

General chemistry

Chapter 2

Atoms, Molecules, Ions and chemical formulas

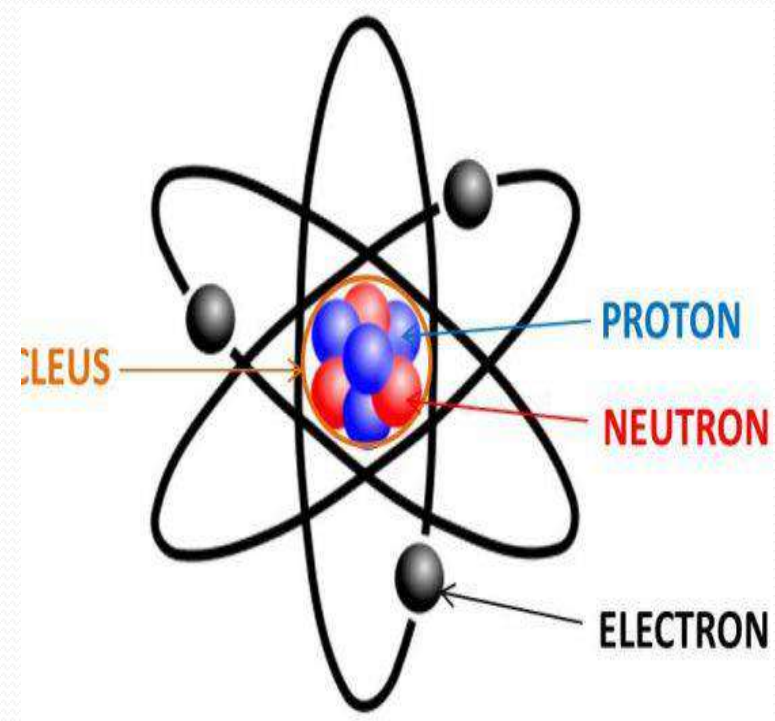
Atoms

Definition

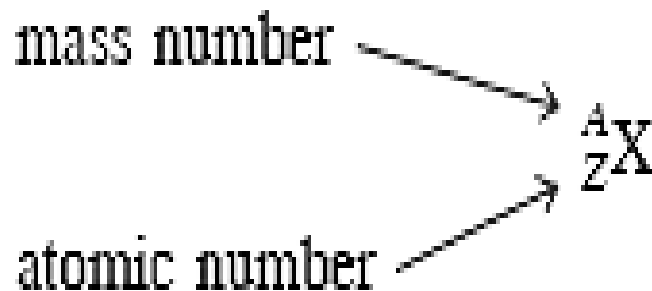
It is the basic unit of an element that can enter into chemical combination.

Structure

- An atom consists of a very dense central nucleus made up of **protons and neutrons**. Around the nucleus **electrons** move and shown as clouds.
- Protons are positively charged, neutrons have no charge, and electrons are negatively charged.



Atomic symbol



- **X** denotes the symbol of the element.
- **Z** denotes the number of protons in the nucleus is called the **atomic number**.
- In a neutral atom: The number of protons = the number of electrons.
- **(A)** denotes the **mass number** which is:

$$\begin{aligned} \text{mass number} &= \text{number of protons} + \text{number of neutrons} \\ \text{(A)} &= \text{(Z)} + \text{number of neutrons} \end{aligned}$$

Molecules

- A **molecule** is an aggregate of at least two atoms held together by chemical forces or bonds.
- **Examples:**
 - *Molecules of the same element:* nitrogen (N₂), oxygen (O₂), iodine (I₂) and ozone (O₃).
 - *Molecules contain atoms of different elements (compounds):* hydrogen chloride (HCl), carbon monoxide (CO), water (H₂O) and ammonia (NH₃).

Ions

- An **ion** is an atom or a group of atoms that has a net positive or negative charge as electrons may be lost or gained.
- The loss of electrons results in a **cation**, *an ion with a net positive charge*.

Examples: Na^+ , Mg^{2+} , Fe^{3+} , NH_4^+ (ammonium ion).

- Gain of electrons results in an **anion**, *an ion whose net charge is negative*

Examples: Cl^- , S^{2-} , N^{3-} , OH^- (hydroxide ion), CN^- (cyanide ion).

The charge of an ion

- Charge of ion = number of protons - number of electrons
- So, number of electrons = number of protons - charge of ion
- **Problems:**

1- How many electrons are there in ${}_{13}\text{Al}^{+3}$?

${}_{13}\text{Al}^{+3}$ have 13 proton .

$$\begin{aligned}\text{number of electrons} &= \text{number of protons} - \text{charge of ion} \\ &= 13 - (+3) = 10\end{aligned}$$

2- How many electrons are there in ${}_{16}\text{S}^{-2}$?

${}_{16}\text{S}^{-2}$ have 16 proton .

$$\begin{aligned}\text{number of electrons} &= \text{number of protons} - \text{charge of ion} \\ &= 16 - (-2) = 18\end{aligned}$$

3- What is the atomic symbol of F that contain 9 protons and 10 neutrons and 10 electrons?

$$Z = 9, \quad A = 9 + 10 = 19$$

$$\begin{aligned} \text{Charge of ion} &= \text{number of protons} - \text{number of electrons} \\ &= 9 - 10 = -1 \end{aligned}$$

So, atomic symbol is $({}^{19}_9\text{F}^-)$, so it is anion.

4- What is the atomic symbol of Fe that contain 26 protons and 30 neutrons and 24 electrons?

$$Z = 26, \quad A = 26 + 30 = 56$$

$$\begin{aligned} \text{Charge of ion} &= \text{number of protons} - \text{number of electrons} \\ &= 26 - 24 = +2 \end{aligned}$$

So, atomic symbol is $({}^{56}_{26}\text{Fe}^{+2})$, so it is cation.

Isotopes

- **Isotopes** are atoms of the same element that have the same number of protons but different numbers of neutrons.
- Give the number of protons, neutrons, and electrons in each of the following species:



- **Solution**

(a) There are 80 protons. The number of neutrons is $199 - 80 = 119$.
The number of electrons is 80.

(b) The number of protons is 80. The number of neutrons is $200 - 80 = 120$. The number of electrons is 80.

The species in (a) and (b) are chemically similar isotopes of mercury.

Chemical Formulas

- **Chemical formula:** formula that represent the composition of molecules in terms of chemical symbols and ratio.
- **Three types of chemical formulas:** molecular, empirical and structural formulas.
 - 1- **Molecular Formula:** shows the exact number of atoms in each element in a molecule.
 - 2- **Empirical formula:** shows the simplest whole-number ratio of atoms, but not necessarily the actual number of atoms.
 - 3- **Structural formula:** shows how atoms are bonded to one another in a molecule.

Chemical Formulas

- For many molecules, the molecular formula and empirical formula are one and the same.

	Hydrogen	Water	Ammonia	Methane
Molecular formula = empirical formula	H_2	H_2O	NH_3	CH_4
Structural formula	$H-H$	$H-O-H$	$\begin{array}{c} H-N-H \\ \\ H \end{array}$	$\begin{array}{c} H \\ \\ H-C-H \\ \\ H \end{array}$

Chemical Formulas

For other molecules, the molecular formula and empirical formula are not the same.

	Hydrogen peroxide	Hydrazine	Acetylene	Glucose
Molecular formula	H_2O_2	N_2H_4	C_2H_2	$\text{C}_6\text{H}_{12}\text{O}_6$
Empirical formula	HO	NH_2	CH	CH_2O
Structural formula	