Chemical Bonding

7.1 Octet Rule

You have learnt that the atoms having eight electrons in its valence shell are stable. The atoms other than hydrogen tends to form bonds until it is surrounded by eight valence electrons. They do so by gaining, losing or sharing electrons. It is called **Octet rule** and is quite useful in describing the formation of simple molecules. It is important to note that the octet rule is just a guiding principle and not a law. In case of hydrogen, the valence shell attains the electron configuration of helium, i.e., a total of two electrons.

7.1.1 Lewis Approach

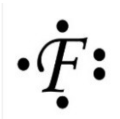
Lewis Symbol :- The Valance electron of an atom in terms of dot is written around the atom.

For Example:

Fluorine (F=9) Electronic configuration=2,7

Valence electron=7

Hence is represented as:

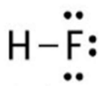


Bonding in molecule:

Duing bonding the valance electrons are written around the atoms and then electrons are shared in such a way so as to complete the octet of each atom.

For Example the Lewis formula for Hydrogen Fluoride is

or



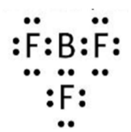
Here the pair of dots (representing electrons) placed between the symbols of the combining atoms represent the bonding electrons. The remaining dots represent the non-bonding electrons. As the name suggests, the non-bonding electrons do not contribute to the bonding. You may note that the hydrogen atom in this molecule has only two electrons (a duplet) around it. The line here indicates the bond between hydrogen and fluorine atom.

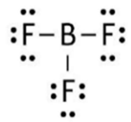
7.1.2 Exceptions of Octet Rule

Many stable molecules do not follow the octet rule. These are called exceptions to the octet rule. Let us discuss about these exceptions.

Molecules with incomplete octets

In case of some elements the valence shell has less than four valence electrons. In these cases, their atoms cannot form four bonds to complete the octet. Also, these do not have sufficient lone pairs that can complete the octet. As a result, the octet remains incomplete in such cases. For example, in case of lithium, beryllium and boron there are only 1, 2 and 3 valence electrons respectively. Therefore, these can form 1, 2 and 3 bonds respectively. In such cases the central atom would have 2, 4 and 6 electrons respectively on forming the molecule. These represent molecules which do not complete the octet and yet are stable. One common example is that of boron trifluoride. In this molecule, one boron atom makes bonds with three fluorine atoms and is represented as

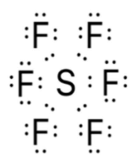




The lines here indicate the bond between boron and fluorine atom.

Molecules with expanded octets

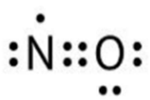
Another exception to the octet rule is observed in the formation of molecules having more than eight valence electrons around central atom. Such molecules are formed by the atoms of the elements having more than four electrons in their valence shell. For example, in case of sulfur hexafluoride one atom of sulphur combines with six atoms of fluorine. The Central sulphur atom has 12 electrons in its valence shell representing an expanded octet. We can represent its structure as

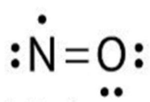


You will learn about the formation of such compounds in higher classes.

Molecules with odd number of electrons

Certain molecules have an odd number of electrons. For example, an atom of nitrogen (having 5 valence electrons) makes two bonds with an atom of oxygen (having six valence electrons) to form a molecule of NO. It has a total of 11 valence electrons, five from N and six from O atom. The Lewis structure for this molecule can be represented as





The two lines here indicate two bonds. Whenever there are odd number of electrons in a molecule then at least one atom would have an incomplete octet. Secondly in such a molecule there would always be an unpaired electron.

Quick Check

1. What is meant by the octet rule?
2. Why does hydrogen not follow the octet rule?
3. Give one example each of the molecule with
   a) incomplete octet
   b) expanded octet
   c) an odd electron
4. Why can boron form compounds with only six electrons around it?
5. What is meant by a duplet configuration?
6. Why is NO considered an exception to the octet rule?
7. Draw the Lewis dot structure of BF_3 and explain why boron does not complete its octet.
8. Assertion: SF_6 violates the octet rule.
   Reason: Sulphur can accommodate more than eight electrons.
   A. Assertion and reason, both are correct and reason is the correct explanation of the assertion.
   B. Assertion and reason, both are correct but reason is not the correct explanation of the assertion.
   C. Assertion is correct but reason is a wrong statement.
   D. Assertion is wrong but the reason is a correct statement.

7.2 Metallic Bonding

You all are familiar with metals like iron, copper, aluminium, and so on. They are hard, they can be beaten into sheets, drawn into wires, and they conduct electricity. You may be wondering how can we explain these properties of metals. We can explain these in terms of a simple model known as the electron sea model for metals. You have learnt about bonding in case of ionic and covalent compounds. In these, the atoms bind by transfer or sharing of electrons between specific atoms. The electron sea model, in fact, is a simple model for bonding in metals. It involves bonding between a very large number of atoms of the metal. Let us understand this model and learn how we can explain the properties of metals by using this model.

7.2.1 Electron Sea Model

A metal atom has a few electrons in its outermost shell. These outer electrons are not held very tightly by the nucleus. Because of this, when many metal atoms come together to form a solid, these outer electrons do not remain attached to any one atom. Instead, they become delocalised and are free to move throughout the entire piece of metal.

You know that when an atom loses an electron it becomes a cation. In metals, the atoms can be thought of as forming positive metal ions arranged in a regular pattern. These ions form a kind of fixed structure. The free electrons move continuously and randomly in all directions around and between these ions. This collection of freely moving electrons is called a “sea of electrons”.

Thus, according to the electron sea model, a metal can be seen as a structure in which positive metal ions are fixed in place, and a “sea” of mobile electrons moves around them. This is why the model is called the electron sea model as shown in Fig.7.1.

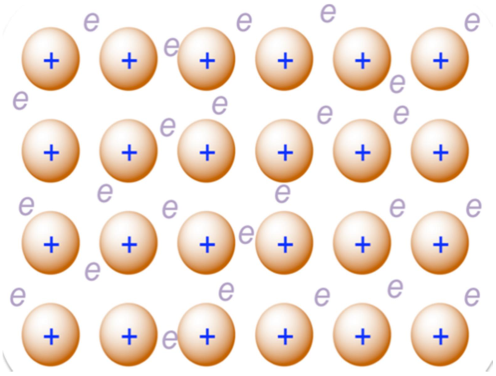


Fig. 7.1: Schematic representation of Electron sea model

These ions and electrons together form a stable structure. The attraction between the positive ions and the sea of electrons is what holds the metal together. This attraction is called **metallic bonding**. So, we can say that metallic bonding is the force of attraction between positive metal ions and the sea of electrons. It is important to note that unlike covalent bonds, metallic bonds are not localised. The electrons are shared by all the atoms collectively, forming a non-directional bond that can adjust to shifting positions of the metal ions.

7.2.1: Electron sea model and properties of metal

Now let us see how this simple electron sea model helps us to understand the properties of metals.

Electrical conductivity

Since electrons are free to move, when we apply an electric field across a metal, these electrons start moving in a particular direction. This movement of electrons is what we call electric current. That is why metals are good conductors of electricity.

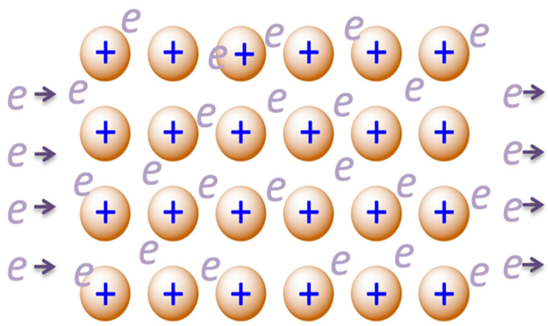


Fig.7.2: Schematic representation of electrical conduction by metals in terms of electron sea model

Thermal conductivity

When one part of a metal is heated, the electrons in that region gain energy and start moving faster. As they move, they transfer this energy to other parts of the metal. At the same time, the metal ions also vibrate more and help in passing the heat along. In this way, heat spreads quickly. This is why metals are good conductors of heat.

Malleability and Ductility

You know that malleability refers to the ability of metals to be beaten into thin sheets. In the electron sea model, the positive metal ions can slide over one another without breaking the structure. This is possible because the electrons are not fixed; they continue to move and hold the ions together. So, even when layers of the metal ions shift, the metal does not break.

Similarly, you know that ductility refers to the ability of metals to be drawn into wires. When we stretch a metal, these metal ions slide past each other without breaking the non-directional metallic bonds, allowing the metal to stretch into wires. The free electrons help maintain the attraction between ions even when the shape changes.

You must remember that the electron sea model gives a simple picture and explains many basic properties of metals. The electrons are not completely lost as in ionic bonding; rather, they are shared collectively by all atoms in the metal. You will learn more detailed models of metallic bonding in your higher classes.

Check Your Understanding

1. What is meant by the term "electron sea" in metals?
2. What type of particles are in a fixed position in a metal according to the Electron sea model?
3. Define metallic bonding.
4. Why are metallic bonds called non-directional?

5. Name two properties of metals explained by the electron sea model.
6. Explain how the electron sea model accounts for electrical conductivity in metals.
7. How does the electron sea model explain thermal conductivity in metals?
8. Why can metals be beaten into thin sheets? Explain using the Electron sea model.
9. What is meant by ductility? How is it explained by the electron sea model?
10. How is metallic bonding different from covalent bonding?
11. Explain the structure of a metal according to the electron sea model.
12. If electrons in a metal were not free to move, which property would be most affected? Explain.
13. Explain why metals do not break when hammered but instead change shape.
14. Copper is used for electrical wiring, while rubber is not. Explain using the electron sea model.
15. Why are metals generally good conductors of heat as compared to non-metals?
19. Assertion (A): Metals are good conductors of electricity.
    Reason (R): Metals contain free electrons that can move under an electric field.
    A. Assertion and reason, both are correct and reason is the correct explanation of the assertion.
    B. Assertion and reason, both are correct but reason is not the correct explanation of the assertion.
    C. Assertion is correct but reason is a wrong statement.
    D. Assertion is wrong but the reason is a correct statement.
20. Assertion (A): Metallic bonds are non-directional.
    Reason (R): Electrons in metals are localised between two atoms.
    A. Assertion and reason, both are correct and reason is the correct explanation of the assertion.
    B. Assertion and reason, both are correct but reason is not the correct explanation of the assertion.
    C. Assertion is correct but reason is a wrong statement.
    D. Assertion is wrong but the reason is a correct statement.
21. Assertion (A): Metals are malleable.
    Reason (R): Layers of metal ions can slide while electrons continue to hold them together.

A. Assertion and reason, both are correct and reason is the correct explanation of the assertion.
B. Assertion and reason, both are correct but reason is not the correct explanation of the assertion.
C. Assertion is correct but reason is a wrong statement.
D. Assertion is wrong but the reason is a correct statement.

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