AP Biology Lecture Notes
Basic Chemistry

I. Overview

A. The study of biology requires an understanding of simple organic chemistry and simple biological chemistry.

B. Carbohydrates, lipids, proteins, and nucleic acids, the players in molecular biology, are themselves composed of smaller building blocks.

II. Chemical Bonds

A. Emphasis is placed on bonds between the six major elements found in biological systems: H, C, N, O, P, and S.

B. **Covalent Bonds**.

1. The strongest chemical bonds.
2. Formed by the sharing of a pair of electrons.
   a. The energy of a typical single covalent bond is ~80 kilocalories per mole (kcal/mol).
   b. Bond energy can vary from ~50 kcal/molto ~110 kcal/mol.
3. Once formed, covalent bonds rarely break spontaneously.
   a. The thermal energy of a molecule at room temperature (298 K) is much lower (~0.6 kcal/mol) than the energy required to break a covalent bond.
4. There are single, double, and triple covalent bonds:

<table>
<tr><th>Bond Number</th><th>Example</th><th>Energy (kcal/mol)</th></tr>
<tr><td>single</td><td><pre>
   H
   |
H--C--H
   |
   H
</pre></td><td>~80</td></tr>
<tr><td>double</td><td><pre>
   H   H
   | |
H--C==C--H
   | |
   H   H
</pre></td><td>~150</td></tr>
<tr><td>triple</td><td><pre>
H
|
C
|||
C
|
H
</pre></td><td>~200</td></tr>
</table>

5. Carbon-carbon bonds are unusually strong and stable covalent bonds.
6. The major organic elements have standard bonding capabilities:

element	**# of Covalent Bonds**	**example**
Nitrogen (N)	4	ammonia

(positive charge on nitrogen)

```
   H
   |+
H--N--H
   |
   H
```

element	**# of Covalent Bonds**	**example**
Oxygen (O)	1	ionized ethanol

(negative charge on oxygen)

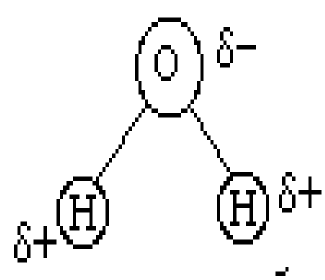
```
   H  H
   |  |    _
H--C--C--O
   |  |
   H  H
```

element	**# of Covalent Bonds**	**example**
Sulfur (S)	1	ionized mercaptoethanol

(negative charge on the sulfur)

```
   H  H
   |  |    _
H--C--C--S
   |  |
   H  H
```

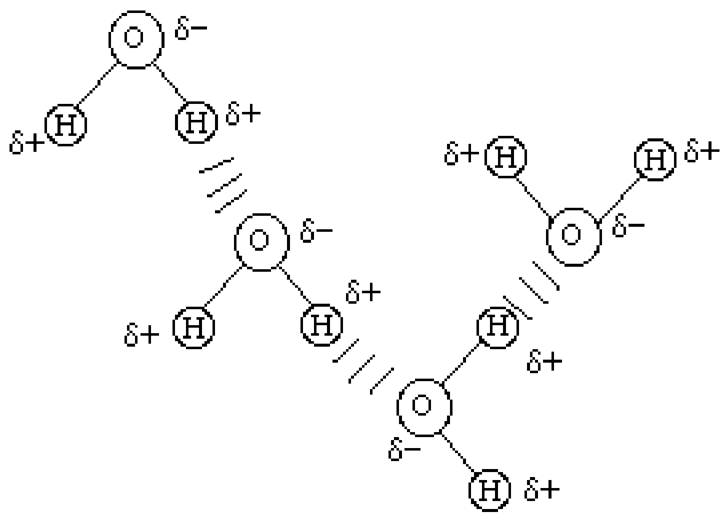
7. Covalent bonds can also have partial charges.
   a. The atoms involved have different electronegativities.
      i. Water is the most obvious example.
         1. The symbols delta+ and delta- are used to indicate partial charges.



         2. Oxygen, because of its high electronegativity, attracts the electrons away from the hydrogen atoms, resulting in a partial negative charge on the oxygen and a partial positive charge on each of the hydrogens.

III. Hydrogen Bonds

A. Formed when a hydrogen atom is shared between two molecules.



B. Hydrogen bonds have polarity.
   1. A hydrogen atom covalently attached to a very electronegative atom (N, O, or P) shares its partial positive charge with a second electronegative atom (N, O, or P).
      a. One example (above) involves the hydrogen bonding between water molecules.

More examples:

```
              H
              |
R--O--H ||| N--R                    R==N--H ||| O==R
              |
              H
```

Note that R stands for any side group.

C. Hydrogen bonds are ~5 kcal/mol in strength.
   1. Frequently found in proteins and nucleic acids.
   2. Keep protein or nucleic acid structure secure by reinforcing each other.
   3. Relative strength of protein-protein H-bonds vs. protein-H2O bonds is smaller than 5 kcal/mol.

IV. Ionic Bonds.

A. Ionic bonds are formed when there is a complete transfer of electrons from one atom to another.
   1. Results in two ions, one positively charged and the other negatively charged.
      a. Example: A sodium atom (Na) donates the one electron in its outer valence shell to a chlorine (Cl) atom, which needs one electron to fill its outer valence shell, NaCl (table salt) results.
   2. Ionic bonds are often 4-7 kcal/mol in strength.

V. Van Der Walls Interactions.

A. Van der Walls interactions are very weak bonds formed between nonpolar molecules or non-polar parts of a molecule.
   1. Usual strength 1 kcal/mol.
   2. Created because a C-H bond can have a transient dipole and induce a transient dipole in another C-H bond.

   Example:

```
H        H
|~~~~  |
CH3   CH3
```

VI. Hydrophobic Interactions

A. Nonpolar molecules cannot form H-bonds with H_2O.
   1. Insoluble in H_2O.
   2. Known as hydrophobic (water hating).

B. Hydrophobic molecules tend to aggregate together in avoidance of H_2O molecules.
   Example: an oil drop on water.
   1. Known as the hydrophobic (fear of water) force.
      a. H_2O molecules surround a "dissolved" molecule and attempt to form the greatest number of hydrogen bonds with each other.
      b. The best energetic solution involves forcing all of the nonpolar molecules together, reducing the total surface area that breaks up the H_2O H-bond matrix.

VII. pH

A. pH is a measure of the concentration of hydrogen ions.
B. The pH value is defined as the negative logarithm of the hydrogen ion concentration in mol/L.
C. The equation is:

$$pH = -log10[H^+]$$

D. Example: The $[H^+]$ in pure water is 10^{-7}; therefore the pH of pure water is:

$$pH = -log10(10^{-7}) \qquad pH = -(-7) \qquad pH = 7$$

E. pH 7 is "neutral pH".
F. Below pH 7 -- higher concentration of H^+ (acidic).
G. Above pH 7 -- lower concentration of H^+ (basic).
H. Can also think of lower pH as having a higher concentration of OH^-.
I. A lower pH always means a higher concentration of H^+.
J. The biochemically useful ends of the scale:
   1. 1 M HCl (pH 0).
   2. 1 M NaOH (pH 14).
   3. Cellular pH is approximately 7.2 - 7.4.
      a. Very closely controlled in the cytoplasm of a healthy cell.

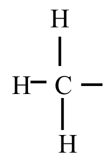
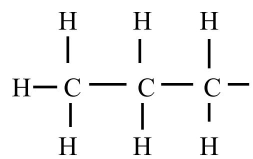
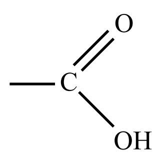
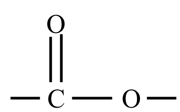
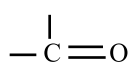
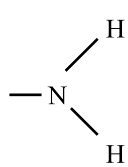
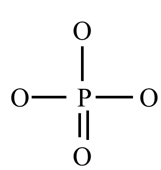
VIII. Chemical Models.

A. Models are key to our visual understanding of chemical molecules.
B. Different types of models use different symbolism to represent the same information.
C. Each type of model has advantages and disadvantages.
   1. **Space-filling models** are the most realistic representation possible of a molecule, but are time-consuming and moderately difficult to make.

2. **Ball-and-stick models** can quickly give you essential (but necessarily simplified) information about the spatial organization of a molecule.

IX. Functional Groups.

This is a chart of the most common chemical functional groups. These functional groups will turn up in later chapters in the biological molecules we study. I recommend studying this chart so you can recognize the functional groups when they appear.

name	**formula**	**structure**	**chemical characterisitcs**
Methyl	CH_3		nonpolar, lowers water solubility
Hydrocarbon chain	$(CH)_n$CH3		nonpolar, insoluble in water
Carboxyl	CO(OH)		polar, acidic, releasing H+ in solution
Hydroxyl	OH	—OH	polar, forms hydrogen bonds
Ester linkage	COO^-		polar
Carbonyl	CO		polar
Amino	NH_2		polar, forms hydrogen bonds
Phosphate	PO_4		polar, acidic, releases H+ in solution