

## Calculus-Based Thermodynamics (Practice Problems)

1. What will be the freezing-point and boiling-point of an aqueous solution containing 10.0 g of glucose,  $C_6H_{12}O_6$ , and 100 g of water? Equations:  $K_f = 1.86^\circ C/m$ ,  $K_b = 0.512^\circ C/m$ .

$$\text{Molality} = \frac{\text{moles solute}}{\text{kg solvent}} = \frac{0.177 \text{ mol}}{0.100 \text{ kg}} = 1.77 \text{ mol/kg}$$

$$\Delta T_f = K_f \cdot m = 1.86^\circ C/m \cdot 1.77 \text{ mol/kg} = 3.30^\circ C \text{ freezing}$$

$\Delta T_f = 1.86^\circ C/m \cdot 1.77 \text{ mol/kg}$   
 $\Delta T_f = 3.30^\circ C$   
 $T_f = 0^\circ C - 3.30^\circ C = -3.30^\circ C$   
 $\Delta T_b = 0.512^\circ C/m \cdot 1.77 \text{ mol/kg}$   
 $\Delta T_b = 0.91^\circ C$   
 $T_b = 100^\circ C + 0.91^\circ C = 100.91^\circ C$

2. What will be the freezing-point and boiling-point of an aqueous solution containing 1.00 g of urea,  $CH_4N_2O$ , and 100.0 g of water? Equations:  $K_f = 1.86^\circ C/m$ ,  $K_b = 0.512^\circ C/m$ ,  $M_{\text{urea}} = 60.06 \text{ g/mol}$ .

$$\text{Molality} = \frac{\text{moles solute}}{\text{kg solvent}} = \frac{0.0167 \text{ mol}}{0.100 \text{ kg}} = 0.167 \text{ mol/kg}$$

$$\Delta T_f = K_f \cdot m = 1.86^\circ C/m \cdot 0.167 \text{ mol/kg} = 0.310^\circ C$$

$\Delta T_f = 1.86^\circ C/m \cdot 0.167 \text{ mol/kg}$   
 $\Delta T_f = 0.310^\circ C$   
 $T_f = 0^\circ C - 0.310^\circ C = -0.310^\circ C$   
 $\Delta T_b = 0.512^\circ C/m \cdot 0.167 \text{ mol/kg}$   
 $\Delta T_b = 0.085^\circ C$   
 $T_b = 100^\circ C + 0.085^\circ C = 100.085^\circ C$

3. A 100.0 mL sample of 0.100 M  $NaCl(aq)$  is electrolyzed by the  $g$  of  $H_2$  evolving the hydrogen gas at the cathode is measured to be 1.20 L. Assume that the electrolyte (aqueous) composition is  $NaCl(aq) = 1.00\%$  (aq).

$$\text{at } T_{25} = 25^\circ C, P = 1 \text{ atm} \rightarrow V_{H_2} = 1.20 \text{ L}$$

$$\text{at } T_{25} = 25^\circ C, P = 1 \text{ atm}$$

$$\rightarrow \text{at } T = 100^\circ C, P = 1 \text{ atm}$$

$$V_{H_2} = 0.41 \text{ L}$$

$$V_{H_2} = \frac{n_{H_2} \cdot RT}{P} \quad \text{at } T_{25} = 25^\circ C, P = 1 \text{ atm}$$

$$\rightarrow 1.20 \text{ L} = \frac{n_{H_2} \cdot (8.314 \text{ J/mol}\cdot K) \cdot 298 \text{ K}}{1 \text{ atm}}$$

$$\text{Mol } H_2 = \frac{1.20 \text{ L} \cdot 1 \text{ atm}}{(8.314 \text{ J/mol}\cdot K) \cdot 298 \text{ K}} = 0.0048 \text{ mol}$$

$$\text{at } T_{100} = 100^\circ C, P = 1 \text{ atm} \rightarrow V_{H_2} = 0.41 \text{ L}$$

4. A solution composed from 10 g of glucose,  $C_6H_{12}O_6$ , and 1.00 g of water is composed. The freezing-point of this solution is  $-1.7^\circ C$ . The normal freezing point of pure water is  $0^\circ C$  and the freezing-point depression constant for water is  $1.86^\circ C/m$ . Determine the molar mass of the compound. Assume  $R = 8.314 \text{ J/mol}\cdot K$ ,  $1 \text{ atm} = 101325 \text{ Pa}$ .

$$\text{at } T_f = -1.7^\circ C, P = 1 \text{ atm} \rightarrow V_{H_2} = 0.41 \text{ L} \rightarrow V_{H_2} = 0.41 \text{ L}$$

$$\text{at } T_f = -1.7^\circ C, P = 1 \text{ atm}$$

$$\rightarrow \text{at } T = 100^\circ C, P = 1 \text{ atm}$$

$$V_{H_2} = 0.41 \text{ L}$$

$$V_{H_2} = \frac{n_{H_2} \cdot RT}{P} \quad \text{at } T_{25} = 25^\circ C, P = 1 \text{ atm}$$

$$\rightarrow 0.41 \text{ L} = \frac{n_{H_2} \cdot (8.314 \text{ J/mol}\cdot K) \cdot 298 \text{ K}}{1 \text{ atm}}$$

$$\text{Mol } H_2 = \frac{0.41 \text{ L} \cdot 1 \text{ atm}}{(8.314 \text{ J/mol}\cdot K) \cdot 298 \text{ K}} = 0.0016 \text{ mol}$$

$$\text{at } T_{100} = 100^\circ C, P = 1 \text{ atm} \rightarrow V_{H_2} = 0.41 \text{ L}$$

$$\text{at } T_{100} = 100^\circ C, P = 1 \text{ atm} \rightarrow V_{H_2} = 0.41 \text{ L}$$

# Rosengarten Colligative Properties Homework Answers

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