Compare the strength of IMFs present in three liquids. The liquids are in separate containers.

A. CH₃CH₂NH₂ (liquid)       B. CH₃CH₂F (liquid)

C. CH₃CH₂OH (liquid)

Draw two 3D Lewis Structures of each compound near enough to have electrostatic attractions

Identify the δ⁺ and δ⁻ atoms

Identify the location of the IMFs by using a dashed or dotted line

Identify the type of IMFs present in each liquid.

Which sample of liquid of each compound has the higher boiling point?
If you and your buddy have a model kit, talk to your neighboring group having the other model kit.

Part A. Each group builds one CH₃CH₂NH₂ model.

Use your Table of Electronegativity Values of the Elements to determine which atom(s) has/have a partial positive charge (δ+) and which atom(s) has/have a partial negative charge (δ+). Determine the ΔEN between the atoms.

Bring the two models closed together. Use the correct rubber band to connect the two CH₃CH₂NH₂ models by the primary IMF at the correct atom locations. How many possible different arrangements are there?

Identify the IMF. Classify the strength of the IMF as weak, medium, or strong.

Sketch two 3D Lewis structures representing the two models and use a dashed line to show the correct location of the IMF.
Hydrogen bond IMF

$\text{CH}_3\text{CH}_2\text{NH}_2$ (liquid)

$\delta^-$ $\delta^+$ $\delta^-$ $\delta^+$

$\Delta EN = EN_N - EN_H$

$\Delta EN = 3.0 - 2.1 = 0.9$

Note: All C-H bonds are assumed to be non-polar.

<table>
<thead>
<tr>
<th>Atom</th>
<th>EN</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>2.1</td>
</tr>
<tr>
<td>C</td>
<td>2.5</td>
</tr>
<tr>
<td>N</td>
<td>3.0</td>
</tr>
<tr>
<td>O</td>
<td>3.5</td>
</tr>
<tr>
<td>F</td>
<td>4.0</td>
</tr>
</tbody>
</table>
Part B  Talk to your neighboring group having the other model kit.

Each group builds one CH$_3$CH$_2$F model.

Use your Table of Electronegativity Values of the Elements to determine which atom(s) has/have a partial positive charge ($\delta^+$) and which atom(s) has/have a partial negative charge ($\delta^+$). Determine the $\Delta$EN between the atoms.

Bring the two models closed together. Use the correct rubber band to connect the two CH$_3$CH$_2$F models by the primary IMF at the correct atom locations. How many possible different arrangements are there?

Identify the IMF. Classify the strength of the IMF as weak, medium, or strong.

Compare the IMF between these two models and the IMF between the two CH$_3$CH$_2$NH$_2$ models. Which is stronger? Explain.

Sketch two 3D Lewis structures representing the two models and use a dashed line to show the correct location of the IMF.
Dipole-dipole IMF

\[
\delta^+ + \delta^+ + \delta^- - \delta^- + \delta^+
\]

\(\text{CH}_3\text{CH}_2\text{F (liquid)}\)

<table>
<thead>
<tr>
<th>Atom</th>
<th>EN</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>2.1</td>
</tr>
<tr>
<td>C</td>
<td>2.5</td>
</tr>
<tr>
<td>N</td>
<td>3.0</td>
</tr>
<tr>
<td>O</td>
<td>3.5</td>
</tr>
<tr>
<td>F</td>
<td>4.0</td>
</tr>
</tbody>
</table>

\(\Delta\text{EN} = \text{EN}_F - \text{EN}_C\)

\(\Delta\text{EN} = 4.0 - 2.5\)

\(\Delta\text{EN} = 1.5\)

\(\delta^+ \text{C} \leftrightarrow \delta^- \text{F}\)
Part B  Talk to your neighboring group having the other model kit.

Each group builds one CH$_3$CH$_2$OH model.

Use your Table of Electronegativity Values of the Elements to determine which atom(s) has/have a partial positive charge (δ+) and which atom(s) has/have a partial negative charge (δ−). Determine the ΔEN between the atoms.

Bring the two models closed together. Use the correct rubber band to connect the two CH$_3$CH$_2$OH models by the primary IMF at the correct atom locations. How many possible different arrangements are there?

Identify the IMF. Classify the strength of the IMF as weak, medium, or strong.

Compare the IMF between these two models and the IMF between the two CH$_3$CH$_2$NH$_2$ models. Which is stronger? Explain.

Sketch two 3D Lewis structures representing the two models and use a dashed line to show the correct location of the IMF.
$\text{CH}_3\text{CH}_2\text{OH (liquid)}$

Ethanol

- \( \text{carbon} \)
- \( \text{oxygen} \)
- \( \text{hydrogen} \)
Which of the following does not form hydrogen bonds with other molecules?

A. CH₃-CH₂-NH₂  
B. CH₃-CH₂-OH  
C. CH₃-CH₂F
Which of the following liquids will have the higher boiling point? Explain.

A. CH₃-CH₂-NH₂
B. CH₃-CH₂-OH
C. CH₃-CH₂F
# Effect of Structure on Boiling Point

<table>
<thead>
<tr>
<th></th>
<th>$\text{CH}_3\text{CH}_2\text{F}$</th>
<th>$\text{CH}_3\text{CH}_2\text{NH}_2$ (liquid)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular weight</td>
<td>48</td>
<td>45 g/mol</td>
</tr>
<tr>
<td>Boiling point, °C</td>
<td>-32</td>
<td>+17°C</td>
</tr>
<tr>
<td>Dipole moment, D</td>
<td>1.9</td>
<td>1.5</td>
</tr>
</tbody>
</table>
The electronegativity of N (3.0) is less than that of F (4.0), so N-H bonds ($\Delta EN = 0.9$) are less polar than O-F bonds ($\Delta EN = 1.5$). However, the total number of hydrogen bonds among CH$_3$CH$_2$NH$_2$ molecules results in a stronger overall attraction than the C - - - F dipole-dipole IMFs between CH$_3$CH$_2$F molecules.

This medium N- - - H hydrogen bonding IMF and the number of H Bonds leads to boiling points for 1° and 2° amines that are higher than those of halogen alkanes of comparable molecular mass.

CH$_3$CH$_2$NH$_2$ (liquid) b.p. = +17°C

CH$_3$CH$_2$F (liquid) b.p. = -32°C
## Effect of Structure on Boiling Point

<table>
<thead>
<tr>
<th></th>
<th>CH$_3$CH$_2$OH (liquid)</th>
<th>CH$_3$CH$_2$NH$_2$ (liquid)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular weight</td>
<td>46 g/mol</td>
<td>45 g/mol</td>
</tr>
<tr>
<td>Boiling point, °C</td>
<td>+78°C</td>
<td>+17°C</td>
</tr>
<tr>
<td>Dipole moment, D</td>
<td>1.69</td>
<td>1.5</td>
</tr>
</tbody>
</table>
The electronegativity of N (3.0) is less than that of O (3.5), so N-H bonds ($\Delta EN = 0.9$) are less polar than O-H bonds ($\Delta EN = 1.4$), and their hydrogen bonds are correspondingly weaker than O-H hydrogen bonds.

This medium N - - - H hydrogen bonding IMF leads to boiling points for 1° and 2° amines that are significantly higher than those of halogen alkanes of comparable molecular mass, but significantly lower than those of comparable alcohols.

\[
\text{CH}_3\text{CH}_2\text{OH (liquid) b.p.} = +78^\circ\text{C}
\]

\[
\text{CH}_3\text{CH}_2\text{NH}_2 (\text{liquid}) \text{ b.p.} = +17^\circ\text{C}
\]
Intermolecular Forces:

Normal Boiling Points

Period

He  Ne  Ar  Kr  Xe

Smallest Least Polarizable “HARD”

Largest Most Polarizable “SOFT”

T (°C)

He  Ne  Ar  Kr  Xe

H₂O  NH₃  HF  H₂S  H₂Se  H₂Te  SnH₄

Intermolecular Forces:

T (°C)

Chapter 12: Intermolecular Forces, Liquids, and Solids
Hydrogen bond IMF between NH$_3$ molecules