CHAPTER 4

4.0 CHEMICAL SYMBOLS, FORMULAS AND EQUATIONS

4.1 CHEMICALSYMBOLS: Chemical symbols are the chemist abbreviated form of writing or representing the names of elements. The principle applied when representing element was put forward by Berzkelius in 1814. The principle entails the following.

1. The first principle uses the first letter, (written in capital letter) of the name of an element as its symbol. Examples includes; Hydrogen (H), Boron (B), Carbon (C), Nitrogen (N) Oxygen(O) Fluorine (F)Phosphorus (P)

2. When the first letter had already been adopted. The first letter and any other letter in the name of the element is used as the symbol. Here, the first letter is written in capital letter while the second letter is written in small letter. Examples includes ; Helium (He),Lithium (Li) Beryllium (Be), Neon (Ne), Magnesium (Mg), Aluminium (Al)

3. When these two methods have been adopted, the symbol of the elements is then derived from the Latin names of the elements using method one and two above. Example includes; Sodium (Natrium, Na), Potassium (kalium, K), Iron (Ferrum, Fe) andCopper (Caprum, Cu).

As earlier stated, these abbreviations s are written in capital letter when the symbol is only one letter. In cases where it has two letters, only the first letter is written in capital letter, while the other letter is written in small letter.

The symbols of an element represent

1. One atom of the element

2. A definite mass of the element often expressed in grams

4.2 CHEMICAL FORMULA

A chemical formula is an expression involving chemical symbols and numerical. The symbols represents the different types of elements present (i.e. composition) in the compound while the numerical indicates the number of atoms in one molecule of a compound, when it is written as a subscript after the symbol of the element. Example is H_2 which show that it contains two atoms of hydrogen; H_2SO_4 shows that the chemical formula contains two atoms of hydrogen, one atom of sulphur and four atoms of oxygen.

There are basically three types of chemical formulas namely empirical, molecular and structural formulas.

i. **EMPIRICAL FORMULA**: This is the simplest formula of a compound that shows the simplest whole number ratio of atoms of different elements present in a compound. Hence the empirical formula of the compound $C_2H_4O_2$ is CH_2O, where the integer multiplier is 2.

Normally, the results of chemical analysis are expressed as percentage by mass of each constituent element, so to know the identity of the compound the empirical formula will be calculated from the percentage composition. Calculation of the empirical formular of the compound entails first determining the relative number of moles of atoms of each elementpresent in the given mass of the compound. Thereafter, the number of moles of each element is then divided by the smallest number of the mole present.

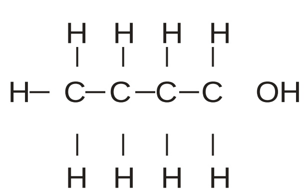
4.2.2 MOLECULAR FORMULA: This is a formula of a compound that shows the exact (actual) number of atoms of different element present in a compound. The molecular formula is given by

Molecular Formula = Empirical formula X integer multiplier

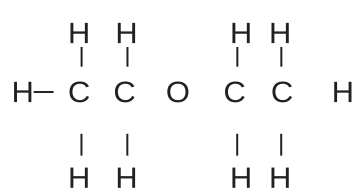
Molecular formula = n (Empirical formula)

Sometimes, empirical formula and molecular formula can be the same. This is when the molecular formula cannot be reduced further. Examples includes NH_3 (ammonia), $CaCO_3$ (calcium trioxocarbonate (IV), H_2O (water) CO_2 (carbon(IV)oxide) etc.

4.2.3 STRUCTURAL FORMULA: - The structural formula shows the way that atoms are joined together in a molecule. Knowledge of the structural formula of compound is important in the study of chemistry because some compounds may have the same molecular formula and empirical formula and the only thing that will show that the compounds are different is their structural formula. As an illustration, Butanol and ethyl ether have the same empirical and molecular formula as $C_4H_{10}O$. The only thing that differentiates the two and gives both their respective unique set of properties is the structural formula.



Butanol



Ethylether

Example 4.1

Find the empirical formula of a compound which contains 80% carbon and 20% hydrogen by mass.

(Relative atomic masses, C = 12, H = 1)

Solution

Step 1: Divide the percentage by mass of each element by the relative atomic mass of the element

For carbon - $\frac{80}{12} = 6.6$

For Hydrogen - $\frac{20}{1} = 20$

Step 2: Divide through by the smallest number since atoms cannot be in fraction

$\frac{6.6}{6.6} = 1, \quad \frac{20}{6.6} = 20$

Therefore empirical formula is CH_3

Example 4.2

An organic compound contains 72% carbon, 12% hydrogen and 16% oxygen by mass. Calculate the empirical formula of the compound (Relatives atomic masses; H = 1, 0 = 16, C= 12)

Solution

Step1

$C = \frac{72}{12.} = 6, O = \frac{16}{16} = 1, H = \frac{12}{1} = 12$

Step2: Dividing through by the smallest number

$$\frac{6}{1.} = 6, \frac{1}{1.} = 1, \frac{12}{1.} = 12,$$

: - Empirical formula = $C_6H_{12}O$

Example 4.3: A pure compound contains 40% carbon, 6.7% hydrogen and 53.3% oxygen. Find

(i) The empirical formula

(ii) The molecular formula if a mole weighs 60g (Relative atomic masses; H = 1, C = 12, O = 16)

Solution

$$C = \frac{40}{12.} = 3.33, H = \frac{6.7}{1} = 6.7, O = \frac{53.3}{16.} = 3.33$$

Dividing through by the smallest we get

$$C = \frac{3.33}{3.33.} = 1, H = \frac{6.7}{3.33} = 2, C = \frac{3.33}{3.33} = 1$$

: - Empirical formula is CH_2O

(ii) Molecular formula = n (empirical formula) ----------------(1)

I mole of molecular formula = n (mole of empirical formula

I mole empirical formula = 12gC + 2gH + 16gO

= 30g

From question, 1 mole molecular formula = 60g

From equation (1)

60 = n (30)

60 = 30n

$$n = \frac{60}{30.} = 2 = integer\ multiplier$$

: - Molecular formula = 2(empirical formula)

= $2(CH_2O)$

= $C_2H_4O_2$

4.3 PREDICTING FORMULAS FROM VALENCIES

Recall that in chapter one we defined vacancy as the number of electrons an atom can lose, gain or share to acquire an octet or duplet electronic configuration. The formulas of compounds canbe deduced from the valences of component elements or radicals using the following rules

Rule 1: Write the symbols of the component elements or radicals

Rule 2: Place the valences of each elements or radical below the respective element or radical

Rule 3: Interchange the valences and write them as subscript immediately after the respective symbols of the atoms.

Rule 4**:** Write the formula of the compound by first writing the metals followed by the non- metals.

Note: When the subscript is one, it is disregarded and when all the subscripts can divide through, they are further reduced.

Examples 4.4

Write the formula of the compound formed when iron (III) reacts with oxygen.

Rule 1: Fe O

Rule 2: Fe O

3 2

Rule3: Fe O

3 2

Rule 4: Fe_2O_3

Example 4.5

What is the formula of aluminum sulphide

Rule 1: Al S

Rule 2: Al S

3 2

Rule3: Al S

3 2

Rule4: Al_2S_3

Example 4.6

Write the formula of sodium oxide

Rule 1: Na O

Rule 2: Na O

1 2

Rule 3: Na O

1 2

Rule 4: Na_2O

These rules are the same even when writing the formulas of compounds involving radicals. Radicals are groups of atoms collectively carrying a single charge. The only modification is that the radical is enclosed in a bracket if it has a value above one. Below in table 4.1 are some radicals and their valences.

Table 4.1Examples of some radicals and their valencies

Radical	Formula	**Valency**
Ammonium	NH_4^+	**1**
Hydroxide	OH^-	**1**
Trioxonitrate (V)	NO_3^-	**1**
Trioxocarbonate(IV)	CO_3^{2-}	**2**
Tetraoxosulphate (VI	SO_4^{2-}	**2**
Tetraoxophosphate (V)	PO_4^{3-}	**3**

Example: 4. 7

Write the formula of calcium sulphate

Rule 1: Ca SO_4

Rule 2: Ca SO_4

2 2

Rule 3: Ca SO_4

2 2

Rule 4: $Ca_2(SO_4)_2$.

Since both subscripts can divide through they can be further reduced, leaning our formula as $CaSO_4$

Example 4.8

Write the formula of sodium trioxocarbonate(IV)

Rule 1: Na CO_3

Rule 2: Na CO_3

1 2

Rule 3: Na CO_3

1 2

Rule 4: Na_2CO_3

In summary, a chemical formula shows how many atoms of each element present in a compound. When a group of atoms is put in a bracket e.g. $Al_2(CO_3)_3$, the subscript that follows the bracket applies to all the atoms inside the bracket only. As an illustration, the formula of aluminum trioxocarbonate(V) implies that for each formula unit of aluminum troxocarbonate(V)

(1) There are two aluminum ions

(2) There are 3 trioxocarbonate ions

(3) In each trioxocarbonate ion there is one carbon atom and three oxygen atoms.

$Al_2\ (CO_3)_3$

2 aluminim ion 3 trioxo carbonate ion

4.4. CHEMICAL EQUATIONS

A chemical equitation is a compressed statement about a chemical reaction, using symbols and formulas. A reaction can be written in words for example oxygen reacting with hydrogen to produce water

$$\text{Oxygen} + \text{Hydrogen} \longrightarrow \text{water.}$$

This type of equation is of little importance to the chemist as it does not indicate the quantities of each reactant taking part in the reaction and the quantities of the product formed in cause of the chemical reaction. It does not even specify the state of the reactant and product.

For a chemical equation to be useful to chemist, the actual quantities of the reactants and products must be specified. This is where the law of conservation of matter comes into place. According to the law, the total quantity of the reactant must equal to the total quantity of the product formed. A chemical equation that has this quality is said to be a balanced chemical equation.

4.5. BALANCING CHEMICAL EQUATIONS

A balanced chemical equation is an exact symbolized expression of a chemical reaction, where all the atoms of the different elements in the reactants are equal to all the atoms of different elements in the products.

In balancing a chemical equation, the following steps should be taken:

Step 1: Write a word equation for the reaction.

Step 2: Write the correct formula of all the reactants and products

Step 3: Select coefficients that will make the equation balanced Note, do not change the subscript in the formulas of the compound while balancing

Example 4.10

Write a balanced chemical equation for the reaction between chlorine and sodium bromide to produce sodium chroride and bromine

Solution

Step 1:

Chlorine + sodium bromide $\longrightarrow$ sodium chloride + Bromine

Step 2:

Determine the formulas of sodium bromide and sodium chloride using methods for predicting formulas, discussed earlier

$$Cl_2 + NaBr \longrightarrow NaCl + Br_2$$

Step 3: Coefficient are selected in order to balance the equation. The subscript must not be changed. Coefficients are whole numbers written before the formula of a compound, element, ion, molecule, indicating the relative number of unit reacting in the chemical reaction.

$$Cl_2 + 2NaBr \longrightarrow 2NaCl + Br_2.$$

Example 3.11

Write a balanced chemical equation for the reaction between hydrochloric acid and calcium trioxocarbonate (IV) to produce calcium chloride, water and carbon(IV) oxide

Solution

Step 1:

Hydrochloric acid + calcium trioxocarbonate (IV) $\rightarrow$ Calcium chloride + water + carbon(IV)oxide

Step 2:

Using the steps for predicting formulas, predict the formulas for calcium trioxocarbonate(IV), calcium chloride, carbon(iv)oxide, hydrochloric acid, and water.

$$HCl + CaCO_3 \longrightarrow CaCl_2 + H_2O + CO_2$$

Step 3: Select coefficient on either sides of equation‟s formulas that will balance the equation.

$$2HCl + CaCO_3 \longrightarrow CaCl_2 + H_2O + CO_2$$

Example 4.12

Write the balanced equation for the reaction between aluminum sulphate and calcium chloride to produce aluminum chloride and a white precipitate of calcium sulphate solution.

Step 1:

Aluminium sulphate + calcium chloride $\longrightarrow$ Aluminum chloride + calcium sulphate

Step 2:

$Al_2(SO_4)_3 + CaCl_2 \longrightarrow AlCl_3 + CaSO_4$

Step 3:

$Al_2(SO_4)_3 + 3CaCl_2 \longrightarrow 2AlCl_3 + 3CaSO_4$

N.B

The oxidation states of elements or radicals with variable oxidation state are always stated e.g. carbon (II) oxide implies that the carbon has the oxidation state of + 2. Iron (III) implies oxidation state of +3.