1. (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

2. (4 pts) Which one of the following has the longest CO bond length? Circle the correct answer.

   CO  H₂CO  CO₃²⁻  \( \text{CH₃OCH₃} \)  CO₂

3. (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 \( \text{N}_3^- \):

   \[
   [:\text{N} = \text{N} = \text{N}:]^- \quad [:\text{N} \equiv \text{N} - \text{N}:]^- \quad [:\text{N} = \text{N} = \text{N}:]^- \quad [:\text{N} = \text{N} - \text{N}:]^- \]

   b) Hybridization on the central chlorine atom in \( \text{ClO}_2^- \):

   \[
   \text{sp} \quad \text{sp}^2 \quad \text{sp}^3 \quad \text{dsp}^3 \quad \text{d}^2\text{sp}^3
   \]

   c) Most polar bond

   C-H  N-H  O-H

   d) Greatest bond energy (as predicted by MO theory)

   \[
   \text{O}_2 \quad \text{O}_2^+ \quad \text{O}_2^- \quad \text{O}_2^{2-}
   \]

   e) Greatest electronegativity

   K  Si  S  Ar

   f) Contains one \( \pi \)-bond

   CN⁻  SO₂  NO⁺  CO₂

   g) Greatest viscosity

   CH₃CH₂CH₂CH₃  CH₃CH₂CH₃OH  \( \text{HOCH₂CH₂OH} \)

   h) Higher vapor pressure at 1 atm, 25°C

   \( \text{CH₂OCH₃} \)  CH₃CH₂OH  H₂O

   i) Lowest freezing point

   H₂O  O₂  He  CO₂

   j) Highest boiling point

   BCl₃  HCN  \( \text{NH₄Cl} \)  SiH₄
4. (8 pts) Indicate the hybridization on the carbon atoms.

\[
\begin{array}{c}
\text{H}_3\text{C} - \text{C} = \text{C} - \text{C} - \text{O} - \text{H} \\
\text{Hybridization on first carbon: } \text{sp}^3 \\
\text{Hybridization on second carbon: } \text{sp} \\
\text{Hybridization on third carbon: } \text{sp} \\
\text{Hybridization on fourth carbon: } \text{sp}^2
\end{array}
\]

5. (4 pts) Indicate the approximate bond angles, a, b, c and d.

\[
\begin{array}{c}
\text{H}_3\text{C} - \text{C} = \text{C} - \text{C} - \text{O} - \text{H} \\
\text{Angle a: } 180 \\
\text{Angle b: } \sim 120 \\
\text{Angle c: } \sim 120 \\
\text{Angle d: } \sim 109
\end{array}
\]

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

(2 pts) Hybridization on carbon: \text{sp}^2

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

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

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

d) (2 pts) Are all the atoms in cyanuric acid in the same plane? Circle the answer.

Yes [ ] No [x]
7. (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 NO₃⁻.

a) H₂O⁺
\[
\begin{array}{c}
\text{Lewis structure} \\
\text{molecular geometry} \\
polarity \\
\end{array}
\]
\[
\begin{array}{c}
\text{H} \\
\text{O} \\
\text{H} \\
\end{array}
\] +

b) NO₂⁻
\[
\begin{array}{c}
\text{Lewis structure} \\
\text{molecular geometry} \\
polarity \\
\end{array}
\]
\[
\begin{array}{c}
\text{O} \\
\text{N} \\
\text{O} \\
\end{array}
\] -

\[
\frac{24-18}{2} = 3 \text{ bonds}
\]

8. (9 pts) Indicate the dominant intermolecular force for each of the following substances.

a) SO₂ dipole-dipole
b) H₂S dipole-dipole
c) HCl dipole-dipole
d) LiF ionic
e) CO₂ LDF
f) SO₃ LDF
g) C₂H₆ LDF
h) CaCl₂ ionic
i) CH₃OH H-bonding

9. (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) metallic
c) molecular
d) covalent (atomic network)

10. (6 pts) Indicate the type of crystalline solid formed for each of the following substances.

a) H₂S molecular
b) P covalent network
c) KBr ionic
d) SiO₂ covalent network
e) Ca metallic
f) Na₂O ionic

11. (6 pts) Draw the Lewis structure for acetate, CH₃COO⁻, including resonance structures.
12. a) (3pts) Consider the phase diagram for water. Label the regions (indicate the phase in region A, B and C).

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

- Liquid $\rightarrow$ Solid
- Liquid $\rightarrow$ Gas
- Gas $\rightarrow$ Solid
- Solid $\rightarrow$ Gas
- Gas $\rightarrow$ Liquid
- Solid $\rightarrow$ Liquid

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

- Liquid $\rightarrow$ Solid
- Liquid $\rightarrow$ Gas
- Solid $\rightarrow$ Liquid
- Gas $\rightarrow$ Solid
- Solid $\rightarrow$ Gas
- Gas $\rightarrow$ Liquid

13. (10pts) 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, $\Delta H_{\text{vap}} = 44$ kJ/mol.

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

**NO WORK = NO CREDIT**

a) **vapor pressure at equilibrium**

$$\ln \left( \frac{P_1}{P_2} \right) = \frac{\Delta H_{\text{vap}}}{R} \left( \frac{1}{T_2} - \frac{1}{T_1} \right)$$

$$\ln \left( \frac{P_1}{1 \text{ atm}} \right) = \frac{44 \text{ kJ/mol}}{(8.3145 \text{ J/mol K})} \left( \frac{1}{373 \text{ K}} - \frac{1}{323 \text{ K}} \right)$$

$$P_1 = 0.111 \text{ atm}$$

b) **calculate P assuming all H$_2$O produced is vapor only**

$$PV = nRT$$

$$0.132 \text{ g H}_2\text{O} \left( \frac{1 \text{ mol}}{18 \text{ g}} \right) = 0.0073 \text{ mol H}_2\text{O}$$

$$P = \frac{nRT}{V} = 0.37 \text{ atm} > P_1 = 0.111 \text{ atm}$$

H$_2$O(g) only

$\Rightarrow$ too much pressure in equilibrium

some vapor will condense to produce liquid water

$\Rightarrow$ Both liquid and vapor are present at 50°C.