Announcements

To join clicker to class today (Clickers with LCD display joins automatically):

- Turn on the Clicker (the red LED comes on).
- Push "Join" button followed by "20" followed by the "Send" button (switches to flashing green LED if successful).

- Discussion is review.
- Next lecture class is exam.

- Please enter through bottom and leave coats and bags.
- Rewritten results section for pigment lab is due week after break.
- Don't forget prelab for part 2 of photometry experiment for week after break.
- It may be nice after break do not forget to wear appropriate clothing to lab!

Hybridization vs. VSEPR
Chang Table 10.4

- When counting groups to determine hybridization, count lone pairs just as you do for VSEPR.
- AX_3 & AX_2E are both sp^2 hybridized.
- These hybrids overlap end-on with orbitals on other atoms to make σ-bonds

AX_2

AX_3

AX_4

AX_5

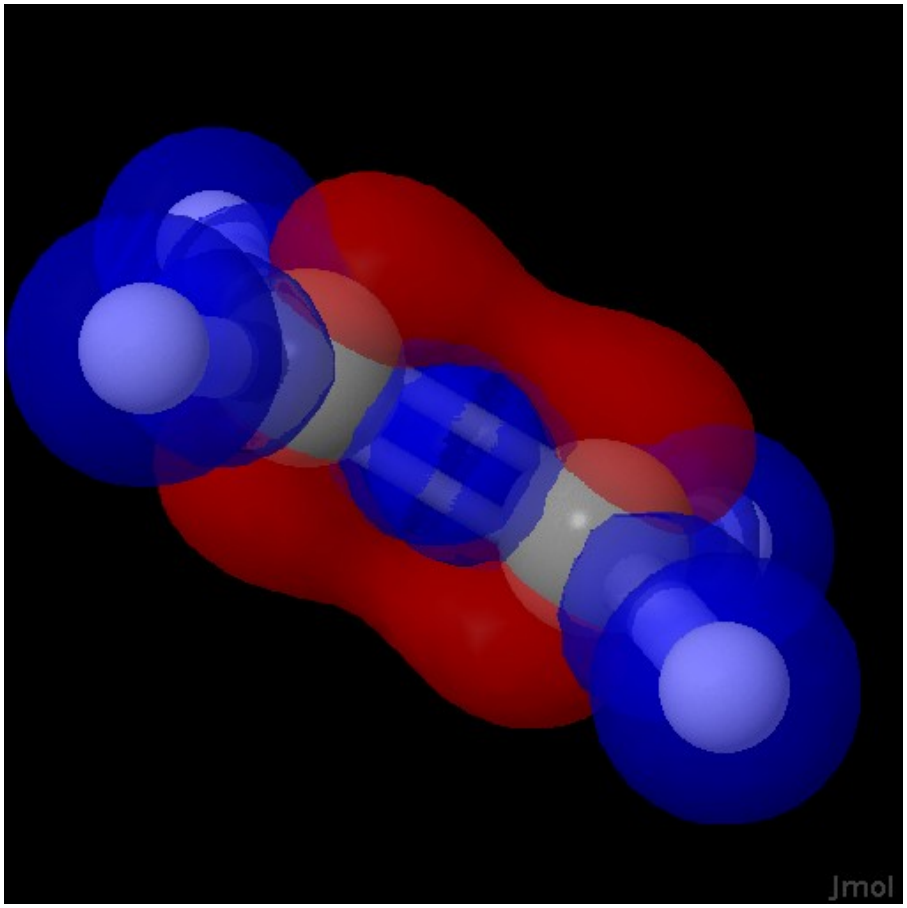
AX_6

sp^3 hybridization in CH_4 and NH_3

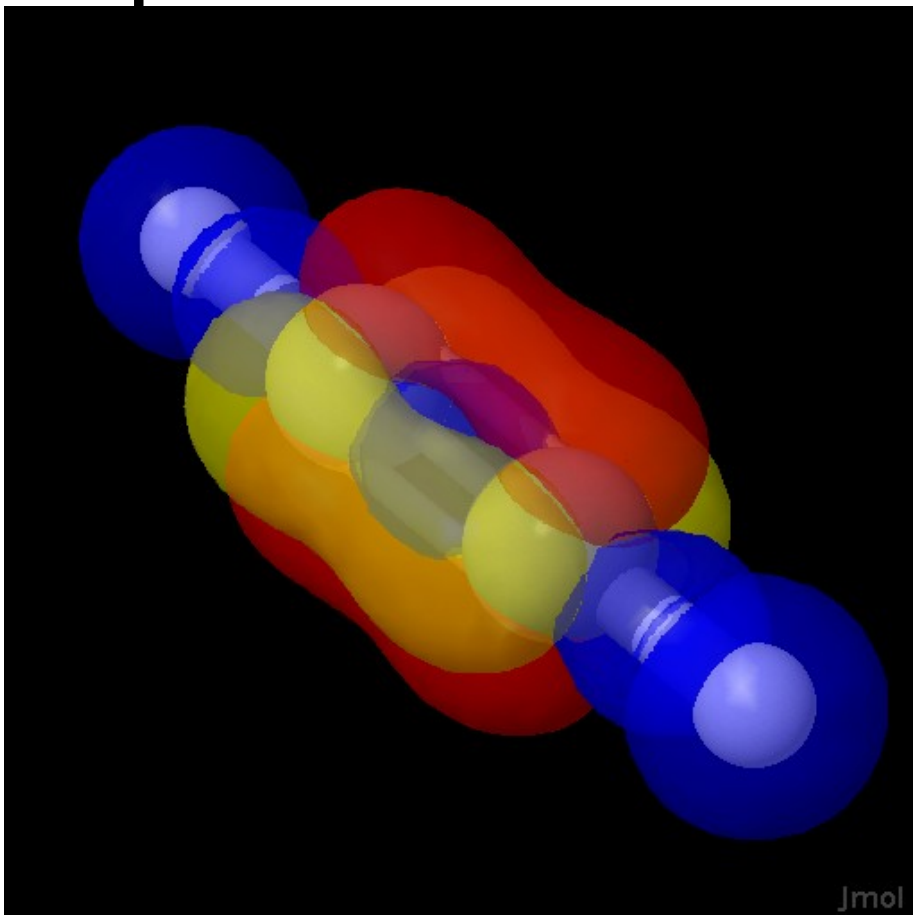
Chang Fig. 10.7

Chang Fig 10.8

Double and Triple Bonds



Ethylene double bond. σ in blue and π in red.



Acetylene triple bond. σ in blue and π in red and yellow.

Intermolecular Interactions

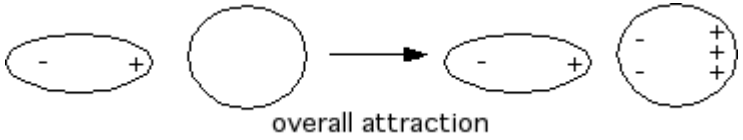
- Ion-dipole
- dipole-dipole
- dipole-induced dipole
- induced dipole-induced dipole
- hydrogen bonding
- interactions, boiling points and melting points
- solvation
- concentration (% by mass and molarity)
- solubility

Summary of Intermolecular Interactions

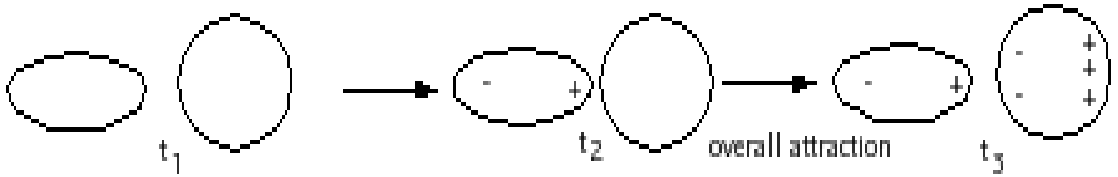
- attractive interactions among molecules:
  - ion-dipole

  - dipole-dipole

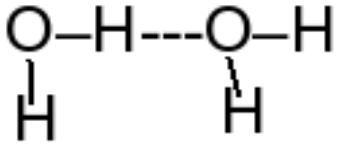
  - dipole - induced dipole



  - Dispersion



  - Hydrogen bonding (directional partial bond, an H bonded to N, O or F). H–F---H–F---H–F and



Effect of H-bonding

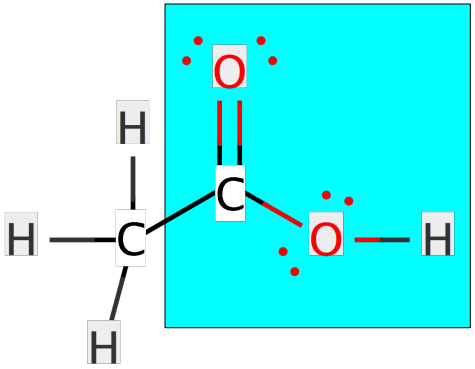
Chang figure 12.6

Effect of Dispersion Interactions (London or van der Waals Forces)

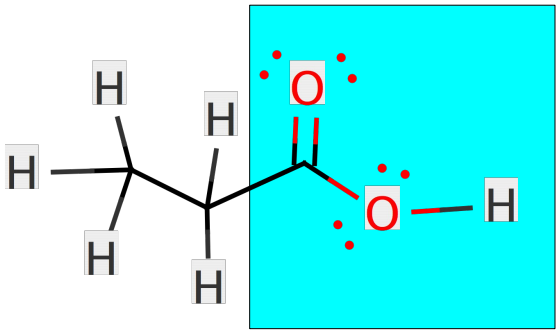
- # of electrons increases down the table. More electrons means more polarizable and thus more induced-dipole induced-dipole interactions.

Chang Table 12.2

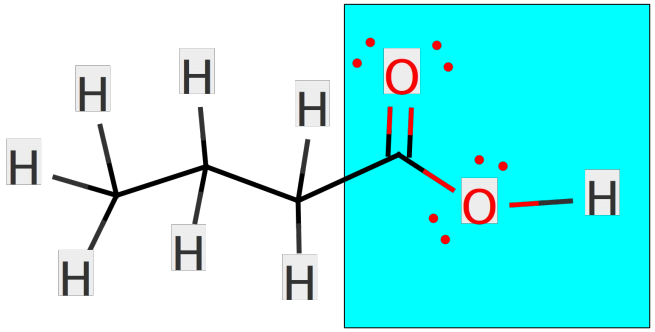
Molecules can have more than one type of interaction.



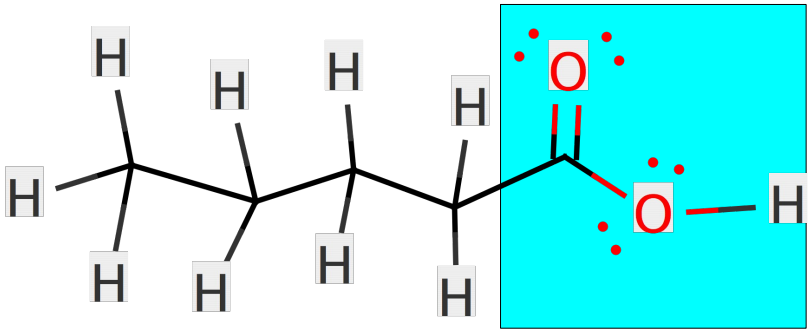
Acetic Acid (vinegar)
Bp =118.1 ˚C



Propionic Acid
Bp = 140.9 ˚C



Butyric Acid
Bp = 163 ˚C



Pentanoic Acid, Bp = 185.9 ˚C

Carboxylic acid groups have polar interactions. The hydrocarbon (C&H) parts have only dispersion interactions.

Review

- Defined:
  - Compound = two or more atoms arranged in a particular geometry in particular ratios. Can be ionic.
  - Molecule = a compound that is not ionic.
  - Empirical formula = formula for a compound with the lowest possible integer subscripts.
  - Molecular formula = subscripts represent the actual number of each type of atom in a single molecule.
- Naming of binary compounds.
  - CO: carbon monoxide – SO_3: sulfur trioxide
  - $CaCl_2$: calcium chloride – Mn_2O_3: manganese (III) oxide
  - H_3PO_4: phosphoric acid – HF: hydrofluoric acid
  - $CuSO_4 \cdot 2H_2O$: copper (II) sulfate dihydrate
- Balancing chemical reactions by inspection.

Review: Balanced RXNs

- $2H_2 + O_2 \longrightarrow 2H_2O$ can be read two ways:
  - 2 molecules of H_2 + 1 molecule of O_2 reacts to form 2 molecules of H_2O
  - 2 moles of H_2 + 1 mole of O_2 reacts to form 2 moles of H_2O, since a mole is just a group like a dozen.
  - 1 mole = Avogadro's # = $N_A = 6.022 \times 10^{23}$ things.

Review

- Molar Mass
  - To get correct significant figures do in two steps.
  - (2 mol H/mol H_2O)(1.00794 g H/mol H) = 2.01588 g H/mol H_2O

    +(1 mol O/mol H_2O)(15.9994 gO/mol O)=15.9995 g O/mol H_2O

    18.0153 g H_2O/mol H_2O

- $$\%\ \text{Composition} = \frac{100\% * (\text{mass of X in molecule})}{molar\ mass}$$

- $$\%\ yield = \frac{amount\ collected}{amount\ \text{exp}ected} \cdot 100\%$$

Stoichiometry/Mole Map

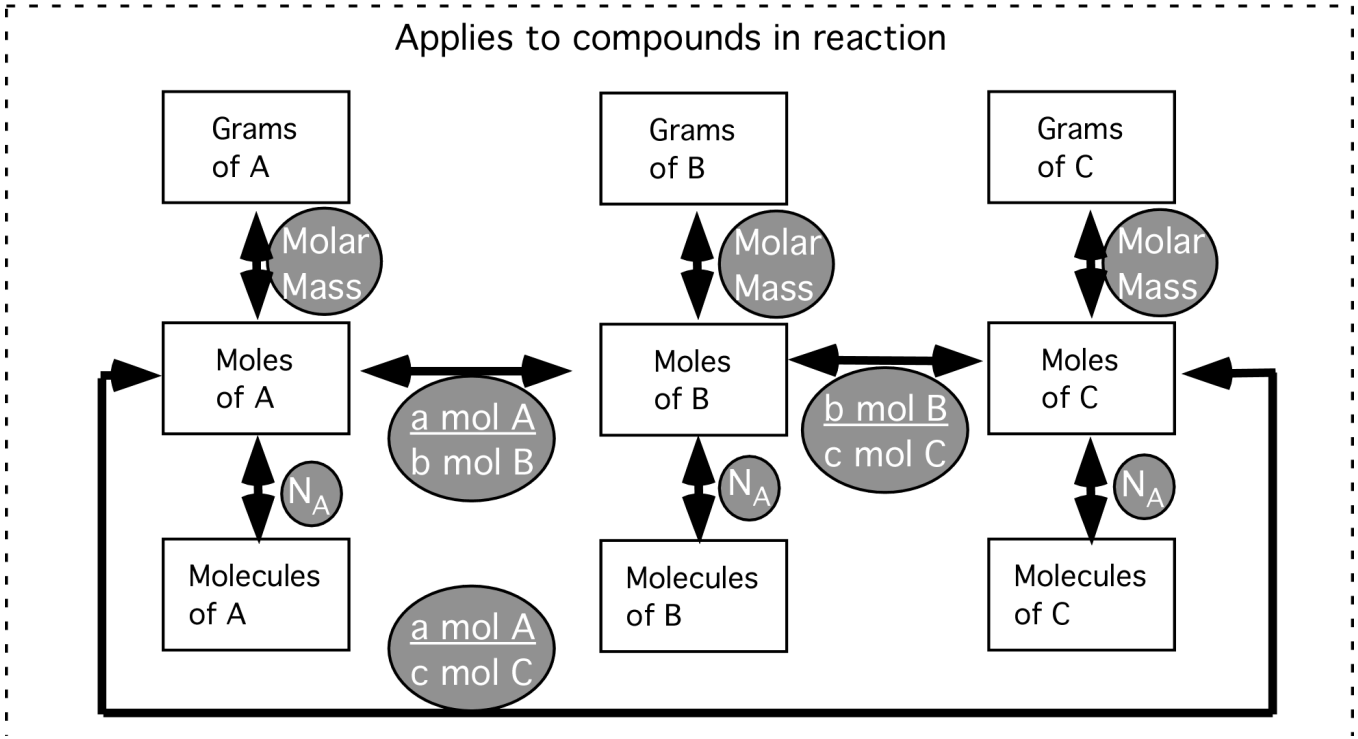
Model Reaction: $aA + bB \longrightarrow cC$

A, B and C represent molecular formulas

a, b and c represent the stoichiometric coefficients

= conversion factor

$N_A = 6.022 \times 10^{23} \frac{\text{things}}{\text{mole}}$



Experimental determination of % Composition

- unknown + O_2 (excess) → oxides (H_2O, CO_2, NO_2, SO_2, etc.)
- Burn 100% of unknown and weigh amount of each oxide.
- Example: ethylene: $C_2H_4 + O_2$(excess) → $CO_2 + H_2O$
  - 1.000 g ethylene yields 1.284 g H_2O and 3.137 g CO_2
  - Calculate moles of H and C in sample to get empirical formula:
  - $$mol\ H = (1.284\,g\ H_2O)\left(\frac{1\,mol\ H_2O}{18.0153\,g\ H_2O}\right)\left(\frac{\mathbf{2\,mol\ H}}{1\,mol\ H_2O}\right) = 0.1426\,mol\ H$$
  - $$mol\ C = (3.137\,g\ CO_2)\left(\frac{1\,mol\ CO_2}{44.010\,g\ CO_2}\right)\left(\frac{1\,mol\ C}{1\,mol\ CO_2}\right) = 7.128\,x\,10^{-2}\,mol\ C$$
  - $n_H/n_C = 0.1426/0.07128 = 2$ as we found before.
  - Can go from that to % composition by mass.
- Note if molecule contains O atoms find mass of O by subtracting mass of C and H in molecule from original mass.

Review: Bonding

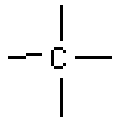
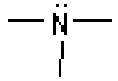
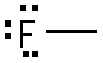
- Valence (outer) e^- take part in bonding. Main group elements form bonds to get "octet".
  - Ionic species exchange e^- and become charged.
  - Covalent bonds are made by sharing e^-.
  - Unequal sharing leads to polar bonds. (look at electronegativities)
- Single, double and triple bonds
  - Length: triple < double < single
  - Strength: triple > double > single
- Formal method for drawing Lewis structures.
- Complication of "resonance":

Systematic Lewis Structures

1. Octet rule: all main group (s and p block) elements except B (6) and H (2) will share electrons to get 8 valence electrons.
2. Count the total number of valence electrons on all atoms. Add or subtract from this to account for the overall charge on the species.
3. Next draw single bonds from each of the outer atoms to the central atom. Subtract two electrons from the total number of electrons for each bond you have made = # electrons you have left to use elsewhere.
4. Put electrons on the outer atoms to give each atom a total of eight (an octet). (H) hydrogen only needs 2 electrons. (B) boron usually only 6 electrons. Keep track of how many electrons you are using. If you run out of electrons before filling the outer atoms' octets, stop.
5. Any electrons that were not used up in step 3 should be put on the central atom. You should now have no unused valence electrons.
6. If any atoms do not have octets, make multiple bonds (double and triple) by sharing electron pairs from atoms that do have octets.
7. Look for resonance structures. If you have made multiple bonds or have odd electron species where all the atoms cannot have octets, there may be more than one way to arrange the multiple bonds or place the odd electron. If so, the molecule is better modelled as an average of all the possible structures.
8. Use “Formal Charge” to pick best resonance structures.

Quick rules for simple Lewis Structures

- Works well for some period two atoms (H, C, N, O, F) and the halogens (group 17) most of the time.

Atom	Number of Bonds	Lewis Cartoon
H	1	H-
C	4	
N	3	
O	2	
F (same for other halogens)	1	

Review

- Lewis structures
  - Resonance
  - Bond order
  - Using formal charge to pick best Lewis or resonance structure.
  - Exceptions to the octet rule.

Review (VSEPR)

Number of Groups	Basic Shape	Bond Angles	Sub-Shapes	Shape Name
Diatomic	Linear Diatomic		AX	Linear
2	Linear Triatomic	180°	AX_2	Linear
3	Trigonal Planar	120°	AX_3	Trigonal Planar
			AX_2E	Bent
4	Tetrahedral	109.5°	AX_4	Tetrahedral
			AX_3E	Trigonal Pyramidal
			AX_2E_2	Bent
5	Trigonal Bipyramidal	90°, 120°	AX_5	Trigonal Bipyramidal
			AX_4E	See-Saw
			AX_3E_2	T-Shaped
			AX_2E_3	Linear
6	Octahedral	90°	AX_6	Octahedral
			AX_5E	Square Pyramidal
			AX_4E_2	Square Planar

Hybridization vs. VSEPR
Chang Table 10.4

- When counting groups to determine hybridization, count lone pairs just as you do for VSEPR.
- AX_3 & AX_2E are both sp^2 hybridized.
- These hybrids overlap end-on with orbitals on other atoms to make σ-bonds

AX_2

AX_3

AX_4

AX_5

AX_6