

**CHEMISTRY 301**  
**11:15 AM Section**  
**EXAM 1**  
**28 Sept 2009**

Name: \_\_\_\_\_

Your exam should consist of 5 pages including the cover page and grade tabulation sheet. The  $pK_a$  and IR tables are on page 5. Skim the entire exam, and solve the easiest problems first. Exams not returned when time is called will not be graded.

|   |                                      |                                       |  |  |   |   |  |  |   |   |                                       |   |   |                                       |  |  |   |                                     |
|---|--------------------------------------|---------------------------------------|--|--|---|---|--|--|---|---|---------------------------------------|---|---|---------------------------------------|--|--|---|-------------------------------------|
| 1 | 1A                                   |                                       |  |  |   |   |  |  |   |   |                                       | 18                                      | 8A                                      |                                       |  |  |   |                                     |
| 1 | 1<br><b>H</b><br>Hydrogen<br>1.01    |                                       |  |  |   |   |  |  |   |   |                                       | 2                                       | 2<br><b>He</b><br>Helium<br>4.00        |                                       |  |  |   |                                     |
| 2 | 3<br><b>Li</b><br>Lithium<br>6.94    | 4<br><b>Be</b><br>Beryllium<br>9.01   |  |  |   |   |  |  |   |   |                                       |   | 5<br><b>B</b><br>Boron<br>10.81         | 6<br><b>C</b><br>Carbon<br>12.01      | 7<br><b>N</b><br>Nitrogen<br>14.01       | 8<br><b>O</b><br>Oxygen<br>16.00       | 9<br><b>F</b><br>Fluorine<br>19.00      | 10<br><b>Ne</b><br>Neon<br>20.18    |
| 3 | 11<br><b>Na</b><br>Sodium<br>22.99   | 12<br><b>Mg</b><br>Magnesium<br>24.31 | 3<br><b>B</b>                          | 4<br><b>4B</b>                             | 5<br><b>5B</b>                            | 6<br><b>6B</b>                          | 7<br><b>7B</b>                         | 8                                      | 9                                       | 10                                      | 11<br><b>1B</b>                       | 12<br><b>2B</b>                         | 13<br><b>Al</b><br>Aluminum<br>26.98    | 14<br><b>Si</b><br>Silicon<br>28.09   | 15<br><b>P</b><br>Phosphorus<br>30.97    | 16<br><b>S</b><br>Sulfur<br>32.07      | 17<br><b>Cl</b><br>Chlorine<br>35.45    | 18<br><b>Ar</b><br>Argon<br>39.95   |
| 4 | 19<br><b>K</b><br>Potassium<br>39.10 | 20<br><b>Ca</b><br>Calcium<br>40.08   | 21<br><b>Sc</b><br>Scandium<br>44.96   | 22<br><b>Ti</b><br>Titanium<br>47.87       | 23<br><b>V</b><br>Vanadium<br>50.94       | 24<br><b>Cr</b><br>Chromium<br>52.00    | 25<br><b>Mn</b><br>Manganese<br>54.94  | 26<br><b>Fe</b><br>Iron<br>55.85       | 27<br><b>Co</b><br>Cobalt<br>58.93      | 28<br><b>Ni</b><br>Nickel<br>58.69      | 29<br><b>Cu</b><br>Copper<br>63.55    | 30<br><b>Zn</b><br>Zinc<br>65.39        | 31<br><b>Ga</b><br>Gallium<br>69.72     | 32<br><b>Ge</b><br>Germanium<br>72.61 | 33<br><b>As</b><br>Arsenic<br>74.92      | 34<br><b>Se</b><br>Selenium<br>78.96   | 35<br><b>Br</b><br>Bromine<br>79.90     | 36<br><b>Kr</b><br>Krypton<br>83.80 |
| 5 | 37<br><b>Rb</b><br>Rubidium<br>85.47 | 38<br><b>Sr</b><br>Strontium<br>87.62 | 39<br><b>Y</b><br>Yttrium<br>88.91     | 40<br><b>Zr</b><br>Zirconium<br>91.22      | 41<br><b>Nb</b><br>Niobium<br>92.91       | 42<br><b>Mo</b><br>Molybdenum<br>95.94  | 43<br><b>Tc</b><br>Technetium<br>(98)  | 44<br><b>Ru</b><br>Ruthenium<br>101.07 | 45<br><b>Rh</b><br>Rhodium<br>102.91    | 46<br><b>Pd</b><br>Palladium<br>106.42  | 47<br><b>Ag</b><br>Silver<br>107.87   | 48<br><b>Cd</b><br>Cadmium<br>112.41    | 49<br><b>In</b><br>Indium<br>114.82     | 50<br><b>Sn</b><br>Tin<br>118.71      | 51<br><b>Sb</b><br>Antimony<br>121.76    | 52<br><b>Te</b><br>Tellurium<br>127.60 | 53<br><b>I</b><br>Iodine<br>126.90      | 54<br><b>Xe</b><br>Xenon<br>131.29  |
| 6 | 55<br><b>Cs</b><br>Cesium<br>132.91  | 56<br><b>Ba</b><br>Barium<br>137.33   | 57<br><b>La</b><br>Lanthanum<br>138.91 | 72<br><b>Hf</b><br>Hafnium<br>178.49       | 73<br><b>Ta</b><br>Tantalum<br>180.95     | 74<br><b>W</b><br>Tungsten<br>183.84    | 75<br><b>Re</b><br>Rhenium<br>186.21   | 76<br><b>Os</b><br>Osmium<br>190.23    | 77<br><b>Ir</b><br>Iridium<br>192.22    | 78<br><b>Pt</b><br>Platinum<br>195.08   | 79<br><b>Au</b><br>Gold<br>196.97     | 80<br><b>Hg</b><br>Mercury<br>200.59    | 81<br><b>Tl</b><br>Thallium<br>204.38   | 82<br><b>Pb</b><br>Lead<br>207.2      | 83<br><b>Bi</b><br>Bismuth<br>208.98     | 84<br><b>Po</b><br>Polonium<br>(209)   | 85<br><b>At</b><br>Astatine<br>(210)    | 86<br><b>Rn</b><br>Radon<br>(222)   |
| 7 | 87<br><b>Fr</b><br>Francium<br>(223) | 88<br><b>Ra</b><br>Radium<br>(226)    | 89<br><b>Ac</b><br>Actinium<br>(227)   | 104<br><b>Rf</b><br>Rutherfordium<br>(261) | 105<br><b>Db</b><br>Dubnium<br>(262)      | 106<br><b>Sg</b><br>Seaborgium<br>(266) | 107<br><b>Bh</b><br>Bohrium<br>(264)   | 108<br><b>Hs</b><br>Hassium<br>(269)   | 109<br><b>Mt</b><br>Meitnerium<br>(268) |   |                                       |   |   |                                       |  |  |   |                                     |
|   |                                      |                                       |  | 58<br><b>Ce</b><br>Cerium<br>140.12        | 59<br><b>Pr</b><br>Praseodymium<br>140.91 | 60<br><b>Nd</b><br>Neodymium<br>144.24  | 61<br><b>Pm</b><br>Promethium<br>(145) | 62<br><b>Sm</b><br>Samarium<br>150.36  | 63<br><b>Eu</b><br>Europium<br>151.96   | 64<br><b>Gd</b><br>Gadolinium<br>157.25 | 65<br><b>Tb</b><br>Terbium<br>158.93  | 66<br><b>Dy</b><br>Dysprosium<br>162.50 | 67<br><b>Ho</b><br>Holmium<br>164.93    | 68<br><b>Er</b><br>Erbium<br>167.26   | 69<br><b>Tm</b><br>Thulium<br>168.93     | 70<br><b>Yb</b><br>Ytterbium<br>173.04 | 71<br><b>Lu</b><br>Lutetium<br>174.97   |                                     |
|   |                                      |                                       |  | 90<br><b>Th</b><br>Thorium<br>232.04       | 91<br><b>Pa</b><br>Protactinium<br>231.04 | 92<br><b>U</b><br>Uranium<br>238.03     | 93<br><b>Np</b><br>Neptunium<br>(237)  | 94<br><b>Pu</b><br>Plutonium<br>(244)  | 95<br><b>Am</b><br>Americium<br>(243)   | 96<br><b>Cm</b><br>Curium<br>(247)      | 97<br><b>Bk</b><br>Berkelium<br>(247) | 98<br><b>Cf</b><br>Californium<br>(251) | 99<br><b>Es</b><br>Einsteinium<br>(252) | 100<br><b>Fm</b><br>Fermium<br>(257)  | 101<br><b>Md</b><br>Mendelevium<br>(258) | 102<br><b>No</b><br>Nobelium<br>(259)  | 103<br><b>Lr</b><br>Lawrencium<br>(262) |                                     |

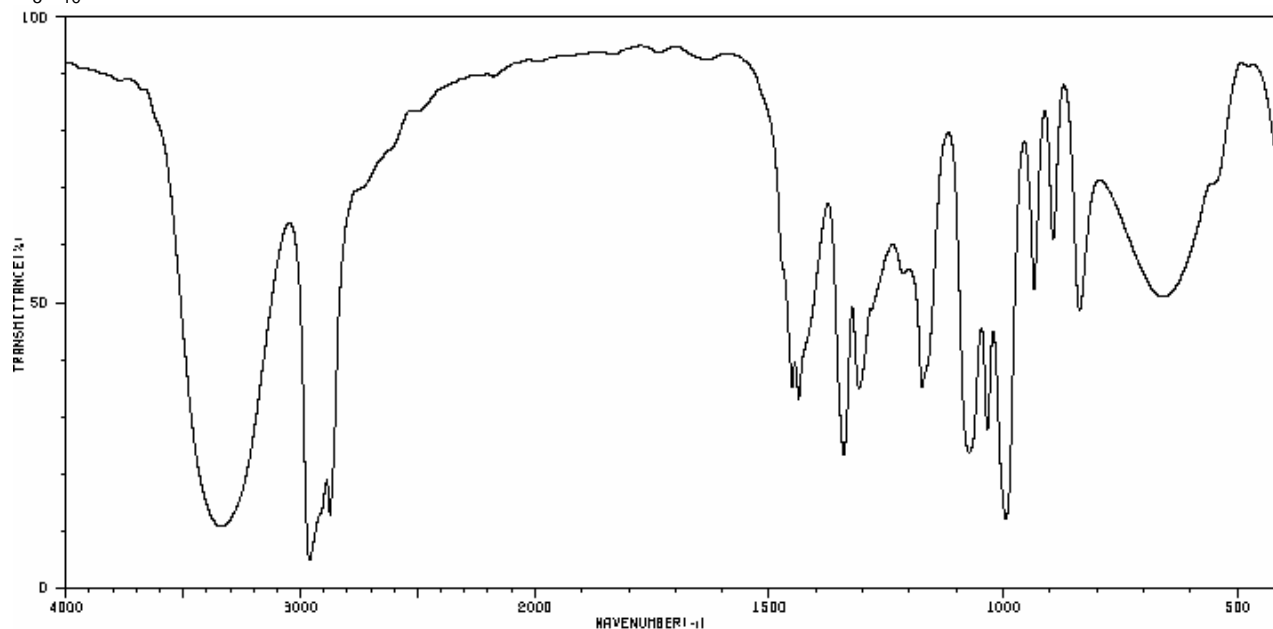
\* If this number is in parentheses, then it refers to the atomic mass of the most stable isotope.

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1. (10 pts) For the molecule  $\text{H}_2\text{CCHNH}_2$ , draw a three dimensional Lewis structure, and label approximate bond angles.

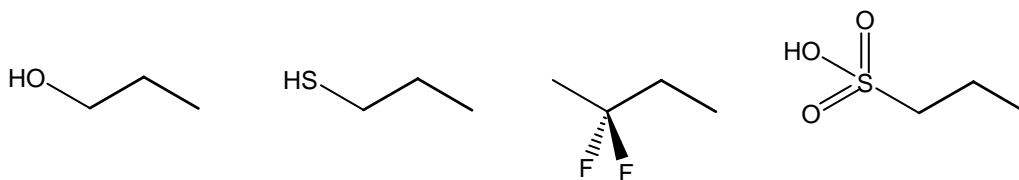
2. a. (10 pts) Use the following IR data to derive a reasonable structure for unknown compound **MARLEY**,  $\text{C}_5\text{H}_{10}\text{O}$ .



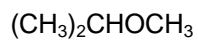
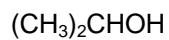
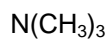
- b. (4 pts) Propose a constitutional isomer of **MARLEY** that is clearly not consistent with the IR data.

3. (12 pts) Which compound of each of the following pairs would you expect to have the larger net dipole moment and why?  
(a)  $\text{HCl}$  or  $\text{HF}$  (b)  $\text{BF}_3$  or  $\text{HI}$  (c)  $\text{CHCl}_3$  or  $\text{CFCl}_3$

4. (12 pts) Draw the conjugate base for each molecule below. Then rank them from most basic (1) to least basic (4). Briefly explain how you arrived at the order. Do not exceed the space provided.



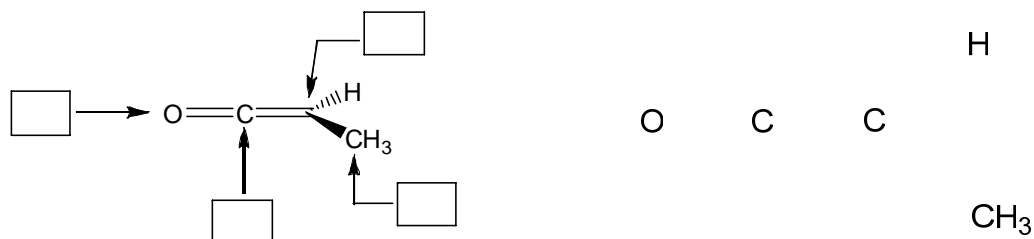
5. (10 pts) Rank the following solvents from highest (1) to lowest (4) solubility in water. Briefly explain how you arrived at the order. Do not exceed the space provided.



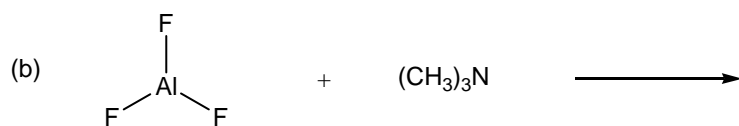
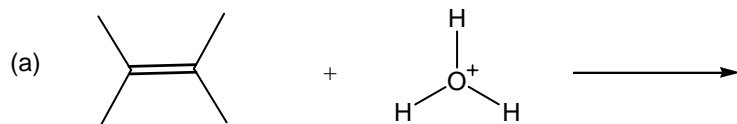
6. (10 pts) It is common for  $\text{NH}_3$  to function as a Brønsted-Lowry base; however, it is possible for it to function as a Brønsted-Lowry acid. Give the structure of a base that will successfully/completely deprotonate  $\text{NH}_3$ . Justify your answer. You must write a balanced reaction and curved arrows for the reaction you propose. [For partial credit, write a balanced reaction and curved arrows for any reaction where  $\text{NH}_3$  is a Brønsted-Lowry acid.]

7. Consider the molecule shown below.

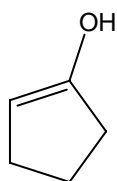
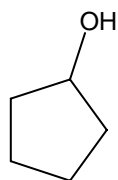
- a. (4 pts) Indicate the hybridization of each of the four atoms indicated in the boxes provided.
- b. (8 pts) On the template below and to the right, use lines, dashes, and wedges for the sigma bonds only. Then draw and identify the orbitals that overlap to form  $\pi$  bonds. Be as clear as possible.



8. (10 pts) Draw Lewis structures for the products of the following acid/base reactions. Include lone pairs and formal charges. You must draw curved arrows for each reaction.



9. (10 pts) (a) Name the functional group(s) in the molecules below. (b) Predict whether **A** or **B** has the lower  $pK_a$ . Clearly justify your answer. Your answer must include a combination of words and relevant structures.



**CHEMISTRY 301**  
**11:15 AM Section**  
**EXAM 1**  
**28 Sept 2009**

Name: \_\_\_\_\_

| Page  | Points | Score |
|-------|--------|-------|
| 2     | 36     |       |
| 3     | 32     |       |
| 4     | 32     |       |
| Total | 100    |       |

| Acid  | $pK_a$ |
|---|--------|
| HI  | -9     |
| H <sub>2</sub> SO <sub>4</sub>                  | -9     |
| HBr   | -9     |
| HCl   | -7.3   |
| CH <sub>3</sub> CH <sub>3</sub> OH <sup>+</sup> | -2.4   |
| C <sub>6</sub> H <sub>5</sub> SO <sub>3</sub> H | -0.6   |
| H <sub>3</sub> O <sup>+</sup>                   | -1.7   |
| HNO <sub>3</sub>                                | -1.3   |
| HF  | 3.2    |
| CH <sub>3</sub> COOH                            | 4.8    |
| H <sub>2</sub> CO <sub>3</sub>                  | 6.5    |
| HCN   | 9.1    |
| NH <sub>4</sub> <sup>+</sup>                    | 9.4    |
| C <sub>6</sub> H <sub>5</sub> OH                | 10.0   |
| HCO <sub>3</sub> <sup>-</sup>                   | 10.2   |
| CH <sub>3</sub> NH <sub>3</sub> <sup>+</sup>    | 10.6   |
| H <sub>2</sub> O                                | 15.7   |
| CH <sub>3</sub> CH <sub>2</sub> OH              | 17     |
| CH <sub>3</sub> COCH <sub>3</sub>               | 19     |
| HC≡CH   | 26     |
| H <sub>2</sub>                                  | 35     |
| NH <sub>3</sub>                                 | 36     |
| H <sub>2</sub> C=CH <sub>2</sub>                | 44     |
| CH <sub>4</sub>                                 | 49     |

| Approx. Freq.<br>(cm <sup>-1</sup> ) | Intensity | Shape | Interpretation         |
|--------------------------------------|-----------|-------|------------------------|
| 3500-3600                            | med       | shrp  | OH no hydrogen bonding |
| 3000-3600                            | med-str   | broad | OH hydrogen bonding    |
| 3300-3500                            | med       | var   | NH hydrogen bonding    |
| 3200-3300                            | med-str   | shrp  | sp CH                  |
| >3000                                | var       | var   | sp <sup>2</sup> CH     |
| <3000                                | var       | var   | sp <sup>3</sup> CH     |
| 2700-2800                            | med       | shrp  | aldehyde CH            |
| 2100-2300                            | wk-med    | shrp  | triple bonds           |
| 1700-2000                            | weak      | var   | aromatic overtones     |
| 1700-1800                            | str       | shrp  | most carbonyl          |
| 1600-1700                            | str       | shrp  | amide carbonyl, etc    |
| 1600                                 | var       | shrp  | CC double bond         |
| 1450-1600                            | med       | mult  | Aromatic               |
| 1500+, 1250+                         | str       | shrp  | Nitro                  |
| 1360-1380                            | weak      | shrp  | methyl bend            |
| 1000-1300                            | str       | shrp  | CO or CN               |
| 700-900                              | var       | shrp  | CCl                    |
| 700-900                              | var       | shrp  | C=CH out-of-plane bend |
| 600-700                              | var       | shrp  | CBr                    |