Chapter 10 problems.

1. (a) (15 points) Write the complete Lewis electron dot formula for H₂CNH in the space below, including any formal charges and/or resonance forms, if needed. The dotted lines merely indicate the connectivity of the atoms and do not represent the number of bonds.

   H
   \_\_\_
   H--C--N--H

(b) (5 points) The C—N—H bond angle in H₂CNH (i.e., the angle around the nitrogen atom) is about ____________ degrees.

c) (5 points) The H—C—H bond angle is about ____________ degrees.

d) (10 points) What is the hybridization at each of the atoms?

   N ________________   C ________________

(e) (15 points) Clearly show the 3-dimensional structure (sketch shape) of the molecule including the orientation of the C-H bonds, etc.

(f) (20 points) Describe the bonding in H₂CNH using Valence Bond concepts (i.e., hybrid atomic orbitals, etc.). Draw and clearly label one or more pictures (I suggest two) to show the types of orbitals that you are using to form the various σ and/or π bonds.

2. (20 points) Sketch the shape or three-dimensional structure of each of the following:

   AsF₄⁻ and ClO₃⁻

3. (10 points) The hybridization in the central atom in AsF₄⁻ is _______ and in ClO₃ is __________.
1. a. (4 points) Complete the **labels** in the following molecular orbital energy level diagram for diatomic molecules and ions.

![Molecular orbital diagram]

b. (4 points) Predict the bond order of NO\textsuperscript{-} and N\textsubscript{2}\textsuperscript{+}.

c. (3 points) Which has the longer bond length? Why?

d. (4 points) Which of these ions is paramagnetic and in what orbitals are the unpaired electrons.
1. (a) (15 points) Write the complete Lewis electron dot formula for $\text{H}_2\text{CNH}$ in the space below, including any formal charges and/or resonance forms, if needed. The dotted lines merely indicate the connectivity of the atoms and do not represent the number of bonds.

\[
\begin{align*}
\text{H} & \quad \text{H} \\
\text{H} - \cdot \text{C} - \cdot \text{N} - \cdot \text{H} & \quad 12 \text{ electrons} \\
\text{H} & \quad \text{C} = \cdot \text{N} = \cdot \text{H} \quad \text{all formal charges are 0}
\end{align*}
\]

(b) (5 points) The C—N—H bond angle in $\text{H}_2\text{CNH}$ (i.e., the angle around the nitrogen atom) is about \_\_\_\_\_\_\_\_\_\_\_ slightly less than 120 \_\_\_\_\_\_\_\_\_\_\_ degrees.

(c) (5 points) The H—C—H bond angle is about \_\_\_\_\_\_\_\_\_\_\_\_ slightly less than 120 \_\_\_\_\_\_\_\_\_\_\_\_ degrees. The double bond has more electrons and these will push slightly on the singly bonded C—H bonds to decrease the H—C—H angle slightly.

(d) (10 points) What is the hybridization at each of the atoms?

\[
\begin{align*}
\text{N} & \quad \text{sp}^2 \\
\text{C} & \quad \text{sp}^2
\end{align*}
\]

(e) (15 points) Clearly show the 3-dimensional structure (sketch shape) of the molecule including the orientation of the C-H bonds, etc.

\[
\text{H} \quad \text{C} = \cdot \text{N} = \cdot \text{H} \quad \text{The geometry is trigonal planar at both C and N, so all atoms and the lone pair are in the plane of this page.}
\]

(f) (20 points) Describe the bonding in $\text{H}_2\text{CNH}$ using Valence Bond concepts (i.e., hybrid atomic orbitals, etc.). Draw and clearly label one or more pictures (I suggest two) to show the types of orbitals that you are using to form the various $\sigma$ and/or $\pi$ bonds.

- Two C-H $\sigma$ bonds formed by overlap of C $\text{sp}^2$ orbitals with H 1s orbitals
- One N-H $\sigma$ bonds formed by overlap of N $\text{sp}^2$ orbital with H 1s orbital
- One C-N $\sigma$ bonds formed by overlap of C $\text{sp}^2$ orbital with N $\text{sp}^2$ orbital
- One C-N $\pi$ bond formed by overlap of C $p_z$ orbital with N $p_z$ orbital
- Lone pair of electrons in N $\text{sp}^2$ orbital
2. (20 points) Sketch the shape or three-dimensional structure of each of the following:
   \( \text{AsF}_4^- \) and \( \text{ClO}_3^- \)

   \[
   \begin{array}{c}
   \text{AsF}_4^- \\
   \begin{array}{c}
   \text{F} \\
   \text{F} \\
   \text{F} \\
   \text{F}
   \end{array}
   \end{array}
   \quad
   \begin{array}{c}
   \text{ClO}_3^- \\
   \begin{array}{c}
   \text{O} \\
   \text{Cl} \\
   \text{O} \\
   \text{O}
   \end{array}
   \end{array}
   \]

   EN = 5, trigonal bipyramidal arrangement of e\(^-\) pairs, see-saw shape
   En = 4, tetrahedral arrangement of e\(^-\) pairs, pyramidal shape

3. (10 points) The hybridization in the central atom in \( \text{AsF}_4^- \) is \( \text{sp}^3 \text{d} \) and in \( \text{ClO}_3^- \) is \( \text{sp}^3 \).

   (20 points) Sketch the shape or three-dimensional structure of each of the following:
   \( \text{BrO}_3^- \) and \( \text{PF}_4^- \)

   \[
   \begin{array}{c}
   \text{BrO}_3^- \\
   \begin{array}{c}
   \text{O} \\
   \text{Br} \\
   \text{O}
   \end{array}
   \end{array}
   \quad
   \begin{array}{c}
   \text{PF}_4^- \\
   \begin{array}{c}
   \text{F} \\
   \text{P} \\
   \text{F}
   \end{array}
   \end{array}
   \]

   En = 4, tetrahedral arrangement of e\(^-\) pairs, pyramidal shape
   EN = 5, trigonal bipyramidal arrangement of e\(^-\) pairs, see-saw shape

   (10 points) The hybridization in the central atom in \( \text{BrO}_3^- \) is \( \text{sp}^3 \) and in \( \text{PF}_4^- \) is \( \text{sp}^3 \text{d} \).
a. (4 points) Complete the labels in the following molecular orbital energy level diagram for diatomic molecules and ions.

![Diagram of molecular orbitals]

b. (4 points) Predict the bond order of NO⁻ and N₂⁺.

Bond order (NO⁻) = \( \frac{1}{2} (8 - 4) = 2 \)
Bond order (N₂⁺) = \( \frac{1}{2} (7 - 2) = 2.5 \)

c. (4 points) Which of these ions is paramagnetic and in what orbitals are the unpaired electrons.

NO⁻ is paramagnetic because it has 2 unpaired electrons in the \( \pi^* \) orbitals while N₂⁺ is also paramagnetic because it has 1 electron in the \( \sigma_{2p} \) orbital.

d. (3 points) Which has the longer bond length? Why?

With a bond order of 2, the NO⁻ anion is the longer bond than the N₂⁺ cation which has a stronger bond, i.e., bond order is 2.5.