

1. (20 points) Multiple choice. Circle the one best answer for each problem below.

A. Which bond in ethanol ( $\text{CH}_3\text{CH}_2\text{OH}$ ) is the most polar?

- a. C-C      b. C-H (from the  $\text{CH}_3$ )      c. C-H (from the  $\text{CH}_2$ )  
d. C-O      e. O-H

B. Which of the following molecules would you expect to have a nonzero dipole moment?

- I.  $\text{CO}_2$       II. HCN      III.  $\text{CHCl}_3$

- a. II and III      b. II only      c. III only      d. all of them      e. none of them

C. When the 1s orbitals of two hydrogen atoms combine to form a hydrogen molecule, how many molecular orbitals are formed?

- a. 1      b. 2      c. 3      d. 4      e. 5

D. Select the most electronegative element.

- a. H      b. O      c. C      d. N      e. B

E. Which is a carboxylic acid?

- a.  $\text{CH}_3\text{CH}_2\text{OH}$       b.  $\text{CH}_3\text{OCH}_3$       c.  $\text{CH}_3\text{CH}_2\text{CO}_2\text{CH}_3$   
d.  $\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$       e.  $\text{CH}_3\text{CH}_2\text{CHO}$

F. Which intermolecular force is the weakest?

- a. Ion-ion forces      b. Dipole-dipole forces      c. van der Waals forces  
d. Hydrogen bonding      e. These are all equally weak

G. An oxygen-containing compound that shows no IR absorption at  $1750\text{ cm}^{-1}$  or at  $3400\text{ cm}^{-1}$  is likely to be what kind of compound?

No C=O, NO OH

- a. an alcohol  
d. an ether
- b. a ketone  
e. a carboxylic acid
- c. an aldehyde

H. The compounds ethane, ethene, and ethyne ( $\text{CH}_3\text{CH}_3$ ,  $\text{CH}_2=\text{CH}_2$ , and  $\text{HC}\equiv\text{CH}$ ) exhibit this order of increasing acidity:

- a. ethyne < ethene < ethane  
c. ethane < ethyne < ethene  
e. ethene < ethane < ethyne
- b. ethene < ethyne < ethane  
d. ethane < ethene < ethyne

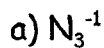
I. Which of the following is the strongest base?

- a.  $\text{CH}_3\text{CH}_2\text{O}^-$   
pk<sub>a</sub> of conj. 16
- b.  $\text{CH}_3\text{CH}_2^-$   
50
- c.  $\text{CH}_3\text{CH}_2\text{CO}_2^-$   
~4.75
- d.  $\text{OH}^-$   
15.7
- e.  $\text{NH}_2^-$   
38

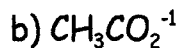
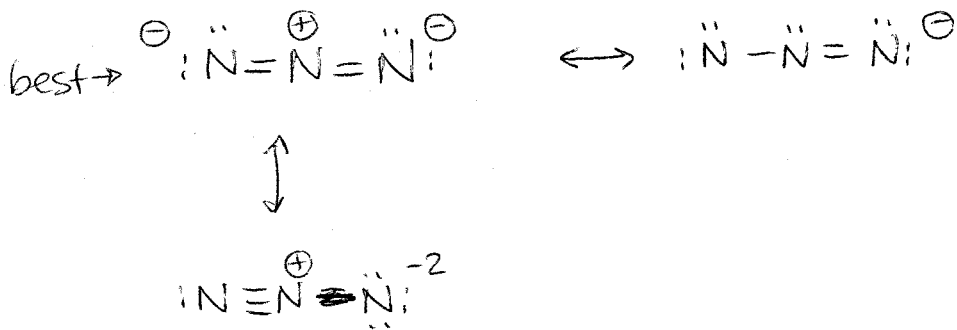
J. Complete the following reaction:  $\text{CH}_3\text{CH}_2\text{OH} + \text{NaH} \rightarrow ?$

- a.  $\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3 + \text{H}_2$   
c.  $\text{CH}_3\text{CH}_2\text{ONa} + \text{H}_2$   
e.  $\text{CH}_3\text{CH}_3 + \text{NaOH}$
- b.  $\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3 + \text{NaOH}$   
d.  $\text{CH}_3\text{CH}_2\text{Na} + \text{NaOH}$

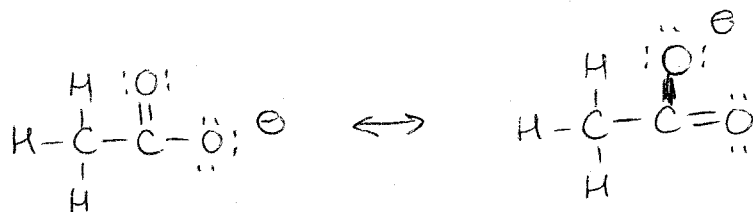
2. (12 points) For each of the compounds below: (a) give the number of valence electrons; (b) draw the best possible Lewis structure; (c) include all non-zero formal charges; and (d) show any important resonance structures.



# of valence electrons = 16

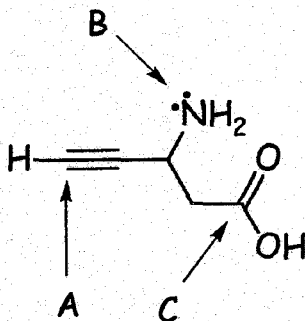


# of valence electrons = 24



equal importance

3. (9 points) For the molecule shown below, give the requested information.



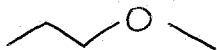
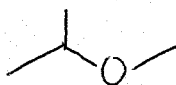
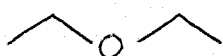
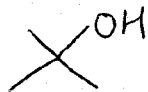
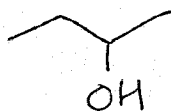
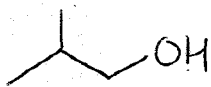
A. For atom A:  
(the C) hybridization = sp  
shape = linear  
geometry = linear

B. For atom B: hybridization = sp<sup>3</sup>  
shape = ~~trig.~~ pyramidal  
geometry = tetrahedral

C. For atom C: hybridization = sp<sup>2</sup>  
shape = trig. planar  
geometry = trig. planar



6. (14 points) Draw all possible isomers of  $C_4H_{10}O$ , using bond line notation. SODAR = 0  
alcohols + ethers only - no rings



-1 for each wrong one

-1 for each duplicate

7. (8 points) At  $25^\circ C$  the enthalpy change,  $\Delta H^\circ$ , for the ionization of trichloroacetic acid is  $+6.3 \text{ kJ/mol}$  and the entropy change,  $\Delta S^\circ$ , is  $+0.0084 \text{ kJ/mol K}$ . The gas constant,  $R$ , is  $+8.314 \text{ J/mol K}$ . Please show your work for your calculations.

a) What is the Gibbs free energy,  $\Delta G^\circ$ , for this reaction?

$$25 + 273 = 298 \text{ K}$$

$$8.314 \text{ J/mol K} \times \frac{1 \text{ kJ}}{1000 \text{ J}} = 8.314 \times 10^{-3} \text{ kJ/mol K}$$

$$\Delta G = \Delta H - T \Delta S$$

$$= 6.3 - (298)(0.0084)$$

$$= 3.797 \text{ kJ/mol}$$

b) What is the  $pK_a$  of trichloroacetic acid?

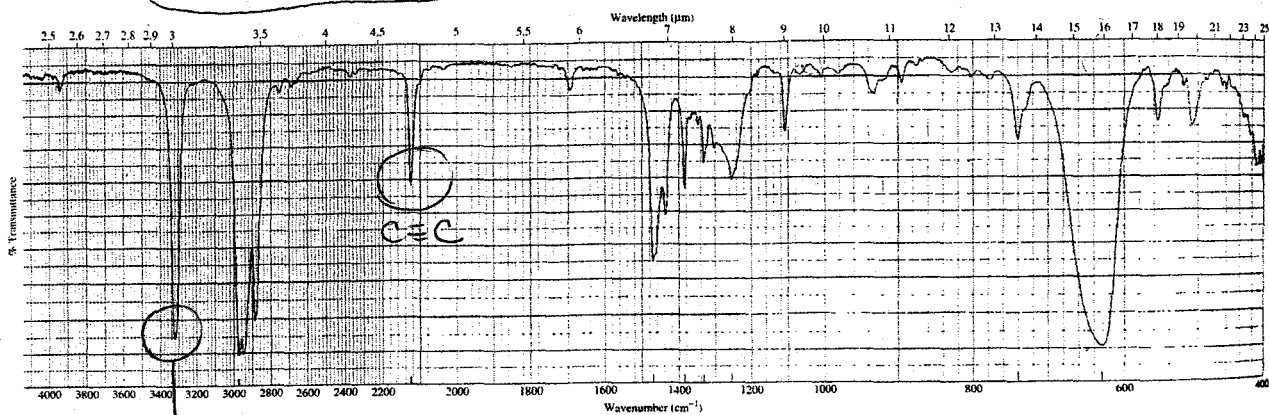
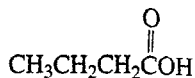
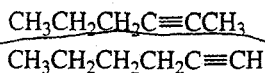
$$\Delta G = -RT \ln K_a = -2.303 RT \log K_a \leftarrow +1$$

$$3.797 = -(8.314 \times 10^{-3})(298) \ln K_a$$

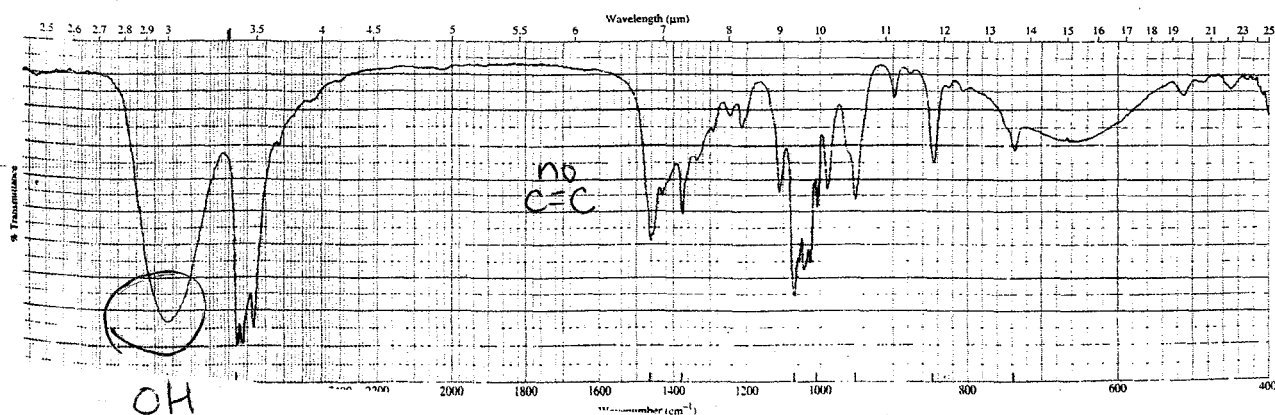
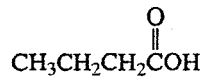
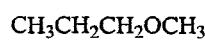
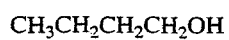
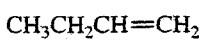
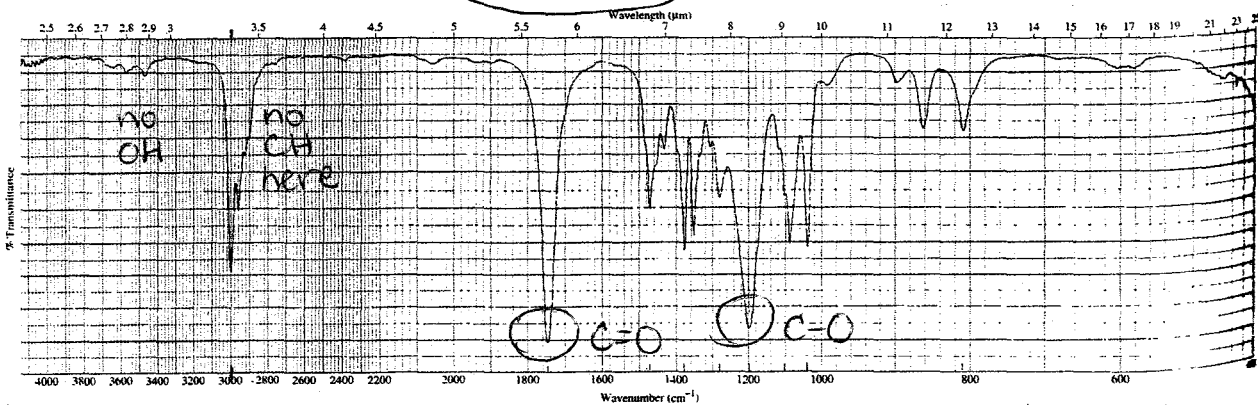
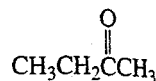
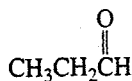
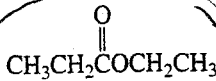
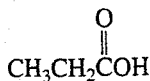
$$K_a = 0.216$$

$$pK_a = -\log K_a = 0.665$$

8. (15 points) Each of the IR spectra below are accompanied by an assortment of structures. Identify which structure goes with the spectrum, and indicate the peaks in the IR that allow you to make that decision.



sp CH



Problem 8 (continued):

