

**10.213 Chemical Engineering Thermodynamics**  
**Spring 2000**  
**Test 2**

March 29, 2000

Open Book/Open Notes  
55 minutes

Instructions

Put Problem 1 and your P-H diagram for ethylene in Book 1; put Problems 2 and 3 in Book 2  
For values obtained from tables or charts, note explicitly the relevant conditions of interest used  
(for example,  $P = ?$  and  $T = ?$  or for  $P_r = ?$  and  $T_r = ?$ ).  
(Hint: Begin each problem by drawing a flow sheet for each process)

Problem 1 (45 points)

In a process that produces a liquefied stream of ethylene at 15 bar, a low pressure gas at 1 bar and 25 °C (1) is first compressed to 15 bar and outputs at 220 °C (2). This gas is cooled to 50 °C at constant pressure (3) before being compressed to 100 bar (4). This stream exits at 240 °C and is then cooled to a temperature below 100 °C (5). The high pressure, cooled gas proceeds through a throttle valve to produce a stream at 15 bar that is 30 % liquid ethylene (6). The vapor stream is recycled into the process.

- a) Draw the process on the enthalpy-pressure diagram for ethylene using (1-6) for the various states. Your process should start with ethylene at 1 bar and 25 °C and end with liquid and vapor streams at 15 bar. (Please put your name on this diagram and submit it with Book 1 for your test.) (15 points)
- b) For the compression of ethylene from 1 bar and 25 °C to 15 bar and 220 °C, what is the efficiency of the compressor? (10 points)
- c) How much cooling (kcal/kg) is required before the gas enters the throttle valve? (10 points)
- d) What are the temperatures of the gas as it i) enters (with 5 °C) and ii) exits (within 2 °C) the throttle valve? (10 points)

Problem 2 (25 points)

A steam power plant operates on the Rankine cycle. In this process, 145 lb<sub>m</sub>/s of liquid water at 950 psia is heated by a combusted fuel to 1000 °F, requiring an input of 192,800 BTUs. This superheated gas enters a turbine ( $\eta = 0.78$ ) at 950 psia and exits at 14.7 psia.

- a) Determine the work produced by the turbine in BTUs. (20 points)
- b) If the work required by the pump is 3.9 BTU/lb<sub>m</sub>, determine the overall efficiency of the power plant. Note: if you could not solve part a), you may assume that the work generated by the turbine was 400 BTU/lb<sub>m</sub>. (10 points)

Problem 3 (30 points)

Propane gas undergoes a change in state from an initial condition of 4.25 bar and 25 °C to 34 bar and 100 °C. Using generalized correlations, determine the value of  $\Delta S$  for this change of state.

The molar heat capacity of propane in the ideal state is given by

$$C_p^{ig} \text{ (cal/mol-K)} = 5.49 + 0.0424 T \text{ (°K)}.$$

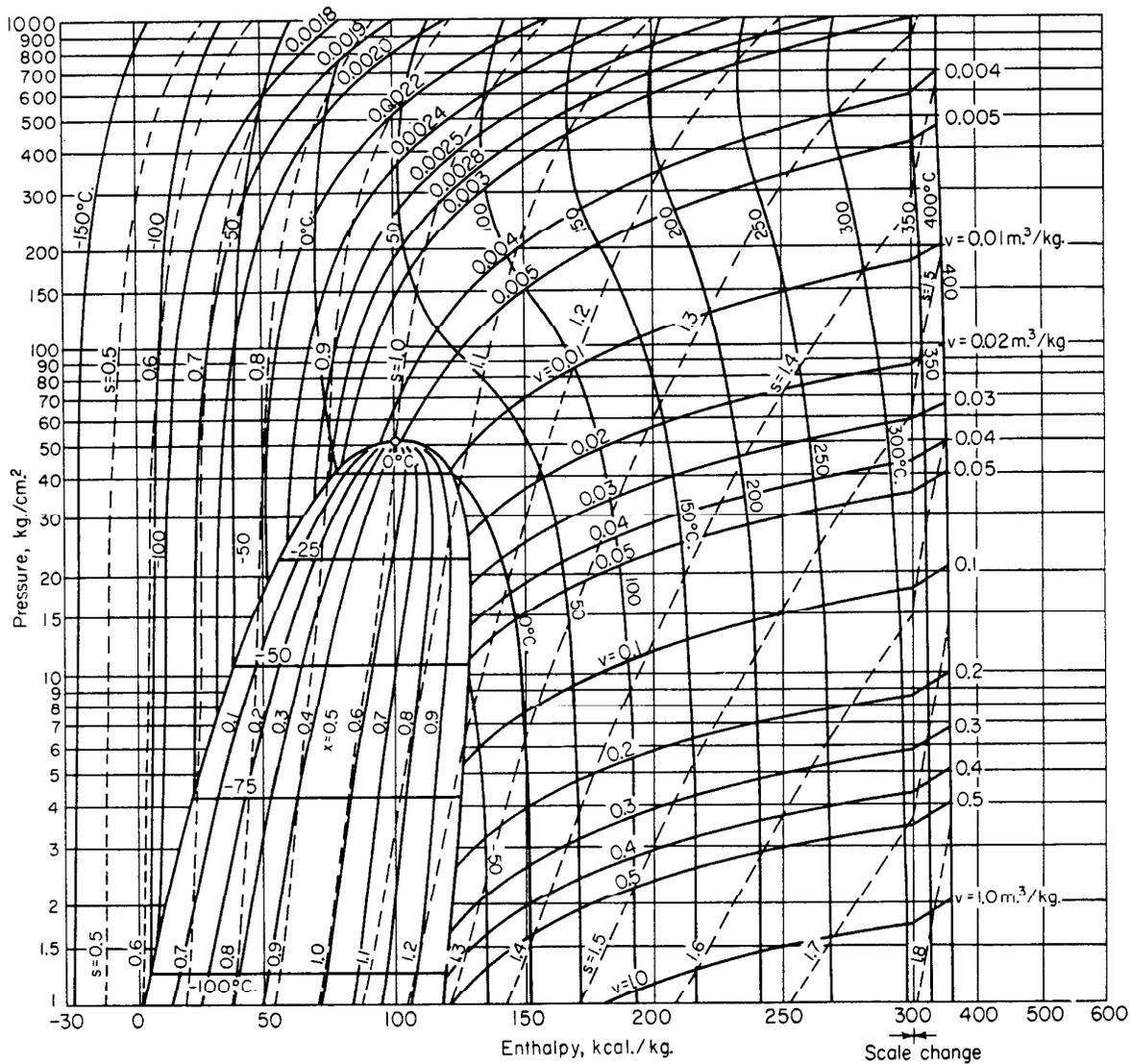


FIG. 3-23 Enthalpy-pressure diagram for ethylene. [From Benzler and Koch, Chem. Ing. Tech., 27, 71 (1955). Copyright Verlag Chemie GmbH, Weinheim, Bergstrasse, Germany.]

**10.213 Chemical Engineering Thermodynamics  
Spring 1999**

**Test 2**

March 31, 1999

Open Book/Open Notes  
55 minutes

Instructions

Put Problem 1 and your P-H diagram for CF<sub>4</sub> in Book 1; put your name on the submitted P-H diagram for CF<sub>4</sub>. Put Problems 2 and 3 in Book 2

For values obtained from tables or charts, note explicitly the relevant conditions of interest used (for example, P = ? and T = ? or for P<sub>r</sub> = ? and T<sub>r</sub> = ?).

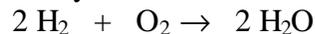
(Hint: Begin each problem by drawing a flow sheet for each process)

Problem 1 (30 points)

- a) Saturated CF<sub>4</sub> vapor at -220 °F is compressed isentropically to 900 psia. Determine the temperature of the resulting CF<sub>4</sub> gas stream and the required work. (10 points)
- b) An inventor claims a process that uses a stream of CF<sub>4</sub> at 100 psia and 200 °F as input and produces two streams of CF<sub>4</sub> at 10 psia and -20 °F and at 10 psia and 310 °F. Provide a thermodynamic analysis that validates (or invalidates) the claim. (20 points)

Problem 2 (40 points)

- a) Steam at 225 °C and 300 kPa exits a turbine as a saturated vapor at 50 kPa. Determine the efficiency of the turbine. If steam at 225 °C and 300 kPa instead exited a throttle valve at 50 kPa, would the exiting fluid contain both liquid and vapor or be superheated? Determine the efficiency for this process. (20 points)
- b) Hydrogen and oxygen in a 2:1 molar ratio at 1 atm and 25 °C are combusted to completion to produce water by the reaction:



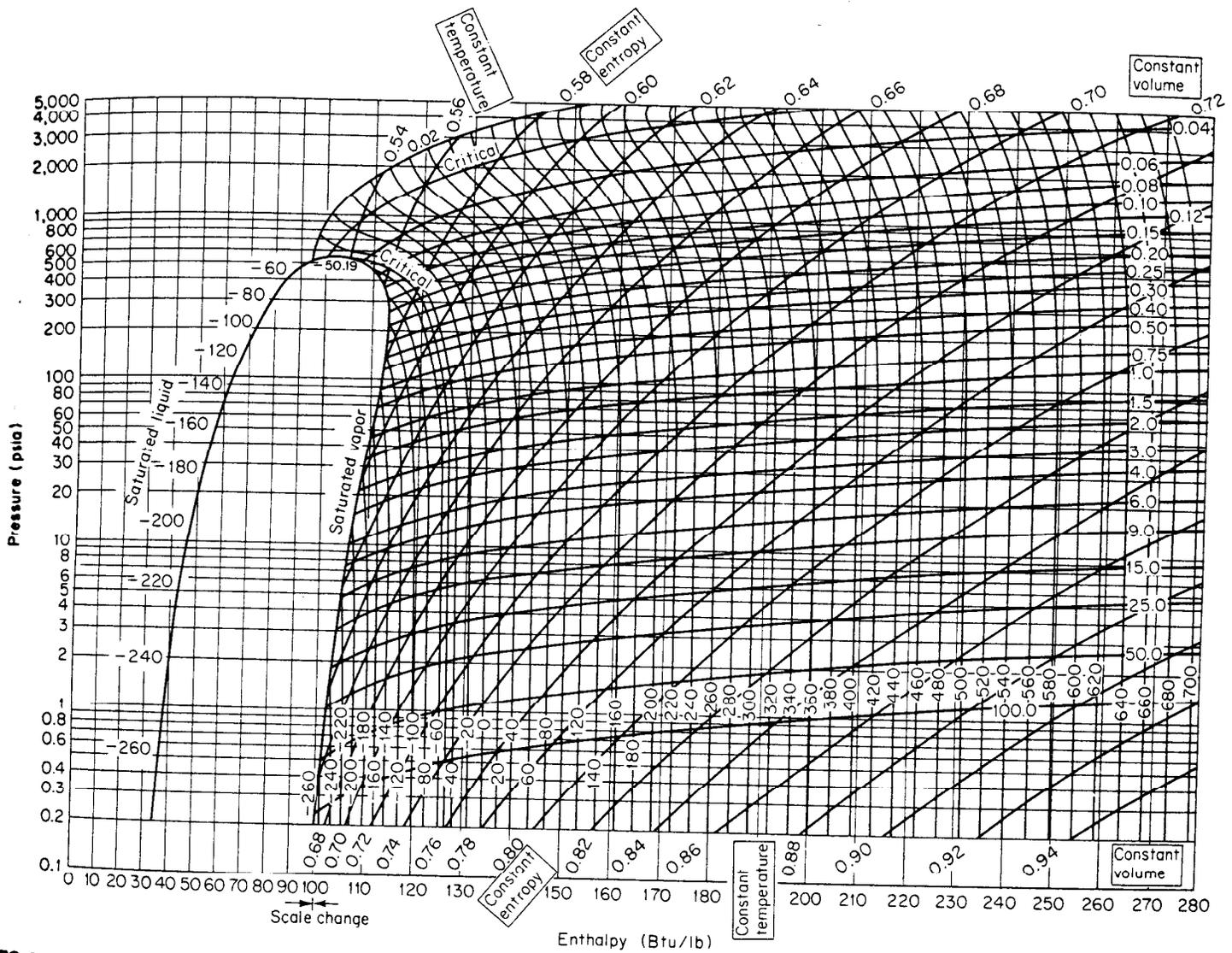
where the generated steam is combined with liquid water at 1 atm and 25 °C to produce an output stream of saturated steam at 1 atm. Determine the relative flow rates of liquid water to hydrogen for this process. Note: you may assume liquid water to be incompressible. (20 points)

Problem 3 (30 points)

Nitrogen at 30 °C and 340 bar undergoes a two-step flow process through a) a throttle valve for a ten-fold reduction in pressure and b) a heat exchanger that adjusts the final temperature of the output gas to -10 °C.

- a) Determine the heat that must be added or removed in the heat exchanger per mole of nitrogen.
- b) Determine the entropic change of the gas.

Note: under these conditions, C<sub>p</sub> for nitrogen may be assumed to be constant and equal 3.5 R. Nitrogen may not be assumed to behave as an ideal gas under these conditions.



**FIG. 3-21** Enthalpy-log-pressure diagram for carbon tetrafluoride. Units: temperature, °F; entropy, Btu/(lb·°F); volume, ft<sup>3</sup>/lb. Reference conditions: enthalpy and entropy zero for solids at 0°R. (Copyright E. I. du Pont de Nemours & Co. Reprinted by permission of the copyright owner.)