1. (6 pts) Indicate the type of crystalline solid formed for each of the following substances.
   a) Na₂O ionic  
   b) Ga metallic  
   c) C(s) covalent network  
   d) NH₄Cl ionic 
   e) SiO₂ covalent network  
   f) H₂S molecular  

2. (3 pts) Circle the correct answer. A certain solid substance is very hard, has a high melting point, and is non-conducting unless melted. Which one of the following substances would likely have these properties?
   a) I₂  
   b) Cu  
   c) CO₂  
   d) H₂O  
   e) NaCl  

3. (9 pts) Indicate the dominant intermolecular force for each of the following substances.
   a) SO₃ LDF  
   b) NH₃ H-bonding  
   c) CH₃OCH₃ dipole  
   d) C₂H₆ LDF  
   e) HCl dipole  
   f) CO₂ LDF  
   g) HOCN H-bonding  
   h) Cl₂ LDF  
   i) NaNO₃ ionic  

4. (2 pts) Circle the correct answer. If the semiconductor silicon (Si) is doped with arsenic (As), does it decrease, increase or have no effect on its conductivity?
   a) Decrease  
   b) Increase  
   c) No effect  

5. (2 pts) Circle the correct answer. Increasing the total pressure above a liquid will cause the boiling point of the liquid to
   a) increase  
   b) decrease  
   c) remain the same  
   d) the affect on the boiling point depends on the liquid  

6. (2 pts) Circle the correct answer. At high altitude, the boiling point of water is
   a) higher than 100°C  
   b) lower than 100°C  
   c) remains the same  

7. (4 pts) Indicate the hybridization on the carbon and the nitrogen atoms.

\[ \text{Hybridization on carbon: } \text{sp}^3 \quad \text{Hybridization on nitrogen: } \text{sp}^2 \]

8. (4 pts) Indicate the approximate bond angles, a and b.

\[ \text{Angle a: } \leq 109 \quad \text{Angle b: } \sim 120 \]

9. (4 pts) For the following molecule indicate the hybridization on the carbon and the nitrogen atoms.

\[ \text{Hybridization on carbon: } \text{sp}^2 \quad \text{Hybridization on nitrogen: } \text{sp}^3 \]

10. (4 pts) Indicate the approximate bond angles, a, b, and c.

\[ \text{Angle a: } \sim 120 \quad \text{Angle b: } \sim 120 \quad \text{Angle c: } \leq 109 \]

11. The molecular orbital energies for NO increase in the following order: \((\sigma_2)(\sigma_1^*)(\pi_1^*)(\pi_2)(\sigma_2^*)(\pi_2^*)\)
a) (4 pts) According to the MO model, what is the bond order for NO, NO\(^+\), and NO\(^-\)?

\[ \text{Bond order: } \text{NO} \quad \text{NO}^+ \quad \text{NO}^- \]

b) (2 pts) Circle the answer. Which is the strongest bond? \[ \text{NO} \quad \text{NO}^+ \quad \text{NO}^- \]

12. a) (2 pts) Draw the Lewis structure for N\(_2\)F\(_2\).

\[ \text{bonds} \]

b) (2 pts) What is the hybridization on the nitrogen atoms?

\[ \text{sp}^2 \]

c) (2 pts) How many \(\pi\)-bonds are there in N\(_2\)F\(_2\)?

d) (2 pts) How many \(\sigma\)-bonds are there in N\(_2\)F\(_2\)?

e) (2 pts) Are all the atoms in N\(_2\)F\(_2\) in the same plane?
13. (10 pts) Circle the formula that best fits each of the following descriptions:

a) polar molecule
   \[
   BF_3 \quad CO_2 \quad \boxed{CH_2Cl_2} \quad SO_3
   \]

b) largest enthalpy of vaporization
   \[
   \boxed{I_2} \quad \boxed{Br_2} \quad F_2 \quad Cl_2
   \]
   Largest intermolecular force

b) highest boiling point
   \[
   CH_4 \quad SO_2 \quad \boxed{H_2O} \quad CO_2
   \]

d) has two π-bonds
   \[
   SO_3^{2-} \quad \boxed{C_2H_2} \quad H_2CO \quad NO
   \]
   \[
   H - C = C - H
   \]

b) hybridization on Xe in XeCl_2
   \[
   \boxed{dsp^3} \quad d^2sp^3 \quad sp \quad sp^3 \quad sp^3
   \]

14. (8 pts) For each of the following molecules, write the Lewis structure, and indicate the hybridization on the carbon atom

\[
\begin{array}{ll}
\text{Lewis structure} & \text{hybridization on carbon} \\
\text{HOCN} & \boxed{\text{C} \equiv \text{N} :} \quad \boxed{\text{SP}} \\
\text{C}_2\text{H}_4 & \boxed{\text{C} = \text{C} - \text{H}} \quad \boxed{\text{SP}^2}
\end{array}
\]

15. (4 pts) Which one of the following has the \underline{shortest} CO bond length? Circle the correct answer.

\[
\begin{array}{ll}
\boxed{\text{CO}_3^{2-}} & \boxed{\text{CH}_3\text{OCH}_3} \\
\boxed{\text{H}_3\text{C}^- \text{O} \cdots \text{H}_3\text{C}^+} & \boxed{\text{H}_2\text{CO}}
\end{array}
\]

16. (8 pts) Circle the correct answers. Which of the following factors affect the vapor pressure of a liquid in a closed container?

a) The intermolecular forces \[\boxed{\text{Yes}} \quad \text{No}\]

b) The size of the container holding the liquid-vapor equilibrium. \[\text{Yes} \quad \boxed{\text{No}}\]

c) The temperature of the liquid. \[\boxed{\text{Yes}} \quad \text{No}\]

d) The volume of liquid in the liquid-vapor equilibrium. \[\text{Yes} \quad \boxed{\text{No}}\]
17. (4 pts) Draw the phase diagram for carbon dioxide. Indicate the location of the triple point, the critical point and the region in which each substance is a solid, liquid and gas. The triple point for carbon dioxide occurs at 5.1 atm and -56.6°C. The critical point occurs at 72.8 atm and 31°C.

18. (10 pts) A 60 g piece of dry ice, CO₂(s), is placed in a 0.400 L container, and the container is sealed. If this container is held at 27°C, what state(s) of matter must be present? Will CO₂ be present only as a solid, only as a liquid, only as a vapor or is CO₂ present as liquid and vapor in equilibrium, or as a solid and gas at equilibrium? The density of liquid carbon dioxide, CO₂(l), is 1.1 g/ml. Hint: The phase diagram in problem 17 may be useful to answer this question.

**SHOW YOUR WORK**

NO WORK = NO CREDIT

\[ 60 \text{ g } \text{CO}_2 \left( \frac{1 \text{ mol}}{44 \text{ g}} \right) = 1.36 \text{ mol } \text{CO}_2 \text{ (s)} \]

If all CO₂(s) converts to CO₂(l),

then \[ P = \frac{nRT}{V} = \left( 1.36 \text{ mol} \right) \left( 0.08206 \frac{\text{L atm}}{\text{mol K}} \right) \left( 300 \text{ K} \right) \]

\[ P = 83.9 \text{ atm} \]

Vapor only

Phase diagram \( \Rightarrow \) 27°C \( P_{\text{vap}} < 72.8 \text{ atm} \)

\[ P = 83.9 \text{ atm} \text{ is too much pressure} \]

Some vapor will condense to form a liquid

\[ \Rightarrow \] liquid and vapor will be present at equilibrium