CLEMSON UNIVERSITY

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)

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Problem 1.

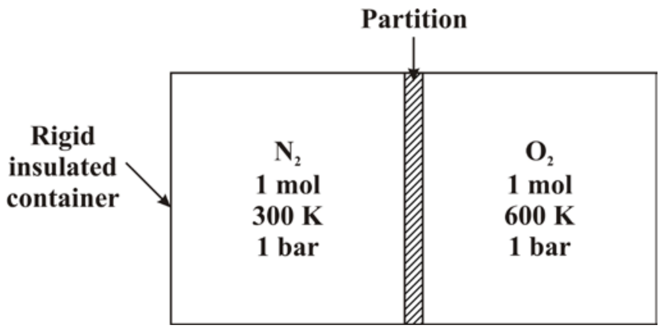
One mole of N_2, initially at 1 bar, 300 K, and 1 mole of O_2, initially at 1 bar, 600 K, are confined to opposite sides of a rigid, well-insulated container, as shown below. The gases are initially separated by a partition. Consider the following two cases:

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 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, 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 $\left(\partial s/\partial p\right)_T$ (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 N_2O_4 undergoes a dissociation reaction to form an equilibrium mixture of N_2O_4 and NO_2 at 25^0C, 1.5atm. Assuming ideal gas behavior, determine the final equilibrium molar compositions of the N_2O_4 and NO_2. The change in the Gibbs function for the dissociation reaction at 25^0C is ΔG^0=5400kJ/kmol.