The Language of Chemistry

Atoms: An Overview

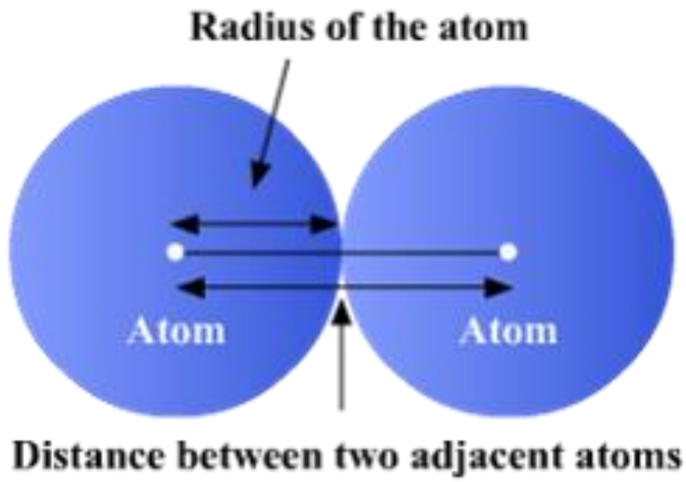
When we talk about atoms, two questions usually strike our mind...

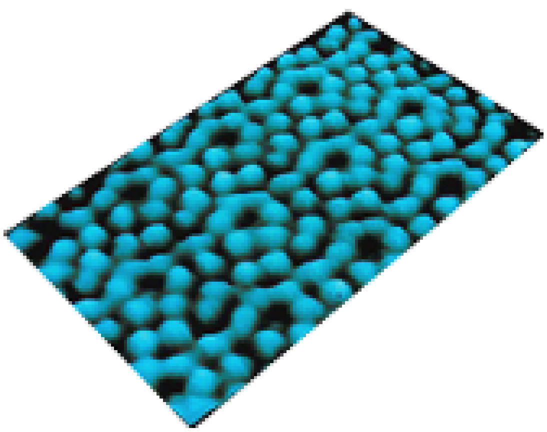
Let us go through this lesson to find the answers to these questions. We will also learn how to represent different atoms in symbolic forms. So, in short, we are going to study:

- **Size of an atom**
- **Representation of atoms**
- **Atomic mass**

Size of an Atom

- The size of an isolated atom cannot be measured; however, we can estimate its size by assuming that its radius is half the distance between adjacent atoms in a solid.
- Atoms are very small in size. They are so small that it is not possible to see them even under a powerful optical microscope.
- The size of an atom is indicated by its radius, called the **atomic radius**.
- Since an atom is very small, we need a very small unit for reporting the atomic radius; thus, the radius of an atom is often expressed in **nanometre**.





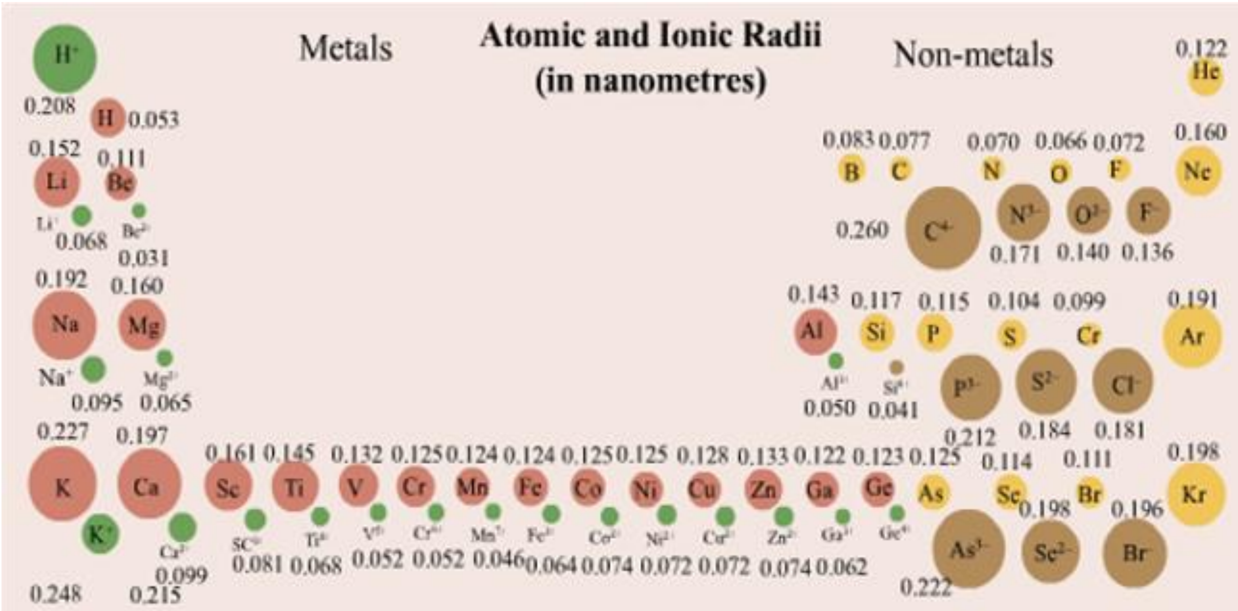
Surfaces of Silicon Atoms

Atoms cannot be seen with the naked eye, but the use of modern techniques has enabled us to see the surfaces of atoms.

The magnified image of the surfaces of silicon atoms is shown in the following figure.

Size of an Atom

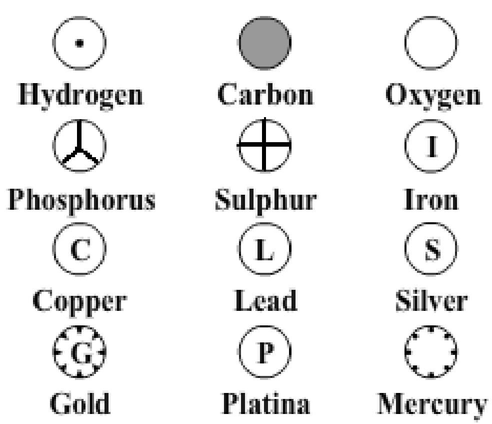
Hydrogen atom is the smallest of all atoms. The given figure shows the atomic radii of some elements.



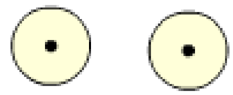
Classical Representation of Atoms

- A large number of elements are known to us today. It would be cumbersome to refer to them by their names all the time in our studies. For the sake of convenience, we need symbols that represent these elements. Toward the end of the nineteenth century, scientists felt this need to assign standard characteristic symbols to the elements.

- John Dalton was the first scientist to use symbols to represent different elements. Dalton's proposed symbols for some elements are shown in given figure.



- Each symbol proposed by Dalton represents an atom of the respective element. For example, if someone wanted to represent two hydrogen atoms, then he would have to draw the symbol of hydrogen atom twice as shown.



Two Hydrogen atoms

Modern Representation of Atoms

- Many of the symbols proposed by Dalton were difficult to draw and remember. Therefore, an alternative method of representing elements was required.
- Another scientist named Jöns Jacob Berzelius suggested that letters of the alphabet can be used as symbols to represent the elements. The modern symbols of elements are based on this idea.
- The International Union of Pure and Applied Chemistry (**IUPAC**) approves the names and symbols for the elements.
- The modern symbol of an element is made up of one or two letters of the English or Latin name of that element.
- As a rule, the first letter of a symbol is always written as a capital letter and the second as a small letter.
- The modern representation of atoms is more convenient and meaningful than the classical representation.
- To conclude, the symbols of the various elements are significant as:
- They represent distinct elements.
- They represent single atoms of the elements.

Modern Representation of Atoms

Table mentioned below shows the modern representation of atoms:

Elements	**Symbols**	**Elements**	**Symbols**
Aluminium	Al	Iron (from Latin: *ferrum*)	Fe
Argon	Ar	Lead (from Latin: *plumbum*)	Pb
Calcium	Ca	Magnesium	Mg

Carbon	C	Nitrogen	N
Chlorine	Cl	Oxygen	O
Copper (from Latin: *cuprum*)	Cu	Potassium (from Latin: *kalium*)	K
Fluorine	F	Silicon	Si
Gold (from Latin: *aurum*)	Au	Silver (from Latin: *argentum*)	Ag
Hydrogen	H	Sodium (from Latin: *natrium*)	Na
Iodine	I	Zinc	Zn

Did You Know?

IUPAC

The International Union of Pure and Applied Chemistry (IUPAC) is an international non-governmental organisation established in 1919.

IUPAC nomenclature, in general, is a system of naming chemical compounds and describing the science of chemistry.

Some man-made elements are given temporary three-letter symbols.

Atomic Mass

- Every atom has some characteristic mass of its own and this **is known as atomic mass.**
- All the atoms of an element have the same atomic mass. Atoms of different elements have different atomic masses.
- **Determination of atomic mass:**

  It is difficult to determine the mass of an individual atom; so, the mass of an atom is ascertained in relation to the mass of C-12 **isotope**. Thus, atomic mass is in fact relative atomic mass.

- C-12 is an isotope of carbon and its mass is used as a standard reference to calculate the relative atomic masses of all elements.
- **The IUPAC** adopted one-twelfth $\left(\frac{1}{12}\right)^{th}$ of the mass of a C-12 isotope as the standard unit to measure relative atomic masses. It named this unit as **atomic mass unit** (amu) or **unified atomic mass unit** (u).

  So,

$$\text{Atomic mass unit} = \frac{1}{12} \times \text{ Mass of C-12 atom}$$

In simple words, Atomic mass is a term which gives the total mass of protons and neutrons in an atom. Also, the atomic mass is measured with respect to mass of 1/12 the mass of one carbon atom.

Atomic Mass

The atomic masses of some common elements are given in the following table.

Elements	Atomic masses (u)	Elements	Atomic masses (u)
Hydrogen	1	Chlorine	35.5
Helium	4	Potassium	39
Carbon	12	Calcium	40
Nitrogen	14	Argon	40
Oxygen	16	Iron	56
Fluorine	19	Copper	63.5
Neon	20	Zinc	65

Sodium	23	Bromine	80
Magnesium	24	Silver	108
Sulphur	32	Gold	197

Atomic Mass Unit

Atomic mass unit (1 u) is defined as exactly one twelfth the mass of an atom of carbon-12. Atomic mass unit is only number and it has no units. On the basis of above unit, the atomic mass of carbon atom is 12 amu.

Relative atomic mass or atomic weight

Definition with respect to hydrogen:

It is the ratio of mass of one atom of an element to the mass of an atom of hydrogen taken as unity.

Definition with respect to carbon:

It is the ratio of mass of one atom of an element to 1/12th mass of an atom of carbon.

Relative molecular mass or molecular weight

Definition with respect to hydrogen:

It is the ratio of mass of one molecule of a substance to the mass of an atom of hydrogen taken as unity.

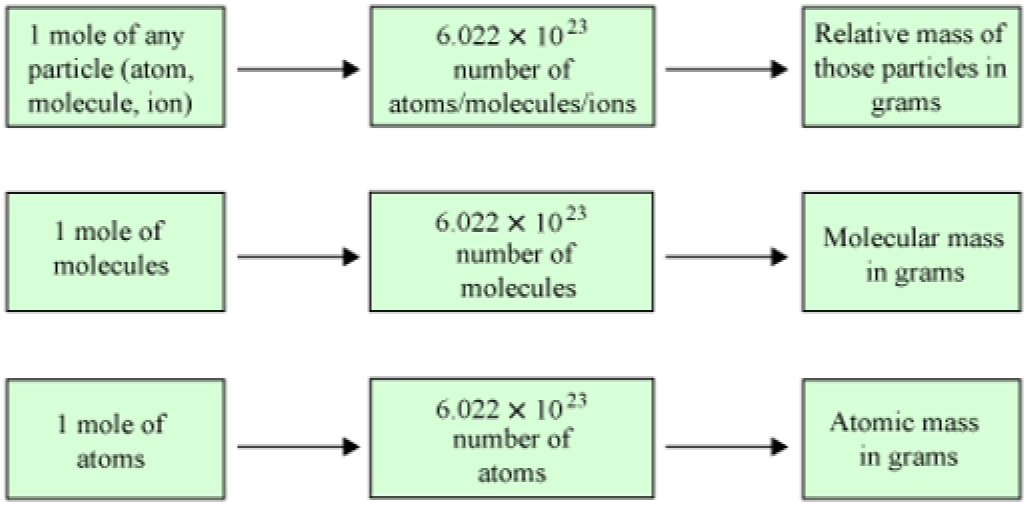
Definition with respect to carbon:

It is the ratio of mass of one atom of an element to 1/12th mass of an atom of carbon.

Gram Molecular Volume

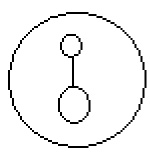
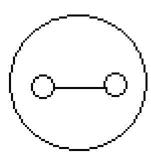
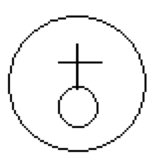
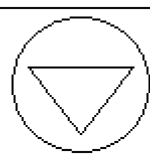
The volume occupied by 1 gram molecule of a dry gas at S.T.P is called gram molecular volume. The experimental value of 1 gram molecular volume of a gas is 22.4 litres at S.T.P.

The relationship between the mole, Avogadro’s number, and mass is summarised as follows:



Symbols are very important in chemistry as they are used to represent different elements. The usage of symbols to represent elements has been in trend from the ancient Greek time. Greeks used symbols to represent the four elements, earth, air, fire and water.

In the era of alchemists, different materials were represented using pictorial symbols. For example,

Element	Symbol
Nickel	
Arsenic	
Antimony	
Water	

Do You Know?
The process of converting a less valuable metal into a more valuable metal like gold is called **alchemy**, and the men who started this process are called **alchemists**.

System for determining symbols for different elements:
Certain rules have been framed to determine symbols of different elements. They are as follows:

1. The symbols of common elements, mainly non-metals, are the first letter of their respective names.

For example, the symbols of oxygen and fluorine are O and F respectively.

2. If the name of an element shares the initial letter with another element, then the first and the second letter of its name are used as the symbol.

For example, symbols used for **B**arium and **B**eryllium are Ba and Be respectively.

3. If the first two letters of the names are the same, then the first and third lettes are used as the symbol.

For example, symbols used for **M**agnesium and **M**anganese are Mg and Mn respectively.

4. Symbols of some elements are based on their old or Latin names. There are 11 elements whose symbols are derived from their Latin names.
For example, symbol of sodium is Na, which is derived from its Latin name Natrium.

5. If the symbol of any element is a single letter, it should be written in capital.

6. If the symbol of any element has two letters then the first one should be in capital followed by small letter.

Significance of symbols:

1. Symbol of an element signifies the name of the element.
2. It also signifies that one atom of that element is present.

Valency:

We know that the outermost shell of an atom can hold a maximum of eight electrons. The elements, whose atoms have a completely filled outermost shell, have very little chemical activity. Such elements are said to have **zero combining capacity** or **valency**. For e.g., helium, neon, argon. (The elements of the 18th group in the periodic table). These elements have either completely filled outermost shells or have 8 electrons in their outermost shell. Hence, their valency is zero. They are called **inert** or **noble gases**.

The combining capacity of atoms of the elements is their tendency to react with other atoms of the same or different molecules to attain a filled outermost shell. The outermost shell, which has eight electrons, is said to possess an **octet** and every atom tends to achieve an octet in its outermost shell.

This is done by gaining, losing, or sharing its electrons. **The number of electrons gained, lost, or shared by an atom to complete its octet is called the combining capacity or valency of that atom.**

Both hydrogen and sodium contain one electron each in their outermost shells. Thus, both can lose one electron. Hence, their valency is one.

It is not always true that the number of electrons present in the outermost shell of an atom represents its valency. For example, in fluorine, there are seven electrons in the outermost shell, but the valency of fluorine is one. This is because it is energetically suitable for fluorine atom to accept one electron, rather than donating seven electrons. Hence, its valency is obtained by subtracting seven electrons from the octet.

Concept of valency

We know that the combining power or the combining capacity of an atom or an element is called its **valency**. The number of atoms of other elements with which one atom of an element combines is decided by the valency of that element.

For example, both hydrogen and chlorine have a valency of 1. Therefore, one atom of hydrogen reacts with one atom of chlorine to form one molecule of hydrogen chloride.

The valency of an ion is equal to the charge on it. The valencies of some common ions are given in the following table.

Name of ion	Symbol	Valency	Name of ion	Symbol	Valency
Aluminium	Al^{3+}	3	Sulphite	SO_3^{2-}	2
Ammonium	NH_4^+	1	Bromide	Br^-	1

Calcium	Ca^{2+}	2	Carbonate	CO_3^{2-}	2
Copper(II)	Cu^{2+}	2	Chloride	Cl^{-}	1
Hydrogen	H^{+}	1	Hydride	H^{-}	1
Iron(II)	Fe^{2+}	2	Hydrogen carbonate	HCO_3^{-}	1
Iron(III)	Fe^{3+}	3	Hydroxide	OH^{-}	1
Magnesium	Mg^{2+}	2	Nitrate	NO_3^{-}	1
Nickel	Ni^{2+}	2	Nitrite	NO_2^{-}	1
Potassium	K^{+}	1	Oxide	O^{2-}	2
Silver	Ag^{+}	1	Phosphate	PO_4^{3-}	3
Sodium	Na^{+}	1	Sulphate	SO_4^{2-}	2

Zinc	Zn^{2+}	2	Sulphide	S^{2-}	2

Relationship Between Valency of Elements and Periodic Table

It is observed that valency of elements increases from 1 to 4 and then decreases to 1. For noble gases, the combining capacity or the valency is zero because of their inert nature.

Since we know, there are 118 elements which are classified with the help of a periodic table, which is divided into horizontal rows and vertical columns. These horizontal rows are called periods, whereas the vertical columns are called groups.

These groups are called IA, II, IIIA, IVA, VA, VIA, VIIA, and zero group.
The periods are numbered as 1, 2, 3, 4, 5, 6 and 7.

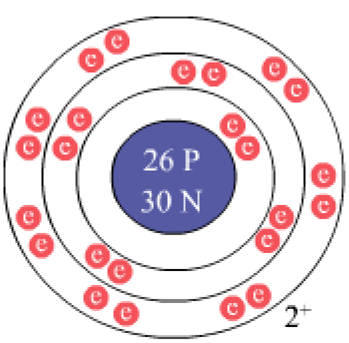
Elements present in the same group have same valency and it also corresponds to the group number up to IV.

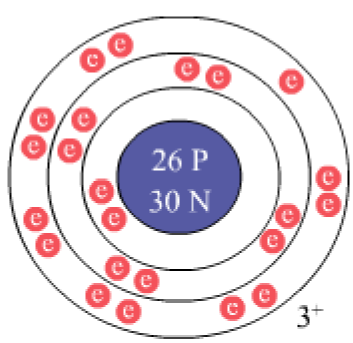
Valencies of elements present in group V, VI and VII are 3, 2, and 1, respectively. Hence, it is clear that metals or non-metals with same valency show similar properties.

Variable valency: - It has been found that certain elements exhibit more than one valency. In such a situation, the element is said to exhibit variable valency.

The **reason for variable valency** is that an atom of some element depending upon the conditions loses more electrons than are present in its outermost shell (valence shell) i.e., it loses some electrons from the shell next to the outermost shell.

Example: - An atom of iron has two electrons in its valence shell. On losing these electrons, it attains a valency of +2. However, sometimes it loses one more electron from its inner shell and hence attains a valency of +3.





Writing Chemical Formulae of Compounds

Molecular Formula: A Brief Overview

Just like each atom has a unique symbol, each compound has a unique molecular formula.

The molecular formula of a compound provides information about the names and numbers of atoms of the different elements present in a molecule of that compound.

Molecular formula is a **chemical formula** that indicates the kinds of atoms and the numbers of each kind of atom in a molecule of a compound.

Examples

- The molecular formula of glucose is $C_6H_{12}O_6$. One molecule of glucose contains 6 atoms of carbon, 12 atoms of hydrogen and 6 atoms of oxygen.
- The molecular formula of water is H_2O. One molecule of water contains 2 atoms of hydrogen and 1 atom of oxygen.

Salient features of chemical formula:

- Compounds are formed when two or more elements combine chemically. Hence, compounds can also be represented using symbols.
- The notation used for representing any compound is called chemical formula of that compound.
- Each compound has a unique chemical formula.
- The chemical formula of any compound tells us about : The different elements which combine to form the compound and the number of atoms of each element present in a molecule of the compound
- For example, H_2O is the chemical formula of water. This denotes that there are two atoms of hydrogen and one atom of oxygen present in one molecule of water.

Chemical Formulae

Let us understand the information derived from chemical formulae by taking the example of carbon dioxide. The chemical formula of carbon dioxide is CO_2. Using this formula, we can derive the following information about carbon dioxide.

- Two elements are present in carbon dioxide: carbon(C) and oxygen (O).
- CO_2 represents one molecule of carbon dioxide.
- Since one atom of carbon combines with two atoms of oxygen, the **valency** of carbon is twice that of oxygen.
- CO_2 is a neutral molecule. It has no charge.
- The relative atomic masses of carbon and oxygen are 12 u and 16 u respectively. So, the ratio by mass between carbon and oxygen is 12 : 32, i.e., 3 : 8.

Writing Chemical Formulae

To write the chemical formula of a compound, one should have prior knowledge of two things.

- **The symbols of the constituent elements.**
- **The combining capacity of the atom of each element constituting the compound.**

The number of atoms of other elements with which one atom of an element combines is decided by the valency of that element.

For example, both hydrogen (H) and chlorine (Cl) have a valency of 1. Therefore, one atom of hydrogen reacts with one atom of chlorine to form one molecule of hydrogen chloride (HCl).

The valency of an ion is equal to the charge on it.

Chemical Formulae

The valencies of some common ions are given in the following table.

Names of ions	Symbols	Valencies	Names of ions	Symbols	Valencies
Aluminium	Al^{3+}	3	Sulphite	SO_3^{2-}	2
Ammonium	NH_4^+	1	Bromide	Br^-	1
Calcium	Ca^{2+}	2	Carbonate	CO_3^{2-}	2
Copper(II)	Cu^{2+}	2	Chloride	Cl^-	1
Hydrogen	H^+	1	Hydride	H^-	1

Chemical Formulae

The valencies of some common ions are given in the following table.

Names of ions	Symbols	Valencies	Names of ions	Symbols	Valencies
Iron(II)	Fe^{2+}	2	Hydrogen carbonate	HCO_3^-	1

Iron(III)	Fe^{3+}	3	Hydroxide	OH^{-}	1
Magnesium	Mg^{2+}	2	Nitrate	NO_3^{-}	1
Nickel	Ni^{2+}	2	Nitrite	NO_2^{-}	1
Potassium	K^{+}	1	Oxide	O^{2-}	2
Silver	Ag^{+}	1	Phosphate	PO_4^{3-}	3
Sodium	Na^{+}	1	Sulphate	SO_4^{2-}	2
Zinc	Zn^{2+}	2	Sulphide	S^{2-}	2

Chemical Formulae

The following rules need to be kept in mind while writing the chemical formulae of compounds.

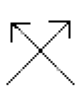
•The valencies or charges on the ions must be balanced. The charge on a cation must be equal in magnitude to the charge on an anion so that the opposite charges cancel each other out and the net charge of the molecule becomes zero.

Examples

- In case of CaO, the valency of Ca is +2 and that of O is −2. These are then crossed over and the compound formed is CaO.

Formula of calcium oxide

Symbols Ca O



Charges 2+ 2−

- The charge on Mg^{2+} is +2 and that on Cl^- is −1. Thus, one Mg^{2+} ion combines with two Cl^- ions to form a molecule with the formula $MgCl_2$.
- In case of a compound consisting of a metal and a non-metal, the symbol of the metal is written first.

Chemical Formulae

Example

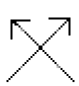
- In calcium chloride ($CaCl_2$) and zinc sulphide (ZnS), calcium and zinc are metals, so they are written first; chlorine and sulphur are non-metals, so they are written after the metals.
- In case of compounds consisting of polyatomic ions, the polyatomic ions are enclosed in brackets before writing the number to indicate the ratio.

Example

- In case of aluminium sulphate, to balance the charges, two SO_4^{2-} ions combine with one Al^{3+} ion. Thus the formula for aluminium sulphate is $Al_2(SO_4)_3$. Here, the brackets with the subscript 3 indicate that three sulphate ions are joined to two aluminium ions.

Formula of aluminium sulphate

Symbols Al SO_4



Charges 3+ 2−

Chemical Formulae

Naming Certain Compounds

Compound	Rule	Example
A metal and a non-metal	Metal is written first Non-metal is written last with suffix −*ide*	Calcium nitride (Ca_3N_2)

Compound	Rule	Example
Two non-metals	Less electronegative non-metal is written first In case, more than one atom of a non-metal is present then prefix like −*di*, −*tri*, −*tetra* etc. is added	Phosphorous pentachloride (PCl_5)
Two elements and oxygen	Oxygen is placed at end of the formula Following prefixes or suffixes are used depending on the number of oxygen atoms present: Less than two oxygen atom: *hypo* (prefix) Two oxygen atoms: −*ite* (suffix) Three oxygen atoms: −*ate* (suffix) More than three oxygen atoms: −*per* (prefix)	Sodium hypochlorite ($NaClO$) Sodium chlorite ($NaClO_2$) Sodium chlorate ($NaClO_3$) Sodium perchlorate ($NaClO_4$)
Acids	Binary acids Prefix: *hydro* Suffix: −*ic* with the name of second element Polyatomic radicals Suffix: −*ic* on the basis of second element Prefix not used	Hydrochloric acid (HCl) Sulphuric acid (H_2SO_4)
Trivial names	Used for specific compounds No systemic rule followed	Ammonia (NH_3) Water (H_2O)

Solved Examples

Easy

Example 1:

Give two examples each of molecules having one atom, two atoms and three atoms.

Solution:

Molecules having one atom (/monatomic molecules): Argon (Ar) and Neon (Ne)

Molecules having two atoms (/diatomic molecules): Nitrogen (N_2) and Oxygen (O_2)

Molecules having three atoms (/triatomic molecules): Nitrogen dioxide (NO_2) and carbon dioxide (CO_2)

Medium

Example 2:

The valencies of a few ions are provided below.

H^+ = 1, SO_4^{2-} = 2, Br^- = 1, Mg^{2+} = 2 and K^+ = 1

Write the formulae for magnesium bromide, magnesium sulphate, hydrogen bromide and potassium sulphate.

Solution:

•Magnesium bromide: $MgBr_2$

•Magnesium sulphate: $MgSO_4$

•Hydrogen bromide: HBr

•Potassium sulphate: K_2SO_4

Hard

Example 3:

Write the names of the following compounds.

i)H_2CO_3

ii)KNO_3

iii)$(NH_4)_3PO_4$

iv)Na_2CO_3

v)$Al(NO_3)_3$

vi)$NaHCO_3$

Solution:

i)H_2CO_3: Hydrogen carbonate

ii)KNO_3: Potassium nitrate

iii)$(NH_4)_3PO_4$: Ammonium phosphate

iv)Na_2CO_3: Sodium carbonate

v)$Al(NO_3)_3$: Aluminium nitrate

vi)$NaHCO_3$: Sodium hydrogen carbonate

Mole Concept and Molar Masses

- 1 mole of any substance can be defined as:
- Amount of a substance that contains as many particles (atoms, molecules or ions) as there are atoms in 12 g of the ^{12}C isotope
- Avogadro number or Avogadro constant (N_A); it is equal to 6.022×10^{23} particles
- Example − 1 mole of oxygen atoms = 6.022×10^{23} atoms of oxygen

  1 mole of carbon dioxide molecules = 6.022×10^{23} molecules of carbon dioxide

  1 mole of sodium chloride = 6.022×10^{23} formula units of sodium chloride

- **Relative atomic mass:** Relative atomic mass of an element is the ratio of the average mass of one atom of an element to one-twelfth of the mass of an atom of carbon-12.

$$\text{Relative atomic mass} = \frac{\text{Average mass of Atom}}{\frac{1}{12} \times \text{Mass of carbon}\left(C^{12}\right)}$$

Molar mass of a substance can be defined as:

- Mass of one mole of a substance in grams
- Numerically equal to atomic/molecular/formula mass in u.
- Example − Molar mass of CO_2 = 44.011 g mol^{-1}
- **Relative molecular mass:** It is defined as the ratio of the mass of a molecule to the atomic mass unit of the molecule. It is a unitless quantity.

$$\text{Relative molecular mass} = \frac{\text{Average mass of Molecule / Compound}}{\frac{1}{12} \times \text{Mass of carbon}\left(C^{12}\right)}$$

Molar mass of NaCl = 58.5 g mol^{-1}

Examples

1. What number of moles contains 3.011 × 10^{23} molecules of glucose?

Solution:

1 mole of glucose is equivalent to 6.022 × 10^{23} molecules of glucose.

Hence, 3.011 × 10^{23} molecules of glucose will be present in

$= \frac{1 \times 3.011 \times 10^{23}}{6.022 \times 10^{23}}$ mol = 0.5 mol (of glucose)

Thus, 0.5 mole of glucose contains 3.011 × 10^{23} molecules of glucose.

2. What is the mass of a fluorine molecule?

Solution:

1 mole of fluorine molecule contains 6.022 × 10^{23} molecules and weighs 38 g.

Therefore, mass of a fluorine molecule = $\frac{38}{6.022 \times 10^{23}}$ g

= 6.31 × 10^{-23} g

Atomicity

- It is defined as the total number of atoms of constituent elements which combine to form a molecule.
- One molecule of hydrogen combines with one molecule of chlorine to form two molecules of hydrogen chloride.
- One molecule of hydrogen or chlorine contains two atoms of each.

Percentage Composition

Mass percent of an element = $\dfrac{\text{Mass of that element in the compound} \times 100\%}{\text{Molar mass of the compound}}$

Example

What is the mass percent of oxygen in potassium nitrate? (Atomic mass of K = 39.10 u, atomic mass of N = 14.007 u, atomic mass of O = 16.00 u)

Solution:

Atomic mass of K = 39.10 u (Given)

Atomic mass of N = 14.007 u (Given)

Atomic mass of O = 16.00 u (Given)

Therefore, molar mass of potassium nitrate (KNO_3)

= 39.10 + 14.007 + 3(16.00)

= 101.107 g

Therefore, mass percent of oxygen in KNO_3

$= \dfrac{\text{Mass of oxygen in } KNO_3 \times 100\%}{\text{Molar mass of } KNO_3}$

$= \dfrac{3 \times 16.00}{101.107} \times 100\%$

= 47.47% (approx)

- Empirical formula and molecular formula:

Empirical formula	Molecular formula

Represents the simplest whole number ratio of various atoms present in a compound	Represents the exact number of different types of atoms present in a molecule of a compound

- Empirical formula is determined if mass % of various elements are known.
- Molecular formula is determined from empirical formula if molar mass is known.

Example

A compound contains 92.26% carbon and 7.74% hydrogen. If the molar mass of the compound is 26.038 g mol^{-1}, then what are its empirical and molecular formulae?

Solution:

Mass percent of carbon (C) = 92.26% (Given)

Mass percent of hydrogen (H) = 7.74% (Given)

Therefore, 100 g of the compound contains 92.26 g and 7.74 g of of hydrogen

Number of moles of carbon present in the compound = $\frac{92.26}{12.011}$

= 7.68 mol

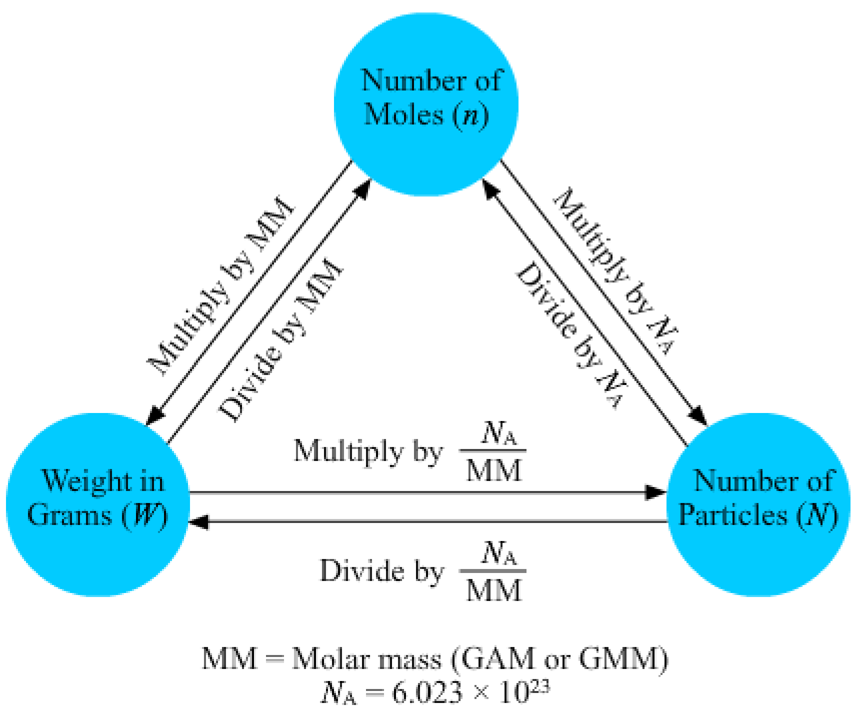
Number of moles of hydrogen present in the compound $= \frac{7.74}{1.008}$

= 7.68 mol

Thus, in the given compound, carbon and hydrogen are present in the ratio C : H = 7.68 : 7.68

= 1 : 1

Therefore, the empirical formula of the compound is CH.

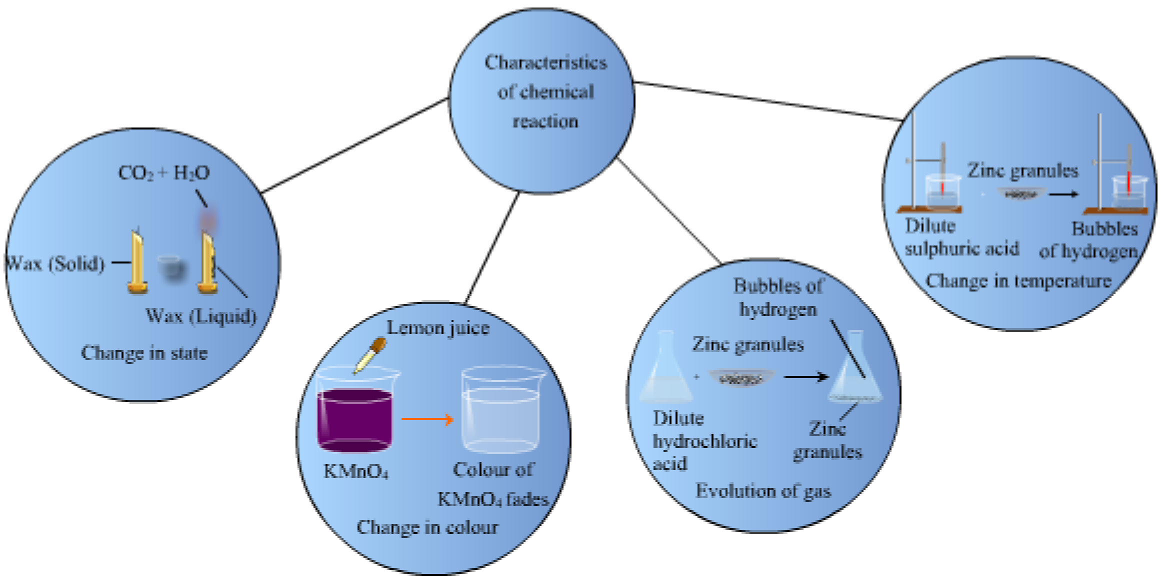
Empirical formula mass of CH = (12.011 + 1.008)g = 13.019 g Molar mass of the compound = 26.038 g (Given) Therefore, $n = \frac{\text{Molar Mass}}{\text{Empirical formula mass}}$ $= \frac{26.038 \text{ g}}{13.019 \text{ g}}$ = 2 Hence, the molecular mass of the compound is $(CH)_n$, i.e., $(CH)_2$ or C_2H_2.
Interconversion Among Number of Moles, Mass and Number of Molecules


Chemical Changes and Their Representation in the Form of Chemical Equations

Chemical Changes

A chemical change can be confirmed by any or all of the following observations-

- change in state
- change in colour
- change in temperature
- evolution of gas
- formation of a precipitate



A chemical change is always accompanied by a chemical reaction. **Reaction** is the term used for depicting a change or transformation in which a substance decomposes, combines with other substances, or interchanges constituents with other substances. Let us see how we can represent a chemical change using a reaction.

Thus, a chemical equation is an easier and more concise method for representing a chemical reaction. It involves writing symbols and formulae (instead of words) for all substances involved in the reaction. A chemical equation also indicates the number of atoms of each element involved in a reaction.

In which reactants are given on left-hand side of a reaction and products are given on right-hand side.

Reactants: The substance which takes part in a chemical reaction.
Products: The new substances produced as a result of chemical reaction.

Try to represent the statements given below as chemical equations.

(a) Potassium metal reacts with water to give potassium hydroxide and hydrogen gas.

(b) Hydrogen gas combines with nitrogen to form ammonia.

Symbols of elements:

Potassium = K

Hydrogen =H

Nitrogen = N

Questions asked in previous years' board examinations

Ques.
Write any two observations in an activity which may suggest that a chemical reaction has taken place. Give an example in support of your answer.

(**2 marks)**

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Sol: A chemical change can be confirmed by any of the following observations:

Change in temperature
Evolution of gas

For example: Calcium oxide reacts vigorously with water to produce calcium hydroxide. During this process, a large amount of heat is also evolved, which increases the temperature of the system. This confirms that a chemical reaction has taken place.

$$\underset{\text{Calcium oxide}}{CaO(s)} + \underset{\text{Water}}{H_2O(l)} \rightarrow \underset{\text{Calcium hydroxide}}{Ca(OH)_2(aq)}$$

Also, when calcium carbonate is heated, it decomposes to form calcium oxide and carbon dioxide.

$$\underset{\text{Calcium carbonate}}{CaCO_3(s)} \xrightarrow{\Delta} \underset{\text{Calcium oxide}}{CaO(s)} + \underset{\text{Carbon dioxide}}{CO_2(g)}$$

In this reaction, calcium carbonate breaks down to form calcium oxide and carbon dioxide. Here, evolution of the gas (carbon dioxide) confirms that a chemical reaction has taken place.

Balanced Chemical Equations

To describe a chemical reaction more concisely, equations of the reactions are written.

Chemical equation

A chemical equation is a concise form which uses symbols and formulae of the chemical compounds or elements involved in the reaction. It also indicates the number of atoms of each element involved in a reaction.

In a chemical reaction, the total mass of the reactants should be equal to the total mass of the products. This means that the total number of atoms of each element should be equal on both sides of a chemical equation. Such an equation is called a **balanced chemical equation**, and the method by which it is obtained is called the balancing of chemical equations.

Another example of a balanced chemical equation is the reaction of limewater with carbon dioxide, that results in the formation of a precipitate of calcium carbonate and water is represented as:

$$\underset{\text{Calcium hydroxide}}{Ca(OH)_2(aq)} + \underset{\text{Carbon dioxide}}{CO_2(g)} \rightarrow \underset{\text{Calcium carbonate}}{CaCO_3(s)} + \underset{\text{Water}}{H_2O(l)}$$

In this reaction, calcium hydroxide is present in the form of a solution in water, carbon dioxide is present as a gas, calcium carbonate is produced as a precipitate i.e. in the solid state, and water is formed in the liquid state.

The energy changes involved in a reaction are denoted by writing the changes involved in the equation itself.

If energy is used in the reaction, then it will be written on the left-hand side. If it is released in the process, then it is written on the right-hand side.

For example, combustion of butane (or any other hydrocarbon i.e., the compounds made up of carbon and hydrogen) is accompanied by the evolution of heat and light energy along with the production of carbon dioxide and water. Therefore, the equation for the same will be written as:

$$2C_4H_{10} + 13O_2 \rightarrow 10H_2O + 8CO_2 + \text{Heat} + \text{Light}$$

The reaction conditions (such as temperature, pressure, catalyst etc.) for a reaction are indicated above or below the forward arrow in a reaction.

Below are some balanced chemical equations:

(1) $CO_{(g)} + 2H_{2(g)} \xrightarrow[ZnO+CrO_3]{300\text{ atm}, 300^\circ C} CH_3OH_{(aq)}$

Carbon monoxide + Hydrogen → Methyl alcohol

(2) $2KClO_{3(s)} \xrightarrow[MnO_2]{\Delta} 2KCl_{(s)} + 3O_{2(g)}$

Potasium chlorate → Potassium chloride + Oxygen

Chemical Reaction	Chemical Equation
One reactant or two or more products	$CaCO_3 \rightarrow CaO + CO_2$
Two reactants and one product	$N_2 + H_2 \rightarrow 2\ NH_3$
Two reactants and two products	$Na_2SO_4 + BaCl_2 \rightarrow BaSO_4 + 2\ NaCl$
Two reactants and three or more products	$Cu + 2\ H_2SO_4 \rightarrow CuSO_4 + 2H_2O + SO_2$

Write the balanced equations for the following chemical reactions.

1. Barium chloride + Sodium sulphate → Barium sulphate + Sodium chloride.

2. Sodium + Water → Sodium hydroxide + Hydrogen

Other questions asked in previous years' board examinations

Ques. On what basis is a chemical equation balanced?

(**1 mark)**

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Sol: Law of conservation of mass forms the basis of balancing chemical equations. In a balanced chemical equation, the number of atoms of each element is equal on both sides of the equation.

Ques. Balance the following chemical equation:

$Pb(NO_3)_2\ (s) \xrightarrow{\text{heat}} PbO\ (s) + NO_2\ (g) + O_2\ (g)$

(**1 mark)**

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Sol: The balanced chemical equation for the given reaction is:

$$2Pb(NO_3)_2(s) \xrightarrow{\text{Heat}} 2\,PbO(s) + 4NO_2(g) + O_2(g)$$

Information conveyed by balanced chemical equations

- Result of the chemical change
- Number of molecules of reactants being consumed and products being formed
- Chemical composition of reactants and product species
- Molecular mass of reactants and products
- Proves the law of conservation of mass

Limitation of a chemical equation
A chemical equation does not provide some other important chacteristics of a chemical reaction, such as:

- time needed to complete the reaction
- physical state of reactants and products
- concentration of each reactant and product
- rate of the reaction

Making a chemical reaction more informative

- Providing the information about catalyst used, temperature and pressure of the reaction above or below the arrow.

$$N_2\ (g)\ +\ H_2\ (g)\ \xrightarrow[450^o\ C,\ 200-900\ \text{atm}]{Fe\ +\ Mo}\ 2\ NH_3\ \ (g)$$

- Stating whether heat is being evolved or absorbed in a chemical reaction

  $C(s) + O_2(g) \longrightarrow CO_2(g) + \text{Heat}$
- Mentioning the physical state of reactants and products.

  $C(s) + O_2\ (g) \longrightarrow CO_2\ (g)$
- Adding concentration of acids and bases

  $Mg\ (s) + H_2SO_4\ (aq) \longrightarrow MgSO_4\ (aq) + H_2\ (g)$