AP® Chemistry
2004 Sample Student Responses
Form B

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7A 1

Answer EITHER Question 7 below OR Question 8 printed on page 24. 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.

$$N_2(g) + 2\,H_2(g) \rightleftarrows N_2H_4(g) \quad \Delta H^\circ_{298} = +95.4 \text{ kJ mol}^{-1}\,;\ \Delta S^\circ_{298} = -176 \text{ J K}^{-1} \text{ mol}^{-1}$$

7. Answer the following questions about the reaction represented above using principles of thermodynamics .

   (a) On the basis of the thermodynamic data given above, compare the sum of the bond strengths of the reactants to the sum of the bond strengths of the product. Justify your answer.

   (b) Does the entropy change of the reaction favor the reactants or the product? Justify your answer.

   (c) For the reaction under the conditions specified, which is favored, the reactants or the product? Justify your answer.

   (d) Explain how to determine the value of the equilibrium constant, K_{eq}, for the reaction. (Do not do any calculations.)

   (e) Predict whether the value of K_{eq} for the reaction is greater than 1, equal to 1, or less than 1. Justify your answer.

a) ΔH°_{rxn} = Σ bonds broken (reactants) − Σ bonds formed (products)

= +95.4 kJ/mol > 0

⇒ the sum of the bond strengths of the reactants is greater than the sum of the bond strengths of the products.

c) $\Delta G = \Delta H - T\Delta S$ = 95.4 kJ − (298)(−176)

= 95.4 kJ + (298)(176) J > 0

∴ $-\frac{\Delta G}{T} < 0$ ∴ the reaction will favour the reactants.

b) The no. of gaseous molecules is greater on the rxts side ∴ the backward rxn will be favoured spontaneous ∴ the reactants will be favoured.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 7.

d) $\Delta G = \Delta G_o + RT \ln Q$

at eq. $\Delta G = 0$

$\Rightarrow 0 = \Delta G_o + RT \ln K$

$\Rightarrow \ln K = -\frac{\Delta G_o}{RT}$

ΔG_o can be found by using $\Delta G = \Delta H - T\Delta S$.

e) $K_{eq} < 1$

because the rxn will favour the reactants

∴ there will be more rxts than products

∴ $K_{eq} = \frac{[N_2H_4]}{[N_2][H_2]^2} < 1$

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(a) ΔH°_{298} is +ve, thus bond energy of the reactants must be larger than bond energy of the product.

(b) ΔS°_{298} is −ve; since reactions tend to proceed in a +ve ΔS° (random) direction, the reactants are favored in this reaction.

(c) $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$

+ve −ve

$\therefore \Delta G^\circ$ is +ve, meaning the reaction is spontaneous in the reverse direction, favoring reactants.

(d) $K_{eq} = e^{\frac{-\Delta G^\circ}{RT}}$, where $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$

T = temperature in K

R = 8.314 J/mol·K

(e) $K_{eq} < 1$; since ΔG° is +ve, $-\Delta G^\circ$ must be −ve, and $e^{(\text{-ve number})} < 1$.

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(a) Bond strength relates to ΔH°, $\Delta H^\circ = \Delta H_p - \Delta H_R$. Since ΔH° is positive $\Rightarrow \Delta H_p > \Delta H_R$.

This means that the strength of the bonds of the products is greater than that of the ~~reaction~~ reactants.

(b) It favours the reactants, because $\Delta G = \Delta H - T\Delta S$

According to the above values, ΔG will allways be posotive (no matter what the value of T is).

$\Delta G > 0 \Rightarrow$ the backward reaction is favoured, therefore we can say that ΔS° being negative favors the reactants.

(c) The reactans, because (as in part (b)) ΔG will always be posotive and therefore the backward

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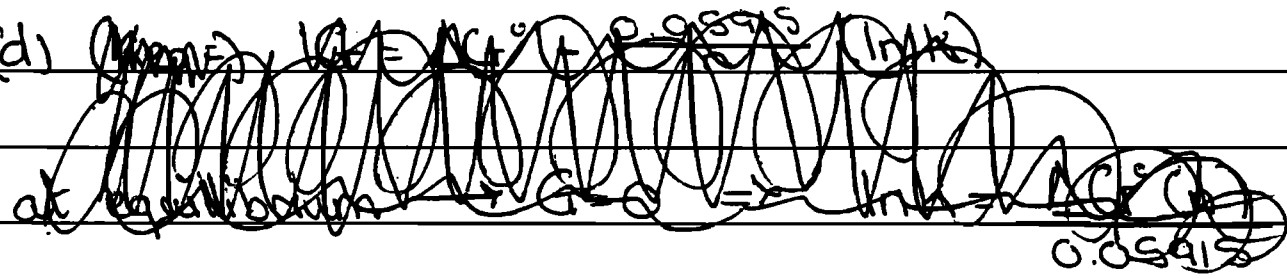
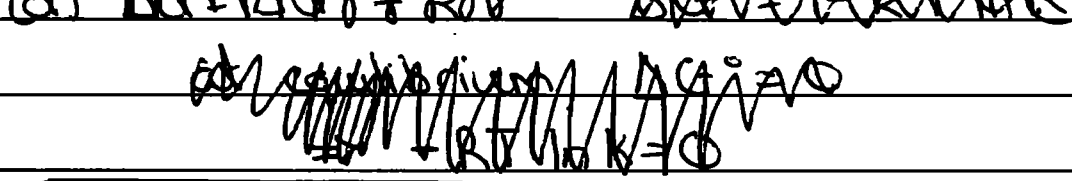
ADDITIONAL PAGE FOR ANSWERING QUESTION 7.

reaction is favored, i.e. the reactants are favoured.

(d) 

(d) 

$\boxed{\Delta G = \Delta G^\circ + RT \ln Q}$, at equilibrium : $\Delta G = 0$

$\Rightarrow 0 = \Delta G^\circ + RT \ln K_{eq}$

$\Rightarrow \ln K_{eq} = \frac{-\Delta G^\circ}{RT} \Rightarrow \boxed{K_{eq} = e^{-\left(\frac{\Delta G^\circ}{RT}\right)}}$

(e) K_{eq} will be less than 1 because:

1: According to the equation ; $K_{eq} = e^{(\text{negative number})}$

$\Rightarrow K_{eq} < 1$

2: Since the backward reaction is favoured.