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## STOICHIOMETRY

Avogadro's Law :-

"Under the same conditions of temperature and pressure, equal volumes of all gases contain the same number of molecules."

Applications of Avogadro's Law

1. To determine the relation between molecular weight and vapour density

Molecular Weight

Mol. wt =  $\frac{\text{mass of one molecule of substance}}{\text{mass of one atom of hydrogen}}$

It is the ratio between the mass of one molecule of a substance and the mass of one atom of hydrogen.

Velocity ratio

Vapour density

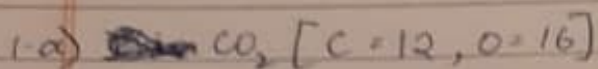
~~VD~~

$\nabla$   $VD = \frac{\text{mass of a certain volume of gas}}{\text{mass of the same volume of hydrogen}}$

The ratio between the mass of a certain volume of a gas to the mass of the same volume of hydrogen.

NOTE:  $VD \times 2 = \text{Mol. wt.}$

## Problems on Percentage Composition Pg 95

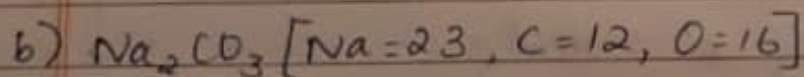


$$\begin{aligned}\text{Molecular wt. of } \text{CO}_2 &= \text{Atomic wt. of C} + 2 \times \text{At. wt. of O} \\ &= 12 + (2 \times 16) \\ &= 12 + 32\end{aligned}$$

$$\boxed{\text{Mol. wt. of } \text{CO}_2 = 44 \text{ g}}$$

$$\begin{aligned}\% \text{Composition of C in } \text{CO}_2 &= \frac{12}{44} \times 100 \\ &= \frac{1200}{44} \\ &= 27.27\end{aligned}$$

$$= \boxed{27.27\%}$$



$$\begin{aligned}\text{Mol. wt. of } \text{Na}_2\text{CO}_3 &= 2(23) + 12 + 3(16) \\ &= 46 + 12 + 48\end{aligned}$$

$$\boxed{\text{Mol. wt. of } \text{Na}_2\text{CO}_3 = 106 \text{ g}}$$

$$\begin{aligned}\% \text{Composition of Na in } \text{Na}_2\text{CO}_3 &= \frac{46}{106} \times 100 \\ &= \frac{4600}{106}\end{aligned}$$

$$= 43.39\%$$

$$\boxed{\approx 43.4\%}$$

2. ~~alg~~  $AlN = 27 + 14$   $AlN [Al=27, N=14]$   
 ~~$= 41 g$~~

Mol. wt of  $AlN = 27 + 14$   
 $[Mol. wt of  $AlN = 41 g$ ]$

$\therefore$  Composition of  $AlN = \frac{27}{41} \times 100$   
 $= 65.85\%$

8.  $K_3Fe(CN)_6 [K=39, Fe=56, C=12, N=14]$

Mol. wt of  $K_3Fe(CN)_6 = (3 \times 39 + 56 + (12 + 14) \times 6)$   
 $= 117 + 56 + (26) \times 6$   
 $= 117 + 56 + 156$   
 $= 329 g$

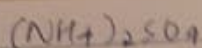
$\therefore$  of Fe in  $K_3Fe(CN)_6$   
 $= \frac{56}{329} \times 100$   
 $= 17.02\%$

3.  $Ca(NO_3)_2 [Ca=40, N=14, O=16]$

RMM =  $40 + 2[14 + 3(16)]$   
 $= 40 + 2[14 + 48]$   
 $= 40 + 2[62]$   
 $= 40 + 124$   
 $= 164 g$

$\therefore$  of N in  $Ca(NO_3)_2 = \frac{28}{164} \times 100 = 17.07\%$   
 $= 17.07\%$





$$\begin{aligned} \text{RMM} &= 2[14 + 4(1)] + 32 + 4 \times 16 \\ &= 2[14 + 4] + 32 + 64 \\ &= 2 \times 18 + 32 + 64 \\ &= 36 + 32 + 64 \\ &= 132 \text{ g} \end{aligned}$$

$$\% \text{ of N} = \frac{28}{132} \times 100 = \frac{700}{33} = 21.21\%$$

Ammonium Sulphate has a higher %age than Calcium nitrate of N, i.e., 21.21% compared to calcium nitrate, i.e., 17.07%.

$$\begin{aligned} 4. \text{ Mol. wt of } Al_2O_3 &= 2(27) + 3(16) \\ &= 54 + 48 \\ &= 102 \text{ g} \end{aligned}$$

$$\% \text{ of Al} = \frac{54}{102} \times 100 = 52.94\%$$

pure Al is of 90% purity

$$\therefore \% \text{ of 90\% pure Al in } Al_2O_3 = \frac{52.94 \times 90}{100}$$

$$= \frac{4764.6}{100}$$

$$= 47.64\%$$

$\therefore$  % of purity of Al in  $Al_2O_3$  maybe 10 kg or else

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$$\begin{aligned} \text{e. RMM of } \text{CaCO}_3 &= 40 + 12 + 3 \times 16 \\ &= 40 + 12 + 48 \\ &= \underline{100} \end{aligned}$$

Weight of carbon in 100g of  $\text{CaCO}_3$  is 12g.  
But, purity of Ca is 55%.

$$\begin{aligned} \therefore \text{Percentage of Ca in } \text{CaCO}_3 &= \frac{12 \times 55 \times 100}{100} \\ &= 4.55 \times 100 \\ &= \underline{455} \\ &= \underline{45.5} \end{aligned}$$

$$\begin{aligned} \text{f. RMM of } \text{CuSO}_4 \cdot 5\text{H}_2\text{O} &= 63.5 + 32 + (4 \times 16) + (10 \times 1) + 16 \\ &= 63.5 + 32 + 64 + 90 + 16 \\ &= \underline{249.5} \end{aligned}$$

1. of water of crystallization

$$\begin{aligned} &= \frac{90 \times 100}{249.5} \times 100 \\ &= \frac{9000}{249.5} = \underline{36.07\%} \end{aligned}$$

$$\begin{aligned} \text{g. Mol. wt. of } \text{CaSO}_4 &= 40 + 32 + 4 \times 16 + 18x \\ &= 40 + 32 + 64 + 18x \\ &= 136 + 18x \end{aligned}$$

136g of  $18x$   $\text{CaSO}_4$  = (100 - 21%)  
= 79% of total mass of

$$\text{CaSO}_4 \cdot x\text{H}_2\text{O} = A$$

$\therefore 79\%$  of  $A = 136$ g of  $\text{CaSO}_4$

$$\Rightarrow \frac{79}{100} \text{ of } A = 136$$

Weight of metallic chloride = 4 g  
 Weight of metal = 1.89 g  
 Weight of chloride = 4 - 1.89  
 = 2.11 g

Element	% Comp	At. weight	Rel. no of atoms	
Element	% Comp	At. wt.	Rel. no of atoms	Simplest ratio
X	1.89	64	$\frac{1.89}{64} = 0.033$	$\frac{0.033}{0.033} = 1$
Cl	2.11	35.5	$\frac{2.11}{35.5} = 0.06$	$\frac{0.06}{0.033} = 2$

simplest ratio = 1:2

empirical formula =  $\text{XCl}_2$

EF =  $\text{CH}_2\text{O}$

EF wt = 12 + 2 + 16

= 30

VD = 30

Mol. wt =  $2 \times 30 = 60$

$n = \frac{\text{mol. wt}}{\text{EF wt}} = \frac{60}{30} = 2$

EF wt 30

MF =  $(\text{EF})_n$

=  $(\text{CH}_2\text{O})_2$

=  $\text{C}_2\text{H}_4\text{O}_2$  [ $\text{CH}_3\text{COOH}$ ]



Pg 95

Q2. Element	% Comp	St. wt	Rel. no. of atoms	simple ratio
C	57.82	12	$\frac{57.82}{12} = 4.8$	$\frac{4.8}{2.41} = 2$
H	3.60	1	$\frac{3.60}{1} = 3.6$	$\frac{3.6}{2.41} = 1.5$
O	38.58	16	$\frac{38.58}{16} = 2.41$	$\frac{2.41}{2.41} = 1$

Total Simplest ratio = 4:3:2  
empirical formula =  $C_4H_3O_2$

$$\begin{aligned} \text{E.F. wt} &= 4 \times 12 + 3 \times 1 + 2 \times 16 \\ &= 48 + 3 + 32 \\ &= 83 \end{aligned}$$

$$\text{VD} = 83$$

$$\begin{aligned} \text{Mol. wt of } &= 83 \times 2 \\ &= 166 \end{aligned}$$

$$n = \frac{166}{83} = 2$$

$$\begin{aligned} \text{Mol. formula} &= \text{EF}_n \\ &= (C_4H_3O_2)_2 \\ &= C_8H_6O_4 \end{aligned}$$

Element	% Comp	At. wt.	Rel. no. of atoms	Simplest ratio
Al	0.2675	27	0.2675	
P	0.3505	31	0.27	$99 = 1$
O	0.6620	16	$= 0.0099 \cdot 99$	99
P	0.3505	31	$\frac{0.3505}{31}$	
				$113 = 1$
O	0.6820	16	$= 0.113 \cdot 113$	99
O	0.6820	16	$\frac{0.6820}{16}$	
			$= 0.426 = 426$	$\frac{426}{99} = 4$

Simplest ratio - 1:1:4  
 empirical formula =  $\text{AlPO}_4$

VD of  $x = 13 \therefore \text{MW} = 2 \times \text{VD} = 2 \times 13 = 26$

VD of  $y = 39 \therefore \text{MV} = 2 \times \text{VD} = 2 \times 39 = 78$

Let the formula of  $x$  be  $\text{C}_m\text{H}_n$   
 Mol. mass of  $x = 12m + 1n$   
 $= 12m + n$

$$26 = 12m + n$$

The only simple whole number values of  $m$  &  $n$  which satisfies this equation are  $m=2$  &  $n=2$

MF of  $x = \text{C}_2\text{H}_2$

Let formula of  $y = \text{C}_x\text{H}_y$  where  $x$  &  $y$  are simple whole nos.

$$\text{Mol. mass} = 12x + y = 78$$

The only simple whole number ratios which satisfies this  $\frac{12x}{y} = \frac{6}{1}$

$\therefore$  Mol. formula =  $\text{C}_6\text{H}_6$



To determine the molecular formula of a compound having

$$C = 26.59\% \quad H = 2.22\% \quad O = 71.19\% \quad VP = 45$$

$$[C = 12 \quad H = 1 \quad O = 16]$$

Calculation of empirical formula

Element	% Composition	At. wt.	Rel. no. of atoms	sample ratio
Element	% Composition	At. wt.	Rel. no. of atoms	ratio
Carbon	26.59%	12	$\frac{26.59}{12} = 2.215$	$\frac{2.215}{2.21} = 1$
Hydrogen	2.22%	1	$\frac{2.22}{1} = 2.22$	$\frac{2.22}{2.21} = 1$
Oxygen	71.19%	16	$\frac{71.19}{16} = 4.44$	$\frac{4.44}{2.21} = 2$

Simplest ratio of whole nos = 1:1:2

$$\therefore \frac{EF}{EF} = CHO_2$$

$$E.F. \text{ wt} = 12 + 1 + 2 \times 16$$

$$= 12 + 1 + 32$$

$$= 45$$

$$VD = 45$$

$$Mol. \text{ wt} = 45 \times 2 = 90$$

$$n = \frac{90}{45} = 2$$

$$\begin{aligned} \text{Mol. formula} &= (CHO_2)_n \\ &= (CHO_2)_2 \\ &= C_2H_2O_4 \end{aligned}$$

Step 1 Calculate the empirical formula wt. from empirical formula

Step 2 Calculate mol. wt from the VD of a compound. If VD is given, calculate molecular weight from it.

Formula:  $\text{Mol. wt} = 2 \times \text{VD}$

Step 3 Determine the value of integer of  $n$  by applying formula.

Formula:  $\text{Mol. wt} = n \times \text{empirical formula wt.}$   
$$n = \frac{\text{Mol. wt}}{\text{E.F. wt}}$$

Step 4 Calculate mol. formula by applying formula  
Molecular formula = E.F.  $\times n$ .

Problems based on empirical formula & molecular formula

Na = 29.11%	S = 40.31%	O = 13.38%
= 23	= 32	= 16

Element	% Comp	At wt	Rel. no. of atoms	Simplest ratio
Zn	22.657	65	$22.657$ $65 = 0.35$	1
S	11.15	32	$11.15$ $32 = 0.35$	1
O	61.321	16	$61.321$ $16 = 3.83$	11
H	4.881	1	$4.881 = 4.88$ 1	14

But all the Hydrogen in the compound is present in combination with  $O_2$  as water of crystallisation.

$$\therefore H_2 : O = 14 : 11$$

7 mols. of  $H_2$  need 7 atoms of  $O_2$  to form

$\therefore 11 - 7 = 4$  atoms of  $O_2$  are left

$$1 : 1 : 4 : 7$$

$$\therefore \text{Formula} = ZnSO_4 \cdot 7H_2O$$



Steps to determine empirical formula of a compound.

step 1: Write down the % age composition & at wt of each element in the compound in tabular form.

step 2: Divide the % age composition of each element by its at. wt. to get the relative no. of atoms

step 3: Select smallest ratio of the and divide the remaining ratio by it to get the simplest ratio

Note: If the simplest ratio is not a whole number, multiply each ratio by the smallest integer to get a whole number for simplest ratio.

### Molecular Formula

It is a chemical formula which represent the actual no. of atoms of each element present in the molecule of the compound.

Ex 1:  $C_6H_{12}O_6$  6 atoms of C

12  
6

Steps to determine the molecular formula of a compound from its empirical formula

$$A = \frac{136 \times 100}{79}$$

2 mols of water = 21% of A

$$= \frac{21 \times 136 \times 100}{100 \times 79}$$

$$= \frac{21 \times 136}{79}$$

$$\begin{array}{r} 136 \\ 21 \\ \hline 126 \\ 272 + \\ \hline 2856 \end{array}$$

$\therefore$  no. of molecules of water ~~are~~ ~~in~~

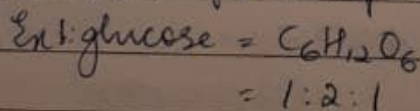
$$n(18) = \frac{21 \times 136}{79}$$

$$\begin{aligned} n &= \frac{21 \times 136 \times 68}{79 \times 18 \times 3} = \frac{21 \times 136 \times 68}{79 \times 18 \times 3} \\ &= \frac{476}{237} = \frac{474}{237} \\ &= 2 \end{aligned}$$

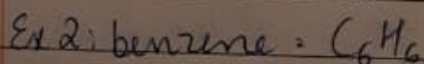
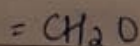
$$\begin{array}{r} 237 \\ 2 \\ \hline 474 \end{array}$$

### Empirical Formula

Definition: Empirical Formula is the formula of a compound which shows the simplest whole number ratio between the atoms of the elements of a compound.



$$= 1:2:1$$



$$= CH:1:1$$

