2.6: Polarity – Bonds and Molecules

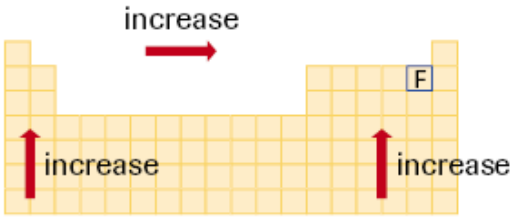
A **polar molecule** is one in which the charge is not distributed symmetrically among the atoms making up the molecule.

Empirical Rules for Polar and Nonpolar Molecules

	Type	Description of molecule	Examples
Polar	AB	diatomic with different atoms	$HCl_{(g)}$, $CO_{(g)}$
	N_xA_y	containing nitrogen and other atoms	$NH_{3(g)}$, $NF_{3(g)}$
	O_xA_y	containing oxygen and other atoms	$H_2O_{(l)}$, $OCl_{2(g)}$
	$C_xA_yB_z$	containing carbon and two other kinds of atoms	$CHCl_{3(l)}$, $C_2H_5OH_{(l)}$
Nonpolar	A_x	all elements	$Cl_{2(g)}$, $N_{2(g)}$
	C_xA_y	containing carbon and only one other kind of atom	$CO_{2(g)}$, $CH_{4(g)}$

Electronegativity and Polarity of Bonds
Linus Pauling saw the need for a theory to explain and predict the polarity of molecules and so combined properties such as bond energies with valence bond theory to create a new property of atoms called **electronegativity**.

Electronegativity of the elements increases as you move up the periodic table and to the right. Fluorine has the highest electronegativity of all atoms.



Polar bond a polar bond results from a difference in electronegativity between the bonding atoms; one end of the bond is, at least partially, positive and the other end is equally negative. Polar bonds are ionic bonds.

Example:

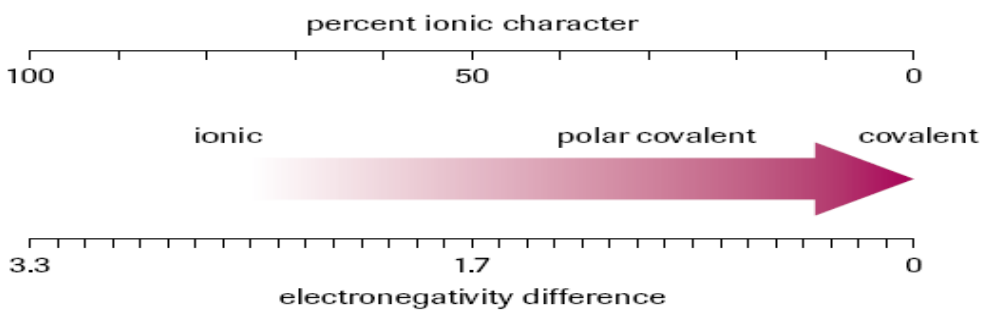
$$\begin{aligned}\Delta EN &= EN_{Cl} - EN_{H}\\ &= 3.0 - 2.1\\ \Delta EN &= 0.9\end{aligned}$$

Table 1 Relationship between Electronegativity Difference and Bond Type

ΔEN	Bond type	Character
<0.5	non-polar covalent	covalent
0.5–1.7	polar covalent	covalent and ionic
>1.7	ionic	ionic

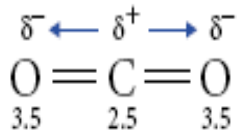
Nonpolar bond a nonpolar bond results from a zero difference in electronegativity between the bonded atoms. Nonpolar bonds are covalent bonds.

A general rule is that when the difference in electronegativity exceeds 1.7, the percent ionic character exceeds 50%.



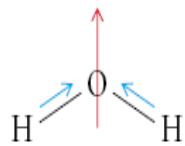
Polar Molecules

The existence of polar bonds in a molecule does not necessarily mean that you have a polar molecule. For example, carbon dioxide is considered to be a nonpolar molecule, although each of the C=O bonds is a polar bond. To resolve this apparent contradiction, we need to look at this molecule more closely. Based on the Lewis structure and the rules of VSEPR, carbon dioxide is a linear molecule. Using electronegativities, we can predict the polarity of each of the bonds. It is customary to show the bond polarity as an arrow, pointing from the positive (δ+) to the negative (δ-) end of the bond. This arrow represents the **bond dipole**.



These arrows are vectors and when added together produce a zero total. In other words, the bond dipoles cancel to produce no polarity for the complete molecule, or a **nonpolar molecule.**

As you know, water is a polar substance and the O-H bonds in water are polar bonds. The Lewis structure and VSEPR rules predict a V-shaped molecule, shown here with its bond dipoles.



In this case, the bond dipoles (vectors) do not cancel. Instead, they add together to produce a non-zero molecular dipole. The water molecule has an overall polarity and that it is why it is a **polar molecule**.

-Both the shape of the molecule and the polarity of the bonds are necessary to determine if a molecule is polar or nonpolar.

- In all symmetrical molecules, the sum of the bond dipoles is zero and the molecule is nonpolar.

Table 1 Types of Molecular Structures with Polar Bonds but No Net Dipole

Type	General example	Cancellation of polar bonds	Specific example	Ball-and-stick model
linear molecules with 2 identical bonds	B—A—B		CO_2	
planar molecules with 3 identical bonds	B, A, B, B, 120°		SO_3	
tetrahedral molecules with 4 identical bonds (109.5° apart)	B, A, B, B, B		CCl_4	

Are NH_3 and CH_4 polar molecules?

Worksheet 2.6: Polarity – Bonds and Molecules

1. Draw the following bonds, label the electronegativities, and label the charges (if any) on the ends of the bond. Classify the bond as ionic, polar covalent, or nonpolar covalent:

a) H - Cl
b) C - H
c) N - O
d) I - Br
e) Mg - S
f) P – H

2. Scientific concepts are tested by their ability to explain current observations and predict future observations. To this end, explain why the following molecules are polar or nonpolar, as indicated by the results of the diagnostic tests.

a) beryllium bromide, $Be_2Br_{(s)}$; nonpolar
b) nitrogen trifluoride, $NF_{3(g)}$; polar
c) methanol, $CH_3OH_{(l)}$; polar
d) hydrogen peroxide, $H_2O_{2(l)}$; nonpolar
e) ethylene glycol, $C_2H_4(OH)_{2(l)}$; nonpolar

3. Predict the polarity of the following molecules. Include shape diagrams and bond dipoles in your reasoning for your prediction.

a) dichlorofluoroethane, $CHFCl_{2(g)}$; a refrigerant (a CFC)
b) ethene, $C_2H_{4(g)}$; monomer of polyethylene
c) chloroethane, $C_2H_5Cl_{(g)}$
d) methylamine, $CH_3NH_{2(g)}$
e) ethanol, $C_2H_5OH_{(l)}$; beverage alcohol
f) diboron tetrafluoride, $B_2F_{4(g)}$