10.213 Chemical Engineering Thermodynamics
Spring 2002
Exam 2

Problem 1 (35 points)
High pressure steam (stream 1) at a rate of 1000 kg/h initially at 3.5 MPa and 350 ºC is expanded in a turbine to obtain work. Two exit streams leave the turbine. Exiting stream 2 is a 1.5 MPa and 225 ºC and flows at 100 kg/h. Exiting stream 3 is at 0.79 MPa and is known to contain a mixture of saturated vapor and liquid. A (negligible) fraction of stream 3 is bled through a throttle value to 0.10 MPa and is found to be 120 ºC (stream 4). The measured output of the turbine is 100 kW.

a) Determine the temperature and quality of stream 3.
b) Determine the rate of heat transfer into or out of the turbine during its operation.

Problem 2 (30 points; 4 points for each except 6 points for e)
The following questions use the attached P-H diagram for CO_2.
a) Determine the critical temperature and pressure for CO_2.
b) Determine the temperature and pressure of CO_2 at its triple point.
c) Estimate the residual enthalpy for CO_2 at 1000 psia and 180 ºF *using the provided P-H diagram*. Generalized correlations should not be used.

A flow process produces CO_2 as 75 mol % liquid CO_2 and the rest vapor at 60 ºF for use in fire extinguishers. In this process, CO_2 at 20 psia and 60 ºF is compressed in two steps: first to 100 psia and then to its final pressure. The gas is cooled to 60 ºF before entering the second compressor. The compressors both operate adiabatically and reversibly.
d) Draw a scheme for this process in your blue book and note its path on the included P-H diagram for CO_2. Number the various streams using the same numbering.
e) Estimate the amount of work required in the process and the required cooling.
f) If the two compressors had efficiencies less than 1, would the i) amount of required work and ii) the amount of required cooling increase, decrease or stay the same as in e)?
g) If a liquid CO_2 fire extinguisher (75 mol % liquid CO_2 and the rest vapor) stored at 60 ºF is discharged at atmospheric pressure (14.7 psia), what phases are generated and what is the dominant phase?

Problem 3 (35 points)
A household refrigeration unit using tetrafluoroethane as refrigerant includes two compartments: the freezer section (colder) and the refrigerator section (less cold). To generate regions of two temperatures, the unit incorporates <u>two</u> throttle valves. Consider a refrigeration unit where the freezer temperature is –20 ºF, the refrigerator temperature is 40 ºF, and the condensation temperature for exchanging heat into the room is 100 ºF. The compressor operates with an efficiency of 0.5.

a) In your blue book, draw the process and number all streams.
b) On the included P-H diagram, draw the process assuming that two-third of the heat is absorbed in the freezer section and the remainder in the refrigerator section. Number the various streams using the same numbering as in a).
c) What are the highest and lowest temperatures in the process?