Reactions can be categorized as Physical or Chemical

Physical reactions occur when a substance transitions from one physical state to another (e.g. water boiling)

* There is NOT a change in the molecule, ONLY intermolecular interactions

$H_2O_{(l)} \longrightarrow H_2O_{(g)}$

Subscripts indicate phase
s = solid, l = liquid, g = gas
aq = aqueous

Chemical reactions occur when the atomic composition of a molecule changes

$$\underbrace{2Na_{(s)} + Cl_{2(g)}}_{\text{Reactants}} \longrightarrow \underbrace{2NaCl_{(s)}}_{\text{Products}}$$

Rules for writing chemical reactions (or physical reactions):

1. Physical states must be shown
2. matter must be conserved
   ↳ If you have 2 Na atoms in your reactants, you must have 2 in the products

Balancing chemical reaction:

$$4Al + 3O_2 \longrightarrow 2Al_2O_3$$

Al	$\cancel{1}$ 4		$\cancel{2}$ 4
O		$\cancel{2}$ 6	$\cancel{3}$ 6

$$C_3H_{4(g)} + 4O_{2(g)} \longrightarrow 3CO_{2(g)} + 2H_2O_{(l)}$$

C	3		$\cancel{1}$ 3		
H	4			$\cancel{2}$ 4	
O		$\cancel{2}$ 8	$\cancel{2}$ 6	$\cancel{1}$ 2	= 8

$$2Na_{(s)} + 2H_2O_{(l)} \longrightarrow 2NaOH_{(aq)} + H_{2(g)}$$

Na	$\cancel{1}$ 2 ✓		$\cancel{1}$ 2 ✓	
H		$\cancel{2}$ 4 ✓	$\cancel{1}$ 2	2 = 4 ✓
O		$\cancel{1}$ 2 ✓	$\cancel{1}$ 2 ✓	

You should be comfortable converting verbal descriptions of chemical reactions to a chemical equation

Solid Phosphorus reacts with oxygen to form Tetraphosphorus decaoxide solid

$$4P_{(s)} + 5O_{2(g)} \longrightarrow P_4O_{10\,(s)}$$

Types of chemical reactions:

Synthesis: $X + Y \rightarrow Z$ $CO_2(g) + H_2O(l) \rightarrow H_2CO_3(aq)$

two or more compounds
react to form one

Decomposition: $Z \rightarrow X + Y$ $2ZnO_{(s)} \rightarrow 2Zn(s) + O_2(g)$

- opposite of synthesis
- one compound breaks apart to form two or more new compounds

Single Replacement $XY + Z \rightarrow X + ZY$ $Na_{(s)} + KCl_{(aq)} \rightarrow K_{(s)} + NaCl_{(aq)}$

- one component of a binary compound exchanges with a monoatomic molecule } commonly ion exchange

Double Replacement $AB + XY \rightarrow AY + BX$ $NaCl + KBr \rightarrow NaBr + KCl$

- Cations in ionic compounds switch place

Combustion $C_xH_y + zO_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$ $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

- Hydrocarbon reacts with molecular oxygen; CO_2 & H_2O are produced

We can also use the mol unit to relate the amount of products and reactants in a chemical reaction:

Stoichiometric coefficient

$$MgO + \boxed{2}NaCl \rightarrow MgCl_2 + Na_2O$$

If I have 10 moles of MgO and excess NaCl, how much $MgCl_2$ can we produce?

- use the stoichiometric as a conversion factor: 1 mol MgO = 1 mol $MgCl_2$

$$\frac{10\ \cancel{\text{mol MgO}}}{} \left| \frac{1\ \text{mol } MgCl_2}{1\ \cancel{\text{mol MgO}}} \right. = 10\ \text{mol } MgCl_2$$

What if we have 10 moles of NaCl and excess MgO, how much $MgCl_2$ will be produced

$$\frac{10\ \text{mol NaCl}}{} \left| \frac{1\ \text{mol } MgCl_2}{2\ \text{mol NaCl}} \right. = 5\ \text{mol } MgCl_2$$

Since it takes 2 moles of NaCl to produce 1 mol of $MgCl_2$, we only get 5 moles

$$4Al_{(s)} + 3O_{2(g)} \rightarrow 2Al_2O_{3(s)}$$

Starting with 0.1 mol Al:

This is the central conversion in stoichiometry calculations!

how much O_2 is consumed?

$$\frac{0.1\ \text{mol Al}}{} \left| \frac{3\ \text{mol } O_2}{4\ \text{mol Al}} \right. = 0.075\ \text{mol } O_2 \text{ consumed}$$

how much Al_2O_3 can be produced?

$$\frac{0.1\ \text{mol Al}}{} \left| \frac{2\ \text{mol } Al_2O_3}{4\ \text{mol Al}} \right. = 0.05\ \text{mol } Al_2O_3 \text{ produced}$$

Sticking with the same reaction: $4Al_{(s)} + 3O_{2(g)} \rightarrow 2Al_2O_{3(s)}$

Determine how many moles of Al_2O_3 can be produced if 10 mol of Al + 10 mol O_2 are combined.

In this case, we are told an amount of 2 different reactants. We can NOT assume that they both run out at the same time.

(think about running out of gas or not having enough bread to make a sandwich)

Convert EACH reactant to product. Determine the lowest amount of product possible.

$$\frac{10 \text{ mol Al} \mid 2\ Al_2O_3}{\mid 4\ Al} = \underline{5 \text{ mol } Al_2O_3}$$

$$\frac{10 \text{ mol } O_2 \mid 2\ Al_2O_3}{\mid 3\ O_2} = 6.67\ Al_2O_3$$

When 5 mol of Al_2O_3 is produced, ALL of the Al is used up. No more product can be made.

Al is the Limiting Reactant

How much O_2 is left over?

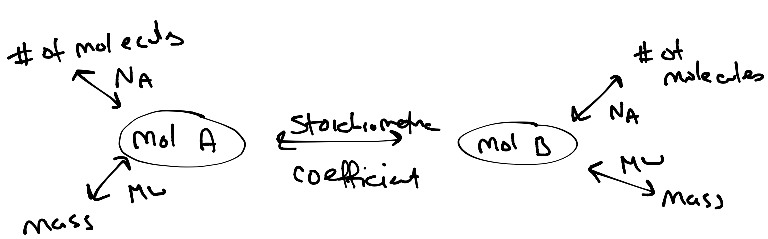
5 mol Al_2O_3 is made, so determine how much O_2 went into it.

$$\frac{5 \text{ mol } Al_2O_3 \mid 3\ O_2}{\mid 2\ Al_2O_3} = \underline{7.5 \text{ mol } O_2}$$

↳ this is the amount of O_2 that was used!

$$\underset{\text{(start)}}{10 \text{ mol } O_2} - \underset{\text{(used)}}{7.5 \text{ mol } O_2} = \underset{\text{(left)}}{2.5 \text{ mol } O_2}$$

These are the core conversions in chemical reaction calculations. You can use the core calculations in many forms, but remember, you are Always going to use the mole to relate amounts of products and reactants



If 1.00 g Al + 1.00 g O_2 are mixed together and allowed to completely react, determine:

① The mass of Al_2O_3 produced (1.89 g)
② The mass of Al remaining when the reaction completes (Ø g)
③ The mass of O_2 remaining when the reaction completes (0.11 g)

Determine the L.R. → this is simple. You need to do two calculations to determine the mass of Al_2O_3 that can be produced. The smallest number is the mass that can be made!

Starting with Al:

$$\frac{1.00\ g\ Al}{} \left| \frac{1\ mol\ Al}{26.98\ g\ Al} \right| \frac{2\ mol\ Al_2O_3}{4\ mol\ Al} \left| \frac{101.96\ g\ Al_2O_3}{1\ mol\ Al_2O_3} \right. = 1.89\ g\ Al_2O_3$$ can be made

this is the answer to ①

Starting with O_2:

$$\frac{1.00\ g\ O_2}{} \left| \frac{1\ mol\ O_2}{32\ g\ O_2} \right| \frac{2\ mol\ Al_2O_3}{3\ mol\ O_2} \left| \frac{101.96\ g\ Al_2O_3}{1\ mol\ Al_2O_3} \right. = 2.12\ g\ Al_2O_3$$

Since 1.00 g Al can only produce 1.89 g Al_2O_3, it is the L.R.

Strategy for ② + ③ : Initial mass − mass used = mass remaining

this is already known

Al = L.R., so ALL of it was consumed → Initial mass = mass used
so nothing remains

③ $$\frac{1.89\ g\ Al_2O_3}{} \left| \frac{1\ mol\ Al_2O_3}{101.96\ g\ Al_2O_3} \right| \frac{3\ mol\ O_2}{2\ mol\ Al_2O_3} \left| \frac{32\ g\ O_2}{mol\ O_2} \right. = 0.89\ g\ O_2$$ ← O_2 used

mass left = 1.00 g − 0.89 g = 0.11 g O_2

- We've been talking about calculations of amounts of products/reactants using a balanced chemical equation:

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

The central conversion is mol → mol

Start with 10 mol N_2 + 35 mol H_2. How much NH_3 is made?

$$\frac{10 \text{ mol } N_2 \mid 2 \text{ mol } NH_3}{\mid 1 \text{ mol } N_2} = 20 \text{ mol } NH_3$$

$$\frac{35 \text{ mol } H_2 \mid 2 \text{ mol } NH_3}{\mid 3 \text{ mol } H_2} = 23.33 \text{ mol } NH_3$$

* so N_2 runs out first *

N_2 is the Limiting Reactant

How much H_2 left?

$$\frac{10 \text{ mol } N_2 \mid 3 \text{ mol } H_2}{\mid 1 \text{ mol } N_2} = 30 \text{ mol } H_2 \text{ consumed}$$

$$\underset{\text{start}}{35 \text{ mol}} - \underset{\text{consumed}}{30 \text{ mol}} = 5 \text{ mol } H_2 \text{ left}$$