Homework 1 Key

1. $m = 250\,g$ of CO_2

$FW_{CO_2} = 44.01\ g/mol$

$V = 1.5\ dm^3 = 1.5\,L$

$T = 25^\circ C = 298\,K$

$$n_{CO_2} = \frac{250\,g}{44.01\,g/mol} = 5.68\,mol$$

if ideal: $PV = nRT$

$$P = \frac{nRT}{V} = \frac{(5.68\,mol)(8.2\times10^{-2}\,\frac{L\,atm}{mol\,K})(298\,K)}{1.5\,L}$$

$$\boxed{P = 92.7\,atm}$$

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

$a = 3.6073\ \frac{L^2\,atm}{mol^2}$

$b = 0.0428\ L/mol$

$$P = \frac{(5.68\,mol)(8.2\times10^{-2}\,\frac{L\,atm}{mol\,K})(298\,K)}{1.5\,L - (5.68\,mol)(0.0428\,L/mol)} - \left(3.6073\,\frac{L^2\,atm}{mol^2}\right)\left(\frac{5.68\,mol}{1.5\,L}\right)^2$$

$P = 110.4\,atm - 51.7\,atm$

$$\boxed{P = 58.7\,atm}$$

$\Rightarrow$ Under these conditions, attractive forces dominate the gas.

2) If VdW + ideal gases are behaving the same:

$$P = \frac{RT}{V_m - b} - \frac{a}{V_m^2} = \frac{RT}{V_m}$$

Solve for T: $$T = \frac{V_m}{R}\left(\frac{RT}{V_m - b}\right) - \frac{V_m}{R}\left(\frac{a}{V_m^2}\right)$$

$$T = \frac{V_m T}{V_m - b} - \frac{a}{RV_m}$$

$$T - \frac{V_m T}{V_m - b} = \frac{-a}{RV_m}$$

$$T\left(1 - \frac{V_m}{V_m - b}\right) = \frac{-a}{RV_m}$$

$$T\left(\frac{V_m - b - V_m}{V_m - b}\right) = \frac{-a}{RV_m}$$

$$T\left(\frac{-b}{V_m - b}\right) = \frac{-a}{V_m R}$$

$$T = \left(\frac{V_m - b}{b}\right)\left(\frac{a}{V_m R}\right)$$

$$\boxed{T = \frac{a(V_m - b)}{V_m R b}}$$

3) $T = 180K,\ 250K$

$$Z = \frac{PV_m}{RT} \qquad P = \frac{RT}{V_m - b} - \frac{a}{V_m^2}$$

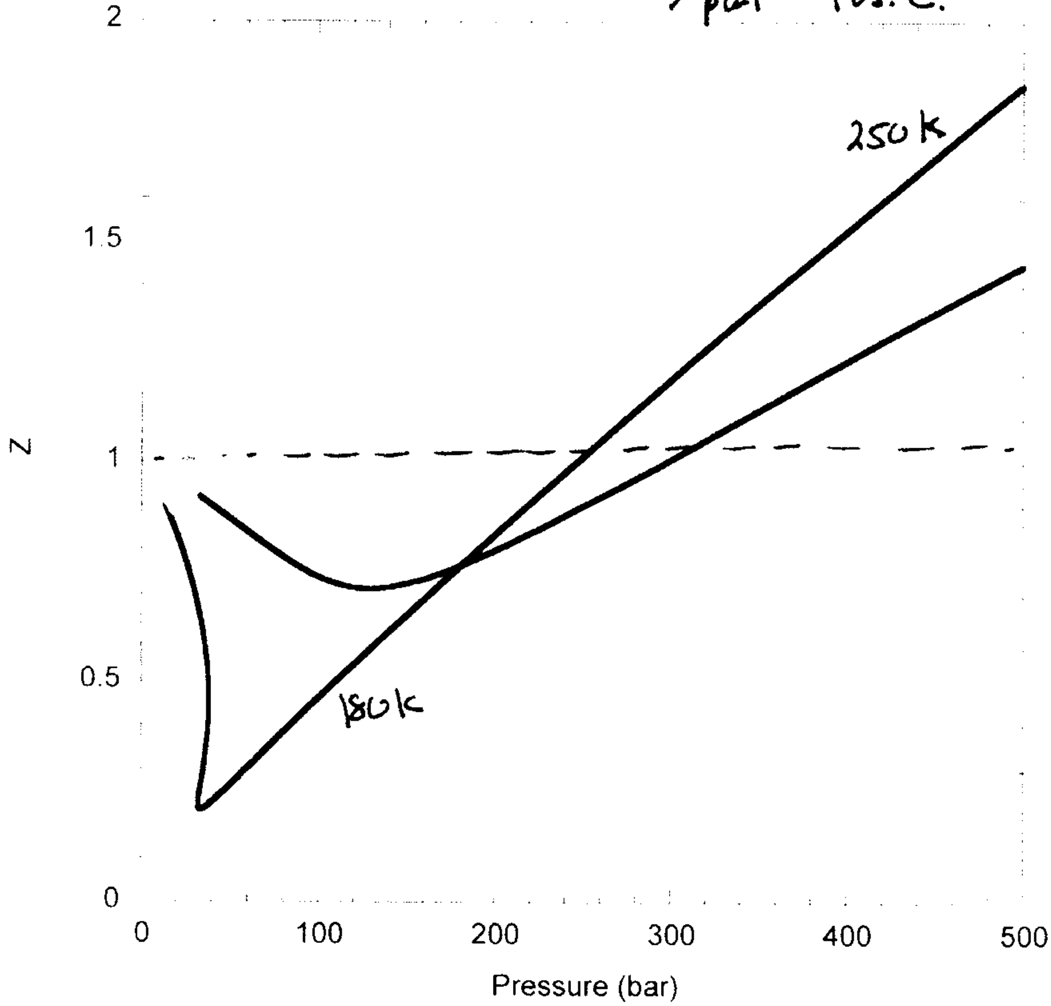
$a = 2.273\ L^2 atm/mol^2$

$b = 0.0437\ L/mol$

→ use vdW equation to find P vs. V_m

→ use Z to find Z vs. V_m

→ plot P vs. Z.



At higher T, repulsive forces become dominant at lower pressure. Higher T will most likely cause more collisions between particles, i.e. more time each particle sits in another particle's space. Repulsive forces are always dominant at very short distance.

4)

@ P_1 : $P_1 = 760$ Torr ≈ 1 atm

$T_1 = 298$ K

$V_1 = \frac{4}{3}\pi r^3$; $r = \frac{c}{2\pi} = \frac{40\text{ cm}}{2\pi} = 6.37$ cm

$V_1 = \frac{4}{3}\pi(6.37\text{cm})^3 = 1082.7\text{cm}^3 \left(\frac{1\text{dm}}{10\text{cm}}\right)^3 \left(\frac{1\text{L}}{1\text{dm}^3}\right) = 1.08\text{L}$

@ P_2 : $T_2 = 294$ K

$V_2 = \frac{4}{3}\pi r^3$; $r = \frac{45.5\text{cm}}{2\pi} = 7.24$ cm

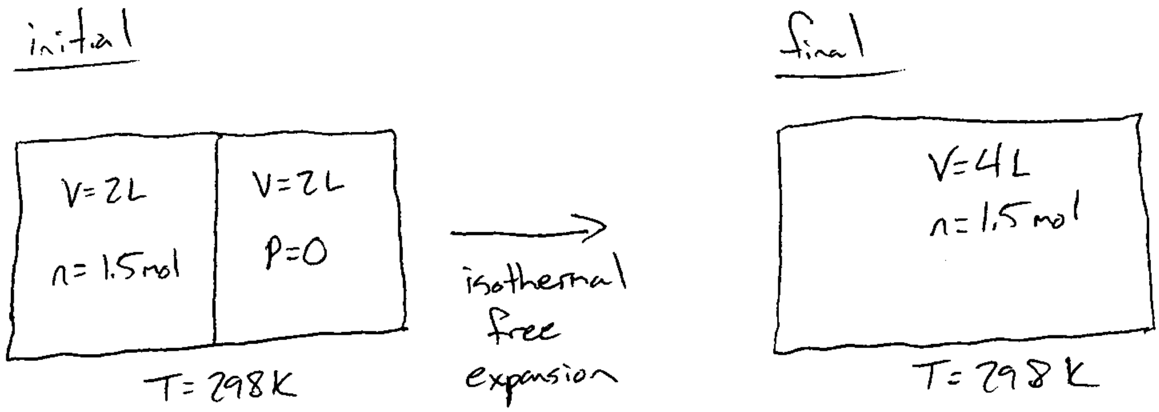
$V_2 = \frac{4}{3}\pi(7.24\text{cm})^3 = 1589.7\text{cm}^3 = 1.59$ L

$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \Rightarrow P_2 = \frac{P_1 V_1 T_2}{T_1 V_2} = \frac{(1\text{ atm})(1.08\text{L})(294\text{K})}{(298\text{K})(1.59\text{L})}$

$\boxed{P_2 = 0.67 \text{ atm}}$

which is why long flights tend to make people feel tired and dehydrated

5) a.



b. $V_i = 2L$
$n_i = 1.5 mol$
$T_i = 298 K$
$P_i = 18 atm$

$V_f = 4L$
$n_f = 1.5 mol$
$T_f = 298 K$
$P_f = 8.9 atm$

c. The heater was not necessary b/c this was a free expansion. Because the gas is pushing against a vacuum, no work was done and no heat was lost.

6) a. Gas from the surroundings enters the system

b. Gas from the system moves to the surroundings

c. We want the $P_{sys} < 1 atm$, say 0.99 atm

$PV = nRT$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \Rightarrow T_2 = \frac{P_2 \cancel{V_2} T_1}{P_1 \cancel{V_1}} \qquad V_2 = V_1$$

$$T_2 = \frac{P_2 T_1}{P_1} = \frac{(0.99 atm)(293 K)}{1.47 atm} \Rightarrow \boxed{T_2 = 197 K}$$

in order to keep all gas in system