Physics 2700H: Assignment V

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Problem 1. Show that the Joule-Kelvin coefficient is zero for an ideal gas.

Solution 1.

Problem 2. At the critical point, $(\partial P/\partial V)T = 0$ and $(\partial^2 P/\partial V^2)T = 0$. Show that, for a van der Waals gas (see Section 3.5.4), the critical point is at

$$P_c = \frac{a}{27b^2}; V_c = 3nb; T_c = \frac{8a}{27Rb}$$

Solution 2.

Problem 3. Show that the chemical potential of an ideal gas at temperature T varies with pressure as

$$\mu = k_B T \ln\left(\frac{P}{P_0}\right) + \mu_0$$

where μ_0 is the value at reference point of pressure P_0 and temperature T. The gas consists of a single type of particle only. This expression is of great use in chemistry.

Solution 3.

Problem 4. The Sackur-Tetrode equation (similar to Equation 5.11) gives the entropy of an ideal gas as

$$S = Nk_B\left[\ln\left(\frac{V}{N}\left[\frac{4\pi mU}{3Nh^2}\right]^{3/2}\right) + \frac{5}{2}\right]$$

(a) Show that the chemical potential can be written in terms of entropy as

$$\mu = -T\left.\frac{\partial S}{\partial N}\right|_{U,V}$$

(b) Use the result of part (a) along with the fact that $U = (3/2)Nk_BT$ for a monatomic gas to find an expression for the chemical potential as a function of V, N, and T.

(c) Evaluate the result in (b) numerically for helium gas at $T = 298\,\mathrm{K}$ and $P = 1\,\mathrm{atm}$.

(d) Discuss the implications of the fact that your answer in (c) is negative.

Solution 4.