IONIC BONDING – GCSE CHEMISTRY

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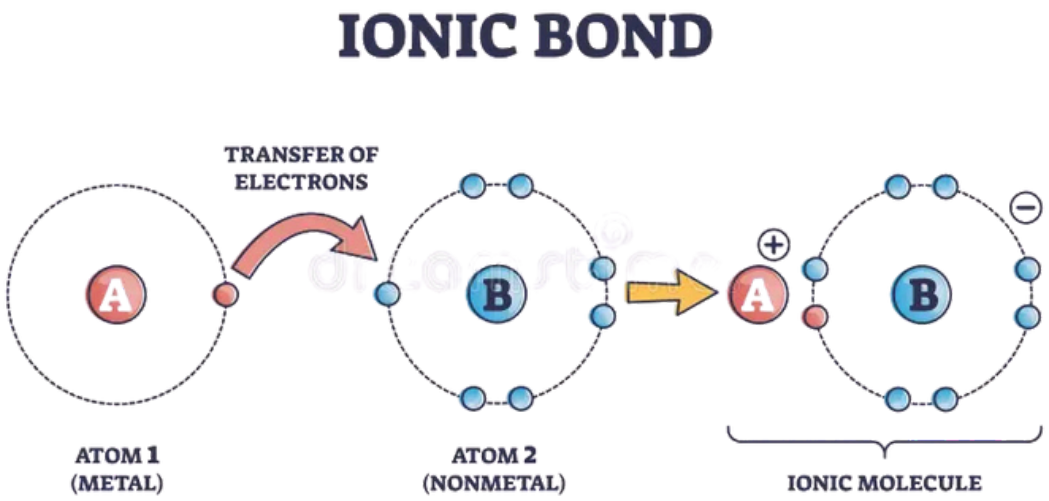
1. Introduction

- Ionic bonding is a type of chemical bond formed between two atoms when one atom transfers one or more electrons to another atom.

- This transfer of electrons results in the formation of ions—positively charged cations and negatively charged anions. These oppositely charged ions attract each other, creating a strong electrostatic force known as an **Ionic Bond**.



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2. How Ionic Bonds are formed?

Ionic bonds form when one atom gives up electrons, and another atom takes them. This happens because atoms want to have a full outer shell of electrons (like noble gases) to become stable.

Step-by-Step Formation:

Step#1: Electron Transfer:

- A metal atom (like sodium, Na) loses its outer electron(s) because it's easier to lose than gain.
- A non-metal atom (like chlorine, Cl) gains electron(s) to fill its outer shell.

Step#2: Formation of Ions:

- The metal becomes a positive ion (cation) because it loses electrons.
- The non-metal becomes a negative ion (anion) because it gains electrons.

Step#3: Electrostatic Attraction:

- The oppositely charged ions attract each other, forming a strong ionic bond.

Example:

- Sodium (Na) has **1 valence electron** (easily lost).
- Chlorine (Cl) has **7 valence electrons** (needs 1 more).
- Na gives 1 electron to Cl:
  - $Na \rightarrow Na^+$ (positively charged)
  - $Cl + e^- \rightarrow Cl^-$ (negatively charged)
- Na^+ and Cl^- attract, forming **NaCl (salt)**.

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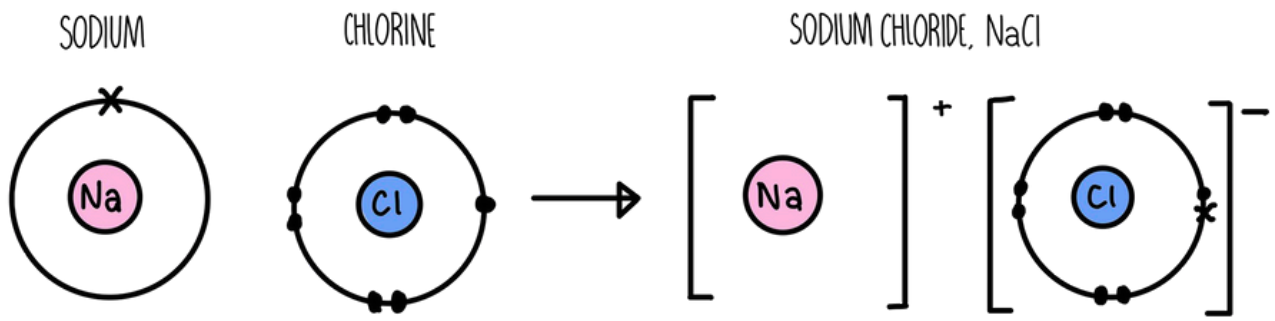
Diagrammatically, it can be represented as:



3. What do you mean by the term 'ION'?

An I**on** is an electrically charged atom or molecule that forms when an atom gains or loses electrons. Unlike neutral atoms, ions have an unequal number of protons (positive charges) and electrons (negative charges), resulting in a net charge.

How Are Ions Created?

Ions form through the transfer of electrons between atoms. This happens because atoms strive to achieve a stable electron arrangement, typically resembling the nearest noble gas.

1. Loss of Electrons → Positive Ion (Cation)

- **Example:** A sodium (Na) atom has 11 protons (+) and 11 electrons (−).
- When it loses 1 electron, it retains 11 protons but only 10 electrons.
- Result: Na^+ (sodium ion) with a +1 charge.

2. Gain of Electrons → Negative Ion (Anion)

- **Example:** A chlorine (Cl) atom has 17 protons (+) and 17 electrons (−).
- When it **gains 1 electron**, it still has 17 protons but now 18 electrons.
- Result: **Cl^-** (chloride ion) with a **−1 charge**.

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4. Structure of Ionic compounds as a Lattice structure.

Ionic compounds form a **giant 3D lattice structure** due to the strong electrostatic forces between oppositely charged ions. This arrangement maximizes stability by balancing attractions and repulsions.

Key Features of Ionic Lattices

- **Alternating Ions**
  - Positive ions (**cations**, e.g., Na^+) are surrounded by negative ions (**anions**, e.g., Cl^-), and vice versa.
  - Example: In **NaCl (salt)**, each Na^+ ion is surrounded by 6 Cl^- ions, and each Cl^- is surrounded by 6 Na^+ ions.
- **High Melting/Boiling Points**
  - Strong ionic bonds require large amounts of energy to break, making ionic compounds solid at room temperature.
- **Brittleness**
  - When force is applied, like charges may align and repel, causing the lattice to split (e.g., salt shatters when hit).
- **No Discrete Molecules**
  - The lattice extends infinitely in all directions, so we write the **empirical formula** (e.g., NaCl, not "NaCl molecules").

Real-World Implications

- **Solubility:** Ionic compounds often dissolve in water because H_2O molecules pull ions apart.
- **Applications:** Used in batteries (Li-ion), ceramics (MgO), and food preservation (NaCl).

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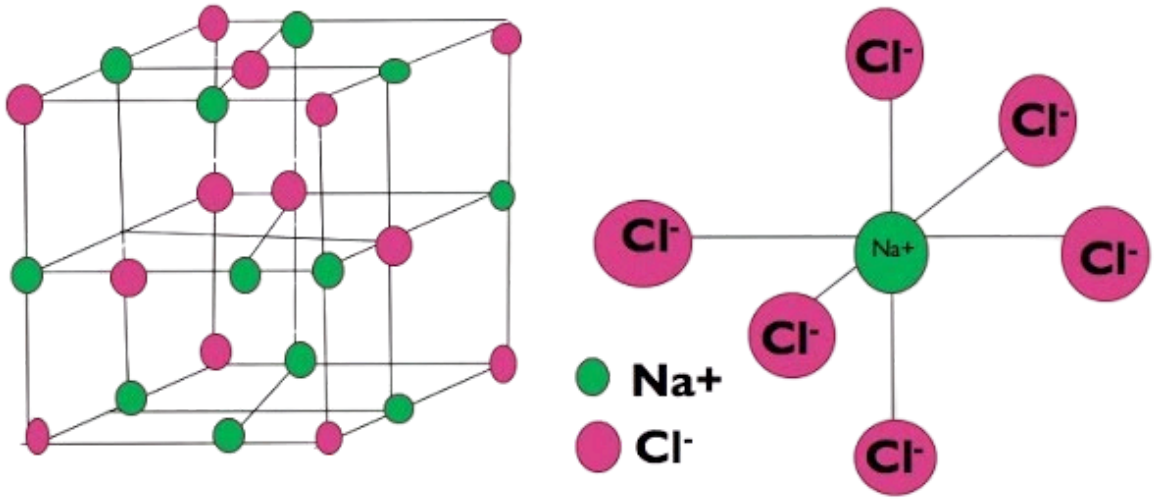
Example: Sodium Chloride (NaCl) Lattice

- Arrangement: Cubic (face-centered).
- Coordination Number: 6:6 (each ion touches 6 oppositely charged ions).
- Visualization: Imagine a 3D chessboard where Na^+ and Cl^- alternate in all directions.



Why Lattice Energy Matters

- **Definition:** Energy released when gaseous ions form a solid lattice.
- **Trends:** Smaller ions or higher charges → stronger lattice

- **Example:**

MgO has a higher melting point than NaCl because Mg^{2+} and O^{2-} attract more strongly than Na^+ and Cl^-).

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5. Naming of Ionic Compounds.

Ionic compounds are named systematically based on their cation (positive ion) and anion (negative ion). Here's how to name them correctly:

- **Binary Ionic (Metal + Non-Metal)**
  - Metal name + non-metal root + "-ide"
  - **Example:** NaCl → **Sodium chloride**

- **Transition Metals (Variable Charges)**
  - Metal name + (Roman numeral) + non-metal + "-ide"
  - **Example:** $FeCl_3$ → **Iron(III) chloride**

- **Polyatomic Ions**
  - Metal name + polyatomic ion name
  - **Example:** $NaNO_3$ → **Sodium nitrate**

- **Hydrated Compounds**
  - Ionic name + "hydrate" + prefix (e.g., penta-)
  - **Example:** $CuSO_4 \cdot 5H_2O$ → **Copper(II) sulfate pentahydrate**

Key Rule: Cation first, anion second.

- Use Roman numerals for transition metals (except Ag^+, Zn^{2+}, Cd^{2+}).
- Memorize common polyatomic ions (e.g., SO_4^{2-} = sulfate).

Quick Examples:

- MgO → Magnesium oxide
- Fe_2O_3 → Iron(III) oxide
- NH_4Cl → Ammonium chloride
- $CaCO_3$ → Calcium carbonate

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Difference between Ionic And Covalent Bonding.

IONIC BONDING	COVALENT BONDING
Ionic bonding occurs primarily between **metals** and **non-metals** due to their contrasting electronegativities.	Covalent bonding occurs when **two non-metals share electrons** to achieve stability.
Ionic bonds generally have **high** melting and boiling points.	Covalent bonds generally have **low** melting and boiling points.
Soluble in **Polar solvents** such as **water**.	Soluble in **Non-Polar solvents** such as **benzene.**
It **conducts** electricity when **dissolved/melted.**	These are **poor conductors** of heat and electricity (except polar solvents such as HCL).
These are usually **solid** or in **crystalline** form.	It can be **liquid**, **solid**, or **gas.**
Examples: NaCl and MgO	**Examples:** H_2O and CH_4

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7. FAQs (Frequently Asked Questions)

1. What is an ionic compound?

An ionic compound is a chemical compound composed of positively charged ions (cations) and negatively charged ions (anions) held together by electrostatic forces (ionic bonds).
Example: Table salt (NaCl) = Na^+ (cation) + Cl^- (anion).

2. What if two reactants are given? How do I know which one limits the product?

Water molecules are polar (have partial charges) and pull ions away from the lattice, dissolving them.
Example: NaCl in water → $Na^+(aq)$ + $Cl^-(aq)$.

3. Why don't ionic compounds conduct electricity as solids?

In solids, ions are locked in place in the lattice. When melted/dissolved, ions become mobile and conduct electricity.

4. Are all ionic compounds salts?

Most are (e.g., NaCl, $CaCO_3$), but some are oxides, hydroxides, or other ionic solids (e.g., MgO, NaOH).

5. Why does salt (NaCl) make ice melt but sugar doesn't?

Salt dissociates into Na^+ and Cl^- ions, which disrupt water's hydrogen bonding, lowering its freezing point. Sugar (covalent) dissolves but doesn't split into charged particles, so it's less effective.

6. Why doesn't gold (Au) form ionic bonds easily?

Its electrons are too "sticky" (high nuclear charge)—it prefers metallic or covalent bonding.