

Homework 1 Key

1. $m = 250 \text{ g of CO}_2$

$$FW_{\text{CO}_2} = 44.01 \text{ g/mol}$$

$$V = 1.5 \text{ dm}^3 = 1.5 \text{ L}$$

$$T = 25^\circ\text{C} = 298 \text{ K}$$

$$n_{\text{CO}_2} = \frac{250 \text{ g}}{44.01 \text{ g/mol}} = 5.68 \text{ mol}$$

if ideal: $PV = nRT$

$$P = \frac{nRT}{V} = \frac{(5.68 \text{ mol})(8.2 \times 10^{-2} \frac{\text{L atm}}{\text{mol K}})(298 \text{ K})}{1.5 \text{ L}}$$

$$P = 92.7 \text{ atm}$$

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

$$a = 3.6073 \frac{\text{L}^2 \text{ atm}}{\text{mol}^2}$$
$$b = 0.0428 \text{ L/mol}$$

$$P = \frac{(5.68 \text{ mol})(8.2 \times 10^{-2} \frac{\text{L atm}}{\text{mol K}})(298 \text{ K})}{1.5 \text{ L} - (5.68 \text{ mol})(0.0428 \text{ L/mol})} - (3.6073 \frac{\text{L}^2 \text{ atm}}{\text{mol}^2}) \left(\frac{5.68 \text{ mol}}{1.5 \text{ L}} \right)^2$$

$$P = 110.4 \text{ atm} - 51.7 \text{ atm}$$

$$P = 58.7 \text{ atm}$$

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

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

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

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

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

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

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

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

3) $T = 180\text{K}, 250\text{K}$

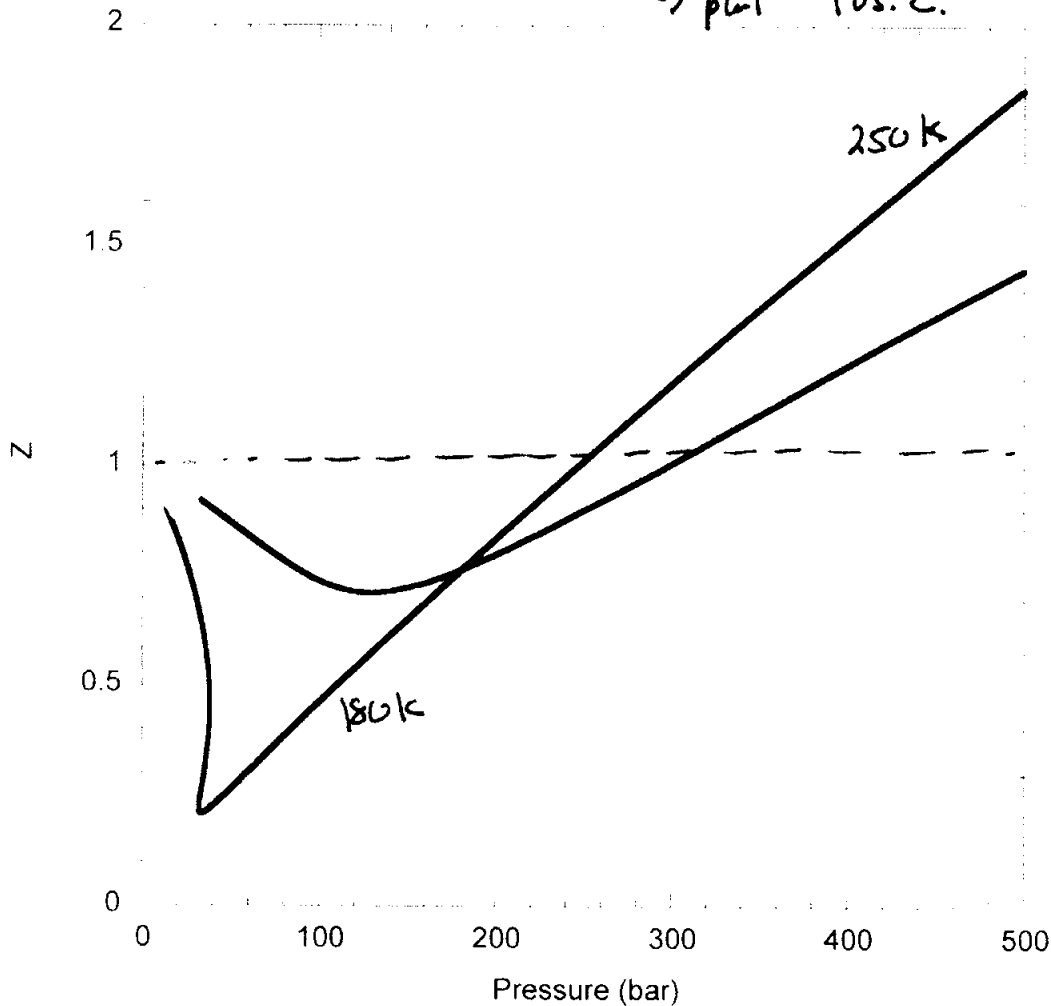
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$$Z = \frac{PV_m}{RT} \quad P = \frac{RT}{V_m - b} - \frac{a}{V_m^2}$$

$a = 2.273 \text{ L}^2\text{atm/mol}^2$

$b = 0.0437 \text{ L/mol}$

- 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 : $P_1 = 760 \text{ Torr} \approx 1 \text{ atm}$

$$T_1 = 298 \text{ K}$$

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

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

@ P_2 : $T_2 = 294 \text{ K}$

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

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

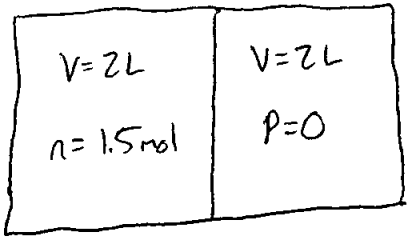
$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \Rightarrow P_2 = \frac{P_1 V_1 T_2}{T_1 V_2} = \frac{(1 \text{ atm})(1.08 \text{ L})(294 \text{ K})}{(298 \text{ K})(1.59 \text{ L})}$$

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

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

5) a.

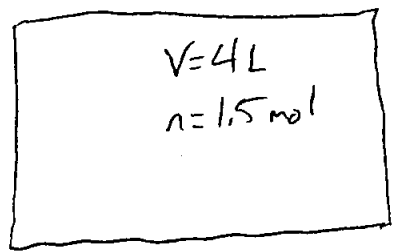
initial



$T=298K$

→
isothermal
free
expansion

final



$T=298K$

b.

$V_i = 2L$
 $n_i = 1.5\text{ mol}$
 $T_i = 298K$
 $P_i = 18\text{ atm}$

$V_f = 4L$
 $n_f = 1.5\text{ mol}$
 $T_f = 298K$
 $P_f = 8.9\text{ atm}$

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 $P_{\text{sys}} < 1\text{ atm}$, say 0.99 atm

$PV = nRT$

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

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

$T_2 = 197K$

in order to keep all gas in system