**Year 10 Chemical Sciences**

**Week 9 and 10 – The Mole**

**Objectives:**

* Define and locate (from a periodic table) the atomic mass of the elements
* Define the mole in terms of Avogadro’s number of particles
* Use the relationship No. of particles = n x 6.02 x 1023 to convert between numbers and moles
* Determine the Molar mass of a substance given its formula
* Calculate the moles of a substances from its mass using n = m / M
* Use the coefficients in a balanced chemical equation to write the mole relationship for the molar amounts of any two substances appearing in a balanced chemical equation.
* Perform calculations on equations relating the amounts of any two substances. Types of calculations:
	+ *Mole to mole*

**The Mole**

The word **mole** represents a **number** and has the symbol “mol”. It is a unit of measurement; just as the word dozen represents 12, the word mole represents 6.02 x 1023 (or 602 000 000 000 000 000 000 000).

Therefore the number of atoms or ions in one mole of an element is 6.02 x 1023 atoms. For example:

1 mol of sulfur trioxide (SO3) molecules contains:

* 1 mol of SO3 molecules
* 6.02 x 1023 SO3 molecules
* 1 mol of S atoms
* 6.02 x 1023 S atoms
* 3 mol of O atoms
* 1.806 x 1024 O atoms

This number used to represent a mole came about through the experimentation of Amedeo Avogadro when he discovered there was 6.02 x 1023 atoms of carbon found in 12 grams of the carbon 12 isotope. Thus 6.02 x 1023 is often referred to as Avogadro’s number.

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**Changing moles to numbers of particles**

If we wish to convert the number of particles of a substance into moles we can use the following formula. You need to memorise this formula as it is not given to you on your data sheet.

Where: n = the number of moles (mol)

$$n= \frac{N}{6.02 x 10^{23}}$$

 N = the number of particles

**EXAMPLE 1:** How many **moles** of sodium are in a sample containing 1.204 x 1024 atoms?

n = N **÷** 6.02 x 1023

 = 1.204 x 1024 **÷** 6.02 x 1023

 = 2 mol of sodium

**EXAMPLE 2:** How many **particles** are there in 3.5 moles of a substance?

Rearranging the equation gives:

N = n x 6.02 x 1023

 = 3.5 x 6.02 x 1023

 = 2.107 x 1024 particles

**EXAMPLE 3:** How many atoms of carbon are there in 2 moles of Aluminium Carbonate?

The formula for Aluminium Carbonate is Al2(CO3)3. Therefore in each molecule of Al2(CO3)3 there are three atoms of carbon. This means that in 1 mole of Al2(CO3)3 there must be 3 moles of Carbon.

Rearranging the equation gives:

N = n x 6.02 x 1023

 = 3 x 6.02 x 1023

 = 1.806 x 1024 atoms of Carbon in 1 mole of Al2(CO3)3.

**Relative Atomic Mass (Ar)**

The relative atomic mass of an element can be located on your **periodic table** below the symbol for that element. It is equal to the average mass of one atom of the element compared to one twelfth the mass of an atom of carbon-12.

**EXAMPLE 1:** Use the periodic table to determine the relative atomic mass of the following elements.

* Sodium Ar (Na) = 22.99
* Chlorine Ar (Cl) = 35.45
* Aluminium Ar (Al) = 26.98
* Oxygen Ar (O) = 16.00

**Relative Formula Mass (Mr)**

The relative formula mass of a substance is calculated by adding the relative masses of all of the atoms in the formula. To get the correct formula mass you must have the correct formula, this is yet another reason why knowing your ions is so crucial!

**EXAMPLE 1:** Use the periodic table to determine the relative formula mass of sodium chloride.

Mr (NaCl) = 22.99 + 35.45 = 58.44

**EXAMPLE 2:** Use the periodic table to determine the relative formula mass of aluminium chloride.

Mr (AlCl3) = 26.98 + (3 x 35.45) = 133.33

**EXAMPLE 3:** Use the periodic table to determine the relative formula mass of sodium oxide.

Mr (Na2O) = (2 x 22.99) + 16.00 = 61.98

**EXAMPLE 4:** Use the periodic table to determine the relative formula mass of aluminium oxide.

Mr (Al2O3) = (2 x 26.98) + (3 x 16.00) = 101.96

**Molar Mass (Mr)**

Molar mass is the mass of one mole of a substance. The value for molar mass is calculated the same way as Relative Atomic Mass and Formula Mass but has the units grams per mole after it. (g mol-1)

**EXAMPLE 1:** Use the periodic table to determine the molar mass of aluminium sulfate.

 Mr (Al2(SO4)3) = (2 x 26.98) + (3 x 32.06) + (12 x 16.00) = 342.14 g mol-1

**EXAMPLE 2:** Use the periodic table to determine the molar mass of ammonium nitrate.

Mr (NH4NO3) = (2 x 14.01) + (4 x 1.008) + (3 x 16.00) = 80.052 g mol-1

**Changing mass to moles**

If we wish to know the number of moles of a substance in a given mass of that substance we can calculate it using the following formula. You need to memorise this formula as it is not given to you on your data sheet.

$$n= \frac{m}{M\_{r}}$$

Where: n = the number of moles (mol)

 m = the mass in grams(g)

Mr = the molar mass (g mol-1)

**EXAMPLE 1:** Calculate the number of moles of aluminium chloride in 500 grams of aluminium chloride.

Step 1: Write down what you know.

m (AlCl3) = 500 g

Mr (AlCl3) = 26.98 + (3 x 35.45) = 133.33 g mol-1

n (AlCl3) = ?

Step 2: Write down the correct formula

$$n= \frac{m}{M\_{r}}$$

Step 3: Substitute in the values

 n = 500 ÷ 133.33

Step 4: Solve and add the correct units

 n = 3.75 mol

**EXAMPLE 2:** Calculate the number of moles of water in 600 grams of water.

Step 1: m (H2O) = 600 g

Mr (H2O) = (2 x 1.008) + 16 = 18.016 g mol-1

n (H2O) = ?

Step 2: $n= \frac{m}{M\_{r}}$

Step 3: n = 600 ÷ 18.016

Step 4: n = 33.3 mol

**Changing moles to mass**

If we wish to know the mass of a given numbers of moles of a substance we can calculate it by rearranging the previous formula.

$n= \frac{m}{M\_{r}}$ becomes $\rightarrow $ $m= n x M\_{r}$

Where: n = the number of moles (mol)

 m = the mass in grams(g)

Mr = the molar mass (g mol-1)

**EXAMPLE 1:** Calculate the mass of aluminium chloride in 2.5 moles of aluminium chloride.

Step 1: Write down what you know.

n (AlCl3) = 2.5 mol

Mr (AlCl3) = 26.98 + (3 x 35.45) = 133.33 g mol-1

m (AlCl3) = ?

Step 2: Write down the correct formula

$$m= n x M\_{r}$$

Step 3: Substitute in the values

 m = 2.5 x 133.33

Step 4: Solve and add the correct units

 m = 333 g

**EXAMPLE 2:** Calculate the mass of water in 4.25 moles of water.

Step 1: n (H2O) = 4.25 mol

Mr (H2O) = (2 x 1.008) + 16 = 18.016 g mol-1

m (H2O) = ?

Step 2: $m= n x M\_{r}$

Step 3: m = 4.25 x 18.016

Step 4: m = 76.6 g

**Linking together the two equations**

The two equations above can be linked together in two step problems. For instance you may be given the mass of a substance and be asked to determine the number of particles it contains. The diagram on the right shows how you can use the equations to solve that type of problem.

**EXAMPLE 1:** Calculate the mass of aluminium chloride in 1.806 x 1024 molecules of aluminium chloride.

Step 1: Write down what you know.

N = 1.806 x 1024

n (AlCl3) = ?

Mr (AlCl3) = 26.98 + (3 x 35.45) = 133.33 g mol-1

m (AlCl3) = ?

Step 2: Write down the correct formula to find the number of moles

$$n= \frac{N}{6.02 x 10^{23}}$$

Step 3: Substitute in the values

n = 1.806 x 1024 ÷ 6.02 x 1023

Step 4: Solve and add the correct units

n = 3 mol

Step 5: Write down the next required formula to find the mass

$$m= n x M\_{r}$$

Step 3: Substitute in the values

m = 3 x 133.33

Step 4: Solve and add the correct units

m = 400 g

**Stoichiometry - Molar Ratios**

Stoichiometry is the study of relative amounts or ratios of substances in a chemical reaction. Stoichiometry is used every day in the home and in industry. For instance, baking lemonade scones requires a recipe to ensure proper quantities of all of the ingredients are used. Without the correct ratio of ingredients the scones could end up too doughy or floury and taste yuck!

Even hairdressers use stoichiometry. A hairdresser needs to ensure she mixes the correct ratios of colour ingredients to get the correct colour of choice and to ensure the chemicals do not burn the head of her customer!

A correctly balanced chemical equation can be used as our recipe in chemical reactions. The coefficients in a balanced chemical equation tell us the relative numbers of moles of reactants and products in the reaction. We refer to this ratio as the “molar ratio” and the good thing is that the ratios never change.

**EXAMPLE 1:** Determine the molar ratio of hydrochloric acid to hydrogen gas produced in the equation below.

2HCl + Mg → MgCl2 + H2

The equation above tells us that **2** moles of hydrochloric acid reacts with **1** mole of magnesium to produce **1** mole of magnesium chloride and **1** mole of hydrogen gas.

Therefore the **molar ratio** of hydrochloric acid to hydrogen gas is **2 : 1**.

**EXAMPLE 2:** Determine the molar ratio of hydrochloric acid to aluminium chloride produced in the equation below.

6HCl + Al2(CO3)3 → 2AlCl3 + 3H2O + 3CO2

The equation above tells us that **6** moles of hydrochloric acid reacts with **1** mole of aluminium carbonate to produce **2** moles of aluminium chloride, **3** moles of water and **3** moles of carbon dioxide gas.

Therefore the **molar ratio** of hydrochloric acid to aluminium chloride is **6 : 2**.

**EXAMPLE 3:** Determine the molar ratio of sulfuric acid to water produced in the equation below.

H2SO4 + MgCO3 → MgSO4 + H2O + CO2

The equation above tells us that **1** mole of sulfuric acid reacts with **1** mole of magnesium carbonate to produce **1** mole of magnesium sulfate, **1** mole of water and **1** mole of carbon dioxide gas.

Therefore the **molar ratio** of sulfuric acid to water is **1 : 1**.

**Calculations from Equations – Mole to Mole**

By using a balanced equation for a reaction it is possible to determine the number of moles of an unknown substance in the reaction, given the number of moles of another substance (the known).

Firstly, the mole ratio needs to be determined using the coefficients from the balanced equation for the reaction.

**mole ratio = coefficient of unknown**

 **coefficient of known**

We can then use the following relationship to determine the number of moles of the other substance.

**n(unknown) = mole ratio x n(known)**

**EXAMPLE 1:** How many moles of Mg would react with 2.54 moles of O2?

2 Mg + O2 → 2 MgO

This means that for one mole of Oxygen (O2), we would need two moles of Mg.

If we had 10 moles of O2, we would need 20 moles of Mg.

If we had 0.1 moles of O2, we would need 0.2 moles of Mg.

This is because the ratio of Mg : O2 will always be 2:1 as this is stated in the balanced equation.



**Questions**

1. How many atoms of gold are found in 0.25 moles of gold?
2. How many moles is in 4.5 x 1024 molecules of nitrogen gas?
3. Determine the molar mass of the following. Show all working.
	1. Ba(OH)2
	2. Copper II nitrate
4. Determine the mass in grams of each of the following showing all working:
	1. 3.15 mol of magnesium bromide (MgBr2)
	2. 12.9 mol of phosphoric acid
5. Determine the number of moles of each of the following showing all working.
	1. 364 grams of water (H2O)
	2. 4.29 grams of ethanoic acid

The following two questions apply to the balanced equation for the combustion of ethane below:

 **2**C2H6 + **7**O2  🡪 **4**CO2 + **6**H2O

1. Calculate the number of moles of:
	1. CO2 produced for the number of moles of C2H6 consumed.
	2. O2 reacted in relation to the number of moles of C2H6 reacted
2. If 3.05 mol of ethane is combusted, use the balanced equation above to calculate:
	1. number of moles of water produced
	2. number of moles of carbon dioxide produced
	3. number of moles of oxygen gas required to react completely with it