Homework assignment #3 for CCB 425/525, Fall 2022

1. One mole of a "van der Waals" gas (not an ideal gas) is compressed quasi-statically and isothermally from volume V_1 to V_2. For a van der Waals gas, the equation of state, giving the pressure, is

$$p = \frac{RT}{V - b} - \frac{a}{V^2},$$

where a and b are postive constants that depend on which gas it is.

   a) Write an expression for the work done in this process.

   b) Is more or less work required than in the low-density limit than for an ideal gas?

   c) Same question as in b), but for the high-density limit.

2. On p. 138 of MDF, you can see the following sentence: "If a process occurs in a test tube held at constant pressure and temperature, it will be at equilibrium when the Gibbs free energy is at a minimum." Write a proof of this statement.

3. The Gibbs free energy G is the fundamental function of the natural variables (T , p, $\mathbf{N}$), but growing biological cells often regulate not the numbers of molecules $\mathbf{N}$, but the chemical potentials μ_i. That is, they control *concentrations*. What is the fundamental function Z of natural variables (T,p,μ)?

4. The heat capacity for liquid n-butane depends on temperature: $C_p(T) = a + bT$, where a = 100 J K^{-1} mol^{-1} and b = 0.1067 J K^{-2} mol^{-1}, from its freezing temperature $T_f \approx 140$ K to $T_b \approx 270$ K, its boiling temperature.

   a) (a) Compute ΔH for heating liquid butane from T_A = 170 K to T_B = 250 K.

   b) (b) Compute ΔS for the same process.

This assignment should be turned in at class on Tuesday, Oct. 4. Please show your work for all problems!