Chem. 1C Exam 1
April 26, 2002

First letter of your last name:  

Name: ________________________________  
Last Name  First Name  
Perm #  

There are a total of four pages (13 problems) in the exam. All work must be shown on the exam. Show your method of calculation clearly. Correct answers not showing the work will not receive credit. Include the UNITS of all answers.

Notes written on one 8.5 X 11 inch page may be used. All other notes and books are not allowed.

| Pg 1 (31) |  |
| Pg 2 (19) |  |
| Pg 3 (22) |  |
| Pg 4 (28) |  |
| Total (100) |  |
1. (6 pts) For each of the following molecules, write the Lewis structure, predict the molecular geometry, and if the molecule is polar indicate the direction of the dipole. Nitrogen is the central atom in NO$_3^-$.

   - **a) H$_2$O$^+$**
     - Lewis structure: \[ \begin{array}{ccc} \text{H} & \cdots & \text{O} \\
     \overset{\text{H}}{\cdots} & \overset{-}{\cdots} & \overset{\text{H}}{\cdots} \end{array} \]
     - molecular geometry: trigonal pyramid
     - polarity: polar

   - **b) NO$_2^-$**
     - Lewis structure: \[ \begin{array}{ccc} \text{O} & \cdots & \text{N} \\
     \overset{-}{\cdots} & \overset{\text{N}}{\cdots} & \overset{-}{\cdots} \end{array} \]
     - molecular geometry: bent
     - polarity: polar

2. (6 pts) Draw the Lewis structure for acetate, CH$_3$COO$^-$, including resonance structures.

   - \[ \begin{array}{ccc} \text{H} & \cdots & \text{C} \\
     \overset{-}{\cdots} & \overset{\text{C}}{\cdots} & \overset{-}{\cdots} \end{array} \]
   - \[ \begin{array}{ccc} \text{H} & \cdots & \text{C} \\
     \overset{-}{\cdots} & \overset{\text{C}}{\cdots} & \overset{-}{\cdots} \end{array} \]

3. (9 pts) Indicate the dominant intermolecular force for each of the following substances.

   - a) CO$_2$ \[ \text{LDF} \]
   - b) HCl dipole-dipole
   - c) H$_2$S dipole-dipole
   - d) LiF ionic
   - e) SO$_3$ \[ \text{LDF} \]
   - f) SO$_2$ dipole-dipole
   - g) CaCl$_2$ ionic
   - h) C$_2$H$_4$ \[ \text{LDF} \]
   - i) CH$_3$OH H-bonding

4. (4 pts) A substance does not conduct electricity in liquid or solid form. It is soft and has a low melting point (below 100°C). These properties are characteristic of which one of the following crystalline solids? Circle the correct answer.

   - a) ionic
   - b) molecular
   - c) metallic
   - d) covalent (atomic network)

5. (6 pts) Indicate the type of crystalline solid formed for each of the following substances.

   - a) Na$_2$O ionic
   - b) P covalent network
   - c) Ca metallic
   - d) SiO$_2$ covalent network
   - e) KBr ionic
   - f) H$_2$S molecular
6. a) (3 pts) Consider the phase diagram for water. Label the regions (indicate the phase in region A, B and C).

\[ A = \text{solid} \]
\[ B = \text{liquid} \]
\[ C = \text{gas} \]

a) (3 pts) Starting at point C, what phase change occurs if the temperature is lowered at constant pressure. Circle the answer.

- Liquid → Solid
- Liquid → Gas
- Solid → Liquid
- Gas → Solid
- Solid → Gas
- Gas → Liquid

b) (3 pts) Starting at point A, what phase change occurs if the pressure is increased at constant temperature. Circle the answer.

- Liquid → Solid
- Liquid → Gas
- Solid → Liquid
- Gas → Solid
- Solid → Gas
- Gas → Liquid

7. (10 pts) As a result of a chemical reaction, 0.132 g of H\(_2\)O is produced and maintained at a temperature of 50.0°C in a closed flask of 525-mL volume. For water, \( \Delta H_{\text{vap}} = 44 \text{ kJ/mol} \).

Will water be present as liquid only, as vapor only, or as liquid and vapor in equilibrium? **SHOW YOUR WORK**

a) vapor only

\[ P \cdot V = n \cdot R \cdot T \]
\[ P = \frac{n \cdot R \cdot T}{V} = 0.37 \text{ atm} \]

c) liquid only

\[ 0.132 \text{ g} \cdot \frac{1 \text{ mL}}{1 \text{ g}} = 0.132 \text{ mL} \]
\[ 0.13 \text{ mL} < < 525 \text{ mL container} \]
\[ \Rightarrow \text{H}_2\text{O}(l) \rightarrow \text{H}_2\text{O}(g) \]
\[ \text{too high} \]
\[ \Rightarrow \text{vapor only} \]

b) liquid/vapor at equilibrium

\[ \ln \left( \frac{P}{P_1} \right) = \frac{\Delta H_{\text{vap}}}{R} \left[ \frac{1}{T_2} - \frac{1}{T_1} \right] \]
\[ \ln(P/\text{atm}) = \frac{44 \times 10^2 \text{ J/mol}}{8.3145 \text{ J/molK}} \left[ \frac{1}{373} - \frac{1}{313} \right] \]
\[ P_1 = 0.111 \text{ atm} \]
\[ \text{vapor pressure at 50°C} \]

\[ 0.37 \text{ atm} > \text{vapor only} \]

\[ \Rightarrow \text{some H}_2\text{O}(g) \rightarrow \text{H}_2\text{O}(l) \]

**water is present as liquid and vapor in equilibrium**
8. (8 pts) Indicate the hybridization on the carbon atoms.

\[
\text{H}_3\text{C}-\text{C}≡\text{C}-\text{C}_4\text{O}-\text{H}
\]

Hybridization on first carbon: \( \text{SP}^2 \)  
Hybridization on second carbon: \( \text{SP} \)  
Hybridization on third carbon: \( \text{SP} \)  
Hybridization on fourth carbon: \( \text{SP}^2 \)

9. (4 pts) Indicate the approximate bond angles, a, b, c and d.

\[
\text{H}_3\text{C}-\text{C}≡\text{C}-\text{C}_4\text{O}-\text{H}
\]

Angle a: \( 180 \)  
Angle b: \( \sim 120 \)  
Angle c: \( \sim 120 \)  
Angle d: \( \leq 109 \)

10. a) Indicate the hybridization on the nitrogen atoms and the carbon atoms in cyanuric acid (the molecule shown).

(2 pts) Hybridization on nitrogen: \( \text{SP}^3 \)
(2 pts) Hybridization on carbon: \( \text{SP}^2 \)

b) (2 pts) How many \( \sigma \)-bonds are there in cyanuric acid? \( 12 \)

c) (2 pts) How many \( \pi \)-bonds are there in cyanuric acid? \( 3 \)

d) (2 pts) Are all the atoms in cyanuric acid in the same plane? Circle the answer.  
Yes \[ \boxed{\text{No}} \]
11. (4 pts) For a given substance which is generally larger, the heat of vaporization or the heat of fusion? Circle the answer.
   a) Heat of vaporization  b) Heat of fusion

12. (4 pts) Which one of the following has the longest CO bond length? Circle the correct answer.
   CO \hspace{1cm} H_2CO \hspace{1cm} CO_2^- \hspace{1cm} CH_3OCH_3 \hspace{1cm} CO_2

13. (20 pts) Circle the formula that best fits each of the following descriptions:
   a) Which of the following is not a valid resonance structure for N_3^-:
      \[ \begin{array}{c}
      [-\hat{N} = N = \hat{N}]^- \\
      [-\hat{N} = N = \hat{N}]^- \\
      \vdots \\
      [-\hat{N} = N = \hat{N}]^- \\
      \end{array} \]
   b) hybridization on the central chlorine atom in ClO_3^-  \quad \text{sp} \qquad \text{sp}^2 \quad \fbox{\text{sp}^3} \quad \text{dsp}^3 \quad \text{d}^2\text{sp}^3
   c) most polar bond  \quad C - H \quad N - H \quad O - H
   d) greatest bond energy (as predicted by MO theory)  \quad O_2 \quad O_2^- \quad O_3^- \quad O_2^{2-}
   e) greatest electronegativity  \quad K \quad Si \quad S \quad Ar
   f) contains one π-bond  \quad CN^- \quad \fbox{SO_2} \quad NO^+ \quad CO_2
   g) greatest viscosity  \quad CH_3CH_2CH_2CH_3 \quad CH_3CH_2CH_2OH \quad \fbox{HOCH_2CH_2OH}
   h) higher vapor pressure at 1 atm, 25°C  \quad \fbox{CH_3OCH_3} \quad CH_3CH_2OH \quad H_2O
   i) lowest freezing point  \quad H_2O \quad O_2 \quad He \quad CO_2
   j) highest boiling point  \quad BCl_3 \quad HCN \quad \fbox{NH_4Cl} \quad SiH_4