MERRYLAND HIGH SCHOOL ENTEBBE
S.2 CHEMISTRY NOTES
BONDING AND STRUCTURE NOTES

BONDING

Bonding is the chemical combination of atoms or elements to form compounds. The force of attraction holding atoms or elements together in a molecule/crystal is referred to as a chemical bond. Chemical bonding /combination occurs mainly in four forms as:

1. Ionic/electrovalent bonding-this involves transfer of electrons from a metal atom to a non metal atom. It occurs between metals and non metals.

2. Covalent bonding-this involves sharing of electrons between two or more non metal atoms/elements. The atoms/elements involved contribute to the bonding electrons.
3. Dative/co-ordinate bonding-this involves sharing of the bonding electrons which are donated by one molecule or atom involved.
4. Metallic bonding-this occurs between atoms of metal elements.

Electrovalent/ ionic bonding

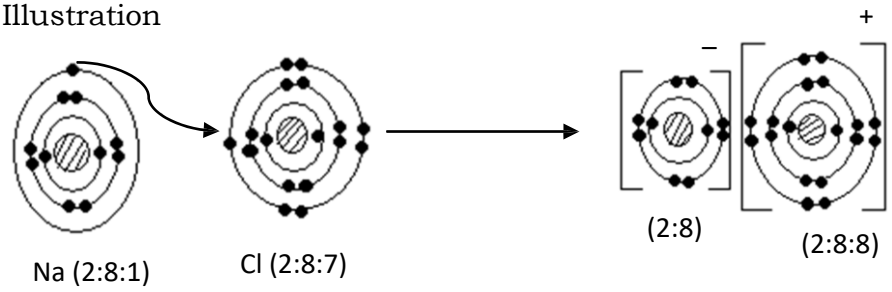
This involves transfer of electrons from a metal to a non metal. The number of electrons lost by the metal atom or gained by non metal atom is equivalent to its valency. The loss of electrons from a metal atom leads to formation of a positively charged ion (cation) and the gain of electrons by a non metal atom leads to the formation of a negatively charged ion (anion). The positively charged ion and the negatively charged ion are attracted to each other and the force of attraction holding them together is known as electrovalent/ionic bond. The compounds formed are referred to as ionic/ electrovalent compounds. Metal atoms lose electrons so as to gain stable electronic configuration of noble gases and non metal atoms also gain electrons to become stable.

Formation of some ionic compounds

Sodium chloride

When sodium burns in chlorine to form sodium chloride, the sodium atom loses an electron and forms a positively charged sodium ion(Na^+) while the chlorine atom gains the electron and forms a negatively charged chloride ion ( ).

Illustration

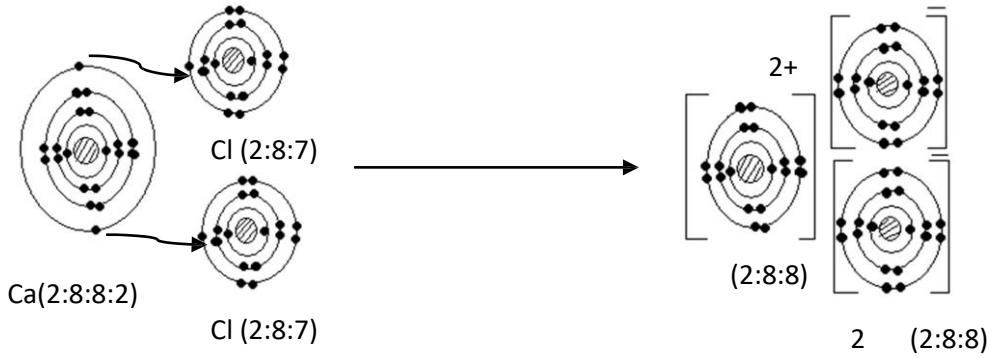


The positively charged sodium ion and negatively charged chlorine ion are attracted to each other by a strong force called ionic bond.

Calcium chloride

During the formation of calcium chloride, calcium atom loses two electrons which are gained by two chlorine atoms. This leads to the formation of and two which are then attracted to each other.

Illustration



Covalent bonding

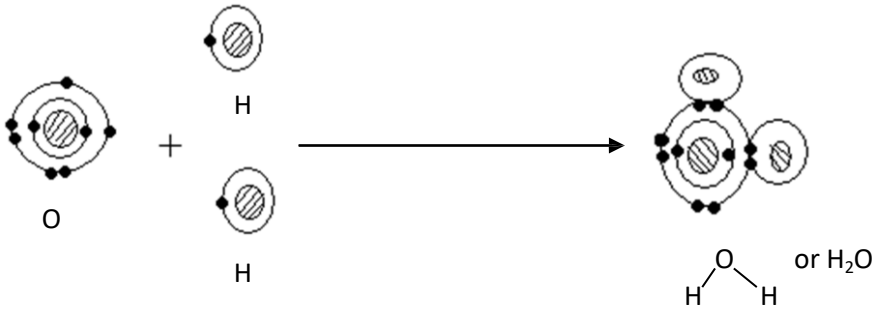
This type of bonding occurs between non metal elements/ atoms to form compounds. Covalent bonding involves mutual sharing of electrons between elements in which each of the atoms involved gives equal number of electrons to be shared. On sharing the electrons, the atoms attain stable electronic structure of noble gases. The compound formed are called covalent compounds. Covalent bonds may by classified as single, double, triple or quadruple depending on the number of electrons shared.

a) Single covalent bond: this is formed when one pair of electron is shared. Each of the atoms involved contribute an electron for the bond formation.

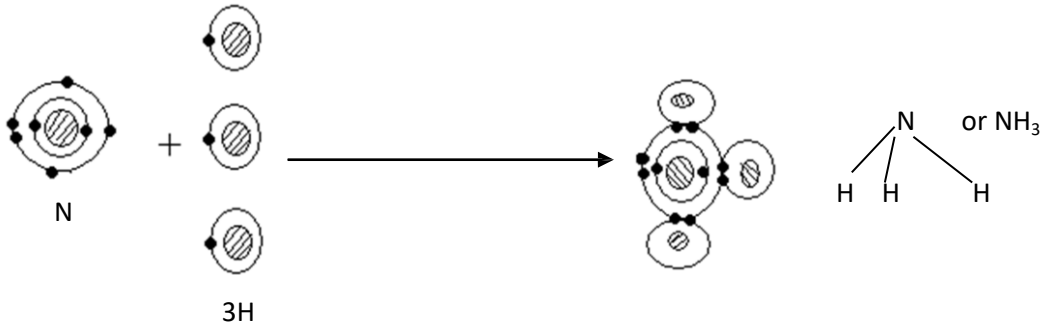
Example

i) Hydrogen molecule (H_2)

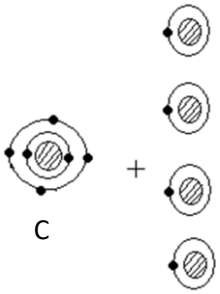
ii) Water molecule (H_2O)

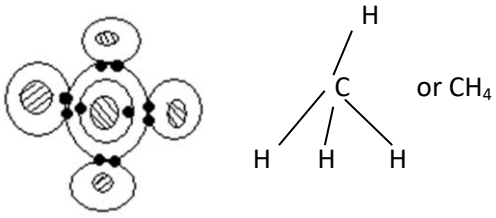


iii) Ammonia (NH_3)



iv) Methane (CH_4)





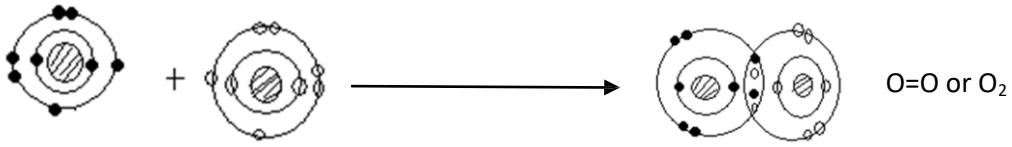
N.B. The pair of electron on the outer most energy level that does not take part in bonding is the lone pair or non bonded pair.

b) Double covalent bond

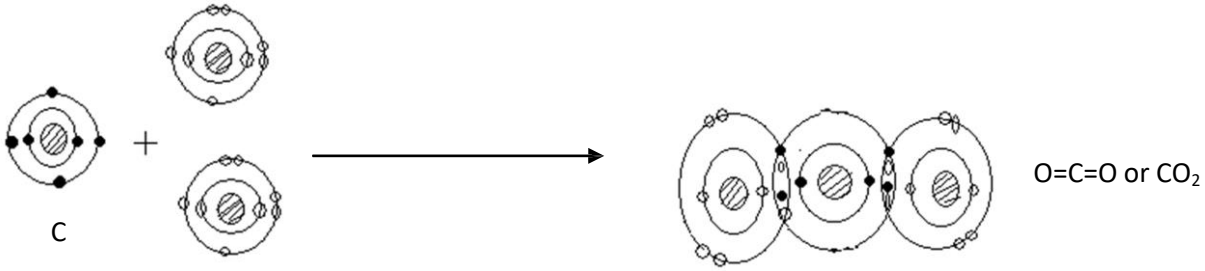
This is formed when two pairs of electrons are shared between two bonded atoms.

Example

i) Oxygen (O_2)



ii) Carbon dioxide (CO_2)

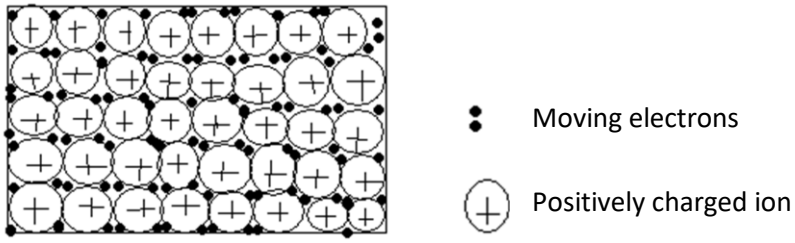


Metallic bonding

This is the type of bonding in metals due to the attraction between metal ions and the
valency electrons within the structure of the metal (metal lattice). In the structure of a metal, the loosely held valency electrons (electrons in the outer mos energy level) are released in to a general pool and the atoms become positively charged. These electrons move freely around the ions formed and are termed as mobile/delocalized electrons. The ions formed and the electrons attract each other forming metallic bond.

The strength of metallic bond increases with increase in the number of electrons released in to the electron cloud. Thus the bond is very strong in metals like iron and aluminum that release up to three electrons each to the electron pool and weak in metals like sodium and potassium that only release one electron each to

the electron pool.
Illustration



Exercise

1. Draw diagrams to show the arrangement of electrons in the following compounds
   a) KCl b) Na_2O c) $MgCl_2$ d) CS_2

2. Draw diagrams to show the arrangement of electrons in the energy levels of atoms in the following molecules. Use only the outer most electrons to illustrate.
   a) Ethane (C_2H_4) b) Ethyne (C_2H_2)

STRUCTURE OF COMPOUNDS/SUBSTANCES

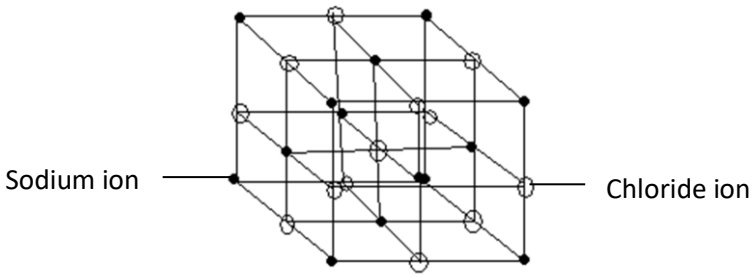
Different types of binds give rise to different types of structures. This is illustrated in the table below.

Bonding	Structure
Ionic/ electrovalent	Giant ionic structure
Covalent	Simple molecular structure Giant molecular structure
Metallic	Giant metallic

Giant ionic structure

This is a giant structure consisting of a regular arrangement of a large number of oppositely charged ions resulting into a three dimensional crystal. Each ion is surrounded by a number of oppositely charged ions and they are held together by strong electrostatic forces of attraction. The number of ions surrounding a given oppositely charged ion is known as the co-ordination number. The examples of structures include: sodium chloride and magnesium chloride.

Structure of sodium chloride



Each sodium ion is surrounded by six chloride ions and each chloride ion is also surrounded by six sodium ions. The co-ordination number is there fore 6:6.

Properties of ionic compounds

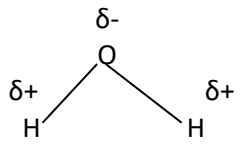
1. They are solids with a regular shape. This is because of the strong electrostatic forces of attraction keeping the ions closely packed.
2. They have high melting points. This is due to the strong electrostatic force af attraction between oppositely charged ions.
3. They do not conduct electricity in solid states but do conduct in their molten states or solution form. This is because in solid states, the ions are localized and the electrons are not mobile but in molten form, the ions and electrons are free to move (electrons become delocalized) and thus conduct electricity.
4. They have high density as the ions are closely packed.
5. Ionic compounds are soluble in water and other polar solvents but they a re insoluble in organic solvents like benzene. Ionic compounds dissolve in polar solvents like water as the ions are attracted by the polar molecule.

A polar compound is a covalent compound in which charge separation exist between atoms. This is due to the differences in electro negativity between the atoms.

Electro negativity is the tendency of an atom to attract bonding electron towards itself. Electro positivity is the tendency of an atom to push away bonding electrons from itself.

For example, in a water molecule oxygen is more electro negative and attracts the bonding electrons towards itself giving it a partial negative charge. Hydrogen attains a partial positive charge.

Structure of a water molecule



NB Most metals are malleable and ductile. This is because, since the bonding agent in a metal is a moving electron cloud, the ions of the metal; usually slide relative to one another under stress (without shattering the lattice and produce a new position of stability).

Simple molecular structures

The structure consists of simple independent molecules joined together by weak intermolecular forces of attraction. E.g. Vander Waal's force of attraction. The atoms in the molecule are held together by strong covalent bond. Compounds with this structure exist as gases, liquids or solids with low melting points. Examples include iodine, carbon dioxide , ammonia and water.

Structure of iodine

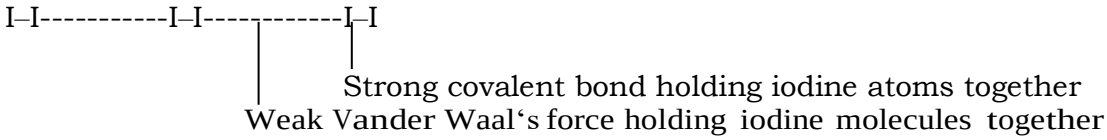
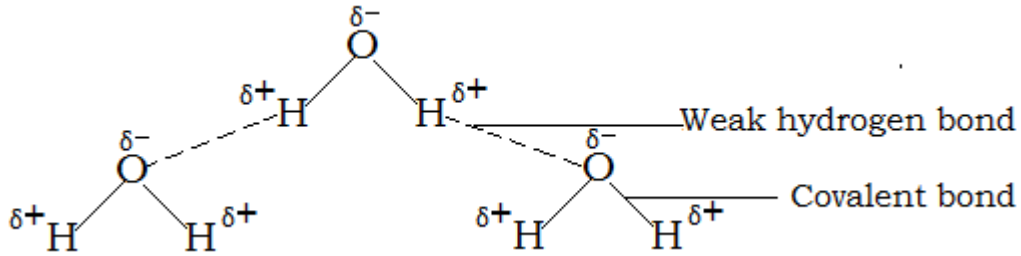


Illustration of weak hydrogen bond in water



Properties of simple molecular structures

1. They have low melting and boiling points because the molecules are held by weak intermolecular forces of attraction.
2. They are non conductors of electricity because they do not have mobile electrons/ ions.
3. Most of them are gases and liquids. Very few are solids.
4. They have low densities as the molecules are not closely packed.
5. They dissolve in organic solvents.

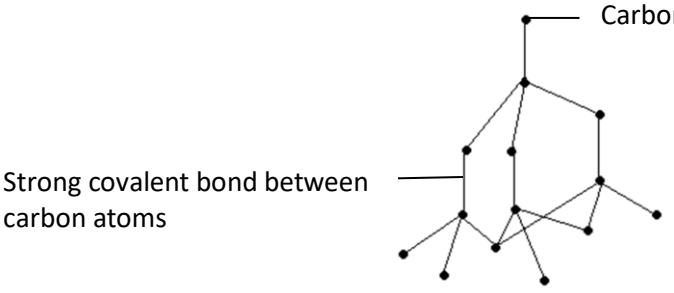
Giant atomic/molecular structure

Compounds with such structures consist of molecules /atoms linked together by strong covalent bonds resulting into a giant three dimensional or three dimensional structures like in graphite and diamond respectively

Diamond

In diamond, the structure consists of infinite number of carbon atoms. Each of the carbon atoms is joined to four other carbon atoms by covalent bonds resulting into a tetrahedral arrangement. This gives a diamond crystal a giant three dimensional structure. Diamond has no mobile electrons so cannot conduct electricity.

Structure of diamond



Physical properties of diamond

- Diamond is the hardest natural substance known. This is because the carbon atoms are closely parked and are joined by strong covalent bonds.
- Diamond has a very high melting pint because of the strong covalent bond between the carbon atoms.
- It has a very high density ($3.5g/cm^3$) because of the closely packed carbon atoms.
- Diamond is transparent, sparkling and glitters.
- Diamond does not conduct electricity because it has no mobile electrons.

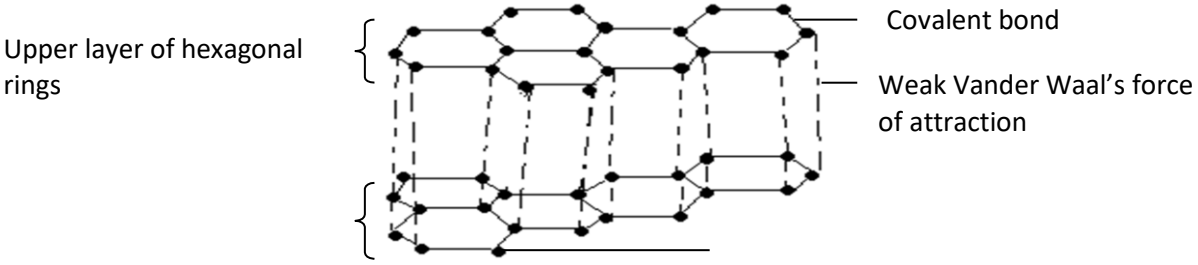
Uses of diamond

1. Diamond is very hard and used as drilling devices, rock borers and glass cutters.
2. Diamond is used jewelry because it's sparkling appearance.
3. Diamond is bright and used to make laser beams.

Graphite

Graphite consists of infinite number of carbon atoms each covalently bonded to three other carbon atoms forming hexagonal rings that are arranged in layers. Each layer is a giant two dimensional structure. The different layers are held by weak Vander Waal's forces of attraction, making them to slide over each other thus they are slippery and soft. Some electrons in a layer are mobile making them to conduct electricity.

Structure of graphite



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Physical properties of graphite
- Graphite conducts electricity because they have free mobile electrons.
- The melting point of graphite is high because of the strong covalent bond between the carbon atoms.
- Graphite is soft and slippery because its layers are held by weak Vander Waals force of attraction.
- Graphite is opaque and dark in color and shiny.

Graphite is less resistant to chemical attack than diamond because of the open spaces between the layers. The density of graphite is $2.3g/cm^3$

Uses of graphite
1. Graphite is soft and can mark therefore used tos make pencil–leads. Graphite is mixed with clay to make pencil leads.
2. Graphite is a good conductor of electricity and thus used as electrodes.
3. It is soft and greasy, therefore used as lubricants especially in small bearings like those in dynamos.
4. Graphite is used to make brushes for electric motors.
5. Graphite (black lead) is used as a protective coating on iron to prevent rusting

Properties of giant molecular structures
1. They have high melting and boiling pints because of great energy needed to break the bonds.
2. They do not conduct electricity except graphite which has delocalized electrons.
3. They are insoluble in water.

Giant metallic structure
Giant metallic structure consists of very many metal ions surrounded by a sea /cloud of electrons. These electrons are released by metal atoms.

Properties of giant metallic structures
1. They are solids with high melting and boiling points except mercury which is a liquid.
2. They conduct electricity in both liquid and solid states due to the presence of mobile electrons.

Sample questions on bonding and structure

Bonding and structure

1. *what is meant by the following types of bonding: electrovalent, covalent, coordinate and metallic. Use examples to illustrate how the above bonds are formed between any two named atoms or molecules.*
2. *Explain what is meant by metallic bond. Explain why a typical metal is (a) a good conductor of electricity (b) a good conductor of heat (c) in some conditions at leas malleable and ductile.*
3. *The compounds named below are all covalent compounds. With the aid of the table of electron structures, give a diagram for a molecule of each of these compounds showing the outer most electron shells only: (i) tetra chloromethane* CCl_4*, phosphorus(III) chloride* PCl_3 *(iii) silane* SiH_4 *(iv) tri chloromethane* $CHCl_3$ *(v) phosphine* PH_3 *and (vi) dichloromethane* CH_2Cl_2
4. *By means of electronic diagrams, show the structure of (a) calcium atom (b) chlorine atom (c) calcium chloride. State the differences between electrovalent and covalent compounds.*
6. *Describe how structures of the following compounds account for their property in term of electrical conduction (a) copper (b) graphite (c) diamond*