24. a. $2200 \text{ psi} \times \frac{1 \text{ atm}}{14.7 \text{ psi}} = 150 \text{ atm}$; b. $150 \text{ atm} \times \frac{1.013 \times 10^5 \text{ Pa}}{\text{atm}} \times \frac{1 \text{ MPa}}{1 \times 10^6 \text{ Pa}} = 15 \text{ MPa}$

c. $150 \text{ atm} \times \frac{760 \text{ torr}}{\text{atm}} = 1.1 \times 10^5 \text{ torr}$

30. The pressure exerted on the balloon is constant and the moles of gas present is constant. From Charles's law, $V_1/T_1 = V_2/T_2$ at constant P and n.

$$V_2 = \frac{V_1T_2}{T_1} = \frac{700.\text{ mL} \times 100.\text{ K}}{(273.2 + 20.0)\text{ K}} = 239 \text{ mL}$$

As expected, as the temperature decreased, the volume decreased.

36. $$P = \frac{nRT}{V} = \frac{\left(0.60 \text{ g} \times \frac{1 \text{ mol}}{32.00 \text{ g}}\right) \times \frac{0.08206 \text{ L atm}}{\text{mol K}} \times (273 + 22)\text{ K}}{5.0 \text{ L}} = 0.091 \text{ atm}$$

42. a. At constant n and V, $\frac{P_1}{T_1} = \frac{P_2}{T_2}$, $P_2 = \frac{P_1T_2}{T_1} = 40.0 \text{ atm} \times \frac{318 \text{ K}}{273 \text{ K}} = 46.6 \text{ atm}$

b. $\frac{P_1}{T_1} = \frac{P_2}{T_2}$, $T_2 = \frac{T_1P_2}{P_1} = 273 \text{ K} \times \frac{150.\text{ atm}}{40.0 \text{ atm}} = 1.02 \times 10^3 \text{ K}$

c. $T_2 = \frac{T_1P_2}{P_1} = 273 \text{ K} \times \frac{25.0 \text{ atm}}{40.0 \text{ atm}} = 171 \text{ K}$

46. PV = nRT, P is constant. $\frac{nT}{V} = \frac{P}{R} = \text{constant}$, $\frac{n_1T_1}{V_1} = \frac{n_2T_2}{V_2}$

$$\frac{n_2}{n_1} = \frac{T_1V_2}{T_2V_1} = \frac{294 \text{ K}}{335 \text{ K}} \times \frac{4.20 \times 10^3 \text{ m}^3}{4.00 \times 10^3 \text{ m}^3} = 0.921$$

52. $2 \text{ NaN}_3(s) \rightarrow 2 \text{ Na}(s) + 3 \text{ N}_2(g)$

$$n_{N_2} = \frac{PV}{RT} = \frac{1.00 \text{ atm} \times 70.0 \text{ L}}{\frac{0.08206 \text{ L atm}}{\text{mol K}} \times 273 \text{ K}} = 3.12 \text{ mol } N_2 \text{ needed to fill air bag.}$$

mass $NaN_3$ reacted $= 3.12 \text{ mol } N_2 \times \frac{2 \text{ mol NaN}_3}{3 \text{ mol N}_2} \times \frac{65.02 \text{ g NaN}_3}{\text{mol NaN}_3} = 135 \text{ g NaN}_3$

56. Since P and T are constant, then V and n are directly proportional. The balanced equation requires 2 L of $H_2$ to react with 1 L of CO (2:1 volume ratio due to 2:1 mol ratio in balanced equation). The actual volume ratio present in one minute is 16.0 L/25.0 L = 0.640 (0.640:1). Since the actual volume ratio present is smaller than the required volume ratio, then $H_2$ is the limiting reactant. The volume of $CH_3OH$ produced at STP will be one-half to the volume of $H_2$ reacted due to the 1:2 mol ratio in the balanced equation. In one minute 16.0 L/2 = 8.00 L $CH_3OH$ are produced (theoretical yield).

$$n_{CH_3OH} = \frac{PV}{RT} = \frac{1.00\text{ atm} \times 8.00\text{ L}}{\frac{0.08206\text{ L atm}}{\text{mol K}} \times 273\text{ K}} = 0.357\text{ mol } CH_3OH \text{ in one minute}$$

$$0.357\text{ mol } CH_3OH \times \frac{32.04\text{ g } CH_3OH}{\text{mol } CH_3OH} = 11.4\text{ g } CH_3OH \text{ (theoretical yield per minute)}$$

$$\%\text{ yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100 = \frac{5.30\text{ g}}{11.4\text{ g}} = 46.5\%\text{ yield}$$

60. $$d = \frac{P \times (\text{molar mass})}{RT} = \frac{(635\text{ torr} \times \frac{1\text{ atm}}{760\text{ torr}}) \times \frac{17.03\text{ g}}{\text{mol}}}{\frac{0.08206\text{ L atm}}{\text{mol K}} \times 300.\text{ K}} = 0.578\text{ g/L for } NH_3$$

62. $$n_{H_2} = 1.00\text{ g } H_2 \times \frac{1\text{ mol } H_2}{2.016\text{ g } H_2} = 0.496\text{ mol } H_2;\ n_{He} = 1.00\text{ g He} \times \frac{1\text{ mol He}}{4.003\text{ g He}} = 0.250\text{ mol He}$$

$$P_{H_2} = \frac{n_{H_2} \times RT}{V} = \frac{0.496\text{ mol} \times \frac{0.08206\text{ L atm}}{\text{mol K}} \times (273 + 27)\text{ K}}{1.00\text{ L}} = 12.2\text{ atm}$$

$$P_{He} = \frac{n_{He} \times RT}{V} = 6.15\text{ atm};\ P_{total} = P_{H_2} + P_{He} = 12.2\text{ atm} + 6.15\text{ atm} = 18.4\text{ atm}$$

68. To calculate the volume of gas, we can use $P_{total}$ and $n_{total}$ ($V = n_{tot}RT/P_{tot}$) or we can use $P_{He}$ and $n_{He}$ ($V = n_{He}RT/P_{He}$). Since $n_{H_2O}$ is unknown, then we will use $P_{He}$ and $n_{He}$.

$P_{He} + P_{H_2O} = 1.00\text{ atm} = 760.\text{ torr} = P_{He} + 23.8\text{ torr},\ P_{He} = 736\text{ torr}$

$$n_{He} = 0.586\text{ g} \times \frac{1\text{ mol}}{4.003\text{ g}} = 0.146\text{ mol He}$$

$$V = \frac{n_{He}RT}{P_{He}} = \frac{0.146\text{ mol} \times \frac{0.08206\text{ L atm}}{\text{mol K}} \times 298\text{ K}}{736\text{ torr} \times \frac{1\text{ atm}}{760\text{ torr}}} = 3.69\text{ L}$$

72. $(KE)_{avg} = (3/2)\,RT$. Since the kinetic energy depends only on temperature, $CH_4$ (Exercise 5.71) and $N_2$ at the same temperature will have the same average kinetic energy. So for $N_2$ the average kinetic energy is $3.40 \times 10^3$ J/mol (at 273 K) and $6.81 \times 10^3$ J/mol (at 546 K).

78.

| | a | b | c | d |
|---|---|---|---|---|
| avg. KE | inc | dec | same ($KE \propto T$) | same |
| avg. velocity | inc | dec | same ($\frac{1}{2}mv^2 = KE \propto T$) | same |
| coll. freq wall | inc | dec | inc | inc |

Average kinetic energy and average velocity depend on T. As T increases, both average kinetic energy and average velocity increase. At constant T, both average kinetic energy and average velocity are constant. The collision frequency is proportional to the average velocity (as velocity increases it takes less time to move to the next collision) and to the quantity n/V (as molecules per volume increases, collision frequency increases).

82. $$\frac{\text{Rate}_1}{\text{Rate}_2} = \left(\frac{M_2}{M_1}\right)^{1/2};\ \text{Rate}_1 = \frac{24.0\text{ mL}}{\text{min}},\ \text{Rate}_2 = \frac{47.8\text{ mL}}{\text{min}},\ M_2 = \frac{16.04\text{ g}}{\text{mol}}\text{ and } M_1 = ?$$

$$\frac{24.0}{47.8} = \left(\frac{16.04}{M_1}\right)^{1/2} = 0.502,\ 16.04 = (0.502)^2 \times M_1,\ M_1 = \frac{16.04}{0.252} = \frac{63.7\text{ g}}{\text{mol}}$$