Student Number: [illegible]

Assignment 1
Distributed Sept 14, Due Sept 21 in class

1. A real gas follows the van der Waals equation of state with a=0.50 m^6 Pa mol^{-2}. The gas occupies a volume of 5.00x10^{-4} m^3 mol^{-1} at 283 K and 4.0 MPa.
   a) Calculate the constant b.
   b) Calculate the compression factor for this gas.

2. A sample of 4.50 g of methane occupies 12.7 L at 310 K. a) calculate the work done when the gas expands isothermally against a constant external pressure of 200 torr until its volume has increased by 3.3 L. B) calculate the work that would be done if the same expansion occurred reversibly.

3. Calculate the thermal expansion coefficient of a gas that obeys the following gas law: $p = \frac{nRT}{V-nb} - a$. The constants are a=1.5x10^3 Pa, b=0.0039 m^3 mol^{-1}, p=1x10^5 Pa, T=298 K, V=0.029 m^3.

1. a) $b = V_m - \left[\frac{RT}{\left(p + \frac{a}{V_m^2}\right)}\right]$

$b = 5.0\times10^{-4}\ \frac{m^3}{mol} - \left[\frac{(8.314\ \frac{J}{mol\cdot K})(283K)}{(4.0\times10^6\ Pa) + \left(\frac{0.50\ m^6\ Pa/mol^2}{(5\times10^{-4}\ m^3/mol)^2}\right)}\right]$

$b = 5\times10^{-4}\ \frac{m^3}{mol} - 3.92\times10^{-4}\ m^3/mol$

$\therefore b = 1.08\times10^{-4}\ m^3/mol$

b) $Z = \frac{pV_m}{RT} = \frac{(4.0\times10^6\ Pa)(5\times10^{-4}\ m^3/mol)}{(8.314\ \frac{J}{mol\cdot K})(283K)} = 0.850$

2. a) $w = -\int_{V_i}^{V_f} p\,dV = -P_{ext}\int_{V_i}^{V_f} dV = -P_{ext}\Delta V$

$\therefore P_{ext} = \frac{nRT}{V_f} = \frac{(0.281\ mol)(8.314\ J/mol\cdot K)(310K)}{(0.016\ m^3)} \doteq 45264.53\ Pa$

$W = -P_{ext}\Delta V = -(45264.53\ Pa)(0.0033\ m^3)$

$\therefore W = -149.37\ J$

2. b) $W = -\int_{V_i}^{V_f} p\, dV = -P_{ext} \ln(\Delta V)$

$W = -nRT \ln\left(\frac{V_f}{V_i}\right)$

$W = -(0.281\ mol)(8.314\ J/mol\cdot K)(310\ K) \ln\left(\frac{0.016\ m^3}{0.0127\ m^3}\right)$

$W = -167.288\ J$

3. (I) $p = \frac{nRT}{V-nb} - a$

$(p+a) = \frac{nRT}{V-nb}$

$V(p+a) - nb(p+a) = nRT$

$V(p+a) = n[RT + b(p+a)]$

$n = \frac{V(p+a)}{RT + b(p+a)}$

$n = \frac{0.029(10^5 + 1.5\times10^3)}{(8.314)(298) + 0.0039(10^5 + 1.5\times10^3)} = \frac{2943.5}{2872.23} = 1.0248\ moles$

(II) $\alpha = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_p$

(III) $(p+a) = \frac{nRT}{V-nb} \Rightarrow V - nb = \frac{nRT}{(p+a)} \Rightarrow V = \frac{nRT}{(p+a)} + nb$

so: $\alpha_I \left(\frac{\partial V}{\partial T}\right)_p = \frac{nR}{p+a}$; $\alpha = \frac{1}{V}\cdot\frac{nR}{p+a}$

$\alpha = \frac{1}{0.029\ m^3} \cdot \frac{(1.0248\ mol)(8.314\ J/mol\cdot K)}{1.0\times10^5 + 1.5\times10^3}$

$\alpha = \frac{8.520}{2.9435\times10^3}$

$\alpha = 2.895\times10^{-3}\ K^{-1}$