1 LANGUAGE OF CHEMISTRY

WHAT WE HAVE LEARNT

- **Charged atoms are called ions.**
- **Charged atom groups are called radicals.**
- **Valency of an element is determined by the number of electrons in the outermost shell.**
- **Some elements show more than one oxidation state.**
- **Molecular mass is the sum of the atomic masses of the different elements in the molecule.**
- **Electronegativity is the tendency of an atom to attract the bonded pair of electrons towards it.**
- **Electronegativity of elements increases as we go from left to right in the periodic table.**

LANGUAGE OF CHEMISTRY

You have discussed many concepts in Chemistry, Physics, Biology and Mathematics. Each branch of science has its own language and modes of communication. You know that the chemical name of the substance known as 'blue vitriol' is copper sulphate. Chemical names are based on certain rules and conventions made by scientists about naming compounds. At times we represent the same compound using the formula - $CuSO_4.5H_2O$. This formula is also based on certain rules. Formulating rules for the naming of compounds is very important in Chemistry. From the formula of a compound we can identify the elements in it as well as the number of atoms of each element. When chemical reactions are explained, it is necessary to take into account the number of molecules and the quantity of each substance that enters into chemical reaction. For this purpose we often use certain calculations in chemistry. Let us take up the calculations related to percentage purity, percentage composition, mole concept and empirical formula in this chapter.

Writing formulae

The formula of a compound is based on the valency of the elements in it. You have already studied how to write the formula of compounds with only two elements in it. You know the valency of carbon and oxygen.

The valency of carbon = 4

The valency of oxygen = 2

Let us examine the different stages in writing the formula of carbon dioxide.

Stage 1 **The symbols of the elements are written adjacent to each other. The element with low electronegativity should be written on the left side while the element with high electronegativity should be written on the right side.**

C O

Stage 2 **The valency of the element is written at the right hand side above the symbol.**

$C^4\ O^2$

Stage 3 **The valencies are interchanged and written as base index**

$\overset{4}{C}\ \overset{2}{O}$ $\quad C_2\ O_4$

Stage 4 **These numbers are divided by the common factor.**

$\rightarrow CO_2$

If the index is '1', it need not be indicated. Therefore C_1O_2 can be written as CO_2.

Now we can write down the formula of calcium chloride.

Valency of calcium = ...

Valency of chlorine = ...

Which element should be written first? What are the different stages in writing the formula?

1. **Ca Cl**
2. **Ca Cl**
3. **Ca Cl**
4. **.....**

Now you can write the formulae of the important compounds formed by the combination of the elements given below:

element	valency
Carbon	**4**
Hydrogen	**1**
Oxygen	**2**
Chlorine	**1**

Table 1.1

Some elements exhibit more than one oxidation state. For instance, iron which is a transition element, shows two different oxidation states, i.e., 2+ and 3+. In Fe^{2+} the valency of iron is 2 and in Fe^{3+} the valency of iron is 3. Write down the formulae of two oxides of iron.

- Write the formula of the two chlorides of iron.

What information is required to write the formula of compounds containing two elements alone? Make a note of it in your science diary.

The names and chemical formulae of some compounds containing more than two elements are given below.

Sodium hydroxide = NaOH

Calcium hydroxide = $Ca(OH)_2$

Sulphuric Acid = H_2SO_4

How are these formulae written? In these compounds there are charged atom groups which take part in chemical reaction as a single unit. They are called radicals.

Can you figure out the radicals present in the compounds listed above?

Na(OH)	**Na^{1+}**	**OH^{1-}**
$Ca(OH)_2$	**Ca^{2+}**	**$2OH^{1-}$**
H_2SO_4	**$2H^{1+}$**	**SO_4^{2-}**

Here OH^{1-} and SO_4^{2-} are called hydroxide and sulphate radicals respectively.

Now you can write the different steps followed to get the formulae of the compounds given above.

Eg : Calcium hydroxide

Stage : 1 $Ca^{2+}\ OH^{1-}$

Stage : 2 . . . . . .

Stage : 3 . . . . . .

Stage : 4 . . . . . .

The name, charge and valency of some radicals are given below. Find out the formulae of sodium carbonate, ammonium phosphate and calcium sulphate with the help of the following table (Table 1.2).

Radicals	Name	Charge	Valency
NH_4^{1+}	Ammonium ion	1+	1
HCO_3^{1-}	Bicarbonate ion	1--	1
CO_3^{2-}	Carbonate ion	2--	2
H_3O^{1+}	Hydronium ion	1+	1
OH^{1-}	Hydroxide ion	1--	1
NO_3^{1-}	Nitrate ion	1--	1
NO_2^{1-}	Nitrite ion	1--	1
PO_4^{3-}	Phosphate ion	3--	3
SO_4^{2-}	Sulphate ion	2--	2
SO_3^{2-}	Sulphite ion	2--	2

Table 1.2

Naming of compounds

Let us examine how a compound is named.

Fill in the name of the compounds given below.

Formula **Name of compound**

- **NaCl** . . . . . .
- **KCl** . . . . . .
- **KOH** . . . . . .

The name of the positive ion forms the first part of the name of the compound. Second part is formed by adding 'ide', 'ite' or 'ate' to the name of the negative ion.

The names of the following compounds can be written with the help of the table 1.2.

- K_2CO_3
- $NaHCO_3$
- NH_4NO_2
- $CaSO_4$
- $Ca_3(PO_4)_2$

Percentage purity

The chemicals that we commonly use in the laboratory may contain impurities.

You must have noticed the percentage purity shown on the label of chemicals. For example, the label on calcium carbonate bottle shows 99.5% percentage purity. What is meant by this?

- **What does the symbol of percentage indicate?**
- **What is the actual amount of $CaCO_3$ in a sample of 100 grams?**
- **What is the amount of impurity?**

'99.5%' actually indicates the percentage of pure $CaCO_3$ in 100g of the sample. In every packet of chemical used in the laboratory, percentage purity is given. Make a list of the name of the compound and the percentage purity.

916 Gold

22 carat gold is known as 916 gold. It means that out of 24 parts, 22 parts contain pure gold and 2 parts contain either silver or copper. When converted into percentage it becomes 91.6%. In other words 1000 milli grams of gold contains 916 milli grams of pure gold in it.

$\frac{2}{18} \times 100$

Percentage composition

You know the chemical formula for water. What are the elements in it? What is the atomic mass of each component?

Molecular mass of water = the sum of the atomic mass of the elements in it

= atomic mass of hydrogen × 2 + atomic mass of oxygen × 1

= 1× 2 + 16×1 = 18

The atomic mass of some elements are given. Fill in the column of molecular mass of the substances given in the table.

H = 1 N = 14 O = 16
S = 32 Cl = 35.5 Ca = 40

Formula	Molecular mass	Gram molecular mass
H_2	1× 2 = 2	2 g
Cl_2		
HCl		
H_2SO_4		
$Ca(NO_3)_2$		

Table 1.3

You are familiar with the method of calculating the molecular mass of each molecule. The atomic mass of each element in a molecule, expressed in percentage is called its percentage composition.

Let us see how the percentage composition of hydrogen in water molecule can be calculated.

Molecular mass of water = 18

Mass of hydrogen in 18 g of water = 2 g

Percentage of hydrogen in 18 g of water (Percentage composition of hydrogen) =

= 11.11%

Calculate the percentage composition of oxygen in water.

Mass of oxygen in 18 g of water = ... g

Percentage composition of oxygen = ...

Let us find out the percentage composition of each element in sulphuric acid.

Formula of sulphuric acid = H_2SO_4

Molecular mass of sulphuric acid = ...

Mass of hydrogen in 98 g of H_2SO_4 = 2 g

Percentage composition of

hydrogen in H_2SO_4= = ...

Mass of sulphur in 98 g of H_2SO_4 = 32 g

Percentage composition of

sulphur = $\frac{.....}{.....} \times 100$ = ...

Now you can calculate the percentage composition of oxygen in H_2SO_4.

- **Calculate the percentage composition of different elements present in glucose ($C_6H_{12}O_6$), sugar ($C_{12}H_{22}O_{11}$), and calcium carbonate ($CaCO_3$).**

Chemical formula and percentage composition

You have studied how to calculate the percentage composition of an element in a compound whose formula is known. How can we calculate the percentage composition, if the formula is not known? In such cases it is calculated by conducting chemical analysis.

Mole concept

You have studied the process of formation of hydrogen chloride by the action of hydrogen and chlorine.

$H_2 + Cl_2 \rightarrow 2HCl$

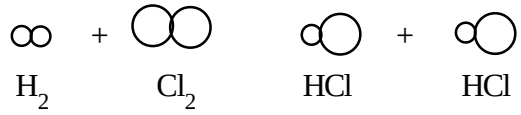
In this reaction, 2 atoms of hydrogen and 2 atoms of chlorine combine to form 2 molecules of HCl.

- **How many hydrogen atoms are there in one molecule of hydrogen?**
- **In one molecule of chlorine, how many chlorine atoms are present ?**

Is it clear that one atom of hydrogen and one atom of chlorine combine to form one molecule of HCl?

What is the mass of chlorine that can combine with 1 g of hydrogen? Look at the equation given below:

1g H_2 + 35.5 g Cl_2 $\rightarrow$ 36.5 g HCl



This means that for accomplishing a total chemical reaction without leaving any atom of hydrogen or chlorine unreacted, the number of atoms in 1 g of hydrogen and 35.5 g of chlorine should be equal.

The mass of **6.022×10^{23}** atoms is known as gram atomic mass or gram atom. This is equal to the atomic mass expressed in grams.

Avogadro discovered that 1 g of hydrogen contains **6.022×10^{23}** atoms. This is known as the Avogadro number. It is denoted by 'N_A'.

Atomic mass of chlorine is 35.5. What will be the number of atoms present in 35.5 g chlorine?

Gram atomic mass of chlorine = 35.5 g

Examine table 1.4.

- **What is the number of atoms in 4 g of helium?**
- **What is the mass of 6.022×10^{23} carbon atoms?**

Why is the mass of same number of helium atoms and carbon atoms different?

Element	Atomic mass	Gram atomic mass	Number of atoms
H	1	1 g	6.022×10^{23}
Cl	35.5	35.5 g	6.022×10^{23}
He	4	4 g	6.022×10^{23}
Na	23	23 g	6.022×10^{23}
N	14	14 g	6.022×10^{23}
C	12	12 g	6.022×10^{23}

Table 1.4

From the table it is clear that the mass of 6.022×10^{23} atoms of any element will be its gram atomic mass.

You have seen that there are 6.022×10^{23} atoms in 1 g of hydrogen. The number of atoms in 2 g of hydrogen can now be calculated. Can you find the number of atoms in given mass of elements in table 1.5? How is the number of atoms related to atomicity?

Each molecule of hydrogen contains two atoms in it. What would be the mass of 6.022×10^{23} molecules of hydrogen?

International Mole Day

Mole is an important unit in chemistry. Chemists celebrate the International Mole Day. Mole day is observed on 23rd October from 6.02 am to 6.02 pm. What is the significance of this day? You know that a mole is equal to 6.02×10^{23}. To indicate 10^{23} the 23rd day of October, the 10th month was selected as the International Mole Day. Time is indicative of the number 6.02. Chemists pay their respect to the mole by raising the flame of the Bunsen burner in the laboratory.

Element	gram atomic mass	Mass of the element in grams	Number of atoms	Number of Molecules
H_2	1 g	2 g	$\frac{2}{1} \times 6.022 \times 10^{23}$	6.022×10^{23}
N_2	14 g	28 g	$\frac{28}{14} \times 6.022 \times 10^{23}$	6.022×10^{23}
O_2	……	48 g	$\frac{\ldots\ldots}{\ldots\ldots} \times 6.022 \times 10^{23}$	……
P_4	31 g	124 g	$\frac{\ldots\ldots}{\ldots\ldots} \times$……	……
O_3	16 g	96 g	$\frac{\ldots\ldots}{\ldots\ldots} \times$……	……

Table 1.5

Mole is defined as the amount of substance which contains 6.022×10^{23} elementary particles.

That is

1 mole hydrogen atoms = 1 g

1 mole hydrogen atoms

= 6.022×10^{23} atoms

1 gram atom H = 1 g

1 gram atom He = 4 g

1 gram atom Cl = ... g

1 gram atom K = ... g

How many mole atoms are there in 4 g helium? How will you find out?

Gram atomic mass of Helium = 4 g

$$\textbf{Moles in 4 g He atom} = \frac{4\text{ g}}{4\text{ g}} = 1$$

Calculate the mole atoms in 40 g helium.

$$\textbf{Mole atoms in 40 g He } \frac{40\text{ g}}{4\text{ g}} = 10$$

Can you derive a common formula?

Number of mole atoms

$$= \frac{\text{Mass in gram}}{\text{Gram atomic mass}}$$

The mass of 6.022×10^{23} molecules stated in grams is known as gram molecular mass or gram mole.

Consider 1 gram molecular mass of different substances. Fill table 1.6 with molecular mass of each and the number of molecules in each substance.

From the table it can be seen that 1 gram molecular mass of a substance is equal to 1 mole.

Substance	Molecular mass	Amount of substance		Number of molecules	Number of moles
		in gram molecules	in grams		
H_2	2	1 gram molecular mass	2 g	6.022×10^{23}	1
N_2	28	1 gram molecular mass	28 g	6.022×10^{23}	1
H_2O	.....	1 gram molecular mass	.....	6.022×10^{23}	1
HCl	.....	1 gram molecular mass	.....	6.022×10^{23}	1
H_2SO_4	.....	1 gram molecular mass	.....	6.022×10^{23}	1

Table 1.6

Find out the number of moles in different masses of the same substance and complete table 1.7

Substance	Molecular mass	Gram molecular mass	Mass in grams	Moles
Water	18	18 g	18	1
			36	2
			54	
			90	
			180	
Nitrogen	28	.....	28	
			70	
			560	
			1400	

Table 1.7

Write down a formula to find out the number of moles in a substance.

Number of

$$\textbf{moles} = \frac{\textbf{Mass in grams}}{\textbf{Gram molecular mass}}$$

$\frac{84}{28} = 3$

- **Calculate the number of moles in 84 g of nitrogen.**

  Mass in grams = 84 g

  Molecular mass of nitrogen = 28

  $\therefore$ **Number of moles =**

- From the table you can now write the mass of 1 mole oxygen atoms and 1 mole oxygen molecules.

  1 mole atom of oxygen = ... g

  1 gram mole of oxygen = ... g

Substance	No. of moles	No. of molecules
32 g oxygen		
16 g oxygen		
18 g H_2O		
12 g carbon		

Table 1.8

- **Calculate the number of moles of water molecules in 90 g of water. What will be the number of molecules of water?**
- **The molecular mass of sugar is 342. Calculate the number of moles in 1 kg sugar.**
- **What will be the mass of 10 moles of carbon dioxide? The molecular mass of CO_2 is 44.**

Empirical formula

Now let us examine how we can derive the formula of a substance from its percentage composition.

The chemical analysis of a compound shows that it contains 75% carbon and 25% hydrogen. If so, is it possible to find the ratio of the number of atoms of carbon and hydrogen?

The atomic mass of carbon is 12. What is the atomic mass of hydrogen?

The percentage composition gives the idea that 100 g of the substance contains 75 g of carbon and 25 g of hydrogen.

We can find out the ratio of the number of atoms by calculating the number of moles in it.

Number of moles in

$$\textbf{75 g of carbon} = \frac{75}{12}$$

Number of moles in

$$\textbf{25 g of hydrogen} = \frac{25}{1}$$

$$\textbf{C:H} = \frac{75}{12} : \frac{25}{1} = \textbf{6.25 : 25}$$

When decimal number is got, each number can be divided by the smallest number to get whole number ratio.

$$\textbf{C:H} = \qquad = \textbf{1 : 4}$$

i.e., each carbon atom combines with 4 hydrogen atoms. In other words, we can write it as CH_4. Empirical formula (EF) of a compound is the simplest formula which indicates the ratio of number of atoms of each element present in one molecule of the compound.

The percentage compositions of benzene are given below.

Carbon = 92.30%

Hydrogen = 7.692%

Find out the empirical formula of benzene. You may refer the format given below as table 1.9.

Element	C	H
Percentage composition		
Atomic mass		
Simplest ratio		
Whole number ratio		

Table 1.9

Empirical formula gives the ratio of the number of atoms of different elements in a compound. It does not tell us the actual number of atoms of each element. For this we have to get the molecular formula. For example, a molecule of glucose contains 6 atoms of carbon, 12 atoms of hydrogen and 6 atoms of oxygen. Its molecular formula is $C_6H_{12}O_6$ whereas its empirical formula is CH_2O.

Molecular mass

We can find out the molecular formula of a compound from its empirical formula. For this we have to know its molecular mass. This can be accurately found out by experiments.

We have found out the empirical formula of benzene. We get the Empirical Formula Mass (EFM) by adding the mass of atoms in the empirical formula.

The EFM of benzene = 12 × 1 + 1×1=13

Through experiments it has been possible to show that the molecular mass of benzene is 78.

Molecular mass

Molecular mass can be found out either by using mass spectroscopy or by analysing the diffraction pattern obtained by passing X-ray through crystals. The molecular mass of a non-volatile solute can be found out by the increase in the boiling point or decrease in the melting point when they are dissolved in a solvent.

$\frac{\text{Molecular mass}}{\text{EFM}}$ Divide the molecular mass by the empirical formula mass.

$$\frac{\text{Molecular mass}}{\text{EFM}} = \frac{78}{13} = 6$$

We get the molecular formula (MF) by multiplying this whole number with the base index of each atom in the empirical formula.

EF of benzene = CH = C_1H_1

MF of benzene = $C_{1\times6}H_{1\times6}$=C_6H_6

Molecular formula

= × EF

The percentage composition of hydrogen and oxygen in hydrogen peroxide is as given below. H = 6%, O = 94%. The molecular mass of hydrogen peroxide is 34. Find out the empirical formula and the molecular formula.

Symbol	H	O
Percentage composition		
Atomic mass		
$\frac{\text{Percentage composition}}{\text{Atomic mass}}$		
Simplest ratio		
Whole number ratio		

EF = ...

EFM = 1 × ... + 16 ×....

= .....

Molecular mass = 34

$\frac{\text{Molecular mass}}{\text{EFM}}$ = $\frac{34}{.....}$

Molecular formula = ...

- The chemical analysis of a compound shows that it contains 28.8% magnesium, 14.4% carbon and 56.8% oxygen in it. Find out its empirical formula.

SUMMARY

- The formula of a compound is based on the valency of elements.
- While naming a compound name of positive ion forms the first part and second part is that of negative ion.
- The amount of pure substance present in 100 g of the sample is called percentage purity.
- The percentage composition of a compound indicates the percentage of each element in it.
- 1 mole substance contains particles equivalent to the Avogadro number (6.022×10^{23}).
- The mass of $6.022\ \ 10^{23}$ atoms of an element in grams is called the gram atomic mass or gram atom.
- The mass of $6.022\ \ 10^{23}$ molecule of a substance in grams is called the gram molecular mass or gram mole.
- The mass of 1 mole atoms is equal to 1 gram atom. The mass of 1 mole molecule is equal to 1 gram mole.
- Empirical formula gives the ratio of the number of atoms of different elements in a compound.
- Molecular formula gives the actual number of atoms in a molecule of a substance.

MORE ACTIVITIES FOR YOU

1. Write the chemical formulae of the following compounds by using Table 1.2 in the text book.
   - **a. Ammonium carbonate**
   - **b. Sodium sulphate**
   - **c. Calcium bicarbonate**
   - **d. Aluminium hydroxide**
2. Name the following compounds
   - **a. $Mg(HCO_3)_2$**
   - **b. KNO_3**
   - **c. $(NH_4)_2 SO_4$**
   - **d. $AlCl_3$**
3. Calculate the percentage composition of each element in the compounds given in question number 2. **(Atomic masses of Mg = 24, K = 39, S = 32, Al = 27)**
4. Calculate the number of atoms present in the following substances.
   - **a. 8 gram helium**
   - **b. 4 mole helium**
5. Calculate the mass of the following in gram.
   - **a. 1 mole water**
   - **b. 1 atom of hydrogen**
   - **c. 1 molecule water**
6. Calculate the number of molecules present in the following substances.
   - **a. 90 g water**
   - **b. 34 g ammonia**
   - **c. 5 mole hydrogen**
   - **d. 1 mole neon**
   - **e. 10 mole chlorine**
   - **f. 1 gram mole oxygen**
7. Haematite, the ore of iron contains 70% iron 30% oxygen. Find out the empirical formula of haematite. (Atomic mass of iron = 55.8)
8. Molecular mass of a compound is 36.5 If this compound contains 2.73% hydrogen and 97.26% chlorine, find out the molecular formula of the compound.
9. Molecular mass of ethene is 28. Chemical analysis of ethene shows that it contains 14.3% hydrogen and 85.7% carbon. Find out the molecular formula of the ethene.
10. A compound with molecular mass 102 contains 52.94% aluminium and the rest is oxygen. What is its molecular formula?

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