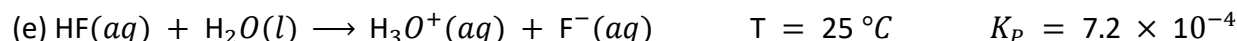
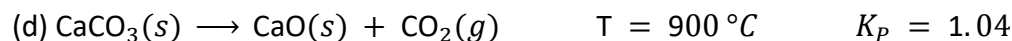
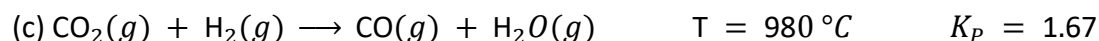


Fundamental Equilibrium Concepts

Section 87 – Gibbs Energy and Equilibrium

1. Calculate ΔG° for each of the following reactions from the equilibrium constant at the temperature given.



Solution

(a) $\Delta G^\circ = -RT \ln K_p = -(8.314\text{ J K}^{-1})(2273.15\text{ K})(\ln 4.1 \times 10^{-4}) = 147\text{ kJ} = 1.5 \times 10^2\text{ kJ}$

(b) $\Delta G^\circ = -(8.314\text{ J K}^{-1})(673.15\text{ K})(\ln 50.0) = -21,893\text{ J} = -21.9\text{ kJ}$

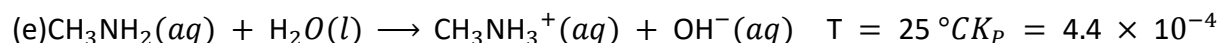
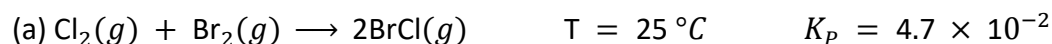
(c) $\Delta G^\circ = -(8.314\text{ J K}^{-1})(1253.15\text{ K})(\ln 1.67) = -5.34\text{ kJ}$

(d) $\Delta G^\circ = -(8.314\text{ J K}^{-1})(1173.15\text{ K})(\ln 1.04) = -0.383\text{ kJ}$

(e) $\Delta G^\circ = -(8.314\text{ J K}^{-1})(298.15\text{ K})(\ln 7.2 \times 10^{-4}) = 17,937\text{ J} = 18\text{ kJ}$

(f) $\Delta G^\circ = -(8.314\text{ J K}^{-1})(298.15\text{ K})(\ln 3.3 \times 10^{-13}) = 71,240\text{ J} = 71\text{ kJ}$

2. Calculate ΔG° for each of the following reactions from the equilibrium constant at the temperature given.



Solution

(a) $\Delta G^\circ = -RT \ln K_p = (8.314 \text{ J K}^{-1})(298.15 \text{ K})(\ln 4.7 \times 10^{-2}) = 7579 \text{ J} = 7.6 \text{ kJ}$;

(b) $\Delta G^\circ = -(8.314 \text{ J K}^{-1})(773.15 \text{ K})(\ln 48.2) = 24,911 \text{ J} = 24.9 \text{ kJ}$;

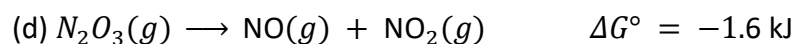
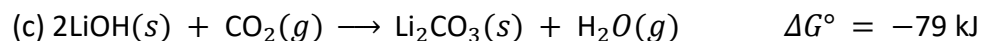
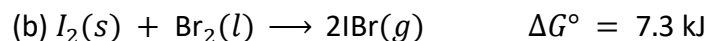
(c) $\Delta G^\circ = -(8.314 \text{ J K}^{-1})(333.15 \text{ K})(\ln 0.196) = 4513.8 \text{ J} = 4.51 \text{ kJ}$;

(d) $\Delta G^\circ = -(8.314 \text{ J K}^{-1})(823.15 \text{ K})(\ln 4.90 \times 10^2) = -42,392 \text{ J} = -42.4 \text{ kJ}$;

(e) $\Delta G^\circ = -(8.314 \text{ J K}^{-1})(298.15 \text{ K})(\ln 4.4 \times 10^{-4}) = 19,158 \text{ J} = 19 \text{ kJ}$;

(f) $\Delta G^\circ = -(8.314 \text{ J K}^{-1})(298.15 \text{ K})(\ln 8.7 \times 10^{-9}) = 103,084 \text{ J} = 1.0 \times 10^2 \text{ kJ}$

3. Calculate the equilibrium constant at 25°C for each of the following reactions from the value of ΔG° given.



Solution

Equilibrium constants are calculated from the equation $\Delta G^\circ = -RT \ln K$, which can be rearranged to $\ln K = \frac{-\Delta^\circ}{RT}$. Note that K is a function of T and thus changes as T changes.

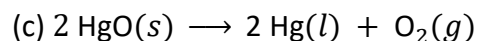
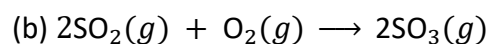
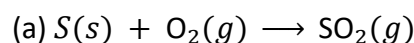
$$(a) \ln K = - \left[\frac{-9.2 \times 10^3 \text{ J}}{(8.314 \text{ J mol}^{-1} \text{ K}^{-1} \times 298.15 \text{ K})} \right] = 3.71, K = 41;$$

$$(b) \ln K = \frac{-7300 \text{ J}}{(8.314 \text{ J mol}^{-1} \text{ K}^{-1} \times 298.15 \text{ K})} = -2.945, K = 0.053;$$

$$(c) \ln K = - \left[\frac{-79 \times 10^3 \text{ J}}{(8.314 \text{ J mol}^{-1} \text{ K}^{-1} \times 298.15 \text{ K})} \right] = 31.870, K = 6.9 \times 10^{13};$$

$$(d) \ln K = - \left[\frac{-1.6 \times 10^3 \text{ J}}{(8.314 \text{ J mol}^{-1} \text{ K}^{-1} \times 298.15 \text{ K})} \right] = 0.645, K = 1.9;$$

4. What happens to ΔG_r (becomes more negative or more positive) for the following chemical reactions when the partial pressure of oxygen is increased?



Solution

(a) Increasing P_{O_2} will shift the equilibrium toward the products, which increases the value of Q . ΔG_r therefore becomes more negative.

(b) Increasing P_{O_2} will shift the equilibrium toward the products, which increases the value of Q . ΔG_r therefore becomes more negative.

(c) Increasing P_{O_2} will shift the equilibrium toward the reactants, which decreases the value of Q . ΔG_r therefore becomes more positive.

5. One of the important reactions in the biochemical pathway glycolysis is the reaction of glucose-6-phosphate (G6P) to form fructose-6-phosphate (F6P):



(a) Is the reaction spontaneous or nonspontaneous under standard thermodynamic conditions?

(b) Standard thermodynamic conditions imply the concentrations of G6P and F6P to be 1 M, however, in a typical cell, they are not even close to these values. Calculate ΔG when the concentrations of G6P and F6P are 120 μM and 28 μM respectively, and discuss the spontaneity of the forward reaction under these conditions. Assume the temperature is 37 °C.

Solution

(a) Nonspontaneous as $\Delta G^\circ > 0$; (b) $\Delta G = \Delta G^\circ + RT \ln Q$, $\Delta G = 1.7 \times 10^3 + \left(8.314 \times 310 \times \ln \frac{28}{120}\right) = -2.1 \text{ kJ}$. The forward reaction to produce F6P is spontaneous under these conditions.