Chapter 2: The Nature of Bonds and Structure of Organic Molecules

Bonds and Polarity. Bond polarity is based on the difference of the electronegativity of each individual atom in a bond. For the hypothetical bond A-B, the extreme picture would be either ionic or covalent. In reality many bonds are somewhere in between.

\[ \text{A} \longrightarrow \text{B} \quad \text{covalent} \quad \text{A} \quad \text{B} \quad \text{ionic} \]

\[ \text{low EN difference} \quad \text{large EN difference} \]

What is the definition of electronegativity?

What is a dipole? A dipole \( \mu \) is proportional to the charge \( x \) charge \( x \) distance between them. The dipole moment is drawn as a crossed arrow with the direction going towards the negative end of the molecule. Here are some examples:

Ammonia :NH\(_3\) On the left, there is the dipole arrow. Right, there is charge density picture with red indicating negative charge and blue indicating positive.

Here is BF\(_2\),

What is the difference between a non-polar, polar-covalent and ionic bond?

Non-polar covalent
Polar covalent
Ionic
Metals, Non-Metals, and Polarity

Metals tend to be electropositive – easy to lose electrons. These have low EN values.

Non-metals (called main group elements) approach the most electronegative element F. H is not really a metal. It is compatible with the main group elements. C is average for a non-metal.

<table>
<thead>
<tr>
<th>Elements</th>
<th>Electronegativity Values (EN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li</td>
<td>1.0</td>
</tr>
<tr>
<td>Be</td>
<td>1.5</td>
</tr>
<tr>
<td>B</td>
<td>2.0</td>
</tr>
<tr>
<td>C</td>
<td>2.5</td>
</tr>
<tr>
<td>N</td>
<td>3.1</td>
</tr>
<tr>
<td>O</td>
<td>3.5</td>
</tr>
<tr>
<td>F</td>
<td>4.1</td>
</tr>
<tr>
<td>Na</td>
<td>0.9</td>
</tr>
<tr>
<td>Mg</td>
<td>1.2</td>
</tr>
<tr>
<td>Al</td>
<td>1.5</td>
</tr>
<tr>
<td>Si</td>
<td>1.7</td>
</tr>
<tr>
<td>P</td>
<td>2.1</td>
</tr>
<tr>
<td>S</td>
<td>2.4</td>
</tr>
<tr>
<td>Cl</td>
<td>2.8</td>
</tr>
<tr>
<td>K</td>
<td>0.8</td>
</tr>
<tr>
<td>Ca</td>
<td>1.0</td>
</tr>
<tr>
<td>Ga</td>
<td>1.8</td>
</tr>
<tr>
<td>Ge</td>
<td>2.0</td>
</tr>
<tr>
<td>As</td>
<td>2.2</td>
</tr>
<tr>
<td>Se</td>
<td>2.5</td>
</tr>
<tr>
<td>Br</td>
<td>2.7</td>
</tr>
</tbody>
</table>

Table taken from Bill Reusch, [http://www.cem.msu.edu/~reusch/VirtualText/intro2.htm#strc2](http://www.cem.msu.edu/~reusch/VirtualText/intro2.htm#strc2)

Classify these fictitious bonds as non-polar or polar and if polar show the δ+ and δ-.

- Polar: A -- B  \( EN_A >> EN_B \)
- Polar: A -- B  \( EN_B >> EN_A \)
- Non-polar: A -- B  \( EN_A \sim EN_B \) (usually < .4-.5)

For some real bonds. Classify as non-polar or polar and if polar show the δ+ and δ-.

- C -- N  C -- H  B -- H  Al -- H  C -- O  C -- F  Li -- H
- F -- F  B -- Cl  Li -- Al  Al -- O  B -- O  Li -- Li  C -- Li

Summary of Polarity concepts:
1. What is polarity?
2. Why is polarity important in molecules.

Assign δ+, and δ- in the molecules below:

- H--Br
- Acetone
- ethyl bromide
- cyclohexanol
- antabuse
Molecular Polarity and Intermolecular Forces

To understand the overall polarity of a molecule, the polarity of each bond and the arrangement of the bonds in the molecule have to be considered. For a molecule with non-polar bonds, it’s easy to see that the molecule overall is non-polar. Consider these molecules:

For a molecule with non-polar bonds, it’s easy to see that the molecule overall is non-polar. Consider these molecules:

\[
\begin{align*}
\text{HCCH} & \quad \text{CC} \\
& \quad \text{H} \\
& \quad \text{H} \\
\text{CC} & \quad \text{H} \\
& \quad \text{HH} \\
& \quad \text{H} \\
\end{align*}
\]

How about molecules with polar bonds: Here the polar vectors must be added based on the shape. Here are some simple examples.

Polar Covalent Bonds and Polar Molecules.
Just having polar bonds does not make the molecule polar. Consider these examples

\[
\begin{align*}
\text{OCO} & \quad \text{BF} \\
& \quad \text{FF} \\
& \quad \text{C} \\
& \quad \text{Cl} \\
& \quad \text{Cl} \\
& \quad \text{Cl} \\
\end{align*}
\]

Intermolecular Forces:
Just as there are attractions within molecules to hold the atoms together, there are forces between molecules that give the ensemble of molecules their physical properties:

<table>
<thead>
<tr>
<th>Physical property</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting point</td>
<td>Strong Weak Forces+</td>
<td>Strong Weak Forces+</td>
</tr>
<tr>
<td>Boiling point</td>
<td>Strong Weak Forces</td>
<td>Strong Weak Forces</td>
</tr>
</tbody>
</table>

+Melting points and boiling points are based on two different pictures.
BP is the liquid -> gas. Molecules are not locked in any arrangement.
MP is solid -> liquid. Molecules are locked in a lattice in the solid. This involves orientation.
Lattice prefers regular shapes. Irregular shapes are liquids.

Fat

Oil

There are 3 main classes of intermolecular forces:

- **Dipole-Dipole** (permanent)
- **H-Bonding**: The elements N, O, and F can share H’s between them. This is a very special force.
- **London, Van der Waals, or Dispersion** (induced dipole)

Relative magnitudes of forces

<table>
<thead>
<tr>
<th>Attractive Force</th>
<th>Covalent bonds</th>
<th>H-bonding</th>
<th>Dipole-dipole</th>
<th>London forces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>~100 kcal/mole</td>
<td>5-10 kcal/mole</td>
<td>&lt; 5 kcal/mole</td>
<td>&lt; 1 kcal/mole</td>
</tr>
</tbody>
</table>

What is the difference between intra and intermolecular forces?
Induced Dipole:

Shape is important, since the interactions between the two atoms or molecules depends on the surface area between the two bodies. These two molecules have the formula $\text{C}_5\text{H}_{12}$.

<table>
<thead>
<tr>
<th>Sphere – Sphere</th>
<th>Rod—Rod</th>
</tr>
</thead>
<tbody>
<tr>
<td>small contact area</td>
<td>large contact area</td>
</tr>
</tbody>
</table>

Interactions between electron clouds increases with larger surface. There are more electron-electron interactions.

| Neo-pentane  (bp = 282.7 K) | n-Pentane  (bp = 309.4 K) |
Boiling Point Trends of Compounds correlated to Molecular Mass

### Increasing Size

<table>
<thead>
<tr>
<th>Atomic</th>
<th>Bp (°C)</th>
<th>Molecular</th>
<th>Bp (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>He (4)</td>
<td>-271</td>
<td>CH$_4$ (16)</td>
<td>-161</td>
</tr>
<tr>
<td>Ar (40)</td>
<td>-186</td>
<td>(CH$_3$)$_4$C (72)</td>
<td>-9.5</td>
</tr>
<tr>
<td>Kr (83)</td>
<td>-153</td>
<td>(CH$_3$)$_4$Si (88)</td>
<td>27</td>
</tr>
<tr>
<td>Xe (131)</td>
<td>-109</td>
<td>CCl$_4$ (154)</td>
<td>77</td>
</tr>
</tbody>
</table>

### Molecular Shape

<table>
<thead>
<tr>
<th>Spherical</th>
<th>Bp (°C)</th>
<th>Linear</th>
<th>Bp (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(CH$_3$)$_4$C (72)</td>
<td>9.5</td>
<td>CH$_3$(CH$_2$)$_3$CH$_3$ (72)</td>
<td>36</td>
</tr>
<tr>
<td>(CH$_3$)$_2$CCl$_2$ (113)</td>
<td>69</td>
<td>Cl(CH$_2$)$_3$Cl (113)</td>
<td>121</td>
</tr>
<tr>
<td>[(CH$_3$)$_3$C]$_2$ (114)</td>
<td>106</td>
<td>CH$_3$(CH$_2$)$_3$CH$_3$ (114)</td>
<td>126</td>
</tr>
</tbody>
</table>

### Molecular Polarity

<table>
<thead>
<tr>
<th>Non-polar</th>
<th>Bp (°C)</th>
<th>Polar</th>
<th>Bp (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H$_2$C=CH$_2$ (28)</td>
<td>-104</td>
<td>H$_2$C=O (30)</td>
<td>-21</td>
</tr>
<tr>
<td>F$_2$ (38)</td>
<td>-188</td>
<td>CH$_3$CH=O (44)</td>
<td>20</td>
</tr>
<tr>
<td>CH$_3$C≡CH$_3$ (54)</td>
<td>-32</td>
<td>(CH$_2$)$_3$O (58)</td>
<td>50</td>
</tr>
<tr>
<td>CF$_4$ (88)</td>
<td>-130</td>
<td>(CH$_3$)$_2$C=O (58)</td>
<td>56</td>
</tr>
</tbody>
</table>

Table adapted from Bill Reusch, [http://www.cem.msu.edu/~reusch/VirtualText/physprop.htm#exp4](http://www.cem.msu.edu/~reusch/VirtualText/physprop.htm#exp4)

**H-Bonds** involve N, O, F sharing bonds with H.
- H bonds are very strong and you always need to be on the lookout for H-bonds.
- H-bonds occur through LP electrons on the highly electronegative atom.
- When a H bonds to a LP, we call this a donor H-bond.
- When a LP bonds to a H, we can this an acceptor H-bond.

H-bonds are the reason why water boils at such a high T.

Consider these trends of molecules that involve H-bonds, dipole and dispersion forces.

[Image of boiling point graph]

[http://www.cem.msu.edu/~reusch/VirtualText/physprop.htm#exp4](http://www.cem.msu.edu/~reusch/VirtualText/physprop.htm#exp4)
H-bonding is sharing of H's between NOF.

Determine if these molecules can be H-bond donors, acceptors or both.

H-F  H₂S  H₂O  CH₃OH  H₂C=O

CH₃-O-CH₃  (CH₃)₃N  CH₃NH₂  H₂Se

**Molecular Properties affected by Hydrogen Bonding**

<table>
<thead>
<tr>
<th>Compound</th>
<th>Formula</th>
<th>Mol. Wt.</th>
<th>Boiling Point</th>
<th>Melting Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimethyl ether</td>
<td>CH₃OCH₃</td>
<td>46</td>
<td>–24 °C</td>
<td>–138 °C</td>
</tr>
<tr>
<td>Ethanol</td>
<td>CH₃CH₂OH</td>
<td>46</td>
<td>78 °C</td>
<td>–130 °C</td>
</tr>
<tr>
<td>Propanol</td>
<td>CH₃(CH₂)₂OH</td>
<td>60</td>
<td>98 °C</td>
<td>–127 °C</td>
</tr>
<tr>
<td>Diethyl ether</td>
<td>(CH₃CH₂)₂O</td>
<td>74</td>
<td>34 °C</td>
<td>–116 °C</td>
</tr>
<tr>
<td>Propyl amine</td>
<td>CH₃(CH₂)₂NH₂</td>
<td>59</td>
<td>48 °C</td>
<td>–83 °C</td>
</tr>
<tr>
<td>Methylaminoethane</td>
<td>CH₃CH₂NHCH₃</td>
<td>59</td>
<td>37 °C</td>
<td></td>
</tr>
<tr>
<td>Trimethylamine</td>
<td>(CH₃)₃N</td>
<td>59</td>
<td>3 °C</td>
<td>–117 °C</td>
</tr>
<tr>
<td>Ethylene glycol</td>
<td>HOCH₂CH₂OH</td>
<td>62</td>
<td>197 °C</td>
<td>–13 °C</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>CH₃CO₂H</td>
<td>60</td>
<td>118 °C</td>
<td>17 °C</td>
</tr>
<tr>
<td>Ethylene diamine</td>
<td>H₂NCH₂CH₂NH₂</td>
<td>60</td>
<td>118 °C</td>
<td>8.5 °C</td>
</tr>
</tbody>
</table>

Table taken from Bill Reusch, [http://www.cem.msu.edu/~reusch/VirtualText/physprop.htm#exp4](http://www.cem.msu.edu/~reusch/VirtualText/physprop.htm#exp4)

True or False:
- Dipole-Dipole is the strongest intermolecular force?
- Electronegativity is the same thing as intermolecular force?
- Boiling points increase as intermolecular forces increase?
- Melting points increase as intermolecular forces increase?
- A molecule with polar bonds must have high intermolecular forces?
**Solubility**: In general like dissolves like. Polar with polar. Non-polar with non-polar.

Predict solubilities of the following in water.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Solubility in Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaCl</td>
<td>Soluble</td>
</tr>
<tr>
<td>HCl (g)</td>
<td>Soluble</td>
</tr>
<tr>
<td>CH₃(CH₂)₅CH₃</td>
<td>Soluble</td>
</tr>
<tr>
<td>CH₃OH methanol</td>
<td>Soluble</td>
</tr>
<tr>
<td>CH₃C₆H₅ toluene</td>
<td>Insoluble</td>
</tr>
<tr>
<td>CH₂Cl₂ Dichloromethane</td>
<td>Insoluble</td>
</tr>
<tr>
<td>CH₃CH₂OCH₂CH₃</td>
<td>Soluble</td>
</tr>
<tr>
<td>Diethyl ether</td>
<td>Soluble</td>
</tr>
<tr>
<td>I₂(s)</td>
<td>Insoluble</td>
</tr>
</tbody>
</table>

What organic functional groups are usually soluble in water?

**Liquid/Liquid Extraction**

Here is the water/hexane (oil) system. Why is hexane on top?

If we put nonpolar solute in the system, which layer will it go to?

If we put polar solute in the system, which layer will it go to?


**Paper Chromatography**

Paper is polar. Solvent carries the solutes through the paper.

Which moves faster polar or non-polar solute?

Which moves slower polar or non-polar solute?

3 compounds have similar components:
Red, pink, blue, and green.
Which component is least polar?
Most polar?

Classifying Polarity in Bonds in terms of Valence Bond Models

Formal Charges

\[
\text{Formal Charge} = \text{Valence Electrons in Neutral Atom} - \left( \frac{\text{Unshared Valence Electrons}}{2} + \frac{\text{Half of the Shared Electrons}}{2} \right)
\]

or Half of the Shared Electrons = # of bonds.

Here is the acid dissociation reaction of the following oxoacids. You must supply the formal charges. Make sure there is charge balance both on molecule and in the reaction. Nitric Acid HNO₃ dissociates to make nitrate. Here are resonance structures of nitrate.

![Resonance structures of nitrate](image)

Sulfuric Acid H₂SO₄ dissociates to make hydrogensulfate. Here are resonance structures of hydrogensulfate.

![Resonance structures of hydrogensulfate](image)

Generally, the best Lewis structure has the least separation of formal charge!

How does the overall charge of a molecule relate to the formal charge of individual atoms?

How does formal charge relate to number of bonds of individual atoms?

**Formal charge vs Oxidation State**

Formal charge is of how charge gets distributed in pure covalent compounds. In pure ionic compounds, the atomic charge is thought of being split by oxidation number. Which model is better at explaining charge separation in molecules? Oxidation or formal charge?

Consider water, H₂O. What is the oxidation state of H? the oxidation of O?

Consider HCl. What is the oxidation state of H? the oxidation state of Cl?

MgBr₂ What is the oxidation state of Mg? the oxidation state of Br?

Consider Mn. What is the oxidation state of Mn?

The most oxidized form of Mn is permanganate, MnO₄⁻. What is the oxidation state of Mn?

Another form of Mn is MnO₂. What is the oxidation state of Mn?

CH₄ H₂C=O the most oxidized form of C?
Resonance

(1) Resonance repairs inadequacy of Lewis Structures.

Experimentally ozone and SO₂ is bent (bond angle 120°) and has equal length S--O bonds (143.2 pm). **Resonance hybrids** (the two structures) are always represented by a double headed arrow.

Draw the resonance structures for cyanate, CNO⁻. Note formal charges.

What does this imply about the bond order of these molecules? Which structure is more important? Why?

(2) Resonance can be used to show molecular properties:

formaldehyde

Which structure(s) are more important?

(3) Wacky resonance structures do not have much effect on the actual properties of the molecule. What is weird about these structures?

**Resonance Summary:**

Resonance structures involve molecules with the same molecular structure and number of electrons. Resonance hybrids have different types of electronic localization. The following factors are important in evaluating the contribution each of these canonical structures makes to the actual molecule.

1. **The number of covalent bonds in a structure.** (The greater the bonding, the more important and stable the contributing structure.)
2. **Formal charge separation.** (Other factors aside, charge separation decreases the stability and importance of the contributing structure.)
3. **Electronegativity of charge bearing atoms and charge density.** (High charge density is destabilizing. Positive charge is best accommodated on atoms of low electronegativity, and negative charge on high electronegative atoms.)

Based on [http://www.cem.msu.edu/~reusch/VirtualText/intro3.htm#strc7](http://www.cem.msu.edu/~reusch/VirtualText/intro3.htm#strc7)
Practice: For the compounds and ions listed below, write Lewis / Kekulé structures for as many reasonable canonical forms as you can.

Formic Acid \( \text{HCO}_2\text{H} \)

Formate Anion \( \text{HCO}_2\text{\(^-\)}} \)

Nitromethane \( \text{CH}_3\text{NO}_2 \)

Methyl Nitrite \( \text{CH}_3\text{ON=O} \)

Considering the resonance hybrid forms written here, which three of these compounds or ions will exhibit the greatest resonance stabilization?

Practice: Reconsider the resonance of \( \text{HNO}_3 \) and \( \text{HNO}_2 \) and their anions. Which is the best structure for each?

True or False?
The more resonance structures you can draw for a molecule the more stable?
All resonance structures have the same effect on the actual structure of a molecule?
Resonance structures are important for chemical structure because electrons want to occupy the most number of positions in a molecule?
Acid/Base chemistry is based on acid dissociation: We talk about $K_a$ and $pK_a$.

$HA \rightleftharpoons H^+ + A^-$

$K_a = \frac{[H^+][A^-]}{[HA]}$ in general products / reactants.

Why don’t we talk about $pK_b$?

When is the ratio $> 1$?
When is the ratio $< 1$?
What about the $\Delta G$? Remember $\Delta G = -RT\ln K_a$
When is the ratio $> 1$?
When is the ratio $< 1$?

Some acid reactions are very favorable. What do we call this kind of acid? ________________

Name the 6 main acids in this group? Are any organic acids?

The $K_a$ of a strong acid is $10^{+x}$
Are the $pK_a$'s of strong acids positive or negative?

| pKa Acidities of Some Common Hydrides |
|-----------------|----------|----------|----------|
| Gr 4 $\text{CH}_3$-H | ca. 50 | Gr 5 $\text{NH}_2$-H | 34  |
| Gr 6 HO-H          | 15.74   | Gr 7 F-H   | 3.2  |
| Not important for this course. |
| HS-H               | 6.97 (pK1) |
| Hse-H              | 3.8 (pK1)  |
| Hte-H              | 2.6 (pK1)  |
| Cl-H               | -3        |
| Br-H               | -6        |
| I-H                | -7        |

$pK_a$ of neutral hydrides above and selected charged hydrogen compounds below.

| $\text{NH}_4^+$ | 9.24 | $\text{OH}_3^-$ | -1.74 | $\text{S-H}^{(-)}$ | 15 (pK2) | $\text{Se-H}^{(-)}$ | 11 (pK2) |

http://www.cem.msu.edu/~reusch/VirtualText/suppmnt2.htm#top4

The main X-H bonds in organic chemistry are C-H, N-H, O-H. Rank them in acidity:

Now let’s look at the acidity of H in respect to X-H bond. With respect to elements, what determines the acid strength? ________________________

Make sure that you understand this order and what the $pK_a$ means.
C-H depends on the electronic state of C? How do we classify these hybrid states?

Of the three states above, rank them in order of acidity: (p.287)

Typical $pK_a$'s of these acids are approximately

$\text{CH}_4$ 50 $\text{H}_2\text{C=}\text{CH}_2$ 45 $\text{HC}≡\text{CH}$ 25

Now let’s review magnitudes. $10^x$

| A photon of light is about $10^x$ m | The number of students in this OCHEM course is about $10^x$ |
| A pore in a good water purifier is $10^x$ m | The thickness of McMurray is about $10^x$ pages |
| The thickness of this paper is about $10^x$ m | The federal deficit is about $10^x$ |
| The length of a child is about $10^x$ m | |

**Unlikely acids**

Most C-H acids are extremely weak.

\[
\begin{align*}
R_3C(\text{sp}^3)-H & \iff H^+ + R_3C(\text{sp}^3)^- \quad \text{Ka} = \quad \text{pKa} = \\
R_3C(\text{sp}^2)-H & \iff H^+ + R_3C(\text{sp}^2)^- \quad \text{Ka} = \quad \text{pKa} = \\
R_3C(\text{sp})-H & \iff H^+ + R_3C(\text{sp})^- \quad \text{Ka} = \quad \text{pKa} = 
\end{align*}
\]

We explain this based on the stability of the anion. The C-H species are all about the same stability, but the anion products are stabilized differently.

\[
\begin{array}{ccc}
E & \quad \text{Ka} \cdot 10^{35} \\
R-H & \quad R^- (\text{sp}^3) & \quad R^- (\text{sp}^2) & \quad R^- (\text{sp})
\end{array}
\]

**N-H acids,**

What are some N-H acids?

- pKa's of N-H:
- pKa's of N^+-H

**O-H acids?**

What are some O-H acids?

- pKa's of O-H:
- pKa's of O^+-H

---

**Summary of weak acids**

- C-H
- N-H
- O-H
- N^+-H
- O^+-H
- What about other strong acids.

---

**Equilibrium and predicting reaction**

To calculate the extent of an acid base reaction is crucial.

Given \( \text{pKa(HCl)} = -5 \) and \( \text{pKa(H}_2\text{O)} = 16 \) and \( \text{pKa(NH}_3) = 33 \). \( \text{pKa(NH}_4^+) = 9 \). Note N-H can have more than one acid strength depending if N is neutral or positive. Write these reactions as ionization reactions.

\[
\begin{align*}
\text{HCl} & \iff \\
\text{H}_2\text{O} & \iff \\
\text{NH}_3 & \iff \\
\text{NH}_4^+ & \iff 
\end{align*}
\]

**Strategy:**

1. Find the acid on left and conjugate acid (CA) on right.
2. The reaction proceeds towards the side with the highest pKa.
3. The magnitude of the Keq = \( 10^+ \) or \( -\text{(pKa1-pKa2)} \).

Left = -, Right = +. This can be derived algebraically. Anyway you want, you're going to have to predict it.
Reactions.

**HO⁻ + H-Cl ⇌ H-OH + Cl⁻** Which direction and what will be the magnitude of the $K_{eq}$?

**HC≡C-H + OH⁻ ⇌ H-OH + HC≡C⁻** Which direction will this reaction go and what will be the magnitude of the $K_{eq}$?

**(Acetylene)C-H + NH₂⁻ ⇌ H-NH₂ + HC≡C⁻** Which direction will this reaction go and what will be the magnitude of the $K_{eq}$?

**Practice:**

1. Write the reaction of amide + ammonium and predict the direction.

2. Given methanol CH₃OH pKa = 16 and water pKa = 16. Why can NaOH not completely deprotonate methanol?

3. Hydride is a strong base, H⁻. What is the CA of hydride? That acid has a pKa of 38.

**Extension to Organic Chemistry:**

<table>
<thead>
<tr>
<th>Acid/Base</th>
<th>Organic Chemistry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid = H⁺</td>
<td>Electrophile = E⁺</td>
</tr>
<tr>
<td>Base =&gt; goes after H⁺</td>
<td>Nucleophile =&gt; goes after Nucleus</td>
</tr>
</tbody>
</table>

**Summaries:**

2. When is a molecule polar? When is a molecule nonpolar?
3. Be able to predict trends in electronegativity of atoms – going down and across the periodic table.
4. Determine dipole moments and direction of the dipole vector based on electronegativity of atoms and the $\delta^+$ and $\delta^-$. 
5. Know the 3 intermolecular forces. How do intermolecular forces affect boiling and melting points.
6. Predict trends in intermolecular forces of molecules that contain atoms going across or down the periodic table.
7. Understand volatility. Be able to predict the volatility of molecules based on intermolecular forces.
8. Predict solubility of molecules in water based on molecular similarity.
9. Be able to calculate formal charges of atoms in molecules. You should be able to write structures with correct formal charge.
10. Be able to write resonance structures.
11. Determine if a resonance structure is important for representing the properties of a molecule.
12. Know approximate pKa’s of C-H, N-H and O-H.
13. Be able to explain why C≡C-H is more acidic than (sp³)C-H
14. Know the strong acids. What kind of acids are most organic compounds? What is the significance of this fact?
15. Be able to predict trends in pKa’s of Y-H bonds going across or down the periodic table.
16. Be able to predict the direction and magnitude of reactions based on pKa’s of the acid and conjugate acids.