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Answer EITHER Question 7 below OR Question 8 printed on page 28. Only one of these two questions will be graded. If you start both questions, be sure to cross out the question you do not want graded. The Section II score weighting for the question you choose is 15 percent.

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>
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<tbody>
<tr>
<td>N ≡ N</td>
<td>160</td>
</tr>
<tr>
<td>N = N</td>
<td>420</td>
</tr>
<tr>
<td>N ≌ N</td>
<td>950</td>
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(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.

(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.

(d) When \(\text{N}_2(g)\) and \(\text{H}_2(g)\) are placed in a sealed container at a low temperature, no measurable amount of \(\text{NH}_3(g)\) is produced. Explain.

\[ a) \Delta H = \Sigma H_{\text{broken}} - \Sigma H_{\text{formed}} \]
\[ = 0 - (950) = \boxed{-950 \text{ kJ}} \]

\[ b) \Delta G^\circ = \Delta H^\circ - \Delta S^\circ T \quad \Delta S^\circ \text{ will be negative; 4 moles of gas become only 2 moles of gas, resulting in less chaos and more order, or a negative entropy change.} \]

\[ c) \Delta G^\circ = \Delta H^\circ - \Delta S^\circ T \quad \text{Since } \Delta H^\circ \text{ and } \Delta S^\circ \text{ are both negative, a high temperature is needed to overcome the low } \Delta G^\circ \text{ value and make } \Delta G^\circ \text{ positive.} \]

GO ON TO THE NEXT PAGE.
If \( \Delta S^\circ T \) is greater than \( \Delta H^\circ \), then \( \Delta H^\circ - \Delta S^\circ T \) will be positive.

A low temperature would not make \( \Delta S^\circ T \) greater than \( \Delta H^\circ \), so \( \Delta H^\circ - \Delta S^\circ T \) will be negative. Since \( \Delta G^\circ = \Delta H^\circ - \Delta S^\circ T \), \( \Delta G^\circ \) will then be negative as well.

d) At low temps, the molecules of \( \text{N}_2 \) and \( \text{H}_2 \) gas move relatively slowly and have less energetic collisions, as well as a smaller number of collisions with enough activation energy to make the reaction take place.
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(d) When \( \text{N}_2(g) \) and \( \text{H}_2(g) \) are placed in a sealed container at a low temperature, no measurable amount of \( \text{NH}_3(g) \) is produced. Explain.

\[ \Delta H = \text{Bond Energy React.} - \text{Bond Energy Prod.} \]

\[ = 0 - 950 \text{ kJ/mol} \]

\[ = 950 \text{ kJ/mol} \]

b) \( \Delta S \) will be negative for this reaction because there is a decrease in disorder. There are 4 moles of gas on the reactants side of the equation, and only 2 on the products side.
3) ΔG is negative at low temperatures but positive at high temperatures. Since ΔS is negative for this reaction, enthalpy controls the spontaneity of the reaction. In this scenario, exothermic reactions are not spontaneous at high temperatures. According to the equation, ΔG = ΔH - TΔS, increasing temp will increase the value of the positive TΔS until it is greater than the value of the negative ΔH term, and ΔG becomes positive.

4) When N₂ (g) and H₂ (g) are placed in a sealed container at low temperature, no measurable amount of NH₃ (g) is produced. This is because the collisions of particles at low temperatures do not result in enough energy to reach the activation energy.
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(d) When \( \text{N}_2(g) \) and \( \text{H}_2(g) \) are placed in a sealed container at a low temperature, no measurable amount of \( \text{NH}_3(g) \) is produced. Explain.

\[ \text{N}_2(g) \rightarrow \text{N} \equiv \text{N} \]
\[ \Delta H = 950 \text{ kJ} \]

\[ \Delta H = 950 \text{ kJ} \quad \text{endothermic} \]

\[ \Delta S \text{ will most likely be negative because you are going from more entropy to less entropy.} \]

\[ \Delta S \text{ran} = \Delta S \text{prod} - \Delta S \text{reactants} \] and \[ \Delta S \text{ of the reactants is greater than } \Delta S \text{ of the products making the } \Delta S \text{ ran (–)} \]

GO ON TO THE NEXT PAGE.
c. $\Delta G = \Delta H - T \Delta S$
   Since $\Delta S$ is (-), the equation can also be written as
   $$\Delta G = \Delta H + T \Delta S$$
   Since $\Delta H$ is (-), if the $T$ is low, not much is being added to the $\Delta H$ value since $T \Delta S$ will be a small value. This will make the $\Delta G$ value remain negative.
   If $T$ is high, the $T \Delta S$ value will be large which means a large value is being added to the $\Delta H$ value making $\Delta G$ positive.

d. Since the temperature is low, the molecules are not moving very fast which means the KE of the molecules is low. The molecules will not collide with much force which will mean that the $NH_3$ molecule will not form, so not as much $NH_3$ will be produced.