HERO EDUCATION

NAME:

PRELIMINARY CHEMISTRY

Properties & Structure of Matter

Module 1

BONDING

Theory Booklet 4/4

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CONTENTS

MODULE 1: PROPERTIES & STRUCTURE OF MATTER

SUBMODULE: BONDING

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4. BONDING

- investigate the different chemical structures of atoms and elements, including but not limited to:
  - ionic networks
  - covalent lattices (including diamond and silicon dioxide)
  - covalent networks
- investigate the role of electronegativity in determining the ionic or covalent nature of bonds between atoms

Metallic Compounds

- Metals are a three-dimension lattice of positive metal cations immersed in a *sea of delocalised (valence) electrons.*

  What is a lattice?

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- Metallic compounds are held together by the metallic bond.

  What is the metallic bond?

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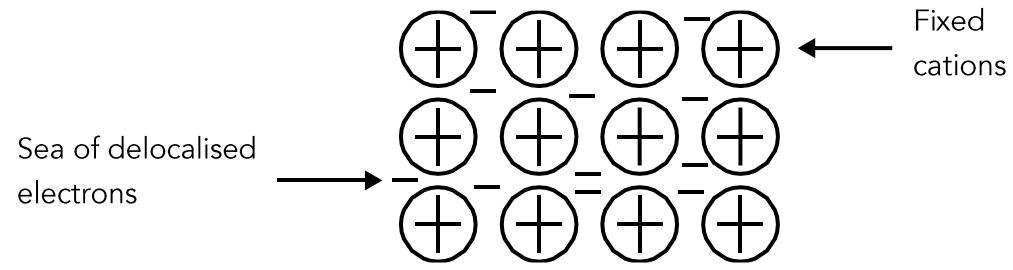
- The strength of the metallic bond increases with the number of valence electrons.



Ionic Compounds

- Ionic compounds are a three-dimensional lattice of oppositely charged ions that are commonly formed in a reaction between a metal and non-metal which involve the *transfer of electrons.*

FORMATION OF IONIC COMPOUNDS

- Ionic compounds consist of metals that form cations (positively charged) and non-metals that form anions (negatively charged).
- In order to obtain a stable electron configuration, elements can either obtain a
    - Full valence electron shell or
    - Have eight valence electrons (octet)

  How do we determine the maximum occupancy of electrons in a shell?

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- Most metals are in Groups I, II and III of the Periodic Table. They have a tendency to lose electrons (oxidation) in order to achieve a stable electron configuration.
- Most non-metals are in Groups IV, V, VI, VII and VIII of the Periodic Table. They have a tendency to gain electrons (reduction) in order to achieve a stable electron configuration.
- Thus, an electron will readily transfer from a metal to a non-metal, causing them to form ions from the deficiency and excess of electrons respectively.

- For example, let's consider the reaction between sodium (Na) and chlorine (Cl).

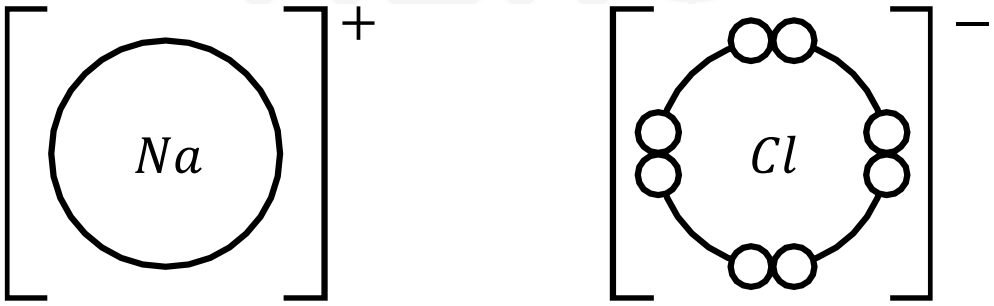
  Sodium is a metallic element in Group I. Hence it has one valence electron and will readily donate it to a non-metal to form a cation.

  Chloride is a non-metallic element in Group VII. Hence it has seven valence electrons and will readily accept an electron from a metal to form an anion.

In the above diagram, only the valence electrons are shown.

- As a result of the electron transfer, a positive sodium ion and a negative chlorine ion are formed. Since both ions are oppositely charged, they experience electrostatic attraction known as *ionic bonds*.

- Hence, the formation of an ionic compounds – sodium chloride ($NaCl$)



- When determining the formula for the ionic compound formed, it is really important to consider the valency of the metal and non-metal.

- For example, consider the reaction between magnesium (Mg) and chlorine (Cl). The valency of magnesium is 2+ while the valency of chlorine is 1-.

  In other words, each magnesium atom will donate TWO electrons while each chlorine atom will accept only ONE electron. Hence, each magnesium atom will react with two chlorine atoms.

  Draw a diagram to represent the chemical reaction between magnesium and chlorine – use the diagrams in Page 3 for reference.

STRUCTURE OF AN IONIC COMPOUND

- Ionic compounds exist in a three-dimensions lattice network of oppositely charged ions.

- The ions (cation, anion) are held together by the ionic bond.

  Describe the nature and strength of ionic bonds.

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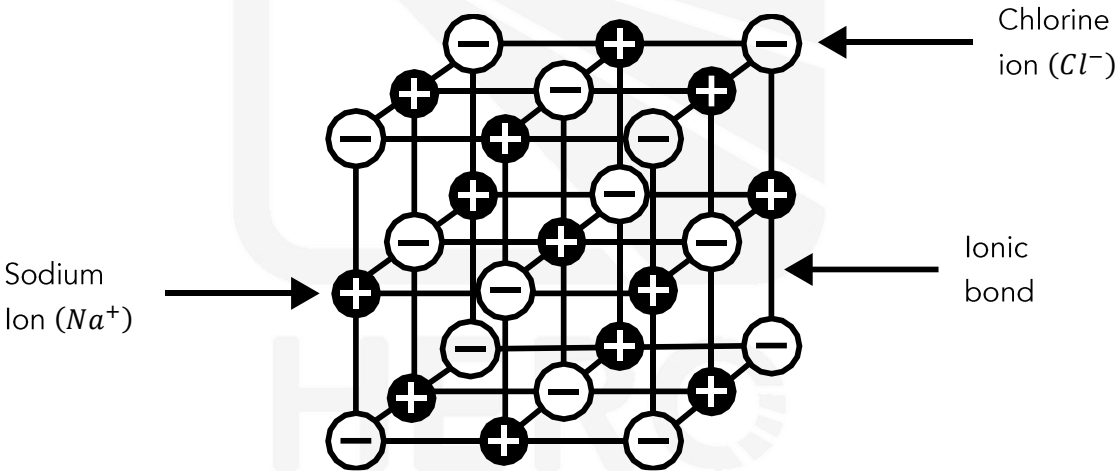
- Below is the structure for a sodium chloride lattice network.



  Ionic compounds always consist of a metal and a non-metal. Explain why this is the case, referring to the role of electronegativity.

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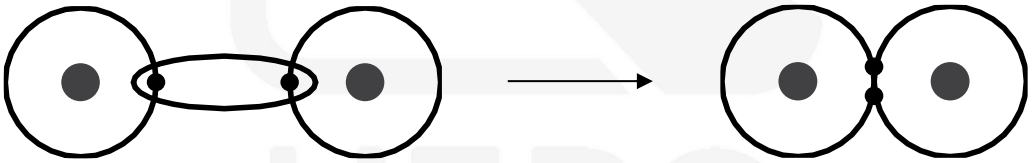
Covalent Compounds

- Covalent compounds always consist of a non-metal and a non-metal.
- Non-metals have a tendency to gain electrons in order to achieve a stable electron configuration with eight valence electrons.
- As such, when two non-metals react, there will *not* be a transfer of electrons as they are both highly electronegative (unlike metals).
- Instead, they will form a covalent bond which involves the *sharing of electrons* where they both co-own a shared pair of electrons.

  Let's consider the example of a hydrogen (H) atom with a single electron in its valence shell. In order to achieve a stable electron configuration, it requires a full outer shell of 2 electrons (using $2n^2$).

  Hence, when two hydrogen atoms react to form a diatomic molecule (H_2), they will form a single covalent bond.



- Covalent bonds are very strong and require a lot of energy to break. It is an *intramolecular* force as it is a force of attraction between atoms inside a discrete molecule.

  The boiling point of hydrogen gas, $H_{2(g)}$, is -259.92^oC. Justify its low boiling point despite the strong covalent bonds between the two hydrogen atoms.

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COVALENT MOLECULAR

- Covalent molecular compounds are DISCRETE.

- Atoms are chemically bonded together by the sharing of electrons (covalent bonds) to form *molecules*, but the molecules exist independently of each other and only experience physical intermolecular attractions – they do not exist in a lattice.

  What are intermolecular forces (IMF) ?

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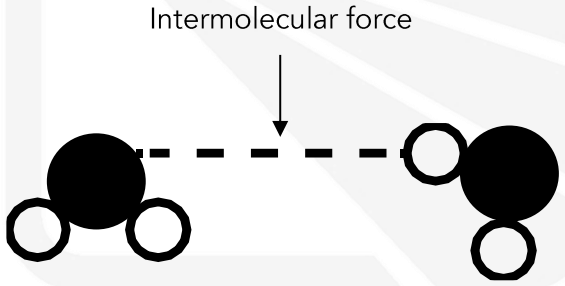
- The diagram below depicts two water molecules (H_2O) that experience intermolecular forces (dotted line).



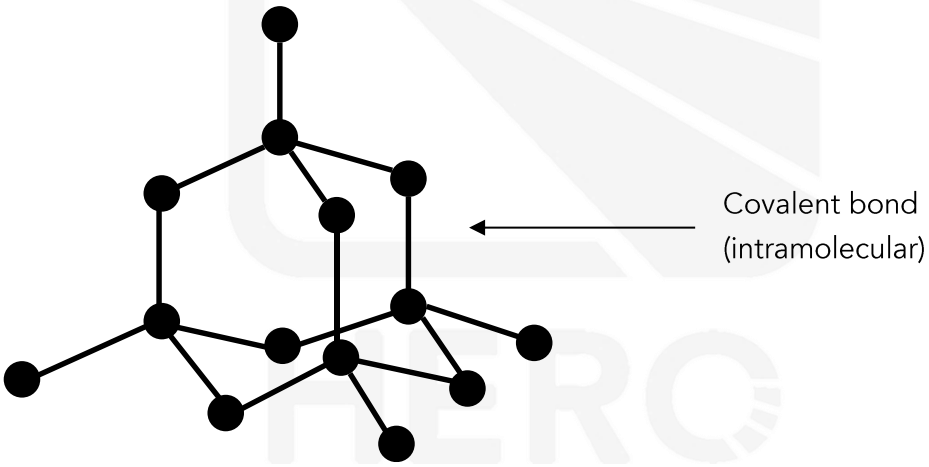
COVALENT NETWORK

- Covalent network compounds are solid LATTICES with the atoms held together by the sharing of electrons – strong covalent bonds.

- Examples of elements that exist in a covalent network are listed below. *Memorise them.*

  - Boron (B)
  - Silicon (Si)
  - Germanium (Ge)
  - Carbon $(C$, diamond)
  - Silicon $(SiO_2$, quartz)

- Below is the covalent network of diamond. Each carbon atom ● is covalently bonded to four other carbon atoms to form a lattice structure.



The boiling point of carbon (diamond) is 3550^oC. Both water and diamond form covalent bonds between atoms. Explain why the boiling point of diamond is so much higher.

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Concept Check 4.1 [DEVELOPMENT] (4 marks)

Compare the structure and bonding of metallic, ionic, covalent molecular and covalent network compounds, including diagrams in your answer. **4**