EN 315: Reaction Engineering & Combustion

Assignment -2, Due Date: 30-8-18

1. What assumptions were made in the derivation of the design equation for:
   (a) the batch reactor?
   (b) the CSTR?
   (c) the plug-flow reactor (PFR)?
   (d) the packed-bed reactor (PBR)?

2. Schematic diagrams of the L. A. basin are shown in Figure 1.1. The basin floor covers approximately 700 square miles ($2 \times 10^{10}\ ft^2$) and is almost completely surrounded by mountain ranges. If one assumes an inversion height in the basin of $2000\ ft$, the corresponding volume of air in the basin is ($4 \times 10^{13}\ ft^3$). We shall use this system volume to model the accumulation and depletion of air pollutants. As a very rough first approximation, we shall treat the Los Angeles basin as a well-mixed container (analogous to a CSTR) in which there are no spatial variations in pollutant concentrations. Consider only the pollutant carbon monoxide and assume that the source of CO is from automobile exhaust and that, on the average, there are 400,000 cars operating in the basin **at** any one time. Each car gives off roughly 3000 standard cubic feet of exhaust each hour containing **2** mol % carbon monoxide.

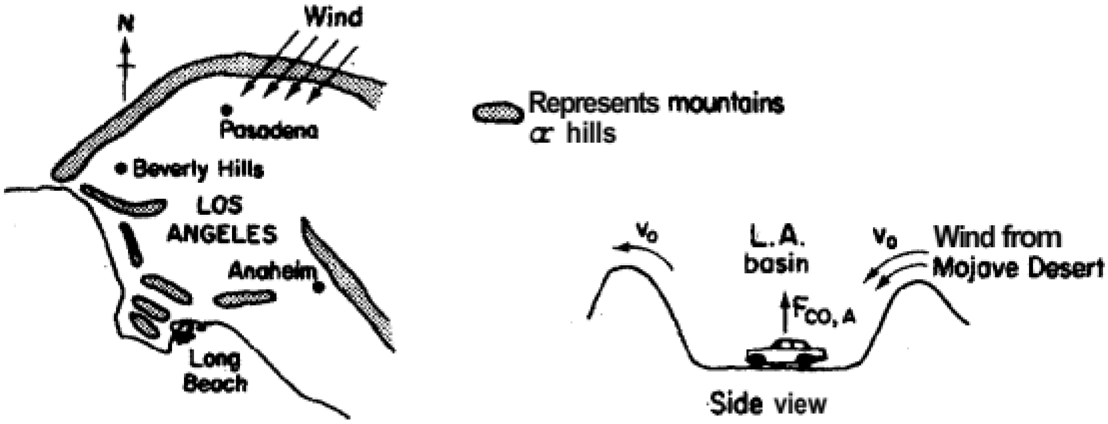

Figure 1.1

We shall perform an unsteady-state mole balance on CO as it is depleted from the basin area by a Santa Ana wind. Santa Ana winds are high-velocity winds that originate in the Mojave Desert just to the northeast of Los Angeles. This clean desert air flows into the basin through a corridor assumed to be 20 miles wide and 2000 ft high (inversion height) replacing the polluted air, which flows out to sea or toward the south. The concentration of CO in the Santa Ana wind entering the basin is 0.08 ppm ($2.04 \times 10^{-10}\ lb\ mol/ft^3$)

a) How many pound moles of gas are in the system volume we have chosen for the Los Angeles basin if the temperature is 75°F and the pressure is 1 atm?
b) What is the rate, $F_{CO,A}$, at which all autos emit carbon monoxide into the basin (*lb mol CO/h*)?
c) What is the volumetric flow rate (ft^3/h) of a 15-*mph* wind through the corridor 20 miles wide and 2000 ft high?
d) At what rate, $F_{CO,C}$, does the Santa Ana wind bring carbon monoxide into the basin ($lb\ mol/h$)?
e) Assuming that the volumetric flow rates entering and leaving the basin are identical, $v = v_o$, derive the unsteady mole balance on CO within the basin and find the concentration of CO as a function of time.
f) If the initial concentration of carbon monoxide in the basin before the Santa Ana wind starts to blow is 8 ppm ($2.04 \times 10^{-8}\ lb\ mol/ft^3$), calculate the time required for the carbon monoxide to reach a level of ***2*** ppm.

3. The gas-phase reaction $A \rightarrow B + C$ is carried out isothermally in a 20-dm^3 constant-volume batch reactor. Twenty moles of pure **A** is initially placed in the reactor. The reactor is well mixed

a) **If** the reaction is first order:

$$-r_A = kC_A\ with\ k = 0.865\ min^{-1}$$

Calculate the time necessary to reduce the number of moles of A in the reactor to 0.5 moles.

(b) If the reaction is second order.

$$-r_A = kC_A^2\ with\ k = \frac{2\ dm^3}{mol.min}$$

Calculate the time necessary to consume 19.5 moles of A.

(c) If the temperature is 127 °C,what is the initial total pressure? What **IS** the final total pressure assuming the reaction goes to completion?

4. There are two reactors of equal volume available for your use: one a CSTR, the other a **PFR.** The reaction is second order $(-r_A = kC_A^2 = kC_{Ao}^2(1-X)^2)$**,** irreversible, and **is** carried out isothermally.

$$A \rightarrow B$$

There are three ways you can arrange your system:

(1) Reactors in series: CSTR followed by PFR

(2) Reactors in series: PFR followed by CSTR

(3) Reactors in parallel with half the feed rate going to each reactor after which the exit streams are mixed

If possible, state which system will give the highest and lowest overall conversion.

5. Figure 2 (a) shows $C_{Ao}/-r_A$ versus $X_A$for a nonisothermal, nonelementary, multiple-reaction liquid-phase decomposition of reactant A

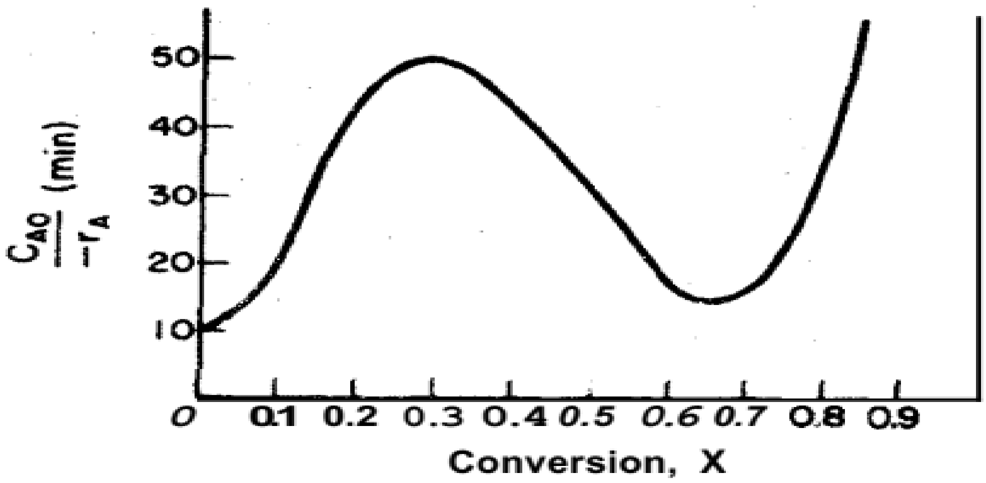

Figure 2(a)

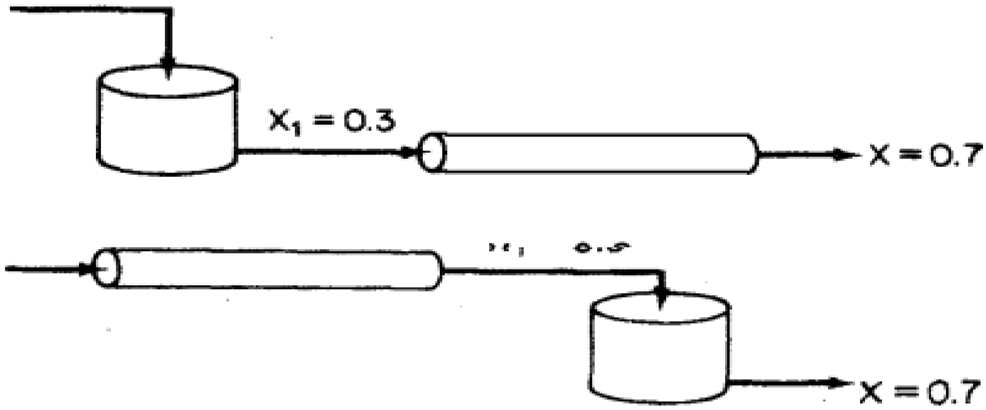

Figure 2(b)

a. Consider the two systems shown in Figure 2 (b) in which a CSTR and plug-flow reactor are connected in series. The intermediate conversion is 0.3 and the final conversion is 0.7. How should the reactors be arranged to obtain the minimum total reactor volume? Explain.

b. If the volumetric flow rate is *50 L/min*, what **is** the minimum total reactor volume?

c. Is there a better means i.e., smallest total volume achieving 70% conversion other than either of the systems proposed above?

d. At what conversion (s) would the required reactor volume be identical for either a CSTR or a tubular PFR?

e. Using the information in Figure (a) together with the CSTR design equation, make a plot of **t** versus X . If the reactor volume is 700 L and the volumetric flow rate 50 Wmin, what are the possible outlet conversions (i.e., multiple steady states) for this reactor?

6. The irreversible gas-phase elementary reaction

$$A + 2B \rightarrow C$$

is to be carried out isothermally in a constant-pressure batch reactor. The feed is at a temperature of 227°C, a pressure of 1013 kPa, and its composition is 33.3% A and 66.7% B. Laboratory data taken under identical conditions are as follows:

$-r_A \quad mol/dm^3sec$ x1000	X
0.01	0.0
0.005	0.2
0.002	0.4
0.001	0.60

The entering total volumetric flow rate is 1 m^3/min.

(a) What are CSTR and PFR volumes necessary to achieve 60 % conversion of reactant A?

(b) Plot the conversion and rate of reaction as a function of PFR reactor volume.