Table 2.3 Molecular elements

Element	Molecular structure
Oxygen	O_2
Nitrogen	N_2
Hydrogen	H_2
Chlorine	Cl_2
Sulfur	S_8

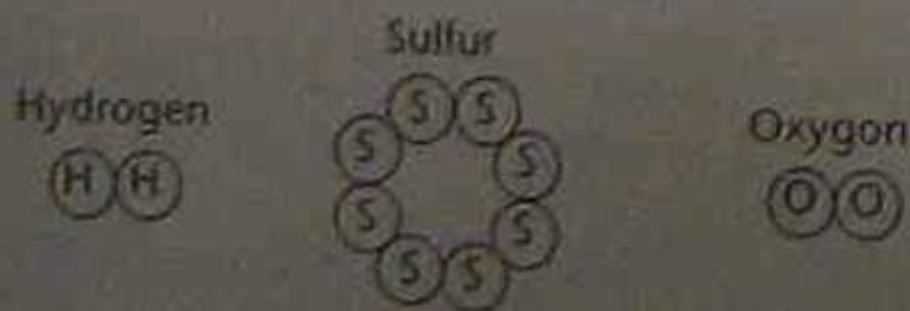


Figure 2.4 Examples of molecules

Periodic Table

The **Periodic Table** is a classification of elements. A full copy of the Periodic Table is reproduced on the **inside back cover** of **this study guide**.

- The elements are arranged in the Periodic Table according to their increasing atomic number (Z).

The elements are arranged in rows and columns.

- The rows are called **periods**. There are seven periods (see Figure 2.5). Not all periods have the same number of elements. The first period contains only 2 elements (hydrogen and helium) whereas the fourth period contains eighteen elements. The last two periods are very long because of the presence of two special series of elements (the lanthanides (Z = 57–71) and actinides (Z = 89–103) which are extracted to the bottom of the table to reduce its width.

- The columns are called **groups**. Each group represents a family of related elements. The group numbers are shown in Figure 2.5. The element hydrogen is sometimes placed with Group I, but in some tables it is not allocated to any group.

Metals, non-metals and semi-metals

The map of the Periodic Table also shows that the elements can be classified into three groups:

- **Metals**—the majority of elements are metals. Metals are usually shiny solids (except mercury) that are good conductors of electricity and heat. They are malleable and ductile.
- **Non-metals**—only 19 elements are classified as non-metals. Some are gases such as oxygen and argon. Bromine is a fuming red-brown liquid and some are soft, brittle solids such as sulfur and phosphorus. They are non-conductors of electricity and heat.

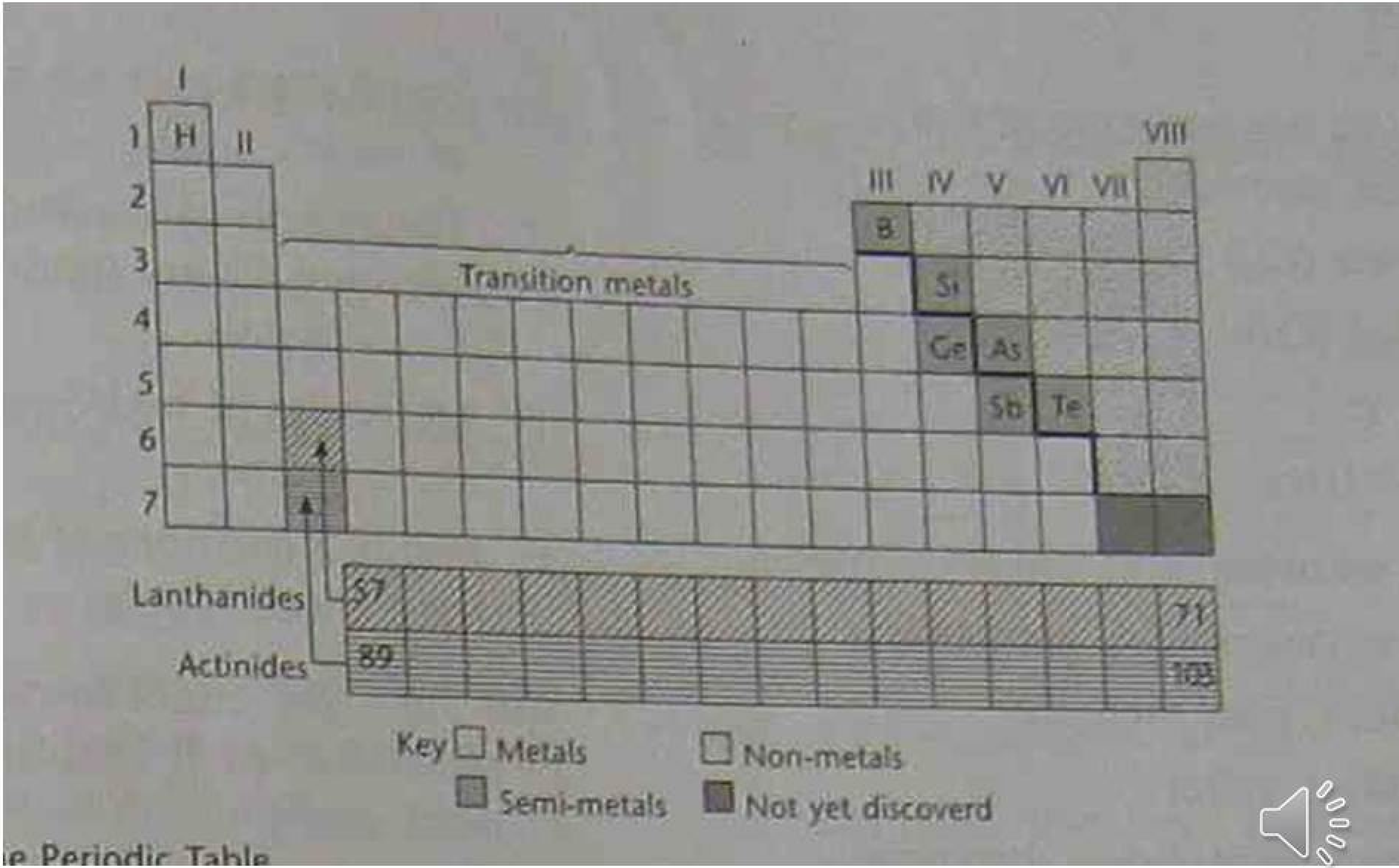

I
II
III IV V VI VII
VIII
1 2 3 4 5 6 7
H
B
Si
Ge
As
Sb
Te
Transition metals
Lanthanides
57
71
Actinides
89
103
Key
Metals
Non-metals
Semi-metals
Not yet discoverd
e Periodic Table

Figure 2.5 Map of the Periodic Table

- **Semi-metals**—six elements are classified as semi-metals. Their properties are intermediate between metals and non-metals. Silicon and germanium are examples of semi-metals.

Families of elements

Each vertical group of elements represents a family. The properties of elements in a family are similar. They show a gradation in properties down the group.

- **Group I—the alkali metal family.** These are soft, highly reactive metals that do not exist as free elements in nature. They react readily with water, oxygen and other non-metals, forming compounds. All Group I metals have one valence shell electron.
- **Group IV—the carbon family.** The elements of Group IV include carbon (a non-metal), silicon and germanium (semi-metals) as well as tin and lead (soft metals). All have four electrons in their valence shell.

- Group VII—the halogen family. These elements are reactive non-metals. Fluorine and chlorine are coloured gases, bromine is a red-brown fuming liquid and iodine is a purple-black solid. All these elements have seven electrons in their valence shell. They are non-conductors of electricity and heat.

- **Group VIII—the noble gases.** These elements are inert or very unreactive gases. Apart from helium they have eight electrons in their valence shell. They are non-conductors of heat and electricity.

Other important zones of the Periodic Table

- **The transition metals.** Between Group II and Group III is a central zone called the transition metals. Many of the important metals used in society (eg. iron, zinc, chromium, gold) are found in this zone. Each vertical group in the transition metal zone is a family of metals with the same number of electrons in their outer valence shell. Elements 104–112 are synthetic, unstable radioactive transition metals.

metals.

- The lanthanide series (Z = 57–71). This is a special sub-group of the transition metals shown near the bottom of the Periodic Table. All metals in this series have similar chemical properties.
- The actinide series (Z = 89–103). This is a group of natural and synthetic radioactive metals.

Compounds and reactions

There are many millions of chemical compounds that can be formed when elements react. Some are natural and others are manufactured. Compounds can be classified according to the types of particles they contain.

Glossary

Anion—a negative ion

Cation—a positive ion

Combustion—the reaction of a fuel and oxidiser (oxygen) to release energy

Compound—a pure substance composed of two or more elements that are chemically combined

Corrosion—the degradation or wearing away of a metal on exposure to environmental agents such as air and water

Covalent bond—a chemical bond in which electron pairs are shared

Ionic compound—a compound composed of positive ions and negative ions

Neutralisation—the destruction of the properties of acids or bases when they react together

Precipitation—the formation of an insoluble solid on mixing solutions of ionic compounds

Valency—the combining power of an element in a compound

Compounds

Compounds are formed when the atoms of two or more elements combine chemically together.

- Compounds are *not* mixtures of elements.
- Compounds have their own unique properties that are different from the elements of which they are composed.

Example

Mercury oxide is a red powder that forms when silvery mercury is gently heated in the presence of oxygen gas. This reaction can be represented by the following word equation:

mercury + oxygen → mercury oxide

The colour difference is not the only indication that something new has formed. The physical properties of the red compound are quite different to the original elements, as shown in Table 2.4.

Table 2.4 Properties of mercury, oxygen and mercury oxide

Substance	Colour	State at 25°C	Melting point (°C)	Density (g/cm³)
Mercury	silvery	liquid	–39	13.5
Oxygen	colourless	gas	–219	0.0013
Mercury oxide	red	solid	decomposes at 500°C	11.1

At higher temperatures (>500°C) the red mercury oxide can be decomposed back into its elements.

- Compounds are formed by the rearrangement of atoms of different elements.

Covalent compound—a compound in which the atoms are joined by covalent bonds

Decomposition—the breakdown of a substance into simpler substances

Effervescence—gas bubbles in a liquid

Indicators—dye molecules that change colour in the presence of an acid or base

Ion—a charged atom

Ionic bond—the electrostatic attraction between oppositely charged ions

Figure 2.7 shows some simple ball-and-stick models of the rearrangement of atoms of elements to form compounds. The balls represent the atoms of different elements. The sticks represent the chemical bonds (or attractive forces) that hold the particles together.

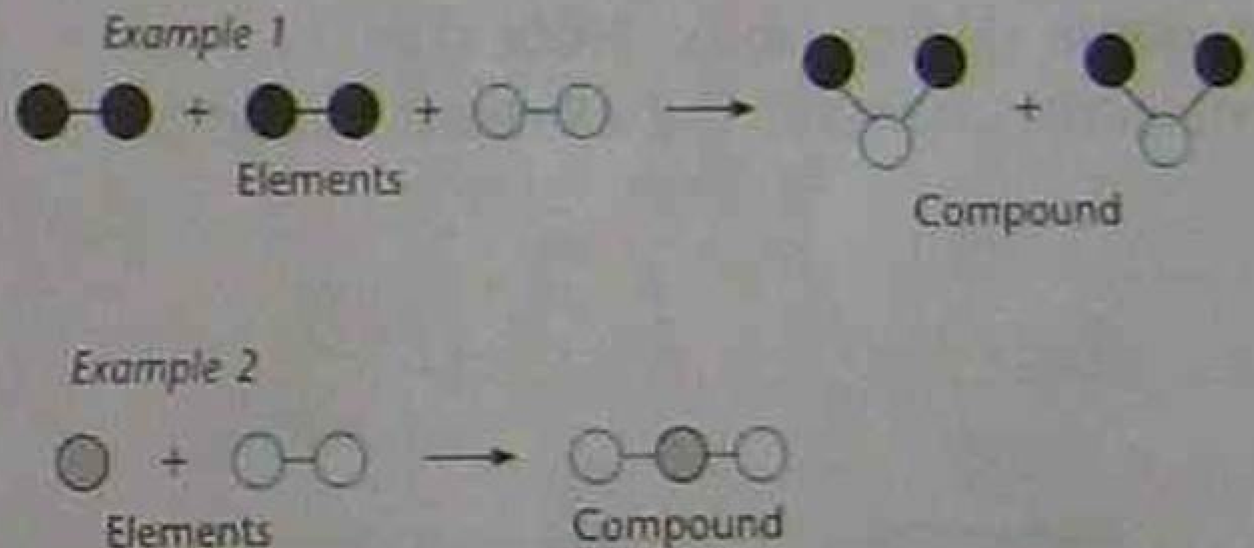


Figure 2.7 Ball-and-stick models of atom rearrangement to form compounds

- Compounds are composed of fixed numbers of atoms of each component element.

Examples

In the following examples the numbers of atoms of each type of element are shown as subscripts.

1. **Water.** Water is a compound composed of two atoms of hydrogen (H) and one atom of oxygen (O). Its chemical formula is H_2O (or HOH).
2. **Methane.** Methane is a compound composed of one atom of carbon (C) and

four atoms of hydrogen (H). Its chemical formula is CH_4.

3. **Carbon dioxide**. Carbon dioxide is a compound composed of one atom of carbon (C) and two atoms of oxygen (O). Its chemical formula is CO_2.

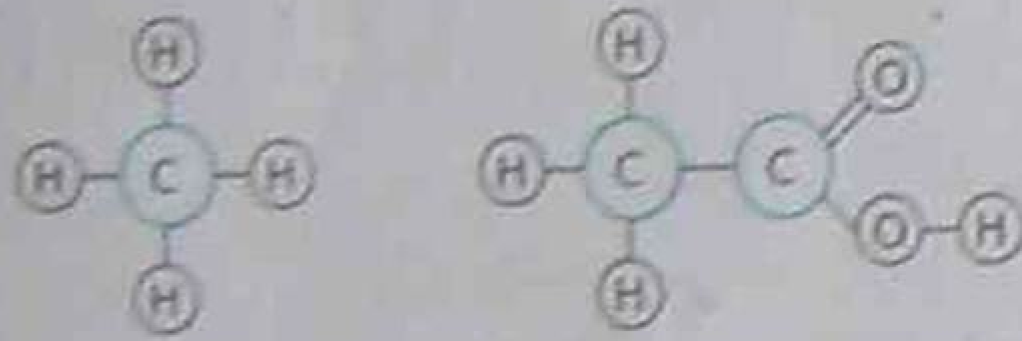
Classification of compounds

Compounds can be classified according to common chemical characteristics such as the types of particles they contain, as well as the type of bonds linking the component atoms. Some compounds belong to more than one classification scheme. Three examples of classification schemes are below.

a. Organic and inorganic compounds

This classification scheme is a simple way of distinguishing compounds that are formed by living organisms and those that are found in the rest of the environment.

Figure 2.8 shows some models of typical **organic compounds**. Note that all these molecules contain the element **carbon**.



Methane CH_4 Acetic acid CH_3COOH

Figure 2.8 Models of simple organic compounds

Figure 2.9 shows some models of typical inorganic compounds. Note that some are composed of molecules and some are composed of charged atoms (called **ions**). The concept of an ion will be examined later.

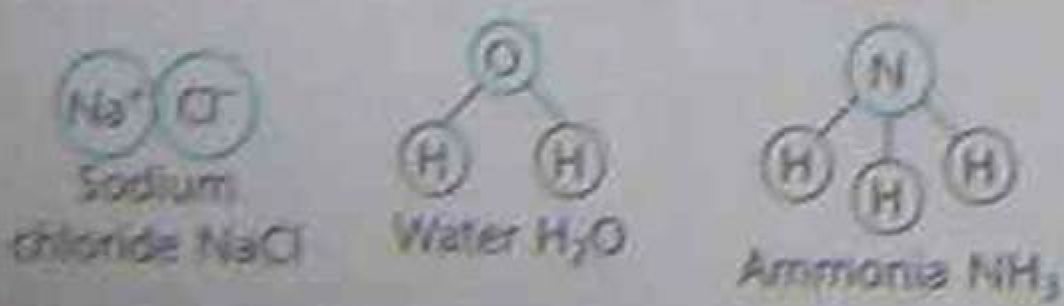


Figure 2.9 Models of simple inorganic compounds

b. Ionic compounds

Many inorganic compounds are composed of charged atoms.

- Charged atoms are called **ions**.

- Positive ions are called **cations**. They a formed when an atom of a **metal** loses one or more valence electrons. (They a attracted to the negative electrode or cathode.)
- Negative ions are called **anions**. They a formed when an atom of a **non-metal** gains one or more electrons into its valence shell. (They are attracted to the positive electrode or anode.)

The following table lists some of the common cations and anions and their Periodic Table group.

Table 2.5 Some common cations and anions in the Periodic Table

Group I	Group II	Group III	Group V	Group VI	[illegible]
sodium ion Na^+	magnesium ion Mg^{2+}	aluminium ion Al^{3+}	nitride ion N^{3-}	oxide ion O^{2-}	[illegible] F^-
potassium ion K^+	calcium ion Ca^{2+}		phosphide ion P^{3-}	sulfide ion S^{2-}	[illegible]

- Table 2.5 shows that the metal ions have positive charges equal to their group number in the Periodic Table. This is also the number of electrons in their valence shell.

  The table also shows that non-metal ions have negative charges equal to their group number minus eight (eg. Group 6 charge = 6 – 8 = –2).

  The table also shows that the name of the anion ends with the suffix 'ide'.

- Ionic compounds are composed of cations and anions. The attraction between these oppositely charged ions is called an **ionic bond.**

  Generally: Metal + Non-metal → Ionic compound

Example

A sodium atom (Na) readily forms a sodium ion (Na^+) by the loss of the single electron in its valence shell. This can be represented by a simple equation:

$$Na \rightarrow Na^{+} + e^{-}$$

A chlorine atom (Cl) readily forms a chloride ion (Cl^{-}) by gaining one electron to make a stable octet in its valence shell. This can be represented by a simple equation:

$$Cl + e^{-} \rightarrow Cl^{-}$$

$$Cl + e^- \rightarrow Cl^-$$

The sodium ion and chloride ion attract one another and form an ionic compound called sodium chloride (Na^+Cl^- or simply NaCl).

Figure 2.10 shows a model of this process.

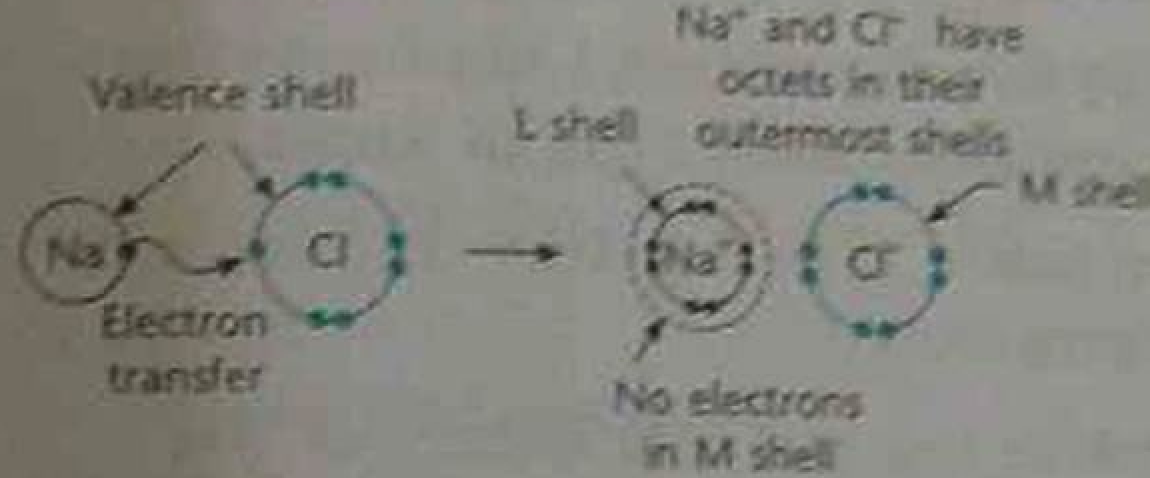


Figure 2.10 Formation of an ionic compound (NaCl)

Table 2.6 lists some common ionic compounds.

Table 2.6 Ionic compounds

Ionic compound	Chemical formula	Cation present	Anion present
Zinc oxide	ZnO	Zn^{2+}	O^{2-}
Magnesium chloride	$MgCl_2$	Mg^{2+}	Cl^-
Copper sulfide	CuS	Cu^{2+}	S^{2-}
Potassium bromide	KBr	K^+	Br^-
Calcium iodide	CaI_2	Ca^{2+}	I^-
Aluminium oxide	Al_2O_3	Al^{3+}	O^{2-}

c. Covalent compounds

When non-metals react with other non-metals to form a compound, there is no gain or loss of electrons. Instead electron pairs are **shared** between atoms.

- This sharing of electron pairs is called a **covalent bond.**
- The atoms in a covalent compound are linked by covalent bonds.

Generally: Non-metal + Non-metal →
Covalent compound

Example

Hydrogen atoms have one valence electron and chlorine atoms have seven valence electrons. When hydrogen atoms bond with chlorine atoms they share an electron pair to form the covalent bond.

Figure 2.11 shows a model of the formation of the covalent bond in hydrogen chloride (HCl).

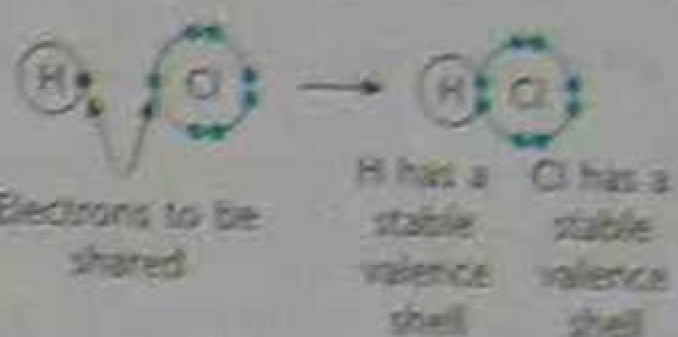


Figure 2.11 Covalent bonding in hydrogen chloride