Question 1 (20 pts). For each species in parts a-d: Draw a valid Lewis structure, showing all bonds, formal charges, unshared electrons and any filled or unfilled orbitals that those unshared electrons are in. Also indicate the hybridization state of each second row atom (either the B or C atoms) in your structures. As an example, see how I drew the structures for NH₃ and NH₄⁺.

- **NH₃**
  - Hybridization: sp³
  - Bonding: 3 bonds, formal charge: 0
  - Unshared electrons: 3

- **NH₄⁺**
  - Hybridization: sp³
  - Bonding: 4 bonds, formal charge: +1
  - Unshared electrons: 1

- **CH₃⁻**
  - Hybridization: sp³ (tetrahedral structure)
  - Bonding: 4 bonds, formal charge: -1
  - Unshared electrons: 1

- **CH₃⁺**
  - Hybridization: sp² (trigonal planar structure)
  - Bonding: 3 bonds, formal charge: +1
  - Unshared electrons: 1

- **BH₃**
  - Hybridization: sp² (trigonal planar structure)
  - Bonding: 3 bonds, formal charge: -3
  - Unshared electrons: 3
**Question 2. (10 pts)** Vinylacetylene (shown below) is used in the synthesis of neoprene.

\[
\begin{array}{c}
\text{H} & \text{C} & \text{C} & \text{H} \\
\text{H} & \text{C} & \text{C} & \text{H} \\
\end{array}
\]

- a) As indicated by the arrow, identify the hybrid orbitals on C2 and C3 that overlap to give the \(\sigma\) bond. Write the answer above on the line provided.
- b) How many \(\pi\) bonds are there in vinylacetylene? \(\underline{3}\) \(\pi\) bonds
- c) How many \(\sigma\) bonds are there in vinylacetylene? \(\underline{7}\) \(\sigma\) bonds
- d) Which carbon has the most acidic H bonded to it? \(\underline{C1}\)
- d) Indicate the longest C-C distance in vinylacetylene: \(\underline{C2-C3}\)

**Question 3 (10 pts)**

a) Carbocation A has another resonance form B. Show arrow(s) indicating electron flow that are required to go from resonance structure A to B and also complete the structure for B showing all bonds and any formal charge (5 pts).

b) (5 pts) Indicate in the blank below the resonance form (A or B) that you think contributes more to the carbocation’s structure.

Resonance form \(\underline{B}\) contributes more to the overall structure of this carbocation.

Briefly (with 10 words or less and with a clear illustration) justify your answer.

**B is a more substituted carbocation (3\(^{\circ}\)) than A (2\(^{\circ}\))**

![Hyperconjugation](image)
Question 4. (20 pts)
a. Provide a reasonable name for the compound shown below. (4 pts)

Name: 3-chloro, 2-methyl pentane

b. Draw Newman projections for the 3 staggered conformations when looking down the bond connecting carbon atoms A and B. Draw the projections so that carbon A is in front. (12 pts)

For conformations 1-3 drawn above, the most stable (lowest energy) conformation is 2.

c. Complete the sentence (4 pts contingent on whether you have part b correct):

For conformations 1-3 drawn above, the most stable (lowest energy) conformation is 2.
Question 5. (20 pts)

\[
\begin{array}{c}
\text{H}_3\text{C} = \text{O} \\
\text{H}_3\text{C} = \text{O} \\
\text{H} \\
\end{array}
\]

\[
\begin{array}{c}
\text{H} \\
\text{C} = \text{N} \\
\text{H} \\
\end{array}
\]

Acetic Acid

Hydrogen Cyanide

\[
\begin{array}{c}
\text{H}_2\text{O} \\
\text{H}_2\text{O} \\
\text{H} \\
\end{array}
\]

\[
\begin{array}{c}
\text{H} \\
\text{O} \\
\text{H} \\
\end{array}
\]

Water

Hydronium Ion

\[
\begin{array}{c}
\text{C} = \text{N} \\
\text{H}_3\text{C} = \text{O} \\
\text{H}_3\text{C} = \text{O} \\
\text{H} \\
\end{array}
\]

Cyanide anion (conjugate base of HCN)

a) (8 pts) Draw an arrow-pushing mechanism for the reaction of acetic acid and cyanide anion. Show all lone pairs, curved arrows and formal charges. Show the products of the reaction. Use the pK\textsubscript{a} values to determine whether the reactants (cyanide and acetic acid) or products are favored.

\[
\begin{array}{c}
\text{H}_3\text{C} = \text{O} \\
\text{H} \\
\text{C} = \text{N} \\
\text{H} \\
\end{array}
\]

\[
\begin{array}{c}
\text{H}_3\text{C} = \text{O} \\
\text{H} \\
\text{C} = \text{N} \\
\text{H} \\
\end{array}
\]

\[
\begin{array}{c}
\text{H}_3\text{C} = \text{O} \\
\text{H} \\
\text{C} = \text{N} \\
\text{H} \\
\end{array}
\]

\[
\begin{array}{c}
\text{H}_3\text{C} = \text{O} \\
\text{H} \\
\text{C} = \text{N} \\
\text{H} \\
\end{array}
\]

Which side of the reaction is favored at equilibrium (circle one)? Reactants Products
a) (8 pts) Draw an arrow-pushing mechanism for the reaction of cyanide anion and water. Show all lone pairs, curved arrows and formal charges. Show the products of the reaction. Use the pKa values to determine whether reactants (cyanide and water) or products are favored.

\[
\text{H}_2\text{O}^- + \text{C}≡\text{N}^- \rightarrow \text{O}⁻\text{H} + \text{H}⁻\text{C≡N}^- \\
\]

Which side of the reaction is favored at equilibrium (circle one)?

- Reactants
- Products

b) (4 pts) Circle any statement that is false (-2 for any wrong answer):

- Hydrogen cyanide is 4 times less acidic acetic acid.
- Acetic acid is 10,000 times more acidic than hydrogen cyanide
- Acetate is a weaker base than cyanide
- Water is the conjugate base of hydronium ion
Question 6. (20 pts) Reaction of alkene below with HCl provided 1-3 in the indicated amounts.

\[ \text{CH}_3 + \text{HCl} \longrightarrow \begin{array}{c}
\text{CH}_3 \\
1 \text{Cl} \hspace{1cm} 40\% \\
2 \hspace{1cm} 35\% \\
3 \hspace{1cm} 25\%
\end{array} \]

a) Draw an arrow-pushing mechanism that explains formation of 3. Show lone pairs, curved arrows and formal charges. Show any intermediates that occur during formation of 3. (15 pts)

b) There are 2 different alkenes with the formula \( \text{C}_6\text{H}_{10} \) that should react regioselectively with HCl to give compound 3 in high yield. For 3 points draw the structure of one of those alkenes. For 5 points draw the structures of both alkenes.