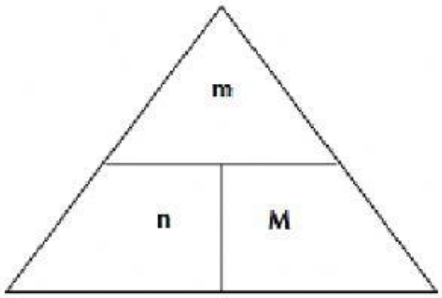
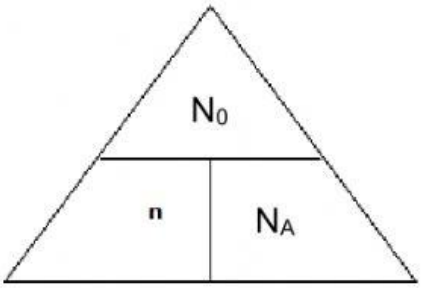
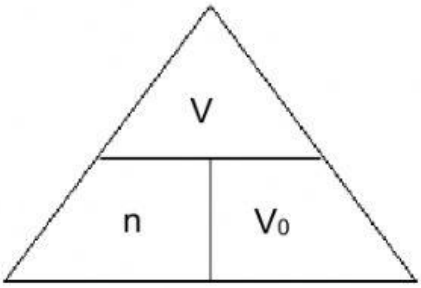
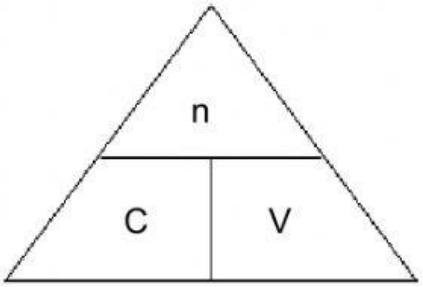
Mole – Part 6

We have now learnt all 4 formulae that we will make use of for mole calculations. These can be represented by the 4 triangles which you should have written into your notes:









(**These formulae will be given in the data sheet in an exam, but the triangles will not.)

We are now going to learn how to use these calculations in chemical reactions. You will need to be confident in <u>balancing equations</u> for this section!

<u>Stoichiometry:</u>

- A chemical equation is a chemical balance sheet for a chemical reaction
- The relationship of how the substances react (ratios) is known as **stoichiometry**
- The numbers in front of the substances are known as the **stoichiometric coefficients**
- These give the proportions in which the substances react and the proportions of products formed

Stoichiometry is the calculation of relative quantities of reactants and products in chemical reactions.

- **Start with <u>balanced</u> equations**

Balance the following equation (use a 1 if no other number is required):

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

- **<u>Coefficients</u> of equation give you the <u>mole ratio</u>**

So **1 mole $CaCO_3$** will react with **2 moles HCl** to produce **1 mole of $CaCl_2$**, **1 mole of CO_2** and **1 mole of H_2O**. We call this the **mole ratio** because it is the ratio in which the substances will always react with each other.

We can never work with MASS ratios because the masses of reactants do not combine in fixed ratios due to the different molar mass of each substance. We must ALWAYS convert to moles before working with these ratios.

<u>Mole ratio calculations:</u>

1.) $2H_2 + O_2 \rightarrow 2H_2O$

This means that the ratio is:

2 moles of H_2 will react with 1 mole of O_2 to produce 2 moles of H_2O

20 moles of H_2 will react with 10 moles of O_2 to produce 20 moles of H_2O

40 moles H_2 will react with 20 moles O_2 to produce 40 moles of H_2O

_____ moles of H_2 + 3 moles of O_2 → 6 moles of H_2O

8 moles of H_2 + _____ moles of O_2 → 8 moles of H_2O

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

1 mole of N_2 will react with 3 moles of H_2 to form 2 moles of NH_3

4 moles of N_2 + _____ moles of H_2 → _____ moles of NH_3

Exercise on mole ratio:

Use simple ratios to calculate the number of moles that will react in the following reactions.

1.) $2\,SO_2 + O_2 \rightarrow 2\,SO_3$

8 moles + _____ moles → moles

2.) $4\,NH_3 + 5\,O_2 \rightarrow 4\,NO + 6\,H_2O$

÷4 x5

Hint: 2 decimal places

3 moles + _____ moles → _____ moles + 4,5 moles

3.) $\mathbf{1\,CH_4(g) + 2\,O_2(g) \rightarrow 1\,CO_2(g) + 2\,H_2O(g)}$

8 moles + _____ moles → 8 moles + _____ moles

4.) $H_2SO4\ (aq) + 2NH_3\ (g) \rightarrow (NH_4)_2SO_4$

6 moles + 12 moles → _____ moles

5.) $N_2 + 3H_2 \rightarrow 2NH_3$

2 moles + _____ moles → _____ moles

Now express this as mass NH_3 produced:

$m(NH_3) = n \times M =$ _____ g NH_3
(using the mass/mole triangle)

6) $2H_2 + O_2 \rightarrow 2H_2O$

_____ moles + 3 moles → _____ mol = _____ **g**

7.) $2\,Al + 3\,Cl_2 \rightarrow 2\,AlCl_3$

108 g Al + chlorine → _____ **g**

n (Al) = m/M = 108 / 27 = 4 mol

n ($AlCl_3$) = n (Al) ÷2 x2 = 4 mol

m ($AlCl_3$) = n x M = 4 x _____ = _____ g

(you need to convert mass of Al to moles, work out the moles of $AlCl_3$ and then mass of $AlCl_3$.)

8.) $2H_2 + O_2 \rightarrow 2H_2O$

Excess of H_2 + 16g of O_2 → _____ g of H_2O

We will follow this format every time we do a mole ratio problem:

- Balance the equation
- Coefficients of equation give you the mole ratio
- Calculate the molar mass of the reactants
- Calculate the number of moles of the given substance
- Apply the mole ratio to determine no. of moles of substance you are looking for
- Convert back to grams or volume as required

We set the calculations out in a table format – see the example below. Check each step in the procedure above and see how it ties in to the calculations in the table.

Example 1:

Calculate the mass of oxygen obtained when 29,4g potassium chlorate decomposes completely to potassium chloride:

We don't do any calculations for KCl because it was not part of the question.

	$KClO_3$	→	KCl	+	O_2
GIVEN:					
Mole ratio:	2		2		3 (from the balancing)
Mass:	29,4g				
Molar mass:	122,5 $g.mol^{-1}$				32 $g.mol^{-1}$
No. of moles:	n = m/M = / = mol				
PRODUCE:					
No. of moles:					0,24 mol **÷2x 3** = 0,36 mol
Mass:					m = n x M = 0,36 x 32 = g

This part of the calculation is where we use the mole ratio from the balanced equation to change the number of moles reactant into the number of moles product. The values come from the coefficient in the balanced equation.
Take the no. of moles of reactant,
÷ coefficient of reactant and x coefficient of product.
So ÷ by the one you know and x by the one you are calculating.

Your answer!

Example 2:

A sample of limestone ($CaCO_3$) of mass 200g is treated with excess dilute hydrochloric acid (HCl). Calculate what mass of carbon dioxide should be formed.

(Step 1: Balance the equation)

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

GIVEN:

Mole ratio:

Mass: 200g

Molar mass: $g.mol^{-1}$

No. of moles: n = m/M

= /

= mol

PRODUCE:

No. of moles: mol ÷ x = mol

Mass: m = n x M

= x

= g

Example 3:

A sample of impure limestone ($CaCO_3$) of mass 200g is treated with excess dilute hydrochloric acid (HCl). Calculate what volume of carbon dioxide should be formed.

$$CaCO_3 + \mathbf{2}\,HCl \rightarrow CaCl_2 + CO_2 + H_2O$$

GIVEN:					
Mole ratio:	1			1	
Mass:	200 g				
Molar mass:	100 $g.mol^{-1}$			44 $g.mol^{-1}$	
No. of moles:	n = 2 mol				
PRODUCE:					
No. of moles:			mol ÷	x =	mol
Volume:			V = n x V_0		
			=	x	
			=	dm^3	

Mole/mass ratio exercises:

Use the tabular method shown above to do the following calculations in your notebooks. (These exercises are from your printed notes.)

Pg 151

Question 7

$H_2 + O_2 \rightarrow H_2O$

7.1 How many moles of H_2O are formed when 5 moles of O_2 react with excess H_2

7.2 What mass of H_2O is formed when 5 moles of O_2 react with excess H_2

Question 8

$H_2 + O_2 \rightarrow H_2O$

8.1 What mass of H_2 is needed to react with 64g of O_2

Question 9

$H_2 + O_2 \rightarrow H_2O$

9.1 What volume of O_2 at STP is required to react with 11,2dm^3 of H_2

Pg 143

1. Consider the following reaction: $N_2 + 3\,H_2 \rightarrow 2\,NH_3$.

   Determine the number of moles of ammonia which form when 2 moles of nitrogen react with sufficient hydrogen.

2. Potassium chlorate, $KClO_3$, is heated to produce potassium chloride and oxygen.
   Here is the unbalanced equation: $KClO_3 \rightarrow KCl + O_2$

   What mass of $KClO_3$ should be heated to produce 24,0 g of oxygen?

3. Calculate the mass of SO_2 formed when 2,4 kg of sulphur are burned completely in oxygen.
   Here is the chemical equation: $S + O_2 \rightarrow SO_2$

4. If 160 g of SO_2 reacts with sufficient O_2, how much SO_3 will be formed?

   Here is the unbalanced equation: $SO_2 + O_2 \rightarrow SO_3$

Mole/No of particles ratio exercises (pg 147)

1. Consider the following reaction: $N_2 + 3\,H_2 \rightarrow 2\,NH_3$.

a. Determine the number of moles of ammonia which form when 8 moles of nitrogen react with sufficient hydrogen.

b. Determine the number of moles of ammonia that are formed when $1{,}6 \times 10^{24}$ molecules of hydrogen react with sufficient oxygen.

2. Potassium chlorate, $KClO_3$, is heated to produce potassium chloride and oxygen.

Here is the chemical equation: $KClO_3 \rightarrow KCl + O_2$

Calculate the number of molecules of oxygen produced, if 5 moles of $KClO_3$ decompose to form potassium chloride and oxygen.

Eg1 Consider the following reaction:

$$\mathbf{CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g)\ + 2\ H_2O(g)}$$

Calculate the number of molecules of water produced when 0,5 dm^3 of methane is burned in O_2

Mole/Volume ratio exercise

Pg 132

7.6) Consider the following reaction:
$2NH_4NO_3\ (s) \rightarrow 2N_2(g) + 4H_2O(g) + O_2(g)$
If 3 moles of NH_4NO_3 decomposes, calculate the volume of O_2 that forms at STP.

7.7) Consider the following reaction
$2C_8H_{18}(g) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)$
If 342,54 g of C_8H_{18} combusts, calculate the mass of CO_2 that forms

7.8) Consider the following reaction
$2NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$
If 5,5 moles of NaN_3 decomposes, then calculate the mass of Na that forms