An Example of Equilibrium and Non-Equilibrium Vapor Pressure Calculations

Problem 13.53

A 0.240-g sample of $H_2O(l)$ is sealed into an evacuated 3.20-L flask. What is the pressure of the vapor in the flask if the temperature is (**a**) 30.0°C; (**b**) 50.0°C; (**c**) 70.0°C?

This is a problem to assess if you understand the nature of equilibrium vapor pressure. If, in the container, there is sufficient water that once the equilibrium vapor pressure is established water remains, then the pressure in the container will be due to the equilibrium vapor pressure of the water. If, however, the entire amount of water vaporizes, then the pressure becomes a simple "gas laws" calculation.

$$m_{H_2O} = 0.240 \text{ g} \qquad n_{H_2O} = \frac{0.240 \text{ g}}{18.02 \text{ g/mol}} = 0.01332 \text{ H}_2\text{O}$$

$$V = 3.20 \text{ L}$$

Temp (°C)	**v.p. (mm Hg)**	**v.p. (atm)**
30.0	31.8	0.0418
50.0	92.5	0.1217
70.0	233.7	0.3075

a. $T = 30.0°\text{C} = 303.2 \text{ K}$

$$P = \frac{nTR}{V} = \frac{(0.01332 \text{ mol})(303.2 \text{ K})(0.0821 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}})}{3.20 \text{ L}} = 0.1036 \text{ atm}$$

This would be the pressure if all of the water is vaporized. However, the equilibrium vapor pressure is 0.0418 atm. The pressure in the container will rise to 0.0418 atm and hold there since liquid water remains.

b. $T = 50.0°\text{C} = 323.2 \text{ K}$

$$P = \frac{nTR}{V} = \frac{(0.01332 \text{ mol})(323.2 \text{ K})(0.0821 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}})}{3.20 \text{ L}} = 0.1105 \text{ atm}$$

This will be the pressure if all of the water is vaporized. The equilibrium vapor pressure would be 0.1217 atm if any liquid water remained. Since all of the water vaporizes before the equilibrium vapor pressure is achieved, the pressure in the container will rise only to 0.1105 atm.

c. $T = 70.0°\text{C} = 343.2 \text{ K}$

$$P = \frac{nTR}{V} = \frac{(0.01332 \text{ mol})(343.2 \text{ K})(0.0821 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}})}{3.20 \text{ L}} = 0.117 \text{ atm}$$

This will be the pressure if all of the water is vaporized. The equilibrium vapor pressure would be 0.3075 atm if any liquid water remained. Since all of the water vaporizes before the equilibrium vapor pressure is achieved, the pressure in the container will rise only to 0.117 atm.