CHEMISTRY ONLINE
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CHEMISTRY

REVISION NOTES

AMOUNT OF SUBSTANCE -1

Amount of Substance

Moles

One mole of a substance contains Avogadro's number of particles, which is approximately 6.022 x 10^{23} particles. For example, one mole of an apple contains about 6.022 x 10^{23} apples, and one mole of Nitrogen molecules contains about 6.022 x 10^{23} Nitrogen molecules.

This number is known as the **Avogadro constant** (= 6.022 x 10^{23} mol^{-1})

Relative atomic mass

Relative atomic mass is the **average mass** of one atom compared to one-twelfth of the mass of one atom of carbon-12.

Relative molecular mass

Relative molecular mass is the **average mass** of a molecule compared to one-twelfth of the mass of one atom of carbon-12

Relative Isotopic mass

Relative atomic mass is the **mass** of one atom compared to one-twelfth of the mass of one atom of carbon-12.

Exam Question

Define the term relative atomic mass.

Important equations to remember

For gases, liquids, and Solids

- **Moles = Given mass / Molar mass**

  Where,
  Mass = grams
  Units = mol

The molar mass (Mr) of a compound is calculated by adding the mass numbers of its elements from the periodic table.

Example 1:
$CaCl_2$ = 40.1 + (35.5 x 2) = 111.1

Example 2:
What is the number of moles in 35.0mg of
H_2SO_4?

Moles = mass/Mr
Convert mg into grams by dividing it by 1000

= 0.035/ (2 + 32.0 +16.0 x4)
= 3.57 x 10^{-4} mol

One mole of any gas irrespective of its mass at RTP occupies a volume of 24000cm^3 or 24dm^3

Therefore,

Moles = given volume / Molar volume.

Example

Calculate the moles of oxygen having a volume of 6000cm^3.

Moles = 6000/24000
= 0.25 moles.

For gases,

Ideal Gas Equation:

- **PV = nRT**

Where,

Unit of Pressure (P): Pa
Unit of Volume (V): m3
Unit of Temp (T): K
n= moles
R = 8.31

Example
Calculate the mass of N_2 gas that has a pressure of 100 kPa, temperature 40 Celcius, volume 400 cm^3. (R=8.31)

Moles = PV/RT

= 100 000 x 0.0004 / (8.31 x 293)
= 0.01537 mol

100 kPa = 100 000 Pa

40 Celcius = 40+273= 313K
400 cm3 = 0.0004 m^3

Mass = moles x Mr
= 0.01537 x (28 x2)
= 0.86072 g

Changing the Conditions of a gas.

Occasionally, there are questions that relate to the quantity of gas in different conditions.

<u>Example</u>

80 cm^3 of nitrogen and 40 cm^3 of carbon monoxide, each at 298 K and 100 kPa, were placed into an evacuated flask of volume 0.70 dm^3. What is the pressure of the gas mixture in the flask at 298 K?

<u>There are two ways to solve this problem</u>:

1. Calculate the moles of gas using the ideal gas equation. Then, substitute the new conditions back into the same equation.

2. Alternatively, you can use the equation n = PV/RT by combining all the variables below. This method works because the number of moles of gas remains constant throughout the process.

$$P_1V_1 / T_1 = P_2V_2 / T_2$$

As the Temperature is the same, we can make the above equation $P_1V_1 = P_2V_2$

$P_2 = P_1V_1 / V_2$

= 100000 x 1.2 x 10^{-4} / 7 x 10^{-4}
= 17142Pa

For Solutions

- **Concentration = Moles / Volume**

Unit of concentration: mol dm-3 or M
Unit of Volume: dm3

Conversion of Volumes

cm3 to dm3 ÷ 1000

cm3 to m3 ÷ 1000 000
dm3 to m3 ÷ 1000

Example
Calculate the solution concentration made by dissolving 7g of K_2CO_3 in 400 cm^3 water.

moles = mass/Mr

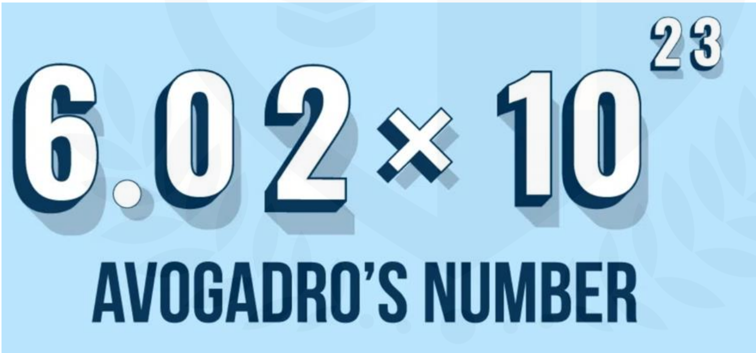
= 7 / (39.0 x2 + 12 +16 x3)
= 0.05072 mol

Concentration = moles/Volume
= 0.0507/ 0.400
= 0.126 mol dm^3

Avogadro's Constant

There are 6.022 x 10^{23} atoms in 12 grams of carbon-12. Therefore, explained in more straightforward terms 'One mole of any specified entity contains 6.022 x 10^{23} of that entity.

Avogadro's Constant can be used for atoms, molecules, and ions.



One mole of Zinc atoms will contain 6.022 x 10^{23} atoms of zinc.
One mole of water molecules will contain 6.022 x 10^{23} molecules of water.
One mole of sodium ions contains 6.022 x 10^{23} ions of sodium.

You might be asked to calculate the number of atoms/particles in a question. Once you have calculated the moles, use the following equation to get the particle number.

No of particles/atoms/ions = moles of substance (in mol) X Avogadro's constant

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Example:

How many atoms of zinc are there in a 12.00 g sample of Zinc metal?

Moles = mass/Ar
= 12.00/ 65.38

= 0.18354 mol

Number atoms = moles x Avogadro’s number

= 0.18354 x 6.022 x 10^{23}
= 1.105277 x 10^{23}

- **Density = Mass/volume**

Density is usually given in g cm-3

<u>Example:</u>

How many molecules of ethanol are there in a 0.300 dm^3 of propanol ($CH_3CH_2CH_2OH$) liquid?

The density of ethanol is 0.789 g cm-3

Number of molecules= moles x 6.022 x 1023
= 8.576 x 6.022 x 1023
= 5.16 x1024(to 3 sig fig)

Mass = density x Volume
= 0.789 x 500
= 394.5g
ethanol
moles = mass/Mr
= 394.5/ 46.0
= 8.576 mol

<u>Empirical formula</u>

An empirical formula represents the simplest whole-number ratio of atoms of each element in a compound.

There are three steps to follow to find the empirical formula of a substance.

Step 1: Divide each mass (or % mass) by the atomic mass of the element.

Step 2: Divide each answer from step 1 by the smallest one of those numbers.

Step 3: Sometimes, the numbers calculated in step 2 will need to be multiplied up to give whole numbers. These whole numbers will be the empirical formula.

You can use this method for the following data types:

1. masses of each element in the compound given
2. percentage mass of each element in the compound

Example

A compound P contains 73.47% carbon and 10.20% hydrogen by mass, the remainder being oxygen. It is found from other sources that P has a Relative Molecular Mass of 98 g mol-1.

Calculate the molecular formula of P.

	C	**H**	**O**
	73.47	10.20	(100 – 73.47 – 10.20) = 16.33
By r.a.m	$\frac{73.47}{12}$ = 6.1225	$\frac{10.20}{1}$ = 10.20	$\frac{16.33}{16}$ = 1.020
By smallest	$\frac{6.1255}{1.020}$	$\frac{10.20}{1.020}$	$\frac{1.020}{1.020}$
Ratio of atoms	6	10	1

Therefore the empirical formula is $\mathbf{C_6H_{10}O}$.

Molecular formula

A molecular formula is the actual number of atoms of each element in the compound.

Element	Molecular Formula	Empirical Formula
Water	H_2O	H2O
Glucose	$C_6H_{12}O_6$	CH_2O
Hydrogen Peroxide	H_2O_2	HO
Butane	C_4H_{10}	C_2H_5
Banzene	C_6H_6	CH

<u>Example</u>

Work out the molecular formula for the compound with an empirical formula of C_3H_6O and a Mr of 116

C_3H_6O has a mass of 58

The empirical formula fits twice into Mr of 116

So molecular formula is $C_6H_{12}O_2$

<u>Limiting Reactant</u>

In a chemical reaction, the reactant that is used up first and restricts the amount of product that can be produced is called the limiting reactant. This reactant is responsible for determining the maximum amount of product that can be produced.

<u>Example:</u>

Propane reacts with oxygen as shown:

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

How many moles of products are formed when 1 mole of C_3H_8 is mixed with 8 moles of O_2?

	C_3H_8	+ $5O_2$	$\rightarrow$	$3CO_2$	+ $4H_2O$
moles at the start	1 mol	8 mol			
change in moles	1 mol react	5 mol react		3 mol made	4 mol made
moles at the end	1 – 1 = 0 mol	8 – 5 = 3 mol		0 + 3 = 3 mol	0 + 4 = 4 mol

Therefore,

C_3H_8 = limiting reagent
O_2 = in excess (excess reagent)

Percentage yields

You might not get the expected amount of product when you create a new substance through a chemical reaction. For instance, if you react 12 grams of Carbon with 32 grams of oxygen, you may end up with less than 44 grams of water. The reasons for this could be:

• The reaction may be reversible, which means that both the forward and backward reaction can occur.

• Some of the product may be lost during the separation process from the reaction mixture.

• Some of the reactants may react with other substances in other chemical reactions.

$$\% \text{ yield} = \frac{\text{mass of product obtained}}{\text{maximum theoretical mass of product}} \times 100$$

Example Percent Yield Calculation

First, here is a simple example of the percent yield calculation in action:
The decomposition of magnesium carbonate forms 12 grams of magnesium oxide in an experiment. The theoretical yield is 19 grams.

What is the percent yield of magnesium oxide?

MgCO3 → MgO + CO2

Here, you know the actual yield (15 grams) and the theoretical yield (19 grams), so plug the values into the formula:

Percent Yield = Actual Yield/Theoretical Yield x 100%

Percent Yield = 12g / 19g x 100 %
Percent Yield = 63.15 %

Atom Economy

Atom economy is a metric used to evaluate the efficiency of a chemical reaction.

It measures the proportion of the desired product to the amount of waste generated during the reaction. The higher the atom economy value, the greater the percentage of starting materials that are converted into the desired product, resulting in less waste.

A reaction with a high atom economy is preferable in terms of cost and environmental impact, as it reduces the amount of resources needed and the amount of waste generated.

$$\boxed{\%\ \text{atom economy} = \frac{\text{mass of desired product as shown in equation}}{\text{total mass of products as shown in equation}}\ x\ 100}$$

Example

Calculate the percentage atom economy to make sodium from sodium chloride.

$$2\ NaCl \rightarrow 2\ Na + Cl_2$$

First, calculate the mass of the desired product,

Atomic mass of Sodium = 23

So, 23 x 2 = 46 grams.

Second, calculate the total mass of the products,

= 46 + (35.5 x 2)
= 117 grams.

Now apply the formula,

= 46 / 117 x 100

= 39.3 %

Exam Questions

Calcium sulfide reacts with calcium sulfate as shown.

$$CaS + 3\ CaSO_4 \rightarrow 4\ CaO + 4\ SO_2$$

2.50 g of calcium sulfide are heated with 9.85 g of calcium sulfate until there is no further reaction.

Show that calcium sulfate is the limiting reagent in this reaction.

Calculate the mass, in g, of sulfur dioxide formed.

M_r (CaS) = 72.2
M_r ($CaSO_4$) = 136.2

A compound contains 40.0% carbon, 6.7% hydrogen and 53.3% oxygen by mass.

Which could be the molecular formula of this compound?

A $C_2H_2O_2$

B C_2H_2O

C $C_2H_4O_2$

D C_2HO_2

What is the percentage atom economy for the production of ethanol from glucose?

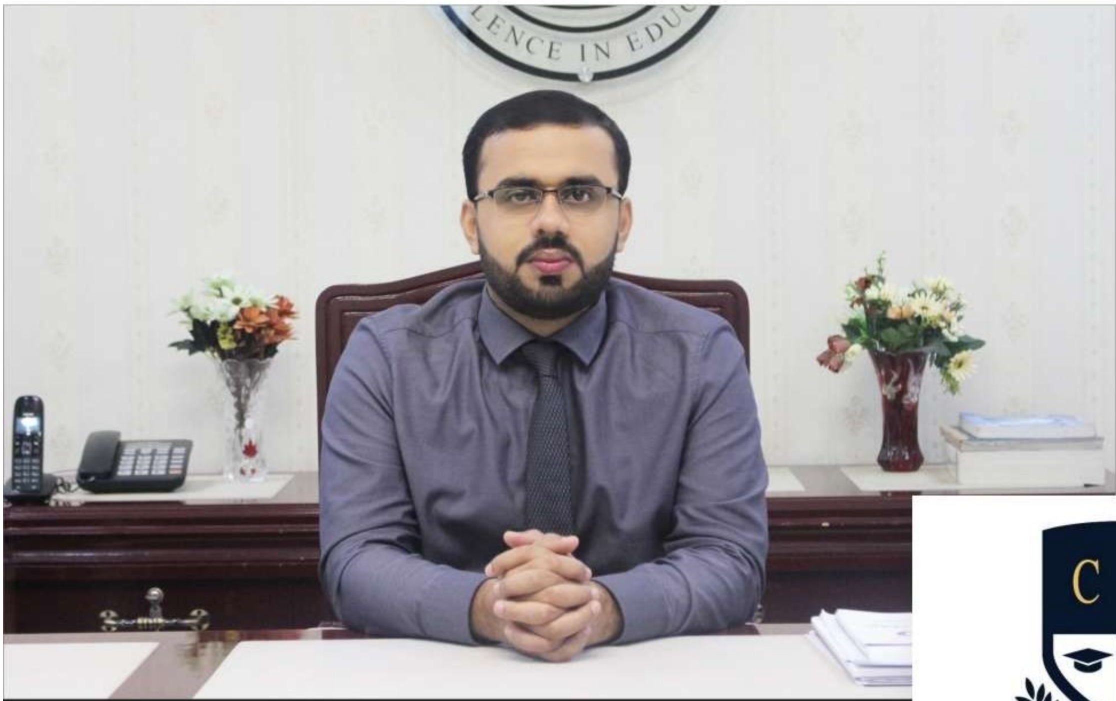
$$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$$

A 25.6%

B 27.1%

C 51.1%

D 54.2%



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