7. Answer the following questions that relate to the chemistry of nitrogen.

(a) Two nitrogen atoms combine to form a nitrogen molecule, as represented by the following equation.

\[ 2 \text{N}(g) \rightarrow \text{N}_2(g) \]

Using the table of average bond energies below, determine the enthalpy change, \( \Delta H \), for the reaction.

<table>
<thead>
<tr>
<th>Bond</th>
<th>Average Bond Energy (kJ mol(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (-) N</td>
<td>160</td>
</tr>
<tr>
<td>N (\equiv) N</td>
<td>420</td>
</tr>
<tr>
<td>N (\equiv) N</td>
<td>950</td>
</tr>
</tbody>
</table>

\[ \Delta H = -950 \text{kJ} \]

The reaction is exothermic because the chemical equation shows the formation of the N \(\equiv\) N bond.

(b) The reaction between nitrogen and hydrogen to form ammonia is represented below.

\[ \text{N}_2(g) + 3 \text{H}_2(g) \rightarrow 2 \text{NH}_3(g) \quad \Delta H^\circ = -92.2 \text{kJ} \]

Predict the sign of the standard entropy change, \( \Delta S^\circ \), for the reaction. Justify your answer.

\( \Delta S^\circ \) is negative. There are fewer moles of product gas (2 mol) compared to reactant gases (4 mol), so the reaction is becoming more ordered.

(c) The value of \( \Delta G^\circ \) for the reaction represented in part (b) is negative at low temperatures but positive at high temperatures. Explain.

\[ \Delta G^\circ = \Delta H^\circ - T\Delta S^\circ \]

\( \Delta H^\circ \) and \( \Delta S^\circ \) are negative. At low temperatures, the \( T\Delta S^\circ \) term is smaller than \( \Delta H^\circ \), and \( \Delta G^\circ \) is negative. At high temperatures, the \( T\Delta S^\circ \) term is higher than \( \Delta H^\circ \), and \( \Delta G^\circ \) is positive.
(d) When \( \text{N}_2(\text{g}) \) and \( \text{H}_2(\text{g}) \) are placed in a sealed container at a low temperature, no measurable amount of \( \text{NH}_3 \) is produced. Explain.

| Even though the reaction is spontaneous at low temperature, the reaction is very slow. The speed of a reaction depends on the fraction of colliding molecules with energy that exceeds the activation energy for the reaction. At low temperature, few reactant particles collide with an energy greater than the activation energy. | 1 point for indicating that the frequency of collision (or kinetic energy) of molecules is low at low temperature (thus the rate is slow)  
1 point for indicating that at low temperature the kinetic energy will likely be too small to exceed the activation energy |