Homework #4

Chapter 5

Gases

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) $P_{External}: 760\ mmHg$

$P_{Change}: -118\ mmHg$ (negative because Hg went down)

$P_{Flask}: P_{External} + P_{Change} = 760\ mmHg - 118\ mmHg$

$= 642\ mmHg$

$P_{flask} = 642\ mmHg\left(\frac{1\ atm}{760\ mmHg}\right) = 0.845\ atm$

$P_{flask} = 642\ mmHg\left(\frac{760\ torr}{760\ mmHg}\right) = 642\ torr$

$P_{flask} = 0.845\ atm\left(\frac{101{,}325\ Pa}{1\ atm}\right) = 85{,}600\ Pa$

b) $P_{External}: 760\ mmHg$

$P_{Change}: +215\ mmHg$ (positive because Hg went up)

$P_{Flask}: P_{External} + P_{Change} = 760\ mmHg + 215\ mmHg$

$= 975\ mmHg$

$P_{flask} = 975\ mmHg\left(\frac{1\ atm}{760\ mmHg}\right) = 1.28\ atm$

$P_{flask} = 975\ mmHg\left(\frac{760\ torr}{760\ mmHg}\right) = 975\ torr$

$P_{flask} = 1.28\ atm\left(\frac{101{,}325\ Pa}{1\ atm}\right) = 1.29 \times 10^5\ Pa$

c) $P_{External}: 635\ mmHg$

$P_{Change}: -118\ mmHg$ (negative because Hg went down)

$P_{Flask}: P_{External} + P_{Change} = 635\ mmHg - 118\ mmHg$

$= 517\ mmHg\left(\frac{760\ torr}{760\ mmHg}\right) = 517\ torr$

d) $P_{External}: 635\ mmHg$

$P_{Change}: +215\ mmHg$ (positive because Hg went up)

$P_{Flask}: P_{External} + P_{Change} = 635\ mmHg + 215\ mmHg$

$= 850.mmHg\left(\frac{760\ torr}{760\ mmHg}\right) = 850.torr$

29. What was given:

$P_{I(H_2)} = 475\ torr$

$V_{I(H_2)} = 2.00\ L$

$P_{I(N_2)} = 0.200\ atm\left(\frac{760\ torr}{1\ atm}\right) = 152\ torr$

$V_{I(N_2)} = 1.00\ L$

$V_F = V_{I(N_2)} + V_{I(H_2)} = 3.00\ L$

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:

$P_{I(H_2)}V_{I(H_2)} = P_{F(H_2)}V_{F(H_2)}$

$(475\ torr)(2.00\ L) = P_{F(H_2)}(3.00\ L)$

$P_{F(H_2)} = 316\ torr$

Calculate the final pressure of the N_2

$P_{I(N_2)}V_{I(N_2)} = P_{F(N_2)}V_{F(N_2)}$

$(152\ torr)(1.00\ L) = P_{F(N_2)}(3.00\ L)$

$P_{F(N_2)} = 50.7\ torr$

Calculate the total pressure

$P_{tot} = P_{F(H_2)} + P_{F(N_2)} = 316\ torr + 50.7\ torr = 367\ torr$

33. What is given

$m_I = 1.00 \times 10^3\ g$

$n_I = 1.00 \times 10^3\ g\left(\frac{1\ mol\ Ar}{39.948\ g\ Ar}\right) = 25.0\ mol$

$P_I = 2{,}050.\ psi$

$T_I = 18℃ = 18 + 273.15 = 291K$

$P_F = 650.\ psi$

$T_F = 26℃ = 26 + 273.15 = 299K$

Need to calculate m_F

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

$PV = nRT$

$\frac{P_I}{n_I T_I} = \frac{P_F}{n_F T_F}$

$n_F = \frac{P_F n_I T_I}{T_F P_I} = \frac{(650.\ psi)(25.0\ mol)(291K)}{(299K)(2{,}050.\ psi)} = 7.71\ mol$

$m_F = 7.71\ mol\left(\frac{39.948\ g\ Ar}{1\ mol\ Ar}\right) = 308\ g$

34. What was given

$P_I = 1.00\ atm$

$V_I = 1.00\ L$

$T_I = 23℃ = 23 + 273.15 = 296K$

$P_F = 220.\ torr\left(\frac{1\ atm}{760\ torr}\right) = 0.289\ atm$

$T_F = -31℃ = -31 + 273.15 = 242K$

Need to calculate ΔV

$\Delta V = V_F - V_I$

Determine V_F

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

$$PV = nRT$$

$$\frac{P_I V_I}{T_I} = \frac{P_F V_F}{T_F}$$

$$V_F = \frac{P_I V_I T_F}{T_I P_F} = \frac{(1.00\ atm)(1.00\ L)(242K)}{(296K)(0.289\ atm)} = 2.83\ L$$

Calculate the change in volume

$$\Delta V = V_F - V_I = 2.83\ L - 1.00\ L = 1.83\ L$$

36. What was given

$$P_I = 710\ torr$$
$$V_I = 5.0 \times 10^2\ mL$$
$$T_I = 30.\text{℃} = 30. + 273.15 = 303K$$
$$V_F = 25\ mL$$
$$T_F = 820\text{℃} = 820 + 273.15 = 1{,}090K$$

Need to calculate P_F

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

$$PV = nRT$$

$$\frac{P_I V_I}{T_I} = \frac{P_F V_F}{T_F}$$

$$P_F = \frac{P_I V_I T_F}{T_I V_F} = \frac{(710\ torr)(5.0 \times 10^2\ mL)(1{,}090K)}{(303K)(25\ mL)} = 51{,}000\ torr$$

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

$$P = 2.70\ atm$$
$$V = 200.0\ L$$
$$T = 24\text{℃} = 24 + 273.15 = 297K$$

Calculate the number of moles

$$PV = nRT$$

$$n = \frac{PV}{RT} = \frac{(2.70\ atm)(200.0\ L)}{\left(0.08206\ \frac{L \cdot atm}{mol \cdot K}\right)(297K)} = 22.2\ mol$$

Determine the mass of He

$$22.2\ mol\ He\left(\frac{4.00\ g\ He}{1\ mol\ He}\right) = 88.8\ g\ He$$

Determine the mass of H_2

$$22.2\ mol\ H_2\left(\frac{2.02\ g\ H_2}{1\ mol\ H_2}\right) = 44.8\ g\ H_2$$

40. What is given

$$P_I = 400.\ torr$$
$$n_I = 1.50\ mol$$
$$T_I = 25\text{℃} = 25 + 273.15 = 298K$$
$$P_F = 800.\ torr$$
$$n_F = 1.50\ mol + n_{added}$$
$$T_F = 50.\text{℃} = 50. + 273.15 = 323K$$

Need to calculate n_{add}

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

$$PV = nRT$$

$$\frac{P_I}{n_I T_I} = \frac{P_F}{n_F T_F}$$

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

Calculate n_{add}

$$n_F = 1.50\,mol + n_{added}$$

$$n_{added} = n_F - 1.50\,mol = 2.76\,mol - 1.50\,mol = 1.26\,mol$$

41. What was given

$$V_{NO_2} = 25.0\,mL$$

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 ½ the number of moles of NO_2 because

$$V_{N_2O_4} = \frac{V_{NO_2} n_{N_2O_4}}{n_{NO_2}} = \frac{V_{NO_2}(0.5 n_{NO_2})}{n_{NO_2}} = 0.5 V_{NO_2} = 0.5(25.0\,mL) = 12.5\,mL$$

42. What was given

$$P_I = 75\,psi$$

$$T_I = 19℃ = 19 + 273.15 = 292K$$

$$V_F = V_I 1.040$$

$$T_F = 58℃ = 58 + 273.15 = 331K$$

Need to calculate P_F

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

$$PV = nRT$$

$$\frac{P_I V_I}{T_I} = \frac{P_F V_F}{T_F}$$

$$P_F = \frac{P_I V_I T_F}{T_I V_F} = \frac{(75\,psi) V_I (331K)}{(292K)(V_I 1.040)} = 82\,psi$$

43. What was given

$$V_I = 4.00 \times 10^3\,m^3$$

$$P_I = P_F = 745\,torr$$

$$T_I = 21℃ = 21 + 273.15 = 294K$$

$$V_F = 4.20 \times 10^3\,m^3$$

$$T_F = 62℃ = 62 + 273.15 = 335K$$

Need to find $\frac{n_F}{n_I}$

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

$$PV = nRT$$

$$\frac{V_I}{n_I T_I} = \frac{V_F}{n_F T_F}$$

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

46. What was given

$$T = 20.\,℃ = 20 + 273.15 = 293K$$
$$P = P_{N_2} + P_{H_2O} = 1.00\ atm$$
$$P_{H_2O} = 17.5\ torr\left(\frac{1\ atm}{760\ torr}\right) = 0.0230\ atm$$
$$P_{N_2} = 1.00\ atm - P_{H_2O} = 1.00atm - 0.0230\ atm = 0.977\ atm$$
$$V = 2.50 \times 10^2\ mL\left(\frac{1\ L}{1000\ mL}\right) = 0.250\ L$$

Calculate the number of moles of N_2

$$P_{N_2}V = n_{N_2}RT$$
$$n_{N_2} = \frac{P_{N_2}V}{RT} = \frac{(0.977\ atm)(0.250\ L)}{\left(0.08206\ \frac{L \cdot atm}{mol \cdot K}\right)(293K)} = 0.0101\ mol\ N_2$$

Convert moles to grams

$$0.0101\ mol\ N_2\left(\frac{28.02\ g\ N_2}{1\ mol\ N_2}\right) = 0.283\ g\ N_2$$

49. What was given

$$P_{O_2} = 0.250\ atm$$
$$P_{CH_4} = 0.175\ atm$$
$$P_{tot} = P_{O_2} + P_{CH_4} = 0.250\ atm + 0.175\ atm = 0.425\ atm$$

a) Calculate the mole fraction of CH_4, $\chi_{CH_4} = \frac{n_{CH_4}}{n_{tot}}$

$$P_A = \chi_A P_{tot}$$
$$\chi_{CH_4} = \frac{P_{CH_4}}{P_{tot}} = \frac{0.175\ atm}{0.425\ atm} = 0.412$$

Calculate the mole fraction of O_2, $\chi_{O_2} = \frac{n_{O_2}}{n_{tot}}$

$$\chi_{O_2} = \frac{P_{O_2}}{P_{tot}} = \frac{0.250\ atm}{0.425\ atm} = 0.588$$

b) What is given

$$V = 10.5\ L$$
$$T = 65℃ = 65 + 273.15 = 338K$$
$$P = 0.425\ atm$$

Calculate n

$$PV = nRT$$
$$n = \frac{PV}{RT} = \frac{(0.425\ atm)(10.5\ L)}{\left(0.08206\ \frac{L \cdot atm}{mol \cdot K}\right)(338K)} = 0.161\ mol$$

c) Calculate the grams of CH_4

$$n_{CH_4} = \chi_{CH_4} n_{tot} = (0.412)(0.161\ mol) = 0.0663\ mol\ CH_4$$
$$0.0663\ mol\ CH_4\left(\frac{16.05\ g\ CH_4}{1\ mol\ CH_4}\right) = 1.06\ g\ CH_4$$

Calculate the grams of O_2

$$n_{O_2} = \chi_{O_2} n_{tot} = (0.588)(0.161\ mol) = 0.0947\ mol\ O_2$$
$$0.0947\ mol\ O_2\left(\frac{32.00\ g\ O_2}{1\ mol\ O_2}\right) = 3.03\ g\ O_2$$

55. Determine the empirical formula

Assume 100 g (87.4 g N and 12.6 g H)

Calculate mole N and H

N

$$87.4\ g\ N\left(\frac{1\ mol\ N}{14.01\ g\ N}\right) = 6.24\ mol\ N$$

H

$$12.3\ g\ H\left(\frac{1\ mol\ H}{1.01\ g\ H}\right) = 12.2\ mol\ H$$

Divide through by smallest number of moles (6.24 mol)

N

$$\frac{6.24\ mol}{6.24\ mol} = 1.00$$

H

$$\frac{12.2\ mol}{6.24\ mol} = 1.96$$

Empirical Formula

NH_2

Determine the molecular weight

What is given

$$P = 710\ torr\left(\frac{1\ atm}{760\ torr}\right) = 0.934\ atm$$

$$d = 0.977\ \frac{g}{L}$$

$$T = 100.\ ℃ = 100. + 273.15 = 373K$$

Relate density to molar mass

$$M = \frac{m}{n}$$

$$d = \frac{m}{V}$$

$M = \frac{dV}{n}$ or $n = \frac{dV}{M}$

Plug into ideal gas law

$$PV = nRT = \frac{dVRT}{M}$$

$$M = \frac{dRT}{P} = \frac{\left(0.977\ \frac{g}{L}\right)\left(0.08206\ \frac{L \cdot atm}{mol \cdot K}\right)(373K)}{(0.934\ atm)} = 32.02\ \frac{g}{mol}$$

Determine molecular formula

$$\frac{M_{N_xH_{2x}}}{M_{NH_2}} = \frac{32.02\ \frac{g}{mol}}{16.03\ \frac{g}{mol}} = 2.00$$

N_2H_4

56. What was given

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

$$P = 750\ torr\left(\frac{1\ atm}{760\ torr}\right) = 0.987\ atm$$

$$T = 373K$$

$$m = 0.800\ g$$

Calculate the molar mass

$$PV = nRT$$

$$n = \frac{m}{M}$$

$$M = \frac{mRT}{PV} = \frac{(0.800\ g)\left(0.08206\ \frac{L \cdot atm}{mol \cdot K}\right)(373K)}{(0.987\ atm)(0.256\ L)} = 96.9\ \frac{g}{mol}$$

Calculate molecular formula

$$\frac{M_{C_xH_xCl_x}}{M_{CHCl}} = \frac{96.9\,\frac{g}{mol}}{48.47\,\frac{g}{mol}} = 2.0$$

Molecular Formula

$C_2H_2Cl_2$

60. What was given

$$P = 1.00\ atm$$

$$m = 1.00 \times 10^3\ kg\ Mo$$

$$n = 1.00 \times 10^3\ kg\ Mo\left(\frac{1000\ g}{1\ kg}\right)\left(\frac{1\ mol\ Mo}{95.94\ g\ Mo}\right) = 10{,}400\ mol\ Mo$$

$$T = 17℃ = 17 + 273.15 = 290.\ K$$

Calculate the moles of O_2

$$10{,}400\ mol\ Mo\left(\frac{1\ mol\ MoO_3}{1\ mol\ Mo}\right)\left(\frac{^7/_2\ mol\ O_2}{1\ mol\ MoO_3}\right) = 36{,}400\ mol\ O_2$$

Calculate the volume of O_2

$$PV = nRT$$

$$V = \frac{nRT}{P} = \frac{(36{,}400\ mol)\left(0.08206\,\frac{L\cdot atm}{mol\cdot K}\right)(290.\ K)}{1.00\ atm} = 8.66 \times 10^5\ L$$

Calculate the volume of air

$$8.66 \times 10^5\ L = V_{air}(0.21)$$

$$V_{air} = 4.1 \times 10^6\ L$$

Calculate the moles of H_2

$$10{,}400\ mol\ Mo\left(\frac{3\ mol\ H_2}{1\ mol\ Mo}\right) = 31{,}200\ mol\ H_2$$

Calculate the volume of H_2

$$V = \frac{nRT}{P} = \frac{(31{,}200\ mol)\left(0.08206\,\frac{L\cdot atm}{mol\cdot K}\right)(290.\ K)}{1.00\ atm} = 7.42 \times 10^5\ L$$

62. What is given

$$P_{NH_3} = 90.\ atm$$

$$T = 223℃ = 223 + 273.15 = 496K$$

Rate of flow of NH_3 $500.\frac{L}{min}$

$$P_{CO_2} = 45\ atm$$

Rate of flow of CO_2 $600.\frac{L}{min}$

This is a limiting reagent problem.

Calculate the rate of flow of NH_3 in $\frac{mol}{min}$

$$PV = nRT$$

$$n = \frac{PV}{RT} = \frac{(90.\ atm)\left(500.\frac{L}{min}\right)}{\left(0.08206\,\frac{L\cdot atm}{mol\cdot K}\right)(496K)} = 1{,}100\,\frac{mol}{min}$$

Calculate the rate of flow of CO_2 in $\frac{mol}{min}$

$$n = \frac{PV}{RT} = \frac{(45\ atm)\left(600.\frac{L}{min}\right)}{\left(0.08206\,\frac{L\cdot atm}{mol\cdot K}\right)(496K)} = 660\,\frac{mol}{min}$$

Calculate the amount of NH_3 need to fully react the CO_2

$$660\,\frac{mol}{min}\,CO_2\left(\frac{2\,mol\,NH_3}{1\,mol\,CO_2}\right) = 1{,}300\,\frac{mol}{min}\,NH_3$$

	NH_3 (L.R.)	CO_2	H_2NCONH_2	H_2O
I	$1{,}100\,\frac{mol}{min}$	$660\,\frac{mol}{min}$	$0\,\frac{mol}{min}$	$0\,\frac{mol}{min}$
C	$-2x = -1{,}100\,\frac{mol}{min}$	$-x = -550\,\frac{mol}{min}$	$+x = 550\,\frac{mol}{min}$	$+x = 550\,\frac{mol}{min}$
F	$0\,\frac{mol}{min}$	$110\,\frac{mol}{min}$	$550\,\frac{mol}{min}$	$550\,\frac{mol}{min}$

Change rate of urea formation to $\frac{g}{min}$

$$550\,\frac{mol\,urea}{min}\left(\frac{60.07\,g\,urea}{1\,mol\,urea}\right) = 3.3\times10^4\,\frac{g\,urea}{min}$$

65. What was given

$$m = 150\,g\,(CH_3)_2N_2H_2$$

$$n = 150\,g\,(CH_3)_2N_2H_2\left(\frac{1\,mol\,(CH_3)_2N_2H_2}{60.12\,g\,(CH_3)_2N_2H_2}\right) = 2.5\,mol\,(CH_3)_2N_2H_2$$

$$T = 27℃ = 27 + 273.15 = 300.K$$

$$V = 250\,L$$

Calculate the moles of N_2

$$2.5\,mol\,(CH_3)_2N_2H_2\left(\frac{3\,mol\,N_2}{1\,mol\,(CH_3)_2N_2H_2}\right) = 7.5\,mol\,N_2$$

Calculate the moles of H_2O

$$2.5\,mol\,(CH_3)_2N_2H_2\left(\frac{4\,mol\,H_2O}{1\,mol\,(CH_3)_2N_2H_2}\right) = 10.mol\,N_2$$

Calculate the moles of CO_2

$$2.5\,mol\,(CH_3)_2N_2H_2\left(\frac{4\,mol\,CO_2}{1\,mol\,(CH_3)_2N_2H_2}\right) = 5.0\,mol\,CO_2$$

Calculate the total moles of gas

$$n_{tot} = n_{N_2} + n_{H_2O} + n_{CO_2} = 7.5\,mol + 10.mol + 5.0\,mol = 23\,mol$$

Calculate the total pressure

$$PV = nRT$$

$$P = \frac{nRT}{V} = \frac{(23\,mol)\left(0.08206\,\frac{L\cdot atm}{mol\cdot K}\right)(300.K)}{(250\,L)} = 2.3\,atm$$

Calculate the partial pressure of N_2

$$P_{N_2} = \chi_{N_2}P_{tot} = \left(\frac{7.5\,mol}{23\,mol}\right)2.3\,atm = 0.75\,atm$$

66. What is given

$$P = 1.00\,atm$$

$$V = 70.0\,L$$

$$T = 0.℃ = 0.+273.15 = 273K$$

Calculate the number of moles of N_2 gas produced

$$PV = nRT$$

$$n = \frac{PV}{RT} = \frac{(1.00\,atm)(70.0\,L)}{\left(0.08206\,\frac{L\cdot atm}{mol\cdot K}\right)(273K)} = 3.12\,mol\,N_2$$

Calculate the g of NaN_3 need to produce 3.12 mol N_2

$$3.12\,mol\,N_2\left(\frac{2\,mol\,NaN_3}{3\,mol\,N_2}\right)\left(\frac{65.02\,g\,NaN_3}{1\,mol\,NaN_3}\right) = 135\,g\,NaN_3$$

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 and 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.)	O_2	NO	H_2O
I	$\frac{1.00\ atm \cdot L}{RT}$	$\frac{1.50\ atm \cdot L}{RT}$	0	0
C	$-4x = -\frac{1.00\ atm \cdot L}{RT}$	$-5x = \frac{1.25\ atm \cdot L}{RT}$	$+4x = \frac{1.00\ atm \cdot L}{RT}$	$+6x = \frac{1.50\ atm \cdot L}{RT}$
F	0	$\frac{0.25\ atm \cdot L}{RT}$	$\frac{1.00\ atm \cdot L}{RT}$	$\frac{1.50\ atm \cdot L}{RT}$

Calculate the partial pressure of NO

$$P_{NO}V = n_{NO}RT$$

$$P_{NO} = \frac{n_{NH_3}RT}{V} = \frac{\left(\frac{1.00\ atm \cdot L}{RT}\right)RT}{V} = \frac{1.00\ atm \cdot L}{3.00\ L} = 0.333\ atm$$

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 $\left((KE)_{ave} = \frac{3}{2}RT\right)$ 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) ii = vi < i = iv = v = viii < iii = vii

b) all are the same

c) Helpful Hint: $m_{Ne} = 2m_{Ar}$

ii < i = iv = vi < iii = v = viii < vii

d) v = vi = vii = viii< i = ii = iii = iv

81. Calculate the $(KE)_{ave}$ at 273 K for CH_4

$$(KE)_{ave} = \frac{3}{2}RT = \frac{3}{2}\left(8.3145\,\frac{J}{mol\cdot K}\right)(273K) = 3.40\times10^{3}\,\frac{J}{mol}$$

Change to per molecules

$$3.40\times10^{3}\,\frac{J}{mol}\left(\frac{1\,mol}{6.02214\times10^{23}\,molecules}\right) = 5.65\times10^{-21}\,\frac{J}{molecule}$$

Since the $(KE)_{ave}$ does not depend on type of gas molecule, the $(KE)_{ave}$ of N_2 at 273 K would be the same as the $(KE)_{ave}$ of CH_4 at 273 K.

Calculate the $(KE)_{ave}$ at 546 K for CH_4

$$(KE)_{ave} = \frac{3}{2}RT = \frac{3}{2}\left(8.3145\,\frac{J}{mol\cdot K}\right)(546K) = 6.80\times10^{3}\,\frac{J}{mol}$$

Change to per molecules

$$6.80\times10^{3}\,\frac{J}{mol}\left(\frac{1\,mol}{6.02214\times10^{23}\,molecules}\right) = 1.13\times10^{-20}\,\frac{J}{molecule}$$

Since the $(KE)_{ave}$ does not depend on type of gas molecule, the $(KE)_{ave}$ of N_2 at 546 K would be the same as the $(KE)_{ave}$ of CH_4 at 546 K.

82. Calculate the u_{rms} at 273 K for CH_4

$$M_{CH_4} = 16.05\,\frac{g}{mol}\left(\frac{1\,kg}{1000\,g}\right) = 0.01605\,\frac{kg}{mol}$$

$$u_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3\left(8.3145\,\frac{J}{mol\cdot K}\right)(273K)}{0.01605\,\frac{kg}{mol}}} = 651\,\frac{m}{s}$$

Calculate the u_{rms} at 273 K for N_2

$$M_{N_2} = 28.02\,\frac{g}{mol}\left(\frac{1\,kg}{1000\,g}\right) = 0.02802\,\frac{kg}{mol}$$

$$u_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3\left(8.3145\,\frac{J}{mol\cdot K}\right)(273K)}{0.02802\,\frac{kg}{mol}}} = 493\,\frac{m}{s}$$

Calculate the u_{rms} at 546 K for CH_4

$$u_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3\left(8.3145\,\frac{J}{mol\cdot K}\right)(546K)}{0.01605\,\frac{kg}{mol}}} = 921\,\frac{m}{s}$$

Calculate the u_{rms} at 546 K for N_2

$$u_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3\left(8.3145\,\frac{J}{mol\cdot K}\right)(546K)}{0.02802\,\frac{kg}{mol}}} = 697\,\frac{m}{s}$$

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 with each other	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)

$$n_C = 58.51\ g\ C\left(\frac{1\ mol\ C}{12.01\ g\ C}\right) = 4.87\ mol$$

$$n_H = 7.37\ g\ H\left(\frac{1\ mol\ H}{1.01\ g\ H}\right) = 7.30\ mol$$

$$n_N = 34.12\ g\ N\left(\frac{1\ mol\ N}{14.01\ g\ N}\right) = 2.43\ mol$$

Divide through by smallest moles, 2.43 mol

C $\frac{4.87\ mol}{02.43\ mol} = 2.00$ H $\frac{7.30\ mol}{2.43\ mol} = 3.00$ N $\frac{2.43\ mol}{2.43\ mol} = 1.00$

Empirical Formula

C_2H_3N

Determine Molecular Formula

$$\frac{rate\ of\ effusion\ He}{rate\ of\ effusion\ C_{2x}H_{3x}N_x} = \frac{\sqrt{M_{C_{2x}H_{3x}N_x}}}{\sqrt{M_{He}}}$$

$$\frac{3.20x}{x} = \frac{\sqrt{M_{C_{2x}H_{3x}N_x}}}{\sqrt{4.00\frac{g}{mol}}}$$

$$M_{C_{2x}H_{3x}N_x} = 40.96\frac{g}{mol}$$

$$\frac{M_{MF}}{M_{EF}} = \frac{40.96\frac{g}{mol}}{41.06\frac{g}{mol}} = 0.998$$

Molecular Formula

C_2H_3N

90. $rate\ of\ effusion\ of\ He = \frac{V}{t} = \frac{1.0\ L}{4.5\ min} = 0.22\ \frac{L}{min}$

$\frac{rate\ of\ effusion\ He}{rate\ of\ effusion\ Cl_2} = \frac{\sqrt{M_{Cl_2}}}{\sqrt{M_{He}}}$

$$\frac{0.22\ \frac{mL}{min}}{rate\ of\ effusion\ Cl_2} = \frac{\sqrt{70.90\ \frac{g}{mol}}}{\sqrt{4.00\ \frac{g}{mol}}}$$

$rate\ of\ effusion\ of\ Cl_2 = 0.052\ \frac{L}{min}$

Calculate the time it takes for 1.0 L to effuse

$1.0\ L\left(\frac{1\ min}{0.052\ L}\right) = 19\ min$

91. What is given

$V = 1.0000\ L$

$n = 0.5000\ mol$

$T = 25.0℃ = 25.0 + 273.15 = 278.2K$

$a = 1.39\ \frac{atm \cdot L^2}{mol^2}$

$b = 0.0391\ \frac{L}{mol}$

a) $PV = nRT$

$$P = \frac{nRT}{V} = \frac{(0.5000\ mol)\left(0.08206\ \frac{L \cdot atm}{mol \cdot K}\right)(298.2K)}{(1.0000\ L)} = 12.24\ atm$$

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

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

$$P = \frac{(0.5000\ mol)\left(0.08206\ \frac{L \cdot atm}{mol \cdot K}\right)(298.2)}{\left(1.0000\ L - (0.5000\ mol)\left(0.0391\ \frac{L}{mol}\right)\right)} - \left(1.39\ \frac{atm \cdot L^2}{mol^2}\right)\left(\frac{0.5000\ mol}{1.0000\ L}\right)^2 = 12.13\ atm$$

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

92. What is given

$V = 10.0000\ L$

$n = 0.5000\ mol$

$T = 25.0℃ = 25.0 + 273.15 = 278.2K$

$a = 1.39\ \frac{atm \cdot L^2}{mol^2}$

$b = 0.0391\ \frac{L}{mol}$

a) $PV = nRT$

$$P = \frac{nRT}{V} = \frac{(0.5000\ mol)\left(0.08206\ \frac{L \cdot atm}{mol \cdot K}\right)(298.2K)}{(10.0000\ L)} = 1.224\ atm$$

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

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

$$P = \frac{(0.5000\ mol)\left(0.08206\ \frac{L \cdot atm}{mol \cdot K}\right)(298.2)}{\left(10.0000\ L - (0.5000\ mol)\left(0.0391\ \frac{L}{mol}\right)\right)} - \left(1.39\ \frac{atm \cdot L^2}{mol^2}\right)\left(\frac{0.5000\ mol}{10.0000\ L}\right)^2$$

$$= 1.222\ atm$$

c) The two numbers are within 0.002 atm of each other.

d) The two value 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 gases 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

Cl_2 A

Since the $u_{rms} = \sqrt{\frac{3RT}{M}}$ and 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.

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

$M_{N_2} = 28.02\,\frac{g}{mol}\left(\frac{1\,kg}{1000\,g}\right) = 0.02802\,\frac{kg}{mol}$

$T = 227℃ = 227 + 273.15 = 500.\,K$

Calculate the root mean square velocity

$$u_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3\left(8.3145\,\frac{J}{mol\cdot K}\right)(500.\,K)}{0.02802\,\frac{kg}{mol}}} = 667\,\frac{m}{s}$$

Calculate the most probable velocity

$$u_{mp} = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2\left(8.3145\,\frac{J}{mol\cdot K}\right)(500.\,K)}{0.02802\,\frac{kg}{mol}}} = 545\,\frac{m}{s}$$

Calculate the average velocity

$$u_{rms} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8\left(8.3145\,\frac{J}{mol\cdot K}\right)(500.\,K)}{\pi 0.02802\,\frac{kg}{mol}}} = 615\,\frac{m}{s}$$

119. What is given

$m_{Mn} = 2.747\ g$

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

$V = 3.22\ L$

$P = 0.951\ atm$

$T = 373K$

Mn(s) + xHCl(g) → $\frac{x}{2}H_2(g)$ + $MnCl_x(s)$

From equation

$n_{Cl} = n_H$

Determine the moles of H

$PV = nRT$

$$n_{H_2} = \frac{P_{H_2}V}{RT} = \frac{(0.951\ atm)(3.22\ L)}{\left(0.08206\ \frac{L \cdot atm}{mol \cdot K}\right)(373K)} = 0.100\ mol\ H_2\left(\frac{2\ mol\ H}{1\ mol\ H_2}\right)$$
$$= 0.200\ mol\ H$$

Divide through by smallest moles, 0.0500 mol

Mn

$\frac{0.0500\ mol}{0.0500\ mol} = 1.00$

Cl

$\frac{0.200\ mol}{0.0500\ mol} = 4.00$

Formula

$MnCl_4$

127. What was given

$P_{I(He)} = 200.\ torr\left(\frac{1\ atm}{760\ torr}\right) = 0.263\ atm$

$V_{I(He)} = 1.00\ L$

$P_{I(Ne)} = 0.400\ atm$

$V_{I(Ne)} = 1.00\ L$

$P_{I(Ar)} = 24.0\ kPa\left(\frac{1000\ Pa}{1\ kPa}\right)\left(\frac{1\ atm}{101{,}325\ Pa}\right) = 0.237\ atm$

$V_{I(Ar)} = 2.00\ L$

$V_{tot} = 1.00\ L + 1.00\ L + 2.00\ L = 4.00\ L$

$PV = nRT$

Find an expression for moles of He

$$n_{Ar} = \frac{P_{I(He)}V_{I(He)}}{RT} = \frac{(0.263\ atm)(1.00\ L)}{RT} = \frac{0.263\ L \cdot atm}{RT}$$

Calculate the P_{He}

$$P_{F(He)} = \frac{n_{He}RT}{V_{tot}} = \frac{\left(\frac{0.263\ L \cdot atm}{RT}\right)RT}{(4.00\ L)} = 0.0658\ atm\ He$$

Find an expression for moles of Ne

$$n_{Ne} = \frac{P_{Ne}V_{I(Ne)}}{RT} = \frac{(0.400\ atm)(1.00\ L)}{RT} = \frac{0.400\ L \cdot atm}{RT}$$

Calculate the P_{Ne}

$$P_{F(Ne)} = \frac{n_{Ne}RT}{V_{tot}} = \frac{\left(\frac{0.400\ L \cdot atm}{RT}\right)RT}{(4.00\ L)} = 0.100\ atm\ Ne$$

Find an expression for moles of Ar

$$n_{Ar} = \frac{P_{I(Ar)}V_{I(Ar)}}{RT} = \frac{(0.237\ atm)(2.00\ L)}{RT} = \frac{0.474\ L \cdot atm}{RT}$$

Calculate the P_{Ar}

$$P_{F(Ar)} = \frac{n_{Ar}RT}{V_{tot}} = \frac{\left(\frac{0.474\ L \cdot atm}{RT}\right)RT}{(4.00\ L)} = 0.119\ atm\ Ar$$

Calculate total pressure

$$P_{tot} = P_{F(He)} + P_{F(Ne)} + P_{F(Ar)} = 0.285\ atm$$