## CHEMISTRY 104 – Help Sheet #4 – Organic (Part III)
Chapters 2.7 (condensed, structural drawings), 6.3 (line drawings), 6.9a (benzene), 7.2e (hybrid orbitals in organic structures), and Appendix E (functional groups)

Prepared by Dr. Tony Jacob
http://www.chem.wisc.edu/areas/clc (Resource page)

### Nuggets: Functional Groups Part II, Naming and drawing organic molecules

<table>
<thead>
<tr>
<th>Functional Group</th>
<th>Suffix</th>
<th>Formula</th>
<th>Other Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol</td>
<td>(an)ol</td>
<td>R-O-H</td>
<td>R ≠ H; 1°, 2°, 3°; polar; H-bonding; polar; e.g., 3-methyl-2-butanol</td>
</tr>
<tr>
<td>Ether</td>
<td>---</td>
<td>R-O-R'</td>
<td>R, R' ≠ H; polar; alphabetize branches+&quot;ether&quot; e.g., diethylether</td>
</tr>
<tr>
<td>Aldehyde</td>
<td>(an)al</td>
<td>R=C=O-H or RCHO</td>
<td>one H must be attached to the carbonyl; pol e.g., 3-chloro-1-butanal</td>
</tr>
<tr>
<td>Ketone</td>
<td>(an)one</td>
<td>R-C=O-R' or R(C=O)R'</td>
<td>R, R' ≠ H; polar; e.g., 4,5-dimethyl-3-hexanone</td>
</tr>
<tr>
<td>Carboxylic acid</td>
<td>(an)oic</td>
<td>R-C=O-H or RCOOH</td>
<td>R can be H; H-bonding; polar; pH &lt; 7; acidic; e.g., 3,3-dimethyl-1-butanoic acid</td>
</tr>
<tr>
<td>Ester</td>
<td>---</td>
<td>R-C=O-R' or R(COO)R'</td>
<td>R can be H; R' ≠ H; nice odors; R' named 1° + &quot;yl&quot; then R-(C=O) named 2°d + &quot;anoate&quot; e.g., ethylbutanoate</td>
</tr>
<tr>
<td>Amide</td>
<td>---</td>
<td>R-N-R' or R(CO)NR'R''</td>
<td>R can be H; can have H-bonding if R’ or R” = H; N has sp(^2) hybridization rather than sp(^3) because of resonance; hence triangular planar for both C and N; planar; no naming e.g., ethylmethylamine NH(CH(_2))(_2)(CH(_3)CH(_3))</td>
</tr>
<tr>
<td>Amine</td>
<td>---</td>
<td>NRR'R'' (1 R must ≠ H)</td>
<td>1°, 2°, 3°, 4° (+1); can have H-bonding; polar; pH &gt; 7; basic; NR(_3) + H(_2)O \rightleftharpoons NR(_3)H(^+) + OH(^-); alphabetize branches+&quot;amine&quot; e.g., ethylmethylamine NH(CH(_2))(_2)(CH(_3)CH(_3))</td>
</tr>
</tbody>
</table>
OTHER INFORMATION

<table>
<thead>
<tr>
<th>Primary (1°) alcohol: C with –OH (labeled) has 1 C attached (labeled as ●)</th>
<th>Secondary (2°) alcohol: C with –OH (labeled) has 2 C’s attached (labeled as ●)</th>
<th>Tertiary (3°) alcohol: C with –OH (labeled) has 3 C’s attached (labeled as ●)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Primary alcohol structure" /></td>
<td><img src="image" alt="Secondary alcohol structure" /></td>
<td><img src="image" alt="Tertiary alcohol structure" /></td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Primary (1°) amine: N has 1 C attached (labeled as ●)</th>
<th>Secondary (2°) amine: N has 2 C’s attached (labeled as ●)</th>
<th>Tertiary (3°) amine: N has 3 C’s attached (labeled as ●)</th>
</tr>
</thead>
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<td><img src="image" alt="Primary amine structure" /></td>
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<td><img src="image" alt="Tertiary amine structure" /></td>
</tr>
</tbody>
</table>

**SOLUBILITY:** Liquids dissolving into liquids = miscibility (page 565-567):

- polar substances dissolve into polar substances (dissolve into = miscible);
- nonpolar substances (e.g., hydrocarbons!) dissolve into nonpolar substances (dissolve into = miscible);
- polar and nonpolar substances don’t dissolve into one another (don’t dissolve into = immiscible)
- more H-bonding more soluble

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**–O– Functional Groups**

**Alcohol:** a –OH (hydroxyl) group attached; condensed: R—OH; H-bonding

- primary (1°): C with –OH has 1 C atom attached
- secondary (2°): C with –OH has 2 C atoms attached
- tertiary (3°): C with –OH has 3 C atoms attached to it

**Ether:** bridging oxygen atom; condensed: R—O—R'; R and R' ≠ H otherwise it becomes an alcohol

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**Carbonyl Functional Groups** (\(\text{C} = \text{O}\))

**Aldehyde:** contains a carbonyl with at least one H attached to C of carbonyl; condensed: RCHO; line: \(\text{R} \overset{\text{O}}{\text{C}} \text{H}\)

**Ketone:** a carbonyl with two C attached; condensed: R—CO—R' or R(C=O)R'; line: \(\text{R} \overset{\text{O}}{\text{C}} \text{H}\)

R and R' ≠ H otherwise it’s an aldehyde

**Carboxylic acid:** a carbonyl with a –OH attached; condensed: RCOOH; line: \(\text{R} \overset{\text{O}}{\text{C}} \text{H}\)

- acidic solution (pH < 7); H⁺ can dissociate: \(\text{R} \overset{\text{O}}{\text{C}} \text{H} \rightleftharpoons \text{R} \overset{\text{O}}{\text{H}} + \text{H}^+\); has H-bonding;

- the COO⁻ group (carboxylate) has a resonance structure:

**Ester:** condensed: R(COO)R'; line: \(\text{R} \overset{\text{O}}{\text{C}} \text{H}\)

R and R' ≠ H otherwise it’s a carboxylic acid; esters smell pleasant

**Amide:** condensed: R(C=O)NR’R”; line: \(\text{R} \overset{\text{O}}{\text{C}} \text{H}\)

R’, R” can be H; H-bonding

**Amine:** N with a C attached to it; condensed: NRR’R”; H-bonding; creates basic solution (pH > 7)

- primary (1°): N has 1 C attached
- secondary (2°): N has 2 C attached
- tertiary (3°): N has 3 C attached

---

1. Draw the following condensed molecular structures in a) the Lewis dot format, b) line notation, and c) wedge-dash 3D structures.

I. \(\text{CH}_3\text{CH}_2\text{CH(OH)}\text{CH}_3\)  
II. \(\text{CH}_3\text{CH}_2\text{CHO}\)  
III. \((\text{CH}_3\text{CH}_2\text{CH}_2)_2\text{O}\)  
IV. \(\text{CH}_3\text{CH}_2(\text{CO})\text{CH}_3\)
2. Circle each functional group present and name it. If it is an alcohol or amine functional group identify it as a 1°, 2°, or 3° alcohol or amine. If there is an alkene present, identify it as a cis, trans, or neither isomeric version. (Hint: There are 13 functional groups in the molecule.)

3. Give the IUPAC name for each of the following molecules. (Skip if naming not covered)

4. Using line notation, draw the molecules given their names.
   a. 2-butanoate
   b. 3,3-diethyl-1-pentanal
   c. 2-methyl-1-butanoic acid
   d. 4-ethyl-1-hexanoic acid
   e. cis-2,6-dimethyl-3-heptene
   f. 3-ethyl-4-methyl-2-pentanol
   g. pentylpropanoate
   h. ethylethanoate
   i. 2,2-dimethyl-3,3-dichloro-4-heptanone
   j. 3-tert-butyl-1-cyclohexanol
   k. 1-propanal
   l. ethylmethylether
   m. diethylisopropylamine
5. Give the IUPAC name for each molecule.

![Molecules A to L](image)

6. Write the **condensed structures** for the molecules given the names with bonds drawn between the groups (e.g., for ethane draw CH$_3$CH$_3$).

<table>
<thead>
<tr>
<th>Name</th>
<th>Condensed Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,2-dimethyl-1-propanal</td>
<td>CH$_3$CH(CH$_3$)$_2$CH$_3$</td>
</tr>
<tr>
<td>isopropanol</td>
<td>CH$_3$CH$_2$CH$_2$OH</td>
</tr>
<tr>
<td>1,1,1-trichloro-3-pentanone</td>
<td>Cl$_2$CH$_2$CH$_2$CH$_2$CH$_3$</td>
</tr>
<tr>
<td>2,2-diethyl-1-butanoic acid</td>
<td>CH$_3$CH$_2$CH$_2$CH$_2$COOH</td>
</tr>
</tbody>
</table>

7. Which of the following molecules are **secondary alcohols**?

- I. 1-butanol
- II. 2-pentanol
- III. 1-cyclopentanol
- IV. 2-methyl-2-butanol

- a. I, II, III, IV
- b. II, III, IV
- c. II
- d. II, III
- e. IV
- f. I

8. Place the following chemicals in order from **low to high solubility** in water.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Solubility Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH$_3$CH(CH$_3$)CH$_2$CH$_3$</td>
<td>I</td>
</tr>
<tr>
<td>CH$_3$(CO)CH$_2$CH$_3$</td>
<td>II</td>
</tr>
<tr>
<td>CH$_3$CH$_2$CH$_2$CH$_2$COOH</td>
<td>III</td>
</tr>
</tbody>
</table>

- a. I < II < III
- b. III < II < I
- c. II < III < I
- d. I < III < II
- e. III < I < II

9. Place the following chemical in order from **low to high boiling point**.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Boiling Point Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH$_3$CH(OH)CH(OH)CH$_3$</td>
<td>I</td>
</tr>
<tr>
<td>CH$_3$CH$_2$CH$_2$CH$_2$OH</td>
<td>II</td>
</tr>
<tr>
<td>HOOCCH$_2$CH$_2$COOH</td>
<td>III</td>
</tr>
</tbody>
</table>

- a. I < II < III
- b. III < II < I
- c. II < III < I
- d. I < III < II
- e. III < I < II
ANSWERS

I. a.  

```
C C C C C H
H H :O: H
```

b.  

```
C C C C C H
H H H H C
```

c.  

```
C C C C C H
H H H H H
```

II. a.  

```
C C C C C H
H H H H C
```

b.  

```
C C C C C H
H H H H O
```

III. a.  

```
C C C C C H
H H H H H
```

b.  

```
C C C C C H
H H H H H
```

c.  

```
C C C C C H
H H H H O
```

IV. a.  

```
C C C C C H
H H H H C
```

b.  

```
C C C C C H
H H H H O
```

2.  


3. a. 2,2-dimethyl-1-propanol  
b. 2,3,4,4-tetrachloro-1-butanal (aldehydes is always on the 1st position; sometimes called: 2,3,4,4-tetrachlorobutanal)  
c. 3-ethyl-3-pentanol  
d. 4-chloro-4,4-difluoro-2-butanal  
e. ethylisopropylamine  
f. ethanoic acid (common name: acetic acid)  
g. 3,5-dimethyl-1-hexanoic acid (carboxylic acids is always on the 1st position; sometimes called: 3,5-dimethylhexanoic acid)  
h. ethylpropanoate
5. a. trans-2,5-dimethyl-3-hexene  b. 1-butanal  c. 3-ethyl-2-hexanol  d. 2,2-dimethyl-1-butanol  
   e. 2-pentanone  f. cis-2-hexene  g. 3-chloro-4-ethyl-2-hexanone  h. 4,4-dimethylpentanal  
   i. 2,2-dimethylpentanoic acid  j. 2,2,2-trifluoroethanoic acid  k. methylbutanoate  l. propylpentanoate  

6. a. CH₃(CH₃)₂CHO  b. (CH₃)₂CH(OH)CH₃ or CH₃CH(OH)CH₃  c. CC₁₃₂(CO)CH₂CH₃  
   d. CH₃CH₂C(CH₂CH₃)₂COOH

7. d  {I. 1° alcohol: OH  II. 2° alcohol:  III. 2° alcohol:  IV. 3° alcohol:  
   }  

8. a  {for solubility, 1. polar substances dissolve into polar substances; 2. ions more readily dissolve into water; 3. molecules with H-bonding more readily dissolve into water;  
   I:  ; II:  ; III:  
   I. hydrocarbon: nonpolar  →  low solubility in water;  
   II. polar because of the carbonyl  →  more soluble in water than molecule I;  
   III. polar because of the carbonyl; also can dissociate to create an ion and ions are more soluble in water; can H-bond to the water  →  all of these increase the solubility of molecule III in water as compared to the other molecules}

9. e  {as IMFs increase  →  boiling point increases; I:  has H-bonding in 2 locations;  II:  has H-  
   bonding in 1 location;  III:  has H-bonding in 2 locations plus the O in the −COOH group without the H can also H-bond to another molecule with the H coming from the other molecule; hence more H-bonding in molecule III}
