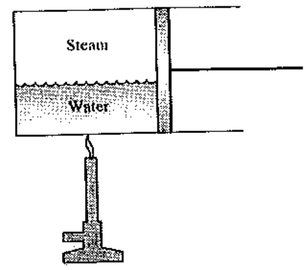
2009Spring **Chemical Engineering Thermodynamics Qualify Exam.**

Part I

1. (10) A bullet coming out from a rifle reaches a speed of 500 m/s before hitting its target. If it is stopped by the target, what will be the fraction it melts? The bullet is made of lead and its temperature is 100 °C before hitting the target. The specific heat, melting point, and fusion heat of lead is 0.022 cal/g/°C, 327.5 °C, and 26 cal/g, respectively.

2. (20) Consider the vaporization (boiling) of liquid water inside the frictionless piston-and-cylinder device as shown. Calculate the work done by the water + steam when 1 kg of water is vaporized at 100 °C. What is the heat needed to vaporize this 1 kg of water? You will need to use the steam table attached. Clearly specify all of your assumptions. A student suggests to place a stop at the initial equilibrium position (before the vaporization of 1 kg water) of the piston, wait till the vaporization is done, and then let go of the piston. He thinks it may provide more work. Comment on his proposal. The properties of liquid water and water vapor at 100 °C and 101.35 kPa are given below.



	V (m^3/kg)	U (kJ/kg)	H (kJ/kg)	S (kJ/kg K)
Liquid	0.001044	418.94	419.04	1.3069
Vapor	1.6729	2506.5	2676.1	7.3549

3. (20) An ideal gas, initially at 30 °C and 100 kPa, undergoes the following cyclic processes in a closed system. Calculate the heat, work, changes in internal energy and in enthalpy of the gas in each process. You can assume $C_P = (7/2)R$ and $C_V = (5/2)R$.
   (i) In mechanically reversible processes, it is first compressed adiabatically to 500 kPa, then cooled at a constant pressure to 30 °C, and finally expanded isothermally to its original state.
   (ii) The cycle traverses exactly the same changes of state as in (i), but each step is irreversible with an efficiency of 80 % compared with the above reversible process.

Qualify Exam

Chemical Engineering Thermodynamics

Part (II) Graduate level (50 %)

1. Show that the azeotrope condition for a binary system is

$$\frac{\gamma_1}{\gamma_2} = \frac{P_2^{sat}}{P_1^{sat}} \cdot \qquad (15\ \%)$$

where γ_i and P_i^{sat} are the activity coefficient and the vapor pressure of component i, respectively. List all the assumptions have been made in your derivation.

2. The molar enthalpies of a binary mixture, $\underline{H}$, can be expressed as

$$\underline{H} = 16x_1 + 22x_2 + x_1x_2[5 + 2(x_1 - x_2)]$$

where x_i is the mole fraction of component i in the solution.

(a) Find the partial molar enthalpy of component 1 at $x_1 = 0.3$. (10 %)

(b) Calculate the excess molar enthalpy at $x_1 = 0.6$. (5 %)

3. Figure 1 is the vapor-liquid equilibrium (VLE) phase diagram of n-hexane + trimethylamine system at 60°C. A mixture is initially manipulated at condition a as indicated in the graph. If we isothermally reduce mixture's pressure from point a to point e gradually, please describe the change of phase behavior of the system during the pressure reduction process, through points a => b => c => d => e step by step. (20 %)

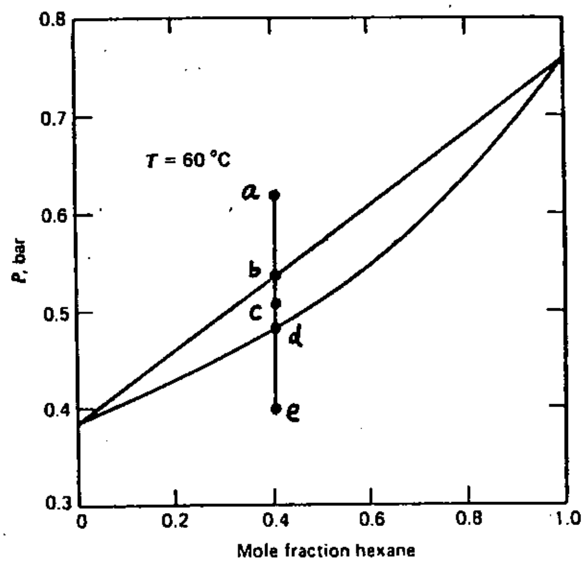


Figure 1