Problem 1 (20%)

For the reaction scheme of

$$2A \underset{k_2}{\overset{k_1}{\rightleftharpoons}} A_2^*$$

$$A_2^* + B \underset{k_4}{\overset{k_3}{\rightleftharpoons}} A + AB$$

where A_2^* is an intermediate substance, derive the rate equation for the formation of AB (r_{AB}) in terms of the rate constants k_1, k_2, k_3, k_4, and the concentrations [A], [B], [AB].

Problem 2 (20%)

For the following liquid reaction A→R which is catalyzed by enzyme, the reaction rate $-r_A$ is found to be proportional to the initial enzyme concentration C_{E0}, and $-r_A$ is proportional to the reactant concentration C_A at low reactant concentration. However, the reaction rate is independent of C_A at high reactant concentration. The volume does not change during the reaction.

(a) Develop a mechanism to show that this reaction follows the kinetics

$$k_1 \cdot C_{E0} \cdot C_A / (1 + k_2 C_A)$$

where k_1 and k_2 are rate constants. (5%)

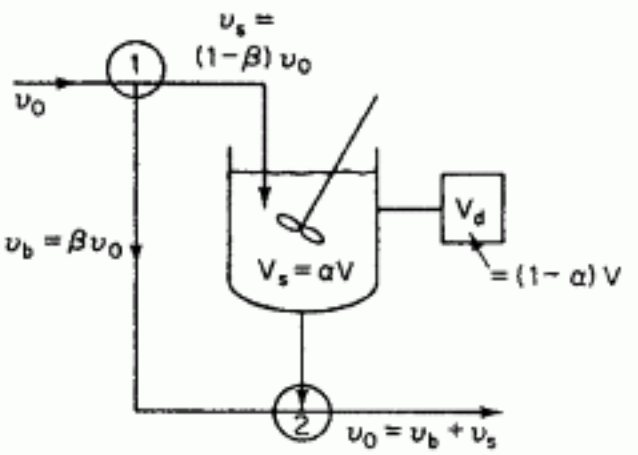
(b) If this reaction occurs in a batch reactor, develop the relationship between C_A and time t for given C_{E0} and initial concentration of A, C_{A0}. (5%)

(c) For a given C_{E0}, schematically illustrate how you are going to design the experiments to find k_1 and k_2. (5%)

(d) If this reaction occurs in a steady state CSTR, develop a relationship between C_A and space time τ for given C_{E0} and initial concentration of A, C_{A0}. (5%)

Problem 3 (20%)

A real CSTR could be modeled as a combination of an ideal CSTR of volume V_s, a dead zone of volume V_d, and a bypass with a volumetric flow rate υ_b (see the following figure). How do you use a tracer experiment to verify this model?



Problem 4 (20%)

Please determine the validity of the following statement and explain why:

(i) When a gas is expanded adiabatically PV^{γ}=constant

(ii) When an ideal gas is expanded adiabatically PV^{γ}=constant

(iii) When a system's entropy increases, it must have undergone an irreversible process

(iv) When a closed (no mass exchanged with surrounding) system's entropy increases, it must have undergone an irreversible process.

(v) When oil is dispersed in water, the entropy of water increases

(vi) When oil is dispersed in water, the entropy of oil increases

(vii) When oil is dispersed in water, the total entropy of water and oil increases

(viii) A bottle (with cap closed and half full) of water put on the table at room temperature, there are 2 degrees of freedom left

(ix) A bottle (with cap closed and half full) of water put on the table at room temperature, there is 1 degree of freedom left

Problem 5 (20%)

(a) Vapor and liquid phases coexist in a binary system which has A and B constituents. What is the mathematical expression which indicates that the system follows the Raoult's law?

(b) What are the two major assumptions required for a system obeying the Raoult's law?

(c) Please draw a schematic diagram which indicates the relationship between the Gibbs free energy vs. the composition for the liquid phase in a system which obeys the Raoult's law.

(d) What is the definition of a partial free energy in a solution?

(e) How to determine the partial free energies of A and B respectively from the Gibbs free energy-composition relationship as shown in (c)?