CYL100 2013–14 I semester Homework 2

Handed out: August 5, 2013 | Due in: August 9, 2013

1. Consider a well-insulated piston-cylinder assembly. It is well-insulated and on the 0.05 m^2 piston rests two 5000-kg blocks. The initial temperature is 500 K. The ambient pressure is 5 bar. One mole of an ideal gas is contained in the cylinder. The gas is compressed in a process in which another 5000-kg block is added. The heat capacity at constant volume can be taken to have a constant value of $(5/2)R$.
   (a) What are the initial and final pressures of the gas in the system?
   (b) Do you expect the temperature to rise or fall? Explain.
   (c) What is the final temperature?
   (d) Calculate ΔS_{sys} and ΔS_{surr}.
   (e) Does this process violate the second law of thermodynamics? Explain.

2. For the process given in the problem above, calculate ΔS_{sys} using each of the following paths:
   (a) a reversible, adiabatic compression, followed by a reversible, isothermal expansion
   (b) a reversible, isobaric heating followed by a reversible, isothermal compression
   (c) a reversible, isochoric heating followed by a reversible, isothermal compression

3. A salesperson claims that a mysterious black box, with no moving parts, can take an inlet stream of ideal gas at 2 kg/s and 4 bar and 50 ℃ and cool 0.5 kg/s of it to −10 ℃ and 1 bar while the rest of the gas is raised to 70 ℃ at 1 bar. Is this possible? Explain.

4. Calculate the maximum work and the maximum non-expansion work that can be obtained from the freezing of supercooled water at −5 ℃ and 1.0 atm. The densities of water and ice are 0.999 and 0.917 g cm^{-3}, respectively at −5 ℃.

5. One mole of He is heated from 200 ℃ to 400 ℃ at a constant pressure of 1 atm. Given that the absolute entropy of He at 200 ℃ is 810 JK^{-1} mol^{-1}, and assuming He is a perfect gas, comment on the spontaneity of the process.

6. Derive the relations: (i) $C_p - C_v = T\left(\frac{\partial P}{\partial T}\right)_V\left(\frac{\partial V}{\partial T}\right)_P$; (ii) $C_p - C_v = \frac{\alpha^2 TV}{\beta}$; (iii) $\mu_{JT} = -(V/C_p)(\beta C_v\mu_J - \beta P + 1)$ (iv) $\left(\frac{\partial H}{\partial V}\right)_S = \gamma/\beta$ (v) $\left(\frac{\partial V}{\partial T}\right)_P = \frac{C_V\beta}{T\alpha}$.

7. (a) Calculate the change in the chemical potential of a perfect gas when its pressure is increased isothermally from 1.8 atm to 29.5 atm at 40 ℃. (b) The molar Gibbs energy of a certain gas is given by
$$G_m = RT\ln p + A + Bp + \frac{1}{2}Cp^2 + \frac{1}{3}Dp^3$$
where A, B, C, D are constants. Obtain the equation of state of the gas.

8. At 1 atm the $S_{rh} \to S_{mon}$ transition takes place at 95.5 ℃, and the melting point of S_{mon} is 119.3 ℃. The latent heat of the rhombic to monoclinic transition is 1.16 x 10^4 J kg^{-1} and the latent heat of fusion of S_{mon} is 5.53 x 10^4 J kg^{-1}. The densities of rhombic, monoclinic, and liquid sulphur are 2.07 x 10^3, 1.96 x 10^3, 1.90 x 10^3 kg.m^{-3}. Estimate the rhombic, monoclinic, and liquid triple point.

9. The vapor pressure of zinc varies with temperature as
$$\log p(mmHg) = -\frac{6850}{T} - 0.755\log T + 11.24$$
and that of liquid zinc as
$$\log p(mmHg) = -\frac{6620}{T} - 1.255\log T + 12.34.$$
Calculate (a) the boiling point of zinc, (b) the triple point, (c) the heat of evaporation at the boiling point, (d) the heat of fusion, and (e) the difference in the C_ps of solid and liquid zinc.

10. The Planck function defined as
$$Y = -\frac{H}{T} + S$$
is a thermodynamic potential similar to the Gibbs energy. Obtain a "TdS" type equation for dY and from it a Maxwell relation. Also, what is the thermodynamic criterion for spontaneity in terms of Y.

11. It is often claimed that one can skate on ice because the pressure of the skate causes the ice to melt, thus dramatically reducing the friction between skate and ice. While this makes a good story, is this quite correct? Consider a skater with a mass of 75 kg on a skate that is 3 mm wide and 20 cm long. The densities of water and ice are 0.999 and 0.917 g cm^3 respectively, and the heat of fusion is 6.004 kJ mol^{-1}. Since common experience is that ice skating is possible even when the ambient temperature is well below the normal freezing point, does the pressure induced lowering of the melting point explain clearly this observation?