CHAPTER 14 | THE IDEAL GAS LAW AND KINETIC THEORY

PROBLEMS

1. **REASONING AND SOLUTION** Since hemoglobin has a molecular mass of 64,500 u, one mole of hemoglobin has a mass of 64,500 g. One mole of hemoglobin contains Avogadro's number or \(6.022 \times 10^{23}\) molecules. Therefore, one molecule of hemoglobin has a mass (in kg) of

\[
(64,500 \text{ g/mol}) \left(\frac{1 \text{ mol}}{6.022 \times 10^{23}}\right) \left(\frac{1.00 \text{ kg}}{1.0 \times 10^{3} \text{ g}}\right) = 1.07 \times 10^{-22} \text{ kg}
\]

10. **REASONING AND SOLUTION** PV = nRT; therefore, \(n = \frac{PV}{RT} = 9.6 \times 10^{-11}\) mol, and the number of molecules is

\[
N = nN_A = (9.6 \times 10^{-11} \text{ mol})(6.022 \times 10^{23} \text{ mol}) = 5.8 \times 10^{13}
\]

26. **REASONING AND SOLUTION**

a. Since the heat gained by the gas in one tank is equal to the heat lost by the gas in the other tank, \(Q_1 = Q_2\), or (letting the subscript 1 correspond to the neon in the left tank, and letting 2 correspond to the neon in the right tank) \(cm_1 \Delta T_1 = cm_2 \Delta T_2\),

\[
cm_1(T - T_1) = cm_2(T_2 - T)
\]

\[
m_1(T - T_1) = m_2(T_2 - T)
\]

Solving for \(T\) gives

\[
T = \frac{m_2 T_2 + m_1 T_1}{m_2 + m_1}
\]

(1)

The masses \(m_1\) and \(m_2\) can be found by first finding the number of moles \(n_1\) and \(n_2\). From the ideal gas law, \(PV = nRT\), so

\[
n_1 = \frac{PV_1}{RT_1} = \frac{(5.0 \times 10^{-5} \text{ Pa})(2.0 \text{ m}^3)}{(8.31 \text{ J/(mol} \cdot \text{K})/(220 \text{ K})} = 5.5 \times 10^{-2} \text{ mol}
\]

This corresponds to a mass \(m_1 = (5.5 \times 10^{-2} \text{ mol})(\frac{20.179 \text{ g}}{1 \text{ mol}}) = 1.1 \times 10^4 \text{ g} = 1.1 \times 10^1 \text{ kg}\). Similarly, \(n_2 = 2.4 \times 10^2 \text{ mol}\) and \(m_2 = 4.9 \times 10^3 \text{ g} = 4.9 \text{ kg}\). Substituting these mass values into Equation (1) yields

\[
T = \frac{(4.9 \text{ kg})(580 \text{ K}) + (1.1 \times 10^1 \text{ kg})(220 \text{ K})}{(4.9 \text{ kg}) + (1.1 \times 10^1 \text{ kg})} = 3.3 \times 10^2 \text{ K}
\]

b. From the ideal gas law,

\[
P = \frac{nRT}{V} = \frac{[(5.5 \times 10^2 \text{ mol})(2.4 \times 10^2 \text{ mol})][8.31 \text{ J/(mol} \cdot \text{K})]3.3 \times 10^2 \text{ K}}{(2.0 \text{ m}^3 + 5.8 \text{ m}^3)} = 2.8 \times 10^5 \text{Pa}
\]
30. **REASONING AND SOLUTION** Using $\overline{KE} = \frac{1}{2} m v_{\text{rms}}^2 = \frac{3}{2} kT$, we can solve for $v_{\text{rms}}$.

\[
v_{\text{rms}} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3(1.38 \times 10^{-23} \text{ J/K})(6.0 \times 10^3 \text{ K})}{1.67 \times 10^{-27} \text{ kg}}} = 1.2 \times 10^4 \text{ m/s}
\]

37. **SSM REASONING** The internal energy of the neon at any Kelvin temperature $T$ is given by Equation 14.7, $U = \frac{2}{3} nRT$. Therefore, when the temperature of the neon increases from an initial temperature $T_i$ to a final temperature $T_f$, the internal energy of the neon increases by an amount

\[
\Delta U = U_f - U_i = \frac{3}{2} nR \left( \frac{T_f}{T_i} - 1 \right)
\]

In order to use this equation, we must first determine $n$. Since the neon is confined to a tank, the number of moles $n$ is constant, and we can use the information given concerning the initial conditions to determine an expression for the quantity $nR$. According to the ideal gas law (Equation 14.1),

\[
nR = \frac{PV_i}{T_i}
\]

These two expressions can be combined to obtain an equation in terms of the variables that correspond to the data given in the problem statement.

**SOLUTION** Combining the two expressions and substituting the given values yields

\[
\Delta U = \frac{3}{2} \left( \frac{PV_i}{T_i} \right) \left( \frac{T_f}{T_i} - 1 \right)
\]

\[
= \frac{3}{2} \left[ \frac{(1.01 \times 10^5 \text{ Pa})(680 \text{ m}^3)}{(293.2 \text{ K})} \right] (294.3 \text{ K} - 293.2 \text{ K}) = 3.9 \times 10^5 \text{ J}
\]