(1) (28 pts. total.) Methyl isocyanate, a compound that killed thousands and blinded tens of thousands of people in Bhopal, India, in 1984, has the formula C₂H₃NO.

(a) (4 pts.) How many total valence electrons does methyl isocyanate have?

\[2 \times 4 + 3 \times 1 + 5 + 6 = 22.\]

(b) (6 pts.) The σ-bond network (atom-to-atom connectivity) of methyl isocyanate is sketched below. Fill in the remainder of electrons to draw the BEST resonance structure for methyl isocyanate. Include all unshared pairs of electrons and any formal charges.

(c) (6 pts.) What are the hybridizations of:

1. the terminal C atom? \(\text{sp}^3\)
2. the N atom? \(\text{sp}^2\)
3. the internal C atom? \(\text{sp}\)

(In 2, if you mentioned or drew a resonance structure, sp was OK.)

(d) (4 pts.) What are the bond angles about:

1. the N atom? \(120^\circ\)
2. the internal C atom? \(180^\circ\)
(e) (8 pts.) Draw a diagram showing all of the atomic orbitals in CH$_3$N=C=O. Indicate which atomic orbitals overlap to form $\sigma$ bonds, which ones overlap to form $\pi$ bonds, and which ones hold unshared electrons. I’ve drawn out the orbitals around O to get you started. (Note: For sake of clarity, please don’t draw the small back lobes of the hybrid orbitals.)
(2) (14 pts. total.) Consider the vinyl cation, whose structure is shown below.

\[ \text{H}_2\text{C} = \text{CH}^+ \]

(a) (5 pts.) What is the hybridization of the electron-deficient carbon in the vinyl cation?

\[ \text{sp} \]

(b) (4 pts.) Based on your answer to (a), what are the ideal bond angles about the electron-deficient carbon in the vinyl cation?

\[ 180^\circ \]

(c) (5 pts.) The phenyl cation, shown below, is much higher in energy than the vinyl cation. Why? (Think about the optimum bond angles about the electron-deficient carbon.)

The geometric constraints of the ring prevent the electron-deficient C from achieving its ideal bond angles of 180°, enforcing an angle closer to 120°. As a result, 1/3 of the low-energy s orbital is “wasted” by not being occupied, so the molecule as a whole is much higher in energy than in the acyclic vinyl cation.
(3) (16 pts. total.) Consider the compound with the formula C₅H₈F₂. A compound with this formula has either one ring or one π bond.

(a) (8 pts.) Draw two skeletal isomers of C₅H₈F₂. (There are many correct answers.)

For example:

(b) (8 pts.) Draw two stereoisomers of C₅H₈F₂. (There are many correct answers.)

For example:
(4) (4 pts. each, 24 pts. total.) For each pair of compounds, indicate the relationship of the first compound to the second by circling the correct answer.

(a) \(
\begin{align*}
\text{is a skeletal isomer of} \\
\text{is a configurational diastereomer of} \\
\text{is a conformational diastereomer of} \\
\text{is an enantiomer of} \\
\text{is a resonance structure of} \\
\text{is the same compound as} \\
\text{has none of the above relationships to}
\end{align*}
\)

(b) \(
\begin{align*}
\text{is a skeletal isomer of} \\
\text{is a configurational diastereomer of} \\
\text{is a conformational diastereomer of} \\
\text{is an enantiomer of} \\
\text{is a resonance structure of} \\
\text{is the same compound as} \\
\text{has none of the above relationships to}
\end{align*}
\)

(c) \(
\begin{align*}
\text{is a skeletal isomer of} \\
\text{is a configurational diastereomer of} \\
\text{is a conformational diastereomer of} \\
\text{is an enantiomer of} \\
\text{is a resonance structure of} \\
\text{is the same compound as} \\
\text{has none of the above relationships to}
\end{align*}
\)
(d) is a skeletal isomer of is a configurational diastereomer of is a conformational diastereomer of is an enantiomer of is a resonance structure of is the same compound as has none of the above relationships to

(e) is a skeletal isomer of is a configurational diastereomer of is a conformational diastereomer of is an enantiomer of is a resonance structure of is the same compound as has none of the above relationships to

(f) is a skeletal isomer of is a configurational diastereomer of is a conformational diastereomer of is an enantiomer of is a resonance structure of is the same compound as has none of the above relationships to
(5) (6 pts. each, 18 pts. total.) Using the curved arrow formalism, draw the best resonance structure of each of the following compounds.

(a)

(b)

(c)