

## ATOMS, MOLECULES, AND IONS

In ancient times, Chemistry existed despite the principles not yet being set. It is evident in practice such as the extraction of iron from iron ore. Chemicals such as sulfuric acid, nitric acid, and sodium sulfate are already used in various ways. In the eighteenth century, gases such as nitrogen and oxygen had been isolated. Chemistry began to formalize when the process of combustion had been studied.

### Dalton's Atomic Theory

Dalton's atomic theory is a fundamental concept in the field of chemistry. Here are its main postulates:

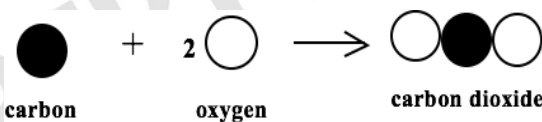
1. All matter is composed of tiny, indivisible particles called atoms.
2. All atoms of a specific element are identical in mass, size, and other properties. However, atoms of different elements exhibit different properties and vary in mass and size.



3. Atoms can neither be created nor destroyed. Furthermore, atoms cannot be divided into smaller particles.
4. Atoms of different elements can combine in fixed whole-number ratios to form compounds.



5. Atoms can be rearranged, combined, or separated in chemical reactions.



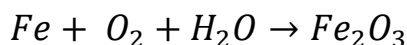
However, parts of Dalton's theory had to be modified based on the discovery of subatomic particles and isotopes. For instance, Dalton's theory stated that atoms were indivisible, but the discovery of subatomic particles (such as protons, electrons, and neutrons) disproved this postulate. Also, according to Dalton's theory, all atoms of an element have identical masses and densities. However, different isotopes of elements have different atomic masses.

### Laws of Matter

#### Law of Conservation of Mass

The total mass of substances present after a chemical reaction is the same as the total mass of substances before the reaction.

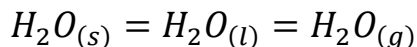
Example: When iron is oxidized and transformed to rust, the iron content of rust is still the same by mass as the unoxidized iron.



#### Law of Constant Composition

All samples of a compound have the same composition—the same proportions by mass of the constituent elements.

Example: Water in any form; ice, liquid water, or water vapor is composed of the same molecules: 2 moles of hydrogen and 1 mole of oxygen. Sodium Chloride or salt is 1 mole of sodium (Na) and 1 mole of chlorine (Cl), whether it is in solid form or dissolved in water.



## Atomic Structure

**Atoms** are essential to everything, from the air we breathe to the stars in the sky. It is the fundamental building block of all matter and chemistry. An atom consists of three primary subatomic particles.

### Subatomic Particles

- Electrons – small negatively charged particles that orbit around an atom's positively charged nucleus.
- Protons – a smaller bit of positively charged matter or sub-atomic particle within the nucleus. The mass of a proton is 1800 times greater than an electron.
- Neutrons – particles located inside the nucleus with a similar mass to their partner proton but with no electrical charge.

### Atomic Number (Z)

The atomic number of an element is taken from the number of protons in the nucleus of an atom.

Example: Boron (B): Atomic number (Z) = 5

Gold (Au): Z = 79

Zinc (Zn): Z = 30

Mercury ( $_{80}\text{Hg}$ ): Z = 80

### Mass Number (A)

The mass number is defined as the total number of protons and neutrons in an atom.

Example: Boron (B): A = 10.18

Carbon (C): A = 12.01

Lithium ( $^{6.94}_{3}\text{Li}$ ): A = 6.94

## Molecules and Ions

Matter is composed of a combination of atoms in a specific geometrical arrangement. Most matter usually appears homogenous at first inspection, such as water composed of hydrogen and oxygen atoms.

**Molecules** are composed of atoms chemically bonded by attractive forces.

### Diatomic Molecules

Elements that occur naturally in pairs or as two-atoms. Examples are oxygen ( $\text{O}_2$ ), nitrogen ( $\text{N}_2$ ), hydrogen ( $\text{H}_2$ ), fluorine ( $\text{F}_2$ ), and chlorine ( $\text{Cl}_2$ ), which occur in pairs at room temperature.

### Chemical Bond

The force that binds two or more atoms together.

- A **covalent bond** is a bond wherein electrons are shared equally.
- An **ionic bond** is when electrons are transferred from one atom to another.

## Chemical Formula

**Molecular Formula** – gives the exact number of atoms of each element in a molecule

Example: Sodium chloride =  $\text{NaCl}$  = 1 atom of sodium and 1 atom of chlorine

Water =  $\text{H}_2\text{O}$  = 2 atoms of hydrogen and 1 atom of oxygen

Sucrose =  $\text{C}_6\text{H}_{12}\text{O}_6$  = 6 atoms of carbon, 12 atoms of hydrogen, and 6 atoms of oxygen

**Structural Formula** – shows how specific atoms are ordered and arranged in compounds. It makes it easier to see how atoms are bonded.

Example:

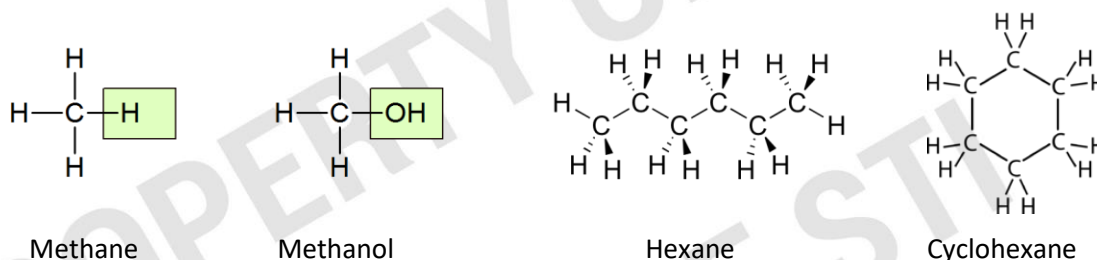


Figure 1. Structural formula of some compounds

**Ions** – are atoms that lose or gain electrons. Atoms are electrically neutral or uncharged. The change in the number of electrons makes it either negatively charged (gain) or positively charged (loss).

**Cation** – positively charged ion

**Anion** – negatively charged ion

Examples:

- 1) sodium ( $^{22.9}_{11}\text{Na}$ ): protons = 11, electrons = 11; neutral

When sodium loses an electron: protons = 11, electrons = 10; charge = (+)

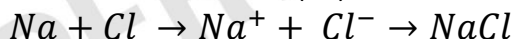
Sodium ion =  $\text{Na}^+$

- 2) chlorine ( $^{35.5}_{17}\text{Cl}$ ): protons = 17, electrons = 17; neutral

When chlorine gains an electron from bonding: protons = 17, electrons = 18; charge = (-)

Chlorine ion =  $\text{Cl}^-$

- 1) An electron is transferred when sodium (Na) bonds with chlorine (Cl).



## Naming Ionic Compounds

- A. For ionic compounds containing common monatomic ions, we give the name of the cation first, simply using its element name. To name the anion, we add the suffix *-ide* to the root of the name of the element that corresponds to the anion. Generally, for ionic compounds, a prefix indicating the atomic ratio is not used.

Examples: **NaCl** is composed of **Na<sup>+</sup>** and **Cl<sup>-</sup>** ions and is named sodium chloride.

The compound with the formula **AlBr<sub>3</sub>** is composed of **Al<sup>3+</sup>** ions and **Br<sup>-</sup>** ions and is named aluminum bromide.

- B. Naming ionic compounds containing polyatomic anions is like naming compounds with monatomic anions. The cation is named first, followed by the name of the polyatomic ion.

Examples: The compound that contains the sodium ion,  $\text{Na}^+$ , and the sulfate ion,  $\text{SO}_4^{2-}$ , has the formula  $\text{Na}_2\text{SO}_4$  and is called sodium sulfate. Some ionic compounds contain the ammonium ion  $\text{NH}_4^+$ . An example is ammonium chloride,  $\text{NH}_4\text{Cl}$ .

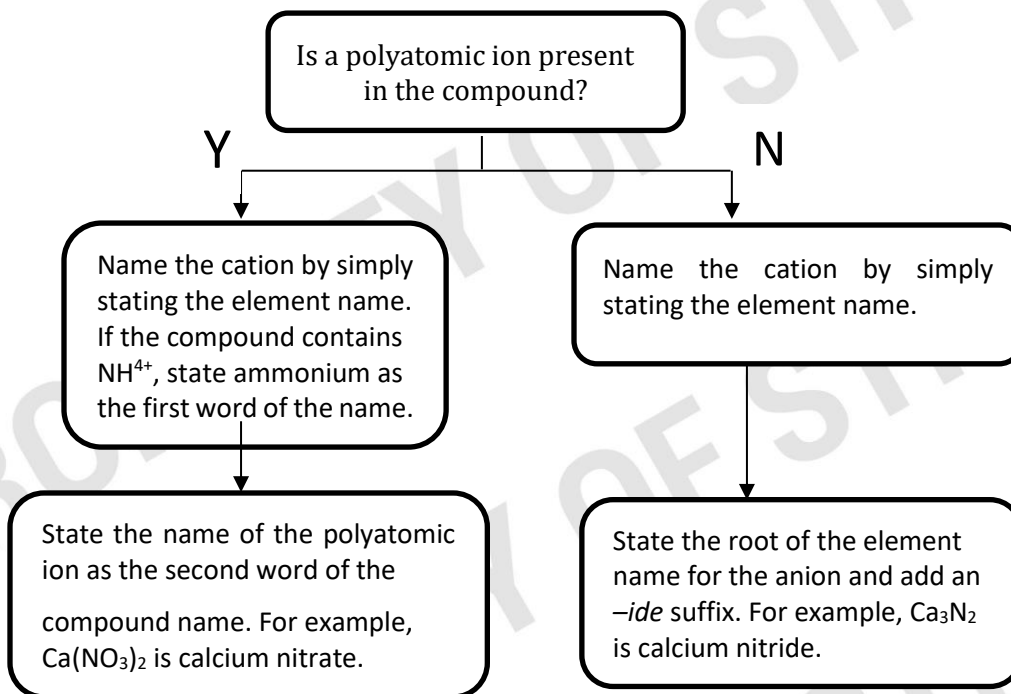


Figure 2. Flowchart for naming ionic compounds

**Examples:** Name the compounds given by the formulas

(a)  $\text{Na}_2\text{O}$

The first compound,  $\text{Na}_2\text{O}$ , comprises monatomic cations and anions whose charges can be predicted from the periodic table. We state the name of the metal ion first, followed by the root of the name for the nonmetal with an  $-ide$  ending. The name of the compound is *sodium oxide*.

(b)  $\text{Ca}_3(\text{PO}_4)_2$

The charge on a calcium ion can be predicted from the periodic table. The polyatomic ion is  $\text{PO}_4^{3-}$  named phosphate ion. The name of the compound is *calcium phosphate*.

## Ions

Group	Element	Symbol	Simple Ion Charge
Group VA	Nitrogen	N	-3 nitride
	Phosphorus	P	-3 phosphide
	Arsenic	As	-3 arsenide
Group VIA	Oxygen	O	-2 oxide
	Sulfur	S	-2 sulfide
Group VIIA	Fluorine	F	-1 fluoride
	Chlorine	Cl	-1 chloride
	Bromine	Br	-1 bromide
	Iodine	I	-1 iodide

Table 1. The main group elements and their charges are in ionic form.

Element	Symbol	Simple Ion Charge
Chromium	Cr	Chromium (II) – +2
		Chromium (III) – +3
Manganese	Mn	+2
Iron	Fe	Ferrous – +2
		Ferric – +3
Cobalt	Co	Cobaltous – +2
		Cobaltic – +3
Nickel	Ni	+2
Copper	Cu	Cuprous – +2
		Cupric – +1
Zinc	Zn	+2
Silver	Ag	+1
Cadmium	Cd	+2
Mercury	Hg	+2

Table 2. The ionic charges of transition metals.

Ion	Name	Ion	Name
$\text{NH}_4^+$	Ammonium	$\text{CO}_3^{2-}$	Carbonate
$\text{NO}_2^-$	Nitrite	$\text{HCO}_3^-$	Bicarbonate
$\text{NO}_3^-$	Nitrate	$\text{ClO}_4^-$	Perchlorate
$\text{SO}_3^{2-}$	Sulfite	$\text{ClO}_3^-$	Chlorate
$\text{SO}_4^{2-}$	Sulfate	$\text{ClO}_2^-$	Chlorite
$\text{HSO}_4^-$	Bisulfate	$\text{ClO}^-$	Hypochlorite
$\text{OH}^-$	Hydroxide	$\text{C}_2\text{H}_3\text{O}_2^-$	Acetate
$\text{PO}_4^{3-}$	Phosphate	$\text{Cr}_2\text{O}_7^{2-}$	Dichromate
$\text{HPO}_4^{2-}$	Hydrogen phosphate	$\text{CrO}_4^-$	Chromate
$\text{H}_2\text{PO}_4^-$	Dihydrogen phosphate	$\text{CN}^-$	Cyanide

Table 3. The Nomenclature of different polyatomic ions.

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