

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 CH_3) c. C-H (from the CH_2)
 d. C-O e. O-H

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

- I. CO_2 II. HCN III. 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. CH_3OCH_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 cm^{-1} or at 3400 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 (CH_3CH_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

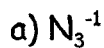
I. Which of the following is the strongest base?

- a. $\text{CH}_3\text{CH}_2\text{O}^-$
pk_a of conj. 16
- b. CH_3CH_2^-
50
- c. $\text{CH}_3\text{CH}_2\text{CO}_2^-$
~4.75
- d. OH^-
15.7
- e. NH_2^-
38

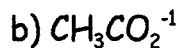
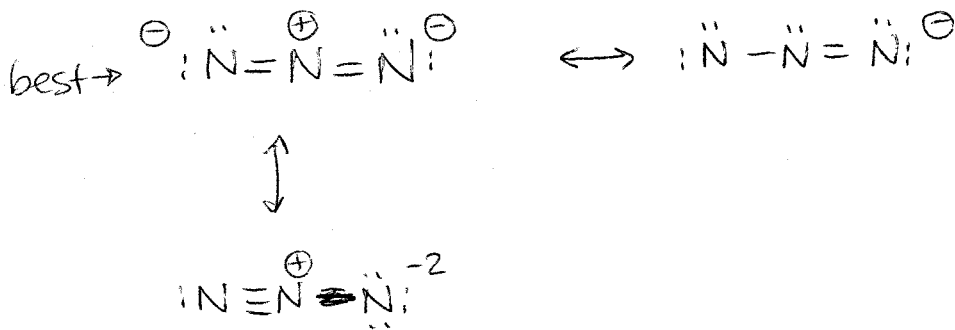
J. Complete the following reaction: $\text{CH}_3\text{CH}_2\text{OH} + \text{NaH} \rightarrow ?$

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

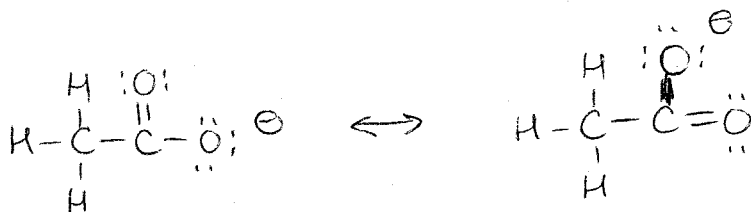
2. (12 points) For each of the compounds below: (a) give the number of valence electrons; (b) draw the best possible Lewis structure; (c) include all non-zero formal charges; and (d) show any important resonance structures.



of valence electrons = 16

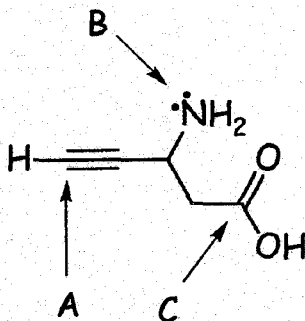


of valence electrons = 24



equal importance

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

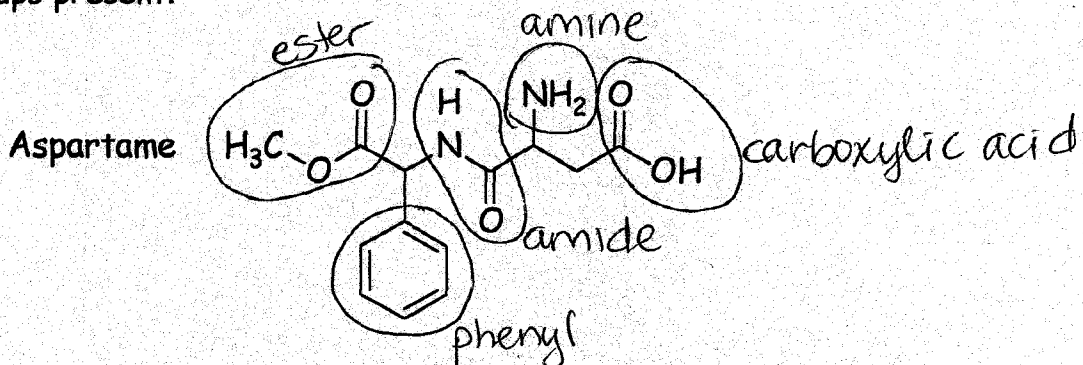


A. For atom A:
(the C) hybridization = sp
shape = linear
geometry = linear

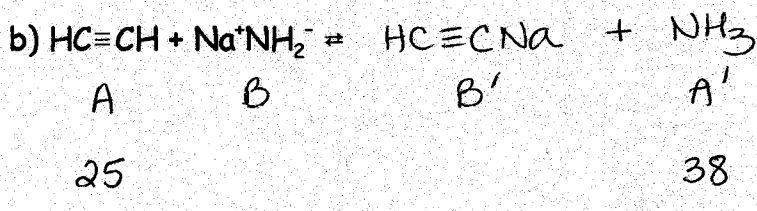
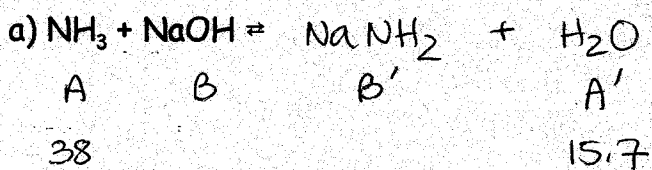
B. For atom B: hybridization = sp³
shape = trig. pyramid
geometry = tetrahedral

C. For atom C: hybridization = sp²
shape = trig. planar
geometry = trig. planar

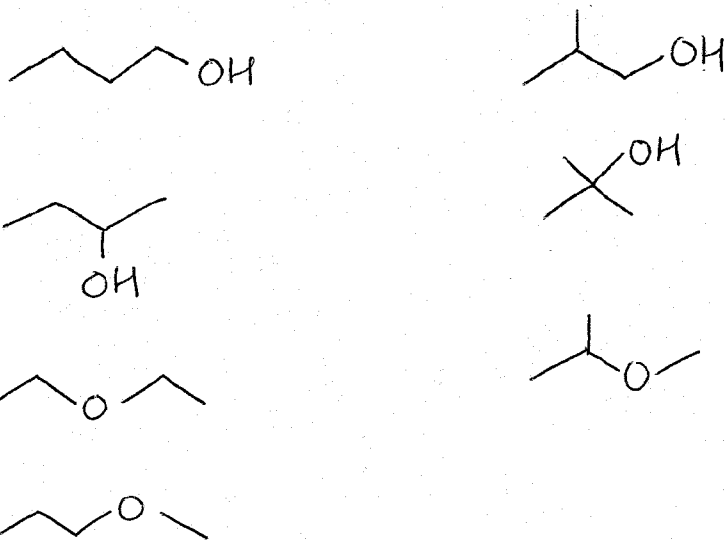
4. (10 points) For the molecule shown below, circle and identify all of the functional groups present.



5. (12 points) Complete each of the following reactions (fill in the hypothetical products), identify the acids, including pK_a values, and indicate the *actual* direction of the equilibrium with an arrow.



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



-1 for each wrong ones

-1 for each duplicate

7. (8 points) At $25^\circ C$ the enthalpy change, ΔH° , for the ionization of trichloroacetic acid is $+6.3 \text{ kJ/mol}$ and the entropy change, ΔS° , 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, ΔG° , for this reaction?

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

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

+1
↙

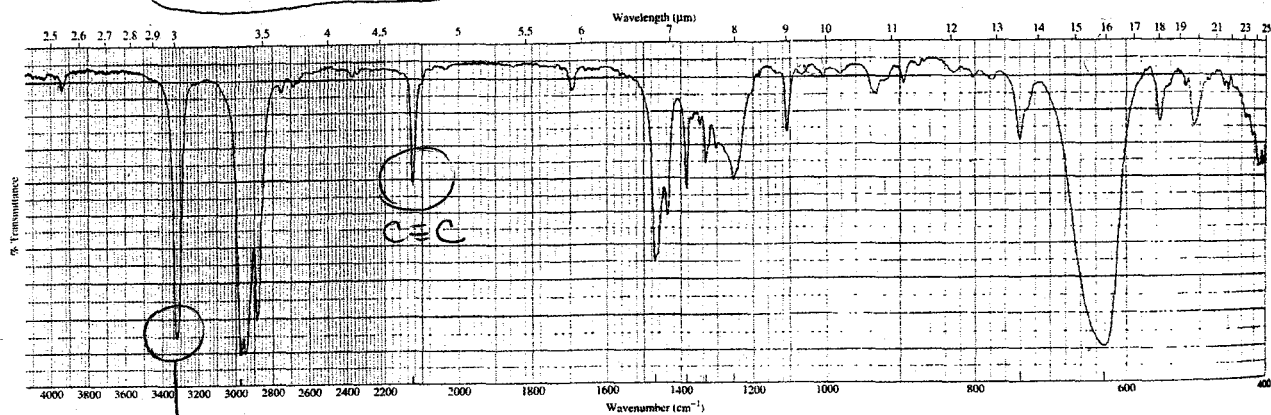
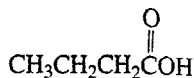
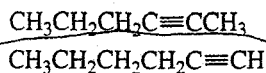
$\Delta G = \Delta H - T \Delta S$
 $= 6.3 - (298)(0.0084)$
 $= 3.797 \text{ kJ/mol}$

b) What is the pK_a of trichloroacetic acid?

$\Delta G = -RT \ln K_a = -2.303 RT \log K_a \leftarrow +1$
 $3.797 = -(8.314 \times 10^{-3})(298) \ln K_a$
 $K_a = 0.216$
 $pK_a = -\log K_a = 0.665$
 -7-



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.

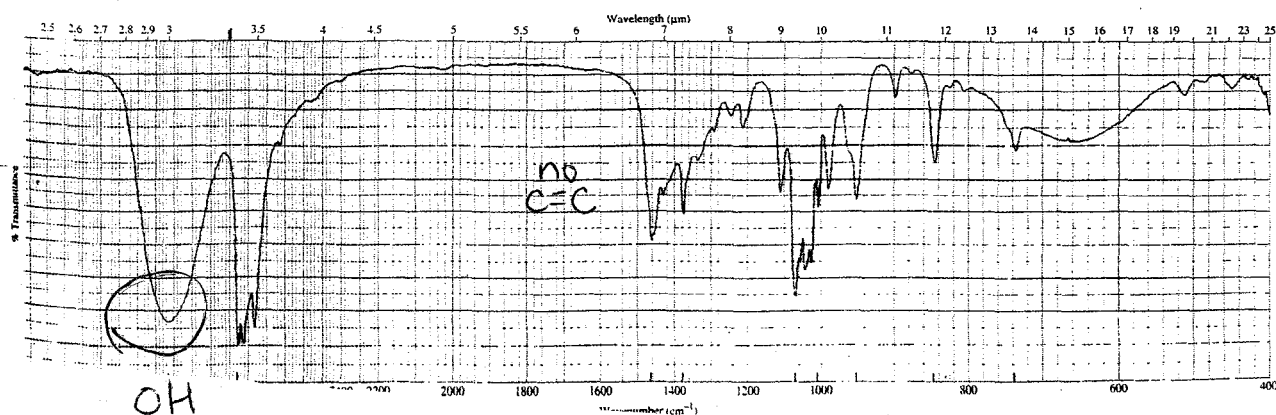
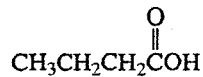
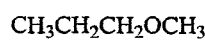
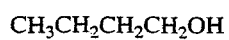
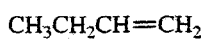
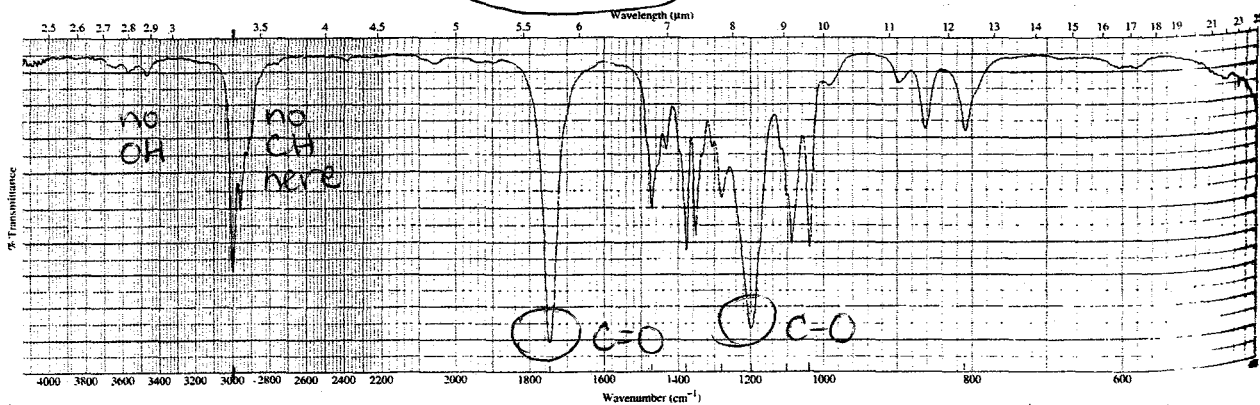
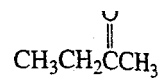
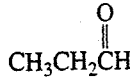
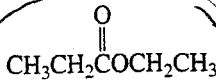
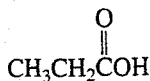


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OH

Problem 8 (continued):

