

General chemistry

Chapter 2 Atoms, Molecules, Ions and chemical formulas

Atoms

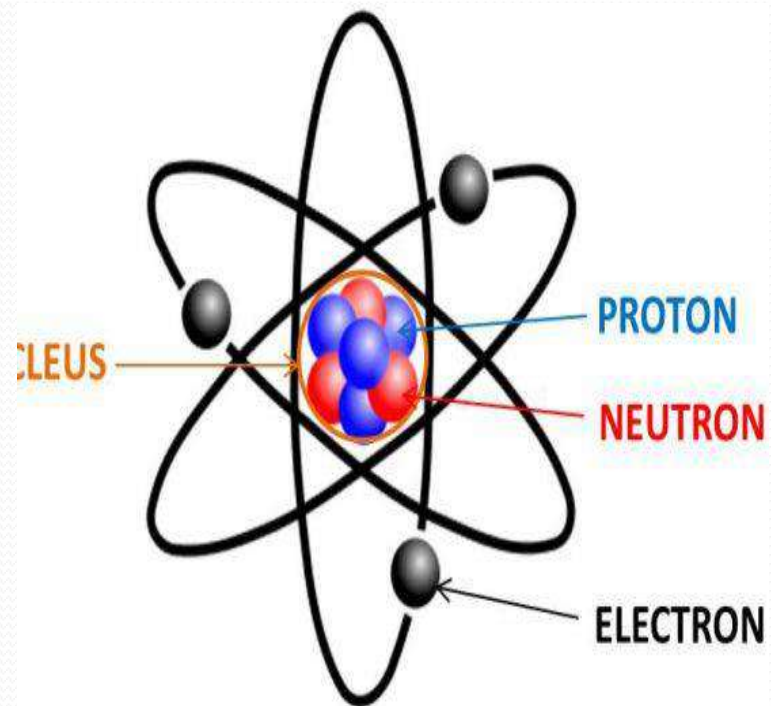
Definition

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

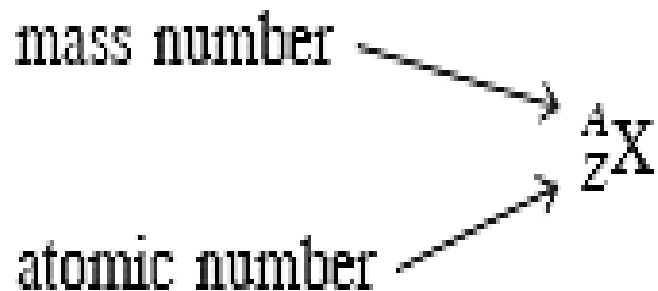
Structure

➤ 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:

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

Problems

- Give the number of protons, neutrons, and electrons in each of the following species:



- **Solution**

(a) The atomic number is 8, so there are 8 protons. The mass number is 17, so the number of neutrons is $17 - 8 = 9$. The number of electrons is the same as the number of protons, that is, 8.

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

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

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

Isotopes are atoms of the same element that have the same number of protons but different numbers of neutrons.

Quiz

Indicate the number of protons, neutrons, and electrons in each of these species:



Write the appropriate symbol for each of these isotopes: (a) $Z = 11, A = 23$; (b) $Z = 28, A = 64$.

Write the appropriate symbol for each of these isotopes: (a) $Z = 74, A = 186$; (b) $Z = 80, A = 201$.

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 (N_2), oxygen (O_2), iodine (I_2) and ozone (O_3).
 - *Molecules contain atoms of different elements (compounds):* hydrogen chloride (HCl), carbon monoxide (CO), water (H_2O) and ammonia (NH_3).

Identify the following as elements or compounds:
 NH_3 , N_2 , S_8 , NO , CO , CO_2 , H_2 , SO_2 .

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.

Quiz

Give the number of protons and electrons in each of the following common ions: Na^+ , Ca^{2+} , Al^{3+} , Fe^{2+} , I^- , F^- , S^{2-} , O^{2-} , N^{3-} .

Give the number of protons and electrons in each of the following common ions: K^+ , Mg^{2+} , Fe^{3+} , Br^- , Mn^{2+} , C^{4-} , Cu^{2+} .

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.

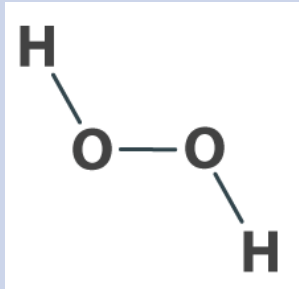
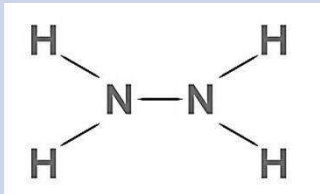
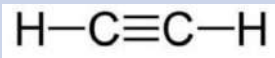
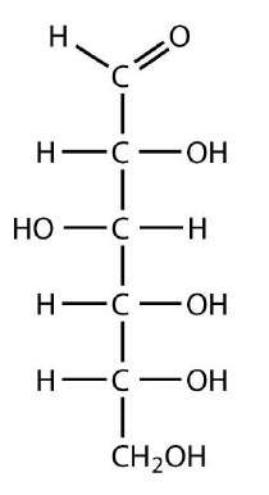
Chemical Formulas

- 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	$\text{H}-\text{H}$	$\text{H}-\text{O}-\text{H}$	$\begin{array}{c} \text{H}-\text{N}-\text{H} \\ \\ \text{H} \end{array}$	$\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{H} \\ \\ \text{H} \end{array}$

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				

Quiz

- Write the empirical formula for caffeine ($\text{C}_8\text{H}_{10}\text{N}_4\text{O}_2$), a stimulant found in tea and coffee.

What are the empirical formulas of the following compounds? (a) C_2N_2 , (b) C_6H_6 , (c) C_9H_{20} , (d) P_4O_{10} , (e) B_2H_6

What are the empirical formulas of the following compounds? (a) Al_2Br_6 , (b) $\text{Na}_2\text{S}_2\text{O}_4$, (c) N_2O_5 , (d) $\text{K}_2\text{Cr}_2\text{O}_7$

End of the chapter