Kinetics & Reactor Design 2: Liquid Reactors

Continuing Ed workshop by Richard Skeirik,PE

PFR Design Exercise

The reaction is a simple irreversible isomerization: A -> B
The reaction rate is $r_a = -k_f A$. the units of k_f are min^{-1}

Our design objective is a reactor to create 8 mol/min of B

$\Big\}$ Same as the CSTR Design Exercise

The PFR balance is a differential equation. I solved this in one slide for you. You may remember these three equivalent forms of the solution

$$\ln\left(A_{z_{final}}\right) - \ln(A_{z=0}) = -\frac{X_C}{q} k_f z_{final}$$

or

$$\ln\left(\frac{A_{z_{final}}}{A_{z=0}}\right) = -\frac{X_C}{q} k_f z_{final}$$

or

$$A_{z_{final}} = A_{z=0} \exp\left(-\frac{X_C}{q} k_f z_{final}\right)$$

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
$V = X_C \bullet z_{final}$		m^3

Our design spec means 8 mol/min of B is formed, thus 8 mol/min of A is reacting.

Let's use the **same spec as our CSTR: 80% of A is reacted**. Thus 80% of the A fed is reacted. Knowing this, we can calculate the mol/min of A in the feed. Ain is given, so we can calculate q. Do it.

Our choice of conversion specification works very nicely with the middle form of the PFR solution above. We know everything except Xc and Zfinal (You may also note that $X_C \bullet z_{final}$ is V.) Go ahead and calculate V

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As you can tell from this, a PFR design is indifferent to how long/skinny the reactor is. It only needs to be skinny enough that the flow is turbulent, since turbulence will give plug flow. The R_e calculation needs to be done, but let's not worry about fluid mechanics in the midst of our reactor design workshop.

Set V

Let's try to same fixed volume as we did the CSTR. What if you already have a 5l pipeline 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

In this case, the last form serves very well since we only need to know Aout.

$$A_{z_{final}} = A_{z=0} \exp\left(-\frac{X_C}{q} k_f z_{final}\right)$$

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?

Compare that to the CSTR volume. Which is more likely to be built?

Why is the PFR so much more efficient?