Ionic, Covalent and Metalic Bonding

Atoms, Elements and Compounds

Elements, Compounds and Mixtures

- **Elements**: A substance made of atoms that share the **SAME number of protons** and cannot be broken down into simpler substances by chemical methods.

    - There are 118 elements in the periodic table, such as sodium.
- **Compounds**: Two or more elements **chemically bonded together (in a fixed proportion).**

e.g. Carbon Dioxide, Sodium Chloride

- **Mixtures**: Two or more elements **not chemically bonded together.**
    - e.g., Sand and Water, Oil and Water

Atomic Structure

All substances are made of tiny particles called **atoms,** the building blocks of all matter.

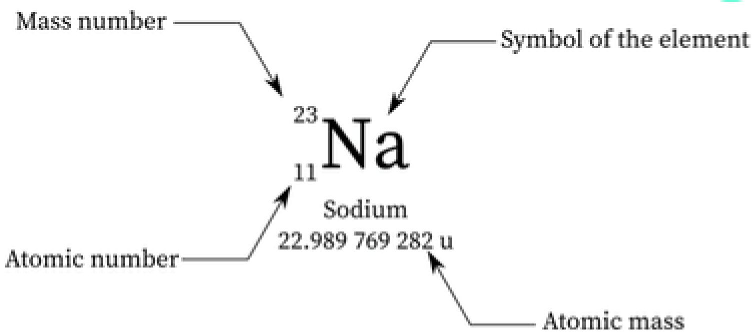
- The structure of the atom as a **central nucleus** containing neutrons and protons surrounded by electrons in shells
- The characteristics of neutrons, protons and electrons are as follows:

Subatomic particle	Relative Mass	Relative Charge
Proton	1	+1
Neutron	1	0
Electron	1/1840	-1

- Since electrons and protons have opposing and equal charges, **the atom's overall charge is neutral.**
- Neutrons have the purpose of holding the nucleus together. The larger the nucleus gets, the more neutrons are required to hold the nucleus together.

Proton and Nucleon Number

- The **Proton Number (Atomic Number)** is **the number of protons in the nucleus of an atom**.
- It is unique to each element. It is denoted by the letter “Z”. For a neutral atom, the number of protons and electrons are equal; therefore, the proton number (Z) also corresponds to the number of electrons.
- The **Nucleon Number (Mass Number)** is **the total number of protons and neutrons** in the nucleus of an atom.
- **Mass number = number of protons + number of neutrons**
  Number of protons = mass number – number of neutrons
  Number of neutrons = mass number – number of protons
- The following format (AZX Notation) is shown below:



Electronic Configurations of Elements & Ions

Atoms have electrons that orbit around a central nucleus, and these orbits are referred to as electron shells.

- The energy levels of the shells increase as their distance from the nucleus increases.
- The first shell has a max capacity of **2 electrons**, while the subsequent shell can hold up to **8**.

For this syllabus, we only need to know the **general complete electronic configuration as (2.8.8)**

- Group VIII noble gases have **an entire outer shell**
- the **number of outer shell electrons** is equal to the **group number in Groups I to VII.**
- the number of occupied electron shells is **equal to the period number**

Isotopes

Isotopes: different atoms of the same element with the same number of protons but different numbers of neutrons.

- The isotopes of an element have the **same chemical properties** because **they contain the same number of outer shell electrons** and, therefore, have the **same electronic configuration**.
- The difference in mass affects the physical properties, such as density, boiling point and melting point

Relative Atomic Masses

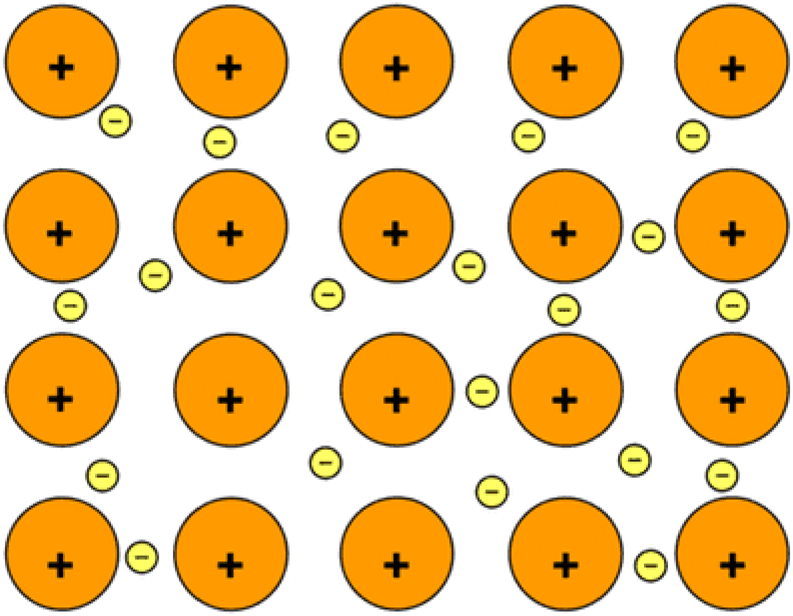
- Most elements exist naturally as a mixture of their isotopes. Using the data on the abundance of these naturally occurring isotopes, we can calculate the mass relative atomic mass of the element.
- The Formula: $A_r = \frac{(\text{ \% of isotope 1 x mass number of isotope 1}) + (\text{ \% of isotope 2 x mass number of isotope 2})}{100}$
- An example for calculating the relative mass and abundance:

Q. Iridium has two isotopes. These isotopes are Iridium - 191 and Iridium - 193. A natural sample consists of of 37.3% of Iridium - 191. Calculate the relative atomic mass (A_r) of the natural sample of Iridium

A. $\rightarrow$
Step 1. Identify the percentage of Iridium - 193
$\rightarrow$ if the sample consists of 37.3% of Iridium - 191, it must consist of 100% - 37.3% of Iridium - 191
$\rightarrow$ 100 - 37.3 = 62.7%
$\rightarrow$ the sample consists of 62.7% of Iridium - 193
Step 2. Consider a sample of 100 atoms of Iridium. In that sample, 37.3 of atoms should have a mass of 191 and 62.7 atoms should have the mass of 193
THEN
average mass $= \frac{(37.3 \times 191) + (62.7 \times 193)}{100} = 192.2$ (4 significant figures)
Answer: 192.4

Metallic Bonding

Metallic Bonding: the electrostatic attraction between the positive ions in a giant metallic lattice and a “sea” of delocalised electrons.

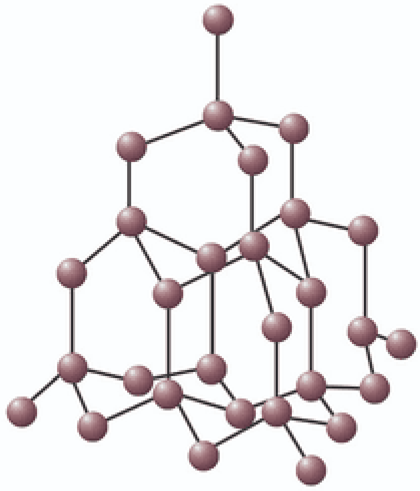


Properties of Metallic Bonding

1. Metallic Bonds have good electrical conductivity: **Delocalised electrons can move through the structures and carry current.**
2. High Melting and Boiling Point: **More energy to overcome strong forces of attraction between positive metal ions and the sea of delocalised electrons and vibrate/transfer heat**
3. Malleability: Can be **hammered into shapes** as **layers can slide over each other.**
4. Ductility: Can be **drawn into thin wires**

Giant Covalent Structures

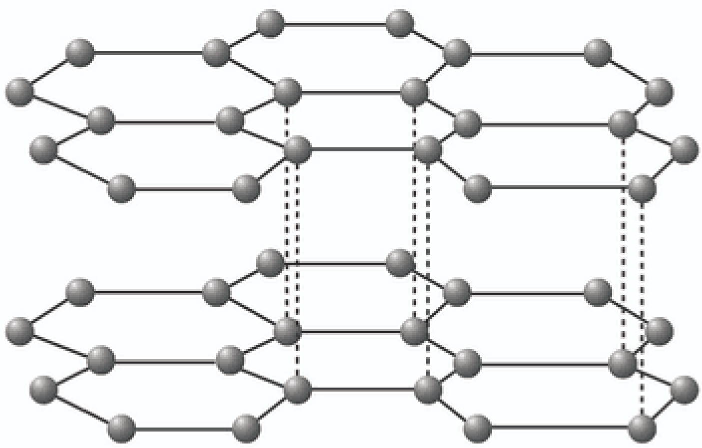
Giant Covalent (Macromolecular) Structures: solids with very high melting points, where all the atoms are made of pure carbon.



Diamond

Properties

1. Each carbon atom is joined with **four other carbon atoms**
2. **High Melting and Boiling Points** - Strong Covalent Bonds
3. **No Delocalised/Free Moving Electrons**
4. It cannot be scratched easily
5. Transparent colour (Extra information)
6. Cannot conduct electricity **due to no free-moving electrons**
7. **Hard** in structure
8. **Giant Lattice Arrangement**
9. Uses are for **cutting tools**

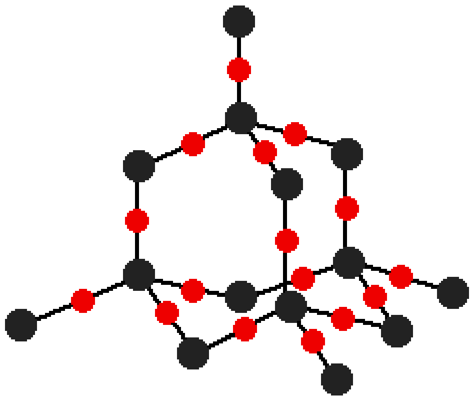


Graphite

Properties

1. Each carbon atom is joined with **three other carbon atoms**

2. **High Melting and Boiling Points** - Strong covalent bonds within the layers (but the layers are attracted to each other by weak intermolecular forces)
3. Contains **Delocalised/Free Moving Electrons**
4. It can be scratched easily
5. Opaque/Black
6. Can conduct electricity **due to free-moving electrons**
7. Soft - **Layers can slide easily**
8. **Layers of hexagonal rings held by weak intermolecular forces**
9. Uses are for **lubricant and electrode** in Electrolysis



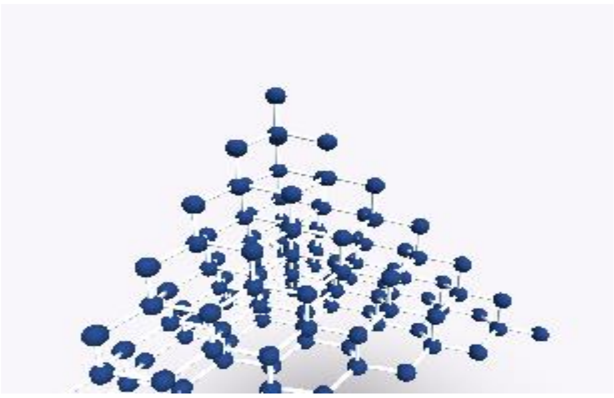
Silicon (IV) Oxide

Properties

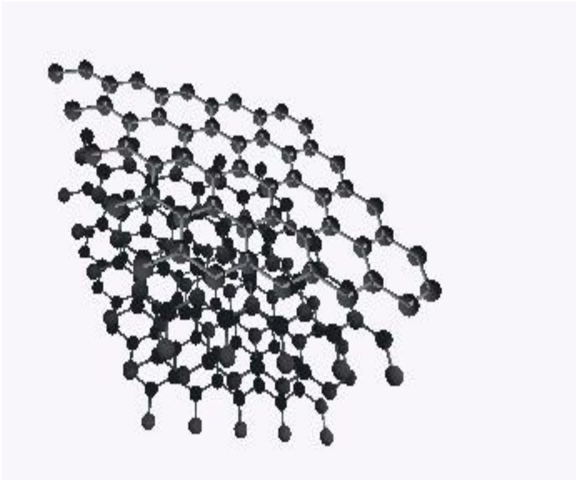
1. The structure of Silicon (IV) Oxide is **similar/resemblance to that of a diamond.**
2. **Hard Structure**
3. **High melting and boiling point** - More energy to overcome
4. **Rigid Tetrahedral Structure**
5. Does **not conduct electricity**

- **Each Silicon atom** is covalently bonded with **4 Oxygen Atoms**
- **Each Oxygen atom** is covalently bonded with **2 Silicon Atoms**

Interactive 3D diagram: Diamond Structure



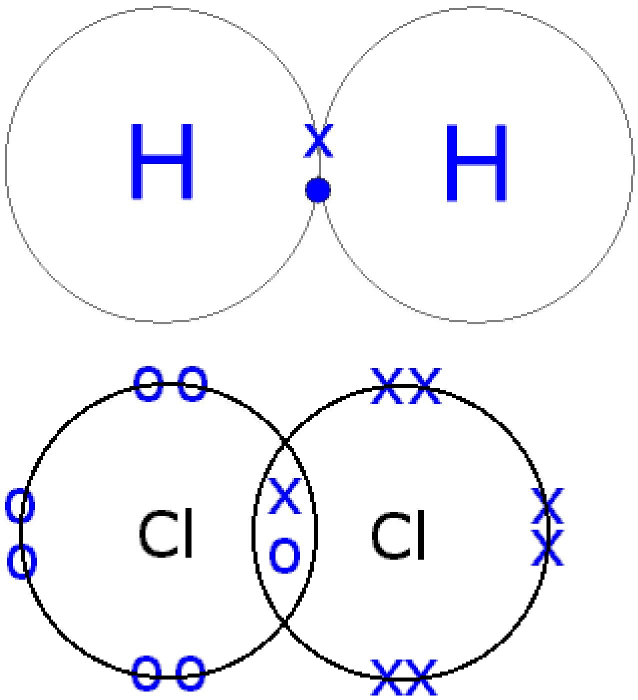
Interactive 3D diagram: Graphite Structure

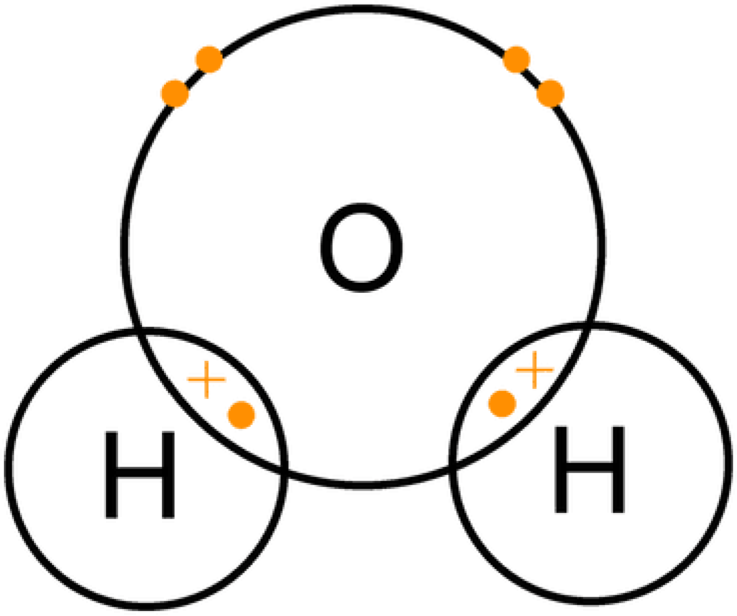


Simple Molecules and Covalent Bonds

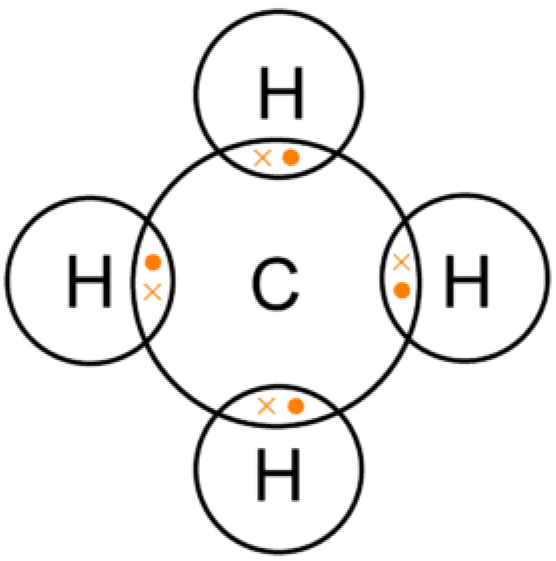
Covalent Bond: Pairs of electrons shared between two atoms leading to noble gas electronic configuration (2.8.8)

Covalent Bonds Dot and Cross Diagram

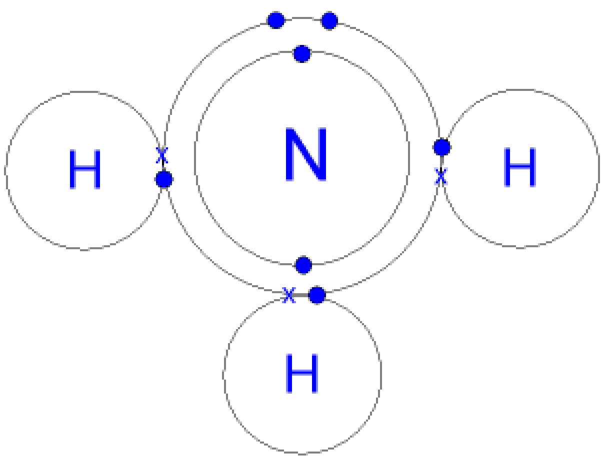




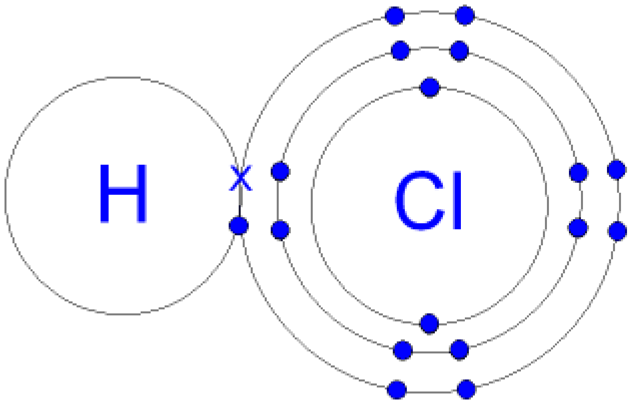
O
H
H



H
H
C
H
H



H
N
H
H



Different Types of Covalent Bonds

1. Single Bonds - e.g., Chlorine
2. Double Bonds - e.g., Carbon Dioxide
3. Triple Bonds - e.g., Nitrogen

Properties of Covalent Compound

1. The intermolecular forces in covalent compounds are **weak** but have **strong covalent bonds**.
2. Covalent Compounds have low melting and boiling point. They require less energy to break the weak intermolecular forces (same as attractive forces).
3. Poor Electrical Conductivity - **No free electrons or ions present** to carry an electrical current

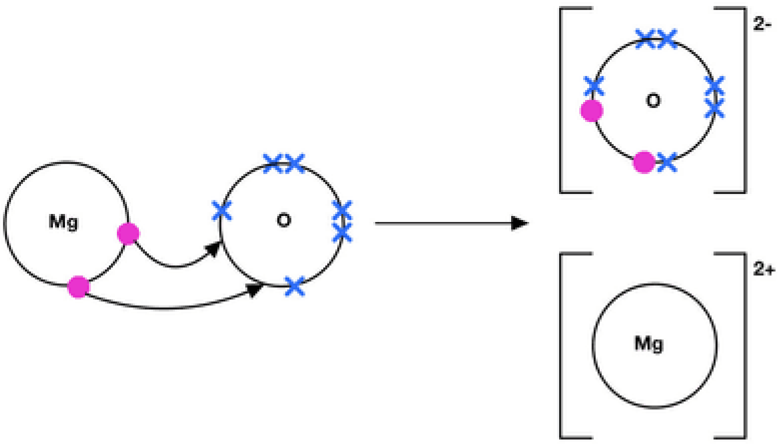
Ions and Ionic Bonds

Cations: Positive Ions

Anions: Negative Ions

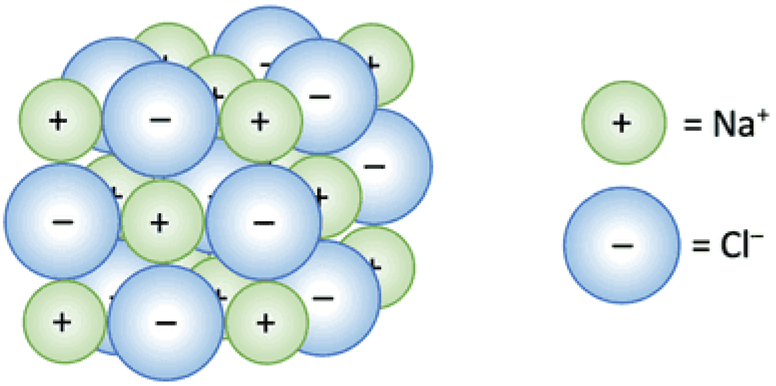
Ionic Bonds: strong electrostatic attraction between oppositely charged ions (metals + non-metals)

Ionic Compounds Dot and Cross Diagram



Typical ionic compounds are usually **giant lattice structures** with a **regular arrangement of alternating positive and negative ions.**

- Using an X and a dot in your drawings will help differentiate the two ions.



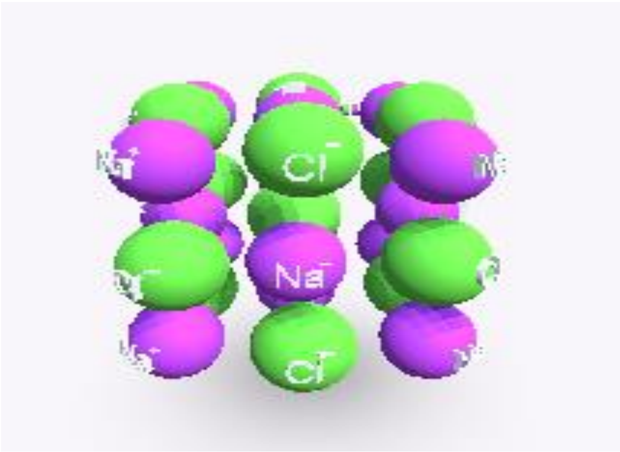
Properties of Ionic Compound

1. High Boiling and Melting Point: A lot of energy is needed to overcome the strong electrostatic forces between oppositely charged ions
2. Good Electrical Conductivity when **molten or aqueous**:
    - As the charges flow, ions can move freely in an aqueous/molten state.
    - Ions are not free to move when in a solid state, as the **charges cannot flow.**

Other Properties of Ionic Compound

1. Brittle
2. Low Volatility

Interactive 3D diagram: NaCl Lattice Structure


Cl⁻
Na⁻
Cl⁻