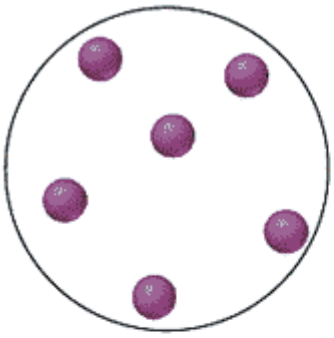
# 1.0 Basic Chemistry

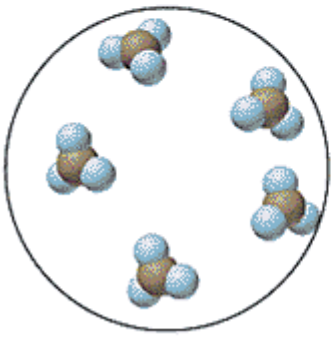
This is the chemistry you should already know from GCSE:

**Elements, mixtures and compounds:**

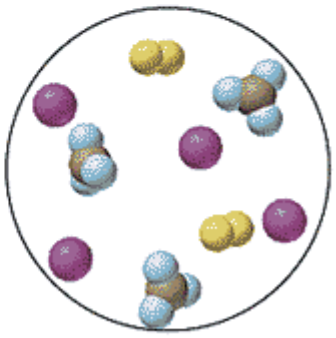


**A** Atoms of an element

**B** Molecules of an element



**C** Molecules of a compound



**D** Mixture of two elements and a compound

| | |
|---|---|
| **Atom** | Simplest building block of matter. |
| **Element** | Made up of 1 type of atom. |
| **Mixture** | 2 or more elements / compounds that are not chemically bonded together. They can be easily separated. |
| **Compound** | 2 or more elements chemically bonded together. |
| **Molecule** | 2 or more atoms chemically bonded together |

## Chemical formulae

### 1) Common molecules

| Name of element | Formula of element | Name compound | Formula of compound | Name of acid | Formula of acid |
|---|---|---|---|---|---|
| Hydrogen | $H_2$ | Water | $H_2O$ | Hydrochloric | HCl |
| Nitrogen | $N_2$ | Carbon dioxide | $CO_2$ | Nitric | $HNO_3$ |
| Oxygen | $O_2$ | Carbon monoxide | CO | Sulphuric | $H_2SO_4$ |
| Halogens | $X_2$ $Cl_2$ | Ammonia | $NH_3$ | Phosphoric | $H_3PO_4$ |

- All gases except Group 0, Noble gases go round in pairs as diatomic molecules.
- All Group VII elements, the Halogens, also go round in pairs as diatomic molecules.

### 2) Simple ions

| Group | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 0 |
|---|---|---|---|---|---|---|---|---|
| e's in outer shell | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Full |
| Gains / loses when reacts to leave a full shell | Loses 1e | Loses 2e | Loses 3e | Loses / gains 4e | Gains 3e | Gains 2e | Gains 1e | |
| Charge on ion | **+1** | **+2** | **+3** | **+/-4** | **-3** | **-2** | **-1** | |
| Example | $Li^+$ | $Be^{2+}$ | $B^{3+}$ | | $N^{3-}$ | $O^{2-}$ | $F^-$ | |

### 3) Compound ions

| Charge on ion | Name | Formula |
|---|---|---|
| **1-** | **Hydroxide** | **$OH^{1-}$** |
| | **Nitrate** | **$NO_3^{1-}$** |
| | **Hydrogen carbonate** | **$HCO_3^{1-}$** |
| **2-** | **Sulphate** | **$SO_4^{2-}$** |
| | **Carbonate** | **$CO_3^{2-}$** |
| **3-** | **Phosphate** | **$PO_4^{3-}$** |
| **1+** | **Ammonium** | **$NH_4^{1+}$** |

### 4) Transition metal ions

- These do not belong to a group so you are told the charge on the ion with a roman numeral

**Roman numerals**

| Charge | 1+ | 2+ | 3+ | 4+ | 5+ | 6+ | 7+ |
|---|---|---|---|---|---|---|---|
| **Roman numeral** | I | II | III | IV | V | VI | VII |

**Writing formula**

- The ions in a chemical formula must **add up to zero**.
- Use subscripts after an ion in a formula to double/triple that ion so the sum = 0. eg. $CuCl_2$
- If you are double/tripling ions that consist of more than one element brackets must be used. eg. $Ca(OH)_2$
- In **f**ormula – these are the numbers 'on the **f**loor'

**Examples:**

**a) Simple formula:**

- Use the Periodic table to look up the chemical symbols and the charges on the ions
- Scale up so the charges cancel out
- Non metal endings change to '**ide**'

**Sodium Chloride –**

| | | | |
|---|---|---|---|
| $Na^+$ | : | $Cl^-$ | Write the ions with charges |
| | | | Scale up if necessary to =0 |
| NaCl | | | Bring together omitting the charges |

**b) Complex formula:**

- One of the ions will **not** be on the Periodic table, it will be a **compound ion**.
- The formula is worked out the same as before.
- If you scale up compound ions, **you must use brackets**
- If you do note scale up compound ions, **you must NOT use brackets**

**Copper (II) Chloride**

| | | | |
|---|---|---|---|
| $Cu^{2+}$ | : | $Cl^-$ | Write the ions with charges |
| $Cu^{2+}$ | : | $Cl^-$ **x 2** | Scale up if necessary to =0 |
| $CuCl_2$ | | | Bring together omitting the charges |

**Calcium Hydroxide**

| | | | |
|---|---|---|---|
| $Ca^{2+}$ | : | $OH^-$ | Write the ions with charges |
| $Ca^{2+}$ | : | $(OH^-)$ **x 2** | Scale up if necessary to =0 |
| $Ca(OH)_2$ | | | Bring together omitting the charges |

**TIP: Once the formulae is written – NEVER CHANGE THE NUMBERS**

**Examples** – have a go at the following:

1 Calcium fluoride

2 Sodium oxide

3 Aluminium chloride

4 Gallium nitride

5 Magnesium hydroxide

6 Sodium nitrate

7 Sodium sulphate

8 Gallium carbonate

## Types of reactions

1. **Combustion –** A reaction with oxygen

   $CH_{4(g)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O(l)$

2. **Exothermic –** A reaction that releases heat energy to the surroundings

   $CH_{4(g)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O(l)$

3. **Endothermic –** A reaction that gains energy from the surroundings

   $6CO_{2(g)} + 6H_2O(l) \rightarrow C_6H_{12}O_{6(aq)}$

4. **REDOX –** A reaction where REDuction (is gain of electrons) and OXidsation (is loss of electrons) takes place

   $2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)}$

5. **Displacement –** Where a more reactive element 'displaces' a less reactive element

   $Cl_{2(aq)} + 2KI_{(aq)} \rightarrow I_{2(aq)} + 2KCl_{(aq)}$

6. **Decomposition –** Where a reactant breaks down into 2 or more products

   $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$

7. **Reversible –** A reaction where reactants → products or products → reactants

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

8. **Precipitation –** A reaction where aqueous reactants → solid insoluble product

   $Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$

9. **Acid reactions –** A reaction where an acid forms a salt

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **a)** | **Metal** | **+** | **Acid** | **→** | **Salt** | **+** | **Hydrogen** | | | |
| | **Na** | **+** | **HCl** | **→** | **NaCl** | **+** | **$H_2$** | | | |
| **b)** | **Metal Oxide** | **+** | **Acid** | **→** | **Salt** | **+** | **Water** | | | |
| | **$Na_2O$** | **+** | **2HCl** | **→** | **2NaCl** | **+** | **$H_2O$** | | | |
| **c)** | **Metal Hydroxide** | **+** | **Acid** | **→** | **Salt** | **+** | **Water** | | | |
| | **NaOH** | **+** | **HCl** | **→** | **NaCl** | **+** | **$H_2O$** | | | |
| **d)** | **Metal Carbonate** | **+** | **Acid** | **→** | **Salt** | **+** | **Water** | **+** | **Carbon dioxide** | |
| | **$Na_2CO_3$** | **+** | **2HCl** | **→** | **2NaCl** | **+** | **$H_2O$** | **+** | **$CO_2$** | |
| **e)** | **Ammonia** | **+** | **Acid** | **→** | **Ammonium salt** | | | | | |
| | **$NH_3$** | **+** | **HCl** | **→** | **$NH_4Cl$** | | | | | |

10. **Ionic equations –** Where the spectator ions are removed revealing the species involved in the reaction

**$OH^-_{(aq)}$ + $H^+_{(aq)}$ → $H_2O_{(l)}$**

**Balancing chemical equations**

- The acid reactions will be used as examples, a few connections first.

**Acid reactions –** A reaction where an acid forms a salt

**a) Metal + Acid → Salt + Hydrogen**

**b) Metal Oxide + Acid → Salt + Water**

**c) Metal Hydroxide + Acid → Salt + Water**

**d) Metal Carbonate + Acid → Salt + Water + Carbon dioxide**

**e) Ammonia + Acid → Ammonium salt**

**a)** $Na + HCl \rightarrow NaCl + H_2$

**b)** $Na_2O + 2HCl \rightarrow 2NaCl + H_2O$

**c)** $NaOH + HCl \rightarrow NaCl + H_2O$

**d)** $Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$

**e)** $NH_3 + HCl \rightarrow NH_3Cl$

**Chemical connections:**

**Water or Hydrogen**

- If you look at the reactants in **(a)**, you'll notice that the metal has **no oxygen present**.
- This means that water, $H_2O$ **cannot be formed, therefore** $H_2$ **is the product**
- If you look at the reactants in **(a) – (d)**, you'll notice that the metal **has oxygen present**.
- This means that water, $H_2O$ **can be formed, therefore** $H_2O$ **is the product**

**Carbon dioxide or not**

- If you look at the reactants in **(d)**, you'll notice that the metal has **3 oxygen's and 1 carbon present**.
- This means that water, $H_2O$ **can be formed, therefore** $H_2O$ **is the product**
- What is left is **1 carbon and 2 oxygen's, so** $CO_2$ **is also formed**

**All salts contain the following**

- A positive cation - usually a metal or ammonium ($NH_4^+$)
- A negative anion derived from an acid

**Salt – where the hydrogen ion in an acid is replaced with a metal or ammonium ion**

| **Acid** | Sulphuric | Nitric | Hydrochloric | Phosphoric |
|---|---|---|---|---|
| **Formula of acid** | $H_2SO_4$ | $HNO_3$ | $HCl$ | $H_3PO_4$ |
| **Salt** | ...sulphate | ...nitrate | ...chloride | …phosphate |
| **Formula …salt** | $...SO_4^{2-}$ | $...NO_3^{1-}$ | $...Cl^{1-}$ | $…PO_4^{3-}$ |

**Note – The number of acidic hydrogen's in the acid = the size of the negative charge on the anion formed:**

**Balancing chemical reactions:**

- **B**alance using **B**ig numbers **B**efore the species with that elements in to scale up the number of moles of reactants → products.
- A rule of thumb to help you balance is to balance the elements in this order - **MACHO:**
  **M**etal
  **A**ny other element
  **C**arbon
  **H**ydrogen
  **O**xygen

  A table helps.

Iron + Hydrochloric acid → Iron (II) chloride + Hydrogen

$Fe + 2HCl \rightarrow FeCl_2 + H_2$

| | | | | |
|---|---|---|---|---|
| **Fe** | 1 | | 1 | |
| **Cl** | | 1 **x** 2 **=** 2 | 2 | |
| **H** | | 2 | | 2 |

- Put the **2** that you have multiplied up by before the molecule with the element you are scaling up.
- You now have the same number of atoms on each side.

**State symbols**

- All that remains is to add state symbols to the balanced chemical reaction

| | |
|---|---|
| **Solid** | **(s)** |
| **Liquid** | **(l)** |
| **Gas** | **(g)** |
| **Aqueous (dissolved in water)** | **(aq)** |

$Fe_{(s)} + 2HCl_{(aq)} \rightarrow FeCl_{2(aq)} + H_{2(g)}$

- All metal elements are solids, (s).
- All acids are dissolved in water, (aq)
- All ionic compounds are either solids or dissolved in water, (s) or (aq)

  A rule of thumb:
  - Ionic compounds dissolve in water.
  - If there is water as a product or water as (aq) in the reactants then the ionic compound's state symbol will be (aq)

- Water is the solvent that (aq) chemistry takes place in. You cannot dissolve water in water so water is a liquid, (l)

**Summary:**

| | |
|---|---|
| **Step 1** | Write out the word equation |
| **Step 2** | Write the correct chemical formula |
| **Step 3** | Balance using **MACHO** |
| **Step 4** | Add the state symbols |

**Examples** – have a go at the following:

**1)** $Mg(OH)_2$ **+** **HCl** → $MgCl_2$ **+** $H_2O$

**2)** **MgO** **+** $HNO_3$ → $Mg(NO_3)_2$ **+** $H_2O$

**3)** $CaCO_3$ **+** $HNO_3$ →

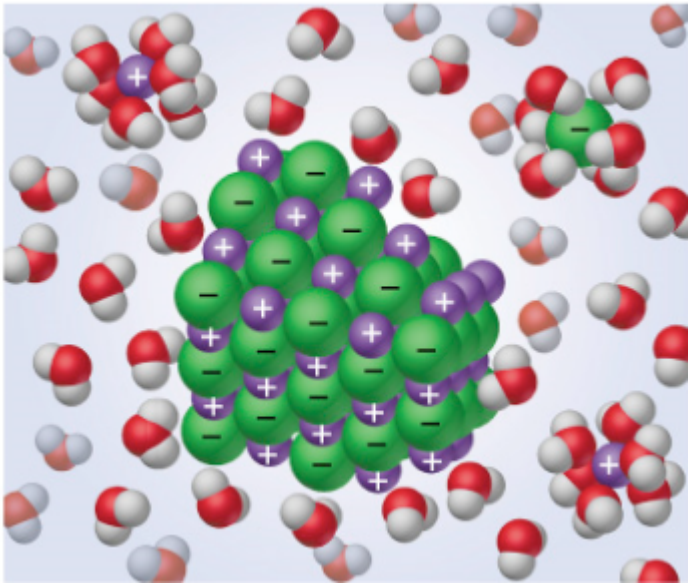
**4)** $Al_2O_3$ **+** $H_2SO_4$ →

**5)** **Sodium carbonate** **+** **Hydrochloric acid** →

**6)** **Gallium carbonate** **+** **Nitric acid** →

## Ionic equations

- Ionic compounds when dissolved in water separate out into their constituent ions
- For example – aqueous NaCl is actually a solution of $Na^+$ ions and $Cl^-$ ions as shown below: Click image for animation



- This allows us to look at the actual aqueous ions involved in the reaction.
- Ions that are not involved in reactions are called **spectator ions** as they do little more than 'watch' the reaction.

**Rules:**

1. **All acids are (aq) therefore can be written with their acidic hydrogens dissociated:**

   **$HCl_{(aq)}$ written as $H^+_{(aq)} + Cl^-_{(aq)}$**

   **$H_2SO_{4(aq)}$ written as $2H^+_{(aq)} + SO_4^{2-}{}_{(aq)}$**

2. **All soluble ionic compounds, (aq) ions dissociated:**

   **$NaCl_{(aq)}$ written as $Na^+_{(aq)} + Cl^-_{(aq)}$**

   **$K_2SO_{4(aq)}$ written as $2K^+_{(aq)} + SO_4^{2-}{}_{(aq)}$**

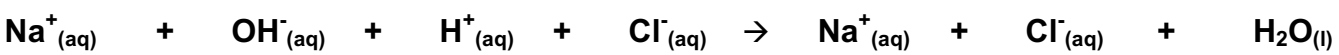
3. **All insoluble ionic compounds, (s) ions will NOT dissociated:**

   **$MgO_{(s)}$ written as $MgO_{(s)}$**

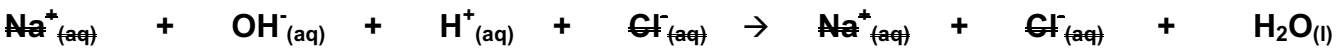
**Example 1:**

1) Write the full balanced chemical equation

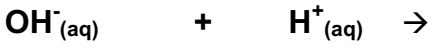
2) Separate any ionic or acids species found with an aqueous state symbols



3) Identify and cross out the spectator ions



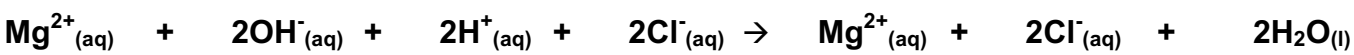
1) Rewrite the **balanced ionic equation** without the spectator ions



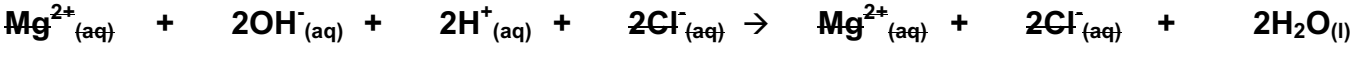
**Example 2:**

1) Write the full balanced chemical equation

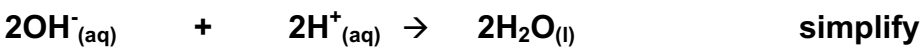
2) Separate any ionic or acids species found with an aqueous state symbols



3) Identify and cross out the spectator ions



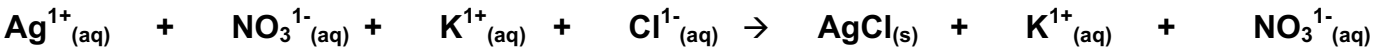
2) Rewrite the **balanced ionic equation** without the spectator ions



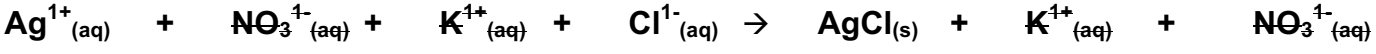
**Example 3: A precipitation reaction**

3) Write the full balanced chemical equation


4) Separate any ionic or acids species found with an aqueous state symbols




5) Identify and cross out the spectator ions




- **$AgCl_{(s)}$** is in an ionic lattice structure.
- **$Ag^{1+}_{(aq)}$ and $NO_3^{1-}{}_{(aq)}$** are dissociated ions
- As they are different, they are **not spectator ions and cannot be cancelled out**

6) Rewrite the **balanced ionic equation** without the spectator ions