Kinetics & Reactor Design 2: Liquid Reactors

Continuing Ed workshop by Richard Skeirik,PE

CSTR Design Exercise

The reaction is a simple irreversible isomerization: A -> B
The reaction rate is r_a =- k_fA. k_f = 5 min^{-1}
An upstream unit dictates a feed concentration of 2.5 mol/ m^3
The business leaders have given us a design objective for a reactor to create 8 mol/min of B

The CSTR balance (you derived this, remember?) is

$$qA_{in} - qA_{out} - Vk_f A_{out} = 0$$

Approach 1: Set Conversion

Name	**Value**	**Units**
Kf	5	min^{-1}
q		m^3/min
Ain	2.5	mol/ m^3
Aout		mol/ m^3
q•Bout	8.0	mol/min
V		m^3

Here is an insight that makes this problem easier. Since A simply goes to B, you form one mole of B for each mol of A that reacts. So the amount of B exiting (your design variable) is simply equal to the amount of A reacting. Now, which term in the balance is that? Write this equivalence:

[design spec] = [amount of a reacting]

We are already close to being finished. Only V and Aout are unknown. One equation, two unknowns. The choice is ours as designer, so let's **set a conversion** of A. Let's say 80% of A is reacted.

$A_{out} = 0.2 * A_{in}$

Compute that and put it in the table. Now we have one equation to give V. What is V?

This is your reactor design
80% conversion
V = ______ m^3

What is q?
q [Ain – Aout] = VkfAout = 8 mol/min.

Add that to your table.

Approach 2: Set V
What if you already have a 5 m^3 reactor? Let's run at the same q, Ain as above.

Name	Value	Units
Kf	5	min^{-1}
q	4.0	m^3/min
Ain	2.5	mol/ m^3
`Aout		mol/ m^3
q•Bout	8.0	mol/min
V	5	m^3

$$qA_{in} - qA_{out} - Vk_f A_{out} = 0$$

Again, the production spec is the rate of reaction of A:
[amount of A reacting] = [design spec of 8 mol/min]

One equation, one unknown. Solve for Aout. Put it in your table

High Conversion
Let's go back to the first case. Instead of 80% conversion, let's design for 99.99% conversion. What reactor volume do you need?

Why is the reactor so big?