Chemical bond:

- **Chemical bonding refers to the force that holds the chemical molecules or atoms together.**
- **Strength of the bond varies considerably, depends on the molecules or atoms involved in the process of bond formation.**

Classes of chemical bonds in biological science:

1) Covalent bonds

2) Non-covalent bonds:

Ionic - Hydrogen - Hydrophobic - Van der waals bonds

The Covalent bond:

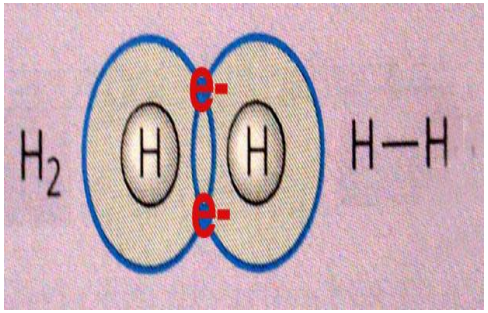
- **The covalent bond is a bond formed between two atoms by electron sharing. (usually formed between two non-metal atoms by sharing electron pairs).**
- **Covalent Bonds are the strongest chemical bonds, formed by the sharing of a pair of electrons.**
- **The energy of a typical single covalent bond is ~80 kilocalories per mole (kcal/mol). However, this bond energy can vary from ~50 kcal/mol to ~110 kcal/mol depending on the elements involved.**
- **Once formed, covalent bonds rarely break spontaneously.**

- **In a single bond, one electron pair is shared.**
- **In double bond, two electron pairs are shared.**
- **In triple bond, three electron pairs are shared.**

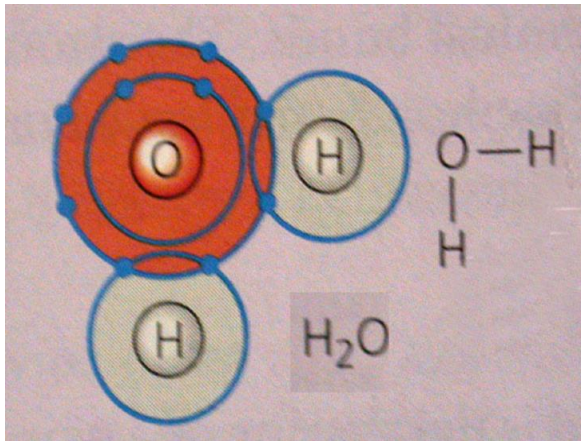
For example:

Single bond

H_2

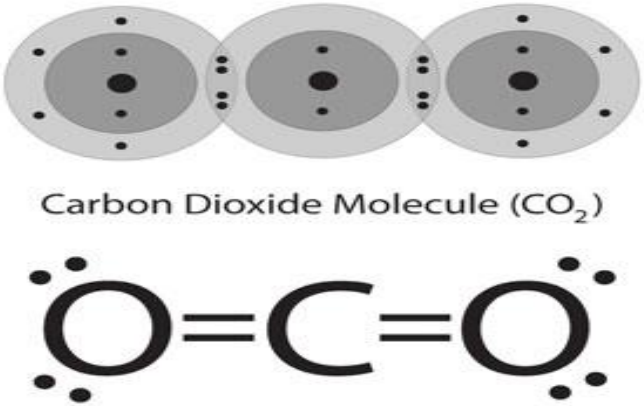


H_2O



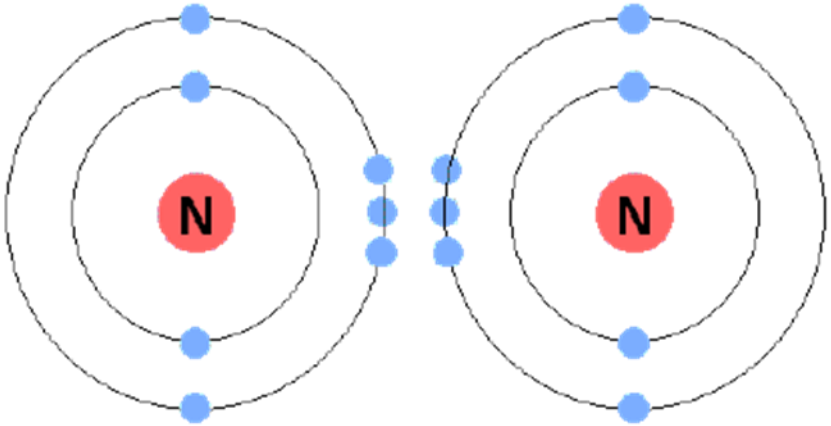
Double bond

CO_2



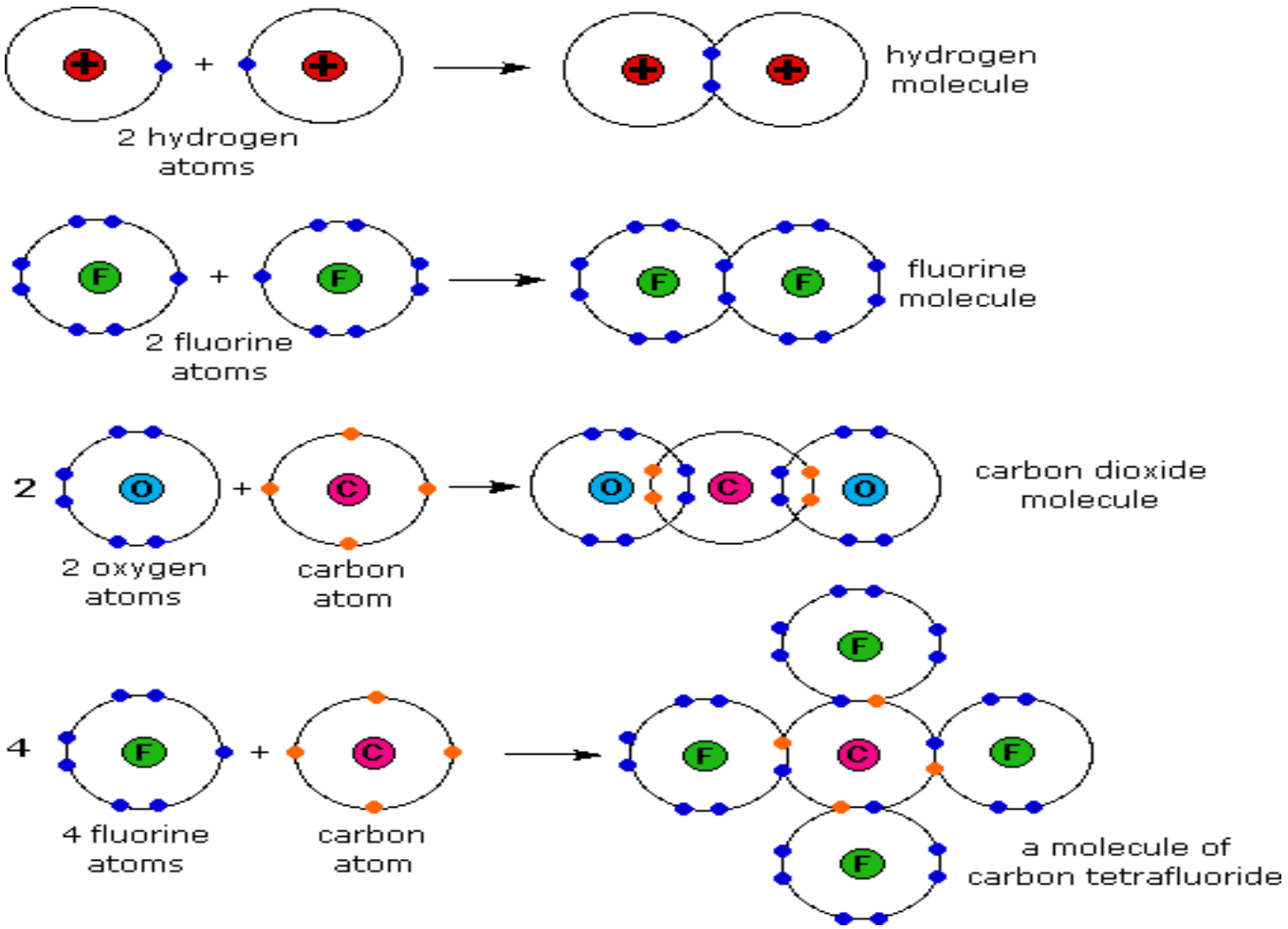
Triple bond

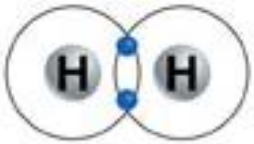
N2



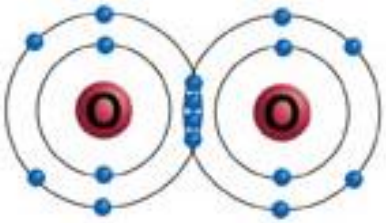
Covalent bonding occurs by a sharing of valence electrons:

Examples of covalent bonding:

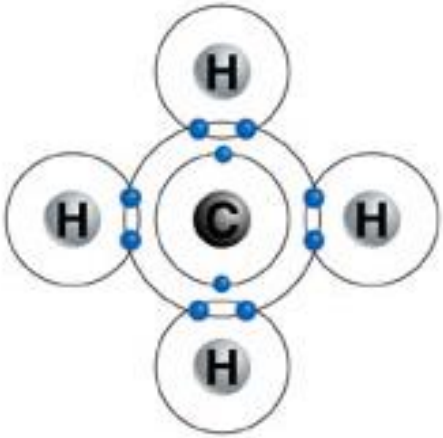
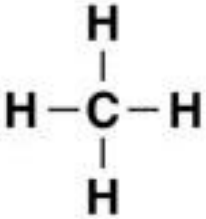


Electron Model	Structural Formula	Molecular Formula
	H – H	H_2

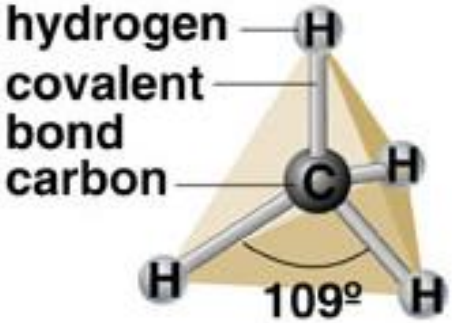
a. Hydrogen gas

	O = O	O_2

b. Oxygen gas

		CH_4

c. Methane

Ball–and–stick Model


Space-filling Model


d. Methane, cont'd.

Types of covalent bonds:

1) Non-polar covalent bond.

2) polar covalent bond.

1) Non-polar covalent bond

- It is a covalent bond in which electrons are shared equally between two atoms.
- Non-polar covalent bonds are formed, when the sharing atoms have the same electronegativity ⇒ so the electrons are shared equally.

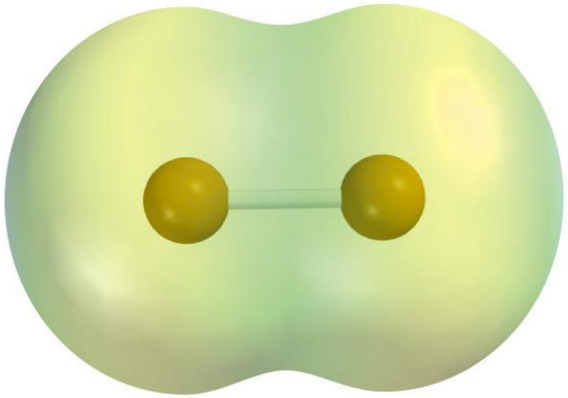
⇒ Electron cloud is not displaced

Example

Covalent bonds that are formed between identical atoms, as in oxygen gas (O_2) and hydrogen gas (H_2), Cl_2

[Since the electrons are equally shared between the two identical atoms, these molecules are said to be nonpolar and the bonds between them are nonpolar covalent bonds].

Cl:Cl A nonpolar covalent bond



2) Polar covalent bond

A type of covalent bond between two different atoms in which electrons are shared unequally. The shared electrons tend to be pulled more toward one atom than the other (because of electronegativity) → and results on partial charges on the atom (i.e one end of the molecule has a slightly negative charge and the other a slightly positive charge.

Example

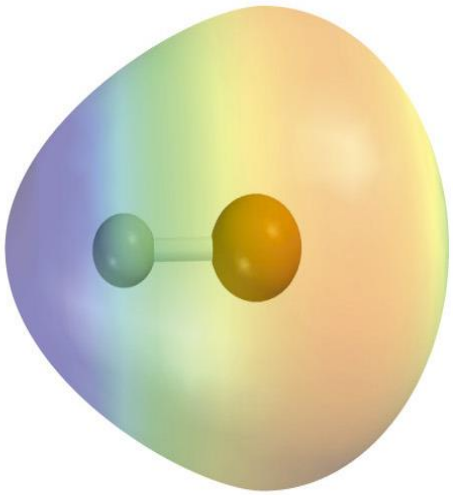
bond between the two atoms H and Cl

$^{\delta+}H - Cl^{\delta-}$

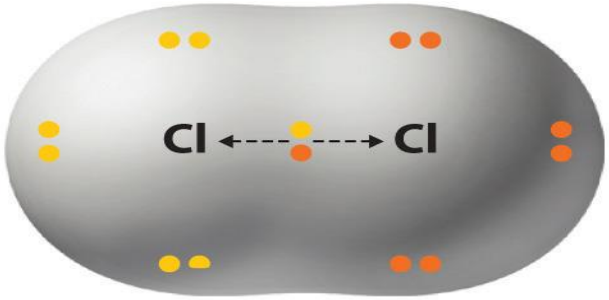
[H :Cl]

A polar covalent bond.

The bonding electrons are attracted more strongly by Cl than by H.



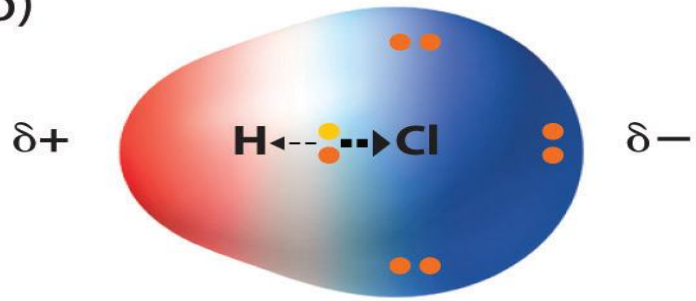
(a)



Nonpolar covalent bond

Bonding electrons shared equally between two atoms. No charges on atoms.

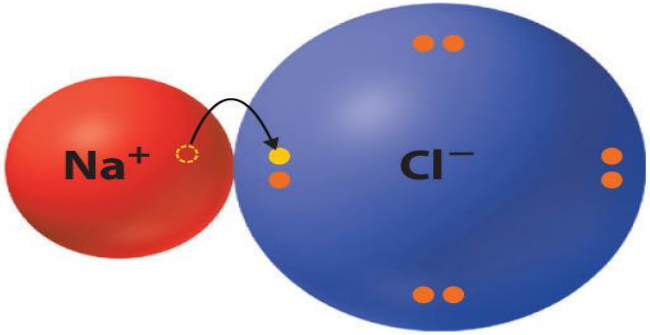
(b)



Polar covalent bond

Bonding electrons shared unequally between two atoms. Partial charges on atoms.

(c)

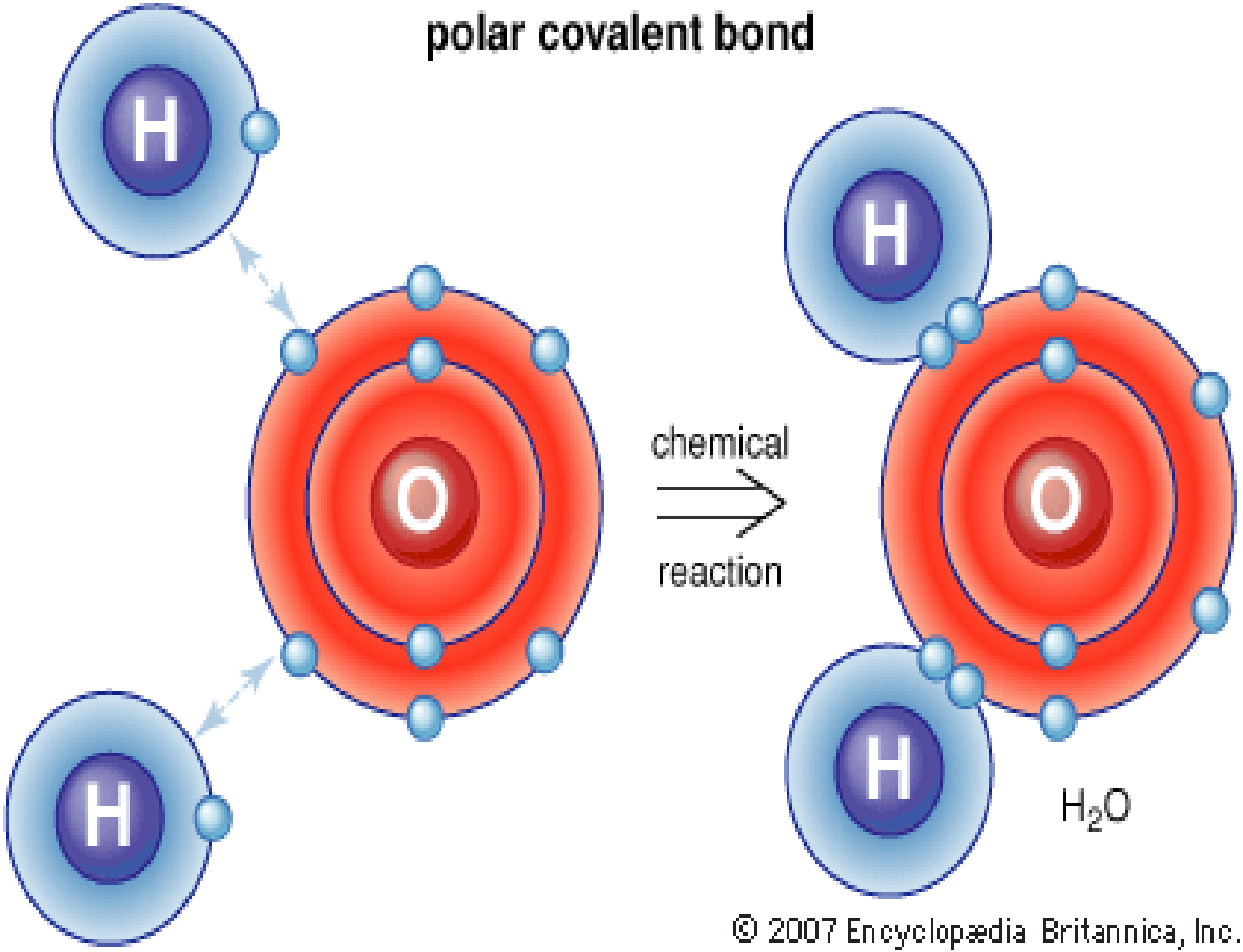


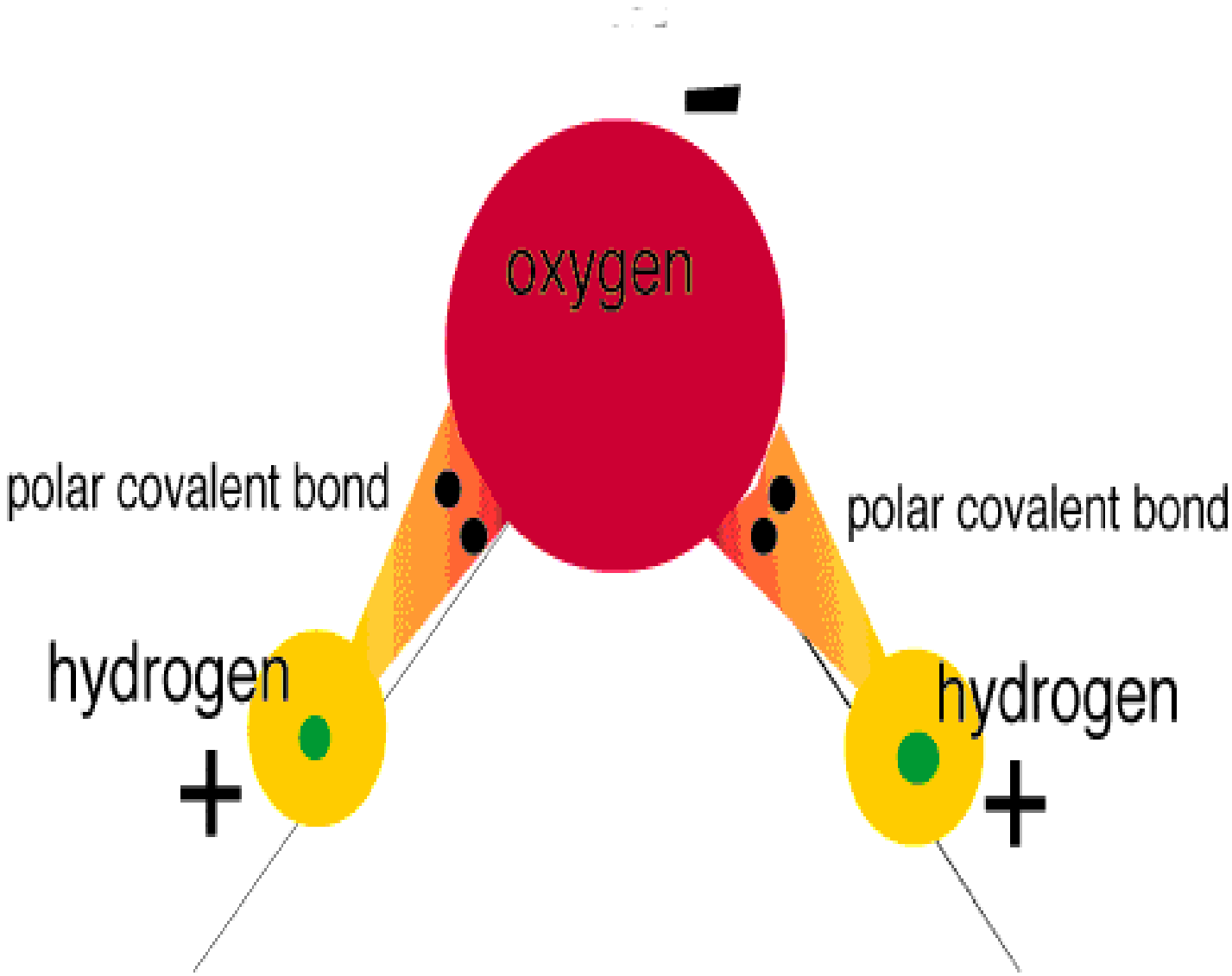
Ionic bond

Complete transfer of one or more valence electrons. Full charges on resulting ions.

Note: **Atoms of oxygen, nitrogen and phosphorus have a particularly strong tendency to pull electrons toward themselves when they bond with other atoms.**

- **Water is the most abundant molecule in the body and serves as the solvent for body fluids.**
- **Water is a good example because it is polar; the oxygen atom pulls electrons from the two hydrogens toward its side of the water molecule, so that the oxygen side is more negatively charged than the hydrogen side of the molecule.**


polar covalent bond
H
O
H
chemical
reaction
H
O
H
H_2O
© 2007 Encyclopædia Britannica, Inc.


oxygen
polar covalent bond
polar covalent bond
hydrogen
hydrogen

Electronegativity and bond type

Electronegativity

- **Electronegativity is a measure of the tendency of an atom to attract a bonding pair of electrons.**
- **The difference in electronegativity's of two elements can be used to predict the nature of the chemical bond.**
  - **If the difference in electronegativity's is between:**

    1.7 to 4.0: Ionic

    0.3 to 1.7: Polar Covalent

    0.0 to 0.3: Non-Polar Covalent

1A	2A											3A	4A	5A	6A	7A
							H 2.1									
Li 1.0	Be 1.5											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0
Na 0.9	Mg 1.2	3B	4B	5B	6B	7B	8B			1B	2B	Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0
K 0.8	Ca 1.0	Sc 1.3	Ti 1.5	V 1.6	Cr 1.6	Mn 1.5	Fe 1.8	Co 1.8	Ni 1.8	Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.4	Nb 1.6	Mo 1.8	Tc 1.9	Ru 2.2	Rh 2.2	Pd 2.2	Ag 1.9	Cd 1.7	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5
Cs 0.7	Ba 0.9	La 1.1	Hf 1.3	Ta 1.5	W 1.7	Re 1.9	Os 2.2	Ir 2.2	Pt 2.2	Au 2.4	Hg 1.9	Tl 1.8	Pb 1.8	Bi 1.9	Po 2.0	At 2.2

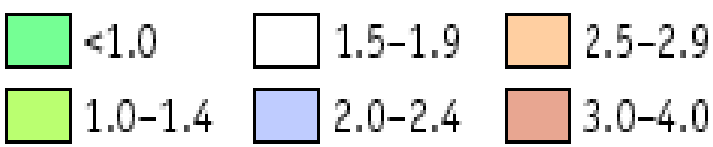


Figure 9.9 Electronegativity values for the elements according to Pauling. Trends for electronegativities are the opposite of the trends defining metallic character. Nonmetals have high values of electronegativity, the metalloids have intermediate values, and the metals have low values.

Example

Na Cl

Na = 0.9, Cl = 3.0

Difference in electronegativity (ΔEN) is 2.1, so

this is an ionic bond

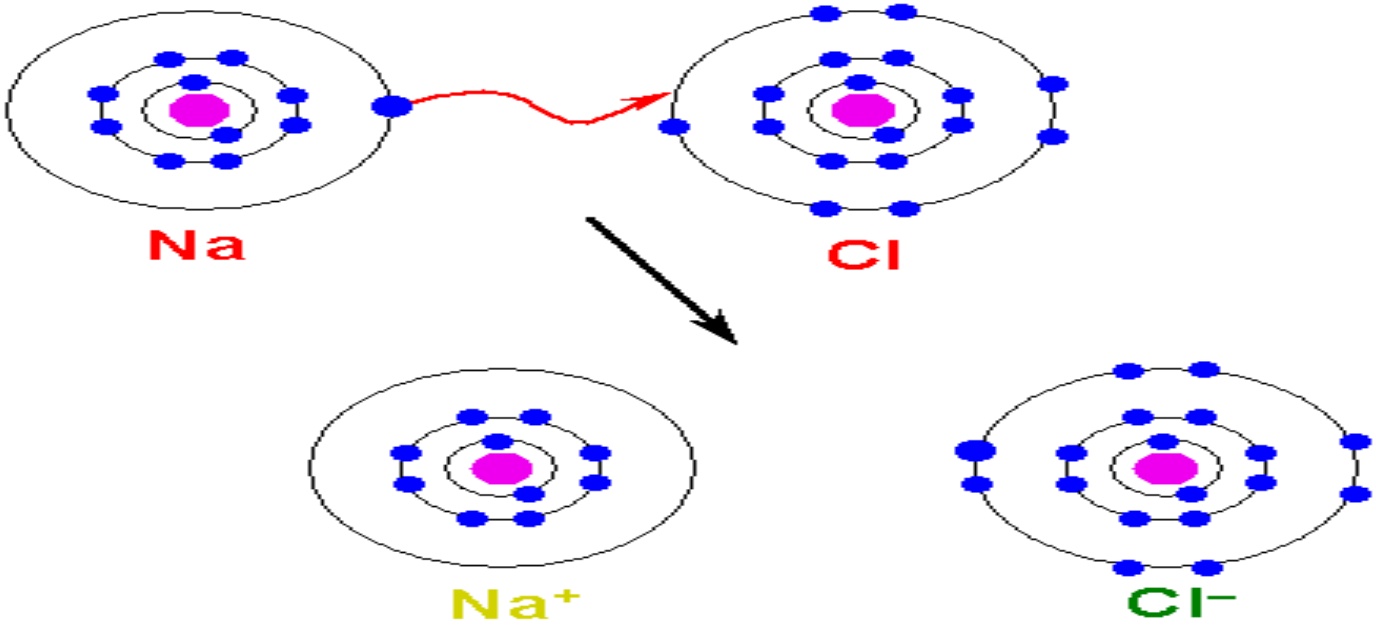
Ionic bond

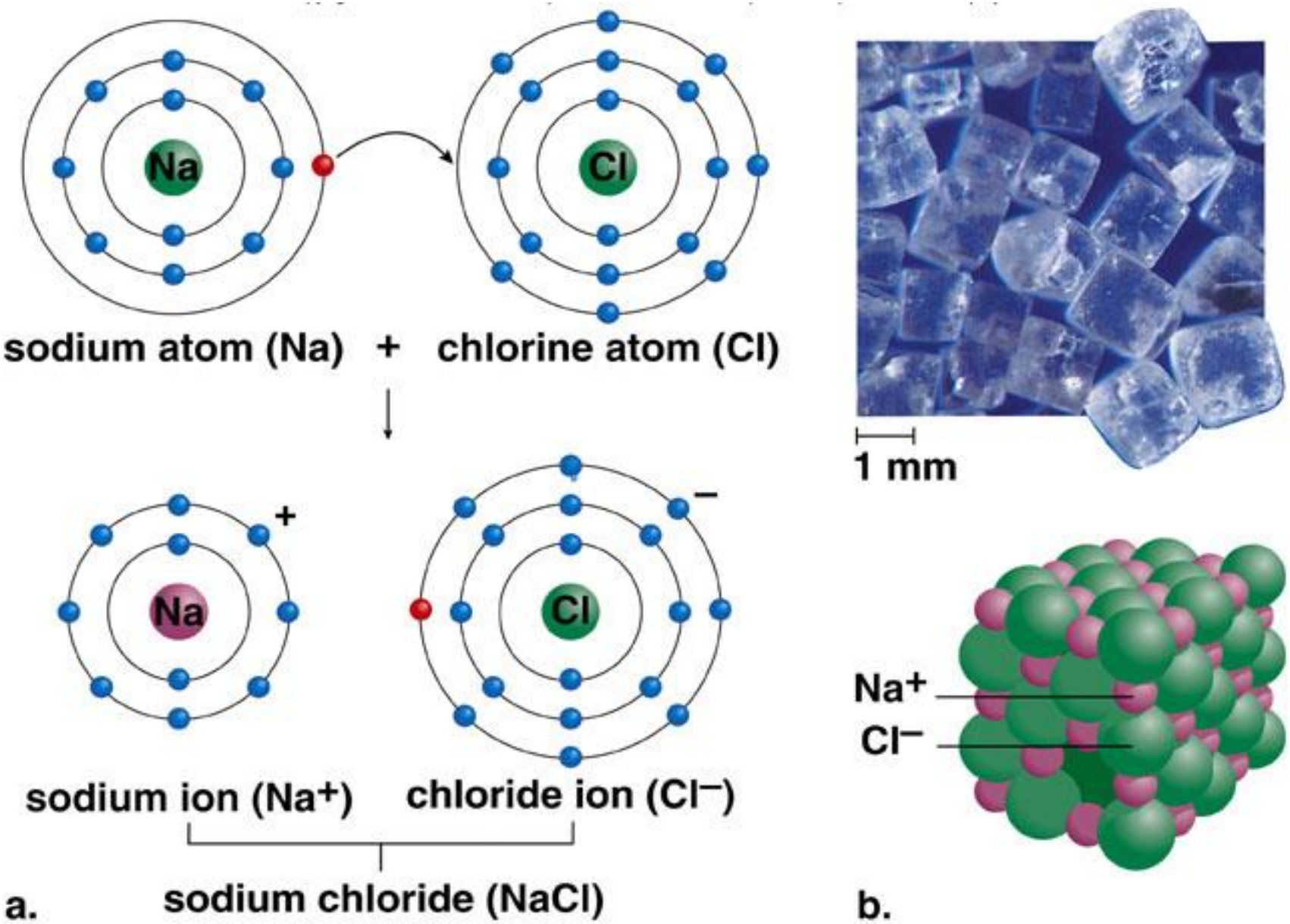
Ionic bond result when one or more valence electrons from one atom are completely transferred to a second atom. Thus, the electrons are not shared at all.

- **The first atom loses electrons → so that its number of electrons become smaller than its number of protons → it becomes a positively charged ion.**
- **The second atom now has more electrons than it has protons → and becomes a negatively charged ion.**

- **Atoms that has positive or negative charges are called ions**
  - **Positively charged ions are called cations.**
  - **Negatively charged ion are called anions.**

Example NaCl




Na
Cl
sodium atom (Na) + chlorine atom (Cl)
+
Na
Cl
−
sodium ion (Na+)
chloride ion (Cl−)
sodium chloride (NaCl)
a.
1 mm
Na+
Cl−
b.

- **The sodium ion and the chloride ion will be attracted to each other and form an ionic bond.**

→ **The ionic bond is due to the attractive forces between the positively charged sodium & the negatively charged chloride.**

→ **Therefore, ionic compounds are usually between metals and nonmetals (opposite ends of the periodic table).**

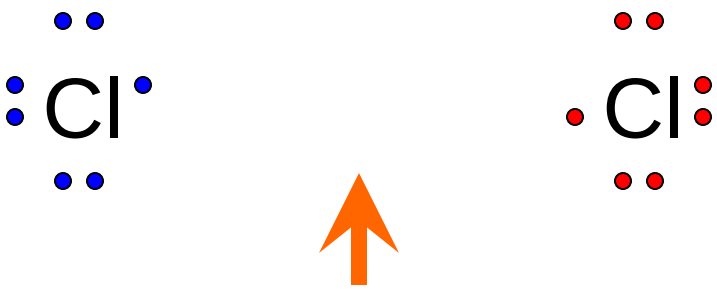
Comparison between ionic and covalent bonds

NaCl This is the formation of an ionic bond.

electron transfer

and the formation of ions

Cl_2 This is the formation of a covalent bond.



sharing of a pair of electrons

and the formation of molecules

Hydrogen bond

- **A hydrogen bond is a type of attractive interaction between an electronegative atom and a hydrogen atom bonded covalently to another electronegative atom.**

Examples

N – H ---------- O=C -

O – H ---------- O=C -

[a chemical bond consisting of a hydrogen atom between two electronegative atoms (e.g., oxygen or nitrogen) with one side be a covalent bond and the other being an ionic Bond]

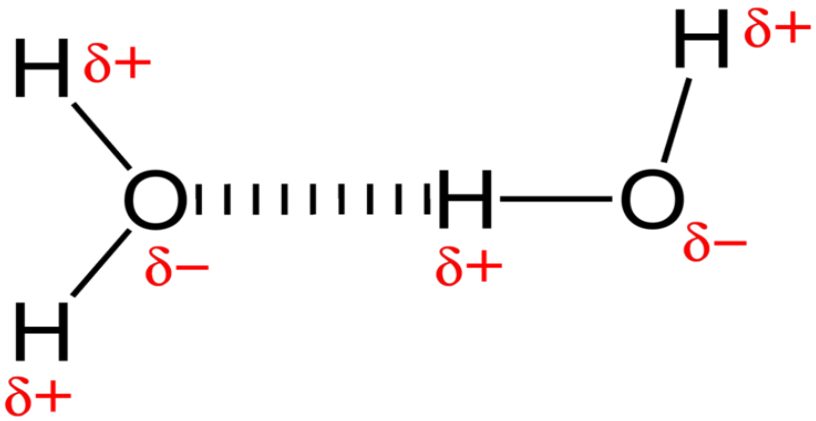
- **This bond always involves a hydrogen atom.**
- **Hydrogen bonds can occur between molecules or within parts of a single molecule. [When a hydrogen atom forms a polar covalent bond with an atom of oxygen or nitrogen, the hydrogen gains a slight positive charge as the electron is pulled towards the other atom. This other atom is thus described as being electronegative. Since the hydrogen has a slight positive charge, it will have a weak attraction for a second electronegative atom (oxygen or nitrogen) that may be located near it. This weak interaction is called a hydrogen bond].**

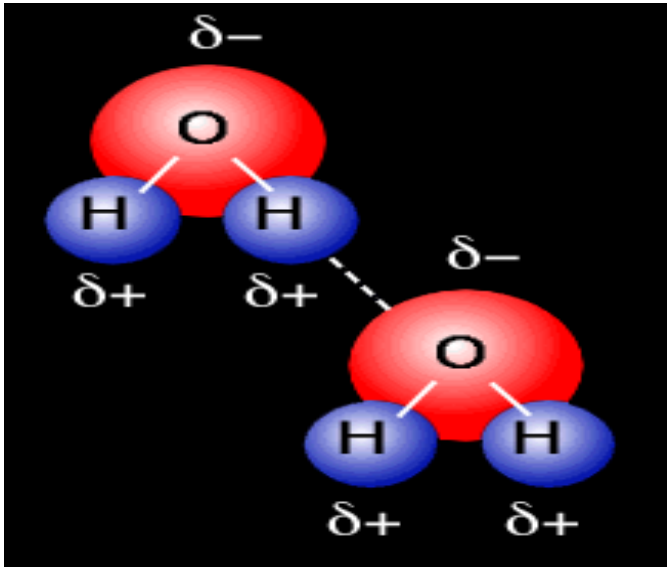
- **A hydrogen bond tends to be stronger than van der Waals forces, but weaker than covalent bonds or ionic bonds.**
- **Although each hydrogen bond is relatively weak, the sum of their attractive forces is largely responsible for:**
  - **The folding and bonding of long organic molecules such as proteins, and for the holding together of the two strands of a DNA molecule**

→ **hydrogen bonds are weak bonds, but there are so many! So, as a collective force, they can be quite strong.**

Example

The hydrogen bonding between water molecules.





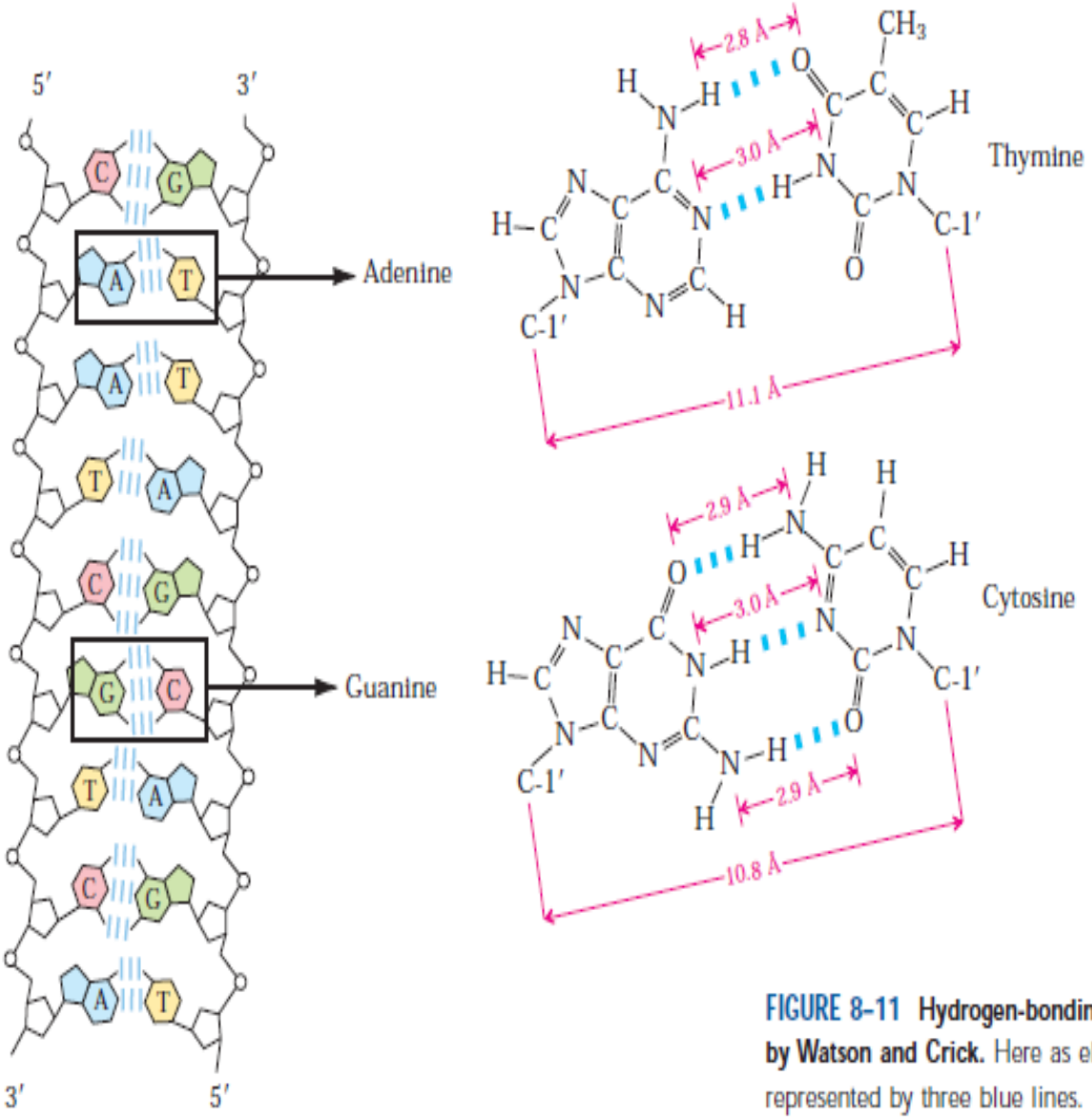


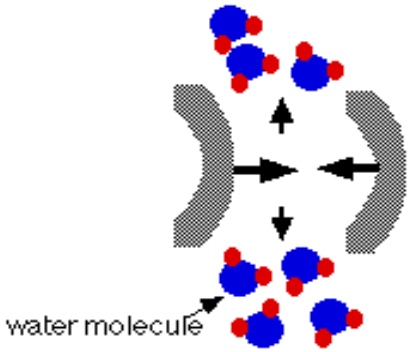
FIGURE 8-11 Hydrogen-bonding patterns in the base pairs defined by Watson and Crick. Here as elsewhere, hydrogen bonds are represented by three blue lines.

Hydrophobic bonds

- **The attraction of hydrophobic (non-polar) molecules (or non-polar parts of molecules) to each other in the presence of water (or another polar fluid).**
- **Hydrophobic (non-polar) molecules do not interact with polar water and cannot form H-bonds.**

➡ **So they interact with each other and repel the water**

(hydro= water; phobic= hating)



Hydrophobic Interactions

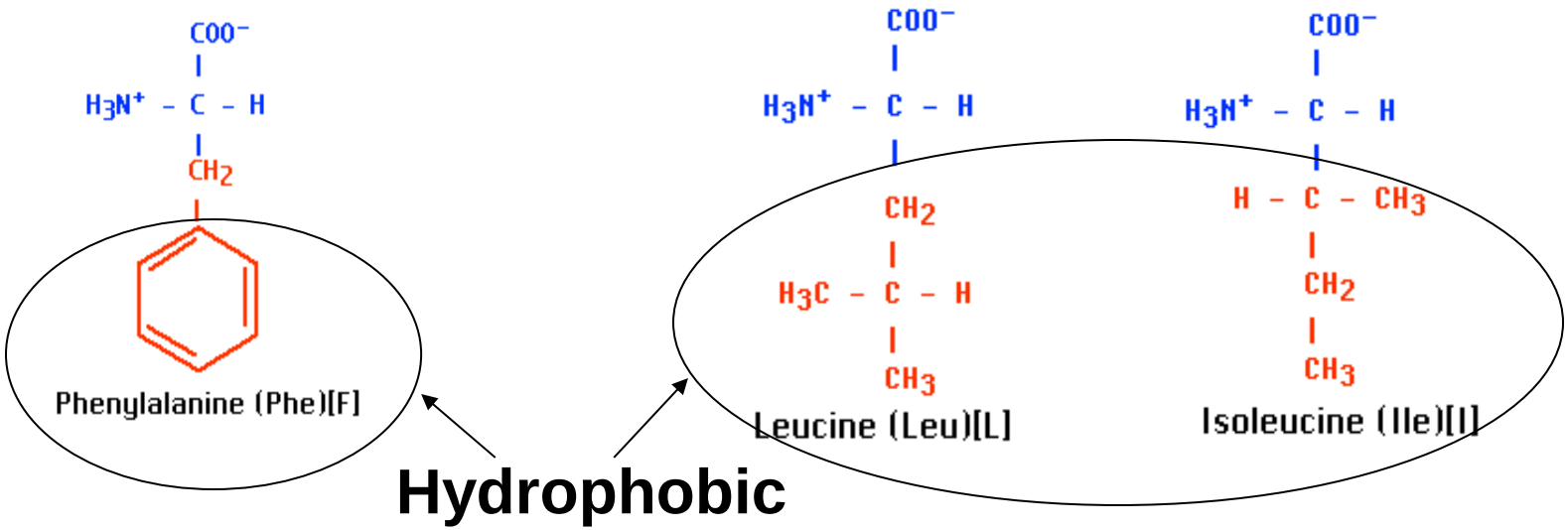
- **Nonpolar molecules (or parts of molecules) will aggregate to avoid water. A similar situation occurs in parts of many proteins.**

Note - Nonpolar dissolves in Nonpolar e.g. oil dissolves in benzene, but not in water.

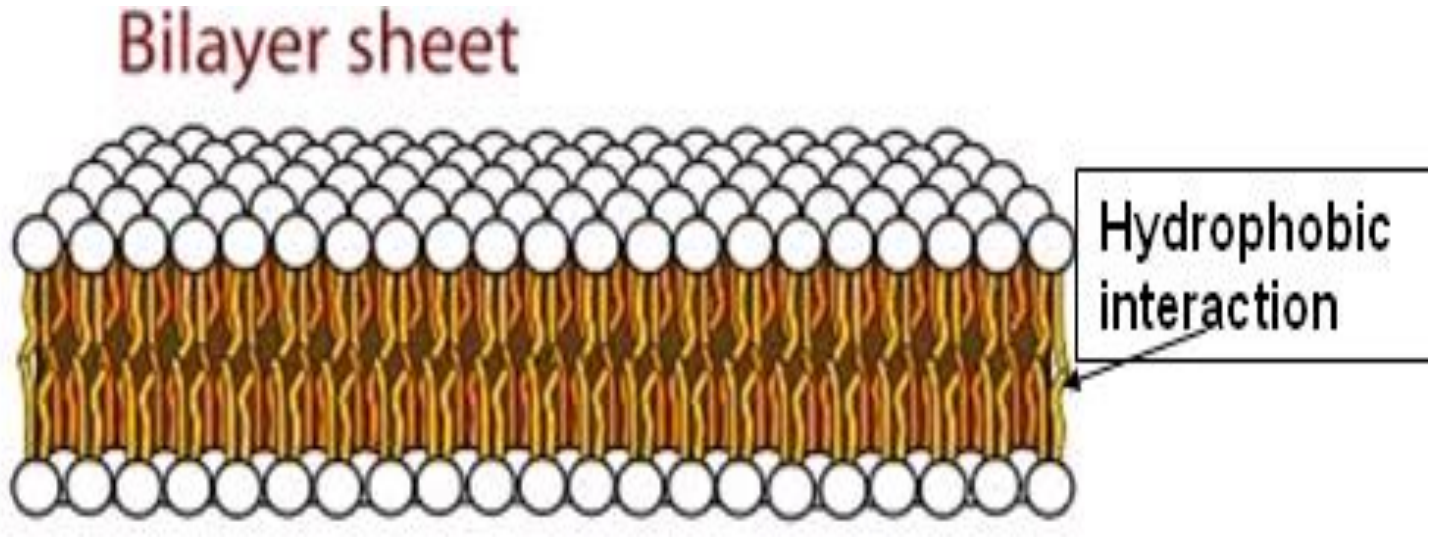
- Polar dissolves in Polar e.g. sugars dissolves in water; NaCl dissolves in water, but not in benzene.

Example

In proteins, the side chains (R groups) of hydrophobic amino acids, such as phenylalanine and leucine are nonpolar

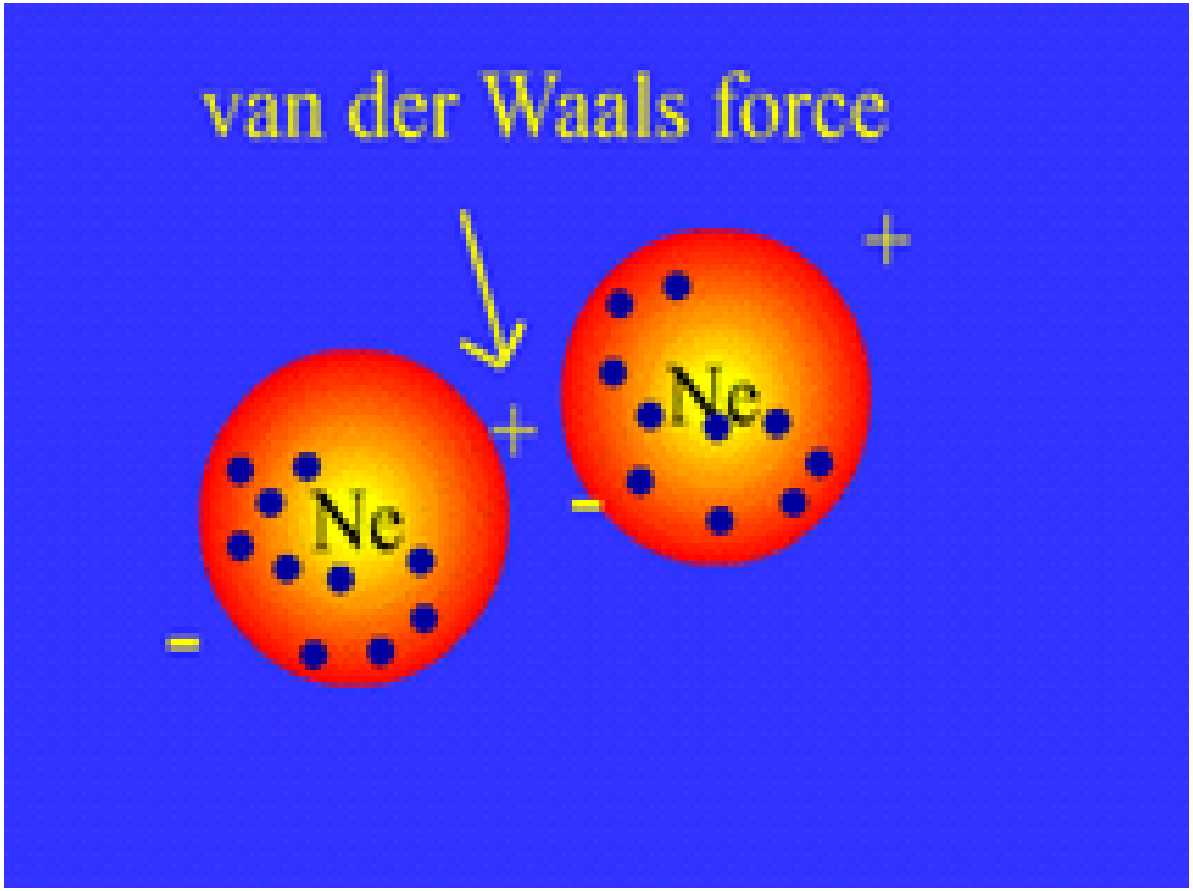


Hydrophobic bonds are very important in the formation of membranes and in enzyme-substrate binding.

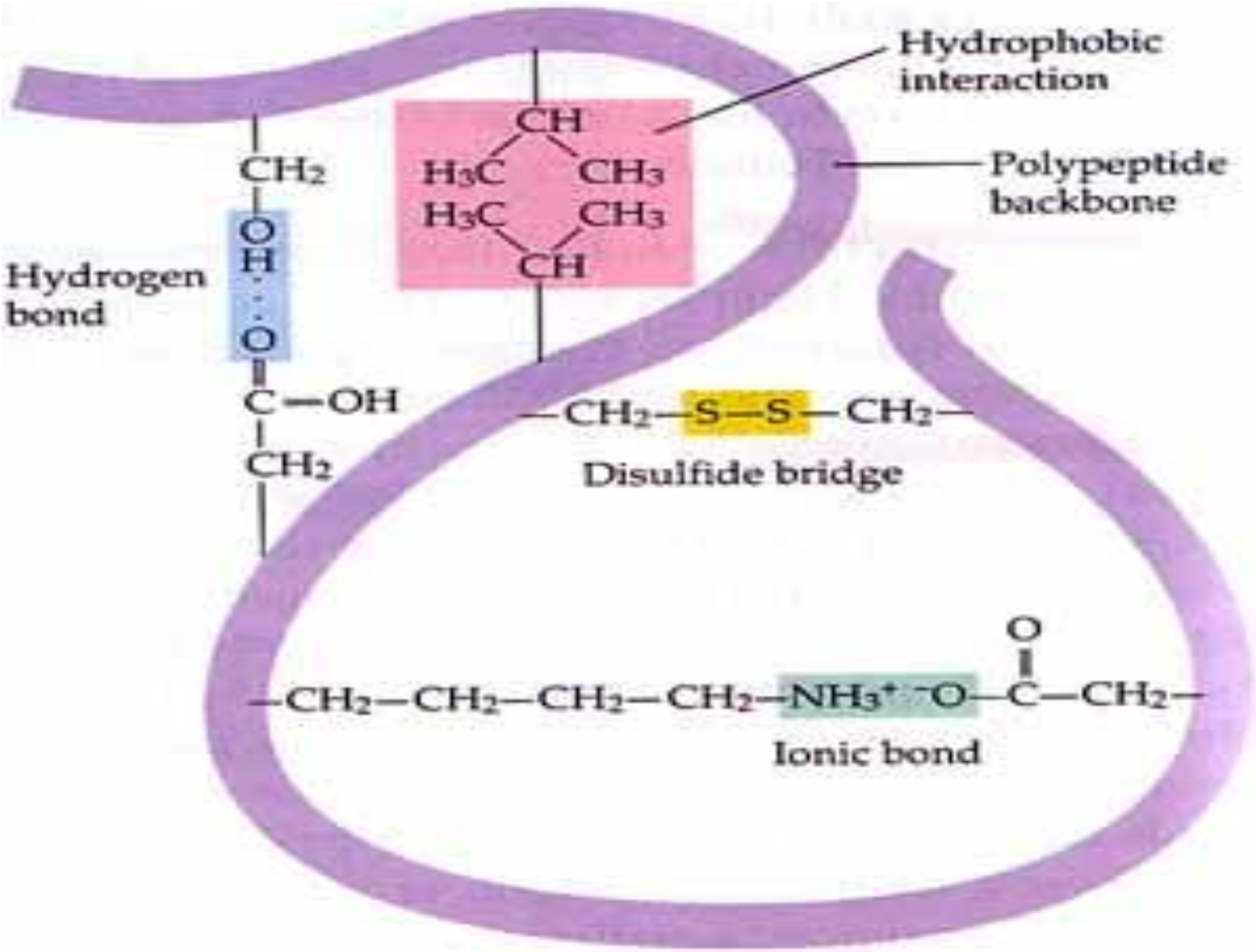


Van der waals force:

- **Attractive force due to fluctuating electrical charges that comes into play between two atoms that are 0.3 – 0.4 nm apart . At a shorter distance repulsive forces begin to separate.**
- **Van der Waals bonds are the weakest of the bonds.**
- **They are caused by small irregularities in the electron clouds around molecules, creating small forces of attraction.**


van der Waals force
Ne
Ne
+
+
–
–

Bonds in proteins



Inter and Intramolecular bonds

Intermolecular bonds: bonds between molecules

Intramolecular bonds: bonds within the same molecule.