

Assignment 2

443 Statistical Physics 2008/2009

Lecturer: Stefan Sint

(due Friday, 14 November 2008 during class)

Problem 1 (6/20 points)

A substance has the following properties:

- At a constant temperature T_0 the work done by it on expansion from V_0 to V is

$$W = RT_0 \ln \frac{V}{V_0}$$

- The entropy is given by

$$S = R \frac{V_0}{V} \left(\frac{T}{T_0} \right)^a$$

where V_0 , T_0 and a are fixed constants.

- Calculate the Helmholtz free energy.
- Find the equation of state.
- Find the work done at an arbitrary constant temperature T .

Problem 2 (6/20 points)

- Calculate the work done by 10 grams of oxygen expanding from 2 liters to 10 liters isothermally at a temperature of 300 K.
- Calculate the difference of specific heats $C_P - C_V$ for the van der Waals gas (see assignment 1). Is this difference larger or smaller than with the ideal gas? Give a physical reason for the result.

Problem 3 (8/20 points)

The van der Waals equation for 1 mol of a gas is

$$\left(P + \frac{\tilde{a}}{V^2}\right)(V - \tilde{b}) = RT. \quad (1)$$

- a) How do the constants \tilde{a} and \tilde{b} relate to a and b of the van der Waals equation as given in assignment 1?
- b) In the $P - V$ diagram the van der Waals equation has extrema at fixed T . Varying T , the extrema lie on a curve in the $P - V$ diagram. Determine the equation of this curve.
- c) Show that this curve has a maximum for

$$V_c = 3\tilde{b}, \quad P_c = \frac{\tilde{a}}{27\tilde{b}^2}, \quad T_c = \frac{8\tilde{a}}{27\tilde{b}R}. \quad (2)$$

This is the so-called critical point.

- d) Express the van der Waals equation through the reduced quantities:

$$\bar{V} = \frac{V}{V_c}, \quad \bar{P} = \frac{P}{P_c}, \quad \bar{T} = \frac{T}{T_c}. \quad (3)$$

- e) Calculate the coefficient of thermal expansion, α , and the isothermal compressibility, κ_T , at $V = V_c$.