

## Assignment 7

1. Consider a mole of steam under very high pressure described by the van der Waals equation of state where  $a = 5.5 \text{ liter}^2 \text{ atm mole}^{-2}$  and  $b = 0.030 \text{ liter/mole}$ . The steam was initially at a pressure of 100 atm and had a volume of 0.3 liter. The steam then expands to twice its initial volume.
  - a) What is the initial temperature of the steam?
  - b) What is the final temperature if the expansion is isobaric?
  - c) What is the final pressure if the expansion is isothermal?

2. A gas undergoing the throttling (Joule Thomson expansion) process is initially at a pressure of 100 atm, temperature of  $0^\circ\text{C}$  and the molar volume is 0.25 liters. The molar heat capacity is  $C_p = 81 \text{ J/mole/K}$  and the coefficient of volume expansion is  $2 \times 10^{-3} \text{ }^\circ\text{C}^{-1}$ . Calculate the change in gas temperature if the pressure is reduced by 1 atm using the formula below.

$$\Delta T = \frac{V}{C_p} (1 - \beta T) \Delta p$$

3. Consider an ideal gas whose molecules each have 5 degrees of freedom, which initially has pressure  $P_i$  and volume  $V_i$ . If this gas undergoes isothermal expansion to volume  $V_f$ :
  - a) What is the amount of work done by the gas in terms of  $P_i$ ,  $V_i$  and  $V_f$ .
  - b) What is the pressure after the expansion,  $P_f$ , in terms of  $P_i$ ,  $V_i$  and  $V_f$ ?
  - c) Repeat parts a and b if the expansion is adiabatic rather than isothermal.

4. Heat Released during Isothermal Compression

- a) Write down the expression for  $dF$  using the definition of the Helmholtz free energy and the first law of thermodynamics.
- b) Derive the following Maxwell relation.

$$\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V$$

- c) Consider an expression for the heat released  $\Delta Q = T \Delta S$  where the entropy  $S = S(T, V)$ .
  - d) Consider a material whose equation of state is  $PV^{10} T^{-5} = \text{constant}$ . The material is initially at atmospheric pressure, has a volume of 0.5 liters and a temperature of 300K. How much heat is released when it is compressed isothermally until its volume is reduced by 1%?
5. A motorcycle engine burns a liter of gasoline every 20 minutes when it does work at a rate of about 6 kW.
    - a) How much heat energy in joules is provided by burning one liter of gasoline? You may assume each gasoline molecule releases 57 eV of energy upon oxidation and has a mass of 114 amu. The mass of one liter of gasoline is 0.7 kg.
    - b) What is the efficiency of the motorcycle engine?