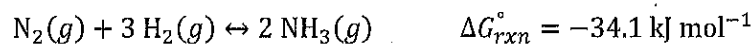


Unit 4: AP Free Response Practice #3 [LTF Free Response #2, 10 points]



3. The following questions relate to the synthesis reaction represented by the chemical equation above.

- a. Is the reaction ~~spontaneous or non-spontaneous~~ ^{thermodynamically favorable} under standard conditions at 298 K? Justify your answer. [1 point]
- b. In terms of the equilibrium constant, K , for the above reaction at 25°C
- Predict whether K will be greater than, less than, or equal to one. Justify your choice. [1 point]
 - Calculate its value. [2 points]
- c. Given the following data, determine the ΔH° for the above reaction. [2 points]

Substance	ΔH_f° (kJ mol ⁻¹)
NH ₃ (g)	-46.1

- d. In terms of the standard entropy change, ΔS°
- Predict the sign of ΔS° for the above reaction. Justify your answer. [1 point]
 - Calculate the value of ΔS° for the above reaction at 25°C. [1 point]
- e. Using the data in the table below and the enthalpy of reaction, $\Delta H_{\text{rxn}}^{\circ}$ determined in part (c), calculate the approximate bond energy of the nitrogen-hydrogen bond in ammonia. [2 points]

Bonds	Approximate Bond Energy (kJ mol ⁻¹)
N - H	???
H - H	430
N \equiv N	960

a) Spontaneous! (thermodynamically favorable) b/c $-\Delta G$

b)(i) $K > 1$, b/c ΔG is negative, products are favored.

(ii) $\Delta G^{\circ} = -RT \ln K \Rightarrow K = e^{-\Delta G/RT}$ (make sure ΔG is in J/mol!)

$$= e^{(34,100 \text{ J/mol} / 8.314 \text{ J/mol}\cdot\text{K} \times 298)}$$

$$= e^{13.763} = \boxed{9.49 \times 10^5}$$

c) $\Delta H_{\text{rxn}}^{\circ} = \sum \Delta H_f^{\circ}(\text{pr}) - \sum \Delta H_f^{\circ}(\text{re})$

$$= [2(\text{NH}_3)] - [\text{N}_2 + 3\text{H}_2]$$

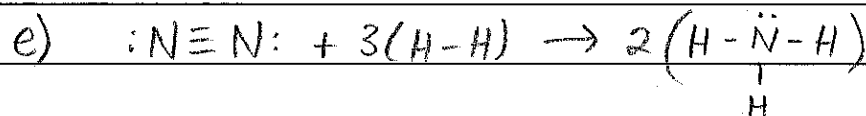
$$= 2(-46.1) - 0 = \boxed{-92.2 \text{ kJ/mol rxn}}$$

d)(i) ΔS should be negative, b/c 4 gas particles are forming 2 gas particles

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

$$\Rightarrow \Delta S^\circ = \frac{\Delta H^\circ - \Delta G^\circ}{T} = \frac{-92.2 \text{ kJ/mol}_{\text{rxn}} - (-34.1 \text{ kJ/mol}_{\text{rxn}})}{298 \text{ K}} = \boxed{-0.196 \text{ kJ/mol}\cdot\text{K}}$$

(or $-196 \text{ J/mol}\cdot\text{K}$)



$$\Delta H^\circ_{\text{rxn}} = \sum \text{BE}(\text{re}) - \sum \text{BE}(\text{pr})$$

$$-92.2 = [1(\text{N}\equiv\text{N}) + 3(\text{H}-\text{H})] - [6(\text{N}-\text{H})]$$

$$= [960 + 3(430)] - 6(\text{N}-\text{H})$$

$$= 2250 - 6(\text{N}-\text{H})$$

$$2342.2 = 6(\text{N}-\text{H})$$

$$\text{BE}(\text{N}-\text{H}) = \boxed{390 \text{ kJ/mol}_{\text{rxn}}}$$