

Phys. 541, Homework Assignment 4

Please pass in your solutions in the 11:45 class on Fri., Nov. 16.

1. (20) Calculate the second virial coefficient for a gas with an intermolecular (or interatomic) interaction potential of the form $U(r) = 0$ for $r > r_1$, $U(r) = -U_0$ for $r_0 \leq r \leq r_1$, and $U(r) = \infty$ for $r < r_0$. This potential involves a square-well attraction for $r_0 \leq r \leq r_1$ together with a “hard core” repulsion that prevents the interparticle distance from being less than r_0 .
2. (20) Consider a (non-ideal, interacting) gas that flows through a tube with thermally insulating walls and passes from a region of higher pressure, p_1 , through a porous plug in the tube to a region of lower pressure, p_2 . Show that this process leaves the enthalpy $U + pV$ of the gas unchanged, where U denotes the internal energy.
3. (20) Show that the change in the temperature of the gas as it passes through the porous plug is determined by

$$\frac{\partial T}{\partial p} = \frac{V(T\alpha - 1)}{C_p} \quad (1)$$

where the derivative is taken at constant enthalpy, and $\alpha = V^{-1}(\partial V/\partial T)_p$ is the coefficient of thermal expansion.

4. (20) Use the expansion of the equation of state in the number density, i.e., the virial expansion, to obtain an approximate expression relating the change in the temperature of the gas as it passes through the plug to the second virial coefficient.
5. (20) Discuss the factors that determine whether this process leads to an increase or a decrease in the temperature of the gas, relating this to the microscopic interaction between the molecules or atoms of the gas.
6. (20) Using our calculation of B_2 for the interaction $U(r) = -U_0/r^6$ for $r > r_0$ and $U(r) = \infty$ for $r < r_0$, derive an analytic estimate for the change in the temperature of the gas as it passes through the plug.