# AP CHEMISTRY

## TOPIC 9: THERMODYNAMICS, PART D, EXAMPLES, PART II

Day 111:

- Free Energy and Equilibrium

Example #2: Octane gas, $C_8H_{18}$, is used in gasoline. Use the data below to answer the following questions about the combustion of octane gas.

| Substance | $\Delta H^0_f$ ( kJ mol$^{-1}$ ) | $S^0$ ( J mol$^{-1}$ K$^{-1}$ ) |
|---|---|---|
| $C_8H_{18\,(g)}$ | -208.4 | 345.3 |
| $O_{2\,(g)}$ | 0 | 205.1 |
| $CO_{2\,(g)}$ | -393.5 | 213.7 |
| $H_2O_{(l)}$ | -285.8 | 188.8 |

Use the data above to answer the questions that follow. Assume all reactions take place at 25 $^0$C.

a) Write a complete balanced chemical equation for the combustion of octane. Assume that carbon dioxide and water are the only products.

$$2\ C_8H_{18\,(g)} + 25\ O_{2\,(g)} \rightarrow 16\ CO_{2\,(g)} + 18\ H_2O_{(l)}$$

b) Calculate the standard enthalpy change, $\Delta H^0$, for the combustion of one mole of octane gas.

$$\Delta H^0_{rxn} = \Sigma\,\Delta H^0_f\ \text{(products)} - \Sigma\,\Delta H^0_f\ \text{(reactants)}$$

$$\Delta H^0_{comb} = \left[16\left(\frac{-393.5\ kJ}{mol}\right)+18\left(\frac{-285.8\ kJ}{mol}\right)\right]-\left[2\left(\frac{-208.4\ kJ}{mol}\right)+25\left(\frac{0\ kJ}{mol}\right)\right] = -11023.6\ \frac{kJ}{mol}$$

Typically the question wants to know the enthalpy change for one mole of octane gas: Therefore,

$$\Delta H^0_{comb} = -11023.6\ \frac{kJ}{mol}\ \text{ for 2 moles of } C_8H_{18\,(g)}$$

$$\text{For 1 mole of } C_8H_{18\,(g)}:\ \frac{-11023.6\ \frac{kJ}{mol}}{2} = -5511.8\ \frac{kJ}{mol}$$

c) Calculate the standard entropy change, $\Delta S^0$, for the combustion of one mole of octane gas.

$$\Delta S^0_{rxn} = \Sigma\,\Delta S^0\ \text{(products)} - \Sigma\,\Delta S^0\ \text{(reactants)}$$

$$\Delta S^0_{rxn} = \left[16\left(\frac{213.7\ J}{mol\cdot K}\right)+18\left(\frac{188.8\ J}{mol\cdot K}\right)\right]-\left[2\left(\frac{345.3\ J}{mol\cdot K}\right)+25\left(\frac{205.1\ J}{mol\cdot K}\right)\right] = +999.5\ \frac{J}{mol\cdot K}$$

$$\text{For 1 mole of } C_8H_{18\,(g)}:\ \frac{+999.5\ \frac{J}{mol\cdot K}}{2} = +499.75\ \frac{J}{mol\cdot K}$$

d) Determine the value of $\Delta G^0$ for the reaction.

$$\Delta G = \Delta H - T\Delta S$$

Convert ( J to kJ ): $\Delta S = \left(+\ 499.75\ \frac{J}{mol \cdot K}\right)\left(\frac{1\ kJ}{1000\ J}\right) = +\ 0.49975\ \frac{kJ}{mol \cdot K}$

$$\Delta G = \left(-5511.8\ \frac{kJ}{mol}\right) - \left(298\ K\right)\left(+\ 0.49975\ \frac{kJ}{mol \cdot K}\right) = -\ 5661\ \frac{kJ}{mol}$$