Your exam should consist of 5 pages including the cover page and grade tabulation sheet. The pK<sub>a</sub> 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. a. (10 pts) Use the following IR data to derive a reasonable structure for unknown compound OSO, C$_4$H$_7$N.

![IR spectrum]

b. (4 pts) Propose a constitutional isomer of OSO that is clearly not consistent with the IR data. In one sentence or less, indicate how you know this structure is not consistent with the IR data.

2. (10 pts) Rank the protons in the following molecule in order of increasing acidity (1 = most acidic). Clearly explain your ranking.

![Molecule]

3. (8 pts) (a) Give an example of a secondary alkyl halide. (b) Give an example of a molecule with IHD = 1 that contains two fluorine atoms and has a dipole moment of zero.

   a.  
   b.  


4. (10 pts) Draw in all lone pair electrons in the molecules below. For (a), supply curved arrows that show how the reactants are transformed into the product. For (b), supply curved arrows that show how the second resonance structure is generated from the first resonance structure.

\[\text{R}_1\text{H} - \text{O} - \text{H} \quad \text{R}_2\]

\[\text{R}_1\text{H} + \text{R}_2\]

\[\text{R}_1\text{H} - \text{O} - \text{H} \quad \text{R}_2\]

b. 

\[\text{O} \quad \text{O} \quad \text{O} \quad \text{O} \quad \text{O} \quad \text{O}\]

\[\text{O} \quad \text{O} \quad \text{O} \quad \text{O} \quad \text{O} \quad \text{O}\]

5. Sodium perborate (NaBO$_3$) has enjoyed recent success as a laundry bleaching agent. The structure of this compound remains in question, and this question examines some of the possibilities.

a. (4 pts) In the box to the right, write the best Lewis structure for an anion with the connectivity OBOO.

b. (4 pts) Would you expect this anion to be bent or linear?

c. (4 pts) Assign hybridization to each atom in your Lewis structure.

d. (4 pts) Identify what orbitals overlap to form each bond in your Lewis structure.

e. (4 pts) The Solvay Chemicals website describes sodium perborate as “containing a cyclic peroxide ring structure” (a peroxide functional group is R-O-O-R). Draw a valid Lewis structure for the BO$_3$ anion that satisfies the Solvay description and contains a single negative formal charge.

f. (5 pts) Another website gave a third perborate anion structure, shown in the box to the right. In the space provided below, write a brief critique of this structure. This answer should not be an essay. A few specific comments about the proposed structure will suffice.
6. (10 pts) Deprotonation of compounds A and B results in the formation of the same conjugate base. Explain and illustrate.

A
\[ \text{H}_2\text{C} \equiv \text{CH}_2 \]

B
\[ \text{H}_2\text{C} \equiv \text{CH}_3 \]

7. (8 pts) Clearly explain why butter and vegetable oil have significantly different melting points.

butter = \text{CH}_3(\text{CH}_2)_{16}\text{COOH}

vegetable oil = \text{CH}_3(\text{CH}_2)_{7}\text{CH}=\text{CH}(\text{CH}_2)_{7}\text{COOH}

8. (15 pts) Circle the correct thermodynamic descriptor for each of the following reactions:

\[ \text{H}_2\text{N} \text{CO}_2\text{H} \quad \text{a. } \Delta G > 0 \quad \text{b. } \Delta G < 0 \quad \text{c. } \Delta G \approx 0 \]

\[ \text{H}_3\text{N} \text{CO}_2 \]

\[ \text{H}_2\text{N} \text{CO}_2\text{H} \]

\[ \text{H}_3\text{N} \text{CO}_2 \]
Name: ________________________________

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**Acid** | $pK_a$  
--- | ---  
HI | -9  
H$_2$SO$_4$ | -9  
HBr | -9  
HCl | -7.3  
CH$_3$CH$_2$OH | -2.4  
C$_6$H$_5$SO$_3$H | -0.6  
H$_3$O$^+$ | -1.7  
HNO$_3$ | -1.3  
HF | 3.2  
CH$_3$COOH | 4.8  
H$_2$CO$_3$ | 6.5  
HCN | 9.1  
NH$_4^+$ | 9.4  
C$_6$H$_5$OH | 10.0  
HCO$_3^-$ | 10.2  
CH$_3$NH$_3^+$ | 10.6  
H$_2$O | 15.7  
CH$_3$CH$_2$OH | 17  
CH$_3$COCH$_3$ | 19  
HC≡CH | 26  
H$_2$ | 35  
NH$_3$ | 36  
H$_2$C=CH$_2$ | 36  
CH$_4$ | 49

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**Group** | Frequency Range (cm$^{-1}$) | Intensity$^a$  
--- | --- | ---  
A. Alkyl | C–H (stretching) | 2853–2962 | (m–s)  
| | C=H (stretching) | 3010–3095 | (m)  
| | C=C (stretching) | 1620–1680 | (v)  
B. Alkenyl | C–H (stretching) | 3010–3095 | (m)  
| | C=C (stretching) | 1620–1680 | (v)  
C. Alkynyl | C≡H (stretching) | 3300 | (s)  
| | C≡C (stretching) | 2100–2200 | (v)  
D. Aromatic | C=C=H (stretching) | 3030 | (v)  
E. Alcohols, Phenols, and Carboxylic Acids | O–H (stretching) | 3590–3650 | (sharp, v)  
| | Alcohols, phenols (dilute solutions) | 3200–3550 | (broad, s)  
| | Alcohols, phenols (hydrogen bonded) | 2500–3000 | (broad, v)  
F. Aldehydes, Ketones, Esters, and Carboxylic Acids | C=O (stretching) | 1630–1780 | (s)  
| | Aldehydes | 1690–1740 | (s)  
| | Ketones | 1680–1750 | (s)  
| | Esters | 1735–1750 | (s)  
| | Carboxylic acids | 1710–1780 | (s)  
| | Amides | 1630–1690 | (s)  
G. Amines | N–H | 3300–3500 | (m)  
H. Nitriles | C≡N | 2220–2260 | (m)

$^a$Abbreviations: s = strong, m = medium, w = weak, v = variable, ~ = approximately.