EXERCISE 3.6

MODULE 3 TOPIC 4 Units 1 to 3, p. 145 – 153
Gr 10 Physical Sciences 3-in-1

QUESTION 1

1.1 Define what is meant by *1 mole*.

1.2 Given 5 moles of ammonia, calculate the number of each of the following in the compound:

1.2.1 molecules 1.2.2 atoms

1.3 Given 4,5 moles of $A\ell(NO_3)_3$, calculate the number of each of the following in the compound:

1.3.1 formula units 1.3.2 moles of ions

1.4 Given 316 g of $KMnO_4$, calculate the number of each of the following in the compound:

1.4.1 atoms 1.4.2 ions

1.5 Given 161 g of NO_2, calculate the number of each of the following in the compound:

1.5.1 moles of molecules 1.5.2 oxygen atoms

QUESTION 2

2.1 A compound contains copper and oxygen. If 27,43 % of the compound is oxygen, determine the empirical formula of this compound.

2.2 Propene is a flammable gas used in the production industry. Propene consists of 86% carbon and 14% hydrogen by mass.

2.2.1 Determine the empirical formula of propene.

2.2.2 The molar mass of propene is 42 $g \cdot mol^{-1}$. Determine the molecular formula of propene.

QUESTION 3

3.1 Calculate the mass of water of crystallisation in 125 g of $CuSO_4 \cdot 5H_2O$.

3.2 Calculate the number of moles of water of crystallisation in hydrated aluminium chloride ($A\ell C\ell_3 \cdot nH_2O$) if 44,72 % of the mass is water.

3.3 If 998 g of hydrated copper sulphate ($CuSO_4 \cdot nH_2O$) is heated, it is found that 638 g of anhydrous $CuSO_4$ remains in the container. Calculate the number of molecules of water of crystallisation per formula unit of hydrated $CuSO_4$:

$$CuSO_4 \cdot nH_2O \xrightarrow[\Delta]{} CuSO_4 + H_2O$$

QUESTION 4

4.1 Consider the compounds NH_4NO_3 and $Fe_2(SO_4)_3$.

4.1.1 Name the compounds above. 4.1.2 Define molar mass.

4.2 Fertilisers like NH_4NO_3 contain nitrogen needed by plants to grow. Calculate:

4.2.1 its molar mass 4.2.2 its percentage composition

4.2.3 the mass of nitrogen in a 50 kg bag of fertiliser, of which only half is fertiliser and the remainder consists of fillers

4.3 NH_4NO_3 and $Fe_2(SO_4)_3$ both consist of particles that are bonded in a crystal lattice. For the crystal lattice of NH_4NO_3, provide:

4.3.1 the names AND formulas of the particles that it consists of

4.3.2 the type of bond that exists between the particles in the crystal lattice

4.3.3 the number of moles of the particles in 2 moles of the compound

4.3.4 TWO physical properties of the compound

4.4 Consider the compound $Fe_2(SO_4)_3$ calculate the:

4.4.1 molar mass

4.4.2 percentage oxygen in the compound

4.4.3 number of moles formula units present in 100 g of the compound

4.4.4 number of iron atoms present in 100 g of the compound

EXERCISE ANSWERS

QUESTION 1

1.1 A mole is the quantity of a substance that contains the same number of particles (atoms, molecules, formula units) as the number of atoms in 12 g of carbon-12.

1.2.1 $N(\text{molecules}) = nN_A$
$= 5 \times (6{,}02 \times 10^{23})$
$= 3.01 \times 10^{24}$ molecules

NOTE
The formula of ammonia is NH_3. It contains 4 atoms per molecule, i.e. 1 O and 3 H.

1.2.2 $N(\text{atoms}) = 4 \times (3{,}01 \times 10^{24})$
$= 1{,}20 \times 10^{25}$ atoms

NOTE
Multiply the number of main substituent particles by a factor, i.e. 4 in this case, to calculate the number of sub-particles.

1.3.1 $N(\text{formula units}) = nN_A$
$= 4{,}5 \times (6{,}02 \times 10^{23})$
$= 2{,}71 \times 10^{24}$ formula units

1.3.2 $n(\text{ions}) = 4 \times 4{,}5 = 18$ mol ions

NOTE
$A\ell(NO_3)_3$ contains 4 ions per formula unit, i.e. 1 $A\ell^{3+}$ and 3 NO_3^- ions.

1.4.1 $n(KMnO_4) = \frac{m}{M}$
$= \frac{316}{158}$
$= 2$ mol

m = 316 g

$M(KMnO_4) = 39 + 55 + (4 \times 16)$
$= 158\ g \cdot mol^{-1}$

$N(\text{formula units}) = nN_A$
$N(\text{atoms}) = 6 \times 2 \times (6{,}02 \times 10^{23})$
$= 7{,}27 \times 10^{24}$ ions

NOTE
$KMnO_4$ contains 6 atoms per formula unit, i.e. 1 K, 1 Mn and 4 O

1.4.2 $N(\text{ions}) = 2 \times 2 \times (6{,}02 \times 10^{23})$
$= 2{,}41 \times 10^{24}$ ions

NOTE
$KMnO_4$ contains 2 ions per formula unit, i.e. 1 K^+, 1 MnO_4^- ions

1.5.1 $n(NO_2) = \frac{m}{M}$
$= \frac{161}{46}$
$= 3{,}5$ mol molecules

m = 161 g

$M(NO_2) = 14 + (2 \times 16)$
$= 46\ g \cdot mol^{-1}$

1.5.2

NOTE

First calculate the number of NO_2 molecules, then multiply by 2 to calculate the number of O atoms

$N(NO_2) = nN_A$

$N(O\ atoms) = 2 \times 3,5 \times (6,02 \times 10^{23})$

$= 4,21 \times 10^{24}$ O atoms

NOTE

NO_2 contains 2 O atoms per molecule

NOTE

*First determine the **number of moles** of the main constituent **particles** (molecules or formula units) of the substance, e.g. $n = \frac{m}{M}$, etc.* . . . ❶

*Then determine the **number of particles** (molecules or formula units), i.e. $N = nN_A$* . . . ❷

*Then determine the **number** of sub-particles, i.e. **atoms** or **ions**, etc. in the molecule or formula unit, i.e multiply the number in ❷ by the number of atoms/ions etc per molecule or formula unit.*

QUESTION 2

2.1 Take the compound as Cu_xO_y

27,43% is oxygen and 100 – 27,43 = 72,57% is Cu

In 100 g of the compound:

$m(Cu) : m(O) = 72,57 : 27,43$

$n(Cu) : n(O) = \frac{72,57}{63,5} : \frac{27,43}{16}$

$= 1,1428 : 1,7144$

$= 1 : 1,5$

$= 2 : 3$

Therefore the empirical formula is Cu_2O_3

$n = \frac{m}{M}$

REMEMBER

Divide by the smallest number. Do not round 1,5 off, but multiply by 2.

2.2.1 Take the compound as C_xH_y

86% is carbon and 14% is H

In 100 g of the compound:

$m(C) : m(H) = 86 : 14$

$n(C) : n(H) = \frac{86}{12} : \frac{14}{1}$

$= 7,16 : 14$

$= 1 : 2$

Therefore the empirical formula is CH_2

2.2.2 $M(CH_2) = 12 + (2 \times 1)$

$= 14\ g \cdot mol^{-1}$

$\frac{M(molecular\ formula)}{M(empirical\ formula)} = \frac{42}{14}$

$= 3$

Molecular formula = C_3H_6

QUESTION 3

3.1 $M(CuSO_4 \cdot 5H_2O) = 63,5 + 32 + (4 \times 16) + 5(2 + 16)$

$= 249,5\ g \cdot mol^{-1}$

NOTE

Determine the %H_2O in hydrated copper sulphate from the given formula of the compound. Use this % to determine the mass of the H_2O in a 125 g sample.

$$\%H_2O \text{ in } CuSO_4 \cdot 5H_2O = \frac{90}{249,5} \times \frac{100}{1}$$

$$= 36,07\%$$

$m(H_2O) = \%H_2O \times$ total mass of compound

$$= \frac{36,07}{100} \times 125$$

$= 45,09\ g$

3.2

REMEMBER

The percentage composition of a compound can be calculated from the empirical or molecular formula of the compound and vice versa, the empirical formula can be calculated from the percentage composition of the compound.

Consider the compound $A\ell C\ell_3 \cdot nH_2O$:

44,72% is H_2O and 100 – 44,72

= 55,28% is $A\ell C\ell_3$

NOTE

Determine the empirical formula from the percentage composition (%$A\ell C\ell_3$ and %H_2O) of the compound.

In 100 g $A\ell C\ell_3 \cdot nH_2O$:

$m(A\ell C\ell_3) : m(H_2O) = 55,28 : 44,72$

$$n(A\ell C\ell_3) : n(H_2O) = \frac{55,28}{27 + (3 \times 35,5)} : \frac{44,72}{2 + 16}$$

$= 0,4141 : 2,4844$

$= 1 : 6$

The number of moles of water is therefore 6, i.e. the compound is $A\ell C\ell_3 \cdot 6H_2O$

3.3 998 g of $CuSO_4 \cdot nH_2O$ contains 638 g anhydrous $CuSO_4$ and

998 – 638 = 360 g H_2O

$m(CuSO_4) : m(H_2O) = 638 : 360$

$$n(CuSO_4) : n(H_2O) = \frac{638}{63,5 + 32 + (4 \times 16)} : \frac{360}{2 + 16}$$

$= 4 : 20$

$= 1 : 5$

$n(H_2O)$ per formula unit = 5 mol

molecules(H_2O) per formula unit $= 5 \times 6,02 \times 10^{23}$

$= 3,01 \times 10^{24}$ molecules

QUESTION 4

4.1.1 NH_4NO_3 – ammonium nitrate $Fe_2(SO_4)_3$ – iron(III) sulphate

4.1.2 The molar mass (M) of a substance is the mass of 1 mole of the substance.

4.2.1 $M(NH_4NO_3) = (2 \times 14) + (4 \times 1) + (3 \times 16)$
$= 80\ g \cdot mol^{-1}$

4.2.2 $\%N = \frac{28}{80} \times \frac{100}{1} = 35\%$

$\%H = \frac{4}{80} \times 100 = 5\%$

$\%O = \frac{48}{80} \times 100 = 60\%$

4.2.3 mass of N in the bag $= \frac{35}{100} \times 25 = 8{,}75\ kg$

4.3.1 ammonium ion (NH_4^+ ion) and nitrate ion (NO_3^- ion)

4.3.2 ionic bond

4.3.3 4 moles

NOTE
n(formula units (NH_4NO_3) : ions) = 1 : 2

4.3.4 ○ it is a solid at room temperature
○ it is soluble in water
○ it can conduct electricity in a solution or if molten *(any 2)*

4.4.1 $M(Fe_2(SO_4)_3) = (2 \times 56) + 3[32 + (4 \times 16)] = 400\ g \cdot mol^{-1}$

4.4.2 $\%O = \frac{192}{400} \times 100$
$= 48\%$

4.4.3 $n = \frac{m}{M}$
$= \frac{100}{400}$
$= 0{,}25$ mol formula units

4.4.4 $N(\text{formula units}) = nN_A$

$N(\text{Fe atoms}) = 2 \times 0{,}25 \times (6{,}02 \times 10^{23})$
$= 3{,}01 \times 10^{23}$ iron atoms

NOTE
$Fe_2(SO_4)_3$ contains 2 Fe^{3+} ions per formula unit.