Chemistry: *Mixed Review*

*Solve each of the following problems, being sure to show your work and include all proper units.*

1. Use the ideal gas law $PV = nRT$, to derive Boyle’s law and Charles’s law.

   If $n$, $R$ and $T$ are constant: $PV = nRT$  
   If $n$, $R$ and $P$ are constant: $V/T = nRP$

   $P_1V_1 = P_2V_2$  (Boyle’s Law)  
   $V_1/T_1 = V_2/T_2$  (Charles’s Law)

2. A container holds 265 mL of chlorine gas, Cl$_2$. Assuming that the gas sample is at STP, what is its mass?

   $V = 265 \text{ mL} = 0.265 \text{ L}$  
   $P = 1 \text{ atm}$  
   $T = 273 \text{ K}$  
   $n = ? \text{ mol}$  
   $R = 0.0821 \text{ L} \cdot \text{atm} / \text{mol} \cdot \text{K}$

   $n = \frac{PV}{RT} = \frac{(1 \text{ atm})(0.265 \text{ L})}{(0.0821 \text{ L} \cdot \text{atm/mol} \cdot \text{K})(273 \text{ K})}$

   $n = 0.0118 \text{ mol Cl}_2$

   $x \text{ g Cl}_2 = 0.0118 \text{ mol Cl}_2 \left( \frac{71 \text{ g Cl}_2}{1 \text{ mol Cl}_2} \right) = 0.84 \text{ g Cl}_2$

3. Suppose that 3.11 mol of carbon dioxide is at a pressure of 0.820 atm and a temperature of 39°C. What is the volume of the sample, in liters?

   $n = 3.11 \text{ mol CO}_2$  
   $P = 0.820 \text{ atm}$  
   $T = 39 \text{ °C} + 273 = 312 \text{ K}$  
   $V = ? \text{ L}$  
   $R = 0.0821 \text{ L} \cdot \text{atm} / \text{mol} \cdot \text{K}$

   $V = \frac{(3.11 \text{ mol})(0.082 1 \text{ L} \cdot \text{atm/mol} \cdot \text{K})(312 \text{ K})}{0.820 \text{ atm}}$

   $V = 97.1 \text{ L}$

4. Compare the rates of diffusion of carbon monoxide, CO, and sulfur trioxide, SO$_3$.

   CO = carbon monoxide  
   SO$_3$ = sulfur trioxide  
   $m_1 = 28 \text{ g}$  
   $m_2 = 80 \text{ g}$  
   $v_1 = ?$  
   $v_2 = ?$

   $\frac{v_1}{v_2} = \sqrt{\frac{m_2}{m_1}}$

   CO diffuses 1.69x faster than SO$_3$ (or SO$_3$ is 0.59x slower)

   $\frac{v_1}{v_2} = \sqrt{\frac{80 \text{ g}}{28 \text{ g}}} = 1.69$

   $\frac{v_1}{v_2} = \frac{1}{1}$

5. A gas sample that has a mass of 0.993 g occupies 0.570 L. Given the temperature is 281 K and the pressure is 1.44 atm, what is the molar mass of the gas?

   $P = 1.44 \text{ atm}$  
   $V = 0.570 \text{ L}$  
   $n = ? \text{ mol}$  
   $R = 0.0821 \text{ L} \cdot \text{atm} / \text{mol} \cdot \text{K}$  
   $T = 281 \text{ K}$

   $n = \frac{PV}{RT} = \frac{(1.44 \text{ atm})(0.570 \text{ L})}{(0.0821 \text{ L} \cdot \text{atm/mol} \cdot \text{K})(281 \text{ K})}$

   $n = 0.0356 \text{ mol}$

   $\text{molar mass} = \frac{g}{\text{mol}} \Rightarrow \frac{0.993 \text{ g}}{0.0356 \text{ mol}} \Rightarrow 28 \text{ g/mol}$

Answers: 1. 2. 0.84 g Cl$_2$ 3. 97.1L 4. CO is 1.69x faster 5. 28 g/mol
6. The density of a gas is 3.07 g/L at STP. Calculate the gas’s molar mass.

\[
\begin{align*}
P &= 1 \text{ atm} \\
V &= ? \text{ L} \\
T &= 273 \text{ K} \\
n &= ? \text{ mol} \\
R &= 0.0821 \text{ L atm/mol K} \\
D &= 3.07 \text{ g/L} \\
\end{align*}
\]

\[
\begin{align*}
\text{Density is an intensive property. Assume mass } &= 1.0 \text{ g} \\
V &= \frac{1.0 \text{ g}}{3.07 \text{ g/L}} = 0.3257 \text{ L} \\
\text{molar mass } &= \frac{1.0 \text{ g}}{0.0395 \text{ mol}} \\
&= 25.7 \text{ g/mol}
\end{align*}
\]

7. How many moles of helium gas would it take to fill a gas balloon with a volume of 1000. cm³ when the temperature is 32°C and the atmospheric pressure is 752 mm Hg?

\[
\begin{align*}
P &= 752 \text{ mm Hg} \\
V &= 1 \text{ L} \\
n &= ? \text{ mol} \\
R &= 0.0821 \text{ L atm/mol K} \\
T &= 32°C + 273 = 305 \text{ K} \\
\end{align*}
\]

\[
\begin{align*}
752 \text{ mm Hg} \left( \frac{1 \text{ atm}}{760 \text{ mm Hg}} \right) &= 0.9895 \text{ atm} \\
n &= \frac{(0.9895 \text{ atm})(1 \text{ L})}{(0.0821 \text{ L atm/mol} \cdot \text{K})(305 \text{ K})} \\
&= 0.0395 \text{ mol}
\end{align*}
\]

8. A gas sample is collected at 16°C and 0.982 atm. If the sample has a mass of 7.40 g and a volume of 3.96 L, find the volume of the gas at STP and the molar mass.

\[
\begin{align*}
P_1 &= 0.982 \text{ atm} \\
V_1 &= 3.96 \text{ L} \\
T_1 &= 16°C + 273 = 289 \text{ K} \\
P_2 &= 1 \text{ atm} \\
V_2 &= ? \text{ L} \\
T_2 &= 273 \text{ K} \\
\end{align*}
\]

\[
\begin{align*}
P_1V_1 &= P_2V_2 \\
\frac{P_1V_1}{T_1} &= \frac{P_2V_2}{T_2} \\
\frac{(0.982 \text{ atm})(3.96 \text{ L})}{289 \text{ K}} &= \frac{(1 \text{ atm})(V_2)}{273 \text{ K}} \\
V_2 &= 3.67 \text{ L} \\
\end{align*}
\]

\[
\begin{align*}
\text{molar mass } &= \frac{7.4 \text{ g}}{0.164 \text{ mol}} \\
&= 45 \text{ g/mol}
\end{align*}
\]

9. An unknown gas effuses at 0.850 times the effusion rate of nitrogen dioxide, NO₂. Estimate the molar mass of the unknown gas.

\[
\begin{align*}
\text{Unknown Gas} \\
m_1 &= ? \text{ g} \\
v_1 &= 0.850 \\
\text{Nitrogen dioxide, NO}_2 \\
m_2 &= 46 \text{ g} \\
v_2 &= 1 \\
\frac{v_1}{v_2} &= \sqrt{\frac{m_2}{m_1}} \\
\frac{0.850}{1} &= \sqrt{\frac{46 \text{ g}}{x \text{ g}}} \\
V_2 &= 63.7 \text{ g}
\end{align*}
\]

10. What will be the pressure if we open:

a. just valve A? \(0.75 \text{ atm}\)

b. just valve C? \(0.5 \text{ atm}\)

c. any two valves? \(0.5 \text{ atm}\)

Use Boyle’s law:

(a) 1.5 atm of gas divided in 2 spheres = 0.75 atm
(b) 1.0 atm of gas divided in 2 spheres = 0.5 atm
(c) 1.5 atm of gas divided in 3 spheres = 0.5 atm

Answers: 6. 68.8 g/mol 7. 0.0395 mol 8. 3.67 L & 45 g/mol 9. 63.7 g/mol