8. Originally the volume occupied by X and Y is N before the reaction takes place. As X and Y react the volume goes down until all of X and Y have all reacted forming XY. Assuming that the number of moles of X equals the number of moles of Y originally the final volume of the system will be ½N. This is due to the fact that pressure is dependent on the number of molecules and after the reaction goes to completion there are half the number of molecules that there were initially.

11. As a balloon goes up into the atmosphere the pressure on the outside of the balloon decreases. In order for the pressure on the outside and the inside of the balloon to equal the balloon must increase in size thereby dropping the pressure inside the balloon. Eventually this expansion will cause the balloon to pop.

22. a) \( P_{\text{External}}: 760 \text{ mmHg} \)
   \( P_{\text{Change}}: -118 \text{ mmHg} \) (negative because Hg went down)
   \( P_{\text{Flask}}: P_{\text{External}} + P_{\text{Change}} = 760 \text{ mmHg} - 118 \text{ mmHg} \)
   \( = 642 \text{ mmHg} \)
   \( P_{\text{flask}} = 642 \text{ mmHg} \left( \frac{1 \text{ atm}}{760 \text{ mmHg}} \right) = 0.845 \text{ atm} \)
   \( P_{\text{flask}} = 642 \text{ mmHg} \left( \frac{760 \text{ torr}}{760 \text{ mmHg}} \right) = 642 \text{ torr} \)
   \( P_{\text{flask}} = 0.845 \text{ atm} \left( \frac{101325 \text{ Pa}}{1 \text{ atm}} \right) = 85,600 \text{ Pa} \)

   b) \( P_{\text{External}}: 760 \text{ mmHg} \)
   \( P_{\text{Change}}: +215 \text{ mmHg} \) (positive because Hg went up)
   \( P_{\text{Flask}}: P_{\text{External}} + P_{\text{Change}} = 760 \text{ mmHg} + 215 \text{ mmHg} \)
   \( = 975 \text{ mmHg} \)
   \( P_{\text{flask}} = 975 \text{ mmHg} \left( \frac{1 \text{ atm}}{760 \text{ mmHg}} \right) = 1.28 \text{ atm} \)
   \( P_{\text{flask}} = 975 \text{ mmHg} \left( \frac{760 \text{ torr}}{760 \text{ mmHg}} \right) = 975 \text{ torr} \)
   \( P_{\text{flask}} = 1.28 \text{ atm} \left( \frac{101325 \text{ Pa}}{1 \text{ atm}} \right) = 1.29 \times 10^5 \text{ Pa} \)

   c) \( P_{\text{External}}: 635 \text{ mmHg} \)
   \( P_{\text{Change}}: -118 \text{ mmHg} \) (negative because Hg went down)
   \( P_{\text{Flask}}: P_{\text{External}} + P_{\text{Change}} = 635 \text{ mmHg} - 118 \text{ mmHg} \)
   \( = 517 \text{ mmHg} \left( \frac{760 \text{ torr}}{760 \text{ mmHg}} \right) = 517 \text{ torr} \)

   d) \( P_{\text{External}}: 635 \text{ mmHg} \)
   \( P_{\text{Change}}: +215 \text{ mmHg} \) (positive because Hg went up)
   \( P_{\text{Flask}}: P_{\text{External}} + P_{\text{Change}} = 635 \text{ mmHg} + 215 \text{ mmHg} \)
   \( = 850. \text{ mmHg} \left( \frac{760 \text{ torr}}{760 \text{ mmHg}} \right) = 850. \text{ torr} \)
29. What was given:

\[ P_I(H_2) = 475 \text{ torr} \]
\[ V_I(H_2) = 2.00 \text{ L} \]
\[ P_I(N_2) = 0.200 \text{ atm } \left( \frac{760 \text{ torr}}{1 \text{ atm}} \right) = 152 \text{ torr} \]
\[ V_I(N_2) = 1.00 \text{ L} \]
\[ V_F = V_I(N_2) + V_I(H_2) = 3.00 \text{ L} \]

R and T are constant

Calculate the final pressure of the H\(_2\)

In addition to R and T being constant if we are just conserved about the H\(_2\), n is also constant:

\[ P_I(H_2)V_I(H_2) = P_F(H_2)V_F(H_2) \]
\[ (475 \text{ torr})(2.00 \text{ L}) = P_F(H_2)(3.00 \text{ L}) \]
\[ P_F(H_2) = 316 \text{ torr} \]

Calculate the final pressure of the N\(_2\)

\[ P_I(N_2)V_I(N_2) = P_F(N_2)V_F(N_2) \]
\[ (152 \text{ torr})(1.00 \text{ L}) = P_F(N_2)(3.00 \text{ L}) \]
\[ P_F(N_2) = 60.7 \text{ torr} \]

Calculate the total pressure

\[ P_{tot} = P_F(H_2) + P_F(N_2) = 316 \text{ torr} + 50.7 \text{ torr} = 367 \text{ torr} \]

33. What is given

\[ m_I = 1.00 \times 10^3 \text{ g} \]
\[ n_I = 1.00 \times 10^3 \text{ g } \left( \frac{1 \text{ mol} \text{ Ar}}{39.948 \text{ g} \text{ Ar}} \right) = 25.0 \text{ mol} \]
\[ P_I = 2,050. \text{ psi} \]
\[ T_I = 18^\circ \text{C} = 18 + 273.15 = 291 K \]
\[ P_F = 650. \text{ psi} \]
\[ T_F = 26^\circ \text{C} = 26 + 273.15 = 299 K \]

Need to calculate m\(_F\)

Find a relationship between P, T, and m (R and V constant)

\[ PV = nRT \]
\[ \frac{n_I}{n_F} \frac{T_I}{T_F} = \frac{P_I}{P_F} \]
\[ n_F = \frac{P_F n_I T_I}{T_F P_I} = \frac{(650. \text{ psi})(25.0 \text{ mol})(291K)}{(299K)(2,050. \text{ psi})} = 7.71 \text{ mol} \]
\[ m_F = 7.71 \text{ mol } \left( \frac{39.948 \text{ g Ar}}{1 \text{ mol Ar}} \right) = 308 \text{ g} \]

34. What was given

\[ P_I = 1.00 \text{ atm} \]
\[ V_I = 1.00 \text{ L} \]
\[ T_I = 23^\circ \text{C} = 23 + 273.15 = 296 K \]
\[ P_F = 220. \text{ torr } \left( \frac{1 \text{ atm}}{760 \text{ torr}} \right) = 0.289 \text{ atm} \]
\[ T_F = -31^\circ \text{C} = -31 + 273.15 = 242 K \]

Need to calculate \( \Delta V \)

\[ \Delta V = V_F - V_I \]

Determine \( V_F \)
Find a relationship between P, V, and T (R and n constant)

\[ PV = nRT \]
\[ \frac{P_iV_i}{T_i} = \frac{P_FV_F}{T_F} \]
\[ V_F = \frac{P_iV_iT_F}{T_iP_F} = \frac{(1.00 \text{ atm})(1.00 \text{ L})(242\text{K})}{(296\text{K})(0.289 \text{ atm})} = 2.83 \text{ L} \]

Calculate the change in volume
\[ \Delta V = V_F - V_i = 2.83 \text{ L} - 1.00 \text{ L} = 1.83 \text{ L} \]

36. What was given
\[ P_i = 710 \text{ torr} \]
\[ V_i = 5.0 \times 10^2 \text{ mL} \]
\[ T_i = 30. \text{ }^{\circ}\text{C} = 30. +273.15 = 303\text{K} \]
\[ V_F = 25 \text{ mL} \]
\[ T_F = 820^\circ\text{C} = 820 + 273.15 = 1,090\text{K} \]

Need to calculate \( P_F \)
Find a relation between P, V and T (R and n constant)

\[ PV = nRT \]
\[ \frac{P_iV_i}{T_i} = \frac{P_FV_F}{T_F} \]
\[ P_F = \frac{P_iV_iT_F}{T_iV_F} = \frac{(710 \text{ torr})(5.0 \times 10^2 \text{ mL})(1,090\text{K})}{(303\text{K})(25 \text{ mL})} = 51,000 \text{ torr} \]

37. The number of moles of the He and H\(_2\) gas will be the same, but the mass of the gases will be different.

What is given
\[ P = 2.70 \text{ atm} \]
\[ V = 200.0 \text{ L} \]
\[ T = 24^\circ\text{C} = 24 + 273.15 = 297\text{K} \]

Calculate the number of moles
\[ PV = nRT \]
\[ n = \frac{PV}{RT} = \frac{(2.70 \text{ atm})(200.0 \text{ L})}{(0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}})(297\text{K})} = 22.2 \text{ mol} \]

Determine the mass of He
\[ 22.2 \text{ mol He} \left(\frac{4.00 \text{ g He}}{1 \text{ mol He}}\right) = 88.8 \text{ g He} \]

Determine the mass of H\(_2\)
\[ 22.2 \text{ mol H}_2 \left(\frac{2.02 \text{ g H}_2}{1 \text{ mol H}_2}\right) = 44.8 \text{ g H}_2 \]

40. What is given
\[ P_i = 400. \text{ torr} \]
\[ n_i = 1.50 \text{ mol} \]
\[ T_i = 25^\circ\text{C} = 25 + 273.15 = 298\text{K} \]
\[ P_F = 800. \text{ torr} \]
\[ n_F = 1.50 \text{ mol} + n_{\text{added}} \]
\[ T_F = 50.^\circ\text{C} = 50. + 273.15 = 323\text{K} \]

Need to calculate \( n_{\text{add}} \)
Find a relationship between P, n, and T (V and R constant)

\[ PV = nRT \]

\[ \frac{P_I}{n_I T_I} = \frac{P_F}{n_F T_F} \]

\[ n_F = \frac{P_F n_I T_I}{T_F P_I} = \frac{(800. \text{ torr})(1.50 \text{ mol})(298K)}{(323K)(400. \text{ torr})} = 2.77 \text{ mol} \]

Calculate \( n_{\text{added}} \)

\[ n_F = 1.50 \text{ mol} + n_{\text{added}} \]

\[ n_{\text{added}} = n_F - 1.50 \text{ mol} = 2.76 \text{ mol} - 1.50 \text{ mol} = 1.26 \text{ mol} \]

41. What was given

\( V_{NO_2} = 25.0 \text{ mL} \)

Need to calculate \( V_{N_2O_4} \)

Find a relationship between V and n (P, R, and T constant)

\[ PV = nRT \]

\[ \frac{V_{NO_2}}{n_{NO_2}} = \frac{V_{N_2O_4}}{n_{N_2O_4}} \]

\[ V_{N_2O_4} = \frac{V_{NO_2} n_{N_2O_4}}{n_{NO_2}} \]

The number of moles of \( N_2O_4 \) is \( \frac{1}{2} \) the number of moles of \( NO_2 \) because

\[ V_{N_2O_4} = \frac{V_{NO_2} n_{N_2O_4}}{n_{NO_2}} = \frac{V_{NO_2}(0.5n_{NO_2})}{n_{NO_2}} = 0.5V_{NO_2} = 0.5(25.0 \text{ mL}) = 12.5 \text{ mL} \]

42. What was given

\( P_I = 75 \text{ psi} \)

\( T_I = 19^\circ \text{C} = 19 + 273.15 = 292K \)

\( V_F = V_I \times 1.040 \)

\( T_F = 58^\circ \text{C} = 58 + 273.15 = 331K \)

Need to calculate \( P_F \)

Find relationship between P, V, and T (n and R constant)

\[ PV = nRT \]

\[ \frac{P_I V_I}{T_I} = \frac{P_F V_F}{T_F} \]

\[ P_F = \frac{P_I V_I T_F}{T_I V_F} = \frac{(75 \text{ psi})V_I(331K)}{(292K)(V_I \times 1.040)} = 82 \text{ psi} \]

41. What was given

\( V_I = 4.00 \times 10^3 \text{ m}^3 \)

\( P_I = P_F = 745 \text{ torr} \)

\( T_I = 21^\circ \text{C} = 21 + 273.15 = 294K \)

\( V_F = 4.20 \times 10^3 \text{ m}^3 \)

\( T_F = 62^\circ \text{C} = 62 + 273.15 = 335K \)

Need to find \( \frac{n_F}{n_I} \)

Find relationship between V, n, and T (P and R constant)

\[ PV = nRT \]

\[ \frac{V_I}{n_I T_I} = \frac{V_F}{n_F T_F} \]
\[
\frac{n_F}{n_I} = \frac{T_I V_F}{V_I T_F} = \frac{(294K)(4.20 \times 10^3 \text{ m}^3)}{(4.00 \times 10^3 \text{ m}^3)(335K)} = 0.921
\]

46. What was given
\[T = 20.0°C = 20 + 273.15 = 293K\]
\[P = P_{N_2} + P_{H_2O} = 1.00 \text{ atm}\]
\[P_{H_2O} = 17.5 \text{ torr} \left(\frac{1 \text{ atm}}{760 \text{ torr}}\right) = 0.0230 \text{ atm}\]
\[P_{N_2} = 1.00 \text{ atm} - P_{H_2O} = 1.00 \text{ atm} - 0.0230 \text{ atm} = 0.977 \text{ atm}\]
\[V = 2.50 \times 10^2 \text{ mL} \left(\frac{1 \text{ L}}{1000 \text{ mL}}\right) = 0.250 \text{ L}\]

Calculate the number of moles of \(N_2\)
\[P_{N_2} V = n_{N_2} RT\]
\[n_{N_2} = \frac{P_{N_2} V}{RT} = \frac{(0.977 \text{ atm})(0.250 \text{ L})}{(0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1})(293K)} = 0.0101 \text{ mol} N_2\]

Convert moles to grams
\[0.0101 \text{ mol} N_2 \left(\frac{28.02 \text{ g} N_2}{1 \text{ mol} N_2}\right) = 0.283 \text{ g} N_2\]

49. What was given
\[P_{O_2} = 0.250 \text{ atm}\]
\[P_{CH_4} = 0.175 \text{ atm}\]
\[P_{\text{tot}} = P_{O_2} + P_{CH_4} = 0.250 \text{ atm} + 0.175 \text{ atm} = 0.425 \text{ atm}\]

a) Calculate the mole fraction of \(CH_4\), \(\chi_{CH_4} = \frac{n_{CH_4}}{n_{\text{tot}}}\)
\[\chi_{CH_4} = \frac{P_{CH_4}}{P_{\text{tot}}} = \frac{0.175 \text{ atm}}{0.425 \text{ atm}} = 0.412\]

Calculate the mole fraction of \(O_2\), \(\chi_{O_2} = \frac{n_{O_2}}{n_{\text{tot}}}\)
\[\chi_{O_2} = \frac{P_{O_2}}{P_{\text{tot}}} = \frac{0.250 \text{ atm}}{0.425 \text{ atm}} = 0.588\]

b) What is given
\[V = 10.5 \text{ L}\]
\[T = 65°C = 65 + 273.15 = 338K\]
\[P = 0.425 \text{ atm}\]

Calculate \(n\)
\[PV = nRT\]
\[n = \frac{PV}{RT} = \frac{(0.425 \text{ atm})(10.5 \text{ L})}{(0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1})(338K)} = 0.161 \text{ mol}\]

c) Calculate the grams of \(CH_4\)
\[n_{CH_4} = \chi_{CH_4} n_{\text{tot}} = (0.412)(0.161 \text{ mol}) = 0.0663 \text{ mol} CH_4\]
\[0.0663 \text{ mol} CH_4 \left(\frac{16.05 \text{ g} CH_4}{1 \text{ mol} CH_4}\right) = 1.06 \text{ g} CH_4\]

Calculate the grams of \(O_2\)
\[n_{O_2} = \chi_{O_2} n_{\text{tot}} = (0.588)(0.161 \text{ mol}) = 0.0947 \text{ mol} O_2\]
\[0.0947 \text{ mol} O_2 \left(\frac{32.00 \text{ g} O_2}{1 \text{ mol} O_2}\right) = 3.03 \text{ g} O_2\]
55. Determine the empirical formula
Assume 100 g (87.4 g N and 12.6 g H)
Calculate mole N and H

\[ 87.4 \, g \, N \left( \frac{1 \, \text{mol} \, N}{14.01 \, g \, N} \right) = 6.24 \, \text{mol} \, N \]

\[ 12.3 \, g \, H \left( \frac{1 \, \text{mol} \, H}{1.01 \, g \, H} \right) = 12.2 \, \text{mol} \, H \]

Divide through by smallest number of moles (6.24 mol)

\[ \frac{6.24 \, \text{mol}}{6.24 \, \text{mol}} = 1.00 \]

\[ \frac{12.2 \, \text{mol}}{6.24 \, \text{mol}} = 1.96 \]

Empirical Formula

\[ \text{NH}_2 \]

Determine the molecular weight

What is given

\[ P = 710 \, \text{torr} \left( \frac{1 \, \text{atm}}{760 \, \text{torr}} \right) = 0.934 \, \text{atm} \]

\[ d = 0.977 \, \frac{g}{L} \]

\[ T = 100. \, ^\circ \text{C} = 100. + 273.15 = 373K \]

Relate density to molar mass

\[ M = \frac{m}{n} \]

\[ d = \frac{\rho}{V} \]

\[ M = \frac{\rho V}{n} \quad \text{or} \quad n = \frac{\rho V}{M} \]

Plug into ideal gas law

\[ PV = nRT = \frac{dVRT}{M} \]

\[ M = \frac{dRT}{P} = \left( 0.977 \, \frac{g}{L} \right) \left( 0.08206 \, \frac{L \cdot \text{atm}}{\text{mol} \cdot K} \right) (373K) \]

\[ = 32.02 \, \frac{g}{\text{mol}} \]

Determine molecular formula

\[ \frac{M_{N_xH_{2x}}}{MNH_2} = \frac{32.02 \, \frac{g}{\text{mol}}}{16.03 \, \frac{g}{\text{mol}}} = 2.00 \]

\[ \text{N}_3\text{H}_4 \]

56. What was given

\[ V = 256 \, mL \left( \frac{1 \, L}{1000 \, mL} \right) = 0.256 \, L \]

\[ P = 750 \, \text{torr} \left( \frac{1 \, \text{atm}}{760 \, \text{torr}} \right) = 0.987 \, \text{atm} \]

\[ T = 373K \]

\[ m = 0.800 \, g \]

Calculate the molar mass

\[ PV = nRT \]

\[ n = \frac{m}{M} \]

\[ M = \frac{mRT}{PV} = \left( 0.800 \, g \right) \left( 0.08206 \, \frac{L \cdot \text{atm}}{\text{mol} \cdot K} \right) (373K) \]

\[ = 96.9 \, \frac{g}{\text{mol}} \]
Calculate molecular formula
\[ \frac{M_{C_xH_xCl_x}}{M_{CHCl}} = \frac{96.9 \text{ g/mol}}{48.47 \text{ g/mol}} = 2.0 \]

Molecular Formula
\[ \text{C}_2\text{H}_2\text{Cl}_2 \]

60. What was given

\[ P = 1.00 \text{ atm} \]
\[ m = 1.00 \times 10^3 \text{ kg Mo} \]
\[ n = 1.00 \times 10^3 \text{ kg Mo} \left( \frac{1000 \text{ g}}{1 \text{ kg}} \right) \left( \frac{1 \text{ mol Mo}}{95.94 \text{ g Mo}} \right) = 10,400 \text{ mol Mo} \]
\[ T = 17\degree C = 17 + 273.15 = 290. K \]

Calculate the moles of O
\[ 10,400 \text{ mol Mo} \left( \frac{1 \text{ mol MoO}_3}{1 \text{ mol Mo}} \right) \left( \frac{7/2 \text{ mol O}_2}{1 \text{ mol MoO}_3} \right) = 36,400 \text{ mol O}_2 \]

Calculate the volume of O
\[ PV = nRT \]
\[ V = \frac{nRT}{P} = \frac{(36,400 \text{ mol})(0.08206 \text{ L at} \text{m} \text{ mol}\text{K})(290. K)}{1.00 \text{ atm}} = 8.66 \times 10^5 \text{ L} \]

Calculate the volume of air
\[ 8.66 \times 10^5 \text{ L} = V_{\text{air}}(0.21) \]
\[ V_{\text{air}} = 4.1 \times 10^6 \text{ L} \]

Calculate the moles of H
\[ 10,400 \text{ mol Mo} \left( \frac{3 \text{ mol H}_2}{1 \text{ mol Mo}} \right) = 31,200 \text{ mol H}_2 \]

Calculate the volume of H
\[ V = \frac{nRT}{P} = \frac{(31,200 \text{ mol})(0.08206 \text{ L at} \text{m} \text{ mol}\text{K})(290. K)}{1.00 \text{ atm}} = 7.42 \times 10^5 \text{ L} \]

62. What is given

\[ P_{NH_3} = 90. \text{ atm} \]
\[ T = 223\degree C = 223 + 273.15 = 496K \]

Rate of flow of NH\(_3\) 500. \(\frac{L}{\text{min}}\)
\[ P_{CO_2} = 45 \text{ atm} \]

Rate of flow of CO\(_2\) 600. \(\frac{L}{\text{min}}\)

This is a limiting reagent problem.

Calculate the rate of flow of NH\(_3\) in \(\frac{\text{mol}}{\text{min}}\)
\[ PV = nRT \]
\[ n = \frac{PV}{RT} = \frac{(90. \text{ atm})(500. \frac{L}{\text{min}})}{(0.08206 \frac{\text{L atm}}{\text{mol K}})(496K)} = 1,100 \frac{\text{mol}}{\text{min}} \]

Calculate the rate of flow of CO\(_2\) in \(\frac{\text{mol}}{\text{min}}\)
\[ n = \frac{PV}{RT} = \frac{(45 \text{ atm})(600. \frac{L}{\text{min}})}{(0.08206 \frac{\text{L atm}}{\text{mol K}})(496K)} = 660 \frac{\text{mol}}{\text{min}} \]
Calculate the amount of NH₃ need to fully react the CO₂
\[
\frac{660 \text{ mol min}^{-1} \text{ CO}_2}{\text{2 mol NH}_3} \left( \frac{\text{2 mol NH}_3}{\text{1 mol CO}_2} \right) = 1,300 \text{ mol min}^{-1} \text{ NH}_3
\]

<table>
<thead>
<tr>
<th></th>
<th>NH₃ (L.R.)</th>
<th>CO₂</th>
<th>H₂NCONH₂</th>
<th>H₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1,100 mol min⁻¹</td>
<td>660 mol min⁻¹</td>
<td>0 mol min⁻¹</td>
<td>0 mol min⁻¹</td>
</tr>
<tr>
<td>C</td>
<td>-2x = -1,100 mol min⁻¹</td>
<td>-x = -550 mol min⁻¹</td>
<td>+x = 550 mol min⁻¹</td>
<td>+x = 550 mol min⁻¹</td>
</tr>
<tr>
<td>F</td>
<td>0 mol min⁻¹</td>
<td>110 mol min⁻¹</td>
<td>550 mol min⁻¹</td>
<td>550 mol min⁻¹</td>
</tr>
</tbody>
</table>

Change rate of urea formation to
\[
\frac{550 \text{ mol urea min}^{-1}}{\text{(60.07 g urea) min}^{-1}} = 3.3 \times 10^4 \text{ g urea min}^{-1}
\]

65. What was given
\[
m = 150 \text{ g (CH}_3\text{)}_2\text{N}_2\text{H}_2
\]
\[
n = 150 \text{ g (CH}_3\text{)}_2\text{N}_2\text{H}_2 \left( \frac{1 \text{ mol (CH}_3\text{)}_2\text{N}_2\text{H}_2}{60.12 \text{ g (CH}_3\text{)}_2\text{N}_2\text{H}_2} \right) = 2.5 \text{ mol (CH}_3\text{)}_2\text{N}_2\text{H}_2
\]
\[
T = 27^\circ \text{C} = 27 + 273.15 = 300 \text{ K}
\]
\[
V = 250 \text{ L}
\]
Calculate the moles of N₂
\[
2.5 \text{ mol (CH}_3\text{)}_2\text{N}_2\text{H}_2 \left( \frac{3 \text{ mol N}_2}{1 \text{ mol (CH}_3\text{)}_2\text{N}_2\text{H}_2} \right) = 7.5 \text{ mol N}_2
\]
Calculate the moles of H₂O
\[
2.5 \text{ mol (CH}_3\text{)}_2\text{N}_2\text{H}_2 \left( \frac{4 \text{ mol H}_2\text{O}}{1 \text{ mol (CH}_3\text{)}_2\text{N}_2\text{H}_2} \right) = 10. \text{ mol N}_2
\]
Calculate the moles of CO₂
\[
2.5 \text{ mol (CH}_3\text{)}_2\text{N}_2\text{H}_2 \left( \frac{4 \text{ mol CO}_2}{1 \text{ mol (CH}_3\text{)}_2\text{N}_2\text{H}_2} \right) = 5.0 \text{ mol CO}_2
\]
Calculate the total moles of gas
\[
n_{\text{tot}} = n_{\text{N}_2} + n_{\text{H}_2\text{O}} + n_{\text{CO}_2} = 7.5 \text{ mol} + 10. \text{ mol} + 5.0 \text{ mol} = 23 \text{ mol}
\]
Calculate the total pressure
\[
P = \frac{nRT}{V} = \frac{(23 \text{ mol}) \left( \frac{0.08206 \text{ L atm}}{\text{mol K}} \right)(300 \text{ K})}{(250 \text{ L})} = 2.3 \text{ atm}
\]
Calculate the partial pressure of N₂
\[
P_{\text{N}_2} = x_{\text{N}_2}P_{\text{tot}} = \left( \frac{7.5 \text{ mol}}{23 \text{ mol}} \right)2.3 \text{ atm} = 0.75 \text{ atm}
\]

66. What is given
\[
P = 1.00 \text{ atm}
\]
\[
V = 70.0 \text{ L}
\]
\[
T = 0. \text{ }^\circ \text{C} = 0. + 273.15 = 273K
\]
Calculate the number of moles of N₂ gas produced
\[
P = nRT
\]
\[
n = \frac{PV}{RT} = \left( \frac{(1.00 \text{ atm})(70.0 \text{ L})}{(0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1})(273 \text{ K})} \right) = 3.12 \text{ mol N}_2
\]
Calculate the g of NaN₃ need to produce 3.12 mol N₂
\[
3.12 \text{ mol N}_2 \left( \frac{2 \text{ mol NaN}_3}{3 \text{ mol N}_2} \right) \left( \frac{65.02 \text{ g NaN}_3}{1 \text{ mol NaN}_3} \right) = 135 \text{ g NaN}_3
\]
73. What was given

\[ V_{NH_3} = 2.00 \, L \]
\[ P_{NH_3} = 0.500 \, atm \]
\[ V_{O_2} = 1.00 \, L \]
\[ P_{O_2} = 1.50 \, atm \]

This is a limiting reagent problem

Find an expression for the number of mole of \( NH_3 \)

\[ PV = nRT \]
\[ n_{NH_3} = \frac{P_{NH_3}V}{RT} = \frac{(0.500 \, atm)(2.00 \, L)}{RT} = \frac{1.00 \, atm \cdot L}{RT} \]

Find an expression for the number of moles of \( O_2 \)

\[ n_{O_2} = \frac{P_{O_2}V}{RT} = \frac{(1.50 \, atm)(1.00 \, L)}{RT} = \frac{1.50 \, atm \cdot L}{RT} \]

Calculate the number of moles of \( O_2 \) needed to fully react \( \frac{1.00 \, atm \cdot L}{RT} \) moles of \( NH_3 \)

\[ \frac{1.00 \, atm \cdot L}{RT} \left( \frac{5 \, mol \, O_2}{4 \, mol \, NH_3} \right) = \frac{1.25 \, atm \cdot L}{RT} \]

Since we have \( \frac{1.50 \, atm \cdot L}{RT} \) moles of \( O_2 \), \( NH_3 \) is the limiting reagent

- NH\(_3\) (L.R.)
  - I
  - C
  - F

- \( O_2 \)
  - \( \frac{1.00 \, atm \cdot L}{RT} \)
  - \( \frac{1.50 \, atm \cdot L}{RT} \)

- NO
  - 0
  - \( \frac{1.00 \, atm \cdot L}{RT} \)

- H\(_2\)O
  - 0
  - 0

Calculate the partial pressure of \( NO \)

\[ P_{NO}V = n_{NO}RT \]
\[ P_{NO} = \frac{n_{NH_3}RT}{V} = \frac{(1.00 \, atm \cdot L)(RT)}{V} = \frac{1.00 \, atm \cdot L}{3.00 \, L} = 0.333 \, atm \]

79. a) Since the containers are the same size the number of particles must be equal in order for the pressure in the two containers to be the same.

b) The average kinetic energy \( (KE)_{ave} = \frac{1}{2}RT \) is only temperature dependent, therefore, since both containers are at the same temperature the average kinetic energy is the same.

c) The average velocity of the molecules is dependent on the mass. Since container A contains the less massive particles they will be at a higher velocity.

d) The particles in container B do collide with the side of the container with more force, but, they are moving slower. Therefore, there are less collisions with the side of the container, whereas the gas molecules in container A have less forceful collisions with the side of the container but they collide more often. Therefore the pressure in the two containers are equal.
80. a) \( i = vi < i = iv < v = vii < iii = vii \)
b) all are the same
c) Helpful Hint: \( m_{Ne} = 2m_{Ar} \)
\( ii < i = iv < iii = v < vii < v = vii \)
d) \( v = vi = vii < i = iii = iv \)

81. Calculate the \((KE)_{ave}\) at 273 K for \( \text{CH}_4 \)
\[
(KE)_{ave} = \frac{3}{2}RT = \frac{3}{2} \left( \frac{8.3145 \text{ J mol}^{-1} \text{K}^{-1}}{\text{mol}} \right) (273\text{K}) = 3.40 \times 10^3 \frac{\text{J}}{\text{mol}}
\]
Change to per molecules
\[
3.40 \times 10^3 \frac{\text{J}}{\text{mol}} \left( \frac{1\text{mol}}{6.02214 \times 10^{23} \text{molecules}} \right) = 5.65 \times 10^{-21} \frac{\text{J}}{\text{molecule}}
\]
Since the \((KE)_{ave}\) does not depend on type of gas molecule, the \((KE)_{ave}\) of \( \text{N}_2 \) at 273 K would be the same as the \((KE)_{ave}\) of \( \text{CH}_4 \) at 273 K.

Calculate the \((KE)_{ave}\) at 546 K for \( \text{CH}_4 \)
\[
(KE)_{ave} = \frac{3}{2}RT = \frac{3}{2} \left( \frac{8.3145 \text{ J mol}^{-1} \text{K}^{-1}}{\text{mol}} \right) (546\text{K}) = 6.80 \times 10^3 \frac{\text{J}}{\text{mol}}
\]
Change to per molecules
\[
6.80 \times 10^3 \frac{\text{J}}{\text{mol}} \left( \frac{1\text{mol}}{6.02214 \times 10^{23} \text{molecules}} \right) = 1.13 \times 10^{-20} \frac{\text{J}}{\text{molecule}}
\]
Since the \((KE)_{ave}\) does not depend on type of gas molecule, the \((KE)_{ave}\) of \( \text{N}_2 \) at 546 K would be the same as the \((KE)_{ave}\) of \( \text{CH}_4 \) at 546 K.

78. Calculate the \(u_{rms}\) at 273 K for \( \text{CH}_4 \)
\[
M_{\text{CH}_4} = 16.05 \frac{\text{g}}{\text{mol}} \left( \frac{1\text{kg}}{1000\text{g}} \right) = 0.01605 \frac{\text{kg}}{\text{mol}}
\]
\[
u_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 \left( \frac{8.3145 \text{ J mol}^{-1} \text{K}^{-1}}{\text{mol}} \right) (273\text{K})}{0.01605 \frac{\text{kg}}{\text{mol}}}} = 651 \frac{\text{m}}{\text{s}}
\]
Calculate the \(u_{rms}\) at 273 K for \( \text{N}_2 \)
\[
M_{\text{N}_2} = 28.02 \frac{\text{g}}{\text{mol}} \left( \frac{1\text{kg}}{1000\text{g}} \right) = 0.02802 \frac{\text{kg}}{\text{mol}}
\]
\[
u_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 \left( \frac{8.3145 \text{ J mol}^{-1} \text{K}^{-1}}{\text{mol}} \right) (273\text{K})}{0.02802 \frac{\text{kg}}{\text{mol}}}} = 493 \frac{\text{m}}{\text{s}}
\]
Calculate the \(u_{rms}\) at 546 K for \( \text{CH}_4 \)
\[
u_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 \left( \frac{8.3145 \text{ J mol}^{-1} \text{K}^{-1}}{\text{mol}} \right) (546\text{K})}{0.01605 \frac{\text{kg}}{\text{mol}}}} = 921 \frac{\text{m}}{\text{s}}
\]
Calculate the \(u_{rms}\) at 546 K for \( \text{N}_2 \)
\[
u_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 \left( \frac{8.3145 \text{ J mol}^{-1} \text{K}^{-1}}{\text{mol}} \right) (546\text{K})}{0.02802 \frac{\text{kg}}{\text{mol}}}} = 697 \frac{\text{m}}{\text{s}}
\]

83. Not all molecules in the sample have the same energy. The energy span is a Boltzmann distribution centered at the average kinetic energy. Like the energy, the molecules have different velocities that can be represented by a Boltzmann curve. The center of the curve is the average velocity.
86. a) average kinetic energy increases
   root mean square velocity increases
   frequency of collisions with each other increases
   frequency of collision with walls increases
   energy of impact increase

   b) average kinetic energy decrease
   root mean square velocity decrease
   frequency of collisions decrease
   frequency of collision with walls decrease
   energy of impact decrease

   c) average kinetic energy remain the same
   root mean square velocity remain the same
   frequency of collisions with each other increase
   frequency of collision with walls increase
   energy of impact remain the same

   d) average kinetic energy remain the same
   root mean square velocity remain the same
   frequency of collisions with each other increase
   frequency of collision with walls increase
   energy of impact remain the same

89. Assume 100 g (58.51 g C, 7.37 g H, and 34.12 g N)

   \( n_C = \frac{58.51 \text{ g C}}{12.01 \text{ g mol}^{-1}} = 4.87 \text{ mol} \)
   \( n_H = \frac{7.37 \text{ g H}}{1.01 \text{ g mol}^{-1}} = 7.30 \text{ mol} \)
   \( n_N = \frac{34.12 \text{ g N}}{14.01 \text{ g mol}^{-1}} = 2.43 \text{ mol} \)

Divide through by smallest moles, 2.43 mol

   C \( \frac{4.87 \text{ mol}}{2.43 \text{ mol}} = 2.00 \)
   H \( \frac{7.30 \text{ mol}}{2.43 \text{ mol}} = 3.00 \)
   N \( \frac{2.43 \text{ mol}}{2.43 \text{ mol}} = 1.00 \)

   Empirical Formula \( \text{C}_2\text{H}_3\text{N} \)

   Determine Molecular Formula

   \( \frac{\text{rate of effusion He}}{\text{rate of effusion C}_x\text{H}_y\text{N}_z} = \sqrt{\frac{M_{\text{C}_2\text{H}_3\text{N}_x}}{M_{\text{He}}}} \)

   \( \frac{3.20}{x} = \sqrt{\frac{40.96}{4.00 \text{ g mol}^{-1}}} \)

   \( M_{\text{C}_2\text{H}_3\text{N}_x} = 40.96 \frac{\text{g}}{\text{mol}} \)
   \( M_{\text{MF}} = 40.96 \frac{\text{g}}{\text{mol}} \)
   \( M_{\text{EF}} = 41.06 \frac{\text{g}}{\text{mol}} \)

   Molecular Formula \( \text{C}_2\text{H}_3\text{N} \)
90. 

rate of effusion of He = \( \frac{V}{t} = \frac{1.0 \text{ L}}{4.5 \text{ min}} = 0.22 \frac{\text{L}}{\text{min}} \)

rate of effusion of He = \( \sqrt{\frac{M_{\text{Cl}_2}}{M_{\text{He}}}} \)

rate of effusion of Cl\(_2\) = \( \frac{0.22 \text{ ml/min}}{70.90} = \frac{\text{g/mol}}{\sqrt{4.00}} \text{ mol} \)

rate of effusion of Cl\(_2\) = 0.052 \( \frac{\text{L}}{\text{min}} \)

Calculate the time it takes for 1.0 L to effuse

\[ 1.0 \text{ L} \times \left( \frac{1 \text{ min}}{0.052 \text{ L}} \right) = 19 \text{ min} \]

91. What is given

\[ V = 1.0000 \text{ L} \]
\[ n = 0.5000 \text{ mol} \]
\[ T = 25.0^\circ \text{C} = 25.0 + 273.15 = 278.2K \]
\[ a = 1.39 \frac{\text{atm-L}^2}{\text{mol}^2} \]
\[ b = 0.0391 \frac{\text{L}}{\text{mol}} \]

a) \( PV = nRT \)

\[ P = \frac{nRT}{V} = \frac{(0.5000 \text{ mol})(0.08206 \frac{\text{L-atm}}{\text{molK}})(298.2K)}{(1.0000 \text{ L})} = 12.24 \text{ atm} \]

b) \[ P + a \left( \frac{n}{V} \right)^2 (V - nb) = nRT \]

\[ P = \frac{nRT}{(V - nb)} - a \left( \frac{n}{V} \right)^2 \]

\[ P = \frac{(0.5000 \text{ mol})(0.08206 \frac{\text{L-atm}}{\text{molK}})(298.2)}{(1.0000 \text{ L} - (0.5000 \text{ mol})(0.0391 \frac{\text{L}}{\text{mol}})} - (1.39 \frac{\text{atm-L}^2}{\text{mol}^2}) \left( \frac{0.5000 \text{ mol}}{10.0000 \text{ L}} \right)^2 = 12.13 \text{ atm} \]

c) The two numbers are within 0.11 atm of each other.

92. What is given

\[ V = 10.0000 \text{ L} \]
\[ n = 0.5000 \text{ mol} \]
\[ T = 25.0^\circ \text{C} = 25.0 + 273.15 = 278.2K \]
\[ a = 1.39 \frac{\text{atm-L}^2}{\text{mol}^2} \]
\[ b = 0.0391 \frac{\text{L}}{\text{mol}} \]

a) \( PV = nRT \)

\[ P = \frac{nRT}{V} = \frac{(0.5000 \text{ mol})(0.08206 \frac{\text{L-atm}}{\text{molK}})(298.2K)}{(10.0000 \text{ L})} = 1.224 \text{ atm} \]

b) \[ P + a \left( \frac{n}{V} \right)^2 (V - nb) = nRT \]

\[ P = \frac{nRT}{(V - nb)} - a \left( \frac{n}{V} \right)^2 \]

\[ P = \frac{(0.5000 \text{ mol})(0.08206 \frac{\text{L-atm}}{\text{molK}})(298.2)}{(10.0000 \text{ L} - (0.5000 \text{ mol})(0.0391 \frac{\text{L}}{\text{mol}})} - (1.39 \frac{\text{atm-L}^2}{\text{mol}^2}) \left( \frac{0.5000 \text{ mol}}{10.0000 \text{ L}} \right)^2 = 1.222 \text{ atm} \]
c) The two numbers are within 0.002 atm of each other.
d) The two values are now closer to each other than they were when the volume was 1.0000 L. This should not be surprising because as the volume is increased the molecules are farther apart from each other, therefore, intermolecular forces play a smaller role and the ideal gas law gives an answer closer to the actual answer.

93. Real gases do not always behave ideally because there are attractions (intermolecular forces) between gas molecules. Gases behave more ideal when:

Temperature is high (gas molecules spend less time in contact with each other i.e. less intermolecular forces)
Pressure is low (less intermolecular forces)
Small molecules (they are closer to the assumption that the particles take up no space and they exert less intermolecular forces)

94. a) He B
   Cl₂ A

Since the \( u_{rms} = \sqrt{\frac{3RT}{M}} \) and \( \text{Cl}_2 \) has a greater molecular weight it must be the slower gas. The heavier the gas the slower it travels at a given temperature because the average kinetic energies of the two samples is equal.

b) 273K A
   1273K B

Raising the temperature raises the velocity. \( \text{O}_2 \) would behave most ideally at 1273K because intermolecular forces play a smaller role at higher temperatures because the gas molecules are in close proximities to each other for a shorter amount of time.

99. What is given

\[ M_{N_2} = 28.02 \text{ g/mol} \left( \frac{1 \text{ kg}}{1000 \text{ g}} \right) = 0.02802 \text{ kg/mol} \]

\[ T = 227°C = 227 + 273.15 = 500. K \]

Calculate the root mean square velocity

\[ u_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3(8.3145 \frac{\text{J}}{\text{mol} \cdot \text{K}})(500. \text{K})}{0.02802 \text{ kg/mol}}} = 667 \frac{\text{m}}{\text{s}} \]

Calculate the most probable velocity

\[ u_{mp} = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2(8.3145 \frac{\text{J}}{\text{mol} \cdot \text{K}})(500. \text{K})}{0.02802 \text{ kg/mol}}} = 545 \frac{\text{m}}{\text{s}} \]

Calculate the average velocity

\[ u_{rms} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8(8.3145 \frac{\text{J}}{\text{mol} \cdot \text{K}})(500. \text{K})}{\pi 0.02802 \text{ kg/mol}}} = 615 \frac{\text{m}}{\text{s}} \]
119. What is given

\[ m_{\text{Mn}} = 2.747 \text{ g} \]

\[ 2.747 \text{ g Mn} \left( \frac{1 \text{ mol Mn}}{54.938 \text{ g}} \right) = 0.0500 \text{ mol} \]

\[ V = 3.22 \text{ L} \]

\[ P = 0.951 \text{ atm} \]

\[ T = 373 \text{ K} \]

\[ \text{Mn(s) + } x\text{HCl(g) } \rightarrow \frac{x}{2}\text{H}_2\text{(g) + MnCl}_x\text{(s)} \]

From equation

\[ n_\text{Cl} = n_\text{H} \]

Determine the moles of H

\[ PV = nRT \]

\[ n_{\text{H}_2} = \frac{P_{\text{H}_2} V}{RT} = \frac{(0.951 \text{ atm})(3.22 \text{ L})}{(0.08206 \text{ L atm mol}^{-1}\text{K}^{-1})(373 \text{ K})} = 0.100 \text{ mol } \text{H}_2 \left( \frac{2 \text{ mol } \text{H}}{1 \text{ mol } \text{H}_2} \right) \]

= 0.200 mol H

Divide through by smallest moles, 0.0500 mol

\[ \frac{0.0500 \text{ mol}}{0.0500 \text{ mol}} = 1.00 \]

\[ \frac{0.200 \text{ mol}}{0.0500 \text{ mol}} = 4.00 \]

Formula

MnCl₄

127. What was given

\[ P_{\text{f(He)}} = 200. \text{ torr} \left( \frac{1 \text{ atm}}{760 \text{ torr}} \right) = 0.263 \text{ atm} \]

\[ V_{\text{f(He)}} = 1.00 \text{ L} \]

\[ P_{\text{f(Ne)}} = 0.400 \text{ atm} \]

\[ V_{\text{f(Ne)}} = 1.00 \text{ L} \]

\[ P_{\text{f(Ar)}} = 24.0 \text{ kPa} \left( \frac{1000 \text{ Pa}}{1 \text{ kPa}} \right) \left( \frac{1 \text{ atm}}{101,325 \text{ Pa}} \right) = 0.237 \text{ atm} \]

\[ V_{\text{f(Ar)}} = 2.00 \text{ L} \]

\[ V_{\text{tot}} = 1.00 \text{ L} + 1.00 \text{ L} + 2.00 \text{ L} = 4.00 \text{ L} \]

\[ PV = nRT \]

Find an expression for moles of He

\[ n_{\text{Ar}} = \frac{P_{\text{f(He)}} V_{\text{f(He)}}}{RT} = \frac{(0.263 \text{ atm})(1.00 \text{ L})}{RT} = \frac{0.263 \text{ L} \cdot \text{atm}}{RT} \]

Calculate the \( P_{\text{He}} \)

\[ P_{\text{f(He)}} = \frac{n_{\text{He}} RT}{V_{\text{tot}}} = \frac{(0.263 \text{ L} \cdot \text{atm}) RT}{(4.00 \text{ L})} = 0.0658 \text{ atm He} \]

Find an expression for moles of Ne

\[ n_{\text{Ne}} = \frac{P_{\text{f(Ne)}} V_{\text{f(Ne)}}}{RT} = \frac{(0.400 \text{ atm})(1.00 \text{ L})}{RT} = \frac{0.400 \text{ L} \cdot \text{atm}}{RT} \]

Calculate the \( P_{\text{Ne}} \)

\[ P_{\text{f(Ne)}} = \frac{n_{\text{Ne}} RT}{V_{\text{tot}}} = \frac{(0.400 \text{ L} \cdot \text{atm}) RT}{(4.00 \text{ L})} = 0.100 \text{ atm Ne} \]
Find an expression for moles of Ar

\[ n_{Ar} = \frac{P_{f(\text{Ar})}V_{l(\text{Ar})}}{RT} = \frac{(0.237 \text{ atm})(2.00 \text{ L})}{RT} = \frac{0.474 \text{ L} \cdot \text{ atm}}{RT} \]

Calculate the \( P_{Ar} \)

\[ P_{F(\text{Ar})} = \frac{n_{Ar}RT}{V_{tot}} = \frac{(0.474 \text{ L} \cdot \text{ atm})RT}{(4.00 \text{ L})} = 0.119 \text{ atm Ar} \]

Calculate total pressure

\[ P_{tot} = P_{F(\text{He})} + P_{F(\text{Ne})} + P_{F(\text{Ar})} = 0.285 \text{ atm} \]