國立清華大學 103 學年度碩士班考試入學試題

系所班組別：化學工程學系

考試科目（代碼）：化工熱力學及化學反應工程(0902)

　　*請在【答案卷】作答

Problem 1 (10 Points)

A vessel is divided into two parts by a partition. One part contains 2 moles of ideal gas at 400K and 4 bar, and the other part contains 3 moles of ideal gas at 300K and 3 bar. (a) If the partition is removed and the gases mix adiabatically and completely, what is the temperature of the gas? (b) What is the pressure of the gas? (c) What is the enthalpy change of this mixing process? (d) What is the entropy change of this mixing process? The heat capacity of the ideal gas, $Cv=2.5R$.
(R= 8.314 J mol^{-1} K^{-1} = 8.314 m^3 Pa mol^{-1} K^{-1}=83.14cm^3 bar mol^{-1} K^{-1})

Problem 2 (10 Points)

(a) A power plant generates steam at 600K and discards heat at 300K. The power plant is rated at 1,000,000 kW. The thermal efficiency of the plant is 65% of the maximum possible value. How much heat is discarded at the rated power? (b) Draw a Carnot cycle for an ideal gas on a *P-V* diagram. (c) Draw a Carnot cycle of a steam power plant on a *T-S* diagram. ($1kw = 10^3 \frac{kg \bullet m^2}{s^3} = 10^3 \frac{J}{s}$)

Problem 3 (10 Points)

Given an ideal gas with constant volume heat capacity $C_V = \dfrac{5R}{2}$ and initially at 10 atm and 400 K:

a. (2 %) What is the constant pressure heat capacity of the ideal gas?

b. (4 %) If 1 mole of this gas underwent a constant enthalpy process and expanded to 1 atm, what is the final temperature of the gas?

c. (4 %) If 1 mole of this gas underwent a constant entropy process and expanded to 1 atm, what is the final temperature of the gas?

Problem 4 (10 Points)

The following data is given for water

$$\ln P^{sub}(ice) = 28.8926 - \frac{6140.1}{T}$$

$$\ln P^{vap}(water) = 26.3026 - \frac{5432.8}{T}$$

where $P^{sub}(ice)$, $P^{vap}(water)$ are saturation sublimation and vaporization pressure of solid ice and liquid water respectively. In the above equations, the unit of temperature is degree K and unit of pressure is in Pa. Calculate, at the triple point, the values of the following properties of water:

a. (2%) the triple point of water,

b. (2%) the saturation pressure,

c. (2%) the heat of sublimation,

d. (2 %) the heat of vaporization, and

e. (2%) the heat of fusion.

Problem 5 (12 Points)

(a) For a regular liquid mixture (i.e., $\Delta\underline{H}_{mix} \neq 0$ and $\Delta\underline{V}_{mix} = 0$) of organic solution containing 3 moles of A and 2 moles of B at 300K and 10 bar, please calculate the $\Delta\underline{H}_{mix}$ and $\Delta\underline{S}_{mix}$ of the mixture. Known that the excess Gibbs free energy of the mixture, $\underline{G}^{ex}$, is $RT\,x_A x_B$.

(b) Please calculate the final compositions of the mixture in the liquid and vapor phases and the corresponding molar ratio if a vapor-liquid equilibrium of above solution is reached by decreasing the pressure to 0.4 bar. Known that the temperature-dependent data of saturated pressure for A and B are $ln\ P_A = 10.42 - 26800/RT$ and $ln\ P_B = 11.43\text{-}35200/RT$ for P in bar and T in K, respectively, and assume that the mixture is an ideal liquid mixture. R=8.314 J/(mol K).

Problem 6 (8 Points)

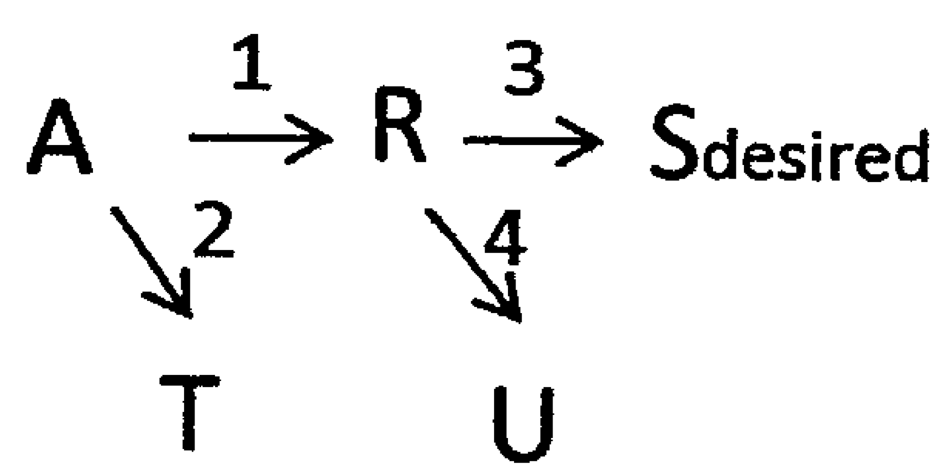
A distillation column has been designed to separate A and B components at 1 bar. The initial composition is 0.5 molar fraction of A and the final goal is to get 0.95 molar fraction of A. Known that the temperature-dependent data of saturated pressure for A and B are $ln\ P_A = 10.42 - 26800/RT$ and $ln\ P_B = 11.43\text{-}35200/RT$ for P in bar and T in K, respectively, and assume that the mixture is an ideal liquid mixture. Please list the equations to solve the dew point temperature and the liquid mixture composition at the first column (i.e., the top column) of the distillation column. R=8.314 J/(mol K).

Problem 7 (10 Points)

A gas phase reaction, $\mathbf{A \rightarrow 2R}$, is carried out in a tubular plug flow reactor at T = 45°C and P_t = 4.75 atm. The feed consists of 50 mol% A and 50 mol% inert at a rate of 4000 kg/h. The molecular weights of A and inert are 30 and 15, respectively, and the rate coefficient is k = 2000 h^{-1}. Determine the reactor size for 35% conversion of A.

Problem 8 (10 Points)

The first-order reactions



$k_1=10^9e^{-6000/T}$

$k_2=10^7e^{-4000/T}$

$k_3=10^8e^{-9000/T}$

$k_4=10^{12}e^{-12000/T}$

are to be run in two mixed flow reactors in series anywhere between 20 and 100 ˚C. If the reactors may be kept at different temperatures, what should these temperatures be for maximum fractional yield of S ?(4%) Find this fractional yield (6%) ?

Problem 9 (20 Points)

Consider a gas-solid (catalyst) reaction, $A_{(g)}$ ➔products, in which the reaction is zero order, and the solid particles have "slab" or "flat-plat" geometry with one face permeable to A. Let $\varphi=C_A/C_{AS}$ (C_{AS} is the bulk concentration of A), z=x/L (x is the length along the particle axis, L is the total length), Thiele modulus

$\phi=L\sqrt{\frac{k_A}{D_e C_{AS}}}$ (note the difference in the definition of Thiele modulus)

(a) Show that $\frac{d^2\varphi}{dz^2}-\phi^2=0$ (10%)

(b) Solve the equation in (a) to give the nondimensional concentration profile $\varphi(\phi, z)$, on the assumption that $\varphi>0$ for all values of z. (10%)