# Homework Assignment 2

**Practice Solved Problems**

1. 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)**

1. [10 points] The coefficient of thermal expansion of mercury at 0○C is $18\times10^{-5}$ (°C)$^{-1}$. The isothermal compressibility at the same temperature is $5.32\times10^{-6}$ (bar)$^{-1}$. If the mercury were heated from 0°C to 1°C in a constant-volume system, what pressure would be observed?

2. [10 points] Derive an expression for $(\partial T/\partial V)_S$ for the Redlich-Kwong fluid:
$$p = \frac{RT}{V-b} - \frac{a}{V(V-b)\sqrt{T}} \tag{1}$$

3. [10 points] The relationship between the temperature and volume of an adiabatic, reversible expansion of an ideal gas with constant heat capacity is:
$$\frac{T_2}{T_1} = \left(\frac{V_2}{V_1}\right)^{1-\gamma} \qquad \text{where } \gamma = \frac{C_p^{ig}}{C_v^{ig}} \tag{2}$$
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
$$\frac{C_V^{ig}}{R} = A + BT + CT^2 + DT^{-2} \tag{3}$$
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.

4. [10 points] Consider a gas under conditions where its behaviour is described by the virial expansion
$$Z = \frac{pv}{RT} = 1 + \frac{Bp}{RT} \qquad \text{where } B = a - \frac{b}{T^2}, \text{with } a \text{ and } b \text{ constant} \tag{4}$$
Compute the change internal energy for the gas going, at temperature $\tau$, from very low pressure to a pressure $\pi$.

5. [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.

6. [20 points] Calculate the entropy change:
   (a) of the water,
   (b) 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:
$$6\mathrm{CH_3OH}(g) \leftarrow \mathrm{C_6H_{12}}(g) + 6\mathrm{H_2O}(g) \tag{5}$$
Compare the standard heat of combustion at 25°C of $6CH_3OH$ ($g$) with the standard heat of combustion at 25°C of $C_6H_{12}$ ($g$) for reaction products $CO_2$ ($g$) and $H_2O$ ($g$).

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 $m^3$ 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 if adiabatic? What is $\Delta S_{\text{total}}$? What is the irreversible feature of the process?