**CM 3230**
**Fall 2016**
**Exam 1**

**Name** ________________________________________

1. (20 pts) A rigid vessel contains two compartments of the same volume separated by a thin membrane and is in equilibrium with the surrounding temperature, $T_{init} = T_{surr} = 25°C$. One compartment contains 10 moles of ideal gas $A$, having a heat capacity $c_{P,A} = 3.2R$, while the other compartment contains 15 moles of ideal gas $B$, having a heat capacity $c_{P,B} = 1.5R$. Afterwards, the membrane ruptures and both gases mix completely, settling to one pressure and to the same surrounding temperature, $T_{final} = T_{surr} = 25°C$. Calculate the total change in entropy of the universe ( in $kJ/K$) ) from the point before rupture to the point where it equilibrates to the final pressure and temperature.

2. (40 pts) An engine containing an ideal gas having molar heat capacity $c_P = 3R/2$ operates with a cycle shown in Figure 1. At point $a$, the gas expands isobarically at $P_a$ to point $b$. Then it expands adiabatically from point $b$ to point $c$ where the pressure is at point $c$ is given by $P_c = 2P_b/3$. Afterwards, it is compressed isobarically to point $d$. Finally, it is compressed adiabatically back to point $a$. All the paths are assumed to be reversible. The temperatures at points $a$ and $c$ were measured to be $T_a = 110°C$ and $T_c = 250°C$. Calculate the net work done by each mole of the gas (in $kJ/mol$) for one cycle and the molar heat input to the gas (in $kJ/mol$) as it expands from point $a$ to point $c$.

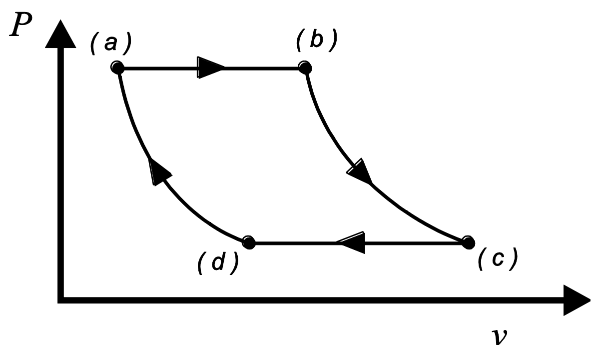


Figure 1. Engine cycle with paths $a \rightarrow b$ and $c \rightarrow d$ reversible isobaric, while paths $b \rightarrow c$ and $d \rightarrow a$ are reversible adiabatic.

*(**Note:** More questions on the back page. )*

3. (20 pts) A refrigerant with quality $x_{in} = 0.2$ flows adiabatically through the throttle from $P_{in} = 3\ bars$ and $T_{in} = 80°C$ to $P_{out} = 2.5\ bars$ and $T_{out} = 60°C$. Calculate the specific entropy change (in $kJ/(kg \cdot K)$) of the refrigerant as it undergoes the throttling process using the following data (based on a common reference condition):

Data: 1) @ $(T_{in}, P_{in})$:

$$\hat{h}_{in,vap} = 2824 \frac{kJ}{kg} \quad ; \quad \hat{s}_{in,vap} = 7.52 \frac{kJ}{kg \cdot K}$$

$$\hat{h}_{in,liq} = 450.7 \frac{kJ}{kg} \quad ; \quad \hat{s}_{in,liq} = 1.44 \frac{kJ}{kg \cdot K}$$

2) @ $(T_{out}, P_{out})$:

$$\hat{h}_{out,vap} = 2550 \frac{kJ}{kg} \quad ; \quad \hat{s}_{out,vap} = 8.31 \frac{kJ}{kg \cdot K}$$

$$\hat{h}_{out,liq} = 90.3 \frac{kJ}{kg} \quad ; \quad \hat{s}_{out,liq} = 0.687 \frac{kJ}{kg \cdot K}$$

4. An ideal gas of $c_p = 3R/2$ inside a piston-cylinder undergoes a sudden pressure drop from initial pressure $P_{init}$ to a constant external pressure $P_{ext}$ causing an irreversible expansion of the gas. The final pressure is $P_{final} = (0.4\ P_{init}) = P_{ext}$ and $T_{final} = T_{surr}$. The expansion ratio was also found to be $\hat{v}_{final}/\hat{v}_{init} = 3$.
   a) (20 pts) Evaluate the molar change in entropy of the gas during the expansion process in $J/(mol \cdot K)$.
   b) (Bonus: 5 pts) Will $T_{final} > T_{init}$ or $T_{init} > T_{final}$? Explain using equations.