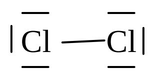
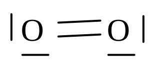
AP Chemistry
Unit 2- Homework Problems
Covalent Bonding, Molecular Geometry, & IMFs

Lewis Dot Structure

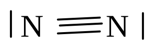
1. What kind of atoms are involved in a covalent bond? Non-metals
2. What do these atoms do with their electrons to become stable? Share electrons
3. What is the octet rule? Most atoms need 8 electrons to become stable
4. Draw the Lewis Dot Structure for each of the following simple molecules:
   a. Cl_2



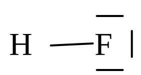
   b. O_2



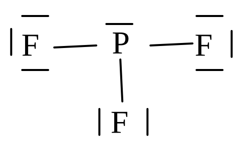
   c. N_2



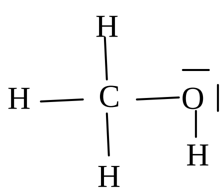
   d. HF



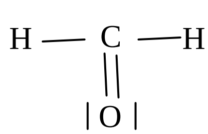
   e. PF_3



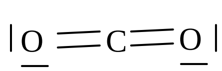
   f. H_3COH



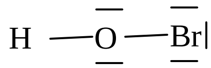
   g. H_2CO



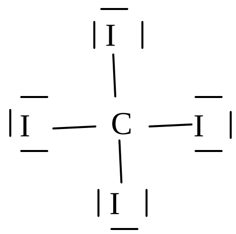
   h. CO_2



i. HOBr

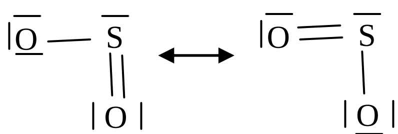


j. CI_4

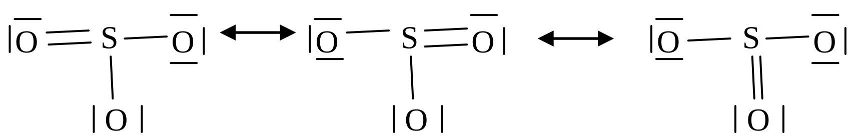


5. What is the formal charge of each of the atoms in #4? 0
6. What is a resonance structure? The possible structures of a molecule for which more than one Lewis structure can be written, differing by the number of bond pairs between a give pair of atoms
7. Draw the Lewis Dot Structure for each of the resonance structure below:

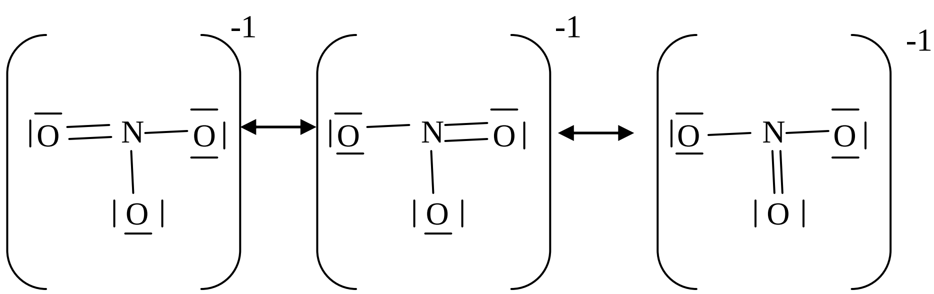
a. SO_2



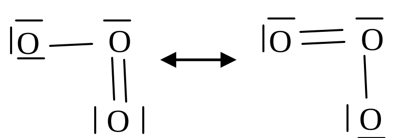
b. SO_3



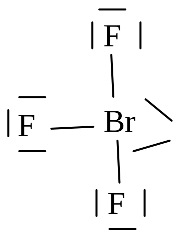
c. NO_3^{-1}



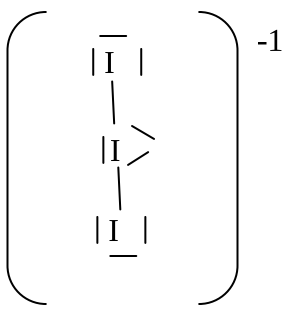
d. O_3



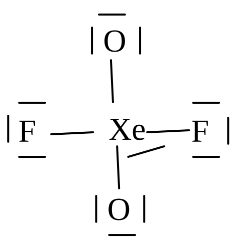
8. What is the bond order of each of the atoms in #7?
   a. SO_2 = 1.5
   b. SO_3 = 1.33
   c. NO_3^{-1} = 1.33
   d. O_3= 1.5
9. Which atoms can have an extended valence? Why? Any atom with n greater than or equal to 3. They have available d orbitals that are often not being used for bonding so can have >4 bonds.
10. Draw the Lewis Dot structure for each of the following expanded valence substances:
   a. BrF_3



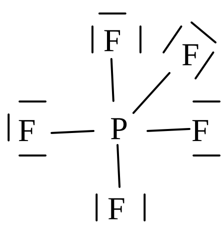
   b. I_3^{-1}



   c. XeO_2F_2

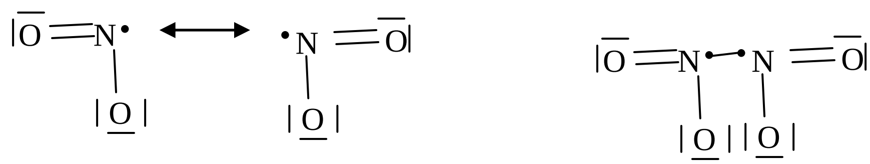


   d. PF_5



11. Why do B compounds often have less than a full octet? It is a non-metal that only brings 3 electrons to a covalent bond

12. What is a coordinate covalent compound and why do B compounds often make them? A bond where both electrons have come from the same atom. B has less than an octet so aggressively grabs lone pairs from other atoms.
13. What is a dimer? A molecule where 2 of the same molecules bond together to form a new molecule.
14. What is the Lewis Dot Structure of NO_2? Show how NO_2 makes a dimer.



15. What is bond order? The number of bonds being shared between the number of bonding sites
16. How does bond length relate to bond order? As bond order increases, bond length decreases
17. How does bond strength relate to bond order? As bond order increases, bond strength increases
18. Put the following N---O bonds in order of increasing bond length: NO_3^{-1}, NO_2^{+1}, NO_2^{-1}
$NO_2^{+1} < NO_2^{-1} < NO_3^{-1}$
19. Put the following N---O bonds in order of increasing bond strength: NO_3^{-1}, NO_2^{+1}, NO_2^{-1}
$NO_3^{-1} < NO_2^{-1} < NO_2^{+1}$

Covalent Naming

1. Name the following covalent compounds:
   a. CO_2 carbon dioxide
   b. N_2O_5 dinitrogen pentoxide
   c. N_2O dinitrogen monoxide
   d. SF_6 sulfur hexafluoride
   e. BrF_3 bromine trifluoride
2. What is the formula for the following covalent compounds:
   a. Sulfur tetrafluoride SF_4
   b. Boron trichloride BCl_3
   c. Dinitrogen trioxide N_2O_3
   d. Carbon disulfide CS_2
   e. Phosphorous pentiodide PI_5
3. Why are prefixes used in covalent compounds and not in ionic compounds? Ionic compounds are simply repeating crystals of the empirical formula only. Covalent compounds are molecular in nature which means that they exist in different forms of the same empirical ratio.

4. What is the difference between a molecular substance and an ionic crystal? Molecules are discrete combinations of atoms that have a definite beginning and end. Crystals repeat the same empirical ratio over and over in 3d.

Molecular Formulas & Calculations

1. A substance is 94.4% C and 5.6% H and has a mass of 178 g/mole. What are the empirical and molecular formulas of the compound?

   94.4 g C *(1mole/12 g) = 7.87 moles C

   5.6 g H *(1 mole/1 g) = 5.6 moles H

   Empirical: $C_{1.4}H_1$ or C_7H_5 = 89 g/mole

   since molecular has a mass of 178 g/mole

   Molecular: $C_{14}H_{10}$

2. A substance is 75.5% C, 4.4% H, and 20.1% O and has a mass of 318 g/mole. What are the empirical and molecular formulas of the compound?

   75.5 g C *(1mole/12 g) = 6.29 moles C

   4.4 g H *(1 mole/1 g) = 4.4 moles H

   20.1 g O *(1 mole/16 g) = 1.256 moles O

   Empirical: $C_5H_{3.5}O_1$ or $C_{10}H_7O_2$ = 159 g/mole

   since molecular has a mass of 318 g/mole

   Molecular: $C_{20}H_{14}O_2$

3. A hydrocarbon C_xH_y is burned. If 2 grams of it is burned and 6.29 g CO_2 and 2.57 g H_2O are made, what is the empirical formula? If the substance actually has a mass of 56 g/mole, what is the molecular formula?

   6.29 g CO_2*(1 mole/44g) = 0.143 moles CO_2 = 0.143 moles C

   2.57 g H_2O*(1 mole/18 g) = 0.143 moles H_2O = 0.286 moles H

   Empirical: CH_2 = 14 g/mole

   Molecular: 56 g/mole/14 g/mole = 4 so **C_4H_8**

4. A hydrocarbon C_xH_y is burned. If 5 grams of it is burned and 8.59 g CO_2 and 2.815 g H_2O are made, what is the empirical formula? If the substance actually has a mass of 136 g/mole, what is the molecular formula?

   8.59 g CO_2*(1 mole/44g) = 0.1952 moles CO_2 = 0.1952 moles C

   2.815 g H_2O*(1 mole/18 g) = 0.1564 moles H_2O = 0.3128 moles H

   Empirical: $C_1H_{1.6}$ = C_5H_8 = 68 g/mole

   Molecular: 136 g/mole/68 g/mole = 2 so **$C_{10}H_{16}$**

5. A hydrocarbon $C_xH_yO_z$ is burned. If 8 grams of it is burned and 15.998 g CO_2 and 6.545 g H_2O are made, what is the empirical formula? If the substance actually has a mass of 88 g/mole what is the molecular formula?

   15.998 g CO_2*(1 mole/44g) = 0.3636 moles CO_2 = 0.3636 moles C
   6.545 g H_2O*(1 mole/18 g) = 0.3636 moles H_2O = 0.7272 moles H

   0.3636 moles C *(12 g/mole) = 4.363 g C
   0.7272 moles H *(1 g/mole) = 0.7272 g H

   8 g CHO – 4.363 g C – 0.7272 g H = 2.9098 g O

   2.9098 g O *(1 mole/16 g) = 0.1819 moles O

   Empirical: $C_2H_4O_1$ = 44 g/mole
   Molecular: 88 g/mole/44 g/mole = 2 so **$C_4H_8O_2$**

6. A hydrocarbon $C_xH_yO_z$ is burned. If 0.25 grams of it is burned and 0.60 g CO_2 and 0.1226 g H_2O are made, what is the empirical formula? If the substance actually has a mass of 110 g/mole what is the molecular formula?

   0.60 g CO_2*(1 mole/44g) = 0.01364 moles CO_2 = 0.01364 moles C
   0.1226 g H_2O*(1 mole/18 g) = 0.00681 moles H_2O = 0.01362 moles H

   0.01364 moles C *(12 g/mole) = 0.16368 g C
   0.01362 moles H *(1 g/mole) = 0.01362 g H

   0.25 g CHO – 0.16368 g C – 0.01362 g H = 0.0727 g O

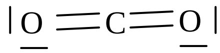
   0.0727 g O *(1 mole/16 g) = 0.004544 moles O

   Empirical: $C_3H_3O_1$ = 55 g/mole
   Molecular: 110 g/mole/55 g/mole = 2 so **$C_6H_6O_2$**

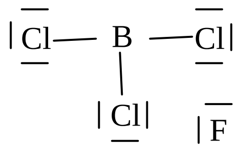
Molecular Geometry, Hybridization, & Polarity

1. For each substance below, draw the Lewis Dot Structure, give the base (electron pair) geometry and the actual (molecular) geometry:

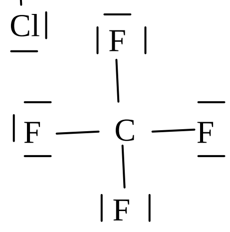
   a. CO_2 Linear, Linear

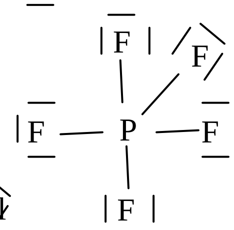
   b. BCl_3 Trig Planar, Trig Planar

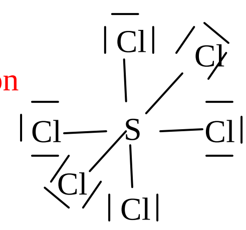
   c. CF_4 Tetrahedral, Tetrahedral

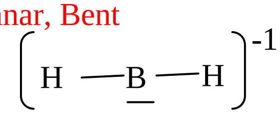
   d. PF_5 Trig Bipyramidal, Trig Bipyramidal

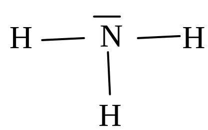
   e. SCl_6 Octahedron, Octahedron

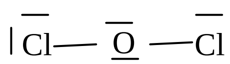
   f. BH_2^{-1} Trig Planar, Bent

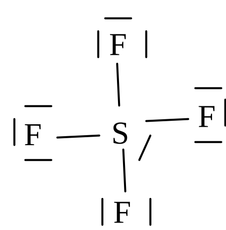
   g. NH_3 Tetrahedral, Trig Pyramidal

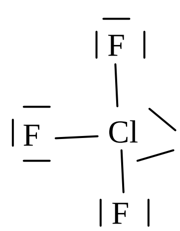
   h. OCl_2 Tetrahedral, Bent

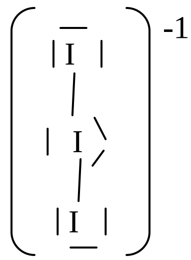
   i. SF_4 Trig Bipyramid, Irregular Tetrahedron (see-saw)

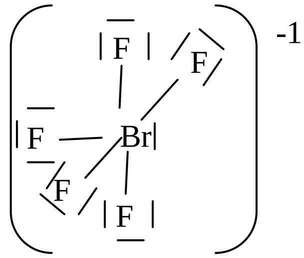
   j. ClF_3 Trig Bipyramid, T-shaped

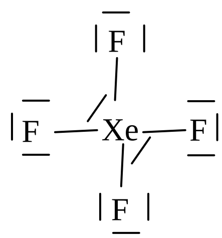
k. I_3^{-1} Trig Bipyramid, Linear



l. BrF_5^{-1} Octahedron, Square Pyramid

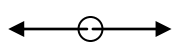


m. XeF_4 Octahedron, Square Planar



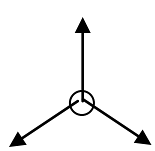
2. For each of the bonds below, decide whether each is ionic, non-polar, or polar:
    a. I-Na Ionic
    b. O-C Polar covalent
    c. C-H Non-polar covalent
    d. P-F Polar covalent
    e. C-Cl Polar covalent
    f. H-N Polar covalent
    g. C-S Non-polar covalent
3. How can you tell if a molecule is overall polar or non-polar? The molecule must have asymmetrical polar bonds
4. For each of the substances in #1 above, sketch the polarity. If the molecule is non-polar, write NP.

    a. CO_2 Linear, Linear



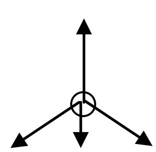
Non-polar

    b. BCl_3 Trig Planar, Trig Planar



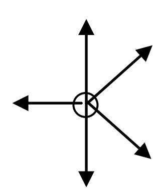
Non-polar

    c. CF_4 Tetrahedral, Tetrahedral



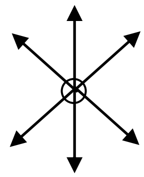
Non-polar

    d. PF_5 Trig Bipyramidal, Trig Bipyramidal



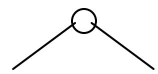
Non-polar

e. SCl_6 Octahedron, Octahedron



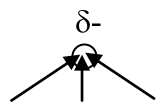
Non-polar

f. BH_2^{-1} Trig Planar, Bent



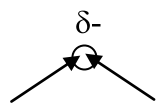
Non-polar

g. NH_3 Tetrahedral, Trig Pyramidal



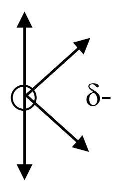
Polar

h. OCl_2 Tetrahedral, Bent



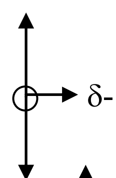
Polar

i. SF_4 Trig Bipyramid, Irregular Tetrahedron (see-saw)



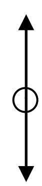
Polar

j. ClF_3 Trig Bipyramid, T-shaped



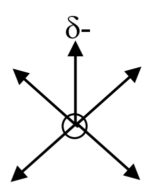
Polar

k. I_3^{-1} Trig Bipyramid, Linear



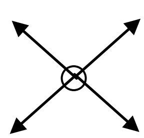
Non-Polar

l. BrF_5^{-1} Octahedron, Square Pyramid



Polar

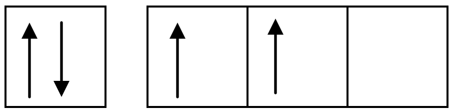
m. XeF_4 Octahedron, Square Planar



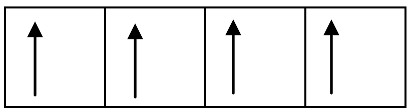
Non-Polar

5. What is a hybrid orbital? A molecular orbital that maximizes the number of bonds that can be made by combining individual atomic orbitals into equal orbitals that are in-between pure s, p, d, or f orbitals.
6. Show how carbon, which has the valence electron configuration s^2p^2, can make four sp^3 bonds by hybridizing.

Atomic C
s^2p^2



Molecular C
sp^3

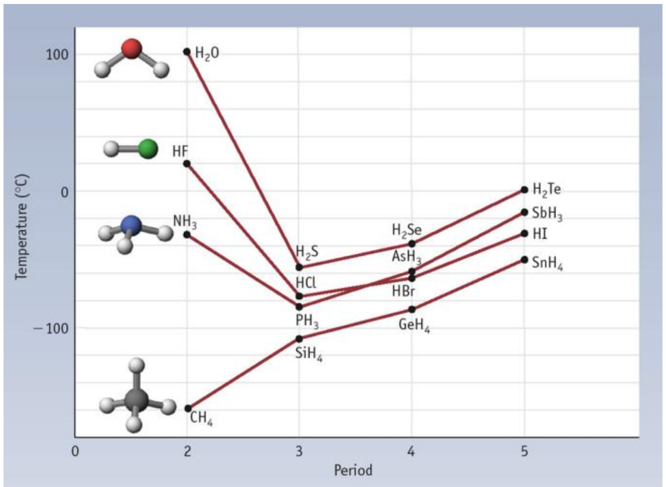


7. For each of the molecules in #1, give the hybridization.
    a. CO_2 Linear, sp
    b. BCl_3 Trig Planar,sp^2
    c. CF_4 Tetrahedral, sp^3
    d. PF_5 Trig Bipyramidal, dsp^3
    e. SCl_6 Octahedron, d^2sp^3
    f. BH_2^{-1} Trig Planar, sp^2
    g. NH_3 Tetrahedral, sp^3
    h. OCl_2 Tetrahedral, sp^3
    i. SF_4 Trig Bipyramid, dsp^3
    j. ClF_3 Trig Bipyramid, dsp^3
    k. I_3^{-1} Trig Bipyramid, dsp^3
    l. BrF_5^{-1} Octahedron, d^2sp^3
    m. XeF_4 Octahedron, d^2sp^3

Intermolecular Forces

1. What are London forces? What kind of molecules do they apply to? What causes London Forces to increase? London forces are IMFs that arise from electron clouds being temporarily induced to be polar by surrounding molecules. They apply to non-polar molecules. Larger molecules have larger electron clouds which are easier to induce and therefore have more London forces.
2. What are Dipole forces? What kind of molecules do they apply to? Dipole forces arise from there being an asymmetrically polar molecule. A molecule that has polarity vectors that do not cancel out or molecules that have a greater electron density on one side of the molecule than another due to an imbalance in the shift of electrons due to differing electronegativity values. Dipole forces apply to molecules that are polar.
3. What are H-bonds? How do you know if a molecule exhibits H-bonding? H-bonds are super-strong version of dipole forces that arise from H being directly attached to a small, highly electronegative atom (NOF)
4. What kind of IMFs do each of the molecules below exhibit (the strongest)?
   a. CH_4 London Forces b. CH_3OH H-bonds c. CH_3F Dipole
5. How is the boiling point of a substance related to the IMFs present? BP increases as IMFs increase
6. Rank the following substances in order of increasing boiling point:
   NH_3 CO Ne $Ne < CO < NH_3$
7. Rank the following substances in order of increasing boiling point:
   H_3CCH_2O C_2H_6 H_3CCH_2OH $C_2H_6 < H_3CCH_2O < H_3CCH_2OH$

8. In the diagram below, explain the shape of each of the four lines.

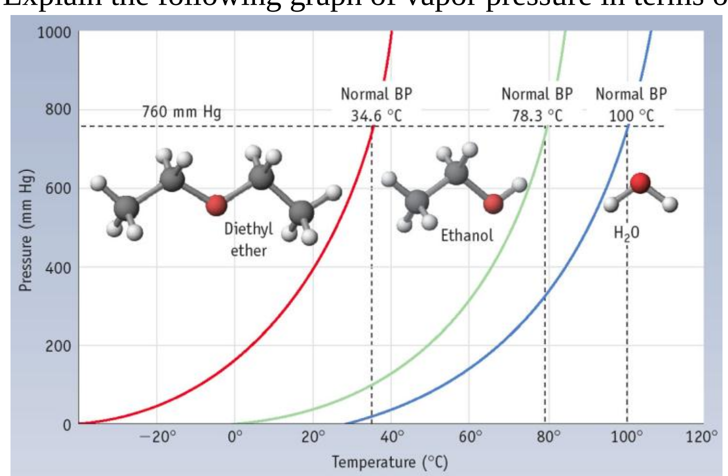


In the bottom line you see a gradual increase in boiling point as the size of the molecules increase from left to right. The same pattern holds true in the top 3 lines except the smallest of each line has the *largest* boiling point. This is because these smallest molecules exhibit H-bonding where none of the others in their line do. H-bonds are the strongest IMFs so the BP is highest for these substances.

9. How does vapor pressure (evaporation) relate to IMFs?

Vapor pressure is inversely proportional to IMFs. Molecules with strong IMFs have the least VP or evaporate the slowest.

10. Explain the following graph of vapor pressure in terms of IMFs:



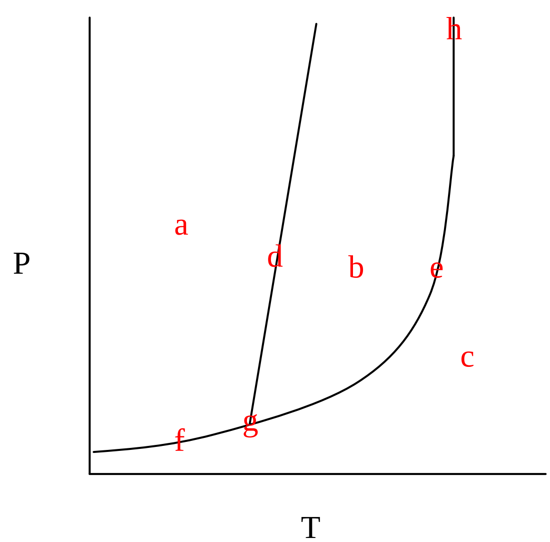
Diethyl ether has only dipole forces while ethanol has 1 H-bonding site and water has 2 H-bonding sites. We see that the VP of ether is far greater than the ethanol which is greater than water due to the differences in their IMFs.

11. Explain the saying “like dissolves like”. Polar dissolves polar. Non-polar dissolves non-polar

12. Explain why I_2 crystals are more likely to dissolve in benzene (C_6H_6) than water. Both non-polar

Phase Diagrams

1. On the diagram below, label each of the following:
    a. solid
    b. liquid
    c. gas
    d. equilibrium between solid and liquid
    e. equilibrium between liquid and gas
    f. equilibrium between solid and gas
    g. triple point
    h. critical point



2. What is the significance of the triple point? All 3 phases in equilibrium together
3. What is the significance of the critical point? Past this T, substance can only be a gas
4. Will the solid phase of the substance sink or float in the liquid phase? How do you know?
    Sink. The solid/liquid line has a positive slope
5. Draw a phase diagram for water. How is it different than the phase diagram seen in #1?