This examination paper contains SIX (6) questions and comprises THREE (3) printed pages.

(Question 1)

One mole of an ideal gas with a constant-volume heat capacity of $C_V = 20$ J/(mol K) at 100°C and 8 bar undergoes the following change:

　　Step (1): It is expanded reversibly and isothermally to a pressure.

　　Step (2): After step 1, it is cooled at constant volume to 0 °C with a final pressure of 2 bar. Please calculate the <u>work</u>, the <u>heat transferred</u>, and the <u>changes in internal energy and enthalpy</u> in the 1st and 2nd steps.　　**[20%]**

[The universal gas constant R = 8.314 J/(mol K) = 83.14 (bar cm^3)/(mol K)]

(Question 2)

Consider a metal bar of length L conducting heat between two reservoirs with a temperature difference. One end (at $x=0$) of the bar is in contact with a hot reservoir at temperature T_0 while the other (at $x=L$) is kept cold at temperature T_L. At steady state the temperature distribution along the bar is given by $T_i(x) = T_0 - \frac{T_0 - T_L}{L} x$ and can be regarded as an "initial" state of the system. The cross-sectional area of the bar is A. The bar has density ρ and heat capacity C_p. After removing the bar away from the reservoirs, the bar is kept *adiabatic* and *isobaric* and finally reaches an equilibrium at a uniform temperature T_f.

(a) What is T_f?　　**[5%]**

(b) Since the above process starts at a *non-equilibrium* state and finally reaches at an equilibrium state, it is clearly *irreversible*. One would like to calculate the change in entropy ΔS (combining both contribution from the bar and the reservoirs) to identify the reversibility of the process. To do so, you can choose an arbitrary *reversible* path to carry out the calculation. Why allow you to do such?　　**[5%]**

(c) Choose a plausible path and determine ΔS. Suppose $T_0 = 400$K and $T_L = 200$K. Identify the sign of ΔS.　　**[10%]**

In the derivation, you might need to invoke the formulae: $\int \ln(a+bx)dx = \frac{1}{b}(a+bx)\ln(a+bx) - x$.

Page 1/3. Continue to next page.

(Question 3)

John Ericsson invented an engine, known as the Ericsson engine, based on the Ericsson cycle shown schematically as Figure 1. The regenerator operates at constant pressure of each stream.
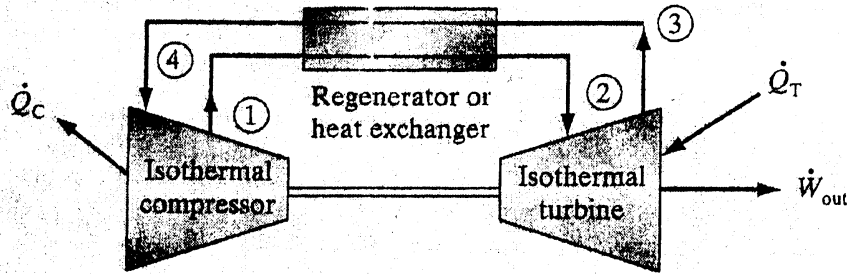

Figure 1

(1) Please sketch the whole Ericsson cycle on a P (pressure) – V (volume) diagram. Label clearly each process using the denotations shown in Figure 1.   **[5%]**

(2) Please estimate the efficiency of an Ericsson engine, in which air as the working fluid behaves ideally.   **[15%]**

(Question 4)

For the system ethyl ethanoate (1)/n-heptane (2) at 343.15 K,

$$G^E = 0.95 x_1 x_2 RT$$

where G^E is the excess Gibbs energy, R is gas constant, T is absolute temperature, and x_1 and x_2 are the mole fractions of ethyl ethanoate and n-heptane, respectively.

(1) Derive the expressions for $\ln \gamma_1$ and $\ln \gamma_2$, where γ means the activity coefficient.   **[6%]**

(2) The saturated vapor pressures of ethyl ethanoate and n-heptane are 79.8 and 40.5 kPa, respectively. Estimate the pressure (P) and gaseous composition (y_1) for the bubble point at T=343.15 K and $x_1 = 0.05$.   **[6%]**

(3) What is the azeotrope composition and pressure at 343.15 K?   **[8%]**

(Question 5) Please answer the following questions with **True or False**.

(1) At constant T and P, for a binary system, $x_1 \cdot d\overline{S}_1^{id} + x_2 \cdot d\overline{S}_2^{id} = 0$ **[2%]**

(2) For adiabatic mixing at constant P, the assumption of $\Delta H = 0$ is valid.   **[2%]**

(3) For an exothermic mixing of two solutions, the enthalpy curve of the solution after mixing in H vs. x diagram always shows a negative deviation to the straight line connecting the initial two solutions.   **[2%]**

(4) $V^{id} = \sum_i x_i \cdot V_i$ **[2%]**

(5) The Gibbs energy change of mixing ΔG is always negative.   **[2%]**

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(Question 6)

Please calculate the heat effect (in kJ/kmol H_2SO_4) when 1 kmol of water is added to a solution containing 1 kmol of sulfuric acid and 4 kmol of water. The process is isothermal at 25°C.
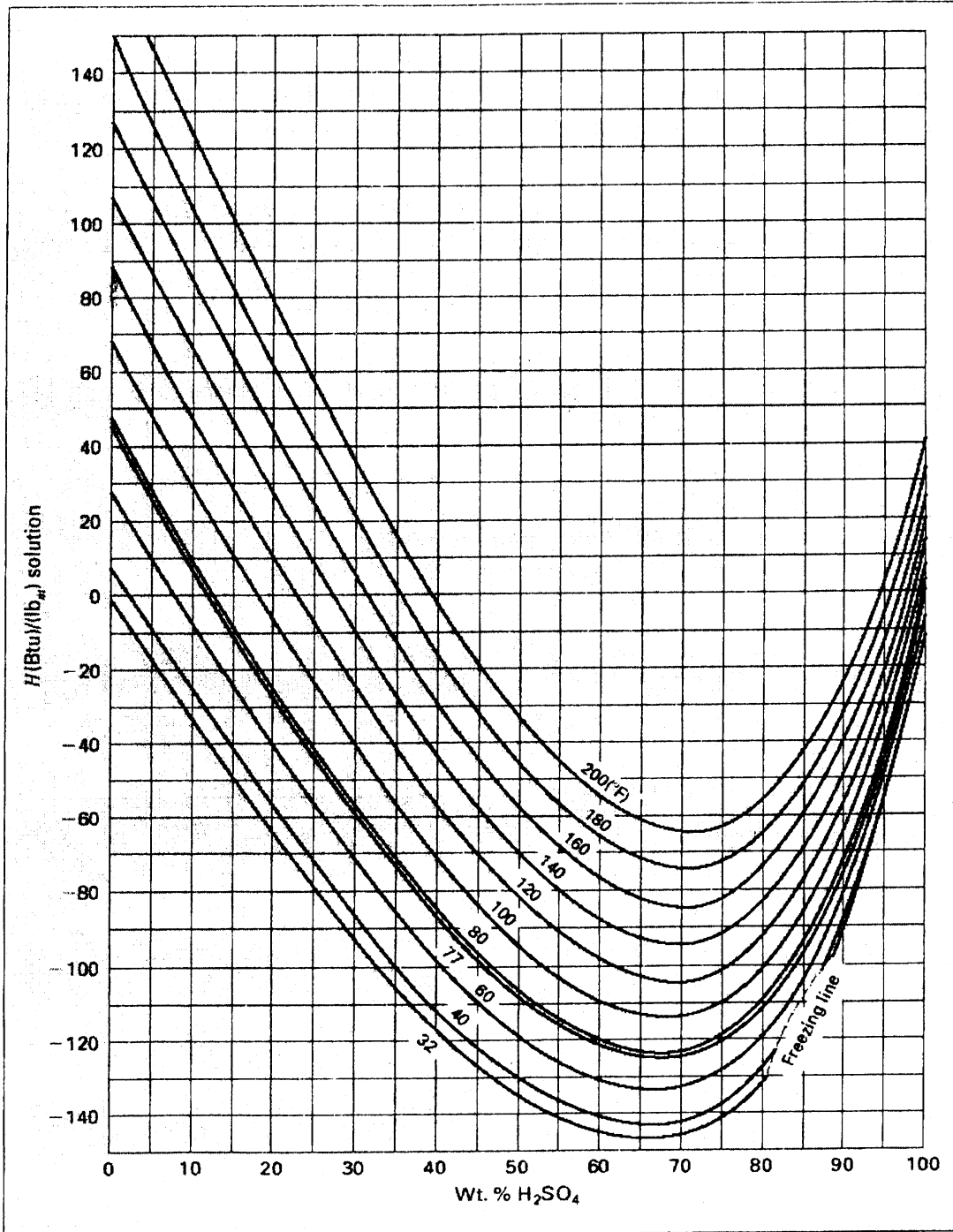
[10%]

[1 Btu = 1.055 J;　1 lbm = 453.6 g]

Figure 12.17: Hx diagram for H_2SO_4(1)/H_2O(2). (Redrawn from the data of W. D. Ross, *Chem. Eng. Prog.*, vol. 48, pp. 314 and 315, 1952. By permission.)

END OF PAPER.