Assignment #8

Due: Monday Nov. 13, 2000

Individual Exercises:

1. Consider the \( \overline{G}_p(T) \) and \( \overline{G}_f(P) \) plots shown in M&S Figs. 9.10 and 9.11. What restrictions, if any, apply to the slopes and curvatures of such plots?

2. Use the “steam chart” from the Topic 9 handout to estimate the following:
   (a) the mole fraction of liquid water in a 500 L drum containing 5 kg of saturated steam at 150°C.
   (b) the work done and the heat released when steam is compressed isothermally and reversibly at 200 °C between pressures of 0.1 bar and 100 bar.

3. (a) What is the relationship between chemical potential and fugacity?
   (b) M&S 9-38

4. (a) M&S 9-4
   (b) M&S 9-6

5. Nearly all boiling and melting points in the literature are reported as the normal (1 atm) values. The difference between the normal and standard melting points of a substance is completely negligible (Why?). However, the difference between the normal and standard boiling points, although small, may not be negligible for some purposes.
   (a) Using the same approximations that led to Eq. 9.12 in the text, derive the expression:

\[
\frac{\Delta T_b}{T_b} \approx \frac{R}{\Delta_{vap} S} \frac{\Delta P}{P}
\]

(b) Use this expression and Trouton’s rule to obtain an approximate numerical estimate of \( \frac{\Delta T_b}{T_b} \equiv \frac{T_{nb} - T_{ab}}{T_{nb}} \), the relative difference in the normal and standard boiling points, applicable to all substances (at least to within the approximations specified).
   (c) Estimate the standard boiling points of H₂O, CCl₄, and benzene using the data tabulated in the Topic 9 handout. Compare your results to the accurate values of 372.77, 349.34, and 352.89 K determined for these liquids.
5. M&S 9-22 with the following modifications:
   (a) First solve this problem using the exact relation between \((dP/dT)_v\) and \(\Delta_{vap} H\).
   (b) Solve this problem again using the more approximate Clausius-Clapyron relation.
   (c) Calculate the % error in the estimate of part (b) and identify the largest source of error in this approximation.

6. M&S 9-23

Group Problems:

7. (a) M&S 9-10
   (b) M&S 9-11
   (c) A variety of “scaling laws” describe how the properties of a fluid vary as a function of the distance from the critical point. One such law describes the vanishing difference between the coexisting liquid and vapor densities as \((\rho_L - \rho_v) \rightarrow (T_c - T)^\beta\). \(\beta\) in this expression is termed a “critical exponent”. Determine the value of \(\beta\) for ethane using the data provided in M&S 9-10 and assuming that \(T_c = 305.4\) K.

8. Assuming that the formation of liquid water is a requirement for ice skating, and that the pressure-dependence of the freezing point of water is the only mechanism for producing the requisite liquid, estimate the lowest temperature (in °C) ice-skating should be possible. Clearly discuss any assumptions and/or approximations you employ.


10. This problem examines the quality of corresponding states correlations under sub-critical conditions.
   (a) M&S 2-29 (yes, chapter 2).
   (b) You should find a good correlation between \(T_b\) and \(T_c\) in part (a), but you should ask yourself whether this is really corresponding states behavior? (What’s being done with the pressure variable.) Use the perspectives provided by Ch. 9 to rationalize why the correlation is as good as it is.
   (c) Compare \(T_f\) and \(T_c\) in the same manner as in part (a). Note that \(T_f\) provides a good approximation to the triple-point temperature, \(T_{tp}\) in most cases. Explain why this is true and comment on the quality of the corresponding states behavior you observe.