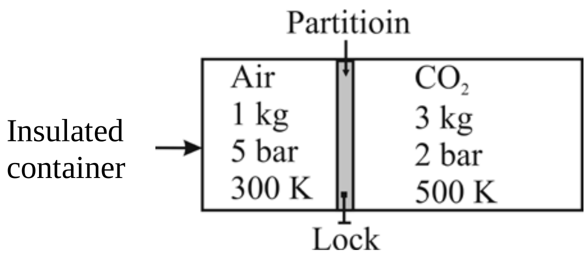
INSTRUCTIONS: You have two hours to complete the following four thermodynamics problems. You may use a calculator in this exam. A set of tables is provided, but other than this, the exam is closed book and closed notes.

(1) Separate streams of carbon dioxide and oxygen in a 1:2 (1 CO_2 : 2O_2) molar ratio enter a reactor operating at steady state. The CO_2 enters at 1atm and 400 K, and the O_2 enters at 1atm and 550 K. An equilibrium mixture of CO_2, CO, and O_2 is formed by the dissociation reaction $CO_2 \leftrightarrow CO + \frac{1}{2} O_2$ and exits the reactor at 1atm. If the mole fraction of CO in the exiting stream is 0.1, determine the temperature of the exiting stream.

(2) One kilogram of air, initially at 5 bar, 300 K, and 3 kg of carbon dioxide (CO_2), initially at 2 bar, 500 K, are confined to opposite sides of a rigid, well-insulated container, as shown below. Both gases behave as an ideal gas with constant specific heats. When unlocked, the partition is free to move and allows heat conduction from one gas to another without energy storage in itself. The volume of the partition is negligible.

Now the partition is unlocked, and the air and CO_2 reach an equilibrium state. Determine the entropy generation during this process.

The molecular weight of air is 29 g/mole, and of CO_2 is 44 g/mole. The specific heat under constant volume (c_V) is 726 J/(kg*K) for air and 750 J/(kg*K) for CO_2; and under constant pressure (c_P) is 1000 J/(kg*K) for air and 940 J/(kg*K) for CO_2.



(3) The van der Waals equation of state is:

$p = (\bar{R}T)/(\bar{v}-b) - (a)/(\bar{v}^2)$

where $\bar{R}$ and $\bar{v}$ are the molar values of the ideal gas constant and the specific volume, respectively. Using your knowledge of the behavior of p versus $\bar{v}$ for a substance at the critical temperature, derive equations for the constants a and b in the van der Waals equation.

(4) A heat pump maintains a dwelling at a temperature T when the outside temperature is 5°C. The heat transfer rate through the walls and roof is 2000 kJ/hr per degree of temperature difference between the inside and outside. If electricity costs 8 cents per hW•hr. Determine the minimum theoretical operating cost for each day of operation when T = 20°C.