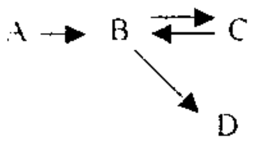
1. What is the meaning by "multiple steady states"? Please make a description for it. You have to specify the type of reactor which you are talking about. [6%]

2. Sketch the concentration profile of each component along a plug-flow reactor for the following reactions. All specific reaction rates are the same. [7%]



3. Reversible elementary reaction $A_{(g)} \rightleftharpoons B_{(g)}$ is to be carried out in 640 °C. The feed is pure A at a total pressure of 3 atm and 640 °C. The feed rate is 4 gmole/min. The specific reaction rate of the forward reaction is 2 liter/gmole·min and the concentration equilibrium constant is 0.3. [20%]
   (a) Calculated the reactor volume necessary to achieve 95% of the equilibrium conversion of A in a plug-flow reactor.
   (b) What will the volume change if the feed is diluted with other inert gas with when the other conditions remain unchanged? You should give your reason for this answer.

4. The following observations have been made about the reaction

$$2\,GCH_3 \rightarrow 2\,GCH_2 + H_2$$

   1. The reaction rate is independent of hydrogen concentration.
   2. The reaction rate decreases with increasing concentrations of GCH_2.
   3. The initial rate appears to be first-order with respect to GCH_3.
   4. When there is an extremely high concentration of GCH_2 and a low concentration of GCH_3, the reaction appears to be second-order with respect to GCH_3.

   (a) Deduce a rate expression for the decomposition of GCH_3. [5%]
   (b) Suggest a mechanism and prove its correctness using pseudo-steady-state approximation. [10%]

5. A chemical reaction, its reaction rate at 227℃ is 10 times of the rate at 127℃. Use Arrhenius' law to determine the activation energy of this reaction. (gas constant = 1.987 cal/mol K)[6%]

6. Assuming a stoichiometry A → R for a first-order gas reaction, we calculate the size of a mixed reactor needed for a given duty (90% conversion of a pure A feed) to be V = 32 liters. In fact, however, the reaction stoichiometry is A → 3 R. With this corrected stoichiometry, what is the required reactor volume? [13%]

7. Supported Rh catalysts have been employed to remove NO with CO addition:

$$CO + NO \xrightarrow{Rh} products\,(N_2, CO_2)$$

The mechanism is believed to be

$$CO + S \Leftrightarrow CO \bullet S$$
$$NO + S \Leftrightarrow NO \bullet S$$
$$NO \bullet S + S \rightarrow N \bullet S + O \bullet S$$
$$CO \bullet S + O \bullet S \rightarrow CO_2 + 2S$$
$$N \bullet S + N \bullet S \rightarrow N_2 + 2S$$

When the ratio of P_{CO}/P_{NO} is small, show that the rate law is

$$-r_{CO} = \frac{kP_{CO}}{(1 + k_{CO}P_{CO})^2}$$ [13%]

8. Curves A, B and C in Figure 1 show the variations in reaction rate for three different reactions catalyzed by solid catalyst pellets. What can you say about each reaction? [6%]

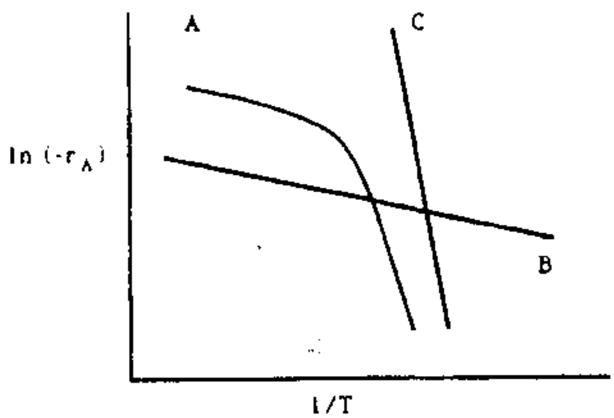


Figure 1

9. (a) Define the effectiveness factor and Thiele modulus. [6%]

(b) In the case of the reactions catalyzed by solids,

$$\phi = \frac{V}{S}\sqrt{\frac{n+1}{2}\frac{k(C_s)^{n-1}\rho_s}{D_{eA}}} \quad nth-order\ irreversible\ reaction\ (n > -1)$$

$$\eta = \frac{1}{\phi}\left(\frac{3\phi\coth(3\phi) - 1}{3\phi}\right)$$

where ϕ: Thiele modulus.

S, V: the external surface area and volume of the catalyst pellet.

k: reaction rate coefficient (mg^3/kgcat.s).

C_s: the concentration of the reactant on the external surface of the pellet.

ρ_s: the density of the pellet.

D_{eA}: internal diffusion constant.

η: effectiveness factor

Explain that for the internal diffusion control, the true reaction order is related to the measured reaction order by $n_{true} = 2n_{apparent} - 1$ and the true and apparent activation energies are related by $E_{true} = 2E_{app}$. [8%]