KEY

1 - Chemical equations (part 1)

In mathematics an **equation** shows a relationship between the left- and right-hand sides, most of the time **equality**. This is shown using the = sign.

Chemical equations, on the other hand, show the **transformation** of a substance (in other words, a chemical reaction). A reaction is shown with the arrow symbol ⟶, with the starting materials ("reactants", "reagents") on the left, and the products on the right:

1. Using the arrow sign

reagents ⟶ products

ALSO CALLED OR STARTING MATERIAL / REACTANTS

SHORTHAND:
RGT | REAGENT
RXT | REACTANT
S/M. | STARTING MATERIAL
PRD | PRODUCT

Your first skill with a chemical reaction lies in transforming a verbal description into a chemical equation.

Prerequisite: common chemical names, state symbols.

(a) Two bromide ions react with chlorine (Cl_2) to give two chloride ions and bromine.

IMPLICIT

$$2\,Br^{\ominus} + Cl_2 \longrightarrow 2\,Cl^{\ominus} + Br_2$$

(b) In an aqueous solution, nitric acid combines with sodium hydroxide to give aqueous sodium nitrate and water.

WORLD ROUND

$$HNO_{3(aq)} + NaOH_{(aq)} \longrightarrow NaNO_{3(aq)} + H_2O_{(l)}$$

LIQUID AND NOT AQ: WATER IS ITSELF; NOT "DISSOLVED IN ITSELF"

(c) Solid calcium carbonate $CaCO_3$ reacts with two units of hydrochloric acid to produce water, carbon dioxide, and calcium chloride $CaCl_2$ solution.

$$CaCO_{3(s)} + 2\,HCl_{(aq)} \longrightarrow H_2O_{(l)} + CO_{2(g)} + CaCl_{2(aq)}$$

GASES AND SOLIDS CAN ALSO BE REPRESENTED AS ↑ AND ↓ TO SHOW THAT THEY ESCAPE OR PRECIPITATE

2. Adorning the arrow sign

A chemical reaction may only work when certain conditions are met. For example, a reaction may happen only when it is heated. These conditions are often specified above or below the arrow. Here are some common decorations:

Temperature $X \xrightarrow{T:100°C} Y$

Time $X \xrightarrow{t:5h} Y$. Case-sensitive!

Reflux Reflux means boiling the solution without it evaporating (how?? we'll show you later). This is shown with a symbol Δ: $X \xrightarrow{\Delta} Y$

UV light $X \xrightarrow{uv} Y$ or $X \xrightarrow{h\nu} Y$. You will see what the symbols $h\nu$ means in Topic 2.

Catalyst $X \xrightarrow{c:MnO_2} Y$ or $X \xrightarrow{cat:MnO_2} Y$. A catalyst doesn't get consumed so it is not part of the reaction.

Solvent $X \xrightarrow{s:H_2O} Y$

Prerequisite: common chemical names, state symbols, reaction arrow symbol.

(a) **At room temperature,** two bromide ions react with chlorine (Cl_2) to give two chloride ions and bromine.

$Br^{\ominus} + Cl_2 \xrightarrow{T:298K} 2Cl^{\ominus} + Br_2$

IT IS GENERALLY ASSUMED THAT ROOM TEMP. IS 25°C AND TEMP IS PREFERABLY EXPRESS AS KELVIN.

(b) Aqueous hydrogen peroxide H_2O_2 decomposes into water and oxygen gas O_2 when it is heated to 90 °C.

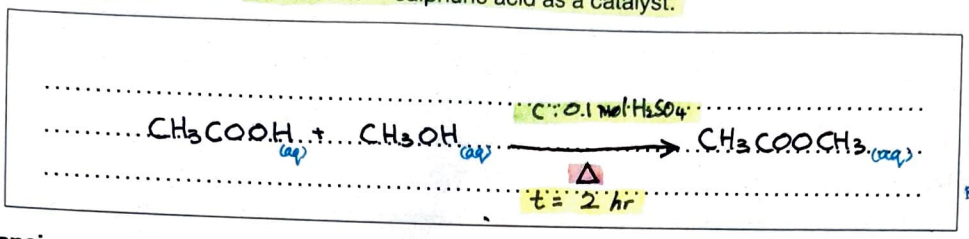
$H_2O_{2(aq)} \xrightarrow{T:363K} H_2O_{(l)} + O_2\uparrow$

NOTE THAT THE EQN IS NOT BALANCED!

(c) Aqueous hydrogen peroxide H_2O_2 decomposes into water and oxygen gas O_2 when manganese(IV) oxide $MnO_{2(s)}$ is added as a catalyst.

$H_2O_{2(aq)} \xrightarrow{c:MnO_{2(s)}} H_2O_{(l)} + O_2\uparrow$

(d) Ethanoic acid reacts with methanol to give $CH_3COOCH_{3(aq)}$, but only after being heated to reflux for 2 hours with 0.1 mol dm^{-3} sulphuric acid as a catalyst.



WRITE MULTIPLE CONDITIONS IN A VERTICAL STACK, ONE ON EACH LINE

BTW, THIS IS STILL NOT BALANCED! WHAT IS MISSING?

3. Balancing an equation

When you first write the equation, there may be different number of atoms on either side (see your unbalanced H_2O_2 reactions above). Because chemists only *transforming* but not *creating* matter (that's God's work), we must end with the same number of particles we start with. The skill of doing this is called "balancing an equation", and is an **iterative** process of changing the numbers in front of the chemical species (the "coefficients").

A general rule of thumb is to balance the atoms of different elements in the following sequence:

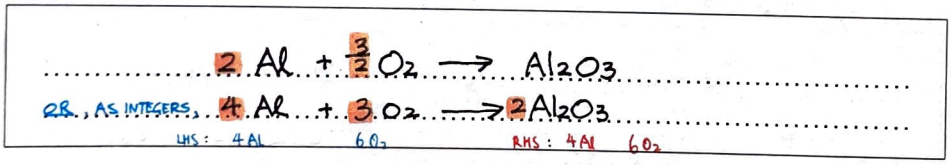
1. Atoms that are present in only one reactant and product
2. Oxygen atoms
3. Hydrogen atoms

Explicitly write down the number of atoms on both sides. This will help you prevent silly errors.

Later on there are cases where you need fractional coefficients, but for now, balance equations with whole numbers.

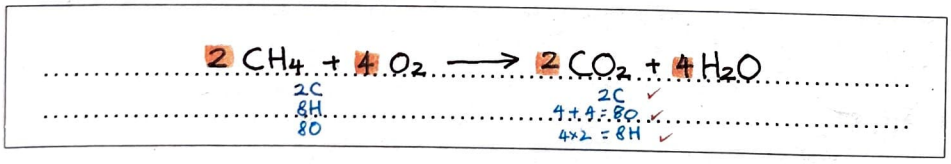
Prerequisite: common chemical names, state symbols, reaction arrow symbol.

(a) $Al + O_2 \longrightarrow Al_2O_3$



NOTE THAT WE CANNOT BALANCE BY WRITING Al_4O_6 — THAT WOULD BE ANS A DIFFERENT Q^{e}.

(b) $CH_4 + O_2 \longrightarrow CO_2 + H_2O$



(c) $N_2 + H_2 \longrightarrow NH_3$

$N_2 + 3H_2 \longrightarrow 2NH_3$

(d) $Fe_2O_3 + CO \longrightarrow Fe + CO_2$

$Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$

(e) $SeCl_6 + O_2 \longrightarrow SeO_2 + Cl_2$

$SeCl_6 + O_2 \longrightarrow SeO_2 + 3Cl_2$

(f) $SnO_2 + H_2 \longrightarrow Sn + \cancel{2}H_2O$

$SnO_2 + 2H_2 \longrightarrow Sn + 2H_2O$

(g) $KNO_3 + H_2CO_3 \longrightarrow K_2CO_3 + HNO_3$

$2KNO_3 + H_2CO_3 \longrightarrow K_2CO_3 + 2HNO_3$

4. Balancing a combustion equation

There is no **universal** method to predict what the products of a reaction is. As such, you will always be given at least *some* of the products.

However, for **selected** reactions you can predict what the products and missing reagents are. Two classes you will encounter includes:

combustions When substances are burnt. O_2 is always a reagent, and for **complete** combustion the products are CO_2 and H_2O.

INCOMPLETE COMBUSTIONS, WHEN NOT ENOUGH O_2 IS AVL., GIVES $CO + H_2O$ OR $C + H_2O$ AS PRODUCTS

neutralization When acids react with bases.

(a) Balance the reaction for the complete combustion of C_2H_6

$C_2H_6 + \frac{7}{2}O_2 \rightarrow 2CO_2 + 3H_2O$

OR $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$

(b) Balance the reaction for the complete combustion of benzene.

1. WRITE UNBALANCED RXN: $C_6H_6 + O_2 \rightarrow CO_2 + H_2O$
2. BALANCE C, H: $1C_6H_6 + O_2 \rightarrow 6CO_2 + 3H_2O$
3. BALANCE O: $C_6H_6 + \frac{15}{2}O_2 \rightarrow 6CO_2 + 3H_2O$ (IMPLICIT)

(c) Balance the reaction for the complete combustion of methanol.

1. $CH_3OH + O_2 \rightarrow CO_2 + H_2O$
2. $1CH_3OH + O_2 \rightarrow 1CO_2 + 2H_2O$
3. $1CH_3OH + \frac{6}{2}O_2 \rightarrow 1CO_2 + 2H_2O$

(d) Balance the reaction for the complete combustion of H_2. How is this reaction an exception to the general rule of combustion?

$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$

NO CARBONS PRESENT, $\therefore$ NO CO_2 AS PRODUCT.

5. **Balancing an acid-hydroxide neutralization equation**

Aqueous strong acids like $H^+Cl^-_{(aq)}$ reacts with hydroxides like $Na^+OH^-_{(aq)}$ to give (1) water and (2) a salt. Here you need to identify the salt from the spectator ("leftover") ions:

$$H^+Cl^-_{(aq)} + Na^+OH^-_{(aq)} \longrightarrow H_2O_{(l)} + Na^+Cl^-_{(aq)}$$

(a) Write a balanced equation for the reaction between nitric acid and sodium hydroxide.

$H^+NO_3^-_{(aq)} + Na^+OH^-_{(aq)} \rightarrow H_2O_{(l)} + Na^+NO_3^-_{(aq)}$

(b) Write a balanced equation for the reaction between sulphuric acid and potassium hydroxide.

1 UNBALANCED EQN: $H_2SO_4 + KOH \rightarrow H_2O_{(l)} + K_2SO_4$

2 BALANCE: $H_2SO_4 + 2\,KOH \rightarrow 2\,H_2O_{(l)} + K_2SO_4$