Understanding Moles - Chapter 6

UNIT 6.1
Introduction
The standard atom is an atom of carbon-12, with a mass of 12 atomic units (6 protons + 6 neutrons)
All other atoms are compared with this standard atom. For example, one magnesium atom is twice as heavy as one carbon-12 atom, so its mass is 2 x 12 = 24 atomic mass units.

12 grams of carbon-12 contains 6.02×10^{23} atoms. This is one mole of carbon-12. One mole of anything contains 6.02×10^{23} units.

- One mole of oxygen atoms has 6.02×10^{23} atoms.
- One mole of oxygen molecules has 6.02×10^{23} molecules.

Definition of a mole:: A mole of a substance is the amount that contains the same number of units as the number of carbon atoms in 12 grams of carbon-12.

Moles and Mass
23 grams of sodium contains one mole of sodium atoms. One sodium atom has a mass of 23 atomic mass units. Similarly, 24 grams of magnesium contains one mole of magnesium atoms. One magnesium atom has a mass of 24 atomic mass units.

However, in the case of an iodine molecule, for example, there are 2 iodine atoms. 1 iodine atom has a mass of 127. So 1 iodine molecule has a mass of 127 x 2 = 254. So 254 grams of iodine will have 1 mole of iodine molecules, or 2 moles of iodine atoms.

Substance	Formula	A_r / M_r	Mass of 1 mole
helium	He	$A_r = 4$	4 g
oxygen	O_2	$M_r = 32$	32 g
ethanol	C_2H_5OH	$M_r = 46$	46 g

Formulae

1. Mass of a given number of moles = mass of 1 mole x number of moles

Q. Calculate the mass of 2 moles of bromine atoms, the Ar of bromine being 80.

1 mole of bromine atoms = 80g; 2 moles = 2 x 80 = 160g.

Eg - Calculate the mass of 2 moles of bromine molecules, the Ar of bromine being 80.

1 bromine molecule = 2 bromine atoms. So bromine molecule's Mr = 2 x 80 = 160. So 1 mole of bromine molecules = 160g, 2 moles = 2 x 160 = 320g.

2. Number of moles in a given mass = mass / mass of 1 mole

   Q. Calculate the number of moles of oxygen molecules in 64 g of oxygen. Mr of oxygen = 32.

   1 mole of oxygen molecules = 32g.

   32 g = 1 mole.

   1 g = 1/32 moles

   64 g = 1/32 x 64 = 2 moles.

UNIT 6.2

Moles and equations

1 C atom + 1 molecule of O_2 →1 molecule of CO_2

So:

1 mole of C atoms + 1 mole of O_2 molecules → 1 mole of CO_2 molecules

So:

12 g C + 32 g O_2 → 44 g CO_2 (Ar values : C = 12, O = 16)

So, from an equation you can calculate :

1. Number of moles of each substance taking part
2. The mass in grams of each substance taking part

The total mass does not change during a chemical reaction, so mass of reactant(s) = mass of product(s).

Calculating masses from equations

Q. Hydrogen burns in oxygen to form water. What mass of oxygen is needed for 1 g of hydrogen?

Ar : H=1,O=16

Mr : H_2 = 2, O_2 = 32, H_2O = 18

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

2 x 2g + 32 g → 2 x 18 g

4 g + 32 g → 36 g

So for 1 g hydrogen, 32/ 4 = 8g of oxygen is needed.

UNIT 6.3

Reactions involving gases

1 mole of every gas occupies the same volume, at the same temperature and pressure. This volume is 24 dm^3 at room temperature (20℃) and pressure(1 atmosphere).

The volume occupied by 1 mole of a gas is called its molar volume. At rtp (room temperature and pressure), the molar volume of a gas is 24 dm^3.

So, for example, 1 mole of oxygen molecules (6.02×10^{23} oxygen molecules) occupies the same volume as 1 mole of nitrogen dioxide molecules (6.02×10^{23} nitrogen dioxide molecules).

However, the mass of each of these gases would differ, even though their volumes

Note that the mass of 1 mole of each gas would be different even though their volumes are the same.

Calculating gas volumes from moles and grams

Q. What volume does 22g of carbon dioxide occupy at rtp? M_r of CO_2 = 44

44g = 1 mole, so 22g = 0.5 moles

1 mole = 24 dm^3, so 0.5 moles = 0.5 x 24 = 12 dm^3

Calculating gas volumes from equations

Q. When sulfur burns in air it forms sulfur dioxide. What volume of sulfur dioxide is formed when 1 g of sulfur burns? A_r of sulfur = 32.

Equation: $S\ +\ O_2 \rightarrow SO_2$

32 g of S = 1 mole, so 1 g = 1/32 moles

Since the mole ratio of S : SO_2 is 1:1, 1/32 moles of SO_2 is formed.

1 mole = 24 dm^3, so 1/32 moles of SO_2 = 1/32 x 24 = ¾ dm^3

UNIT 6.4

Concentration of a solution

A solution that contains 2.5 g of copper(II) sulfate in 1 dm^3 of water has a concentration of 2.5 g/dm^3

- Copper(II)sulfate's formula mass = 250

250 g = 1 mole, 1 g = 1/250 moles, 2.5 g = 2.5/250 = 0.01 moles
So 2.5 g/dm^3 = 0.01 mol/dm^3

Molar solution - a solution of concentration 1 mol/dm^3 or 1M.
Concentration (mol/dm^3) = amount of solute (mol) / volume of solution (dm^3
Definition of concentration: the concentration of a solution is the amount of solute, in grams or moles, that is dissolved in 1 dm^3 of solution.

Q. What is the concentration of 0.1 dm^3 of solution with 0.2 moles of solute?
0.2/0.1 = 2 mol/dm^3

Q. What is the mass of the solute present in 2 dm^3 of NaOH solution of concentration 1 mol/dm^3 ?M_r of NaOH = 40.
Amount of solute present in number of moles= concentration x volume (obtained by rearranging the above equation)
= 1 x 2 = 2 moles
1 mole of NaOH = 40g, so 2 moles = 40 x 2 = 80g.

UNIT 6.5
Empirical formula
The empirical formula shows the simplest ratio in which atoms combine.

If we know the masses of elements that combine to form a compound, we can find the formula of the compound.

Elements that combine	carbon	hydrogen
Masses that combine	80 g	20 g
A_r	12	1
Moles of the atoms	80/12 = 6.67	20/1 = 20
Ratio in which the atoms combine	6.67 : 20 = 1:3	
Empirical formula	CH_3	

- If the question says the compound is 80% carbon and 20% hydrogen, we assume the compound sample is 100g and take the masses of the compounds to be 80 g and 20 g.

An experiment to find the empirical formula

The only way to find the masses of elements that combine is by experiment.

Taking the example of magnesium combining with oxygen:

1. Weigh a crucible and lid, empty. Add a coil of magnesium ribbon and weigh the crucible again to find the mass of the magnesium.
2. Heat the crucible, raising the lid at intervals to let oxygen in. The magnesium burns brightly.
3. When the burning is complete, let the crucible cool, still with its lid on. Weight it again. The increase in mass is due to the oxygen.

Elements that combine	magnesium	oxygen
Masses that combine	2.4 g	1.6 g
Ar	24	16
Moles of the atoms	0.1	0.1
Ratio in which the atoms combine	1:1	
Empirical formula	MgO	

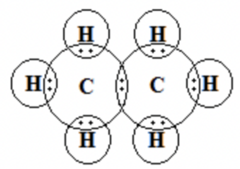
UNIT 6.6

Ionic compound

The formula of an ionic compound is the same as its empirical formula.

Magnesium oxide is an ionic compound, so its ionic formula is its empirical formula which is MgO.

Molecular formula



This is a molecule of ethane. The ratio of carbon: hydrogen is 2:6 - this is used in the molecular formula. The simplest ratio would be 1:3 - this is used in the empirical formula.
Empirical formula = CH_3
Molecular formula = C_2H_6
The molecular formula shows the actual number of atoms that combine to form a molecule.

To find the molecular formula :

1. calculate the value of M_r / empirical mass - n
2. Multiply the numbers of each element in the empirical formula by this value n
   Q. Octane is 84.2 % carbon and 15.8% hydrogen. Its M_r is 114. Find its molecular formula.
   To find its empirical mass, we have to find its empirical formula. Create a table similar to the ones to find a compound's empirical formula:

Elements that combine	carbon	hydrogen
Masses that combine	84.2 g	15.8 g
A_r	12	1
Moles of the atoms	7.02	15.8
Ratio in which the atoms combine	7.02 : 15.8 = 4:9	
Empirical formula	C_4H_9	

The empirical mass = (12 x 4) + (1 x 9) = 57 A_r of C = 12; A_r of H = 1
M_r / empirical formula = 114/57 = 2
So the molecular formula is 2 x C_4H_9 = C_8H_{18}