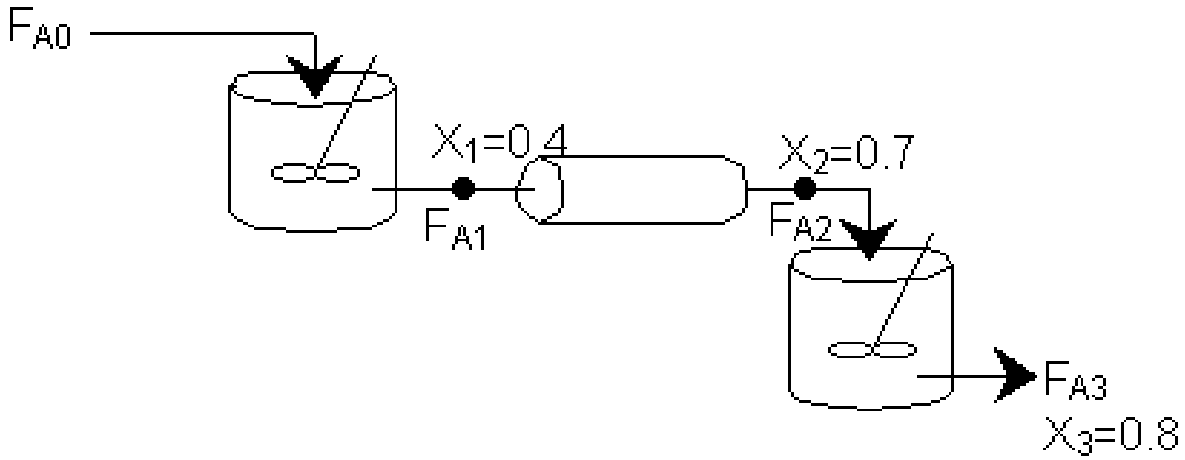
5. Reactors in Series XI

- **Example 3**
  - **- Reactors in Series: CSTR-PFR-CSTR**
    - **Using either the data in Table 1, calculate the reactor volumes V_1, V_2, and V_3 for the CSTR/PFR/CSTR reactors in series sequence shown in Figure 1 along with the corresponding conversion.**



5. Reactors in Series XII

- **Example 3**

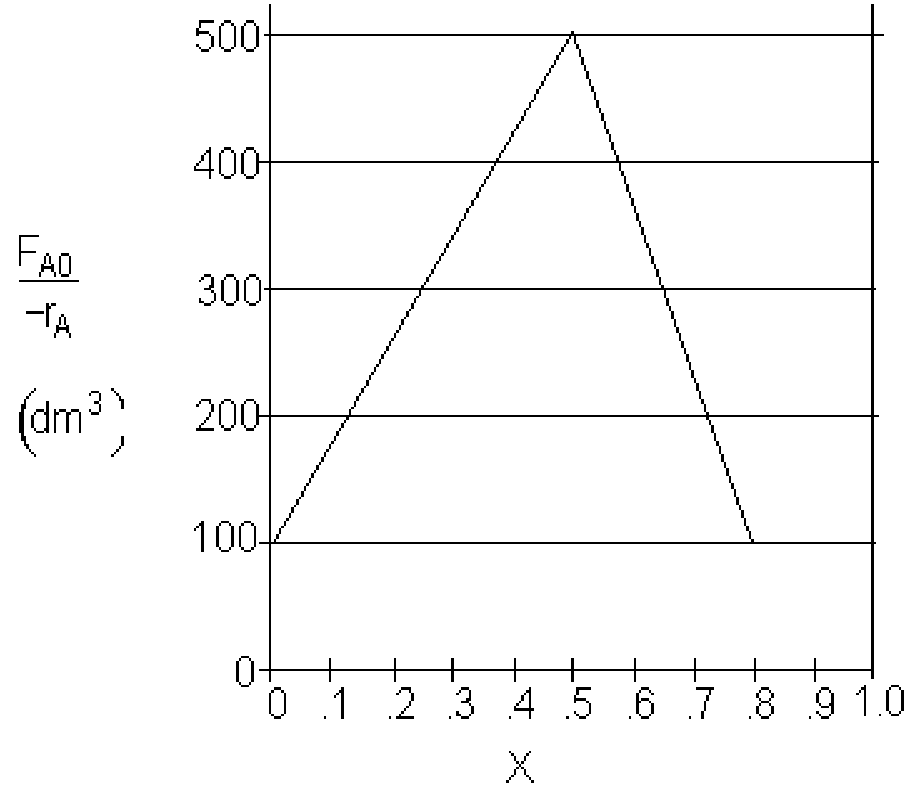
  Table 1 Processed Data

X	0	0.2	0.4	0.6	0.8
$-r_A\left(\frac{mol}{dm^3 \bullet s}\right)$	0.010	0.0091	0.008	0.005	0.002
$(1/-r_A)\left(\frac{dm^3 \bullet s}{mol}\right)$	100	110	125	200	500
$F_{A0}/-r_A\ (dm^3)$	200	220	250	400	1000

5. Reactors in Series XIII

- **Example 4**
  - **- The adiabatic exothermic irreversible gas phase reaction is to be carried out in a flow reactor for a stoichiometric feed of A and B**

$$\frac{1}{2}A + B \longrightarrow 2C$$



5. Reactors in Series XIV

- **Example 4**

  a) What PFR volume is necessary to achieve 50% conversion?

  V_1 = ________________

  b) What CSTR volume is necessary to achieve 50% conversion?

  V_1 = ________________

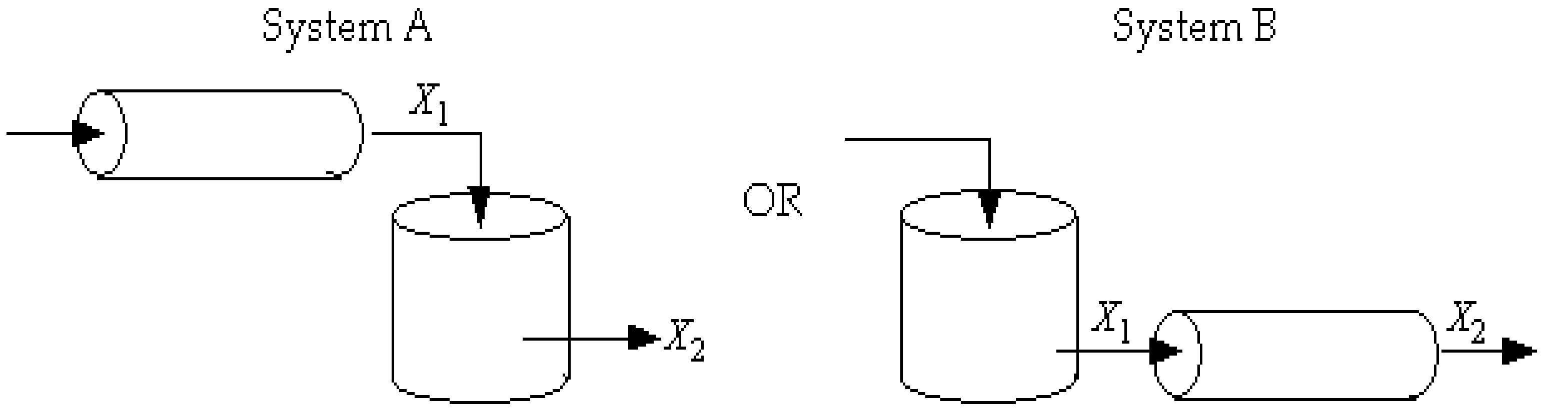
  c) What CSTR volume must be added to raise the conversion in Part (b) to 80%?

  V_2 = ______________________

  d) What PFR volume must be added to raise the conversion in Part (b) to 80%?

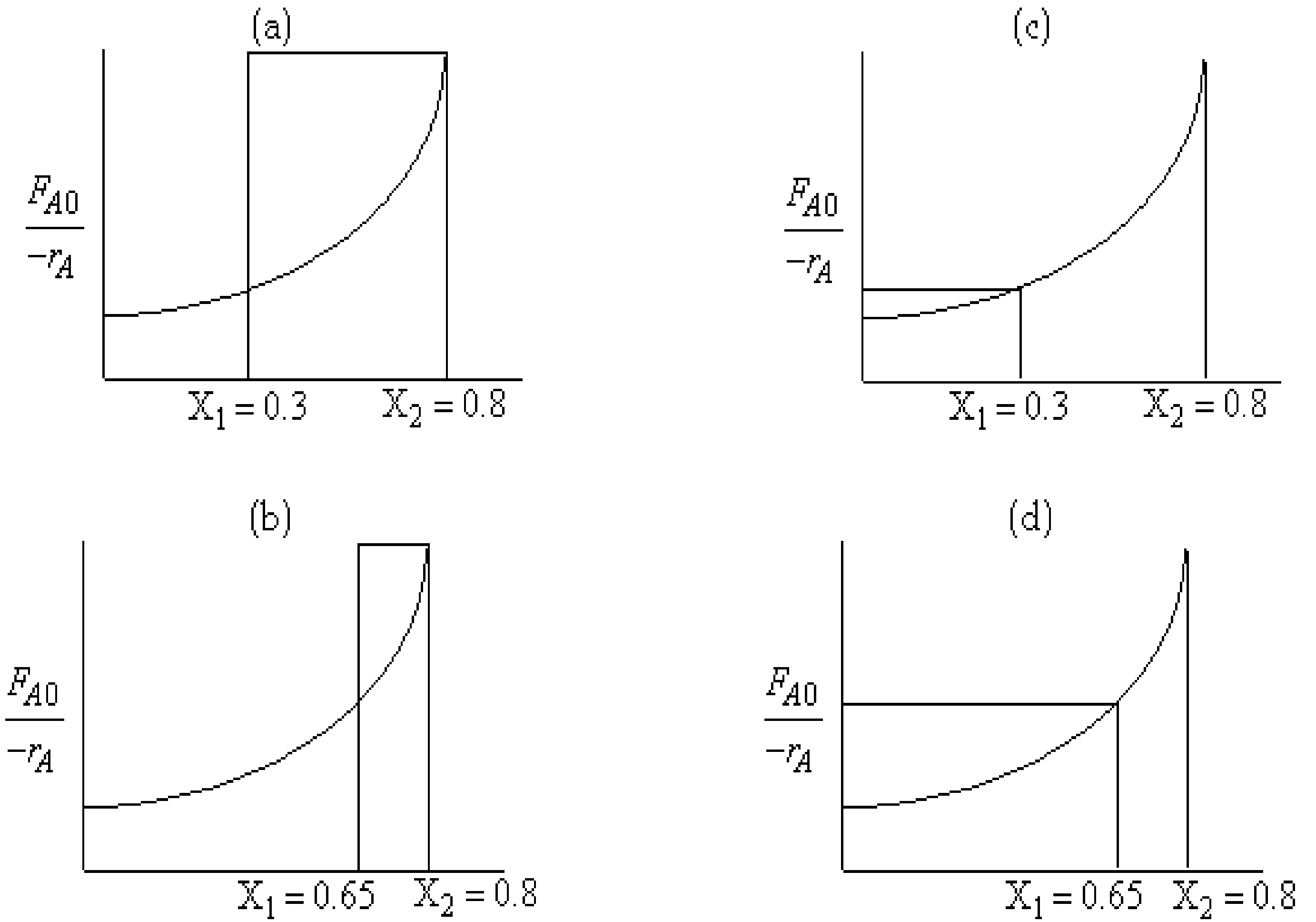
5. Reactors in Series XV

- **Example 5**
  - **a) Which system is most efficient for a intermediate conversion of (0.3)?**
  - **b) Which system is most efficient for a intermediate conversion of (0.65)?**
  - **c) Which system makes the best use of the reactor volume (i.e., least wasted volume)?**



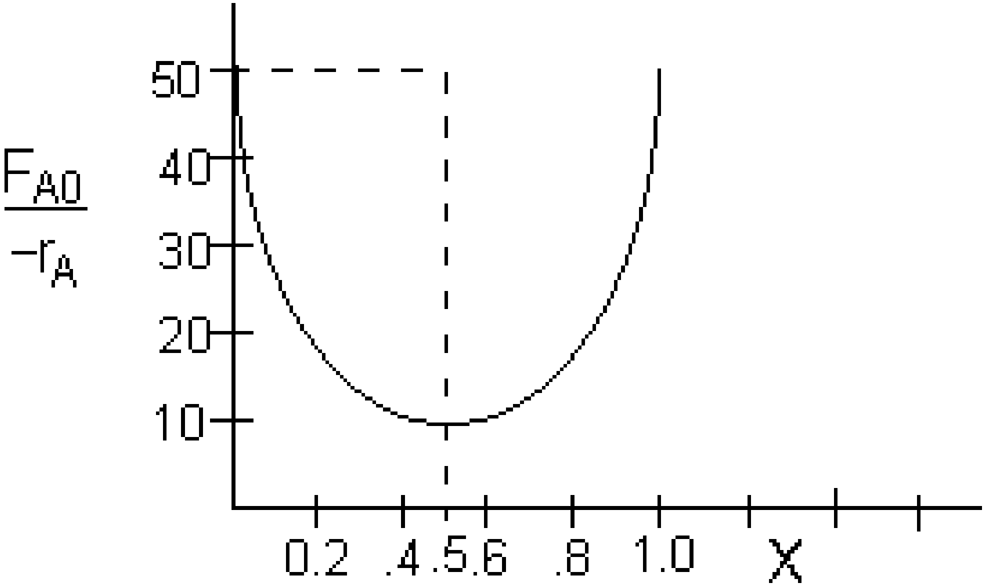
5. Reactors in Series XVI

- **Example 5**



5. Reactors in Series XV

- **Example 6**
  - **- An adiabatic liquid phase exothermic reaction is to be carried out in a 25 dm³ CSTR. The entering molar flow rate of A times the reciprocal of the rate of reaction is shown below as a function of conversion. What is the conversion exiting the CSTR?**



5. Reactors in Series XVI

- **Total volumes and reactor sequencing 1**
  - **- The maximum conversion (minimum volume) in the sequencing reactor**

    ⇒ it depends

    - **not only on the shape of the (F_{A0}/-r_A) vs X plot**
    - **but also the reactor size**
  - **- Calculating the reactor volume necessary to achieve a specified conversion**
    - **rxn rate depends on conversion, initial conc. of the reactants, T, and P**
  - **- To get the right size of the flow reactor, only**

    $-r_A = f(X)$ is needed

6. Some Further Definitions (p. 57)

- **Space time(τ)**

  - Dividing the reactor volume by the volumetric flow rate entering the reactor

$$\tau \equiv \frac{V}{v_0}$$

  - The time necessary to process one volume of reactor fluid at the entrance conditions

  - **the time it takes for the amount of fluid that takes up the entire volume of the reactor to either completely enter or completely exit the reactor**

  ☞ **holding time or mean residence time**

Table 2-5 shows space times for six industrial reactions and reactors.

TABLE 2-5 SAMPLE INDUSTRIAL SPACE TIMES[3]

	Reaction	Reactor	Temperature	Pressure atm	Space Time
(1)	$C_2H_6 \rightarrow C_2H_4 + H_2$	PFR†	860°C	2	1 s
(2)	$CH_3CH_2OH + HCH_3COOH \rightarrow CH_3CH_2COOCH_3 + H_2O$	CSTR	100°C	1	2 h
(3)	Catalytic cracking	PBR	490°C	20	$1\ s < \tau < 400\ s$
(4)	$C_6H_5CH_2CH_3 \rightarrow C_6H_5\ CH = CH_2 + H_2$	PBR	600°C	1	0.2 s
(5)	$CO + H_2O \rightarrow CO_2 + H_2$	PBR	300°C	26	4.5 s
(6)	$C_6H_6 + HNO_3 \rightarrow C_6H_5NO_2 + H_2O$	CSTR	50°C	1	20 min

†The reactor is tubular but the flow may or may not be ideal plug flow.

6. Some Further Definitions II

- **Space velocity(SV)**

- Reciprocal of the space time

$$SV \equiv \frac{v_0}{V} \qquad SV \equiv \frac{1}{\tau}$$

- LHSV, liquid-hourly SV

- **the entering volumetric flow rate is frequently measured as that of liquid feed rate at 60°F or 75 °F, even though vapor or some higher T**

- GHSV, gas-hourly SV

- **measured at STP**

$$\text{SHSV} \equiv \frac{v_0\big|_{\text{liquid}}}{V} \qquad \text{GHSV} \equiv \frac{v_0\big|_{\text{STP}}}{V}$$