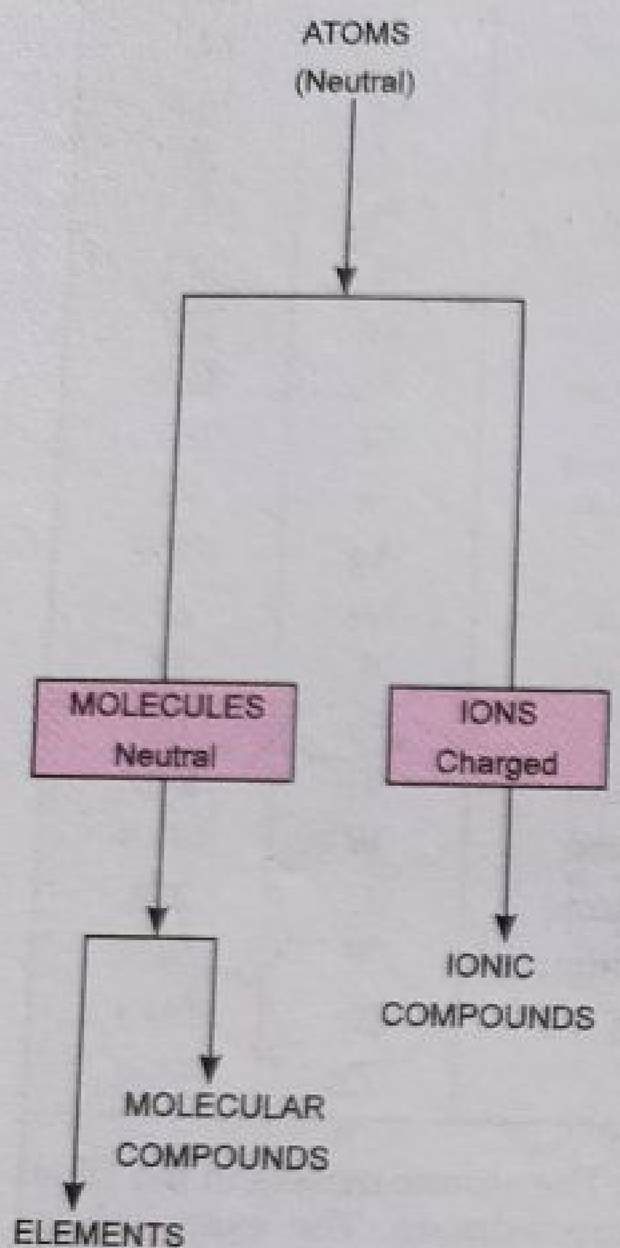


Fig. 5. Aggregation of atoms in different ways.

1 amu is $\frac{1}{12}$th of the mass of carbon -12 atom.

It has been found by experiments that the mass of carbon-12 atom is 1.9926×10^{-23}g.

$$\therefore \quad 1 \text{ amu} = \frac{1.9926 \times 10^{-23} \text{g}}{12} = 1.6605 \times 10^{-24} \text{g}$$

HOW DO ATOMS OCCUR ?

Atoms of most elements donot occur independently. They aggregate (join together) in different ways to form matter that we are able to see, feel, or touch. The atoms may combine to form neutral molecules or charged ions which further form compounds. For example, atoms join together to form neutral molecules which may exist as elements or molecular compounds. The atoms may also form charged species called **ions** which form compounds known as **ionic compounds**. These basic types of aggregation of atoms is shown in Fig. 5.

MOLECULE

What is a Molecule?

As we have learnt a **molecule is the smallest particle of a substance (element or compound) which is capable of independent existence and shows all the properties of that substance**. A molecule may be regarded as a group of two or more atoms that are chemically bonded together. The atoms in a molecule are tightly connected by attractive forces.

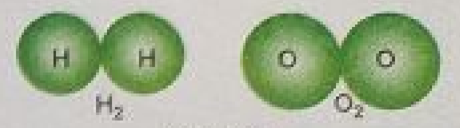
Atoms of same or different elements can join together to form molecules.

Molecules of Elements

Monoatomic

Many elements like helium (He), neon (Ne) argon (Ar), sodium (Na), iron (Fe), etc can be easily represented by their symbols because they contain single atom.

However, some elements especially non-metals donot exist as single atoms. For example, oxygen exists as diatomic, consisting of two atoms. Therefore, it is written as O_2. Similarly, hydrogen gas consists of two atoms of hydrogen, written as H_2, chlorine gas consists of two atoms of chlorine written as Cl_2. **The number of atoms in a molecule of an element** is called **atomicity.**



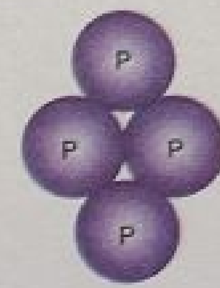
(Diatomic)

For example, noble gases such as helium, neon, argon, etc have only one atom each in their molecules such as He, Ne, Ar, etc. Therefore, their **atomicity is one** and called **monoatomic.**

Hydrogen and nitrogen has two atoms in their molecules and therefore, have **atomicity two** and are called **diatomic molecules.**

Ozone has three oxygen atoms in its molecule and is represented as O_3. Therefore, its **atomicity is three** and is called **triatomic molecule.**

O_3
(Triatomic)



P_4
(Tetra-atomic)

Similarly, phosphorus has four atoms and sulphur has 8 atoms in their molecules. These are represented as P_4 and S_8 respectively and their atomicities are 4 and 8. These are also called **tetra-atomic** or **octa-atomic (or polyatomic** *meaning* **many)** molecules respectively.

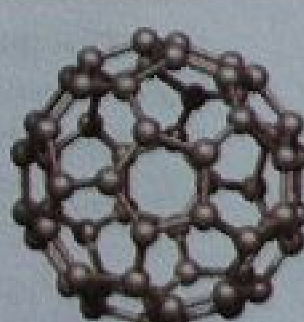
The atomicity of some common elements are given below :

Table 3. Atomicity of some common elements.

Type of Element	Name	Symbol	Atomicity
Non-metal	Helium	He	Monoatomic
	Argon	Ar	Monoatomic
	Neon	Ne	Monoatomic
	Hydrogen	H_2	Diatomic
	Chlorine	Cl_2	Diatomic
	Nitrogen	N_2	Diatomic
	Oxygen	O_2	Diatomic
	Phosphorus	P_4	Tetratomic
	Sulphur	S_8	Polyatomic
Metals	Sodium	Na	All monoatomic
	Iron	Fe	
	Aluminium	Al	
	Copper	Cu	

DO YOU KNOW?

Some elements donot have simple molecular structure but consists of a very large number of atoms bonded together. These elements may be represented by their atomic symbols. For example, a recently discovered form of carbon called **buck minster fullerence** has the molecular formula C_{60}. Its structure is a prefect sphere and looks like a soccer ball. Therefore, it is popularly known as **bucky ball.**


Fullerene molecule (C_{60})


Represented as soccer ball

Molecules of Compounds

Atoms of different elements may join together in definite proportion to form molecules of compounds. For example, as already studied hydrogen and oxygen always combine in the ratio of 1:8 to form water. Similarly, carbon dioxide is a comound whose molecules consist of carbon and oxygen atoms. The molecules of some compounds are given in Table 4.

Table 4. Molecules of some compounds.

Compound	Combining elements	Formula	Ratio by mass
Water	Hydrogen and oxygen	H_2O	1 : 8
Ammonia	Nitrogen and hydrogen	NH_3	14 : 3
Carbon dioxide	Carbon and oxygen	CO_2	3 : 8
Sulphur dioxide	Sulphur and oxygen	SO_2	1 : 1

ION

What is an Ion?

Compounds containing only non-metals consist of molecules. For example, hydrogen and oxygen in water, nitrogen and hydrogen in ammonia and carbon and oxygen in carbon dioxide exist as molecules. However, in some compounds the smallest particles are charged species instead of neutral molecules. An **ion is a charged particle having negative or positive charge.** The compounds containing metal and non-metals consist of ions. For example, sodium chloride (common salt) consists of sodium and chloride ions. These compounds are called **ionic compounds**. For example, sodium chloride has positively charged sodium ions (Na^+) and negatively charged chloride ions (Cl^-). These ions may consist of a single charged atom or a group of atoms that have a charge on them. **A group of atoms carrying a charge on them are** called **polyatomic ions.** For example,

Sodium ion (Na^+), calcium ion (Ca^{2+}) exist as single charged ions while ammonium ion having formula NH^+_4 exist as polyatomic ion.

In ionic compounds also the constituting elements are present in a fixed ratio by mass. This is given below in Table 5.

Table 5. Some ionic compounds.

Ionic compound	Constituting elements	Ratio by mass
Calcium oxide	Calcium and oxygen	5 : 2
Magnesium sulphide	Magnesium sulphur	3 : 4
Sodium chloride	Sodium chlorine	23 : 35.5

Thus, the formula of an ionic compound gives the simplest whole number ratio of ions present in it.

WRITING CHEMICAL FORMULAE

It may be noted that we generally find polyatomic ions under negative charge. Some common monoatomic ions are given in Tables 6 and 7 and polyatomic ions are given in Table 8.

Table 6. Some common monoatomic ions (positively charged)

+1 Charge	+2 Charge	+3 Charge	+4 Charge
Hydrogen H^{+}	Barium Ba^{2+}	Aluminium Al^{3+}	Lead (IV)
Sodium Na^{+}	Calcium Ca^{2+}	iron (III) or	or plumbic Pb^{4+}
Potassium K^{+}	Copper (II) or	Ferric Fe^{3+}	Platinum Pt^{4+}
Copper (I) or	cupric Cu^{2+}	Chromium Cr^{3+}	
cuprous Cu^{+}	Mercuric Hg^{2+}	Bismuth Bi^{3+}	
Mercurous Hg^{+}	Cobalt Co^{2+}		
Silver Ag^{+}	Nickel Ni^{2+}		
	Iron (II) or		
	or ferrous Fe^{2+}		
	Magnesium Mg^{2+}		
	Manganese Mn^{2+}		
	Zinc Zn^{2+}		
	Lead (II) or		
	Plumbous Pb^{2+}		

It may be noted that some metals like copper, mercury, iron, tin etc. form

Pb^{2+} : Lead (II) ion or plumbous ion

Pb^{4+} : Lead (IV) ion or plumbic ion.

Table 7. Some common monoatomic ions (negatively charged)

–1 Charge	–2 Charge	– 3 Charge
Fluoride F^- Chloride Cl^- Bromide Br^- Iodide I^- Hydride H^-	Sulphide S^{2-} Oxide O^{2-}	Phosphide P^{3-} Nitride N^{3-}

The compound ions or polyatomic ions containing more than one elements are given in Table 8.

Table 8. Some common polyatomic ions

Positively charged		Negatively charged	
+1 Charge	– 1 Charge	– 2 Charge	– 3 Charge
Ammonium NH_4^+	Hydroxide OH^- Bicarbonate HCO_3^- Nitrate NO_3^- Acetate CH_3COO^-	Carbonate CO_3^{2-} Sulphite SO_3^{2-} Sulphate SO_4^{2-} Chromate CrO_4^{2-} Dichromate $Cr_2O_7^{2-}$	Phosphate PO_4^{3-} Phosphite PO_3^{3-} Borate BO_3^{3-} Phosphide P^{3-} Nitride N^{3-}

Rules for Writing a Chemical Formula