

※ 考生請注意：本試題可使用計算機。請於答案卷(卡)作答，於本試題紙上作答者，不予計分。

**Problem 1 (8%)**

Answer False (F) or true (T). For those "false", you **MUST** justify your answer. If the answer is incorrect, the problem is considered wrong (gain zero score). (4% each)

- (1)  $Q = n\Delta H$  comes merely from the result of a constant-pressure closed system (homogenous, no chemical reaction, and static (no move) are surely the assumptions as well)
- (2) A Joule-Thomson process is a type of isenthalpic process where a liquid or a gas is cooled as it passes from a lower pressure state to a higher pressure state.

**Problem 2 (14%)**

For a polytropic process  $PV^\delta = \text{constant}$ , as you already know that

$$Q = \frac{(\delta - \gamma) \cdot RT_1}{(\delta - 1)(\gamma - 1)} \cdot \left[ \left( \frac{P_2}{P_1} \right)^{(\delta - 1)/\delta} - 1 \right] \quad \text{Eq. (1)}$$

For an ideal gas undergoes **reversible and constant  $V$**  (isothermal) process, we can get to the result of

$$Q = \Delta U = C_v \cdot \Delta T (= C_v \cdot (T_2 - T_1)) \quad \text{Eq. (2)}. \quad \text{Please derive from Eq. (1) to get to the result of Eq. (2).}$$

[Note] Besides of the two equations as above, you would need, both the equations of ideal gas and polytropics.

**Problem 3 (20%)**

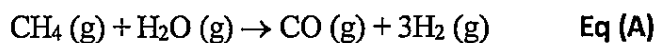
What is the final temperature when heat in the amount of  $1.0 \times 10^5$  Btu is added to 10 lbmol of ammonia initially at  $300^\circ\text{F}$  in a steady-flow process at 1 atm? The coefficients of the ideal-gas heat capacity of ammonia are listed:  $A = 3.60$ ;  $B \cdot 10^3 = 3.02$ ;  $C = 0.0$ ;  $D \cdot 10^{-5} = -0.16$

[Note] Please proceed the calculation **FIVE** times **EXACTLY** by using the initial guess of  $750^\circ\text{F}$  for the final temperature.

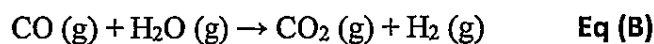
**Problem 4 (8%)**

One method for the manufacture of "synthesis gas" (primarily a mixture of CO and  $\text{H}_2$ ) is the catalytic reforming of  $\text{CH}_4$  with steam at high temperature and atmospheric pressure:

The major reaction for the reforming of  $\text{CH}_4$  with steam is



The only other reaction which occurs to an appreciable extent is the water-gas-shift reaction:



The reactants are supplied in the ratio of 2.5-mole steam to 2.0-mole  $\text{CH}_4$ . It is assumed that  $\text{CH}_4$  is completely converted and the product stream contains 20 mol% CO.

Please use the above two reactions to calculate and obtain the amounts (in moles) of all species in the product stream.

**Problem 5 (15%)**

If the excess Gibbs energy of a binary liquid system,  $G^E$ , is expressed as a function of the mole fractions of the components as  $\frac{G^E}{RT} = Ax_1x_2$  ( $A$ : a constant).

- (1) What is the range of  $A$ , if these two liquids form two coexisting liquid phases? (7%)
- (2) If  $A = 2.5$ , what is the composition range of species 1 leading to the observation of two coexisting liquid phases in this system? (8%)

**Problem 6 (20%)**

A thermodynamic power cycle consists of four sequential thermodynamic processes described as follows:

Process 1: Isentropic compression from state **A** to state **B**.

Process 2: Isobaric heating from state **B** to state **C**.

Process 3: Isentropic expansion from state **C** to state **D**.

Process 4: Isochoric cooling (constant-volume) from state **D** to state **A**.

- (1) Please sketch this cycle on a  $P$ - $V$  diagram. (5%)
- (2) If air is the working fluid of this power cycle and can be regarded as an ideal gas, please estimate the thermal efficiency ( $\eta$ ) of this air-standard power cycle. Please express the thermal efficiency ( $\eta$ ) in terms of  $\gamma = C_P/C_V$ , the compression ratio ( $r = V_A/V_B$ ), the expansion ratio ( $k = V_D/V_C$ ), and other proper thermodynamic variables. (15%)

**Problem 7 (15%)**

A binary system of species 1 and 2 consists of vapor and liquid phases in equilibrium at temperature  $T$ . The overall mole fraction of species 1 is  $z_1 = 0.65$ . At temperature  $T$ , the activity coefficients and the vapor pressures of species 1 and 2 are given as below:

$$\ln(\gamma_1) = 0.67 x_2^2 \text{ and } \ln(\gamma_2) = 0.67 x_1^2, \text{ and}$$

$$P_1^{sat} = 32.27 \text{ kPa and } P_2^{sat} = 73.14 \text{ kPa.}$$

- (1) Over what range of pressures can this binary system exist as coexisting liquid and vapor phases at the given  $T$  and  $z_1$ ? (10%)
- (2) For a liquid phase mole fraction  $x_1 = 0.75$ , what is the pressure  $P$  of the system? (5%)