2-27 continued

(g) \[ \text{angles around } sp^3 \text{ atom } = 109^\circ \]
\[ \text{angles around } sp^2 \text{ atoms } = 120^\circ \]

(h) \[ \text{in front of the plane of the paper} \]
\[ \text{behind the plane of the paper} \]

(i) \[ \text{both } sp^2, \text{ all } = 120^\circ \]

2-28 For clarity in these pictures, bonds between hydrogen and an sp\(^3\) atom are not labeled; these bonds are s-sp\(^3\) overlap.

(a) \[ \text{sp}^3-\text{sp}^3 \]

(b) \[ \text{sp}^3-\text{sp}^3 \]

(c) \[ \text{sp}^3-\text{sp}^2 \]

(d) \[ \text{sp}^3-\text{sp}^2 \]

(e) \[ \text{sp}^3-\text{sp}^2 \]

(f) \[ \text{sp}^3-\text{sp}^3 \]

(g) \[ \text{sp}^3-\text{sp}^3 \]
2-29 The second resonance form of formamide is a minor but significant resonance contributor. It shows that the nitrogen-carbon bond has some double bond character, requiring that the nitrogen be sp² hybridized with bond angles approaching 120°.

\[
\begin{align*}
\overset{\cdot\cdot}{O} & \quad \overset{\cdot\cdot}{\cdot} \quad \overset{\cdot\cdot}{\cdot} \\
H-C-C-N-H & \quad \leftrightarrow \\
\overset{\cdot\cdot}{O} & \quad \overset{\cdot\cdot}{\cdot} \quad \overset{\cdot\cdot}{\cdot}
\end{align*}
\]

2-30

(a) The major resonance contributor shows a carbon-carbon double bond, suggesting that both carbons are sp² hybridized with trigonal planar geometry. The CH₃ carbon is sp³ hybridized with tetrahedral geometry.

\[
\begin{align*}
H:O & \quad \overset{\cdot\cdot}{\cdot} \quad \overset{\cdot\cdot}{\cdot} \\
H-C-C-C=\overset{+}{C}-H & \quad \leftrightarrow \\
H:O & \quad \overset{\cdot\cdot}{\cdot} \quad \overset{\cdot\cdot}{\cdot}
\end{align*}
\]

(b) The major resonance contributor shows a carbon-nitrogen double bond, suggesting that all three carbons and the nitrogen are sp² hybridized with trigonal planar geometry.

\[
\begin{align*}
H:O & \quad \overset{\cdot\cdot}{\cdot} \quad \overset{\cdot\cdot}{\cdot} \\
H-C-C=\overset{+}{C}-C-H & \quad \leftrightarrow \\
H:O & \quad \overset{\cdot\cdot}{\cdot} \quad \overset{\cdot\cdot}{\cdot}
\end{align*}
\]

2-31 In (c) and (d), the unshadowed p orbitals are vertical and parallel. The shadowed p orbitals are perpendicular and horizontal.

(a) H₃C

(b) H₃C

(c) H₃C

(d) CH₃