Department of Mechanical Engineering

Spring 2010 Ph.D. Qualifying Exam

Thermodynamics

Instructions:

• A calculator is permitted for this exam

• A set of thermodynamic tables is provided for this exam

• No other books, notes, or equation sheets are allowed

• All problems are required and are weighted equally

Honors pledge: “I have neither given nor received aid on this examinations.”

Sign here: _____________________________ (use your assigned identifier number)
**Problem 1.**

One mole of $N_2$, initially at 1 bar, 300 K, and 1 mole of $O_2$, initially at 1 bar, 600 K, are confined to opposite sides of a rigid, well-insulated container, as shown below. The gases are initially separated by a partition. Consider the following two cases:

a. Heat transfer occurs through the partition so that the gases in the container reach a uniform temperature.

b. The partition is removed and the gases mix to reach a uniform temperature and composition.

Determine:

1. The uniform temperature for both cases.
2. The entropy generation for both cases.

Model both gases as ideal gas with constant specific heats ($c_P=3.5R$ and $c_v=2.5R$, where $R=8.314 \text{ J/(mol*K)}$ is the universal gas constant), and model the mixture as an ideal gas mixture for case b.
Problem 2.
For the following three-parameter equation of states:

\[ p = \frac{RT}{v - b} - \frac{a}{v^2 - c^2} \]

evaluate the parameters \((a, b, \text{ and } c)\) in terms of the critical pressure \(p_c\), critical temperature \(T_c\), and critical compressibility \(Z_c\).
Problem 3.
At a pressure of 1 atm, liquid water has a state of maximum density at 4°C. Determine the sign of \( \frac{\partial s}{\partial p} \) \( T \) (i.e., zero, positive, or negative) for liquid water at 1 atm and the following temperatures:

(a) 3.5 °C?
(b) 4°C?
(c) 4.5 °C?
Problem 4.
A closed vessel contains CO$_2$ initially at 360K, 740bar. The fluid is then cooled with 100kJ of heat removal and unspecified work to 240K, 75bar. Determine the change in entropy in units of kJ/kg.K.
Problem 5.
1 kmol of N₂O₄ undergoes a dissociation reaction to form an equilibrium mixture of N₂O₄ and NO₂ at 25°C, 1.5atm. Assuming ideal gas behavior, determine the final equilibrium molar compositions of the N₂O₄ and NO₂. The change in the Gibbs function for the dissociation reaction at 25°C is ΔG° = 5400kJ/kmol.