1. (6 pts) Write the electronic configuration and indicate the number of unpaired electrons for each of the following species.

<table>
<thead>
<tr>
<th>species</th>
<th>electronic configuration</th>
<th>number of unpaired electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Co^{2+}</td>
<td>[Ar] 3s^2 3d^5</td>
<td>3</td>
</tr>
<tr>
<td>b) S</td>
<td>[Ne] 3s^2 3p^4</td>
<td>2</td>
</tr>
<tr>
<td>c) Fe</td>
<td>[Ar] 4s^2 3d^6</td>
<td>4</td>
</tr>
</tbody>
</table>

2. a) (2 pts) Draw the Lewis structures CO_3^{2-} and CO_2.

\[
\text{CO}_3^{2-}: \quad \begin{array}{c}
\text{C} \\
\text{O} \\
\text{O} \\
\end{array}
\quad (\text{2-}) \quad \text{CO}_2: \quad \begin{array}{c}
\text{C} \\
\text{O} \\
\text{O} \\
\end{array}
\]

b) (2 pts) Which one has the shortest CO bond length. Circle the answer.

3. (20 pts) Circle the formula that best fits each of the following descriptions:

a) smallest atomic radius

- Na  \( \square \)
- Si  \( \square \)
- K   \( \square \)
- Al  \( \square \)

b) largest ionic radius

- Ba^{2+} \( \square \)
- I^- \( \square \)
- Cs^+ \( \square \)

 c) least polar bond

- C-H  \( \square \)
- N-H  \( \square \)
- Si-H  \( \square \)

d) longest bond length

- O_2  \( \square \)
- CO   \( \square \)
- F_2   \( \square \)
- N_2   \( \square \)

e) greatest electronegativity

- Al  \( \square \)
- C   \( \square \)
- Na  \( \square \)
- Ne  \( \square \)

f) contains two \( \pi \)-bonds

- O_2  \( \square \)
- SO_2  \( \square \)
- CO   \( \square \)
- NO_2^- \( \square \)

g) lowest viscosity

- \( \text{CH}_3\text{CH}_2\text{CH}_3 \)
- \( \text{CH}_3\text{CH}_2\text{OH} \)
- \( \text{HOCH}_2\text{CH}_2\text{OH} \)

h) highest vapor pressure at 25°C

- \( \text{CH}_3\text{OCH}_3 \)
- \( \text{NH}_2\text{CH}_2\text{CH}_3 \)
- \( \text{NH}_4\text{Cl} \)

i) lowest freezing point

- CO  \( \square \)
- CO_2 \( \square \)
- N_2  \( \square \)

j) ionic

- BCl_3  \( \square \)
- HCN  \( \square \)
- NH_4Cl  \( \square \)
- SiH_4  \( \square \)
4. (8 pts) Indicate the hybridization on the carbon and nitrogen atoms.

\[
\text{H}_2\text{C}-\text{C}-\text{N}-\text{C} = \text{CH}_2
\]

Hybridization on first carbon: $\text{sp}^3$  
Hybridization on second carbon: $\text{sp}^2$  
Hybridization on third carbon: $\text{sp}^2$  
Hybridization on nitrogen: $\text{sp}^3$

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

\[
\text{H}_2\text{C}-\text{C}-\text{N}-\text{C} = \text{CH}_2
\]

Angle a: $120°$  
Angle b: $120°$  
Angle c: $\sim 109°$  
Angle d: $120°$

6. a) (2 pts) Draw the Lewis structure for $\text{N}_2\text{H}_4$.

\[
\text{H} - \overset{\text{N}}{\text{N}} - \overset{\text{N}}{\text{N}} - \text{H}
\]

b) (2 pts) Draw the most stable molecular geometry.

\[
\text{N} - \overset{\text{N}}{\text{N}} - \overset{\text{N}}{\text{N}} - \text{H}
\]

see Fig 19.8 p 860

minimize repulsion between lone pairs

7. (6 pts) For each of the following molecules, write the Lewis structure, predict the molecular geometry, and indicate the hybridization on the central atom. $\text{S}$ is the central atom in $\text{SO}_3^{2-}$ and $\text{C}$ is the central atom in $\text{HCN}$.

<table>
<thead>
<tr>
<th>Lewis structure</th>
<th>molecular geometry</th>
<th>hybridization on central atom</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) $\text{SO}_3^{2-}$</td>
<td>$\text{sp}^3$ trigonal pyramid</td>
<td>$\text{sp}^3$</td>
</tr>
<tr>
<td>b) $\text{HCN}$</td>
<td>linear</td>
<td>$\text{sp}$</td>
</tr>
</tbody>
</table>
8. (9 pts) Indicate the dominant intermolecular force for each of the following substances.
   a) Na₂SO₃  ionic  b) SO₃  LDF  c) C₆H₆  LDF
   d) HF  H-bonding  e) CH₂O  dipole-dipole  f) CO₂  LDF
   g) CH₃NH₂  H-bonding  h) CHCl₃  dipole-dipole  i) HCN  dipole-dipole

9. (4 pts) A substance does not conduct electricity unless it is melted. It is hard and has a high melting point. 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) Si  covalent network  b) P₄  molecular  c) HCl  molecular
   d) SiO₂  covalent network  e) CaCO₃  ionic  f) C₁₂H₂₂  molecular

11. a) (3 pts) Draw the Lewis structure for SCN⁻ including resonance structures. Carbon is the central atom.

   \[ 6 + 4 + 5 + 1 = 16 \text{ e}^- \]
   \[ \frac{24 - 16}{2} = 4 \text{ bonds} \]

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

   b) (3 pts) Assign the formal charges on each atom for each of the resonance structures.

   \[ [\cdot \text{S} \equiv C \equiv N:]^- -1 \quad [\cdot \text{S} \equiv C - \text{N}:]^- +1 \quad [\cdot \text{S} = C = \text{N}:]^- 0 \]

   c) (3 pts) Which structure is least stable?

   \[ [\cdot \text{S} \equiv C - \text{N}:]^- \]
12. (6 pts) Write the electron configuration and the bond order predicted by the MO model for each of the following species.

<table>
<thead>
<tr>
<th>species</th>
<th>electron configuration</th>
<th>bond order</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) $\text{B}_2$</td>
<td>$(\sigma_{2s})^2 (\sigma_{2s}^*)^2 (\Pi_{2p})^2$</td>
<td>1</td>
</tr>
<tr>
<td>b) $\text{Be}_2$</td>
<td>$(\sigma_{2s})^2 (\sigma_{2s}^*)^2$</td>
<td>0</td>
</tr>
<tr>
<td>c) $\text{CN}^-$</td>
<td>$(\sigma_{2s})^2 (\sigma_{2s}^*)^2 (\Pi_{2p})^4 (\sigma_{2p})^2$</td>
<td>3</td>
</tr>
</tbody>
</table>

10 valence e's

13. (6 pts) Draw the phase diagram for water and for carbon dioxide. Indicate the location of the triple point and the region in which each substance is a solid, liquid and gas.

Phase diagram for water

Phase diagram for CO$_2$

14. (6 pts) What pressure would have to be applied to steam at 350°C to condense the steam to liquid water? For water, $\Delta H_{\text{vap}} = 44 \text{ kJ/mol}$.

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

\[
\ln \left( \frac{P_1}{1 \text{ atm}} \right) = (44 \frac{\text{kJ}}{\text{mol}}) \left( \frac{1000 \text{J}}{\text{kJ}} \right) \left[ \frac{1}{373 \text{K}} - \frac{1}{623} \right]
\]

$P = 29.6 \text{ atm}$