AUIS ENGR 352 (Thermodynamics), Assignment III

Submission deadline:[1] April 10, 2018

Tutorial discussion: April 19 and 22, 2018

1) An amount of n = 2 mol of a pure fluid is heated reversibly at constant pressure, which is ambient pressure p = 101.3 kPa. The initial temperature is T_1 = 300 K, the final temperature is T_2 = 450 K. Determine the change in molar entropy $s_2 - s_1$ of the fluid for each of the following two cases a) and b), where this transition is applied to two different fluids:

a) Carbon dioxide, assuming that c_p = 40.5 J K^{-1} mol^{-1} is approximately constant.
b) Ideal gas ethylene, assuming $c_p = \alpha T + c_0$ for α = 0.1 J K^{-2} mol^{-1} and c_0 = 13.1 J K^{-1} mol^{-1}.

2) In an air-conditioning system, dry air flows over tubes carrying refrigerant R134a. The air is cooled by transferring heat to the R134a; the air enters with a volume flow rate of 0.75 m^3 s^{-1} at 305 K and 100 kPa, and it exits at 290 K and 95 kPa. The R134a enters at 4 bar in a vapor-liquid coexistence state with a quality of 20%; it exits at 4 bar and 30 °C.

Ignoring heat transfer at the outer surface of the air conditioner, neglecting kinetic and potential energy changes, and assuming a steady state, determine **a)** the mass flow rate of R134a and **b)** the rate of heat transfer between the air and the R134a. Use the available tables, diagrams, and other reliable sources to obtain required thermodynamic data.

3) The following saturated liquid and vapor densities ρ^I and ρ^{II} are given for a pure fluid:

T = 80 °C:	ρ^I = 1170 kg m^{-3}	ρ^{II} = 44 kg m^{-3}	p^{sat} = 790 kPa
T = 90 °C:	ρ^I = 1133 kg m^{-3}	ρ^{II} = 57 kg m^{-3}	p^{sat} = 1010 kPa
T = 100 °C:	ρ^I = 1093 kg m^{-3}	ρ^{II} = 73 kg m^{-3}	p^{sat} = 1260 kPa
T = 110 °C:	ρ^I = 1049 kg m^{-3}	ρ^{II} = 93 kg m^{-3}	p^{sat} = 1570 kPa

Plot the cubic density difference $(\rho^I - \rho^{II})^3$ over T. Extrapolate for $(\rho^I - \rho^{II})^3 \to 0$. What value do you expect for the critical temperature, where the deviation between ρ^I and ρ^{II} goes to zero?

4) The specific entropy of a pure ideal gas is given by the differential form of the Sackur-Tetrode equation, i.e., $ds = Rv^{-1}dv + c_vT^{-1}dT$, wherein $v^{-1}dv$ can also be written as $d\ln v$ and $T^{-1}dT$ can also be written as $d\ln T$. Relating ds to dv and dT, this is a total differential for $s(v, T)$ as a function of v and T. However, s can be given as a function of any combination of two intensive quantities, e.g., pressure and enthalpy. Based on general relations between ideal gas properties, give a total differential for $s(p, h)$, relating ds to dp and dh.

5) Ideal gas ethylene undergoes a reversible adiabatic compression by which its temperature increases from T_1 = 300 K to T_2 = 450 K. The molar entropy in the initial state is given as s_1 = 100 J K^{-1} mol^{-1}, and here, for ethylene, $c_p = \alpha T + c_0$ with α = 0.1 J K^{-2} mol^{-1} and c_0 = 13.1 J K^{-1} mol^{-1}. Determine the change of the molar entropy $s_2 - s_1$ and the change of the chemical potential $\mu_2 - \mu_1$ for the fluid during this process.

6) In a reversible Carnot heat engine which operates between reservoirs at T_{high} = 500 K and T_{low} = 300 K with a net power output of 600 W, methane gas is used as working fluid. Methane can be considered here as an ideal gas with M = 16.043 g mol^{-1}, and average heat capacities c_v = 4 R and c_p = 5 R. The cycle operates in a steady state with a substance flow rate of 0.375 mol s^{-1}. Before the isothermal expansion (transition 1 → 2, at $T_1 = T_2 = T_{high}$), i.e., after the adiabatic compression (transition 4 → 1, from $T_4 = T_{low}$ to $T_1 = T_{high}$), the working fluid has a molar entropy given by s_1 = 120.0 J K^{-1} mol^{-1}.

The Sackur-Tetrode equation, in differential form, is given by $ds = Rv^{-1}\,dv + c_vT^{-1}\,dT$.

a) What is the thermal efficiency of this reversible power cycle?
b) Draw a T–s diagram with the four transitions and the four states of the cycle.
c) Beside s_1, which is given, determine the molar entropy s_2, s_3, s_4 for the other three states.

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1 *Each problem contributes up to one credit to the overall grade. Submissions, individually or in groups of two, can be handed in on April 10 (at lecture time only), or deposited in the B-F2-01 mailbox by April 9.*