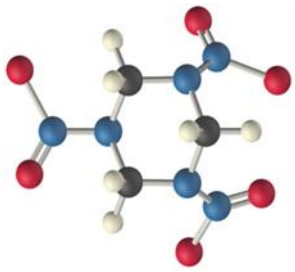
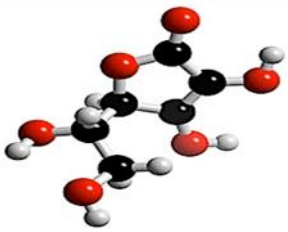
LECTURE 9

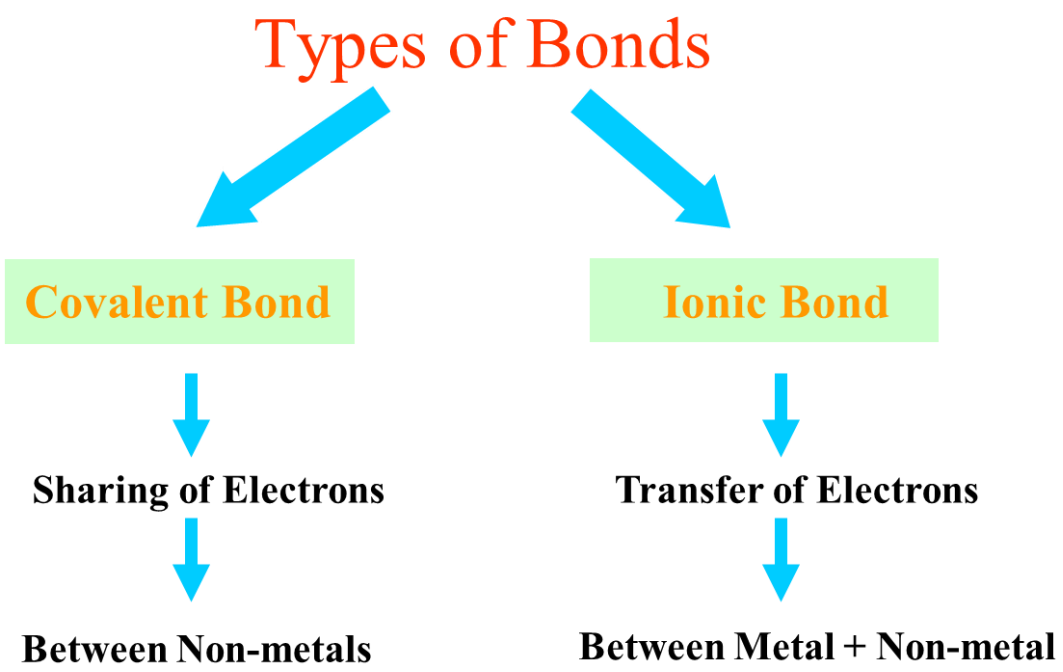
Chemical Bonding

- Explain The Formation of Ionic Bonds.
- Define and Give Examples of Ionic Solids.
- Explain The Formation of Covalent Bonds.
- Define And Give Examples Of Simple Molecular Solids.
- Explain Metallic Bonding.
- Relate the structure of sodium chloride to its properties.
- Distinguish between ionic and simple molecular solids.

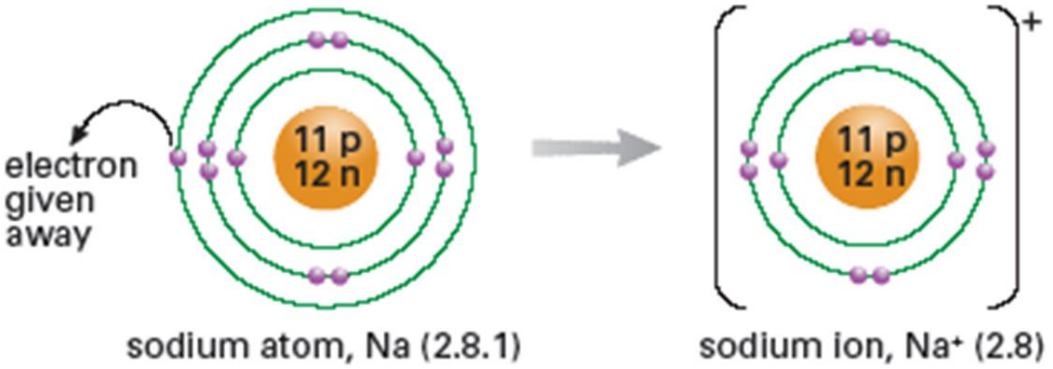
The Electronic Structure of Noble Gases

- The noble gases like helium, neon and argon, which are in Group 0 of the Periodic Table, are very unreactive.
- They do not form bonds with other atoms.
- They have fully filled outermost (valence) shells.
- Except for helium, which has 2 outer electrons, <u>all the other noble gases have 8 outer electrons.</u>
- The outer shell of 8 electrons is called an **octet structure** and it makes the atom very stable. E.g. Helium, neon, argon
- Atoms of other elements become stable like the noble gases by losing or gaining electrons or by sharing electrons.
- They achieve this by forming bonds with other atoms.

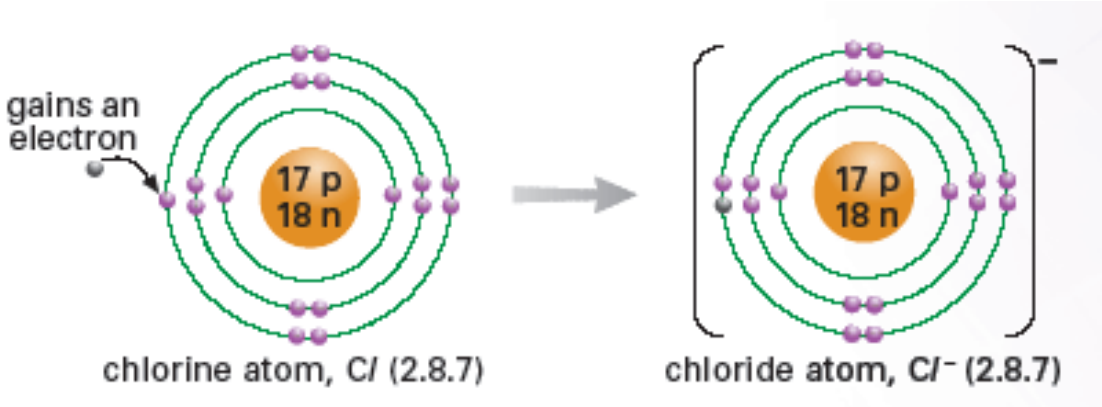


Ionic Bonds

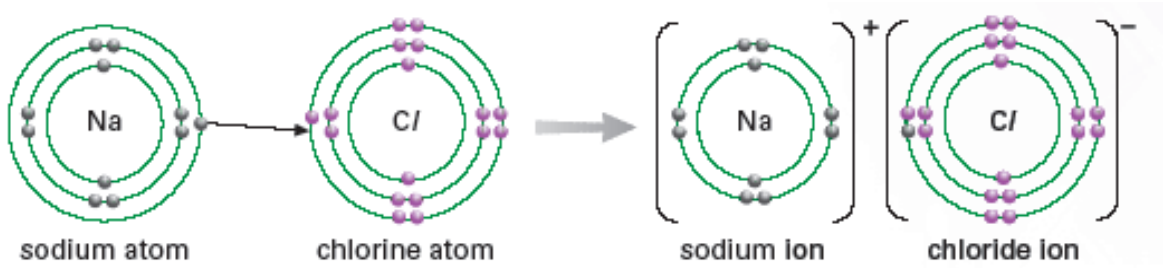
- When sodium reacts with chlorine, the sodium atom **loses** an electron to become **a positively charged** sodium ion:



- The chlorine atom **gains** an electron to become **a negatively charged** chloride ion:



- The positive sodium ion and the negative chloride ion then attract each other to form sodium chloride.

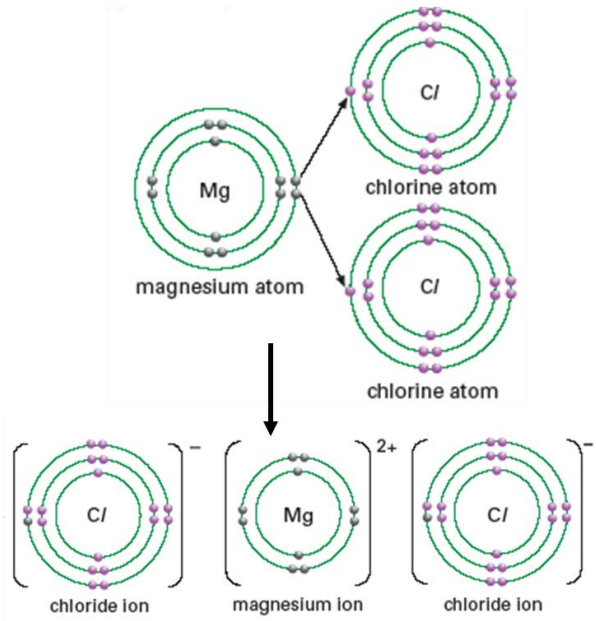


- Sodium chloride is called an ionic compound.

Other ionic compounds

- Another example of an ionic compound is that formed between magnesium and chlorine.

- Each magnesium atom transfers 2 electrons, one to each chlorine atom, to form magnesium chloride.



The formula of magnesium chloride is therefore given as $MgCl_2$.

Exercise One

1. Ionic bonds are formed between a metal and a non-metal.

2.A metal atom loses an electron to form a positive ion while a non-metal gains an electron to become a negative ion.

3. The two oppositely charged ions attract each other to form an ionic compound.

4. An ionic bond is formed by the transfer of electrons.

5. (a) Is aluminium oxide an ionic or covalent compound?

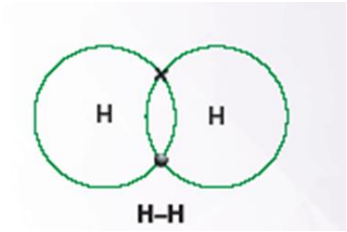
- Aluminium oxide is an ionic compound.

(b) State the formula of aluminium oxide.

- Al2O3

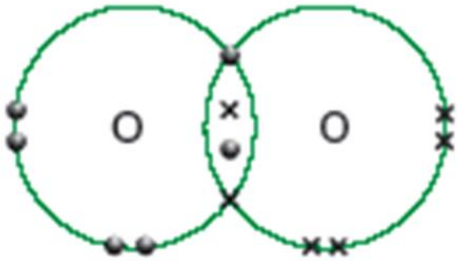
Covalent Bonds

- A hydrogen atom has only one electron in its first shell.
- To achieve a more stable structure like helium, it needs one more electron in the first shell.
- So two hydrogen atoms join together and share their electrons. A hydrogen molecule is formed.



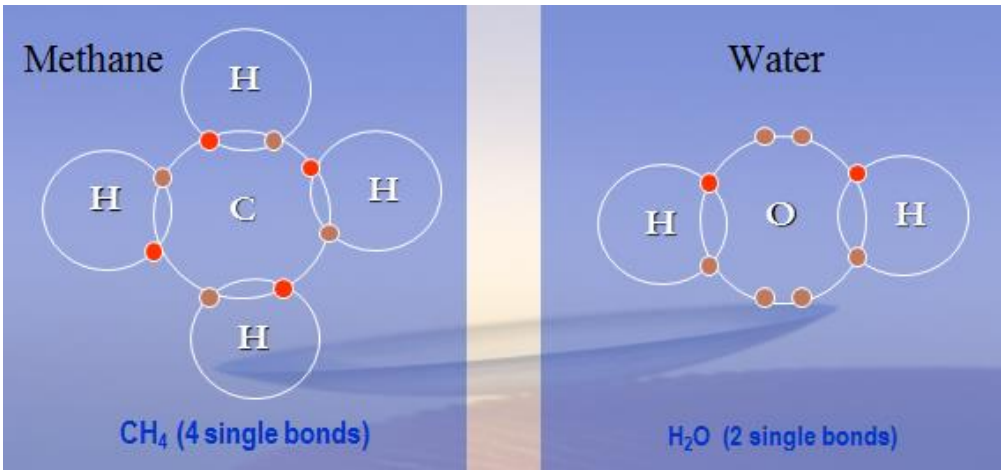
- This sharing of electrons is called <u>covalent bonding</u>.
- In an oxygen atom, the outer shell has 6 electrons, so to achieve an octet structure of 8 electrons like neon, two oxygen atoms combine to share **4 electrons**.

This is called a ***double bond.***



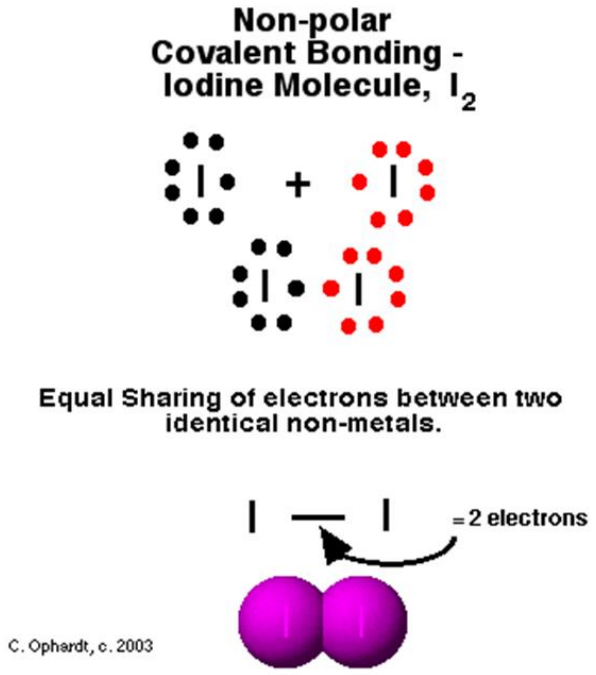
O=O

Other covalent molecules



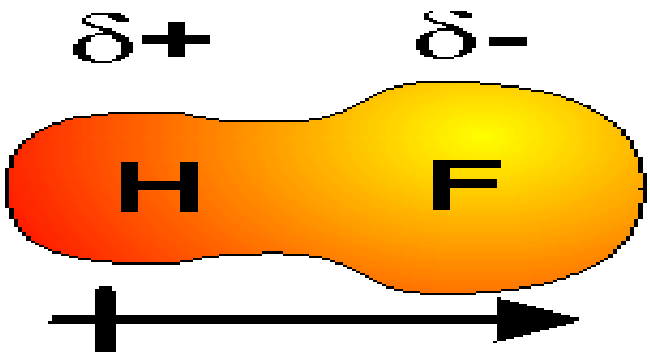
Types of Covalent Bonds

Nonpolar covalent bond – electrons are shared equally



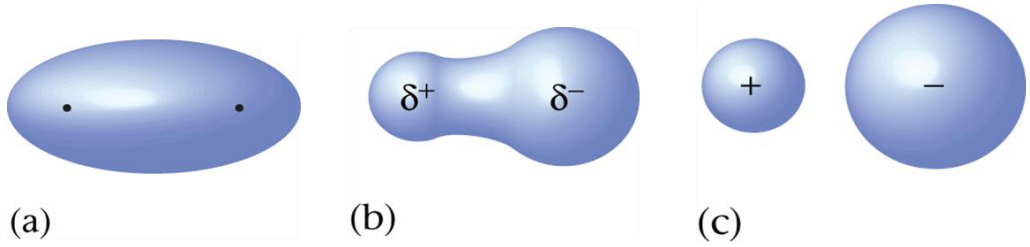
Types of Chemical Bonds

Polar covalent – electrons are not shared equally because one atom attracts the shared electrons more than the other atom.



Classifying Chemical Bonds

- The polarity of a bond depends on the difference between the electronegativity values of the atoms forming the bonds.
- Nonpolar covalent – 0 to 0.3
- Polar covalent – 0.4 to 1.7
- Ionic – greater than 1.8



Practice

❖ Use electronegativity values to classify the following bonds:

a. Sulfur and Hydrogen 2.5 – 2.1 = 0.4; polar covalent

b. Lithium and Fluorine 4.0 – 1.0 = 3.0; Ionic

c. Potassium and Chlorine 3.0 – 0.8 = 2.2; Ionic

d. Iodine and Bromine 2.8 – 2.5 = 0.3; Nonpolar covalent

e. Carbon and Hydrogen 2.5 – 2.1 = 0.4 ; polar covalent

Chemical Bonding

Exercise two

1.The joining of atoms to form a molecule is called chemical bonding.

2. The two types of bonds are covalent bond and ionic bond.

3. Covalent bonds are formed by the sharing of electrons.

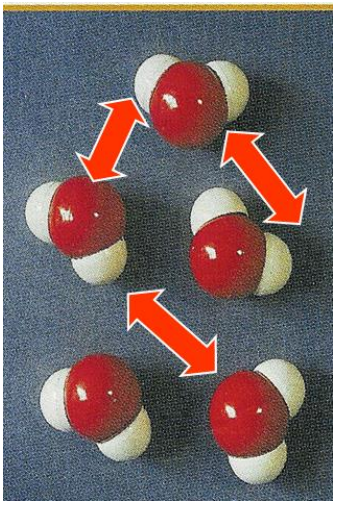
4. Ionic bonds are formed by the transfer of electrons.

5. Covalent bonds are formed between non-metals e.g. hydrogen, oxygen and carbon.

Properties of Covalent Compounds

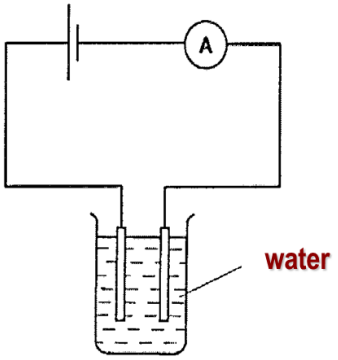
The **intermolecular forces between the molecules are weak** so covalent compounds have **low melting and boiling points**. For example, water, a covalent compound, has a melting point of 0 oC and a boiling point of 100 oC.

Weak intermolecular forces



Properties of Covalent Compounds

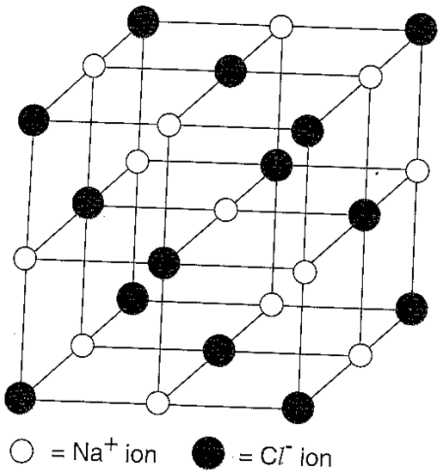
- Covalent compounds do not conduct electricity in any state.
- Most covalent compounds **are insoluble in water**. Instead they are soluble in **organic solvents**.
  For e.g. iodine is insoluble in water, but soluble in ethanol.



Pure water does not conduct electricity

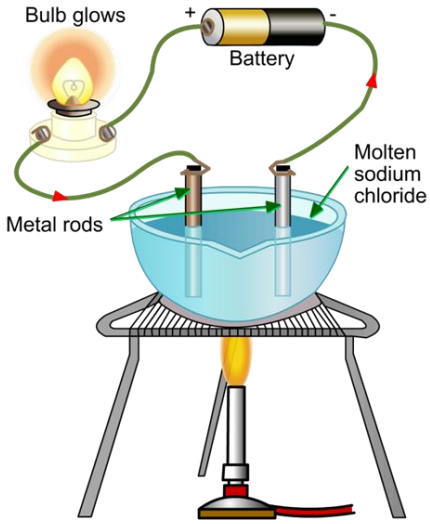
Properties of Ionic Compounds

The electrostatic forces between the oppositely-charged ions are very strong so ionic compounds have very high melting points and boiling points. For e.g. sodium chloride, an ionic compound, has a melting point of 801 oC and a boiling point of 1 517oC.



Properties of Ionic Compounds

- Ionic compounds **conduct electricity** when **molten or dissolved in water**. This is because the ions can move about and conduct electricity.
- Most ionic compounds are **soluble in water**, but insoluble in organic solvents. For e.g. sodium chloride is soluble in water, but insoluble in oil or petrol.



Molten sodium chloride conducts electricity.

Differences between Ionic and Covalent Compounds

Ionic Compounds	Covalent Compounds
Have very high melting and boiling points	Have low melting and boiling points
Conduct electricity when molten or in aqueous solution	Cannot conduct electricity in any state
Are usually soluble in water, but insoluble in organic solvents	Are usually insoluble in water, but soluble in organic solvents

Exercise Three

1. Covalent compounds have weak forces of attraction between the molecules, so they have low melting points and low boiling points.

2.Ionic compounds have very strong forces of attraction between the oppositely charged ions, so they have very high melting points and high boiling points.

3. All covalent compounds cannot conduct electricity.

4. All ionic compounds can conduct electricity when they are molten or dissolved in water.

5. Sugar is a covalent compound but it is soluble in water. State one test you would use to show that sugar is a covalent compound.

- Dissolve some sugar in water, then try to pass electricity through it. The sugar solution will not able to conduct electricity.

6. The table below shows 3 substances.

Substance	Electrical Conductivity	
	when solid	when molten
A	does not conduct	does not conduct
B	does not conduct	conducts
C	conducts	conducts

(a)Which substance is an ionic compound?

- Ionic compound: B

(b)Which substance is a metal?

- Metal: C

(c) Which substance could be a covalent compound?

- Covalent compound: A

Macromolecular Structures

Simple molecules

- Many covalent substances like water, methane, carbon dioxide and iodine exist as small molecules.
- These compounds are said to have simple molecular structures.

Macromolecules

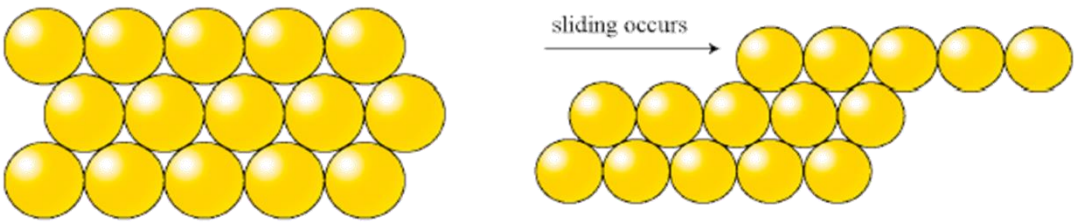
- Some covalent substances like silicon dioxide (SiO2), diamond and graphite are made up of very large molecules.
- These substances are said to have macromolecular structures.

Properties of Macromolecules

- Due to the large structures of these macromolecules, their chemical and physical properties are different from those of the simple molecules.
- The macromolecules are solids with very high melting and boiling points. E.g. The melting point of diamond is 3550 oC, compared to 0 oC for water.
- Due to their sizes, they are also not as reactive compared to the simple molecules.

Metallic bonding

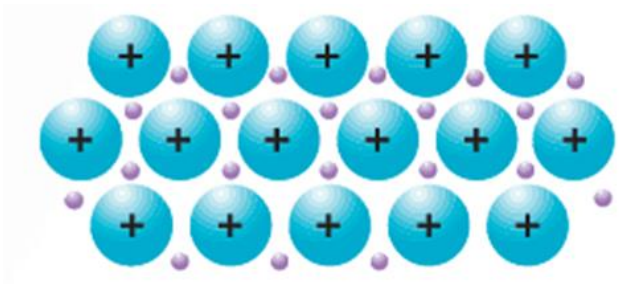
- Metals are also made up of very large lattice structures.
- The metallic structure consists of a lattice of positive ions in a “sea of electrons”.
- Metals are malleable because the layers of atoms can slide over one another easily as they are being arranged in neat layers.



Macromolecular Structures

Properties of Metallic structure

- The closely packed positively charged metallic ions form a lattice structure with the outer electrons moving freely around the whole metallic structure.
- The electrostatic attraction between the metallic ions and the electrons holds the metallic ions tightly in the lattice and this gives the metal a high melting point.
- The free electrons are able to move and conduct electricity and heat.
- This explains why metals are good conductors of heat and electricity.



Metallic bonding occurs as a result of electromagnetism and describes the electrostatic attractive force that occurs between conduction electrons (in the form of an electron cloud of delocalized electrons) and positively charged metal ions. It may be described as the sharing of free electrons among a lattice of positively charged ions (**cations**). In a more quantum-mechanical view, the conduction electrons divide their density equally over all atoms that function as neutral (non-charged) entities. Metallic bonding accounts for many physical properties of metals, such as strength, ductility, thermal and electrical resistivity and conductivity.

Metallic bond

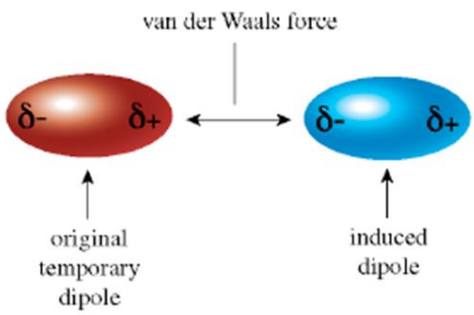
Because the electrons move freely, the metal has some electrical conductivity. It allows the energy to pass quickly through the electrons, generating a current. Metals conduct heat for the same reason: the free electrons can transfer the energy at a faster rate than other substances with electrons that are fixed into position. There also are few non-metals which conduct electricity: graphite (because, like metals, it has free electrons), and ionic compounds that are molten or dissolved in water, which have free moving ions.

Metallic bonding is not the only type of chemical bonding a metal can exhibit, even as a pure substance. For example, elemental gallium consists of covalently-bound pairs of atoms in both liquid and solid state—these pairs form a crystal lattice with metallic bonding between them. Another example of a metal–metal covalent bond is mercurous ion (Hg2+).

Macromolecular Structures

Van der Waals Forces

- Van der Waals forces of attraction can exist between atoms and molecules.
- They are not the same as ionic or covalent bonds. They arise because of fluctuating polarities of nearby particles.
- The shape and size of molecules affect the strength of the van der Waals forces. The larger the force, the higher the melting and boiling point.



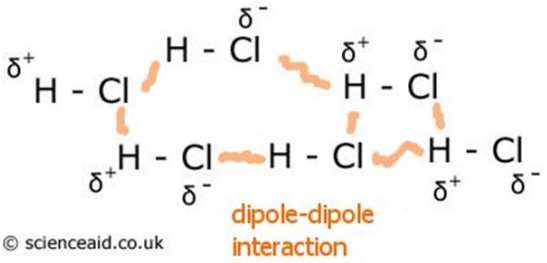
Dipole-Dipole Attraction

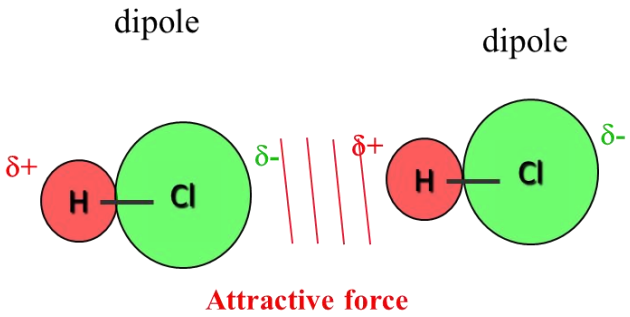
Attractive forces that exist between molecules that have permanent dipoles.

- ✓ These exist in any **polar substance**.

Weaker than Ion-Dipole force

Increased polarity, **stronger dipole-dipole** attraction.





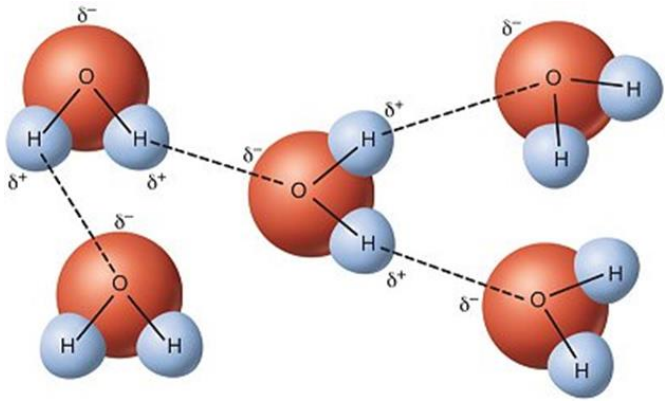
Van der Waals forces

- ➢ Hydrogen bonding, the strongest of the Van der Waals forces, is an especially strong type of dipole-dipole force.

- ➢ Hydrogen bonding arises only between molecules that have hydrogen atoms directly bonded to a very electronegative atom, specifically either fluorine, oxygen or nitrogen, which enhances partial charge development.

Hydrogen bonding

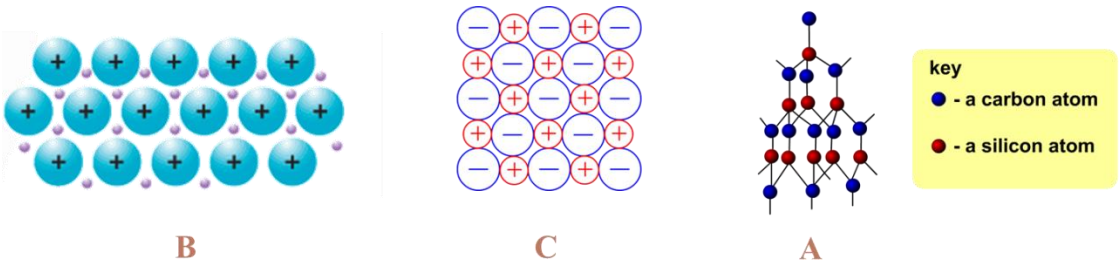
- Water is a great example of a molecule that experiences hydrogen bonding, which gives rise to the many unique properties of this universal solvent!



Macromolecular Structures

Exercise Four

The pictures below show 3 types of molecular structures.



Identify the substance or the type of bonds shown by each structure.

Solution to exercise four

A: silicon dioxide; macromolecular.

B: metallic bonding.

C: ionic crystal lattice.