TORORO GIRLS' SCHOOL

SENIOR FIVE ORGANIC CHEMISTRY, 2020

DETERMINATION OF MOLECULAR FORMULA OF ORGANIC COMPOUNDS BY COMBUSTION METHOD

Many organic compounds can burn in oxygen to produce water and oxygen plus some other products like nitrogen dioxide for amines. The products formed during combustion of organic compounds depend on the constituents of the organic compound.

We can use the knowledge of combustion of organic compounds to determine the empirical formula of organic compounds. The empirical formula of the organic compound can be determined if we have the mass of the organic compound burnt, mass of water produced and mass of carbon dioxide produced.

We use the mass of carbondioxide produced to determine mass of carbon in the organic compound burnt.

We use the mass of the water to produce to determine the mass of hydrogen in the organic compound burnt.

In case the organic compound contains any other elements apart from carbon and hydrogen, we use the mass of the burnt organic compound to determine the mass of the other element.

Determining the mass of carbon

If we are given the mass of carbondioxide gas produced, we can use it to determine the mass of carbon in the carbondioxide gas by applying some knowledge of O-level mole concept.

Example 1. Calculate the mass of carbon in: -

(i) 4.4g of carbondioxide gas.

Solution

44g of carbondioxide contains 12g of carbon

4.4g of carbondioxide contains $\frac{12}{44} \times 4.4 = 1.2g$ of carbon.

(ii) 0.92g of Carbondioxide

solution

44g of carbondioxide contains 12g of carbon

0.92g of carbondioxide contains $\frac{12}{44} \times 0.92 = 0.251g$ of carbon.

(iii) 11.2 dm^3 of carbondioxide gas at s.t.p

At s.t.p 1 mole of a gas occupies 22.4 dm^3.

Solution

First determine the mass of carbon dioxide in the given volume of gas.

22.4 dm^3 contains 1 mole of carbon dioxide

22.4 dm^3 contain 44g of carbon dioxide gas

11.2 dm^3 contain $\frac{44}{22.4} \times 11.2 = 22g$ of carbon dioxide ga.

Remember we need to determine the mass of carbon.

Mass of carbon in 11.2g of carbon dioxide is given by $\frac{12}{44} \times 22 = 6g$ of carbon

Note. In paper one the space is very limited, so we have to make sure we summarize our work.

22.4 dm^3 contains 1 mole of carbon dioxide

22.4 dm^3 contains 12g of carbon.

11.2 dm^3 contains $\frac{12}{22.4} \times 11.2 = 6g$ of carbon

Exercise

Calculate the mass of carbon in each of the following.

(a) 0.3g of carbondioxide gas
(b) 88g carbondioxide gas
(c) 12 dm^3 of carbondioxide at s.t.p
(d) 12 dm^3 of carbon dioxide at r.t.p.
(e) 200 cm^3 of carbondioxide at s.t.p.

Determining mass of hydrogen in water.

In determining the mass of hydrogen we use the same approach as for activity one.

Water has a molar mass of 18g/mole and each mole of water has 2g of hydrogen.

Determine

(i) 1.8g of water.
Solution

18gof water contain 2g of hydrogen.

1.8g of water contain $\frac{2}{18} \times 1.8 = 0.2g$ of hydrogen

(ii) 12g of water

18gof water contain 2g of hydrogen.

12g of water contain $\frac{2}{18} \times 12 = 1.3333g$ of hydrogen

(ii) 30g of water.
(iii) 0.028g of water.

Determining percentage composition of carbon in an organic compound

As explained earlier an organic compound burns in oxygen to produce carbon dioxide, water and some other products depending on the constituents of the organic compound. Knowing the mass of the carbon dioxide and mass of water given off helps us to determine the percentage composition by mass of each element in the organic compound.

Example I

2g of an organic compound on complete combustion gave off 1.2g of carbon dioxide gas. Calculate the percentage composition by mass of carbon in the organic compound.

Solution

- First determine the mass of carbon in the carbon dioxide.

  44g of carbon dioxide contain 12g of carbon

  1.2g of carbon dioxide contain $\frac{12}{44} \times 1.2 = 0.32727g$ of carbon

- Determine the percentage of carbon in the organic compound

Percentage of carbon in the organic compound $= \frac{0.32727}{2} \times 100 = 16.3635\%$

Like I said earlier, with paper one we have to summarize our work to minimize wastage of space

Method two

$$\% \text{ of carbon} = \frac{mass\ of\ carbondioxide \times 12}{molar\ mass\ of\ carbondioxide \times mass\ of\ the\ organic\ compound} \times 100$$

$$= \frac{1.2 \times 12}{44 \times 2} \times 100 = 16.363\%$$

Example II

When 0.27g of an organic compound was completely burnt in oxygen, it gave off 0.28g of carbondioxide. Calculate the % composition by mass of carbon in the organic compound.

Solution

44g of carbon dioxide contain 12g of carbon

0.28g of carbon dioxide contain $\frac{12}{44} \times 0.28 = 0.0764g$ of carbon

Percentage composition of carbon by mass $\frac{0.0764}{0.27} \times 100 = 28.29\%$

OR

Percentage composition of carbon $= \frac{12 \times 0.28}{44 \times 0.27} \times 100 = 28.29\%$

Exercise

(i) When 0.34g of an organic compound containing carbon, hydrogen and oxygen on complete combustion gave 0.43g of carbon dioxide. Calculate the percentage composition by mass of carbon in the organic compound.

(ii) 4.2g of carbon dioxide was given off when 2.9g of an organic compound containing carbon, hydrogen was completely burnt in excess oxygen. Calculate the % composition of carbon by mass in the organic compound.

NOTE; If you are given the volume of carbon dioxide, first use the volume to determine the mass of carbondioxide. Then use the mass to determine the percentage composition by mass of carbon in the organic compound

Example I

3.2g of an organic compound when burnt in excess oxygen produced 5.2dm^3 of carbon dioxide gas at s.t.p. calculate the percentage composition by mass of carbon in the organic compound.

Solution

First determine the mass of carbon in 5.2dm^3 of carbon dioxide

22.4dm^3 contain 1 mole of carbondioxide at s.t.p

22.4 dm^3 contain 12g of carbon

5.2 dm^3 contain $\frac{12}{22.4} \times 5.2 = 2.7857g$ of carbon

Then percentage composition of carbon by mass $= \frac{2.7857}{3.2} \times 100 = 87.05\%$

Example II

0.23g of an organic compound containing carbon, hydrogen and nitrogen on complete combustion produced 380 cm^3 of carbon dioxide at r.t.p. determine the percentage composition of carbon in the organic compound.

<u>Determining the percentage of hydrogen in the organic compound</u>

When determining the percentage of hydrogen, we use the same type of approach we used to determine the percentage of carbon.

Example I

0.34g of an organic compound on complete combustion produced 1.2g of water. Calculate the percentage composition of hydrogen in the organic compound.

Solution

First determine the mass of hydrogen in water.

18g of water contain 2g of hydrogen

1.2g of water contain $\frac{2}{18} \times 1.2 = 0.133g\ of\ hydrogen$

Then % by mass of hydrogen in the organic compound $= \frac{0.133}{0.34} \times 100 = 39.22\%$

OR

% of hydrogen $= \frac{mass\ of\ water \times 2}{molar\ mass\ of\ water \times mass\ of\ organic\ compound} \times 100$

$$\frac{1.2 \times 2}{18 \times 0.34} \times 100 = 39.22\%$$

Example II

3g of water were produced on complete combustion of 2.8g of an organic compound in excess oxygen. Determine the percentage by mass of hydrogen in the organic compound.

DETERMINING EMPIRICAL FORMULA OF ORGANIC COMPOUND

we use knowledge of how to determine the mass of carbon in carbon dioxide and mass of hydrogen in water to determine the empirical formula of an organic compound as shown in the example below

Example I

4.2g of a hydrocarbon Q on complete combustion produced 13.2g of carbon dioxide and 5.4g of water. Calculate the;

(a) Empirical formula of Q

Solution

Step one: determine mass of carbon and hydrogen.

Mass of carbon $= \frac{12 \times 13.2}{44} = 3.6g$

Mass of hydrogen $= \frac{2 \times 5.4}{18} = 0.6g$

Element	C	H
Mass	3.6	0.6
Mole	$\frac{3.6}{12}$	$\frac{0.6}{1}$
	0.3	0.6
Mole ratio	$\frac{0.3}{0.3}$	$\frac{0.6}{0.3}$
	1	2

Empirical formula of Q is CH_2

(b) Calculate the molecular formula of Q, given that Q has a vapour density of 21.

Relative molecular mass of Q = $2 \times vapour\ density = 2 \times 21 = 42$

Let the molecular formula of Q be $(CH_2)_n$

$(CH_2)_n = 42$ there fore $n = 3$

Therefore molecular formula of Q is C_3H_6

Example II

3.6g of an organic compound containing carbon, hydrogen and oxygen on combustion produced 7.92g of carbon dioxide gas and 4.32g of water.

(a) calculate the empirical formula of Z.

Solution

Mass of carbon $\frac{12\times7.92}{44} = 2.16g$

Mass of hydrogen $= \frac{4.32\times2}{18} = 0.48g$

Mass of oxygen $= 36 - (2.16 + 0.48) = 0.96g$

Element	Carbon	Hydrogen	Oxygen
Mass	2.16	0.48	0.96
Moles	$\frac{2.16}{12}$	$\frac{0.48}{1}$	$\frac{0.96}{16}$
Moles	0.18	0.48	0.06
Mole ratio	$\frac{0.18}{0.06}$	$\frac{0.48}{0.06}$	$\frac{0.06}{0.06}$
Mole ratio	3	8	1

The empirical formula of Z == C_3H_8O

(b) The molecular mass of z is 60. write the molecular formula of Z

$(C_3H_8O)_n = 60\ there\ fore\ n = 1$ Molecular formula of Z is C_3H_8O

Example III

2.9g of an organic compound K on complete combustion in excess oxygen produced 3.36dm^3 of carbon dioxide at s.t.p and 2.7g of water.

(a) Calculate the empirical formula of K

HINT: First get the mass of carbon from the volume of carbon dioxide.

22.4 dm^3 contains 1 mole of carbondioxide

22.4 dm^3 contains 12g of carbon.

3.36 dm^3 contains $\frac{12}{22.4} \times 3.36 = 1.8g\ of\ carbon$

Mass of carbon is 1.8g

Mass of hydrogen =$= \frac{2\times2.7}{18} = 0.3g$

Mass of oxygen $= 2.9 - (0.3 + 1.8) = 0.8g$

Element	Carbon	Hydrogen	Oxygen
Mass	1.8	0.3	0.8
Moles	$\frac{1.8}{12}$	$\frac{0.3}{1}$	$\frac{0.8}{16}$
Moles	0.15	0.3	0.05
Mole ratio	$\frac{0.15}{0.05}$	$\frac{0.3}{0.05}$	$\frac{0.05}{0.05}$
Mole ratio	3	6	1

Empirical formula of compound K is C_3H_6O

Example IV

3.72g of an organic compound M containing carbon, hydrogen and nitrogen on complete combustion produced 10.56g of carbondioxide and 2.52g of water.

(a) Calculate the empirical formula of M.

(b) Determine the molecular formula of M, given that relative formula mass of M is 93

Example V

3.6g of an organic compound R containing carbon, hydrogen and oxygen produced 0.72g of water and 3.52g of carbondioxide. Determine the;

(i) empirical formula of R.

(ii) molecular formula of R, given that relative molecular mass of R is 90.

To be continued…….