FACTFILE:
GCE CHEMISTRY

1.3 BONDING

Rewarding Learning

Bonding

Learning Outcomes

Students should be able to:

1.3.1 demonstrate understanding that ionic bonding is the electrostatic attraction between oppositely charged ions formed by electron transfer;

1.3.2 construct dot and cross diagrams for ionically bonded compounds, for example elements in Groups I, II, VI and VII, the ions of which have a noble gas structure;

1.3.3 know that a covalent bond is the electrostatic attraction between a shared pair of electrons and the nuclei of the bonded atoms;

1.3.4 define the term lone pair;

1.3.5 describe the coordinate bond as a shared pair of electrons with both electrons supplied by one atom, for example the ammonium ion, NH_4^+;

1.3.6 construct dot and cross diagrams for molecules and ions with co-ordinate, single, double and triple covalent bonds;

1.3.7 define the octet rule and state its limitations, for example in $BeCl_2$ and BF_3;

1.3.8 define the term electronegativity and explain the trend in the electronegativity of elements across Periods and down Groups;

1.3.9 explain that bond polarity arises when covalently bonded atoms have different electronegativities and use partial charges to show that a bond is polar;

1.3.10 demonstrate understanding that metallic bonding is the attraction between positive ions and delocalised electrons in a lattice;

Bonding

The physical properties of a substance depend on its structure and type of bonding present. Bonding determines the type of structure. There are three main types of bond that can occur between atoms:

- An **ionic bond** occurs between a metal and a non-metal atom (e.g. NaCl)
- A **covalent bond** occurs between two non-metal atoms (e.g. I_2, CH_4)
- A **metallic bond** occurs between atoms in a metal (e.g. Cu)

Ionic Bonding

Metals lose electrons to form **positive** ions (cations) while **non-metals** gain electrons to form **negative** ions (anions). The number of electrons gained or lost by an atom is related to the group in which the element is found.

Group	1	2	3	4	5	6	7	8
Charge	1+	2+	3+	N/A	3-	2-	1-	N/A
Example	Na^+	Mg^{2+}	Al^{3+}	N/A	N^{3-}	O^{2-}	F^-	N/A

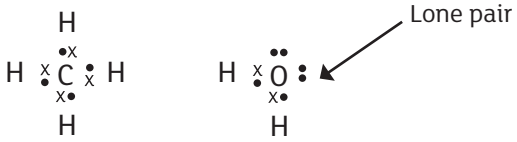
Ionic bonding is the electrostatic attraction between oppositely charged ions formed by electron transfer An ionic bond is formed when electrons are transferred from a **metal** atom to a **non-metal** atom forming oppositely charged ions.

For example, in the formation of magnesium oxide, two electrons are transferred from the outer shell of the magnesium atom to the outer shell of the oxygen atom. This is represented in a dot and cross diagram.

Covalent Bonding

A covalent bond consists of a shared pair of electrons with one electron being supplied by each atom involved in the bond. The atoms are held together by electrostatic attraction because their nuclei, which have an overall positive charge, are attracted to the shared pair of electrons. **A covalent bond is the electrostatic attraction between a shared pair of electrons and the nuclei of bonded atoms.**

Examples of covalently bonded molecules include methane, CH_4 , and water, H_2O.

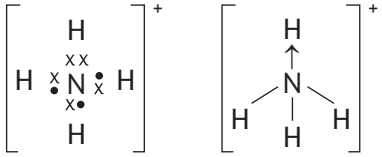


A **bonded pair** of electrons is a pair of electrons shared between two atoms. A **lone pair** of electrons is a pair of unshared electron in the outer shell of an atom.

Some covalently bonded substances have double bonds , for example CO_2 and others have triple bonds for example N_2.

A **co-ordinate** bond (dative bond) is a shared pair of electrons between two atoms. One atom provides both electrons.

Ammonium ion (NH_4^+) has a coordinate bond, shown as two crosses in the dot and cross diagram or in the structure diagram as an arrow.

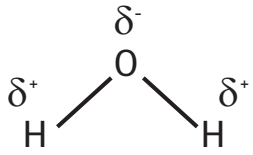


In some cases there is an unequal attraction for the bonding electrons between two covalently bonded atoms. This is due to the different electronegativities of different atoms. **Electronegativity is the extent to which an atom attracts the bonding electrons in a covalent bond.**

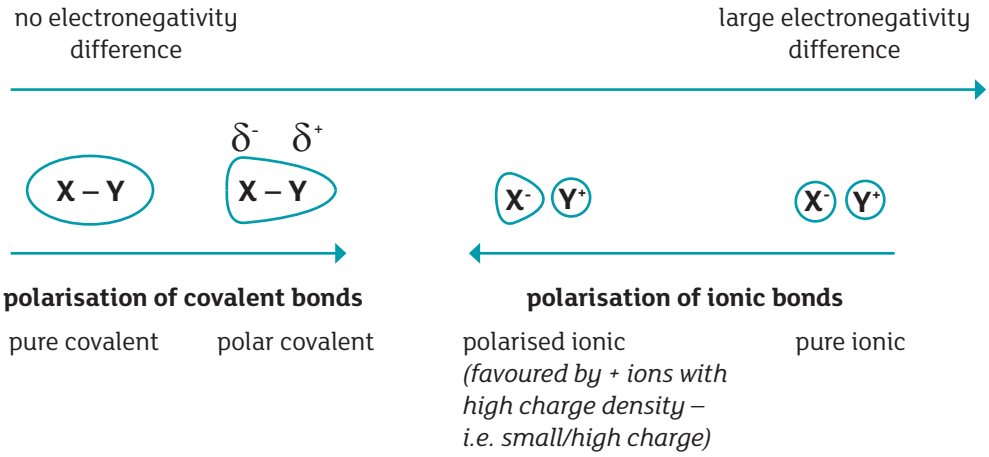
Electronegativity *decreases down groups* due to the increased distance between the bonding electrons and the nucleus of the bonding atom and the corresponding increase in shielding between the nucleus and outer shell electrons; it *increases across periods* due to the increasing effective nuclear charge and hence attraction between the nucleus of the bonding atom and the bonding electrons. The most electronegative atom is fluorine.

A covalent bond between two atoms of different electronegativities is polar; partial charges develop on the two atoms. A $\delta+$ charge develops on the atom with a lower electronegativity value and a $\delta-$ charge develops on the atom with a higher electronegativity value. **A polar bond is a covalent bond in which there is unequal sharing of the bonding electrons.**

For example, the covalent bonds in water are considered to be polar as the oxygen atom is significantly more electronegative than the hydrogen atom. The bonding electrons are attracted more strongly to the oxygen atom and it develops a $\delta-$ charge.



Rather than saying that ionic and covalent are two distinct types of bonding, it is more accurate to say that they are at the two extremes of a scale.



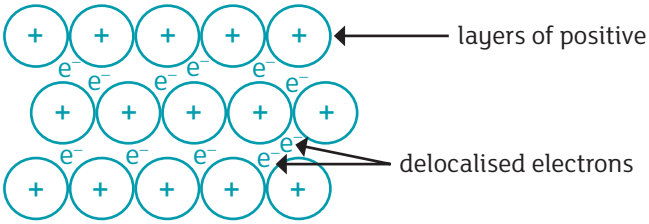
The octet rule states that when reacting, an atom tends to gain, lose or share electrons to achieve eight electrons in its outer shell.

However there are some covalent compounds, which do not follow the octet rule. For example, in beryllium chloride the central beryllium atom does not follow the octet rule as there are only 4 electrons in its outer shell.

In BF_3 the fluorine atom has 8 electrons in its outer shell and follows the octet rule, but boron has 6 electrons in the outer shell and does not follow the octet rule. In SF_6 sulfur has 12 electrons in the outer shell and does not follow the octet rule.

Metallic Bonding

Metallic bonding is the attraction between positive ions and delocalised electrons.



Delocalised electrons are outer electrons which do not have fixed positions but move freely.

Revision Questions

1 Which one of the following contains a co-ordinate bond?

A Ammonium, NH_4^+

B Boron trifluoride, BF_3

C Sulfur hexafluoride, SF_6

D Water, H_2O

2 Fluorine is the most reactive non-metallic element. It combine with both metals and non-metals.

Using dot and cross diagrams, explain how stontium atoms combine with fluorine atoms to form strontium fluoride. Show the outer electrons only.

3 Sulfur and fluorine combine to form sulfur hexafluoride, SF_6. Sulfur and fluorine atoms have different electronegativity values and form a polar bond but sulfur hexafluoride is non-polar.

i) Define the term **electronegativity**.

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ii) Label the diagram below to show the polarity of the S–F bond.

S–F

Revision Questions

3 iii) Draw a dot and cross diagram to show the bonding in SF_6 using outer shell electrons only.

iv) Explain whether the SF_6 molecule obeys the octet rule.

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4 Which one of the following is involved in metallic bonding?

A electron delocalisation

B electron transitions

C gaining electrons to form ions

D sharing electron pairs