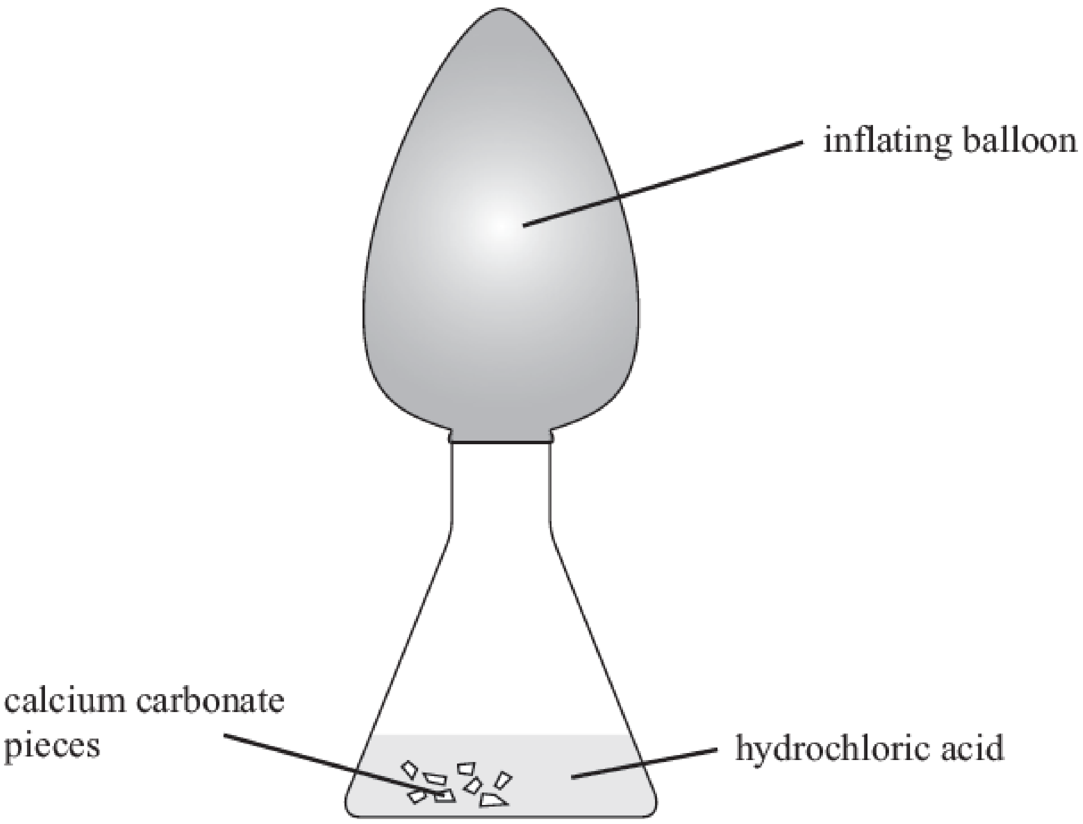


Answer 3b : In section A of the graph the rate is fastest as there are more collisions between the HCl and $CaCO_3$. This is because at the start of the reaction there are more particles available for collision. In section B the rate of reaction is slowing down as the number of particles available for collision is becoming fewer as some of the HCl and $CaCO_3$ have already collided and have been used up, therefore fewer particles and therefore fewer collisions.
In part C the reaction has stopped, as all of the reactants (or one of them) have reacted, and therefore there are no particles present that can collide and react.

NCEA 2014 Reaction Rates - (Part One)

Achieved Question

Question 2a (i) : Calcium carbonate pieces are placed in a flask and hydrochloric acid is added. Immediately a balloon is placed over the top of the flask. The balloon then starts to inflate. Explain why the balloon inflates.

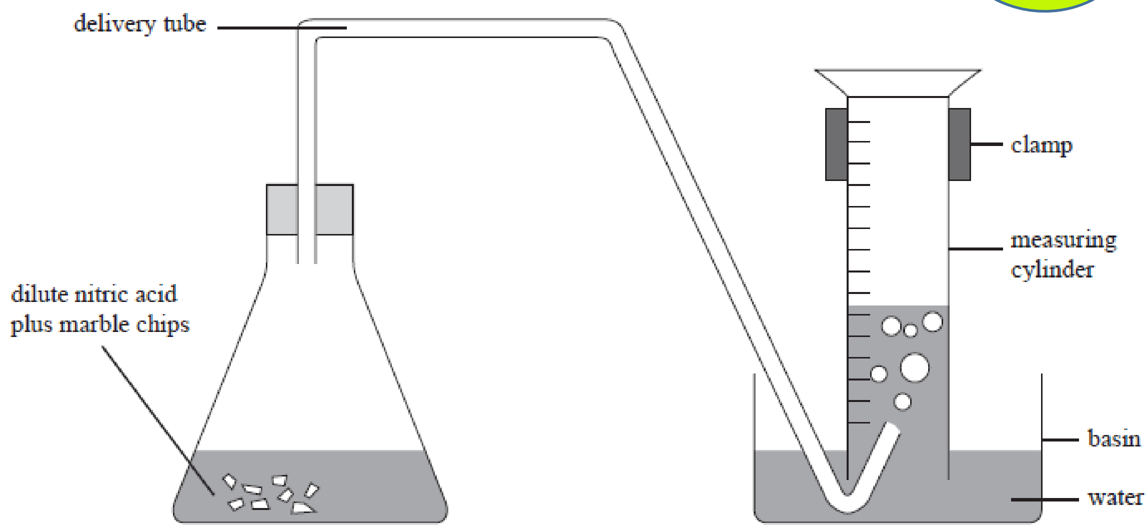


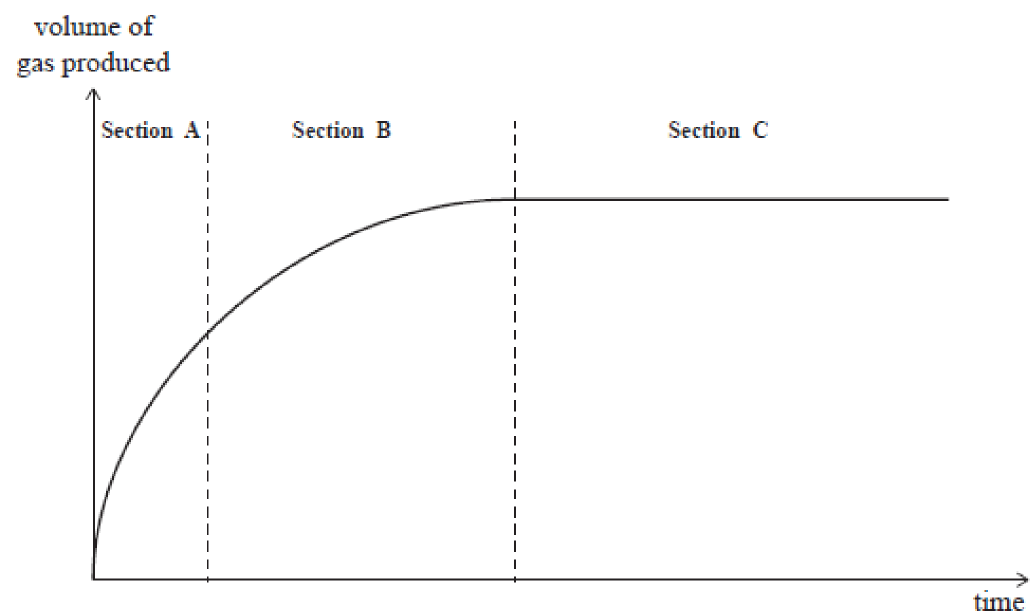
Answer 2a (i) : When a metal carbonate reacts with an acid, carbon dioxide gas is released. This gas causes the balloon to inflate.

NCEA 2015 Reaction Rates

Excellence Question

Question 1a: Marble chips (calcium carbonate) were added to nitric acid in a conical flask. The temperature of the acid was 50°C. The flask was connected to an inverted measuring cylinder in a basin of water to measure the volume of gas produced, as shown in the diagram beside. The graph beside shows the volume of gas produced against time. Explain what is happening in terms of particle collisions and rate of reaction in **each section** of the graph.





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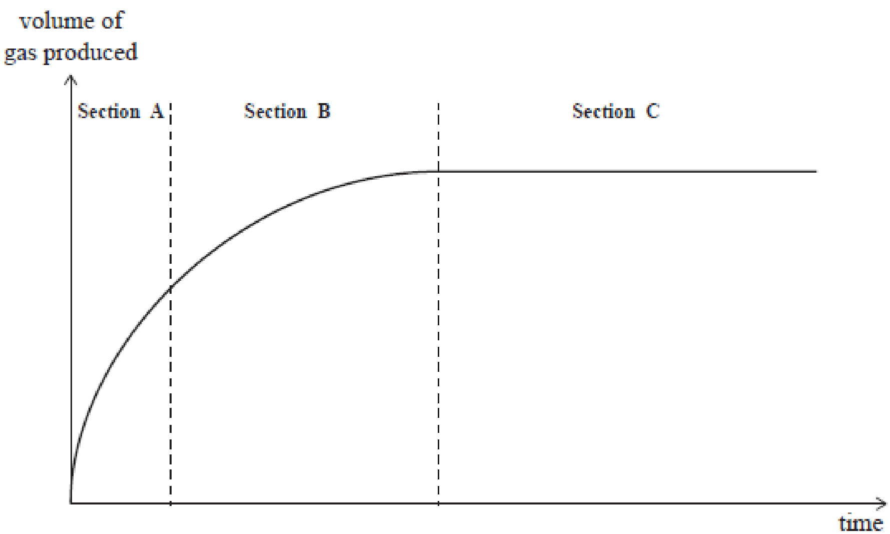
NCEA 2015 Reaction Rates

Excellence Question

Answer 1a: As the reactant particles collide, they form product particles.
As the reaction proceeds, there are fewer and fewer reactant particles left to collide, and so the rate of reaction becomes slower.
At the start (section A) of the reaction, more product particles are being formed. This is because at the start of the reaction there are many particles present; therefore there will be many collisions, and the more collisions (per unit time), the faster the rate of reaction, and the more gas produced.
In section B, there are now fewer (less) reactants, and so there are fewer collisions per second (unit time); therefore a slower rate of reaction and so less product is formed.
In section C, the reaction has stopped, as one of the reactants (marble chips or nitric acid) has run out, so there are no particles left to react.



Link in each section
Relative amount of reactants:products
Collisions per unit of time
Rate of reaction
Amount of gas produced

NCEA 2013 Reaction Rates – (Part Three)

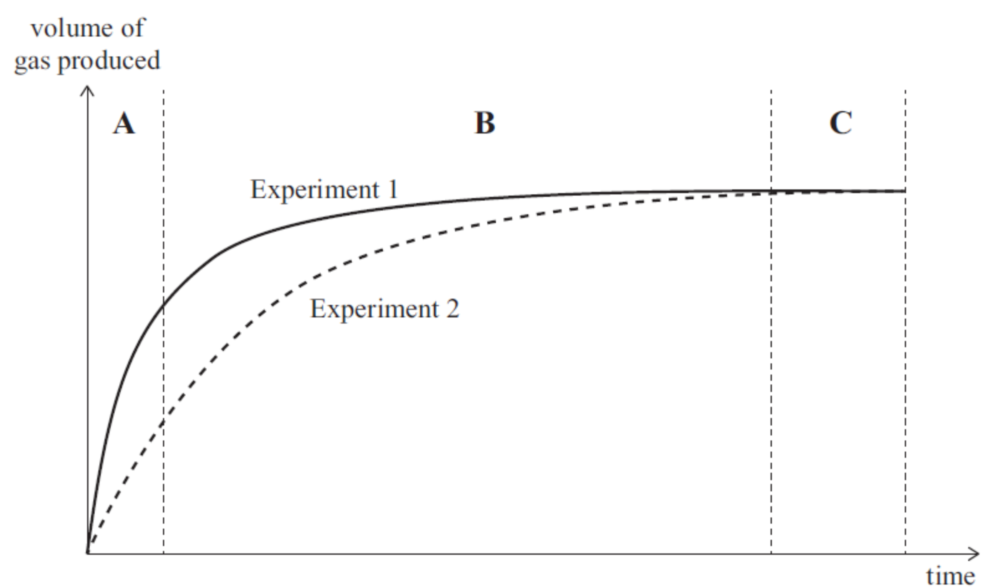
Excellence Question

Question 3c : Explain why **Experiment 1** was faster than **Experiment 2**.
In your answer you should:

- explain how the graph shows that Experiment 1 is faster
- explain how the size of the marble chips affects the number of particle collisions.

Experiment 1: small marble chips.
Experiment 2: large marble chips.

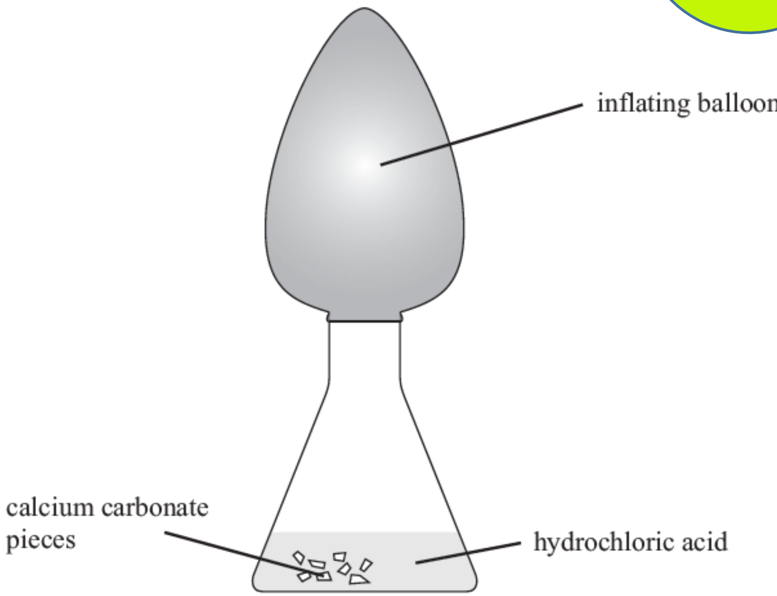
The rate of Experiment 1 is faster as the slope in section A of the graph is steeper than in Experiment 2. It is faster because when smaller chips are used, the surface area of the chips is greater. Because there is more surface area, there is more surface for the HCl particles to collide. Because there are more collisions occurring more frequently, the rate is faster.



NCEA 2014 Reaction Rate Factors - (Part Two)

Excellence Question

Question 2a (ii): In a second experiment, the same mass of calcium carbonate in a powdered form is used.
Explain why the balloon inflates faster when powdered calcium carbonate is used.



Answer 2a (ii): It is faster when powder is used, because the surface area of the powder is greater. Because there is more surface area, there is more surface with which the HCl particles can collide. Because more collisions occur more frequently, the rate is faster, and CO_2 will be generated more quickly.

Explains that when the concentration is increased, there are more particles present in the same volume and so therefore there is a greater chance of collisions occurring per unit time.

NCEA 2014 Reaction Rate Factors - (Part Three)

Excellence Question

Question 2b : Using the same chemical substances (calcium carbonate and hydrochloric acid), discuss a different way to make the balloon inflate faster.
In your answer you should refer to rates of reaction and particle collisions.

Answer 2b : One way of making the reaction occur faster is to increase the concentration of the acid used. When this happens there are more HCl particles in the same volume of acid, and therefore there is a greater chance of collisions occurring more frequently, and so the rate of reaction is faster. Because the rate is faster, CO_2 is produced more rapidly, and the balloon inflates faster.

OR

The other way is to increase the temperature of the acid. When this happens, the HCl particles move faster; because they are moving faster, there is a greater chance of collisions occurring more frequently, and so the rate of reaction is faster. Because the rate is faster, CO_2 is produced more rapidly, and the balloon inflates faster.

NCEA 2015 Reaction Rate Factors

Excellence Question

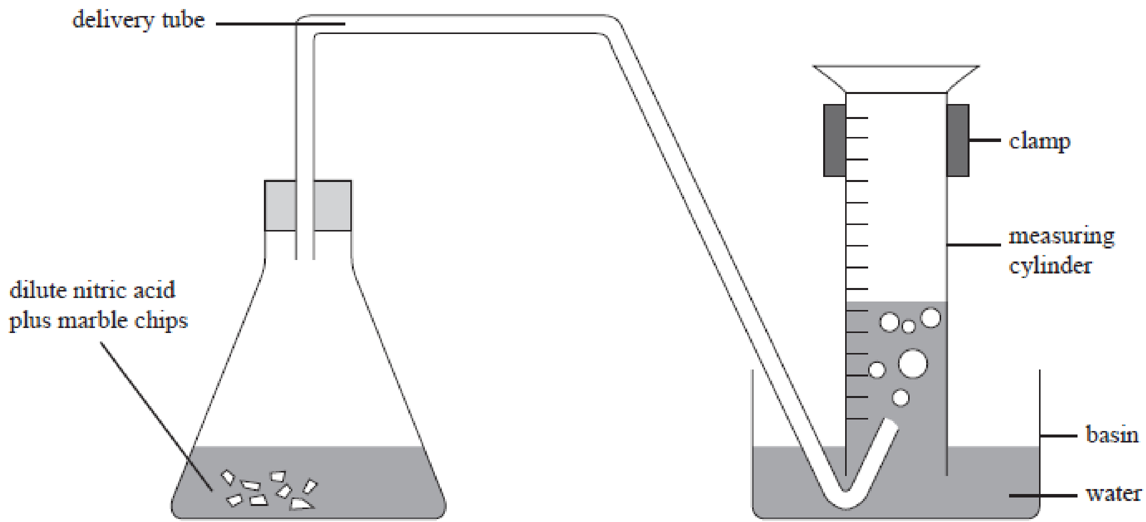
Question 1b: The reaction was carried out again but this time at 20°C. The mass and size of the marble chips, and the concentration and volume of nitric acid used were kept the same.

(i) Draw a line on the graph that represents the reaction at 20°C.

(ii) Explain why you drew this line where you did, and explain if this means that the rate of reaction is slower, the same, or faster.

In your answer you should

- discuss why you drew your line with the slope that you did, and why you stopped the line at the point that you did
- explain the effect of temperature on reaction rate, in terms of particle collisions.

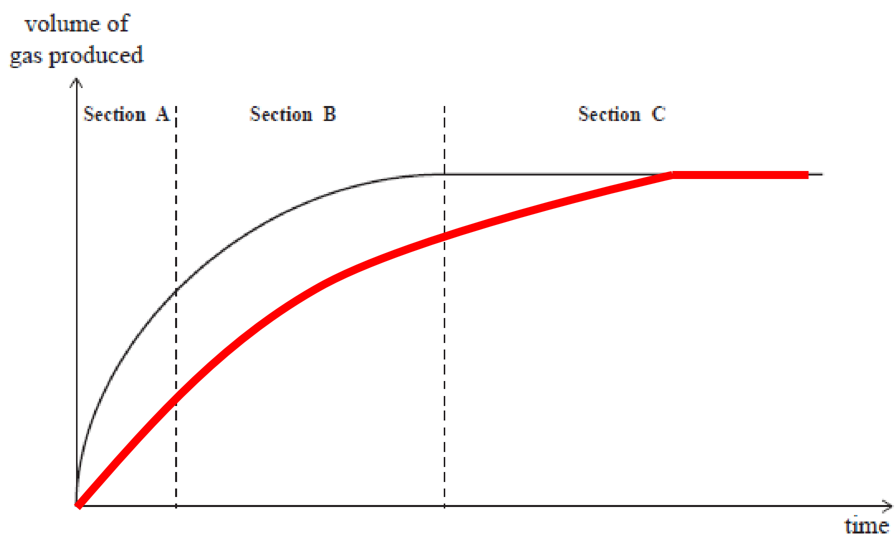


NCEA 2015 Reaction Rate Factors

Excellence Question

Answer 1b: The reaction is slower at the lower temperature, because the particles have less kinetic energy, and therefore are moving slower. When they are moving slower, there will be less frequent collisions, and less of these collisions will be effective, as the particles will collide with less energy. The line drawn represents this slower reaction, as it is less steep at the start.

Both lines become horizontal at the same point on the Y-axis, as this is when both reactions have finished, i.e. one of the reactants has been completely used up and therefore no more gas is produced. Both finished with same amount of gas produced, as both reactions had the same amount of reactants to start with.



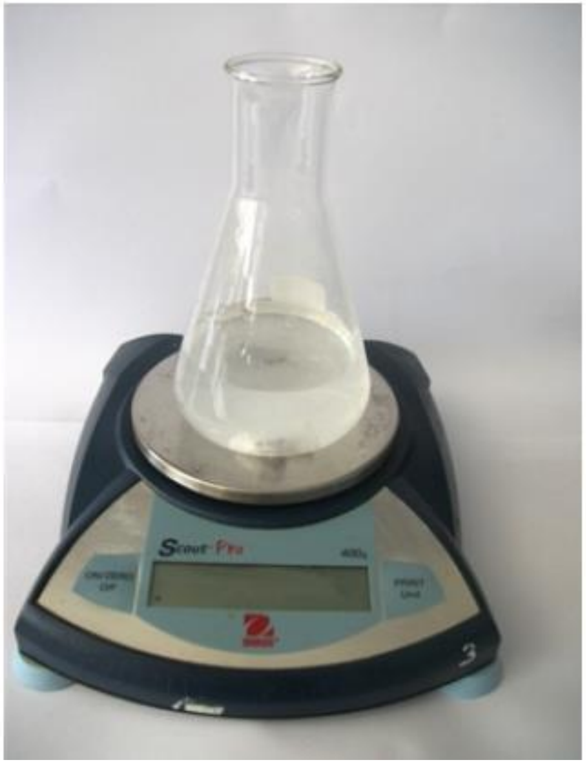
NCEA 2016 Reaction Rates – (Part One)

Achieved Question

Question 2a: A sample of calcium carbonate is added to dilute hydrochloric acid in an open conical flask. The total mass of the flask and contents is measured over time.
Three experiments are carried out at 25°C using the same mass of calcium carbonate, and the same volume of acid:

For each of the experiments reacting calcium carbonate and dilute acid together, the mass of the flask and its contents decreases over time.
Describe why this happens.

	Calcium carbonate pieces	pH of acid
Experiment 1	Chips	1
Experiment 2	Powdered	1
Experiment 3	Powdered	5



The mass of the flask and its contents decreases over time because one of the products is carbon dioxide gas. Since the reaction takes place in an open conical flask, the mass of the CO_2 gas is lost to the surroundings.

NCEA 2016 Reaction Rate Factors – (Part Two)

Question 2b (i) : Identify the factor affecting the reaction rate being investigated in **Experiments 1 and 2**.

Achieved Question

Surface area.

	Calcium carbonate pieces	pH of acid
Experiment 1	Chips	1
Experiment 2	Powdered	1
Experiment 3	Powdered	5

Question 2b (ii) : Explain how this factor affects the rate of reaction in the two flasks, with reference to particle collisions.
Explain any observations, including changes in mass, over the course of **Experiments 1 and 2** until the reactions are finished.

Excellence Question

The mass of the flask and its contents will decrease faster with the powder (experiment 2) compared to the chunks (experiment 1), and the gas production will be faster. This is because the powder has a larger surface area than the large chips, so more particles of calcium carbonate are exposed for the acid to react with / collide with, and therefore experiment 2 has a higher frequency of successful collisions, and subsequently a faster rate of reaction.

Both reactions will get to the same mass, as both have the same amount of reactants and therefore release the same amount of CO_2, but at different rates.

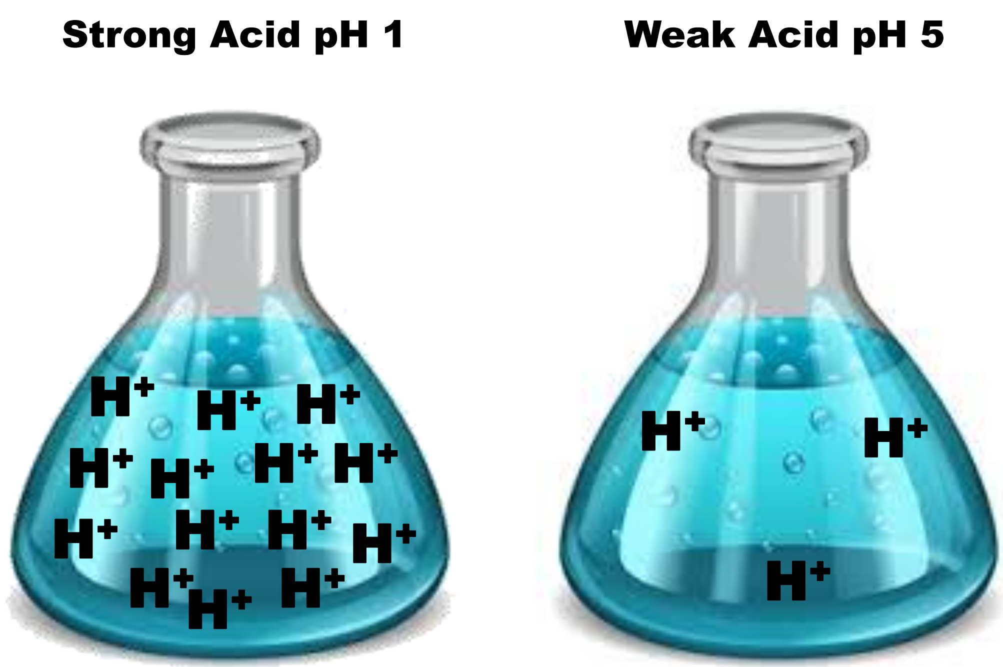
NCEA 2016 Reaction Rate Factors – (Part Three)

Excellence Question

Question 2c: Compare and contrast the rate of reaction of **Experiments 2 and 3**, with reference to particle collisions and the **concentration of hydrogen ions** in the solution.

	Calcium carbonate pieces	pH of acid
Experiment 1	Chips	1
Experiment 2	Powdered	1
Experiment 3	Powdered	5

An acid with a pH of 1 has a higher [H^+] than an acid with a pH of 5. Since experiment 2 has more H^+ ions per unit volume / a higher concentration of H^+ ions, it will have a higher frequency of successful collisions (more successful collisions per second) and subsequently a higher / faster rate of reaction.



Excellence Question

NCEA 2017 Reaction Rate Factors – Acid and Base reactions

Question 1a: A sample of powdered sodium hydrogen carbonate ($NaHCO_3$) was added to sulfuric acid (H_2SO_4) in a flask, and fizzing was observed.

Two experiments were carried out with the acid at different temperatures, using the same amount of powdered sodium hydrogen carbonate and the same concentration and volume of sulfuric acid:

Experiment	Temperature of acid, °C
1	30
2	55

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What caused the fizzing?

The carbon dioxide gas forming which is a product of the neutralisation reaction

Question 1b: Why was the fizzing fastest immediately after the sodium hydrogen carbonate had been added? Your answer should refer to particle collisions.

At the beginning of the experiment the rate is fastest as there are more collisions between the H_2SO_4 and $NaHCO_3$. This is because at the start of the reaction there are more particles available for collision, and therefore **more products are being produced per unit time** so more gas observed fizzing. After a while the rate of reaction is slowing down as the number of particles available for collision is becoming fewer as some of the H_2SO_4 and $NaHCO_3$ have already collided and have been used up, therefore fewer particles and therefore fewer collisions and less gas produced (less fizzing)

Eventually the reaction will stop, as all of the reactants (or one of them) have reacted, and therefore there are no particles present that can collide and react and no gas/fizzing seen.

Excellence Question

NCEA 2017 Reaction Rate Factors – Acid and Base reactions

Question 1c: The rate of reaction for each experiment was found by measuring the volume of gas produced over time, as shown in the graph below.
What is the effect of increasing temperature on the rate of reaction?
Your answer should refer to particle collisions and explain why both lines finish at the same point.

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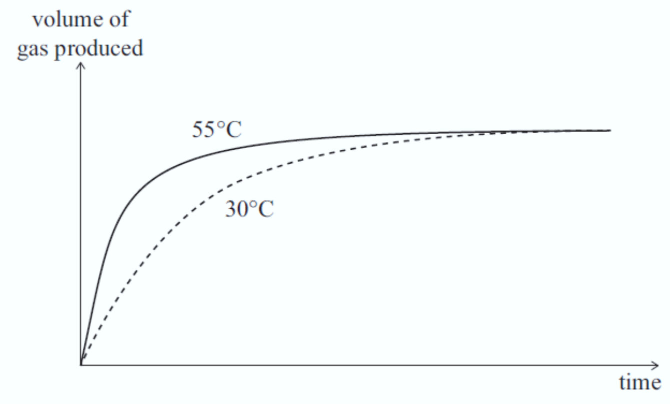

The reaction is faster at the higher temperature (55°C), because the H^+ ions in the acid have more kinetic energy, and therefore are moving faster. When they are moving faster, there will be more collisions per unit time (frequency), and more of these collisions will be effective (successful), as the particles will collide with more energy. Successful reactions produce carbon dioxide gas so the volume of gas will increase faster with the higher temperature.

The solid line represents the faster reaction, as it is steeper at the start. This represents the reaction carried out at 55°C.

Both lines become horizontal at the same point on the Y-axis, as this is when both reactions have finished, ie one of the reactants has been completely used up and therefore no more gas is produced. Both finished with same amount of gas produced, as both reactions had the same amount of reactants to start with. Both times finish at the same point.