Percentage Composition

The percentage of each element present in a compound, known as its **percentage composition**, can be calculated:

$$\% \text{ Element} = \frac{(\text{No. atoms of element})(\text{RAM of element})}{\text{Molar mass of compound}} \times 100$$

Work through the following examples carefully to make sure you understand how these questions can be asked before trying the exercises below.

Examples:

1. **Calculate the percentage composition of sulphuric acid (H_2SO_4).**

$M_{(H_2SO_4)}$ = 2(1) + 32 + 4(16) = **98 g.mol^{-1}**

% H = $\frac{(2)(1\ \text{g.mol}^{-1})}{(98\ \text{g.mol}^{-1})}$ x 100 = **2,04%**

% S = $\frac{(1)(32\ \text{g.mol}^{-1})}{(98\ \text{g.mol}^{-1})}$ x 100 = **32,65%**

% O = $\frac{(4)(16\ \text{g.mol}^{-1})}{(98\ \text{g.mol}^{-1})}$ x 100 = **65,31%**

2. **Calculate the percentage composition of water crystallisation in copper sulphate crystals.**

Formula: $CuSO_4.5H_2O$

$M_{(CuSO_4.H_2O)}$ = 63,5 + 32 + 4(16) + 5[2(1) + 16] = 249,5 g.mol^{-1}

Note: We haven't been asked about the $CuSO_4$ part of the crystal – the question only asked for the % H_2O. So we just take the H_2O part on its own compared to the total molar mass. There are 5 H2O molecules, so it will be 5 x M(H_2O) on the top and M for the total molecule ($CuSO_4.5H_2O$) on the bottom.

$M_{(H_2O)}$ = 2(1) + 16 = 18 g.mol^{-1}

% H_2O = $\frac{5x18}{249,5}$ x 100 = **36,07%**

3. Calculate how many grams of nitrogen are present in 10 g of ammonium nitrate.

Formula: NH_4NO_3

$M_{(NH_4NO_3)}$ = 14 + 4(1) + 14 + 3(16) = 80 g.mol^{-1}

% N = $\frac{2x14}{80}$ x 100 = 35%

∴ 10 g of NH_4NO_3 contains 35% of Nitrogen

= 10 g x 35%

= 10 x $(\frac{35}{100})$

= 3,5 g of Nitrogen

Exercise: Question 9

Calculate the percentage composition of each of the following

9.1 $C_{12}H_{22}O_{11}$ Cane Sugar

M ($C_{12}H_{22}O_{11}$) = 12(12) + 22(1) + 11(16) = g.mol^{-1}

% C = (12x12) x 100 = %

% H = (22 x) x 100 = %

TWO decimal places

% O = (11 x) x 100 = %

Make sure all your percentages add up to 100% to check if you have made a mistake!

9.2 **NH_4NO_3 Ammonium Nitrate**

M (NH_4NO_3) = + (x) + + (x) = g.mol^{-1}

% N = (x) x 100 = %

(Hint: Check carefully – how many N's are there in the formula??!)

% H = (x) x 100 = %

% O = (x) x 100 = %

9.3 **$Fe(NO_3)_2$ Iron II Nitrate**

M ($Fe(NO_3)_2$) = + 2[+ (3 x)] = g.mol^{-1}

% Fe = (x) x 100 = %

% N = (x) x 100 = %

% O = (x) x 100 = %

Determine the percentage of copper in each of the following:

(Note: Only %Cu has been asked for, so you don't need to calculate the other elements)

9.4 $CuCl_2$

M ($CuCl_2$)= g.mol^{-1}

% Cu = _____ x 100 = %

9.5 $Cu(NO_3)_2$

M ($Cu(NO_3)_2$)= g.mol^{-1}

% Cu = _____ x 100 = %

9.6 $CuSO_4.5H_2O$

M ($CuSO_4.5H_2O$) = + + (4 x) + (5 x) = g.mol^{-1}

% Cu = _____ x 100 = %

9.7 What is the mass of carbon present in 454 g propane with the chemical formula of C_3H_8?

Step 1: Calculate %C

M (C_3H_8) = g.mol^{-1}

% C = ____x____ x 100 = %

Step 2: Calculate mass of C

%C x 454 g = mass C

$\frac{\quad}{100}$ x 454 = g

9.8 What is the mass of iron present in 25 g of iron III oxide (Fe_2O_3)?

M (Fe_2O_3) = $g.mol^{-1}$

% Fe = $\frac{\quad x \quad}{}$ x 100 = %

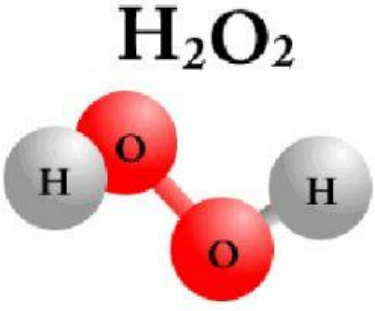
Mass Fe = $\frac{\quad}{100}$ x = g

Empirical Formula

The **empirical formula** is the simplest whole number ratio of atoms in a compound.

The **molecular formula** tells the actual number of each kind of atom in a molecule.

For example – **hydrogen peroxide** has the chemical formula H_2O_2. This means that every molecule contains 2x H and 2x O. If you simplify this down, it would just be HO but that is not a true representation of what the molecule looks like.



We call **HO** the Empirical Formula (the simplest form) and **H_2O_2** the Molecular Formula (the true form). The molecular formula is a multiple of the empirical formula, so H_2O_2 = 2 x (HO).

Other examples:

- **Empirical** formula e.g. HgCl, P_2O_5
- **Molecular** formula e.g. Hg_2Cl_2, P_4O_{10}

The empirical formula of a compound can be calculated if its percentage composition per mass is known.

Examples

Eg 1) **A compound is made up of 36,5% sodium, 24,8% sulphur and 38,1% oxygen. Calculate the empirical formula.**

Answer:

Express the percentage as a mass:

In 100 g:
Na = 36,5 g
S = 24,8 g
O = 38,1 g

Convert the mass of each element to number of moles:

$$n(Na) = \frac{m}{M} = \frac{36.5\ g}{23\ g.mol^{-1}} = 1{,}59\ mol \qquad \div 0{,}78 = 2$$

$$n(S) = \frac{m}{M} = \frac{24.8\ g}{32\ g.mol^{-1}} = 0{,}78\ mol \qquad \div 0{,}78 = 1$$

$$n(O) = \frac{m}{M} = \frac{38.1\ g}{16\ g.mol^{-1}} = 2{,}38\ mol \qquad \div 0{,}78 = 3$$

Divide each answer by the smallest no. of moles to get the ratio

Actual mole ratio 1,59 : 0,78 : 2,38 (÷ 0,78)
Simplified 2 : 1 : 3

2Na : 1S : 3O The empirical formula is **Na_2SO_3**

Eg 2a) **A compound is made up of 26,76% carbon, 71,11% oxygen and 2,22% hydrogen per mass.**

Answer:

In 100g

C = g
O = g
H = g

$n(C) = \frac{m}{M} = \frac{26.76\ g}{12\ g.mol^{-1}} =$ 2,23 mol ÷ = 1

$n(O) = \frac{m}{M} = \frac{71.11\ g}{16\ g.mol^{-1}} =$ 4,44 mol ÷ = 2

$n(H) = \frac{m}{M} = \frac{2.22\ g}{1\ g.mol^{-1}} =$ 2,22 mol ÷ = 1

Mole ratio 1: 2 : 1
CO_2H

b) If the relative formula mass (M) of the compound is 90, calculate the molecular (true) formula of the compound.

The empirical formula is CO_2H

$M(CO_2H) = 12 + (2 \times 16) + 1 = 45\ g.mol^{-1}$

M(True formula) = 90 $g.mol^{-1}$ (given in question)

Molecular (true) mass is **double** the empirical formula mass.

$$\frac{\text{True mass}}{\text{empirical mass}} = \frac{90}{45} = 2$$

Therefore the molecular formula = 2 x CO_2H = $C_2O_4H_2$

Question 5 (Do in back of chemistry notebooks)

Use the method laid out in Example 1 to find the empirical formulae of the compounds having the following percentage composition:

5.1 H = 11,1%
O = 88,9%

5.2 Mg = 20%
S = 26,7%
O = 53,3%

5.3 K = 56,5%
C = 8,7%
O = 34,8%

5.4 Ca = 24,4%
N = 17,1%
O = 58,5%

5.5 Al = 34,6%
O = 61,5%
H = 3,9%

5.6 Na = 17,6%
Cr = 39,7%
O = 42,7%

5.7 C = 48,7%
H = 8,1%
O = 43,2%

5.8 C = 81,8 %
H = 18,2%

Question 6

Follow example 2 to help you find the (a) empirical formulae and (b) molecular formulae of the following compounds from the given information:

6.1 C = 92,3%
H = 7,7 %
The true mass of the above compound is = 78,06g.mol^{-1}

6.2 C = 54,5%
H = 9,1%
O = 36,4%
The true mass of the above compound is = 132,12 g.mol^{-1}