1  For each of the following species 
(i) draw a Lewis structure, writing non-zero formal charges on the atoms that require them 
(ii) indicate the hybridization state of all atoms other than hydrogen 
(iii) characterize the shape of the molecule using the terms linear, bent, planar, tetrahedral or pyramidal 
(iv) if appropriate, draw a resonance structure of the molecule 

a  NO₂⁺ (N is the central atom) 

b  BH₃ (B is the central atom) 

c  N₃⁻ (three N atoms in a row) 

d  CH₂NH (two H’s bonded to C, C bonded to N, one H bonded to N) 

2  (i) Draw a three-dimensionally accurate picture of the molecular orbitals in nitrosomethane; (ii) label each molecular orbital as a sigma (σ), pi (π) or non-bonding (n) orbital.

\[
\text{nitrosomethane}
\]
3 Rank these compounds in order of acidity (1 = most acidic).

\[
\begin{array}{c}
\text{H}_2\text{C} - \text{C} - \text{C} - \text{H} \\
\text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\
\text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\
\text{F} \quad \text{F} \quad \text{F} \quad \text{F} \\
\text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\
\text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\
\text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\
\text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\
\text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\
\text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\
\end{array}
\]

4 Given the pKₐs in the table at right, (i) complete the following acid–base reactions; (ii) indicate whether the equilibrium lies to the left or to the right.

\[
\begin{array}{c}
\text{a} \quad \text{CH}_3\text{SH} + \text{OH}^- \rightarrow \\
\text{b} \quad (\text{CH}_3)_3\text{C} = \text{CH} + (\text{CH}_3)_2\text{N}^- \rightarrow \\
\text{c} \quad (\text{CH}_3)_3\text{C} = \text{CH} + (\text{CH}_3)_3\text{CO}^- \rightarrow \\
\text{d} \quad \text{HCl} + \text{CH}_3^- \rightarrow \\
\end{array}
\]

<table>
<thead>
<tr>
<th>Acid</th>
<th>pKₐ*</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCl</td>
<td>-7</td>
</tr>
<tr>
<td>CH₃SH</td>
<td>10</td>
</tr>
<tr>
<td>HOH</td>
<td>16</td>
</tr>
<tr>
<td>(CH₃)₃COH</td>
<td>19</td>
</tr>
<tr>
<td>(CH₃)₃CC≡CH</td>
<td>25</td>
</tr>
<tr>
<td>(CH₃)₂NH</td>
<td>35</td>
</tr>
<tr>
<td>H₃CH</td>
<td>50</td>
</tr>
</tbody>
</table>

* pKₐs refer to the proton \textit{in bold type}.

5 Circle and identify the functional groups in the antibiotic thienamycin (shown below).

![Thienamycin structure]
6  Name these compounds.

a  \[ \text{CF}_3 \text{H}_3 \text{C} \text{CH}_3 \]

b  \[ \text{H}_3 \text{C} \text{CH}_3 \text{CH}_3 \text{CH}_3 \]

c  \[ \text{H}_3 \text{C} \text{CH}_3 \text{CH}_3 \text{Br} \]

d  \[ \text{H}_3 \text{C} \text{H}_3 \text{CH}_3 \text{CH}_3 \]

7  Draw in Newman projection (i) the most stable conformation of 2,2,3-trimethylbutane with respect to rotation about the C2–C3 bond, (ii) the least stable conformation of 2,2,3-trimethylbutane with respect to rotation about the C2–C3 bond, and (iii) calculate the strain energy of each conformation using the values in the table.

<table>
<thead>
<tr>
<th>Interaction</th>
<th>Strain energy [kcal/mol]</th>
</tr>
</thead>
<tbody>
<tr>
<td>H,H eclipse</td>
<td>1.0</td>
</tr>
<tr>
<td>CH₃,H eclipse</td>
<td>1.4</td>
</tr>
<tr>
<td>CH₃,CH₃ eclipse</td>
<td>2.6</td>
</tr>
<tr>
<td>CH₃,CH₃ gauche</td>
<td>0.9</td>
</tr>
<tr>
<td>CH₃,H 1,3-diaxial</td>
<td>0.9</td>
</tr>
</tbody>
</table>
Draw two additional, reasonable resonance structures of the ions shown below; indicate the movement of electron pairs using the curved-arrow convention.
9. Draw both chair conformations of \((1R,2S,4R)-1,2,4\text{-trimethylcyclohexane}\) and calculate the strain energy of each chair. Use the values in the table in Question 7.

\[
\begin{array}{c}
\text{Interaction} & \text{Strain energy} \\
\text{H,H eclipse} & 1.0 \\
\text{CH}_3\text{,H eclipse} & 1.4 \\
\text{CH}_3\text{,CH}_3\text{ eclipse} & 2.6 \\
\text{CH}_3\text{,CH}_3 \text{ gauche} & 0.9 \\
\text{CH}_3\text{,H 1,3-diaxial} & 0.9 \\
\end{array}
\]