10.213 Chemical Engineering Thermodynamics
Spring 2002

Problem Set F
Due Friday, March 22, 2002 in lecture

Reading Assignments from SVN&A:

Mon 3/11:	6.2-6.6
Wed 3/13:	6.2, 6.7
Fri 3/15:	2.12, pg 257-273
Mon 3/18:	8-8.1
Wed 3/20:	
Fri 3/22:	8.2
Mon 4/1:	9-9.5

Note: In reporting thermodynamic quantities obtained from graphs, charts, and/or tables on your problem sets and tests, please note the relevant conditions. As an example: a solution might note "steam at T_1 = 300 °C and P_1 = 100 kPa, H_1 = 3074.5 kJ/kg (steam table)." Incorrect values that cannot be tracked down will receive no partial credit.

Problem 20

Five moles of calcium carbide are combined with 10 moles of liquid water in a closed, rigid, high-pressure vessel of 750 mL capacity. Acetylene gas is produced by the reaction:

$$CaC_2\ (s) + 2\ H_2O\ (l) \rightarrow C_2H_2\ (g) + Ca(OH)_2\ (s)$$

Initial conditions are 25 °C and 1 bar, and the reaction goes to completion. For a final temperature of 125 °C, determine the final pressure in the chamber and the heat transferred. At 125 °C, the molar volume of $Ca(OH)_2$ is 33.0 cm^3/mol. Ignore the effect of any gas present in the tank initially.

Problem 21

a) A rigid vessel of 2-m^3 capacity contains 0.02 m^3 of liquid water and 1.98 m^3 of water vapor at 101.33 kPa. How much heat must be added to the contents of the vessel so that the liquid water is just evaporated?
b) A turbine operates adiabatically with superheated steam entering at 45 bar and 400 ºC. If the exhaust steam must be "dry", what is the minimum allowable exhaust pressure for a turbine efficiency of 0.75? What would be the work output for the turbine? Suppose the efficiency was 0.80. Would the minimum exhaust pressure be higher or lower? Explain.

Problem 22

Ammonia is compressed from 21 ºC and 200 kPa to 1 MPa in an adiabatic compressor with an efficiency of 0.82. Estimate the final temperature, the work required, and the entropy change of the ammonia

a) By generalized correlations
b) By use of http://webbook.nist.gov/chemistry/fluid/

Problem 23

Steam enters the turbine of a power plant operating on the Rankine cycle at 3,300 kPa and exhausts at 50 kPa. Determine the thermal efficiency of the cycle and the quality of the exhaust stream from the turbine for turbine-inlet stream temperatures of:

a) 400 °C if you last name begins with A-D
b) 500 °C if your last name begins with E-L
c) 600 °C if your last name begins with M-Z
d) For all: Suggest whether an increase in the turbine inlet stream temperature produces an increase or decrease in
   i) the thermal efficiency and
   ii) the quality of the exhaust stream exiting the turbine
e) For all: If the turbine had an efficiency of 0.80, determine its impact on the thermal efficiency of the process at your temperature and its effect on the sizing of equipment (the boiler, condenser, etc.).

Additional Practice Problem (not to be handed in)

Practice Problem P8

a) A stream of water at 85 ºC, flowing at a rate of 5 kg/s, is formed by mixing water at 24 ºC with saturated steam at 0.4 MPa. Assuming adiabatic operation, at what rates are the steam and water fed to the mixer?
b) A 2 m^3 tank initially contains a mixture of saturated-vapor steam and saturated-liquid water at 3 MPa. Of the total mass, 10% is vapor. Saturated-liquid water is bled from the tank through a valve until the total mass in the tank is 40% of the initial total mass. If during the process, the temperature of the contents of the tank is kept constant, how much heat is transferred?

Practice Problem P9

Propane at 100 ºC is compressed isothermally from an initial pressure of 1 bar to a final pressure of 10 bar. Estimate ΔH and ΔS.

Practice Problem P10

Methane is compressed adiabatically from 3,500 kPa and 35 °C to 5,500 kPa at the rate of 1.5 kg-mol/s. If the compressor efficiency is 0.78, what is the power requirement of the compressor and what is the discharge temperature of the methane? A PH diagram for methane is included in SVN&A on page 761.