UNIT 5: BONDING

CHEMICAL BONDS

A. Definition: A chemical bond is the force holding two atoms together in a chemical compound.

B. Bonds form from the attraction
   1. Between the positive nucleus of one atom and the negative electrons of another, OR
   2. Between a positive ion (cation) and a negative ion (anion).

TYPES OF BONDS

A. Covalent Bonds

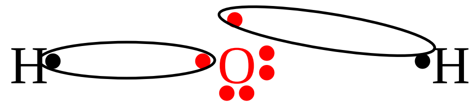
1. Definition: the sharing of electrons between two nonmetals.
2. Electronegativity differences < 1.7 result in covalent bonds.
3. Covalent bonding forms covalent compounds known as molecules. Multiple covalent bonds may form between the same two nonmetal atoms.
   a. One shared pair of electrons forms a single covalent bond.
   b. Two shared pairs of electrons form a double covalent bond.
   c. Three shared pairs of electrons shared form a triple covalent bond.
3. The shared electron pairs complete the outer energy level of both atoms involved; **both** atoms become stable by attaining a noble gas configuration.
4. Diatomic molecules are formed when two atoms of the same element (homonuclear) share electrons. Seven elements exist in nature as diatomic molecules rather than as individual atoms.

H_2 O_2 Br_2 F_2 I_2 N_2 Cl_2

Formation of Covalent Bonds

A. Covalent bonds are formed by the sharing of valence electrons between two nonmetals. The two atoms share an electron pair to attain a stable noble gas configuration.

B. Lewis structures illustrate the lone electrons that are available for sharing as well as the paired electrons that are not and show the formation of covalent bonds.
Example: Draw Lewis dot structures for the atoms below.



- Hydrogen has one valence electron(s) and needs one more to become stable, while oxygen has six valence electron(s) and needs two more to become stable.
- To form water, each atom contributes one electron to the covalent bond, resulting in shared pairs of electrons (circled above).
- In Lewis structures, dashes replace the shared pairs of electrons and represent covalent bonds. H — O — H

Properties of Covalent Compounds

A. Individual particles of covalent compounds are referred to as molecules.

B. Covalent bonds between atoms in molecules are very strong and result from intramolecular forces of attraction.

C. Intermolecular forces (AKA van der Waals forces) are forces of attraction between separate molecules and are weaker than the bonds holding atoms in molecules or ions in ionic compounds.
Examples: London or dispersion forces, dipole-dipole forces, hydrogen bonding

D. The strength of covalent bonds is related to bond length. The shorter the bond length, the stronger the bond.

Type of Bond	# e^- Shared	Bond Length	Bond Strength
Single	2	Longest	Weakest
Double	4	Shorter	Stronger
Triple	6	Shortest	Strongest

E. Many covalent compounds exist as gases or liquids that vaporize readily at room temperature.

F. Most covalent molecules in the solid state are relatively soft and non-crystalline. These molecular solids have relatively low melting and boiling points.

- *Exception*: covalent network solids (quartz or diamond) are similar to ionic compounds

G. Molecules in the solid state form a crystal lattice similar to ionic solids, but there is less attraction between the particles.

H. Covalent molecules are nonelectrolytes, meaning they do not conduct electricity in aqueous solution.

Electronegativity

The difference in electronegativity values for two atoms can be used to predict the nature of the chemical bond. [*Figure 20: Electronegativity Values for Selected Elements, p. 265*]

A. EN difference > 1.7 usually indicates an ionic bond.
   1. Na (EN = 0.93) and Cl (EN = 3.16); EN difference = 2.23

B. 0.4 < EN difference ≤ 1.7 usually forms covalent bonds with some degree of polarity (polar covalent bond).
   1. H (EN = 2.20) and O (EN = 3.44); EN difference = 1.24
   2. C (EN = 2.55) and O (EN = 3.44); EN difference = 0.89

C. EN difference ≤ 0.4 is considered to be a nonpolar covalent bond.
   1. F (EN = 3.98) and F (EN = 3.98); EN difference = 0.00 [diatomic]
   2. N (EN = 3.04) and O (EN = 3.44); EN difference = 0.40

Polarity of Covalent Bonds

A. Covalent bonds can be described as polar or as nonpolar, based on EN differences.

B. Recall the periodic trend for electronegativity: increases L to R and bottom to top; the EN difference between metals and nonmetals is greater than that between two nonmetals.

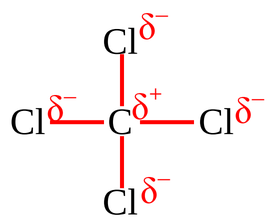
C. The equal sharing of electrons is characteristic of a nonpolar covalent bond, which occurs between atoms with equal or almost equal electronegativity (between two atoms of the same element or two atoms of nonmetals that are very similar in electronegativity).

D. Differences in electronegativity can result in an unequal sharing of electrons in a polar covalent bond. The more electronegative element has a stronger attraction for electrons and leads to a molecule with areas (poles) of partial positive and partial negative charges, indicated by δ^+ and δ^-, respectively. Such molecules are called dipoles or polar covalent molecules.

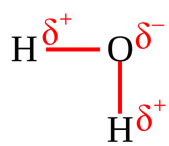
POLARITY OF COVALENT MOLECULES

A. Covalent molecules can also be described as nonpolar or polar.

1. Some nonpolar molecules contain only nonpolar bonds.
    - Diatomic molecules are always formed with nonpolar covalent bonds. The EN difference between two atoms of the same element is always equal to 0. Such molecules are linear in shape.
2. Nonpolar molecules may contain polar bonds, but due to their symmetrical shape, the partial charges are balanced.
    - Carbon tetrachloride consists of one carbon atom bonded to four chlorine atoms. Each carbon-chlorine bond is polar (EN difference = 0.61) with chlorine exerting a stronger attraction for electrons. The molecule, however, is nonpolar due to its symmetrical shape (tetrahedral).



3. Polar molecules contain polar bonds and are asymmetrical in shape. Because the molecule has definite areas of charge, it is a polar molecule, also called a dipole.
    - Water is a polar molecule, with oxygen exerting a stronger attraction for electrons due to its higher electronegativity. The partial negative charge is found on oxygen, and the partial positive charge is found on hydrogen.



    - The shape of a water molecule is described as bent. The electrostatic repulsion between the two lone electrons on the central oxygen atom bends the molecule.

B. The polarity of molecules helps determine the properties of these compounds.

1. Solubility: physical property describing the ability of a substance to dissolve in another substance
   - Solubility is determined by bond type and molecular shape. The basic rule determining solubility is described as *like dissolves like*.
   - Polar and ionic compounds dissolve in polar solvents.
   - Nonpolar molecules will only dissolve in nonpolar solvents.

NAMING COVALENT COMPOUNDS

A. Binary Covalent Compounds

1. Name first element in the formula by simply using element name.
2. The suffix –*ide* is added to the root of the second element.
3. Prefixes are used to indicate the number of atoms of each element as shown by the subscripts in the molecular formula.

# of Atoms	Prefix	# of Atoms	Prefix
1	mono	6	hexa
2	di	7	hepta
3	tri	8	octa
4	tetra	9	nona
5	penta	10	deca

Exceptions:

- *Mono–* is not used for the first element in the formula.
- Drop the final vowel in a prefix when the element name begins with a vowel.

B. Common Names of Molecular Compounds

Formula	Common Name	Molecular Compound Name
H_2O	water	dihydrogen monoxide
NH_3	ammonia	nitrogen trihydride