Homework 4

(Due on 1st November, Wednesday)

1. van der Waals equation of state is given by

$$p = \frac{\rho k_B T}{1 - \rho b} - a\rho^2$$

where $\rho \equiv \frac{N}{V}$ is the number density, and k_B is the Boltzmann constant.

(1) Explain the physical meaning for the parameter *a* and *b*.
(2) Write the equation of state in terms of *P* and *V*. Find the relations between their parameters and *a*, *b*.
(3) Use internet to find the values of *a* and *b* for carbon dioxide. Write the units for the values.
(4) Derive the expression of Helmholtz free energy density, chemical potential, and grand potential density for van der Waals equation of state. (Hint: use $F = -\int pdV$ at fixed *T*.
(5) Calculate the critical point of carbon dioxide.
(6) Use any software to sketch the isotherms in $P - \rho$ diagram for carbon dioxide
(7) Varying the temperature *T*, sketch the isotherms in $P - \mu$ diagram for carbon dioxide, where μ is the chemical potential.
(8) Sketch the binodal lines for carbon dioxide.

2. The fundamental equation of internal energy is

$$dU = TdS - pdV + \mu dN$$

Write all the Maxwell's relations for this equation.