Workshop 02: Conversion and reactor sizing

Lecture notes for chemical reaction engineering

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Try following problems from Fogler 5e(Fogler 2016).

P2-3, P2-4, P2-7, P2-10.

We will go through some of these problems in the workshop.

> **Specimen code**
>
> A collab notebook that contains specimen code can be obtained by clicking on link below.
> Workshop 02 Levenspeil Plots and Reactor sizing - Help

1. **P2-3:** You have two CSTRs and two PFRs, each with a volume of $1.6m^3$. Use Figure 1 to calculate the conversion for each of the reactors in the following arrangements.

(a) Two CSTRs in series.

(b) Two PFRs in series.

(c) Two CSTRs in parallel with the feed, F_{A0}, divided equally between the two reactors.

(d) Two PFRs in parallel with the feed divided equally between the two reactors.

(e) A CSTR and a PFR in parallel with the flow equally divided. Calculate the overall conversion, X_{ov}

$$X_{ov} = \frac{F_{A0} - F_{A,CSTR} - F_{A,PFR}}{F_{A0}}$$

with

$$F_{A,CSTR} = \frac{F_{A0}}{2} - \frac{F_{A0}}{2} X_{CSTR}$$

and

$$F_{A,PFR} = \frac{F_{A0}}{2}(1 - X_{PFR})$$

(f) A PFR followed by a CSTR.

(g) A CSTR followed by a PFR.

(h) A PFR followed by two CSTRs. Is this arrangement a good arrangement or is there a better one?

The data from Figure 1 is provided in file workshop-02-problem-1-data.csv

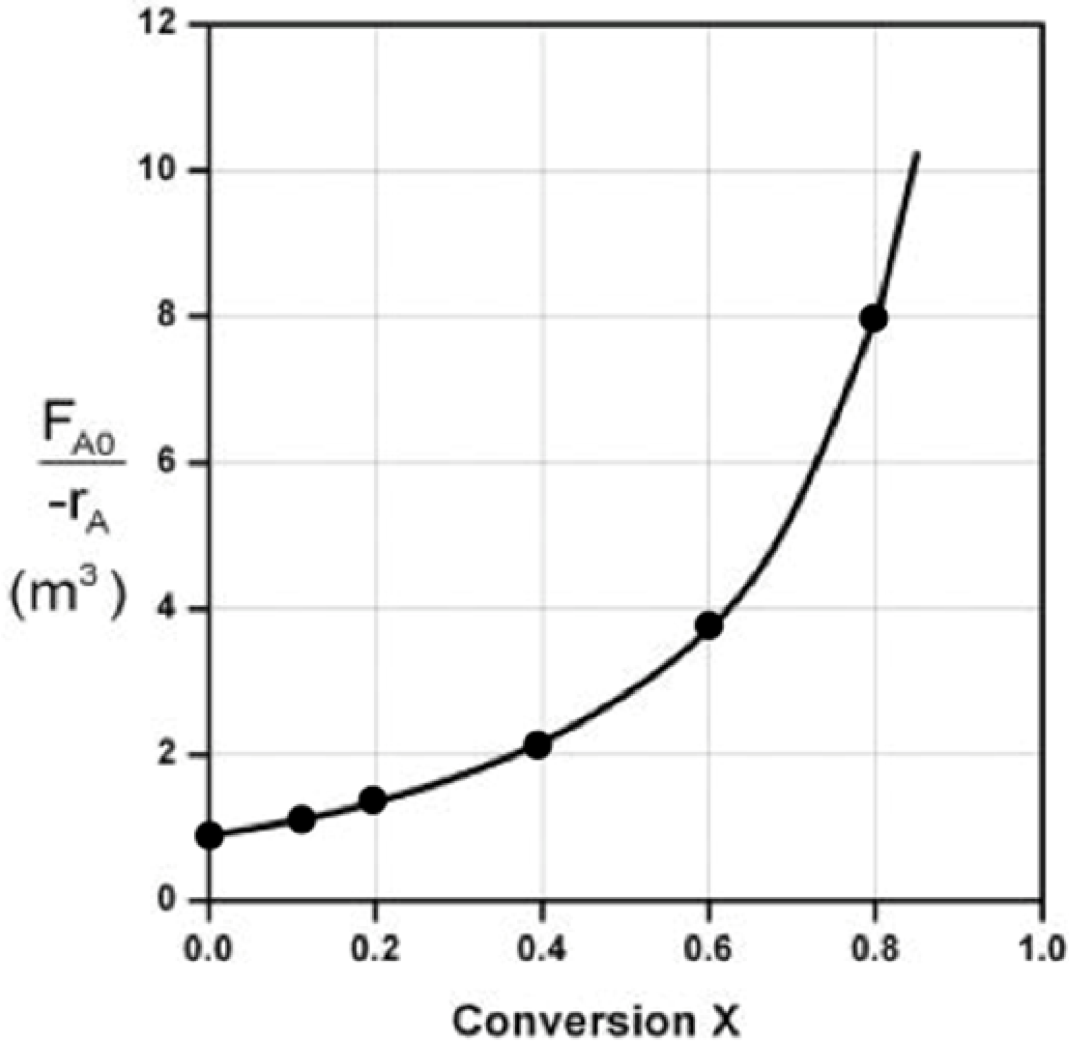

Figure 2-2B Levenspiel plot of processed data 2.

Figure 1: Figure-2-2b

2. **P2-4**: The exothermic reaction of stillbene (A) to form the economically important trospophene (B) and methane (C), i.e.,

$$A \longrightarrow B + C$$

was carried out adiabatically and the following data recorded:

Table 1: Problem 2.4 rate data

X	$r_A (mol/dm^3 min)$
0	1
0.2	1.67
0.4	5
0.45	5
0.5	5
0.6	5
0.8	1.25
0.9	0.91

The entering molar flow rate of A was $300 mol/min$.

(a) What are the PFR and CSTR volumes necessary to achieve 40% conversion?
(b) Over what range of conversions would the CSTR and PFR reactor volumes be identical?
(c) What is the maximum conversion that can be achieved in a $105 dm^3$ CSTR?
(d) What conversion can be achieved if a $72 dm^3$ PFR is followed in series by a $24 dm^3$ CSTR?
(e) What conversion can be achieved if a $24 dm^3$ CSTR is followed in a series by a $72 dm^3$ PFR?
(f) Plot the conversion and rate of reaction as a function of PFR reactor volume up to a volume of $100 dm^3$.

The data from Table 1 is provided in file workshop-02-problem-2.csv

3. **P2-7**: The adiabatic exothermic irreversible gas-phase reaction

$$2\,A + B \longrightarrow 2\,C$$

is to be carried out in a flow reactor for an equimolar feed of A and B. A Levenspiel plot for this reaction is shown in Figure 2 .

(a) What PFR volume is necessary to achieve 50% conversion?
(b) What CSTR volume is necessary to achieve 50% conversion?
(c) What is the volume of a second CSTR added in series to the first CSTR (Part b) necessary to achieve an overall conversion of 80%?
(d) What PFR volume must be added to the first CSTR (Part b) to raise the conversion to 80%?
(e) What conversion can be achieved in a $6 \times 10^4 m^3$ CSTR? In a $6 \times 10^4 m^3$ PFR?
(f) Think critically to critique the answers (numbers) to this problem.

4. **P2.10**: The curve shown in Figure 3 is typical of a gas-solid catalytic exothermic reaction carried out adiabatically.

(a) Assuming that you have a fluidized CSTR and a PBR containing equal weights of catalyst, how should they be arranged for this adiabatic reaction? Use the smallest amount of catalyst weight to achieve 80% conversion of A.
(b) What is the catalyst weight necessary to achieve 80% conversion in a fluidized CSTR?
(c) What fluidized CSTR weight is necessary to achieve 40% conversion?
(d) What PBR weight is necessary to achieve 80% conversion?
(e) What PBR weight is necessary to achieve 40% conversion?
(f) Plot the rate of reaction and conversion as a function of PBR catalyst weight, W.

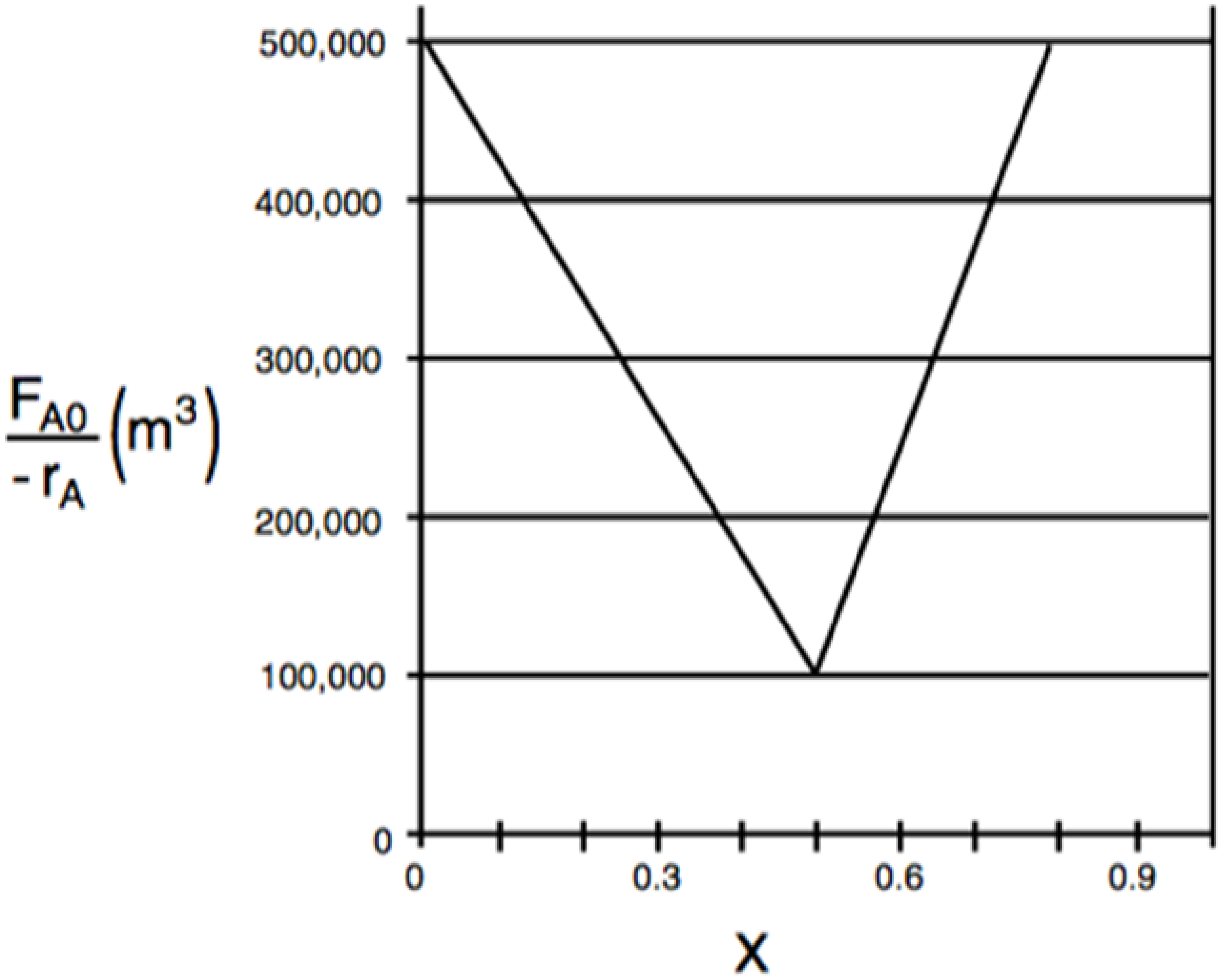

Figure P2-7$_B$ Levenspiel plot.

Figure 2: Figure-p2-7b

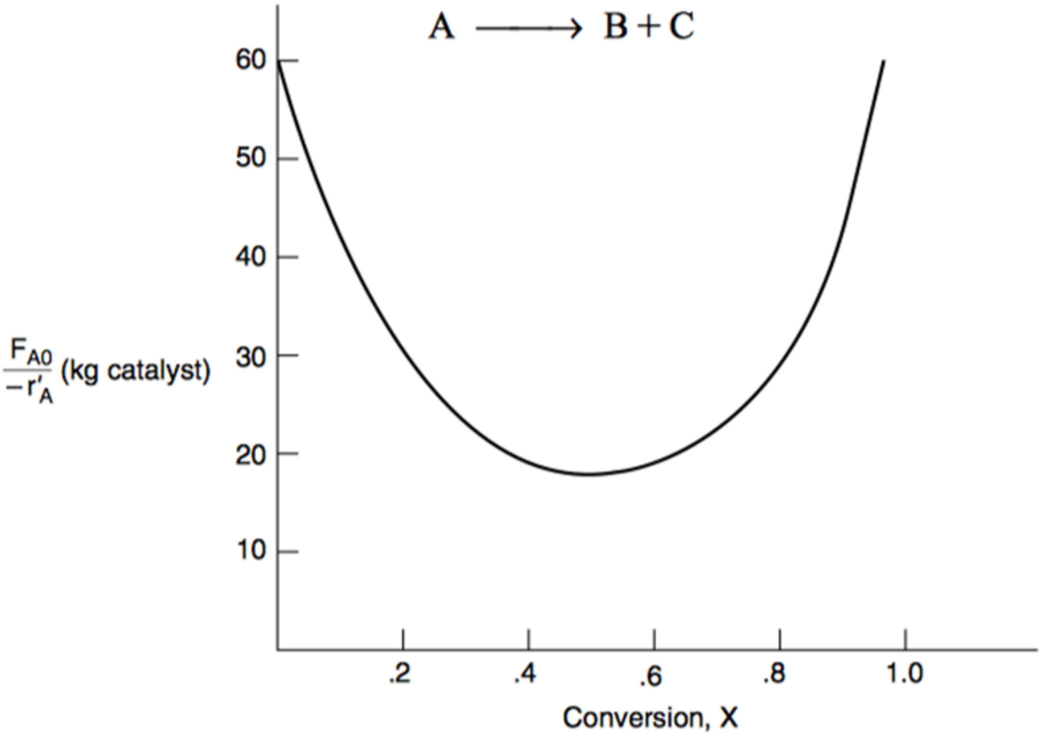

Figure P2-10$_B$ Levenspiel plot for an adiabatic exothermic heterogeneous reaction.

Figure 3: Figure P2-10b

Additional information: FA0 = 2 mol/s.

The data from Figure 3 is provided in file workshop-02-problem-4.csv

Fogler, H. Scott. 2016. *Elements of Chemical Reaction Engineering*. Fifth edition. Boston: Prentice Hall.