AP® Chemistry
2003 Sample Student Responses

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.

$$2\,N(g) \rightarrow N_2(g)$$

Using the table of average bond energies below, determine the enthalpy change, ΔH, for the reaction.

Bond	Average Bond Energy (kJ mol^{-1})
N — N	160
N ═ N	420
N ≡ N	950

:N≡N:

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

$$N_2(g) + 3\,H_2(g) \rightarrow 2\,NH_3(g) \qquad \Delta H° = -92.2\text{ kJ}$$

Predict the sign of the standard entropy change, $\Delta S°$, for the reaction. Justify your answer.

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

(d) When $N_2(g)$ and $H_2(g)$ are placed in a sealed container at a low temperature, no measurable amount of $NH_3(g)$ is produced. Explain.

a) $\Delta H = \Sigma H_{(broken)} - \Sigma H_{(formed)}$

$= 0 - (950) = \boxed{-950\text{ kJ}}$

b) $\Delta G° = \Delta H° - \Delta S° T$ $\Delta°S$ 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) $\Delta G° = \Delta H° - \Delta S° T$ Since $\Delta H°$ and $\Delta S°$ are both negative, a high temperature is needed to over come the low $\Delta H°$ value and make $\Delta G°$ positive.

$\Delta G° = (-) - (-)T$

$\Delta G° = (-) + T$

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If $\Delta S°T$ is > than $\Delta H°$, then $\Delta H° - \Delta S°T$ will be positive. A low temperature would not make $\Delta S°T$ greater than $\Delta H°$, so $\Delta H° - \Delta S°T$ will be negative. Since $\Delta G° = \Delta H° - \Delta S°T$, $\Delta G°$ will then be negative as well.

d) At low temps the molecules of N_2 and H_2 gas move relatively slowly and have less energetic collisions, as well as a smaller # of collisions with enough activation energy to make the reaction take place.

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(c) The value of ΔG° for the reaction represented in part (b) is negative at low temperatures but positive at high temperatures. Explain.

(d) When $N_2(g)$ and $H_2(g)$ are placed in a sealed container at a low temperature, no measurable amount of $NH_3(g)$ is produced. Explain.

a) ΔH = Bond Energy React. − Bond Energy Prod.
= 0 − 950 ✓
= −950 kJ/mol

b) ΔS 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 ✓

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c) 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 $\Delta G = \Delta H - T\Delta S$, increasing temp. will increase the value of the positive $(-T\Delta S)$ term until it is greater than the value of the negative ΔH term and ΔG becomes positive.

d) When $N_2(g)$ and $H_2(g)$ are placed in a sealed container at low temperature, no measurable amount of $NH_3(g)$ 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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(c) The value of $\Delta G°$ for the reaction represented in part (b) is negative at low temperatures but positive at high temperatures. Explain.

(d) When $N_2(g)$ and $H_2(g)$ are placed in a sealed container at a low temperature, no measurable amount of $NH_3(g)$ is produced. Explain.

a. 2 N → N≡N
2(0) → 950
ΔH = ΣΔH products − ΣΔH reactants
= 950 − 0
ΔH = 950 endothermic

b. ΔS will most likely be negative because you are going from more entropy to less entropy and ΔSrxn = ΣΔS prod − ΣΔS reactants and ΔS of the reactants is greater than ΔS of the products making the ΔSrxn (−)

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c. $\Delta G = \Delta H - T\Delta S$
since ΔS is (-), the equation can also be written as
$\Delta G = \Delta H + T\Delta S$
since ΔH is (-), if the T is low, not much is being added to the ΔH value since $T\Delta S$ will be a small value, this will make the ΔG 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 ΔH value making ΔG 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 w/ much force which will mean that the NH_3 molecule will not form, so not as much NH_3 will be produced

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