Handin Homework 5: Chapter 7: Heat, Work and the First Law

1. The isothermal compressibility of methanol is 123.5×10^{-6} bar^{-1} at 25°C (Table 7.6.1). What is the change in volume if the pressure is increased from 1.0 bar to 35.0 bar? Assume an initial volume of 1.00 L. Evaluate the result assuming, firstly, for a small change in pressure and, secondly, for a moderate change in pressure (linear term plus a quadratic correction).

2. Burial of CO_2 in impermeable geological formations or in the deep ocean is the most economically feasible method for carbon sequestration. The equation of state of CO_2 under extreme conditions is then an important environmental concern. (a) Calculate the pressure of CO_2 at 304.14 K and a molar volume of 0.09400 L mol^{-1} using the Van der Waals, Redlich-Kwong, and Virial equations of state [with B(304 K) = -0.1182 L mol^{-1} and C(304 K) = 0.0046 L^2 mol^{-2}].[1] These conditions are at the critical point. Use Tables 7.5.2 and 7.5.3 for the Van der Waals and Redlich-Kwong coefficients. (b). The compressibility factor is a good measure of the non-ideality of a gas. Calculate the compressibility factor, $z = PV/nRT$, for CO_2 with the pressures from part (a) for the Van der Waals, Redlich-Kwong, and Virial Equation. (For comparison with your values, note that the literature value for the compressibility factor at the critical point is z = 0.27443.)

3. The upwelling of deep-sea water is caused by large scale ocean currents such as the Atlantic current, which brings warm water north in the Atlantic. This current keeps Western Europe warmer than other areas at similar latitude. As a packet of water rises, the pressure drops, the volume of the packet expands and the system does work. The work is given by: $đw = PV\kappa_T\, dP$ at constant temperature. (a). Derive this relationship. (b). Integrate the differential to obtain the work for a pressure change from P_o to P. Assume the volume remains constant at the initial volume V_o and that κ_T is constant. [Hint: the answer is similar to but not equal to: $w \neq V_o\kappa_T(P - P_o)$ or $w \neq V_o\kappa_T(P - P_o)^2/2$

4. Find the formula for the work done in the reversible isothermal expansion of a Van der Waals gas [i.e. derive the corresponding equation to the ideal gas result, $w = -nRT \ln(V_2/V_1)$, but with extra terms for a Van der Waals gas].

Literature Cited:

1. L. Meng, Y.-Y. Duan, L. Li, "Correlations for second and third virial coefficients of pure fluids," *Fluid Phase Equilibria*, **2004**, *226*, 109–120.