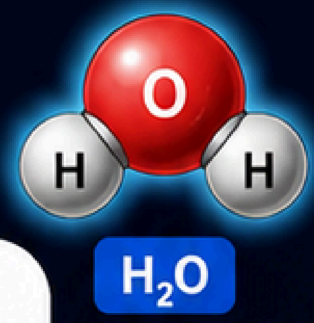


LAW OF CONSTANT PROPORTIONS

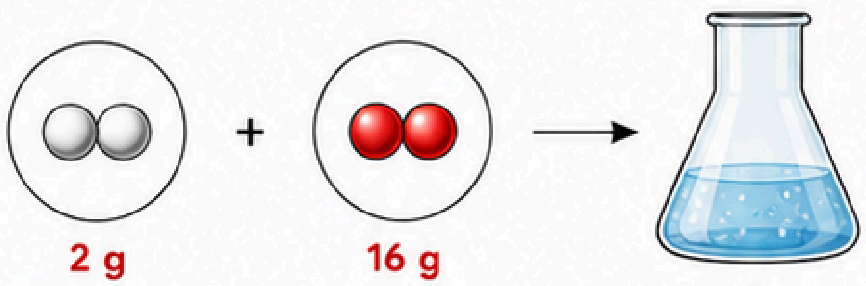
The law of constant proportions states that **a chemical compound always contains the same elements** in a **fixed proportion by mass**, no matter how it is prepared.

EXAMPLE: WATER (H_2O)

Water can be prepared in different ways, but the ratio of masses of hydrogen and oxygen is always **1 : 8**.

EXPERIMENTS

Experiment 1
By burning hydrogen in oxygen



2 g Hydrogen (H_2) + 16 g Oxygen (O_2) → 18 g Water (H_2O)

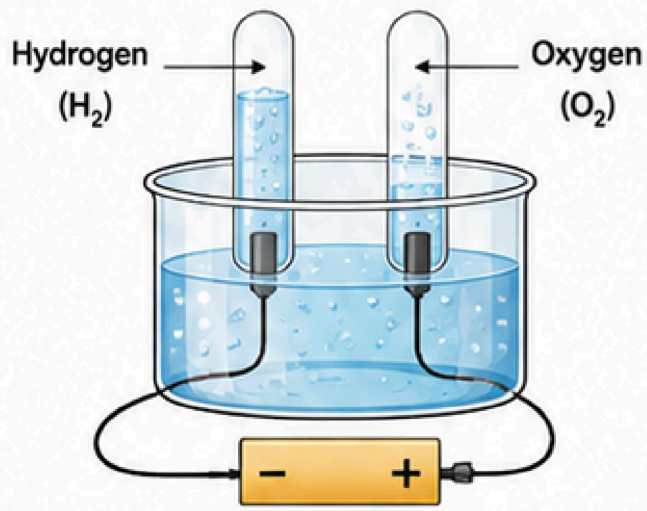
Result

2 g of hydrogen combines with 16 g of oxygen to form 18 g of water.

Ratio by mass

Hydrogen : Oxygen = 2 : 16 = **1 : 8**

Experiment 2
By electrolysis of water



After electrolysis, the gases are collected and weighed.

Result

1 g of hydrogen is always obtained with 8 g of oxygen.

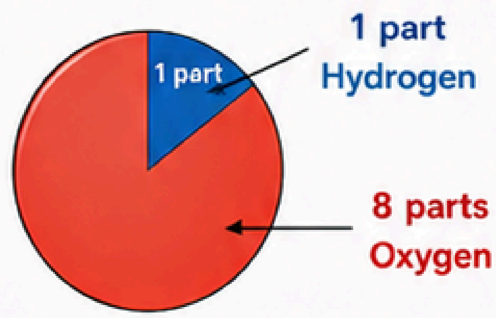
Ratio by mass

Hydrogen : Oxygen = **1 : 8**

CONCLUSION

In both experiments, water is formed with the same ratio by mass of hydrogen and oxygen.

Hydrogen : Oxygen by mass in water = **1 : 8**



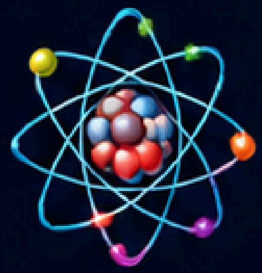
KEY POINTS

- Water is always made of hydrogen and oxygen.
- The ratio of masses of hydrogen to oxygen in water is always 1 : 8.
- This ratio does not change, no matter how or where the water is formed.
- This proves the law of constant proportions.

IN SHORT

A compound always contains the same elements in a fixed proportion by mass.
(For water: H : O = 1 : 8 by mass)

Thus, water (H_2O) **always contains hydrogen and oxygen** in the fixed **proportion** by mass of **1 : 8**.



LAW OF CONSERVATION OF MASS

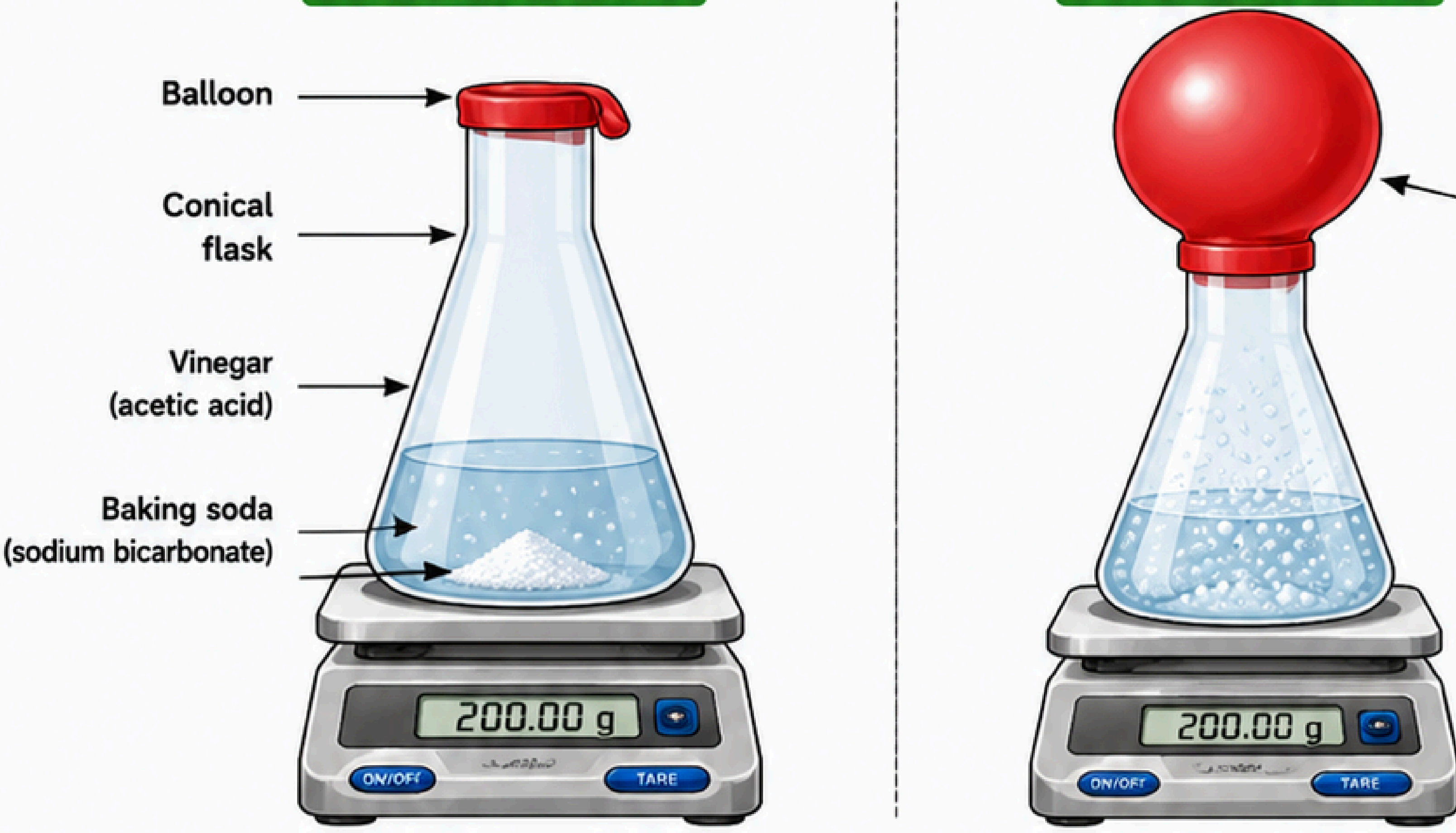
The law of conservation of mass states that
mass can neither be created nor destroyed in a chemical reaction.
The total mass of the reactants is always equal to the total mass of the products.

EXPERIMENTAL SETUP

Reaction between vinegar (acetic acid) and baking soda in a **closed system** (conical flask with a balloon).

1. BEFORE REACTION

2. AFTER REACTION



Bubbles of carbon dioxide gas inflate the balloon, but the gas does not escape because the system is **closed**.

Initial total mass = 200.00 g

Final total mass = 200.00 g

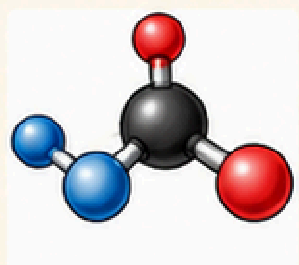
CHEMICAL REACTION

CH_3COOH	+	$NaHCO_3$	$\longrightarrow$	CH_3COONa	+	H_2O	+	CO_2
(Acetic acid)		(Sodium bicarbonate)		(Sodium acetate)		(Water)		(Carbon dioxide)

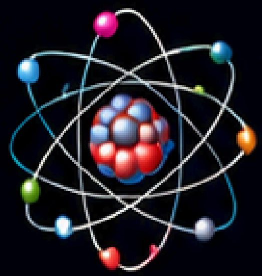
CONCLUSION

- Mass before the reaction = 200.00 g
- Mass after the reaction = 200.00 g
- Therefore, total mass of reactants = total mass of products.

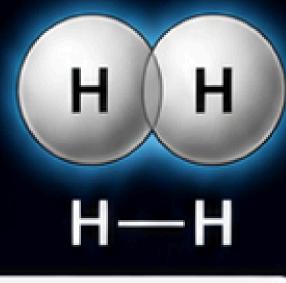
This proves the law of conservation of mass.



In a chemical reaction, mass can **change form** but it is **never lost or gained.**



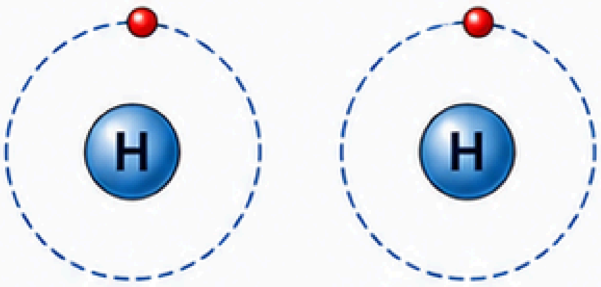
FORMATION OF HYDROGEN MOLECULE (H_2)



Two hydrogen atoms combine by **sharing their electrons** to achieve a **stable electron configuration (duplet)** and form a hydrogen molecule.

STEP-BY-STEP FORMATION

1 Each hydrogen atom separately

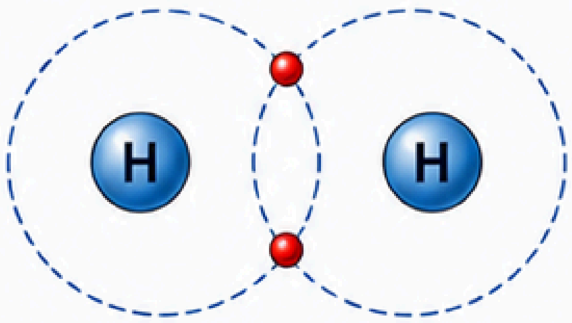


Hydrogen atom (H) — 1 electron

Hydrogen atom (H) — 1 electron

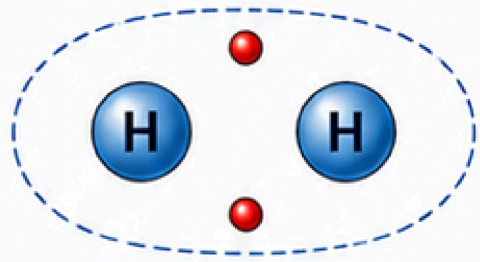
Each hydrogen atom has 1 proton in the nucleus and 1 electron in its outermost shell.

2 The two atoms come closer and share their electrons



The two atoms share their electrons. Each electron is attracted by both nuclei.

3 Formation of hydrogen molecule (H_2)



Hydrogen molecule (H_2)

Both atoms attain a stable duplet (2 electrons) in their outermost shell.

ELECTRONIC (LEWIS) REPRESENTATION

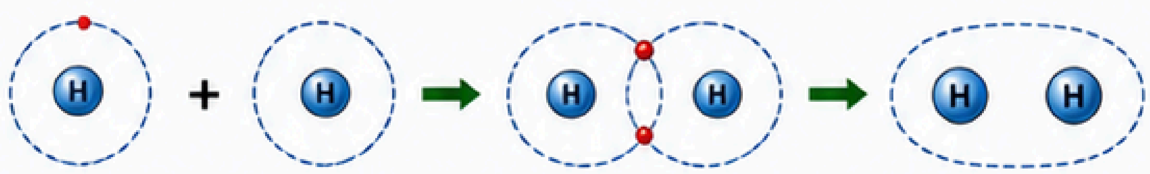
$$\mathrm{H}\cdot + \cdot\mathrm{H} \longrightarrow \mathrm{H}:\mathrm{H} \longrightarrow \mathrm{H{-}H}$$

Two hydrogen atoms → Shared pair of electrons → Hydrogen molecule (H_2)

KEY POINTS

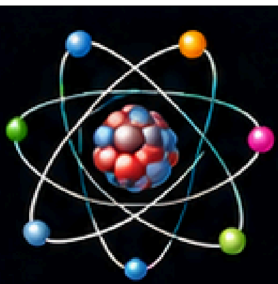
- Hydrogen has atomic number 1, so its electronic configuration is 1 (K shell).
- It needs one more electron to complete its K shell and achieve stability (duplet).
- By sharing electrons, both hydrogen atoms attain a stable duplet.
- The shared pair of electrons forms a single covalent bond (H—H).

SUMMARY

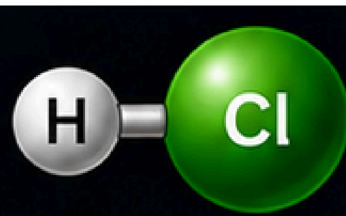


Two hydrogen atoms (unstable) → Sharing of electrons → Hydrogen molecule (H_2) (stable)

Thus, a **hydrogen molecule (H_2)** is formed when two hydrogen atoms **share** one pair of electrons to complete their **duplet**.



FORMATION OF HYDROGEN CHLORIDE (HCl)

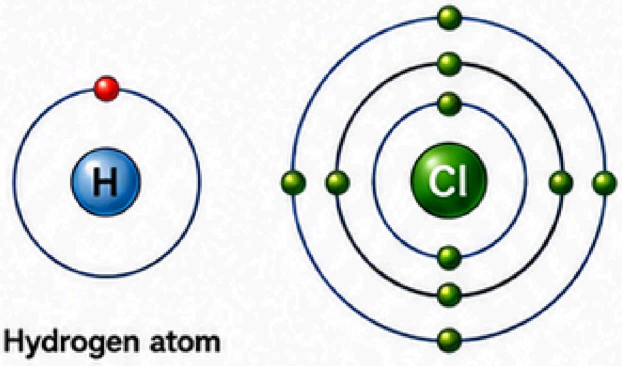


H—Cl

Hydrogen and chlorine atoms combine by sharing one pair of electrons to achieve stable electron configurations and form a hydrogen chloride molecule (HCl).

STEP-BY-STEP FORMATION

1 Each atom separately

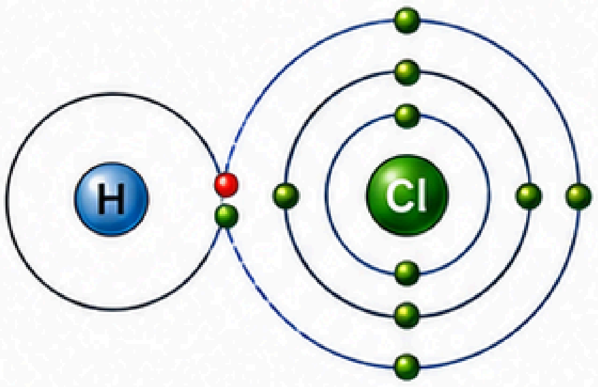


Hydrogen atom (H) — Electronic configuration: 1 (K shell)

Chlorine atom (Cl) — Electronic configuration: 2, 8, 7 (K, L, M shells)

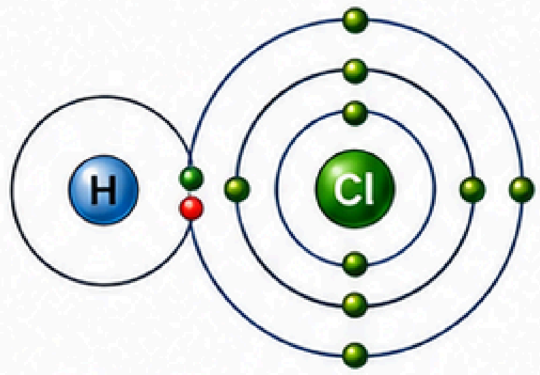
Hydrogen has 1 electron in its outermost shell and needs 1 more to complete duplet.
Chlorine has 7 electrons in its outermost shell and needs 1 more to complete octet.

2 The two atoms come closer and share one pair of electrons



Hydrogen and chlorine share one pair of electrons. The shared electrons are attracted by both nuclei.

3 Formation of hydrogen chloride (HCl)



Hydrogen chloride molecule (HCl)

Hydrogen attains a stable duplet (2 electrons) and chlorine attains a stable octet (8 electrons) in its outermost shell.

ELECTRONIC (LEWIS DOT) REPRESENTATION

$$\mathrm{H}\cdot + :\ddot{\underset{\cdot\cdot}{\mathrm{Cl}}}: \longrightarrow \mathrm{H}:\ddot{\underset{\cdot\cdot}{\mathrm{Cl}}}: \longrightarrow \mathrm{H}-\ddot{\underset{\cdot\cdot}{\mathrm{Cl}}}:$$

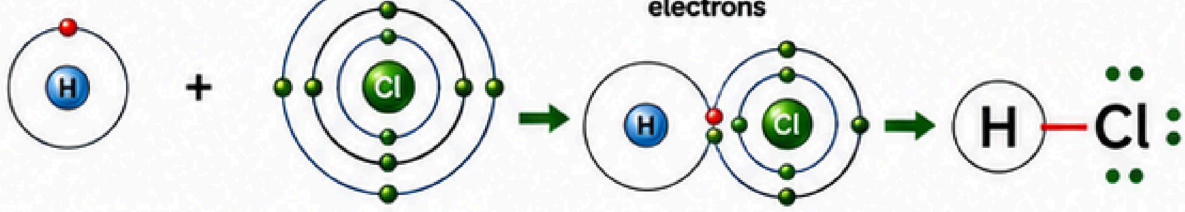
Hydrogen atom | Chlorine atom | Sharing of one pair of electrons | Hydrogen chloride molecule (HCl)

KEY POINTS

- Hydrogen has 1 valence electron and needs 1 more to complete its duplet.
- Chlorine has 7 valence electrons and needs 1 more to complete its octet.
- They share one pair of electrons.
- A single covalent bond (—) is formed between H and Cl.
- Both atoms become stable.

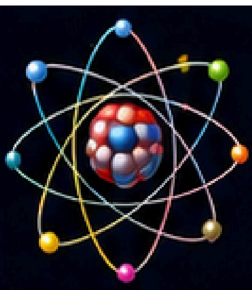
SUMMARY

Hydrogen atom | Chlorine atom | Sharing of one pair of electrons | HCl molecule (Stable)

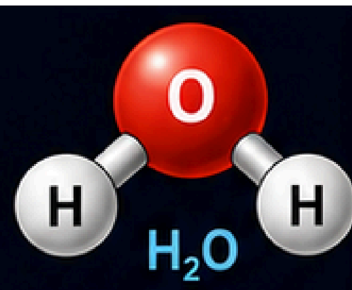


(Needs 1 electron) (Needs 1 electron)

Thus, hydrogen chloride (HCl) is formed when hydrogen and chlorine atoms share one pair of electrons to achieve stable electron configurations.



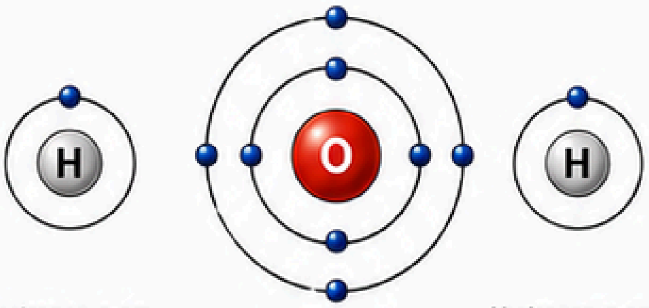
FORMATION OF WATER MOLECULE (H_2O)



Two hydrogen atoms combine with one oxygen atom by **sharing electrons.**
This helps all the **atoms achieve stable electron configurations** and form a water molecule (H_2O).

STEP-BY-STEP FORMATION

1 Each atom separately

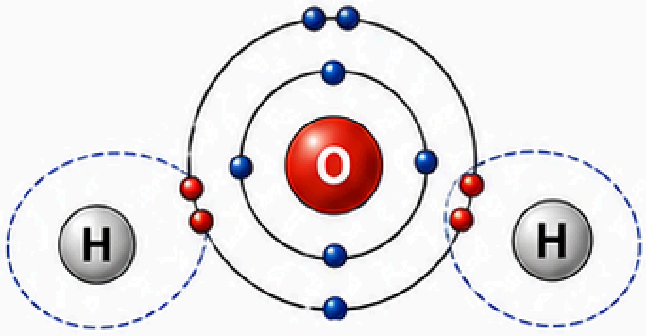


Hydrogen atom (H)	Oxygen atom (O)	Hydrogen atom (H)
Electronic configuration	Electronic configuration	Electronic configuration
1	2, 6	1
(K shell)	(K, L shells)	(K shell)

Hydrogen has 1 valence electron and needs 1 more to complete **duplet**.

Oxygen has 6 valence electrons and needs 2 more to complete **octet**.

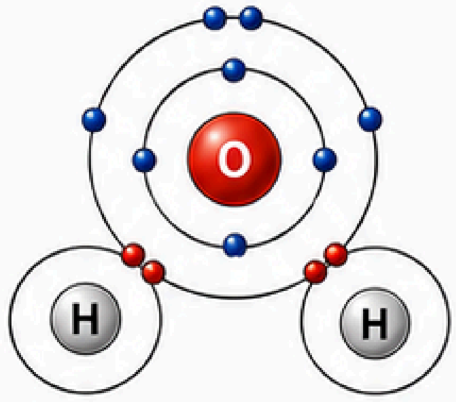
2 The hydrogen atoms come closer to oxygen and share electrons with it



Each hydrogen shares its one electron with oxygen. Oxygen shares one electron with each hydrogen.

(Two shared pairs of electrons)

3 Formation of water molecule (H_2O)



Water molecule (H_2O)

Oxygen attains stable **octet** (8 electrons) and each hydrogen attains stable **duplet** (2 electrons) in its outermost shell.

Thus, all the atoms become stable.

ELECTRONIC (LEWIS DOT) REPRESENTATION

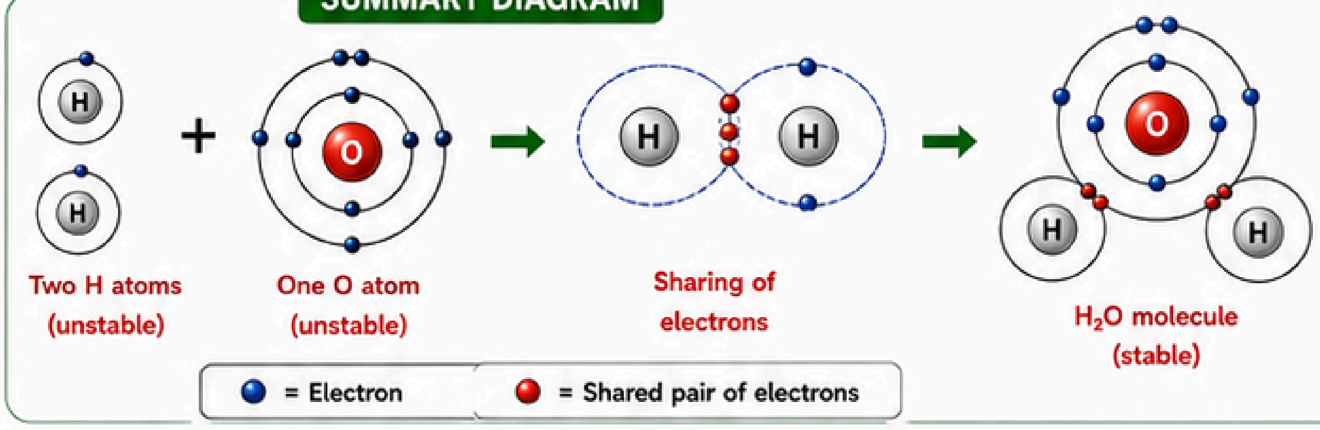
$$\mathrm{H}\cdot \;+\; :\ddot{\underset{\cdot\cdot}{\mathrm{O}}}: \;+\; \cdot\mathrm{H} \;\longrightarrow\; \mathrm{H}:\ddot{\underset{\cdot\cdot}{\mathrm{O}}}:\mathrm{H} \;\longrightarrow\; \mathrm{H}-\ddot{\underset{\cdot\cdot}{\mathrm{O}}}-\mathrm{H}$$

Two hydrogen atoms (Each has 1 valence electron) | Oxygen atom (Has 6 valence electrons) | Sharing of electrons (Two shared pairs) | Water molecule (H_2O)

KEY POINTS

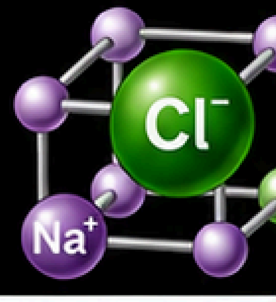
- Hydrogen has 1 valence electron and needs 1 more to complete **duplet**.
- Oxygen has 6 valence electrons and needs 2 more to complete **octet**.
- Each hydrogen shares one electron with oxygen.
- Oxygen shares one electron with each hydrogen.
- Two covalent bonds (O—H) are formed.
- All the atoms attain stable electron configuration.

SUMMARY DIAGRAM



Thus, a **water molecule (H_2O)** is formed when two hydrogen atoms **share their electrons** with **one oxygen atom** to achieve **stable electron configurations**.

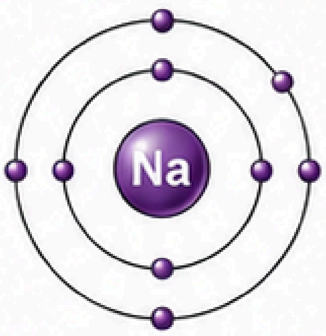
FORMATION OF SODIUM CHLORIDE (NaCl)



Sodium (Na) loses one electron and chlorine (Cl) gains one electron.
This transfer of electrons forms oppositely charged ions which attract each other to form NaCl.

STEP-BY-STEP FORMATION

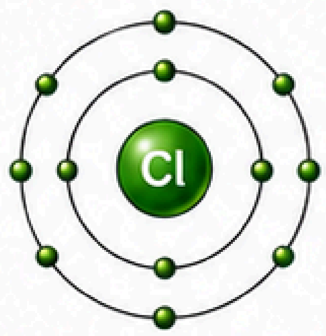
1 Sodium atom (Na)



Electronic configuration
2, 8, 1

Sodium has 1 valence electron in its outermost shell.
It tends to lose this electron to achieve a stable octet.

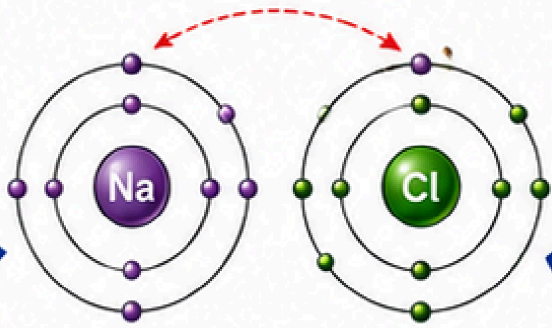
2 Chlorine atom (Cl)



Electronic configuration
2, 8, 7

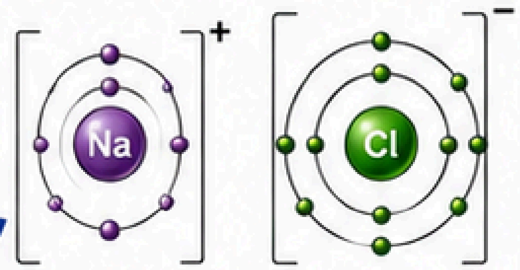
Chlorine has 7 valence electrons in its outermost shell.
It needs 1 more electron to achieve a stable octet.

3 Transfer of one electron



Sodium loses its one valence electron and chlorine gains that electron.

4 Formation of ions



Na^+ ion (2, 8) Cl^- ion (2, 8, 8)

Sodium becomes a positive ion (Na^+) after losing one electron.

Chlorine becomes a negative ion (Cl^-) after gaining one electron.

OVERALL PROCESS

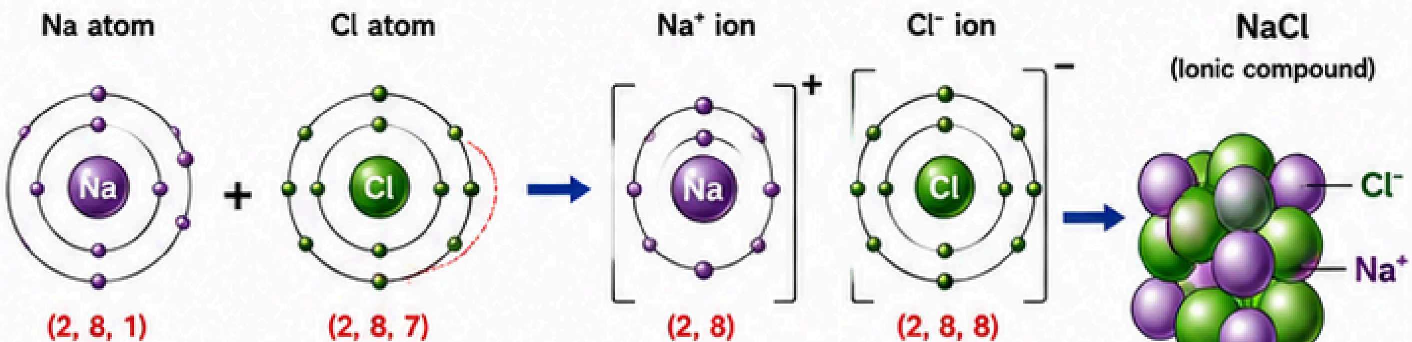
Sodium atom		Chlorine atom		Sodium ion		Chloride ion		Sodium chloride
Na	+	Cl	→	Na^+	+	Cl^-	→	NaCl
(2, 8, 1)		(2, 8, 7)		(2, 8)		(2, 8, 8)		

1 electron is transferred from sodium to chlorine.

Oppositely charged ions are formed.

Ions attract each other to form NaCl.

SUMMARY DIAGRAM



Electrostatic attraction between Na^+ and Cl^- ions forms ionic compound sodium chloride (NaCl).

KEY POINTS

- Sodium (Na) has 1 valence electron (2, 8, 1) and loses it.
- Chlorine (Cl) has 7 valence electrons (2, 8, 7) and gains 1 electron.
- This forms Na^+ and Cl^- ions.
- Oppositely charged ions attract each other strongly.
- The ionic compound formed is sodium chloride (NaCl).
- NaCl has a giant ionic lattice with strong electrostatic forces.

Thus, sodium chloride (NaCl) is formed by the transfer of one electron from sodium atom to chlorine atom.

NaCl CRYSTAL LATTICE

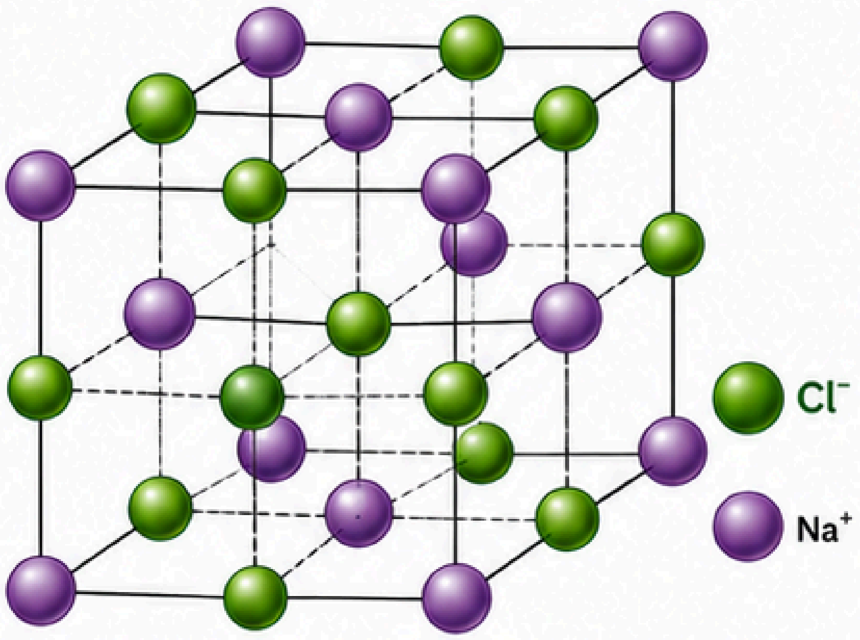
Cl^- Chloride ion
Na^+ Sodium ion

Sodium chloride (NaCl) is an **ionic compound**.
In the solid state, Na^+ and Cl^- ions are arranged in a regular 3–D pattern called a **crystal lattice**.

1. BASIC STRUCTURE (ROCK-SALT STRUCTURE)

In NaCl crystal lattice:

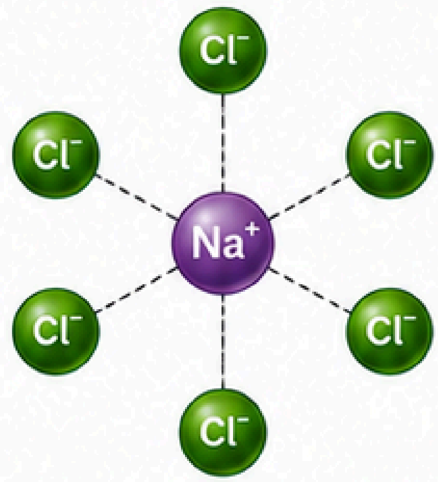
- Each Na^+ ion is surrounded by 6 Cl^- ions.
- Each Cl^- ion is surrounded by 6 Na^+ ions.



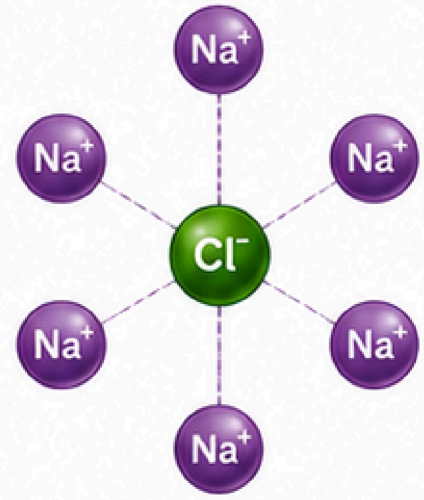
This arrangement repeats in all directions to form a giant crystal.

2. COORDINATION NUMBER

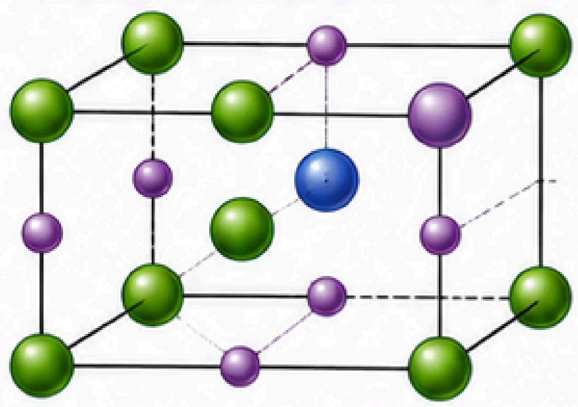
Na^+ is surrounded by 6 Cl^- ions



Cl^- is surrounded by 6 Na^+ ions



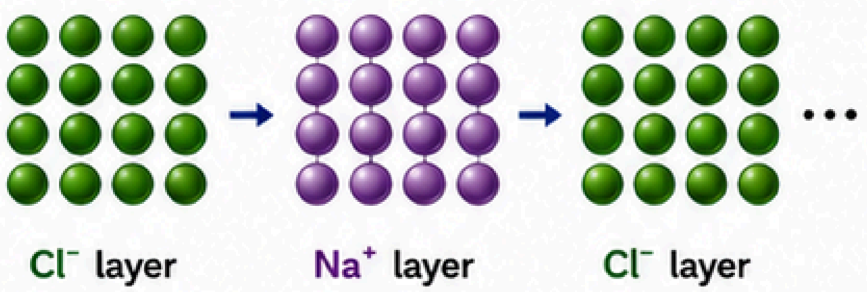
3. UNIT CELL OF NaCl



- Cl^- ions are at each corner and at the centre of each face.
- Na^+ ions are at the centre of each edge and at the body centre.

4. LAYER ARRANGEMENT

Alternate layers of Na^+ and Cl^- ions.



These layers stack one above the other in a repeating pattern.

5. PROPERTIES DUE TO CRYSTAL LATTICE

- Strong electrostatic attraction between Na^+ and Cl^- ions holds the lattice together.
  Hence, NaCl is **hard** and has a **high melting and boiling point**.
- It is **brittle** – it breaks when layers slide over each other, bringing like charges together.
- It is **soluble** in water.
- It **conducts electricity** in molten state or in aqueous solution (ions are free to move), but not in solid state.

Thus, NaCl has a **giant ionic crystal lattice** in which Na^+ and Cl^- ions are arranged in a **regular 3–D pattern**, each ion being surrounded by **6 oppositely** charged ions, giving the compound its characteristic properties.

IONIC vs COVALENT COMPOUNDS

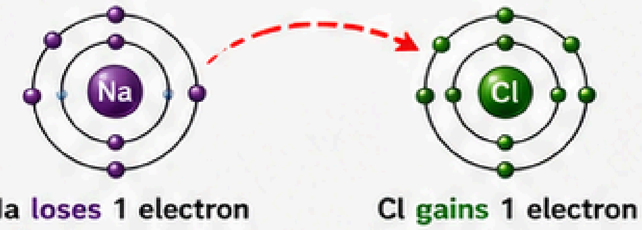
Compounds are formed when atoms combine through chemical bonds.
Ionic compounds are formed by **transfer of electrons**,
whereas **covalent compounds** are formed by **sharing of electrons**.

FORMATION

IONIC COMPOUNDS

Formed by **transfer of electrons**
(between metal and non-metal)

Example: Sodium chloride (NaCl)

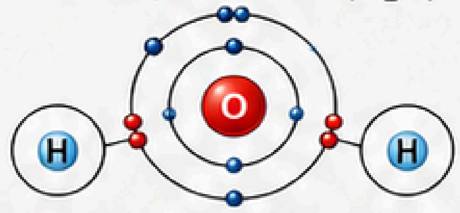


$[Na]^+ + [Cl]^-$

COVALENT COMPOUNDS

Formed by **sharing of electrons**
(between non-metal atoms)

Example: Water (H_2O)

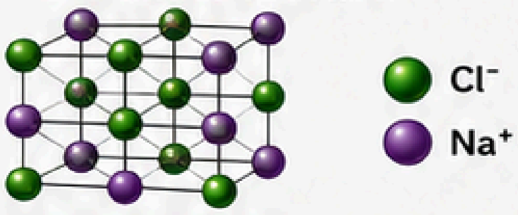


O shares electrons with two H atoms

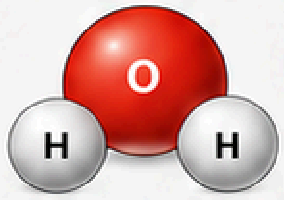
H — O — H

STRUCTURE

Ionic: Ions are arranged in a regular **3-D lattice** structure.



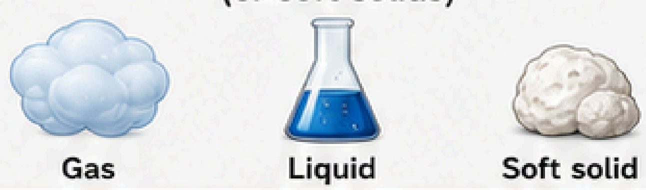
Covalent: Exist as **discrete molecules.**
(Small and simple molecules)



PHYSICAL STATE AT ROOM TEMPERATURE

Ionic: Generally **solids**
(hard and crystalline)

Covalent: Generally **gases** or **liquids**
(or soft solids)



MELTING & BOILING POINT

Ionic: **High** melting and boiling points
(strong electrostatic forces between ions)

High

Covalent: **Low** melting and boiling points
(weak intermolecular forces)

Low

SOLUBILITY IN WATER

Ionic: Generally **soluble** in water
(ions separate and dissolve)

Cl^-
Na^+

Covalent: Generally **insoluble** in water
(do not dissolve)

ELECTRICAL CONDUCTIVITY

Ionic: Conduct electricity in **molten state** or in **aqueous solution**
(ions are free to move)

Covalent: Do not conduct electricity in **any** state
(electrons are **not free** to move)

EXAMPLES

Ionic:

- Sodium chloride (NaCl)
- Calcium oxide (CaO)
- Magnesium sulfate ($MgSO_4$)
- Potassium nitrate (KNO_3)

Covalent:

- Water (H_2O)
- Carbon dioxide (CO_2)
- Methane (CH_3)
- Ammonia (NH_3)

IN SHORT: **Ionic compounds** = transfer of electrons, ionic bonds, ionic lattice, high melting point, conduct in solution/melt.
Covalent compounds = sharing of electrons, molecules, low melting point, do not conduct electricity.