ECHE 363 – Thermodynamics of Chemical Systems
Homework #5

100 points total. Complete the following problems and upload your solutions to the Canvas assignment dropbox by the due date/time.

You are strongly encouraged to collaborate with your classmates on the homework, but each student is required to come up with a unique solution to the homework problems. For full credit, you must show all work. This includes showing all steps involving algebra and/or calculus. Your calculator can only be used for the final evaluation of numerical answers and may not be used for solving algebraic equations and/or integrals.

1. Consider a cylinder fitted with a piston that contains 2 mol of H_2O in a container at 1000 K. Calculate how much work is required to isothermally and reversibly compress this gas from 10 L to 1 L, in each of the following cases:

    a. Use the ideal gas model for water (Note: for comparison only; this is <u>never</u> a good idea in practice!).

    b. Use the Redlich–Kwong equation of state to relate P, v_m, and T:

$$P = \frac{RT}{v_m - b} - \frac{a}{T^{1/2} v_m (v_m + b)}$$

    where

$$a = 14.24 \text{ [J K}^{1/2} \text{ m}^3/\text{mol}^2\text{]}$$
and
$$b = 2.11 \times 10^{-5} \text{ [m}^3/\text{mol]}$$

    c. Use the steam tables and numerically evaluate the integral for work. See the supplemental notes about numerical integration in the Chapter 4 Module on Canvas. Attach your code or spreadsheet (MATLAB, Excel, or Python) used to perform the numerical integration. This can be a separate attachment from your main assignment in .m .xlsx, or .py format.

    d. Compare these three methods.

2. Your goal is to calculate the annual gross sales of your company's superpure-grade nitrogen and oxygen gases.

    a. The total gross sales of N_2 is 30,000 units. Take the volume of the cylinder to be 43 L, the pressure to be 12,400 kPa, and the cost to be \$6.10/kg. Compare your results using the Redlich–Kwong equation of state to that which you would obtain using the ideal gas model.

    b. Repeat for 30,000 units of O_2 at 15,000 kPa and \$9.00/kg.

3. Consider the Berthelot equation of state below. Show how to calculate the constants a and b using only critical point data.

$$P = \frac{RT}{v_m - b} - \frac{a}{Tv_m^2}$$

    Note: your final answer should be expressed in terms of T_c and P_c because $v_{m,c}$ is typically not tabulated in critical point data tables.

4. Answer the following reflection questions (5 points):

    a. What about the way this class is taught is helping your learning?

    b. What about the way this class is taught is inhibiting your learning?