Thermodynamics (PHYS 425/525, APN 525) **Fall 2024**

Extra Credit Project 3 (due on date of Exam II)

(**20 points** undergraduates, **15 points** graduates)

Text problem 5.52 - To clarify what is asked in the problem, I've broken down the problem into multiple parts, and added an additional part c) as well.

a) For the requested isotherm of $T/T_c = 0.95$:, plot the Van der Waals pressure as a function of volume in terms of the reduced quantities. This is similar to your extra credit problem (HW Set 2). From this plot, you can use Maxwell Construction to determine which reduced vapor pressure (horizontal line) can get approximately equal areas under the curves, as described in Fig. 5.21 of the text as well as described / to be described in lecture. ***Hint:*** re-write the van der Waals as a cubic equation and solve for the 3 solutions of *v*. Then use these 3 roots as integration limits to get the areas under the curves.

b) Plot the Gibbs free energy (in units of NkT_c) versus pressure and check that the graph predicts the same vapor pressure, as in part a), i.e.,
check the vertical crossing within the triangle corresponds to the vapor pressure you determine from part a) (as an example, see Fig. 5.21 (left))

When plotting Gibbs free energy versus pressure, it must be done in terms of the reduced variables discussed in Text Problem 5.51, and then factor out NkT_c, and express the Gibbs free energy as : G / NkT_c , which should only be a function of reduced variables, *t* and *v* and an arbitrary constant C(T).
The constant C(T) can be omitted in the plot.

Hint: Starting with Eq. 5.56, express Gibbs free energy G in terms of only reduced variables, and critical constants (Text Problem 5.48), which should end up either cancelling out or being absorbed by the arbitrary constant C(T)

c) Since now you have the machinery (programming code) to determine the vapor pressure from Maxwell construction for a single isotherm, perform the same operation for different isotherms ($T/T_c = 0.85, 0.9, 0.95, 1.0$) to determine the corresponding vapor pressures (from Maxwell construction) at which the gas-liquid transition occurs. Make a plot the vapor pressure determined, P/P_c versus the T/T_c. You should be able to reconstruct the phase boundary, similarly to Fig. 5.23 (right). Also, provide the plot of the overlayed different isotherms in the PV diagram.