

## Homework Assignment 2

### Practice Solved Problems

- Smith, J. M., Van Ness, H. C., & Abbott, M. M. (2005). Introduction to Chemical Engineering Thermodynamics, 7th ed.
  - Chapter 3: 3.9, 3.11
  - Chapter 4: 4.1, 4.3, 4.8
  - Chapter 5: 5.1, 5.2, 5.3, 5.4

### HW Problems (Due 31st January, 2020)

- [10 points] The coefficient of thermal expansion of mercury at 0°C is  $18 \times 10^{-5} (\text{°C})^{-1}$ . The isothermal compressibility at the same temperature is  $5.32 \times 10^{-6} (\text{bar})^{-1}$ . If the mercury were heated from 0°C to 1°C in a constant-volume system, what pressure would be observed?
- [10 points] Derive an expression for  $(\partial T / \partial V)_S$  for the Redlich-Kwong fluid:

$$p = \frac{RT}{V-b} - \frac{a}{V(V-b)\sqrt{T}} \quad (1)$$

- [10 points] The relationship between the temperature and volume of an adiabatic, reversible expansion of an ideal gas with constant heat capacity is:

$$\frac{T_2}{T_1} = \left( \frac{V_2}{V_1} \right)^{1-\gamma} \quad \text{where } \gamma = \frac{C_p^{ig}}{C_v^{ig}} \quad (2)$$

Derive an expression that relates the temperature and volume for an adiabatic, reversible expansion of an ideal gas for which the ideal gas heat capacity at constant volume is

$$\frac{C_v^{ig}}{R} = A + BT + CT^2 + DT^{-2} \quad (3)$$

This expression may be implicit in temperature [i.e.,  $f(T_1, T_2) = g(V_1, V_2)$ ], but it should not contain integrals or partial derivatives.

- [10 points] Consider a gas under conditions where its behaviour is described by the virial expansion

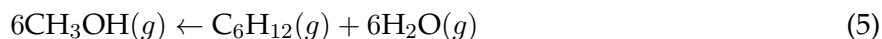
$$Z = \frac{pv}{RT} = 1 + \frac{Bp}{RT} \quad \text{where } B = a - \frac{b}{T^2}, \text{ with } a \text{ and } b \text{ constant} \quad (4)$$

Compute the change internal energy for the gas going, at temperature  $\tau$ , from very low pressure to a pressure  $\pi$ .

- [20 points] The Antoine equation is often used to describe the vapor pressures:  $\ln P^\circ = A - \frac{B}{T+C}$ . For temperatures near the boiling point derive an expression that gives the behaviour of  $\Delta H^{vap}$  as a function of temperature that is thermodynamically consistent with the Antoine equation.
- [20 points] Calculate the entropy change:
  - of the water,
  - of all other bodies,

when 1 g mole of supercooled water freezes at -10°C and 1 atm. Take heat capacity of water and ice as constant at 18 and 9 cal/mol °C, respectively and the latent heat of fusion at 0°C as 1440 cal/mol.

7. [20 points] A rigid adiabatic vessel is divided exactly half internally by a strong diaphragm. On one side, air is present at 300 K and 1 bar; the other side is completely evacuated. The diaphragm breaks and the air expands to fill the entire vessel. What is the entropy change associated with this process?
8. [10 points] Hydrocarbon fuels can be produced from methanol by reactions such as the following, which yields 1-hexene:



Compare the standard heat of combustion at 25°C of  $6\text{CH}_3\text{OH}(g)$  with the standard heat of combustion at 25°C of  $\text{C}_6\text{H}_{12}(g)$  for reaction products  $\text{CO}_2(g)$  and  $\text{H}_2\text{O}(g)$ .

9. [10 points] A particular power plant operates with a heat-source reservoir at 350 °C and a heat-sink at 30 °C. It has a thermal efficiency equal to 55% of the Carnot-engine thermal efficiency for the same temperatures.
- (a) What is the thermal efficiency of the plant?
  - (b) To what temperature must the heat-source reservoir be raised to increase the thermal efficiency of the plant to 35%? Again  $\eta$  is 55% of the Carnot-engine value?
10. [10 points] A rigid vessel of  $0.06 \text{ m}^3$  volume contains an ideal gas,  $C_v = (5/2)R$ , at 500K and 1bar.
- (a) If heat in the amount of 15,000 J is transferred to the gas, determine its entropy change.
  - (b) If the vessel is fitted with a stirrer that is rotated by a shaft so that work in the amount of 15,000 J is done on the gas, what is the entropy change of the gas if the process is adiabatic? What is  $\Delta S_{\text{total}}$ ? What is the irreversible feature of the process?