EXPERIMENT # 17
CHEMICAL BONDING AND MOLECULAR POLARITY

Purpose:

1. To distinguish between different types of chemical bonds.
2. To predict the polarity of some common molecules from a knowledge of bond polarity and molecular geometry.

Principals:

Isolated atoms are seldom found as such in nature because the majority of atoms are too reactive to exist by themselves. In most substances, atoms are joined together by strong forces called chemical bonds.

The way atoms form these chemical bonds is related to their electronic structures and the kind of bonds that exist within compounds is the principal factor determining the chemical properties of these compounds. In binary ionic compounds the two atoms involved in a given ionic bond are a metal and a nonmetal. These atoms are quite different but are complementary to each other; the metallic atom likes to lose electrons and the nonmetallic atom likes to gain electrons. The net result is an electron transfer from the metallic to the nonmetallic atom.

Covalent bonds resulting from electron sharing are formed between similar or identical atoms. In electron sharing, two nuclei attract the same electrons and the resulting attractive forces hold the two nuclei together.

An ionic bond is one where the electrons have transferred from one element to another.

At first glance, the ionic and covalent bonds seem to represent distinctively different forms of bonding. Actually the two bonds are the extremes of a broad continuum of bonding patterns. The relationship between the two bonding models is apparent when the concept of electronegativity is considered. Electronegativity is a measure of the relative attraction an atom has for the shared electrons in a bond.

The higher the electronegativity value for an element is, the greater the electron-attracting ability of the atom for the shared electrons. The difference in the electronegativity values of the atoms in a bond is the key to predicting the polarity of that bond. Polarity is a measure of the inequality in the sharing of bonding electrons.

When two identical atoms (atoms of equal electronegativity) share one or more pairs of electrons, each atom exerts the same attraction for the electrons, which results in the electrons being shared equally. This type of bond is called a nonpolar covalent bond.

A nonpolar covalent bond is one in which the sharing of bonding electrons is equal.

When two atoms involved in a cova1ent bond are not identical (atoms of different electronegativities) the atom that has higher electronegativity attracts the electrons more strongly than the other atom; this results in unequal sharing of electrons. This type of bond is called a polar covalent bond.

A polar covalent bond is one in which the sharing of bonding electrons is unequal.

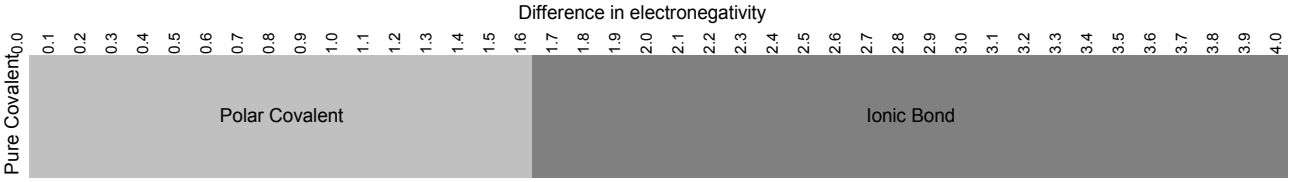
It follows that most chemical bonds are neither 100% covalent (equal sharing) nor 100% ionic (no sharing); instead, they fall somewhere in between (unequal sharing.)

It is still convenient to use the terms ionic and covalent in describing chemical bonds, based on the following guidelines:

1. When there is no difference in electronegativity between bonded atoms, the bond is called a nonpolar covalent bond.

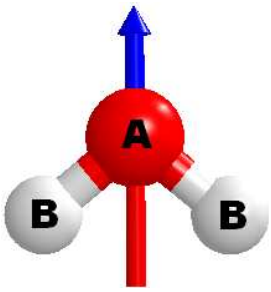
2. When the electronegativity difference between bonded atoms is greater than zero but less than 1.7, the bond is called a polar covalent bond.

3. When the difference in electronegativity between bonded atoms is 1.7 or greater, the bond is called an ionic bond.



When there are three or more atoms bonded together, **it is possible to have a nonpolar molecule even though there are polar bonds present.** When a molecule contains more than two atoms, we must consider its geometry to decide whether it is polar molecule or not.

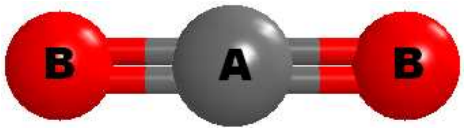
Consider as a simple example, a molecule AB_2. Suppose the central atom, A, is more electronegative than B. Two geometries are possible, bent and linear:



bent, polar

In this molecule the negative pole is located at the central atom, A, and the positive pole is midway between the two B atoms.

Polar bonds → Polar molecule (unsymmetrical arrangement)



linear, nonpolar

The two polar bonds are in exactly opposite directions, at a 180% angle to each other. The two individual bond polarities cancel each other.

Polar bonds → Nonpolar molecule (symmetrical arrangement)

In predicting the polarity of molecules, the following generalizations might prove useful:

1. Molecules containing identical atoms are always non-polar.
2. Molecules containing unlike atoms are:
    a. nonpolar, if the arrangement of the atoms is symmetrical
    b. polar, if the arrangement of the atoms is nonsymmetrical

Procedure:

1. Assemble the first set of seven models of molecules.

    a. Use the following colors to represent the atoms:

H = yellow	F = purple	Br = orange	I = purple	N = blue
Cl = green	O = red	C = black	S = red	

    b. Use a set of spring connectors for multiple bonds.

    c. Evaluate the bond type, note the molecular shape and predict if the molecule is a polar molecule or not.

2. Assemble the second set of seven molecules.

    a. Evaluate the bond types, note the molecular shape and predict if the molecule is polar is not.

    b. If the molecule contains more than one type of bond (three different atoms), each bond should be evaluated individually in order to predict if the molecule is polar or not.

3. Take the models apart and place the balls and the connectors in the kit in the same order you have found them at the beginning of the laboratory period.

Δ Electronegativity	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2
Percent ionic character	0.5	1	2	4	6	9	12	15	19	22	26	30	34	39	43	47	51	55	59	63	67	70	74	77	79	82	84	88	89	91	92	95

1	H 2.20																															He
2	Li 0.98	Be 1.57																				B 2.04	C 2.55	N 3.04	O 3.44	F 3.98						Ne
3	Na 0.93	Mg 1.31																				Al 1.61	Si 1.90	P 2.19	S 2.58	Cl 3.16						Ar
4	K 0.82	Ca 1.00	Sc 1.36	Ti 1.54	V 1.63	Cr 1.66	Mn 1.55	Fe 1.83	Co 1.88	Ni 1.91	Cu 1.90	Zn 1.65	Ga 1.81	Ge 2.01	As 2.18	Se 2.55	Br 2.96	Kr 3.00														
5	Rb 0.82	Sr 0.95	Y 1.22	Zr 1.33	Nb 1.6	Mo 2.16	Tc 1.9	Ru 2.2	Rh 2.28	Pd 2.20	Ag 1.93	Cd 1.69	In 1.78	Sn 1.96	Sb 2.05	Te 2.1	I 2.66	Xe 2.60														
6	Cs 0.79	Ba 0.89	*	Hf 1.3	Ta 1.5	W 2.36	Re 1.9	Os 2.2	Ir 2.20	Pt 2.28	Au 2.54	Hg 2.00	Tl 1.62	Pb 2.33	Bi 2.02	Po 2.0	At 2.2	Rn 2.2														
7	Fr 0.7	Ra 0.9	**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Uuq	Uup	Uuh	Uus	Uuo														
Lanthanoids	*	La 1.1	Ce 1.12	Pr 1.13	Nd 1.14	Pm 1.13	Sm 1.17	Eu 1.2	Gd 1.2	Tb 1.1	Dy 1.22	Ho 1.23	Er 1.24	Tm 1.25	Yb 1.1	Lu 1.27																		
Actinoids	**	Ac 1.1	Th 1.3	Pa 1.5	U 1.38	Np 1.36	Pu 1.28	Am 1.13	Cm 1.28	Bk 1.3	Cf 1.3	Es 1.3	Fm 1.3	Md 1.3	No 1.3	Lr 1.3																		

EXPERIMENT #17

Name: _____

Date: _____

Partner: _____

Set 1

Formula	Electron Dot Formula	Bond Type	Shape of Molecule	Kind of Molecule
H_2		❑ Polar ❑ Nonpolar	❑ linear ❑ bent ❑ pyramidal ❑ tetrahedral	❑ Polar ❑ Nonpolar
F_2		❑ Polar ❑ Nonpolar	❑ linear ❑ bent ❑ pyramidal ❑ tetrahedral	❑ Polar ❑ Nonpolar
Br_2		❑ Polar ❑ Nonpolar	❑ linear ❑ bent ❑ pyramidal ❑ tetrahedral	❑ Polar ❑ Nonpolar
I_2		❑ Polar ❑ Nonpolar	❑ linear ❑ bent ❑ pyramidal ❑ tetrahedral	❑ Polar ❑ Nonpolar
N_2		❑ Polar ❑ Nonpolar	❑ linear ❑ bent ❑ pyramidal ❑ tetrahedral	❑ Polar ❑ Nonpolar
Cl_2		❑ Polar ❑ Nonpolar	❑ linear ❑ bent ❑ pyramidal ❑ tetrahedral	❑ Polar ❑ Nonpolar
HCl		❑ Polar ❑ Nonpolar	❑ linear ❑ bent ❑ pyramidal ❑ tetrahedral	❑ Polar ❑ Nonpolar
HBr		❑ Polar ❑ Nonpolar	❑ linear ❑ bent ❑ pyramidal ❑ tetrahedral	❑ Polar ❑ Nonpolar
BrCl		❑ Polar ❑ Nonpolar	❑ linear ❑ bent ❑ pyramidal ❑ tetrahedral	❑ Polar ❑ Nonpolar

Formula	Electron Dot Formula	Bond Type	Shape of Molecule	Kind of Molecule
H_2O		❑ Polar ❑ Nonpolar	❑ linear ❑ bent ❑ pyramidal ❑ tetrahedral	❑ Polar ❑ Nonpolar
CO_2		❑ Polar ❑ Nonpolar	❑ linear ❑ bent ❑ pyramidal ❑ tetrahedral	❑ Polar ❑ Nonpolar
H_2S		❑ Polar ❑ Nonpolar	❑ linear ❑ bent ❑ pyramidal ❑ tetrahedral	❑ Polar ❑ Nonpolar
NH_3		❑ Polar ❑ Nonpolar	❑ linear ❑ bent ❑ pyramidal ❑ tetrahedral	❑ Polar ❑ Nonpolar
NCl_3		❑ Polar ❑ Nonpolar	❑ linear ❑ bent ❑ pyramidal ❑ tetrahedral	❑ Polar ❑ Nonpolar
CCl_4		❑ Polar ❑ Nonpolar	❑ linear ❑ bent ❑ pyramidal ❑ tetrahedral	❑ Polar ❑ Nonpolar
CH_3Cl		❑ Polar ❑ Nonpolar	❑ linear ❑ bent ❑ pyramidal ❑ tetrahedral	❑ Polar ❑ Nonpolar
CH_2Cl_2		❑ Polar ❑ Nonpolar	❑ linear ❑ bent ❑ pyramidal ❑ tetrahedral	❑ Polar ❑ Nonpolar
$CHCl_3$		❑ Polar ❑ Nonpolar	❑ linear ❑ bent ❑ pyramidal ❑ tetrahedral	❑ Polar ❑ Nonpolar
CH_3Br		❑ Polar ❑ Nonpolar	❑ linear ❑ bent ❑ pyramidal ❑ tetrahedral	❑ Polar ❑ Nonpolar

Questions:

1. Calculate the electronegativity difference and the percentage ionic character for each of the following bonds:

Bond	Electronegativity difference	Percentage of ionic character
H-O		
H-N		
H-Cl		
Br-Cl		
H-S		
H-C		
Cl-Cl		
C-O		
K-Br		
Na-O		

2. Classify each of following molecules

Br_2	❑ ionic crystal ❑ polar covalent ❑ nonpolar covalent	MgS	❑ ionic crystal ❑ polar covalent ❑ nonpolar covalent	MgO	❑ ionic crystal ❑ polar covalent ❑ nonpolar covalent
CCl_4	❑ ionic crystal ❑ polar covalent ❑ nonpolar covalent	BeO	❑ ionic crystal ❑ polar covalent ❑ nonpolar covalent	HI	❑ ionic crystal ❑ polar covalent ❑ nonpolar covalent
CO_2	❑ ionic crystal ❑ polar covalent ❑ nonpolar covalent	H_2O	❑ ionic crystal ❑ polar covalent ❑ nonpolar covalent	N_2	❑ ionic crystal ❑ polar covalent ❑ nonpolar covalent
BaO	❑ ionic crystal ❑ polar covalent ❑ nonpolar covalent	AlN	❑ ionic crystal ❑ polar covalent ❑ nonpolar covalent	CaO	❑ ionic crystal ❑ polar covalent ❑ nonpolar covalent
KCl	❑ ionic crystal ❑ polar covalent ❑ nonpolar covalent	LiBr	❑ ionic crystal ❑ polar covalent ❑ nonpolar covalent	CO	❑ ionic crystal ❑ polar covalent ❑ nonpolar covalent

3. Both water and carbon dioxide are tri-atomic molecules. Explain why one of these is polar and the other is nonpolar.