NCEA AS 90947

S1.8 Chemical Reactions

GZ Science Resources

What is a NCEA Achievement Standard?

When a student achieves a standard, they gain a number of credits. Students must achieve a certain number of credits to gain an NCEA certificate (80 for Level 1)

The standard you will be assessed on is called **Science 1.8 Investigate selected chemical reactions**

It will be internally (in Class) assessed as part of a **Investigation** and will count towards **4 credits** for your Level 1 NCEA

What are the main steps required in this Internal Assessment?

AS90947 Investigate selected chemical reactions

Achievement

This achievement standard involves investigating and classifying chemical reactions by carrying out observations and using equations.
The investigation **write up is done individually** by each student.

- ❑ **Classify precipitation** and at least one other reaction
- ❑ **Observations** for precipitation and at least one other reaction
- ❑ At least three correct **formulae** are given
- ❑ At least two correct **word equations** are given

Aiming for Merit and Excellence

Interpretation of evidence for Merit (Achievement plus)

- **All reactions** classified with justification
- Use of **solubility rules** for precipitation reaction
- At least 2 correct **symbol equations**

Interpretation of evidence for Excellence (Merit plus)

- At least two correct **balanced equations**
- **Links** between classification, products forms and observations plus equations for precipitation and at least one other reaction
- **Links** between solubility rules and precipitates formed

Types of reactions

In this Achievement Standard a selection of the main types of chemical reactions are studied:

1. combination reaction.
2. precipitation (exchange) reaction.
3. displacement reaction.
4. thermal decomposition reaction.

The objectives for this teaching unit include:

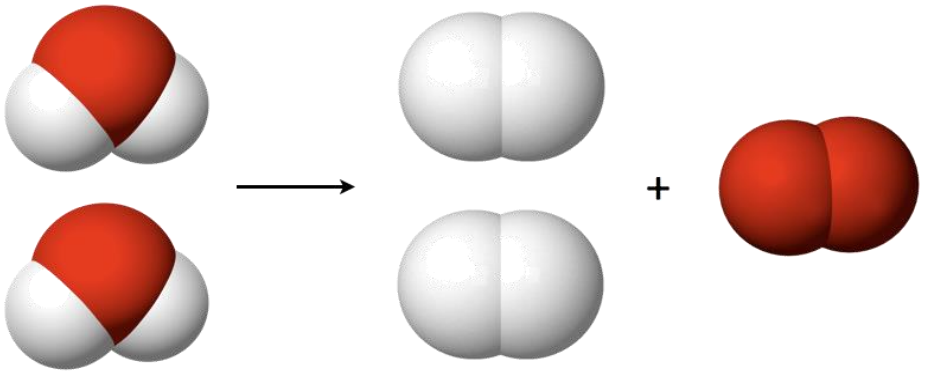
- ❑ Predict the products or precipitates that will form
- ❑ Predict the type of reaction from the list provided
- ❑ Link your prediction to the solubility rules where necessary
- ❑ Complete a word equation for each chemical reaction

- ❑ Carry out each of the chemical reactions and record:
- ❑ Observations for each reaction
- ❑ Names and formulas for any products and precipitates
- ❑ Link observations to the reaction types
- ❑ Complete a balanced symbol equation for each chemical reaction

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**



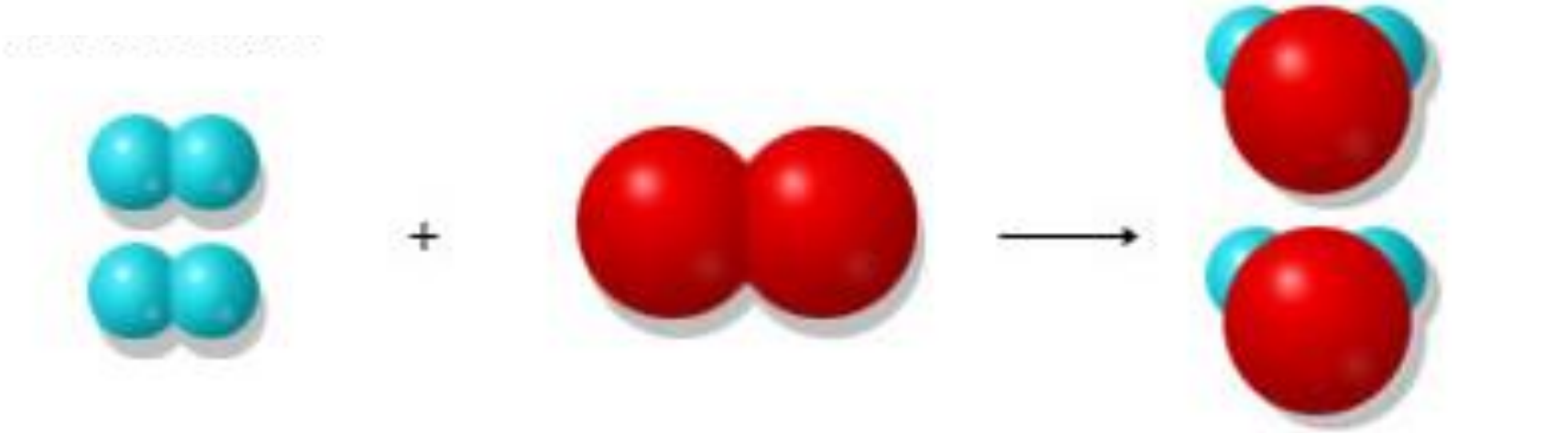
$2H_2O \longrightarrow 2H_2 + O_2$

Reactants join together to form new products during chemical reactions

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

Reactants Products

$2H_2 + O_2 \longrightarrow 2H_2O$



2 hydrogen molecules + 1 oxygen molecule yields 2 water molecules

Writing word equations

In this internal instructions will be given for which reactant(s) to select and react.
A key skill will be writing a word equation showing the reactants and products formed.

For example: When **sodium chloride** solution is mixed with **lead nitrate** solution the colourless solutions form a white precipitate

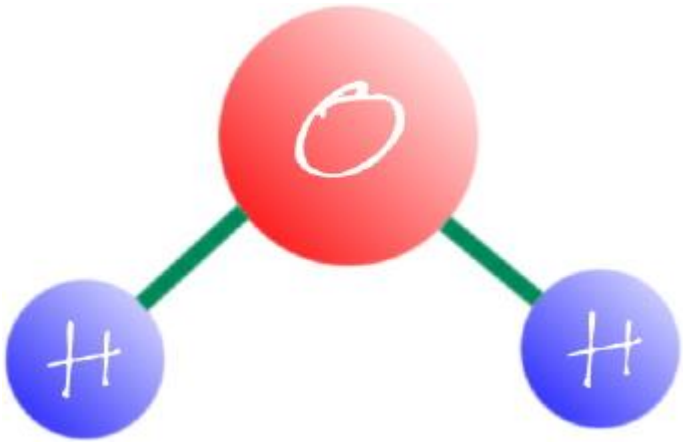
1. Identify the reactants from the question and write a word equation

   sodium chloride + lead nitrate → lead chloride + sodium nitrate

In the next few weeks you will learn how to determine what the products will be based on the reaction type.

Chemical compound formula

Reactants and Products can either be elements (of one type of atoms) or compounds (of more than one type of atom chemically bonded together). 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

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

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

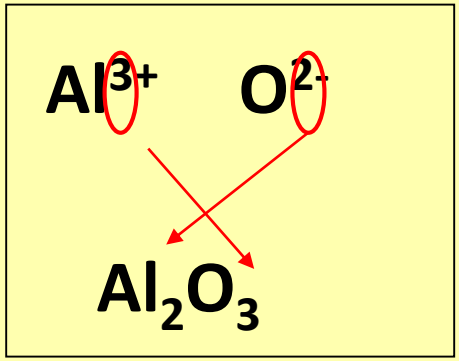
A number in front of the compound tells you how many molecules there are.

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

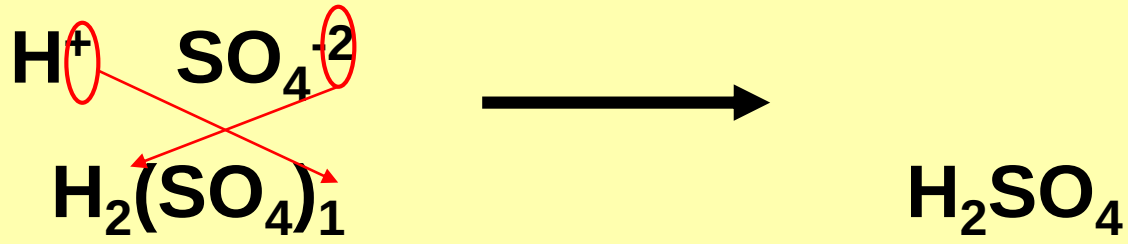
A number after brackets tells you how many times to multiply every atom inside the brackets.

Cross and Drop method for balancing ionic compounds

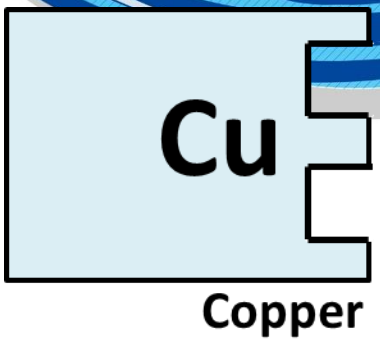
1. Write down the ions (with charges) that react to form the compound. Cation comes before Anion.



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



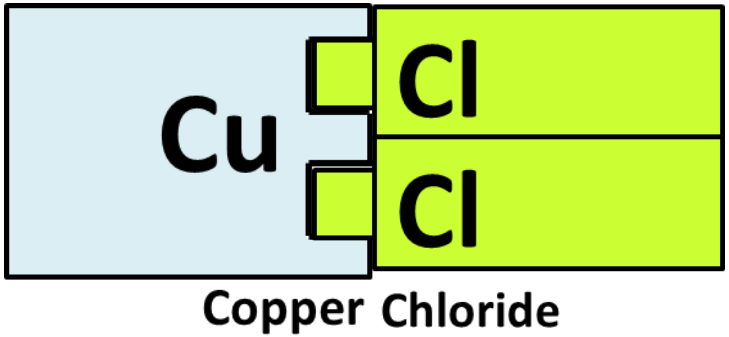
The visual method for balancing compounds



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

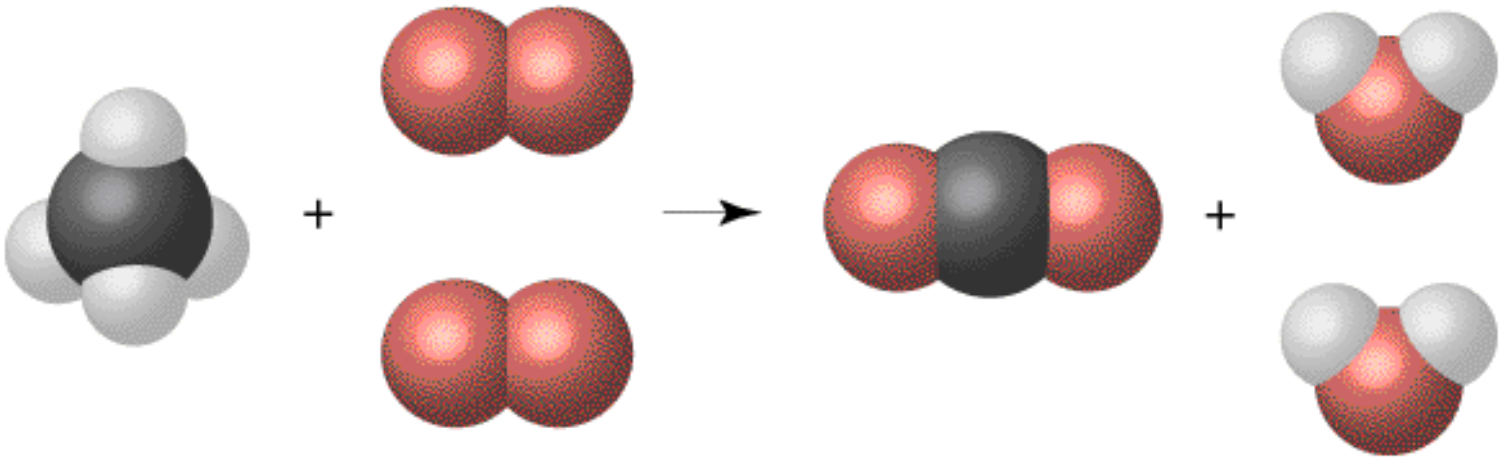
Chlorine forms a negative chloride ion of Cl^- . It gains 1 electron – shown by the 1 "extra tab" in the shape

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.



Balancing Chemical equations

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



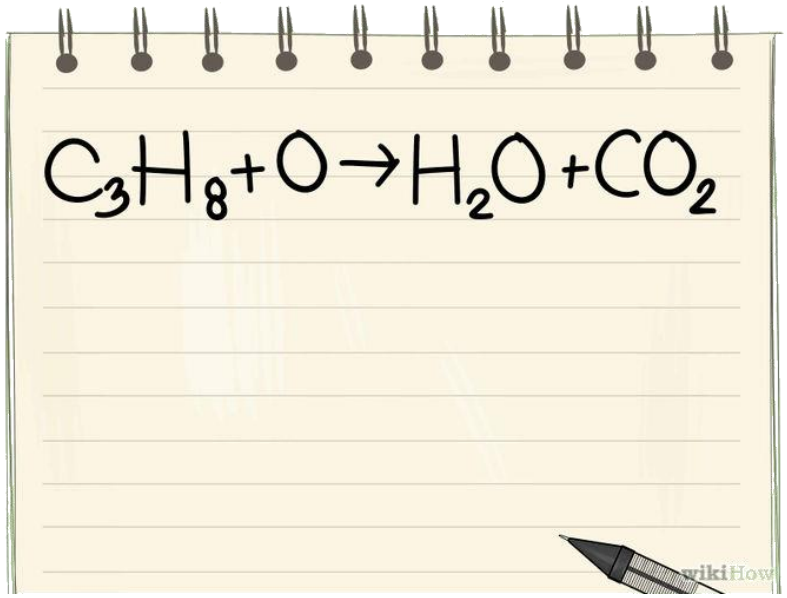
One methane molecule + Two oxygen molecules → One carbon dioxide molecule + Two water molecules

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

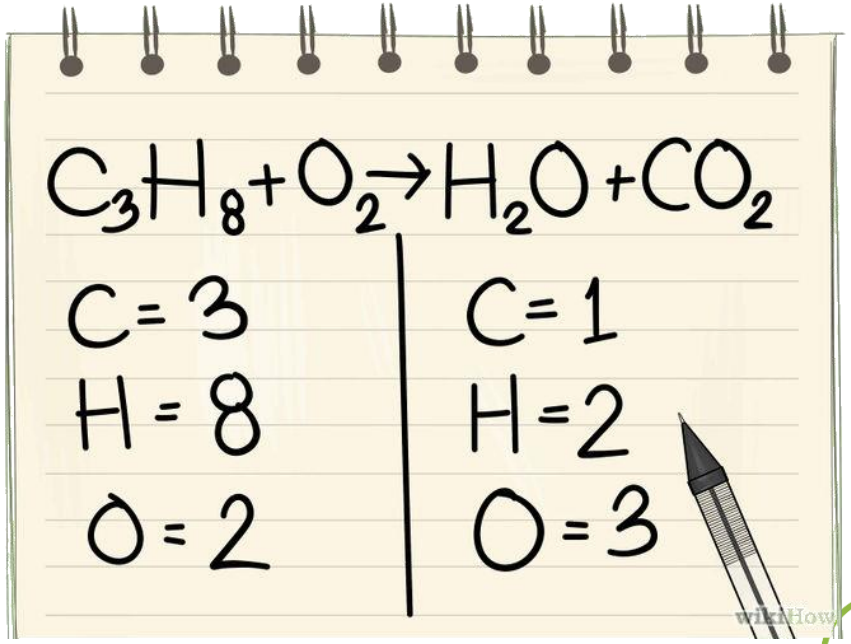
(1 C, 4 H) (4 O) (1 C, 2 O) (2 O, 4 H)

Balancing Chemical equations

1. To balance an equation first write down the equation



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

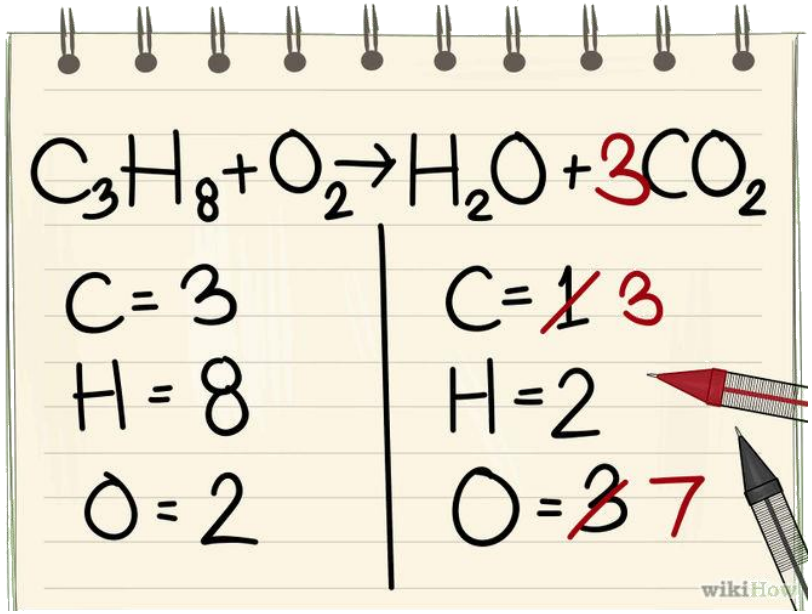


The total number of each type of atom must be the same for reactants and products if they equation is balanced

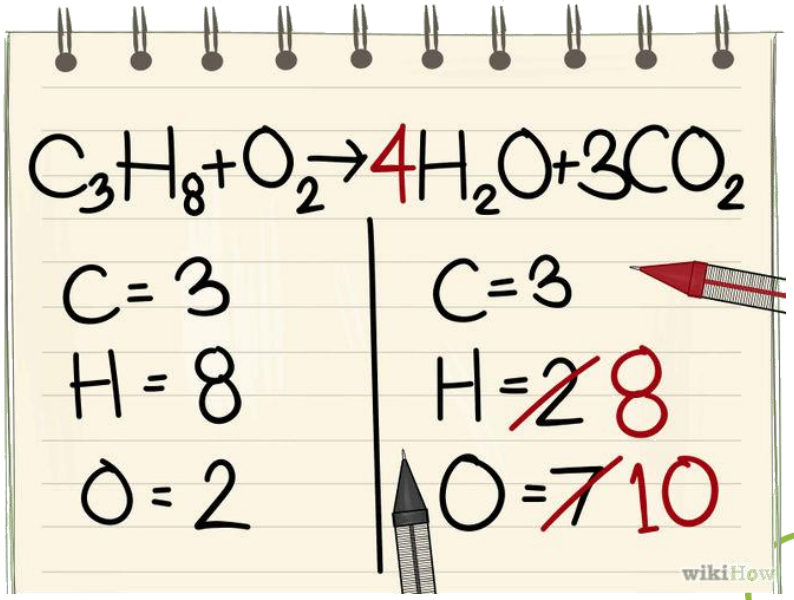
Balancing Chemical equations

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

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



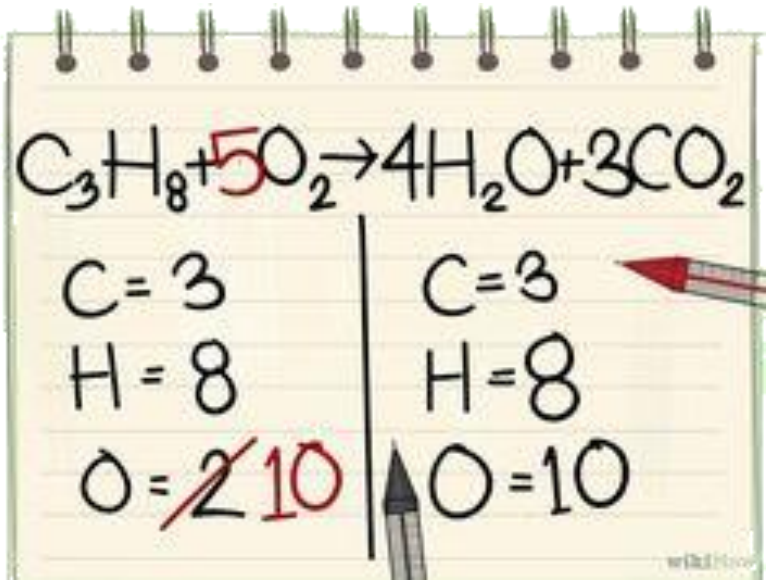
4. Moving down the list to the next atom (H) multiply until both sides are the same – again you may also increase another atom but sort that out after



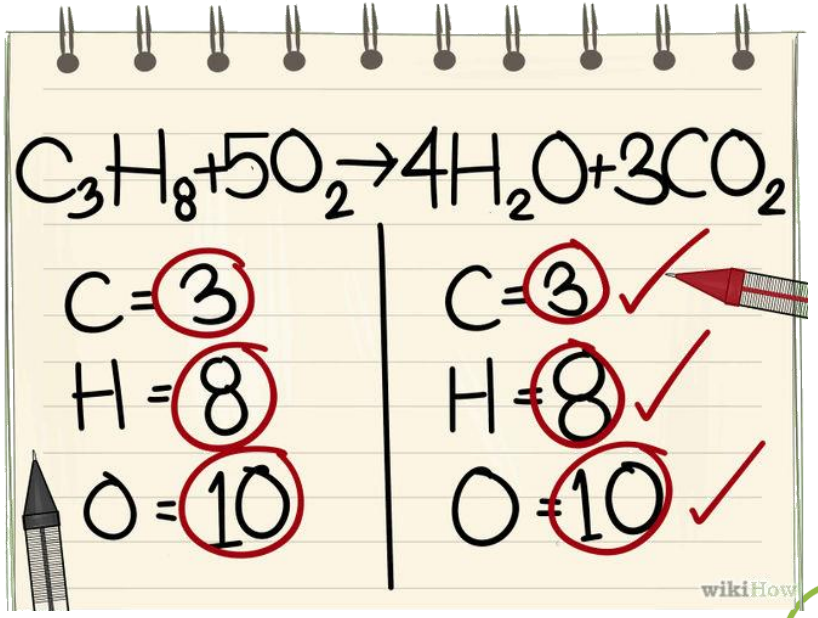
Balancing Chemical equations

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

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



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



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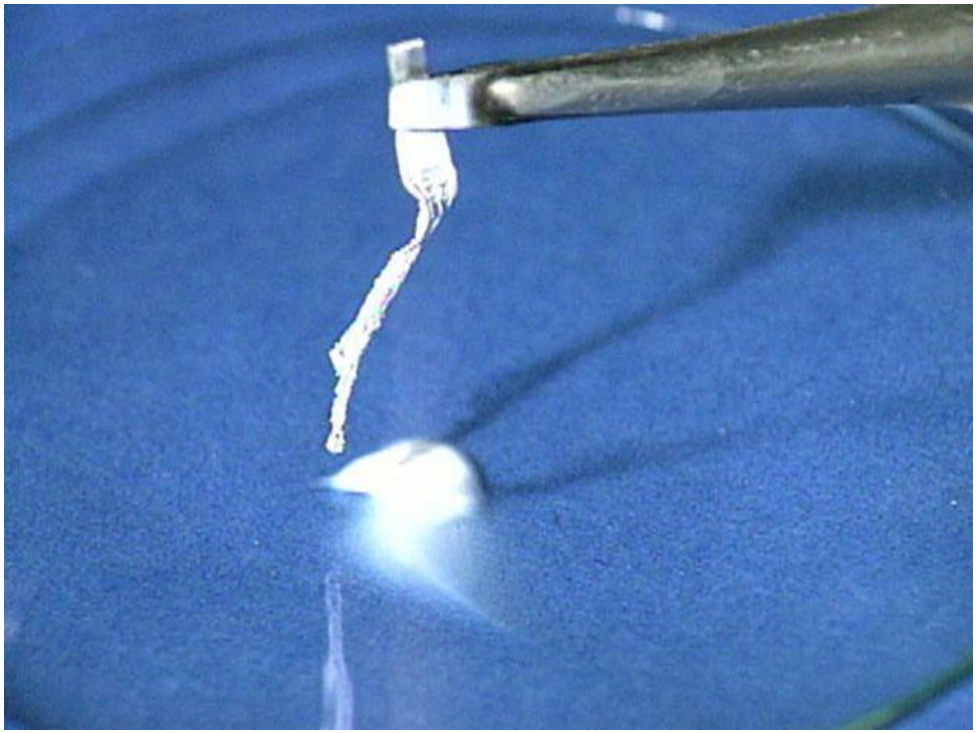
REACTION ONE - Combination reaction



Combination reactions occur when two or more reactants combine to form one product.

An example is a metal and oxygen forming a metal oxide or a metal and a non-metal reacting to form a ionic compound.

These are limited to simple reactions of elements with other elements (such as magnesium or sulfur with oxygen, iron with sulfur etc).

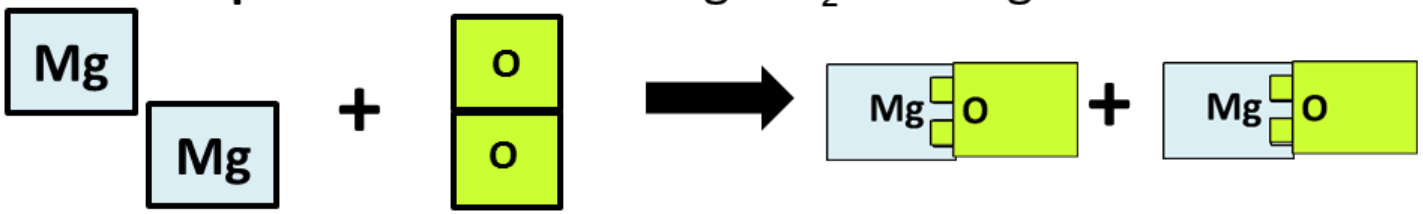
GENERAL EQUATION - Combination reaction

1. Combination

General equation Metal + Oxygen → Metal Oxide

Word equation Magnesium + Oxygen → Magnesium Oxide

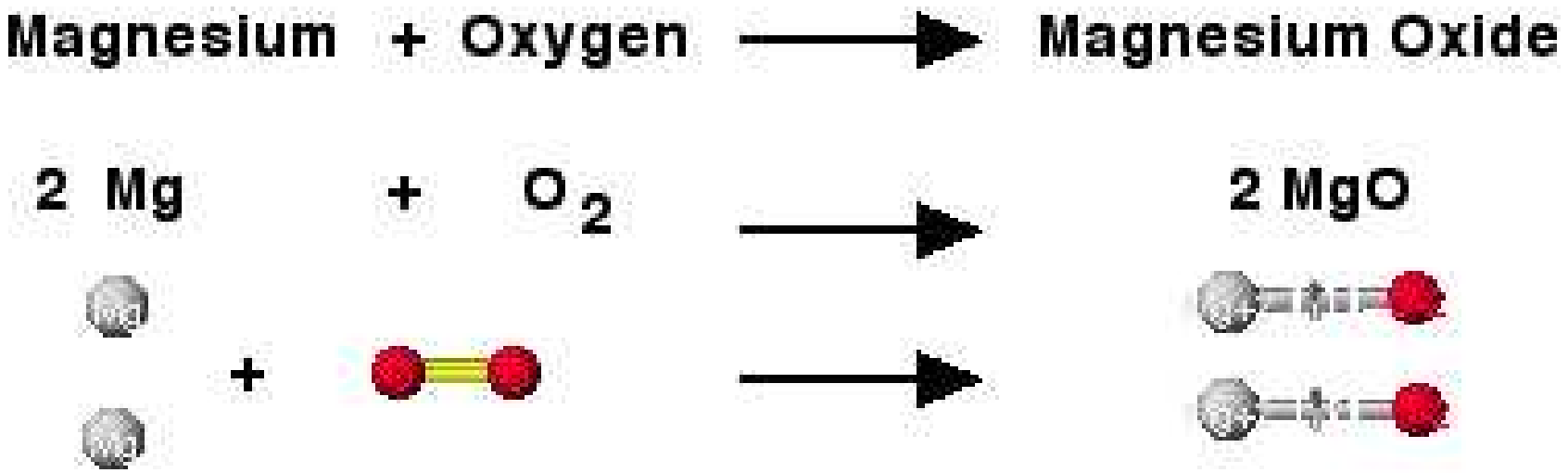
Formula equation **2** $Mg + O_2 \rightarrow 2MgO$



Combination - Metals form oxides by reaction with oxygen

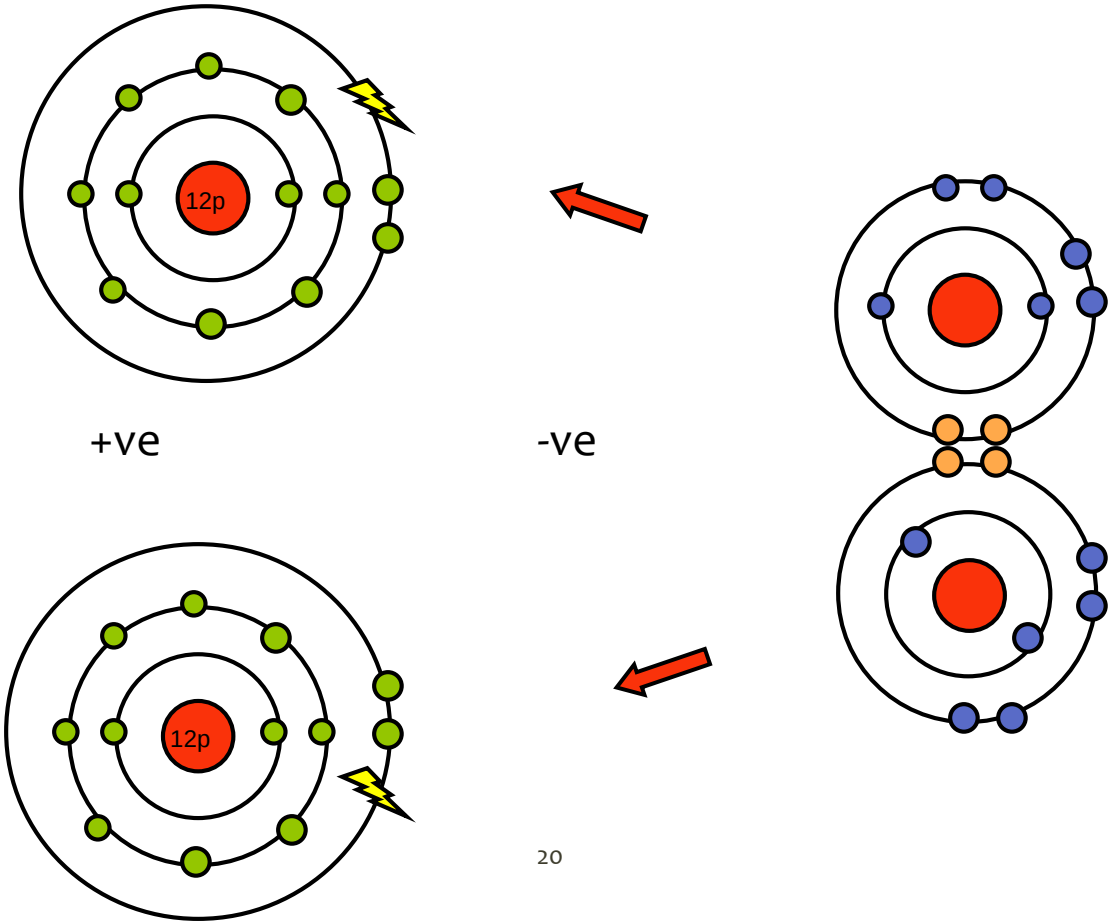
Metals react with oxygen in the air to produce **metal oxides**, like magnesium oxide.

Electrons are lost from the metal to form a cation (positive ion) and gained by the oxygen to form an anion – oxide (negative ion). The cation and anion then join together to form a **neutral** metal oxide joined together by an ionic bond.



Combination - Metals form oxides by reaction with oxygen

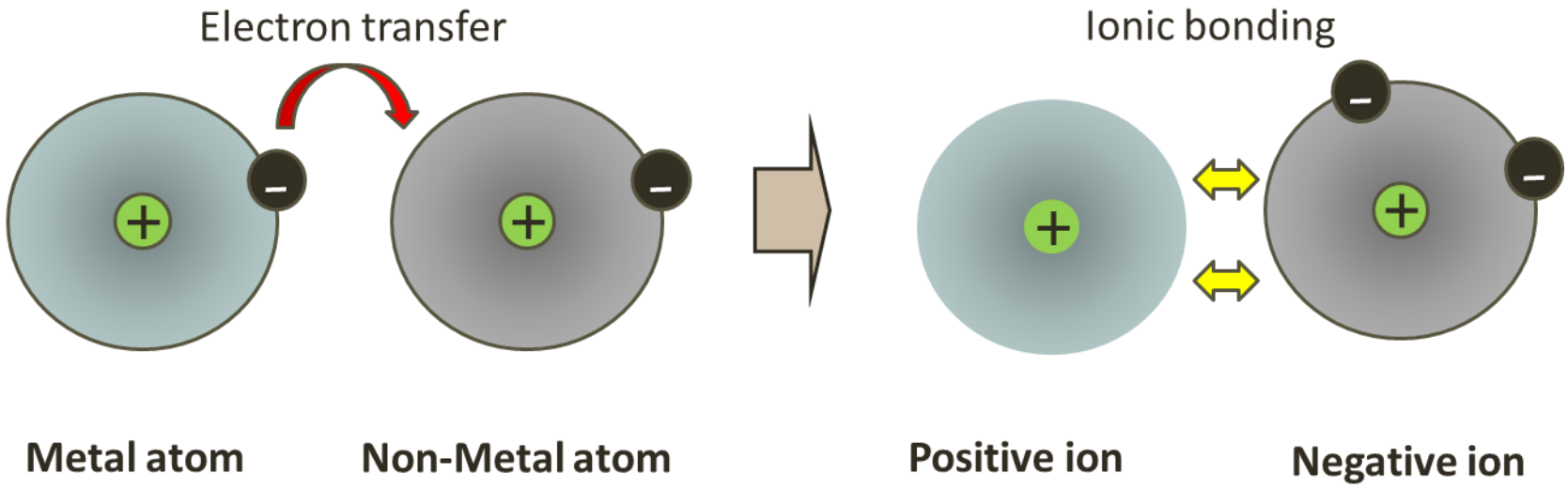
2Mg	+	O_2	→	2MgO
Magnesium	+	Oxygen	⟶	Magnesium Oxide



Ionic Bonding

Ionic Bonding is where one atom completely takes valence 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.



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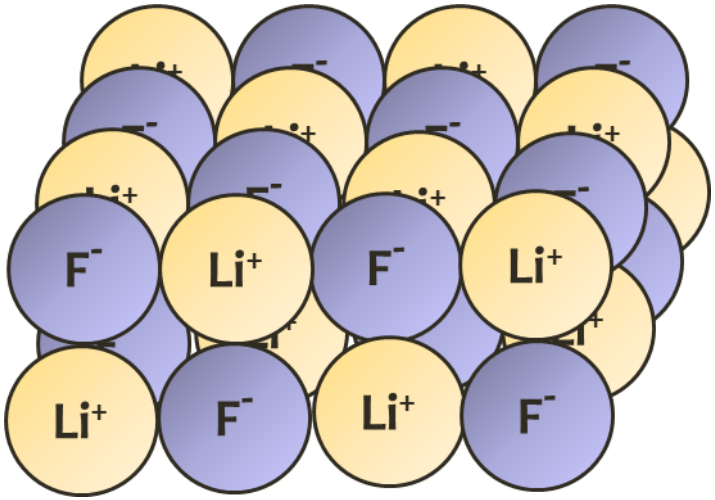
Ionic compounds are the product of chemical reactions between metal and non-metal ions

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

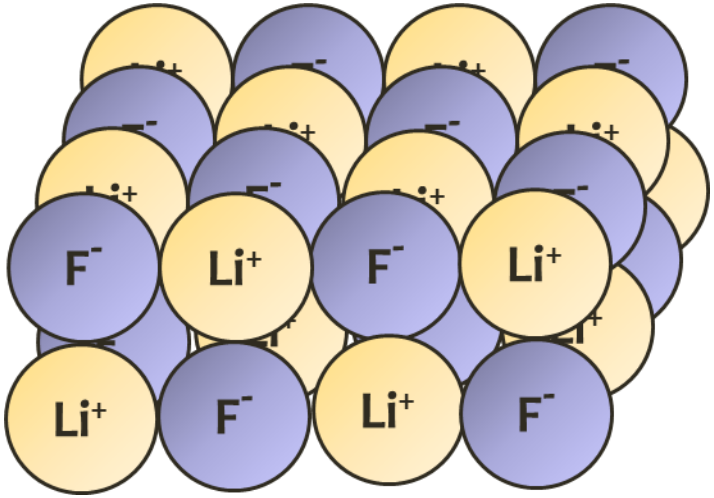


The Anion (F) takes the electrons off the Cation (Li) so their outer energy levels have a stable 8 electrons each.
Anions and Cations have a strong electrostatic attraction for each other so they bond together as a compound.

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

Naming ionic compounds

Ionic compound names are made up of two parts.
The first part of the name is the positive ion (cation) and the second part of the name is the negative ion (anion)



For example: In the ionic compound above the positive ion is called **lithium** and the **negative** ion is called fluoride.
Together the ionic compound is called **lithium fluoride.**

The names and formula of ions can be found on a ion table

Ion table – Positive ions (Cations)

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

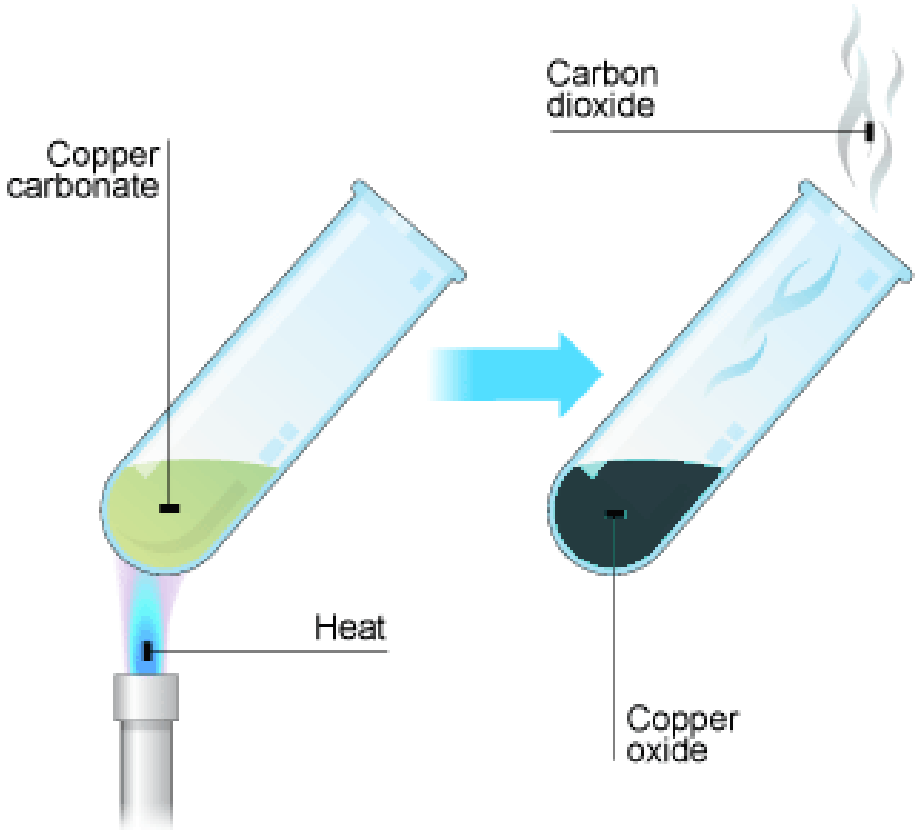
Ion table – Negative ions (Anions)

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

REACTION TWO - Thermal decomposition reaction

Thermal decomposition reactions occur when one substance is broken apart with the use of heat energy into two or more smaller substances.

An example is copper carbonate heated which breaks down into carbon dioxide and copper oxide.



These are limited to thermal decomposition of carbonates and hydrogen carbonates.

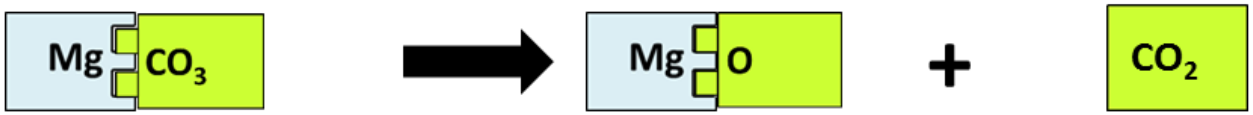
GENERAL EQUATION - Thermal decomposition reaction

3. Thermal Decomposition

General equation Metal Carbonate → Metal Oxide + Carbon Dioxide

Word equation Magnesium Carbonate → Magnesium Oxide + Carbon Dioxide

Formula equation $MgCO_3 \rightarrow MgO + CO_2$

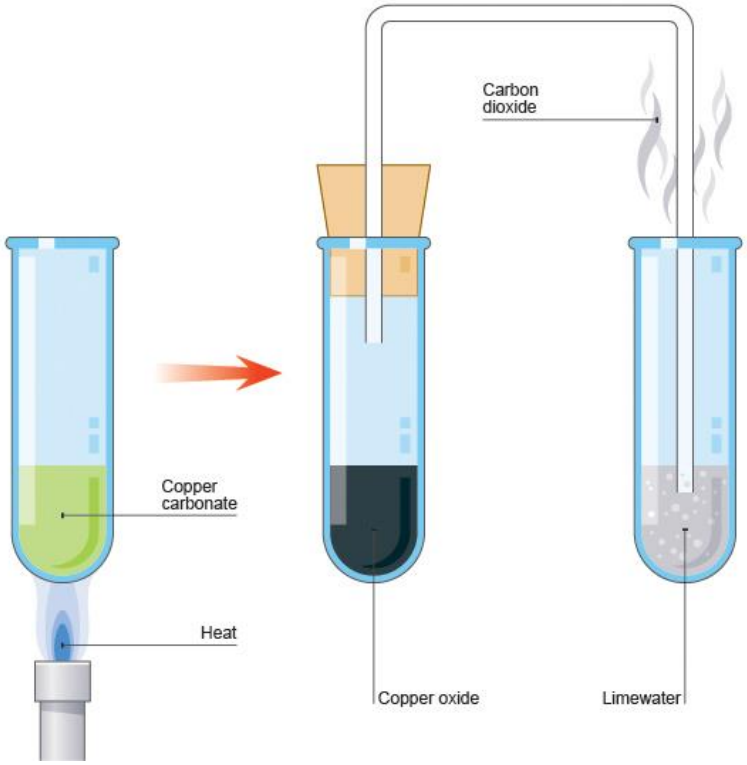


Thermal decomposition equations

Equations for the thermal decomposition of copper carbonate:

copper carbonate $\xrightarrow{\text{heat}}$ copper oxide + carbon dioxide

$CuCO_3 \xrightarrow{\text{heat}} CuO + CO_2$



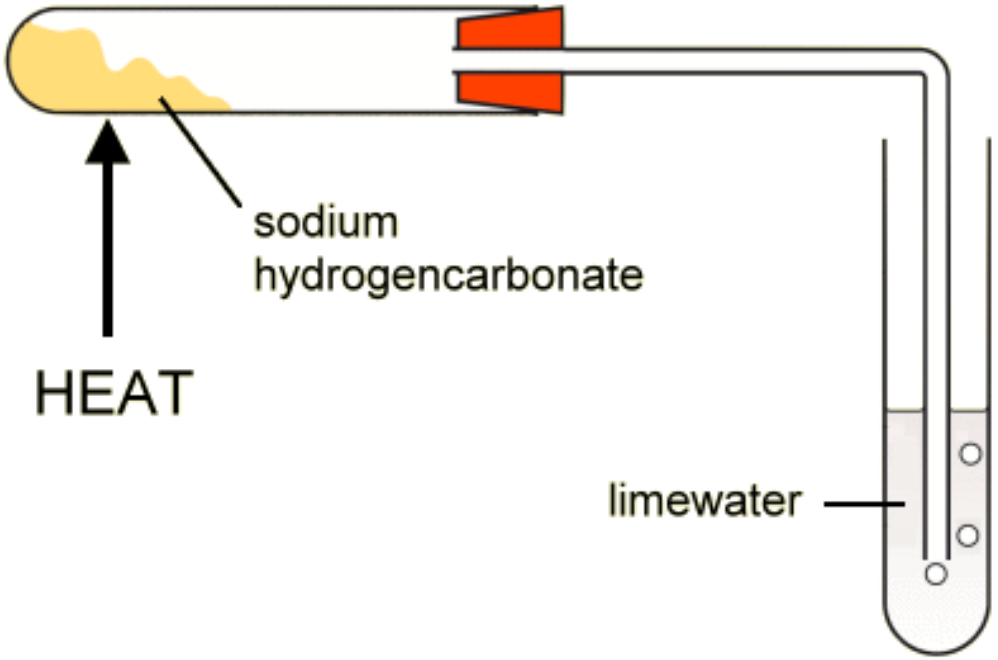
The production of carbon dioxide gas can be tested by a limewater test. The gas is bubbled through clear limewater solution and if the solution turns cloudy then it is a positive for carbon dioxide

Thermal decomposition equations

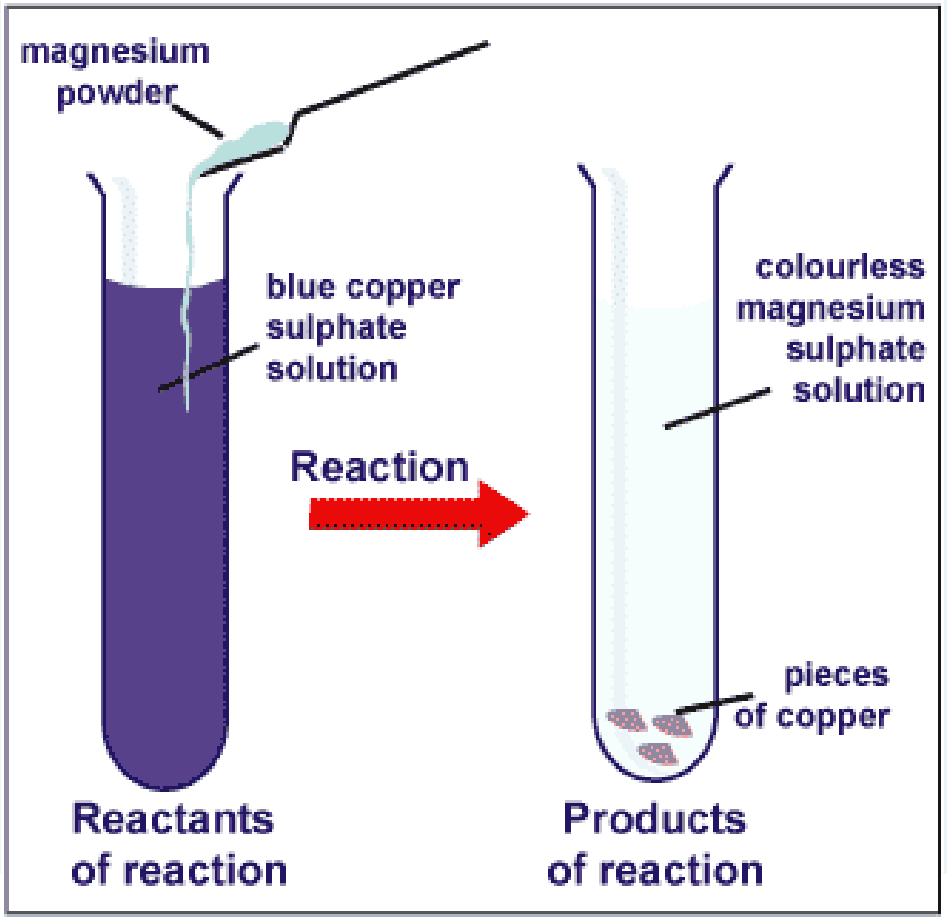
Equations for the thermal decomposition of sodium hydrogen carbonate:

Sodium hydrogen carbonate $\xrightarrow{\text{heat}}$ sodium carbonate + carbon dioxide + water

$2NaHCO_3 \xrightarrow{\text{heat}} Na_2CO_3 + CO_2 + H_2O$



REACTION THREE - Displacement reaction



Displacement reactions occur when a metal and salt (metal + non-metal ionic compound) solution are mixed and the more reactive metal replaces the metal in the salt.

An example would be reacting magnesium metal and copper sulfate to produce magnesium sulfate plus copper metal.

These are limited to the displacement of metal ions in solution by other metals.

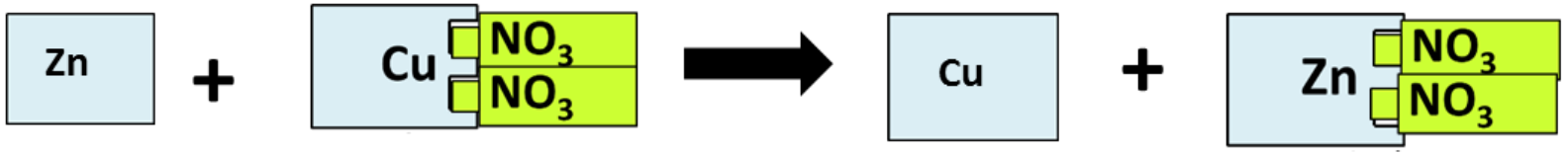
GENERAL EQUATION - Displacement reaction

4. Displacement

General equation Metal (1) + Metal(2) salt → Metal (2) + Metal(1) salt

Word equation Zinc + Copper Nitrate → Copper + Zinc Nitrate

Formula equation $Zn + Cu(NO_3)_2 \rightarrow Cu + Zn(NO_3)_2$



Metal reactivity

Metals show varying reaction rates to other substances. Metals can be put in order on a list called the "**reactivity series**".
In a displacement reaction a metal above another metal in the reactivity series (one that is more reactive) will replace it in a compound.

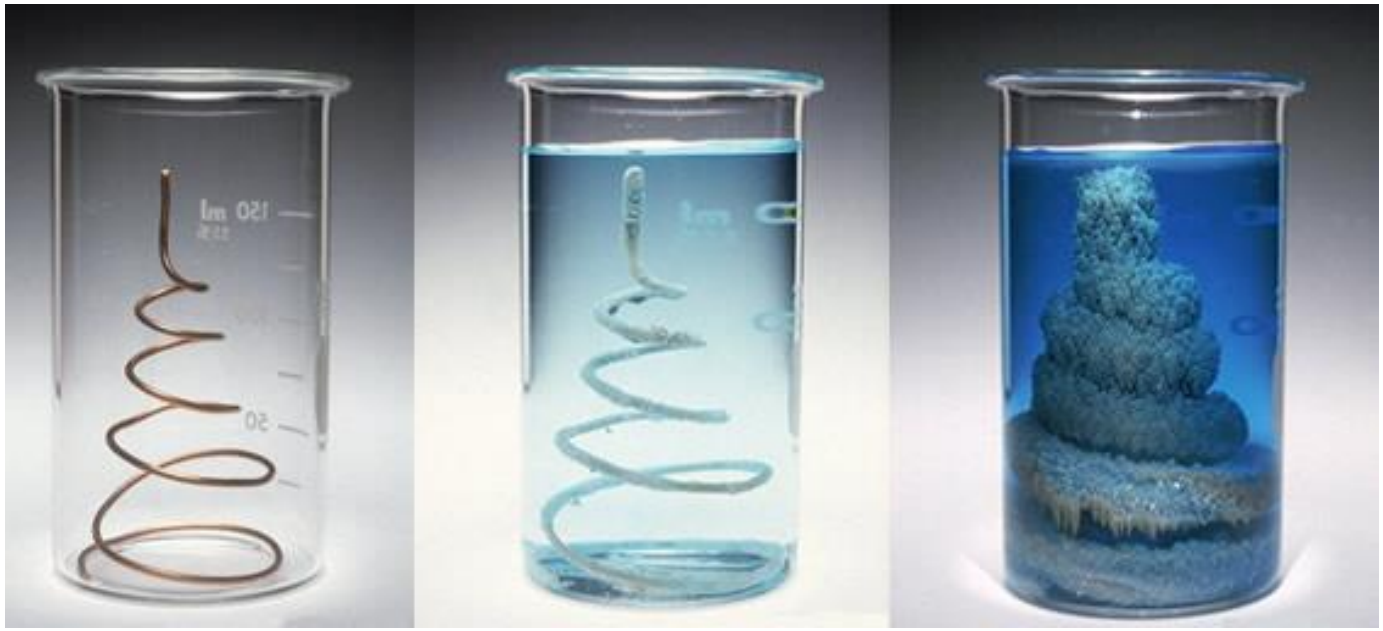
Metals in order	Reaction with water	Reaction with acid
K Potassium Na Sodium Li Lithium	React with cold water	Explode with acid
Ca Calcium Mg Magnesium Al Aluminium Zn Zinc Fe Iron	React with steam	Fizz with acid
Pb Lead	No reaction with steam	Reacts with warm acid
Cu Copper Ag Silver Au Gold	No reaction with steam	No reaction with acid

Displacement reaction equations

A more reactive metal will displace a less reactive metal from a solution. For example, if you place copper in a solution of silver nitrate, the copper atoms will replace the silver ions to form copper nitrate (blue colour) and the silver metal will be deposited around the copper coil . This can be represented by a word equation and formula:

copper + silver nitrate → copper nitrate + silver

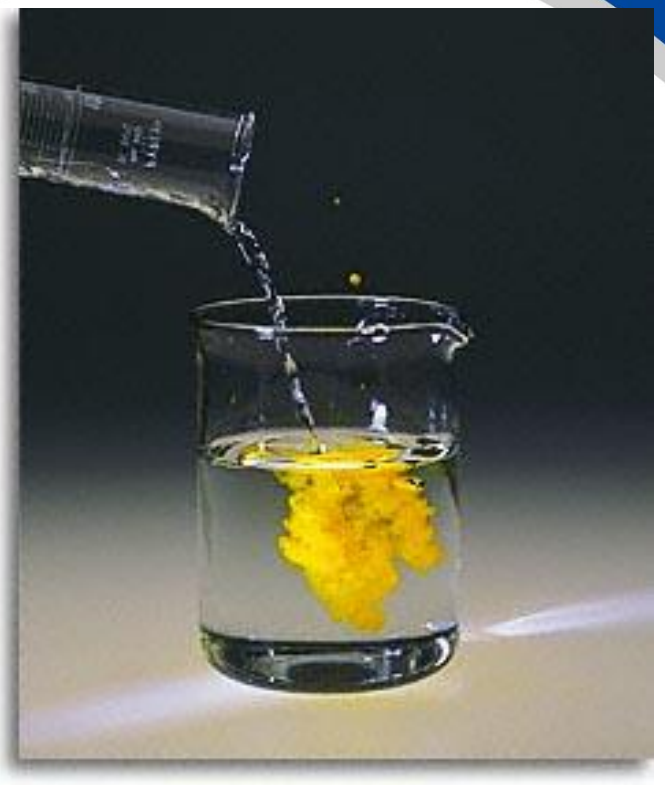
$Cu + 2AgNO_3 \rightarrow Cu(NO_3)_2 + 2Ag$



REACTION FOUR - Precipitation reactions

Precipitation reactions occur when two solutions react together to form a solid that settles out of the solution. The solid formed is called the precipitate.

An example is a lead (II) nitrate solution mixed with a potassium iodide solution to form a lead iodide precipitate.



These are limited to precipitation reactions such as the formation of:

- chlorides of silver and lead
- sulfates of barium and lead
- hydroxides of copper, iron(II), iron(III), calcium, and magnesium
- carbonates of copper, iron(II), zinc, calcium, and magnesium ions.

GENERAL EQUATION - Precipitation reactions

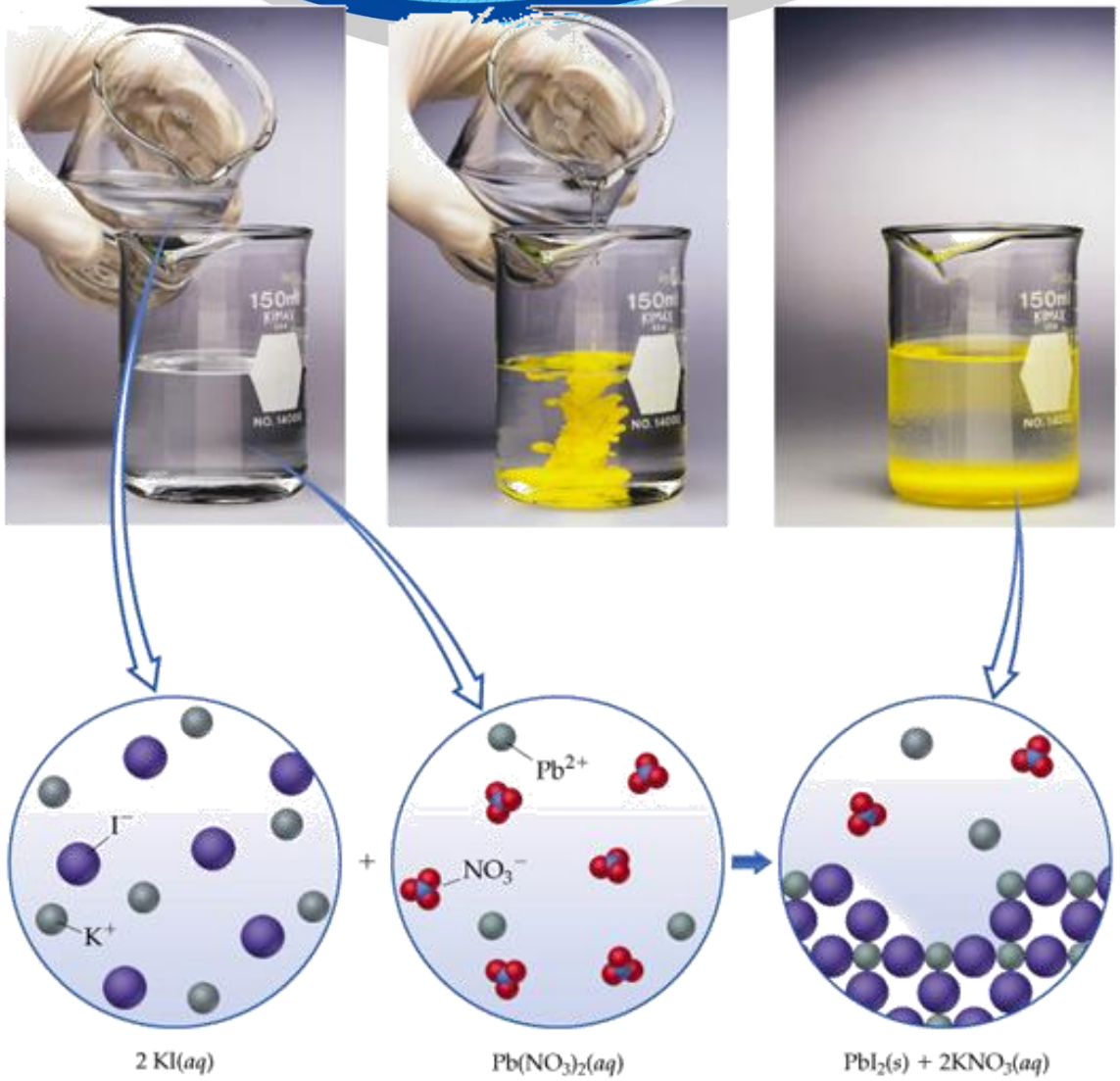
2. Precipitation

General equation Cation(1)Anion(1) + Cation(2)Anion(2)→ Cation(1) Anion(2) + Cation(2)Anion(1)

Word equation Sodium Chloride + Silver Nitrate → Sodium Nitrate + Silver Chloride (precipitate)

Formula equation $NaCl + AgNO_3 \rightarrow NaNO_3 + AgCl_{(ppt)}$

Precipitation - What's going on?



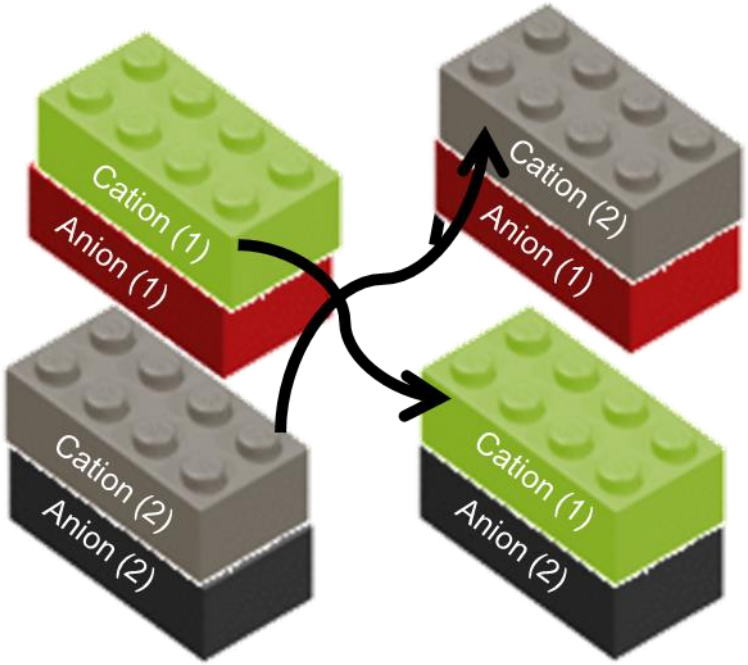
When ionic compounds are in solution the ions remain separated from each other and mixed amongst the water molecules.

If solutions are added to each other and a new combination of ions (an anion and a cation) are more attracted to each other than the water molecules then a solid ionic compound precipitate forms. The other ions not forming a precipitate remain in solution and are known as **spectator ions**.

Some Compounds are soluble and some are not

Before the precipitation reaction the anion and cation of each compound are separate in solutions and dissolved in water.

During a precipitation when the solutions are mixed together, different combinations of anions and cations are possible. If a new combination is not soluble then it forms a solid precipitate



Solubility rules tell us which ions are soluble or not soluble, and the exceptions for them

Solubility Rules

Some ions will join together to form precipitates and are insoluble. Other ions will not form precipitates and are soluble.

Ion	Rule	Exceptions
nitrate	soluble	
chloride	soluble	silver and lead
sulfate	soluble	lead, calcium, barium
carbonate	insoluble	sodium
hydroxides	insoluble	sodium

Solubility Grid

When adding one ionic solution to another we use a solubility grid to decide if a precipitate has formed or not.

e.g.

$CaCl_{2(aq)} + Na_2CO_{3(aq)}$?

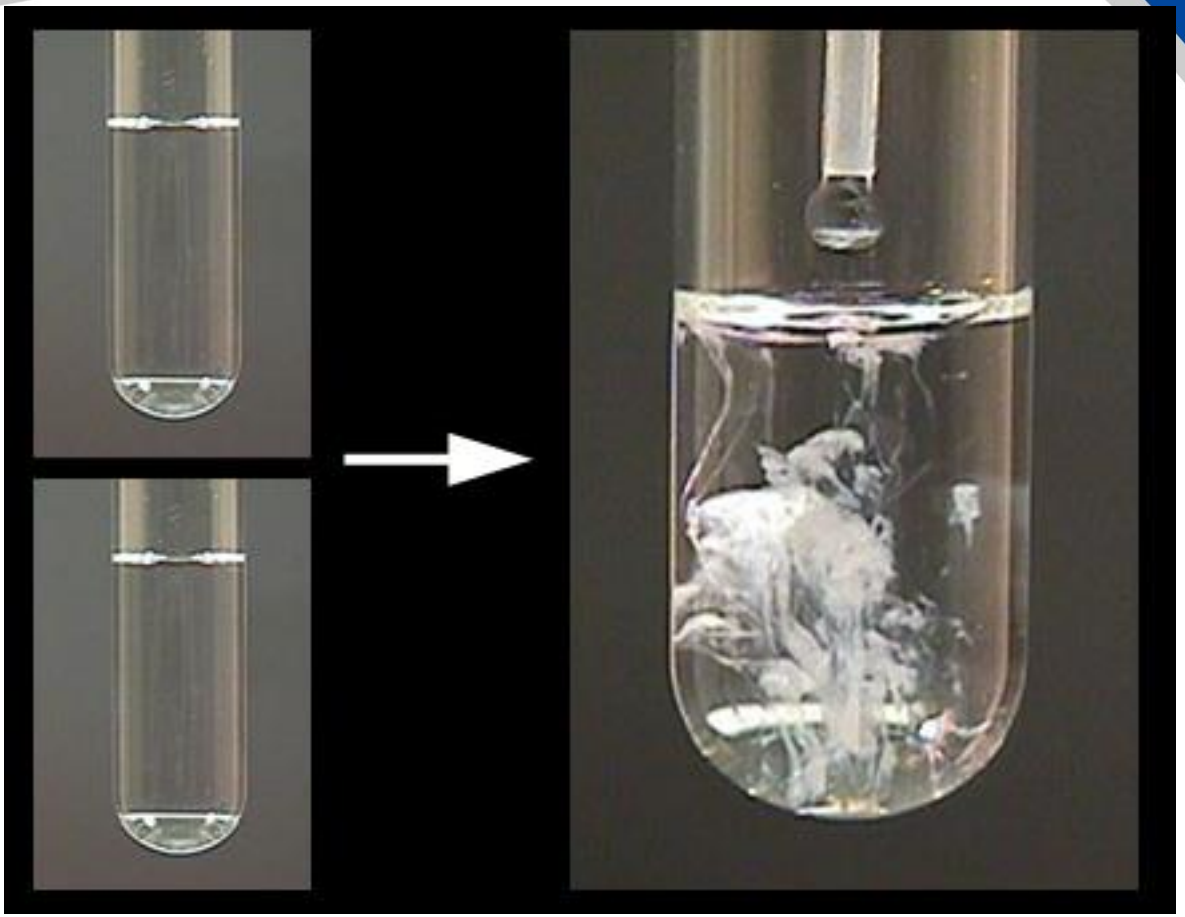
	Na^+	CO_3^{2-}
Ca^{2+}	-	?
$2Cl^-$	?	-

NOTE: the subscript $_{(aq)}$ means aqueous or in solution. The compound is **soluble**.
A compound with the subscript $_{(s)}$ means solid so the compound is **insoluble**.

The Na^+ and the Cl^- ions are dissolved in solution in the beginning and remain in solution at the end. They are not involved in the precipitation reaction so they are known as **spectator ions**.

Observations

In this example lead nitrate and sodium chloride solutions are both colourless.
When mixed together a white precipitate is formed.



It is important to know from your solubility rules which product this is. (Lead nitrate) as the other product (sodium nitrate) remains colourless - and can be left out in a precipitation equation

This is where **actual observation** of the reaction is **important** and **notes are made at the time**.

Observations

Observations must **link** the species (the reactant and the product it changes into) to the colour changes and/or appearance of gas.
Question: Mix sodium chloride solution and lead nitrate solution

When **sodium chloride** solution is mixed with **lead nitrate** solution the colourless solutions form a white precipitate

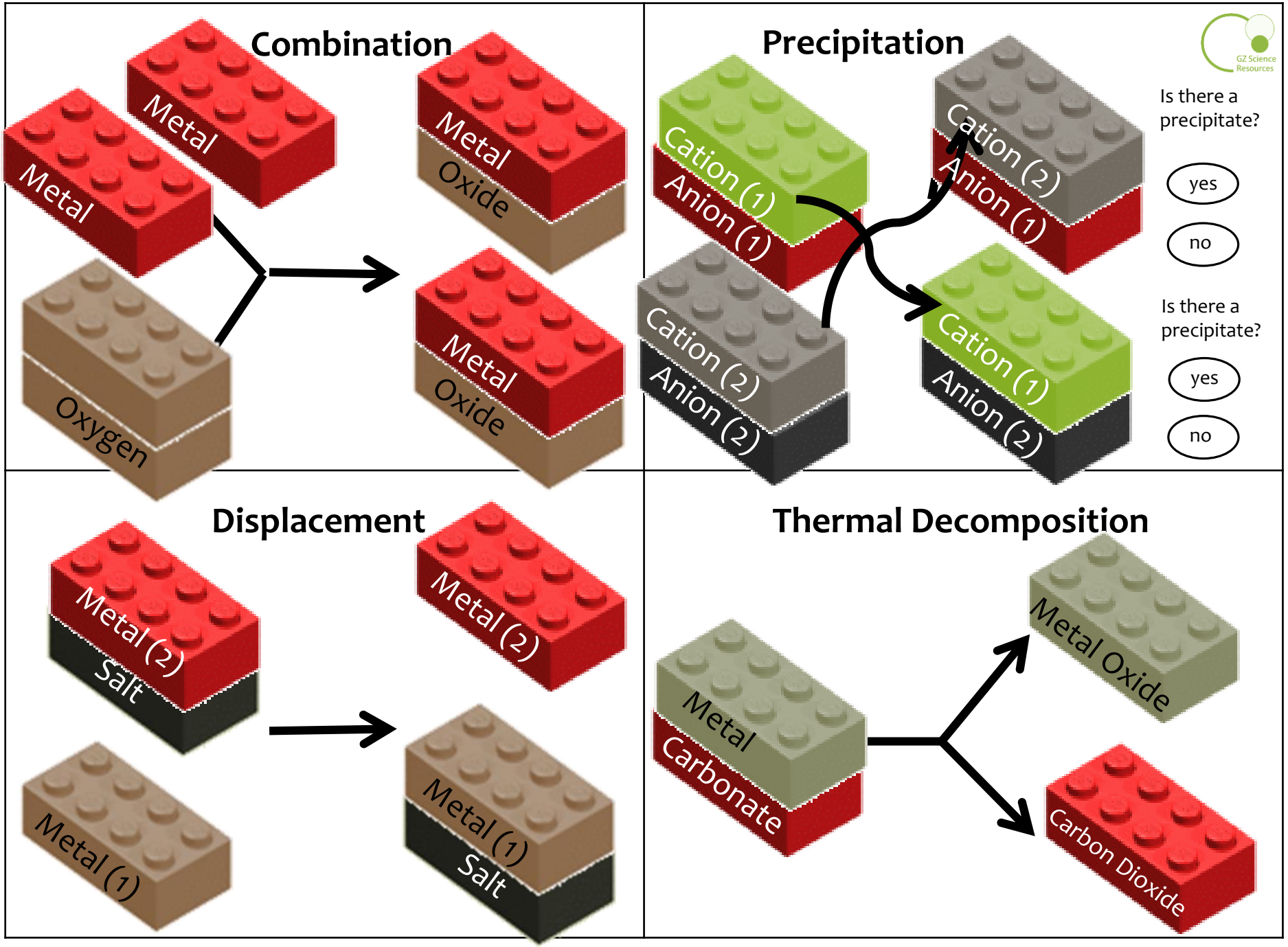
1. Identify the reactants from the question and write a word equation
   sodium chloride + lead nitrate → lead chloride + sodium nitrate

2. Justify your reaction type based on reactants and products formed. If a precipitate is formed use the **solubility rules** to select which of the products is the precipitate.
   all nitrates are soluble, all chlorides are soluble except silver and lead – so lead chloride is the precipitate

3. Write colours beside/underneath each reactant/product of each species – these will be collected from observation of the reaction (or memory/question)
   sodium chloride (colourless solution) lead nitrate (colourless solution) lead chloride (white precipitate) sodium nitrate(colourless solution)

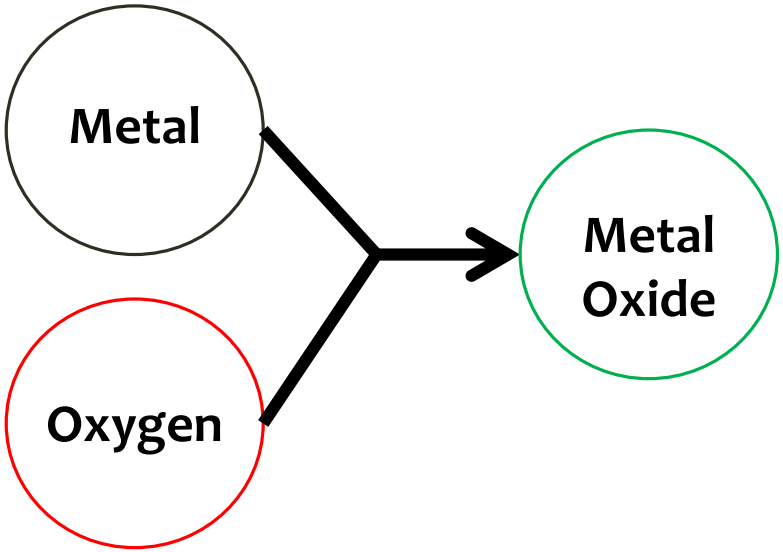
4. Write a comprehensive summary of this information

Sodium nitrate, a colourless solution^{-} is mixed with lead nitrate, a colourless solution and a white precipitate/solid is formed of lead chloride, because although most chlorides are soluble, lead chloride is an exception. The sodium nitrate formed remains as a colourless solution as the solubility rules state all nitrates are soluble. This is a precipitation reaction because the two solutions react together to form a solid that settles out of the solution. The solid formed is called the precipitate.

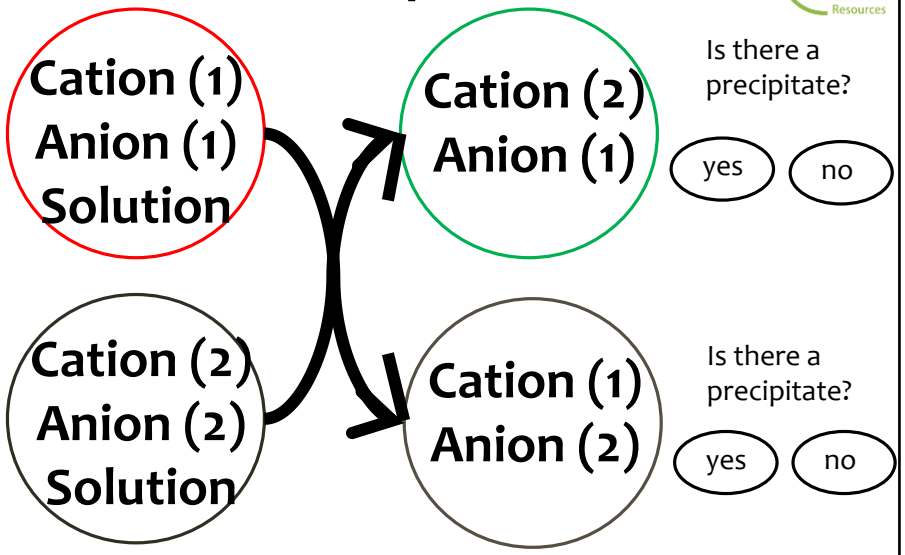

Combination
Metal
Metal
Oxygen
Metal
Oxide
Metal
Oxide
Precipitation
Cation (1)
Anion (1)
Cation (2)
Anion (2)
Cation (2)
Anion (1)
Cation (1)
Anion (2)
Is there a precipitate?
yes
no
Is there a precipitate?
yes
no
Displacement
Metal (2)
Salt
Metal (2)
Metal (1)
Metal (1)
Salt
Thermal Decomposition
Metal
Carbonate
Metal Oxide
Carbon Dioxide

Reaction summary

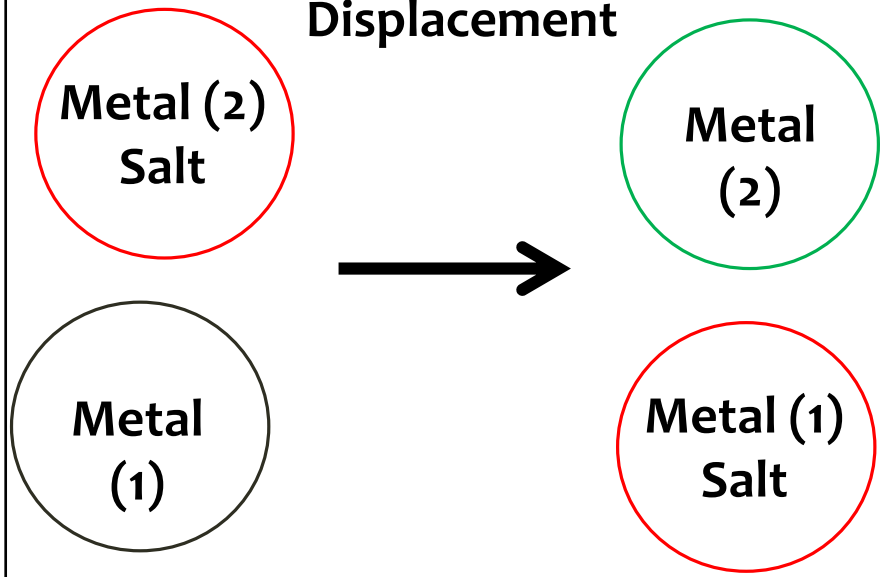
Combination



Precipitation



Displacement



Thermal Decomposition