Department of Chemical Engineering	ChE 110A
University of California, Santa Barbara	Winter 2011

Problem Set No. 3

Due: Wednesday, January 19, 2011

Objective: To understand and perform calculations using the First Law of Thermodynamics, and to assess system energy flows in closed systems.

Note: Numerical values for some problems have been changed from those in the book.

Problem 7 (thought problem)

A friend claims that the work required to compress steam, in general, can be evaluated by looking up enthalpy and other property values before and after the compression in tables (e.g., the steam tables at the back of your book). What is wrong with this assessment? What if the compression is known to be isobaric, specifically?

Problem 8 (*Smith, van Ness, Abbott, 2.8, page 57)*

A closed, nonreactive system contains species 1 and 2 in vapor/liquid equilibrium. Species 2 is a very light gas, essentially insoluble in the liquid phase. The vapor phase contains both species 1 and 2. Some additional moles of species 2 are added to the system, which is then restored to its initial *T* and *P.* As a result of the process, does the total number of moles of liquid increase, decrease, or remain unchanged? Explain your reasoning.

Problem 9 (*Smith, van Ness, Abbott, 2.5, page 56)*

One mole of gas in a closed system undergoes a four-step thermodynamic cycle between equilibrium states 1, 2, 3, and 4. Use the data given in the following table to determine numerical values for the missing quantities, i.e., "fill in the blanks."

Step	ΔU^t / J	Q / J	W / J
12	-300	?	-1100
23	?	-2100	?
34	?	0	500
41	3000	?	?
12341	?	?	800

Problem 10 (*Smith, van Ness, Abbott, 2.30, page 60)*

In the following take $C_V = 20.8$ and $C_P = 29.1 \text{ J mol}^{-1} \text{ °C}^{-1}$ for nitrogen gas:

(a) Five moles of nitrogen at 35 °C, contained in a rigid vessel, is heated to 240 °C. How much heat is required if the vessel has a negligible heat capacity? If the vessel weighs 75 kg and has a head capacity of $0.5 \text{ kJ kg}^{-1} \text{ °C}^{-1}$, how much heat is required?

(b) Three moles of nitrogen at 210 °C is contained in a piston/cylinder arrangement. How much heat must be extracted from this system, which is kept at constant pressure, to cool it to 30 °C if the heat capacity of the piston and cylinder is neglected?

Problem 11 (*Smith, van Ness, Abbott, 2.32, page 60)*

(a) Find the equation for the work per mole of a reversible, isothermal compression of a gas in a piston/cylinder assembly if the molar volume of the gas is well-described by,

$$V = \frac{RT}{P} + b$$

where b is a positive constant.

(b) The gas in part (a) is subjected separately to two isothermal processes that both begin with the system at T_1, P_1. In each, the gas' volume is halved by means of application of an external compressive force. In the first process, the force is applied very slowly. In the second, it is applied rapidly and almost instantaneously. Find expressions for the work per mole of these two processes in terms of R, b, P_1, and T_1. Which is greater?

Problem 12 (*Smith, van Ness, Abbott, 2.36, page 61)*

One kilogram of air is heated reversibly at constant pressure from an initial state of 50 °F and 1 atm until its volume triples. Calculate $W, Q, \Delta U$, and ΔH for the process, in Btu or $Btu/(lb \cdot mol)$ as appropriate. Assume that air is ideal and has $C_P = (7/2)R$. Hint: tables A.1, A.2, and B.1 in the book may be helpful.