Kinetics & Reactor Design 2: Liquid Reactors

Continuing Ed workshop by Richard Skeirik,PE

PFR Balance Exercise

Our reactor is a pipe. To avoid confusion, call the cross sectional area X_C, m^2. We use z as the variable for length along the reactor, in m. The reaction rate is $r_a = k_f A$. the units of k_f are min^{-1}

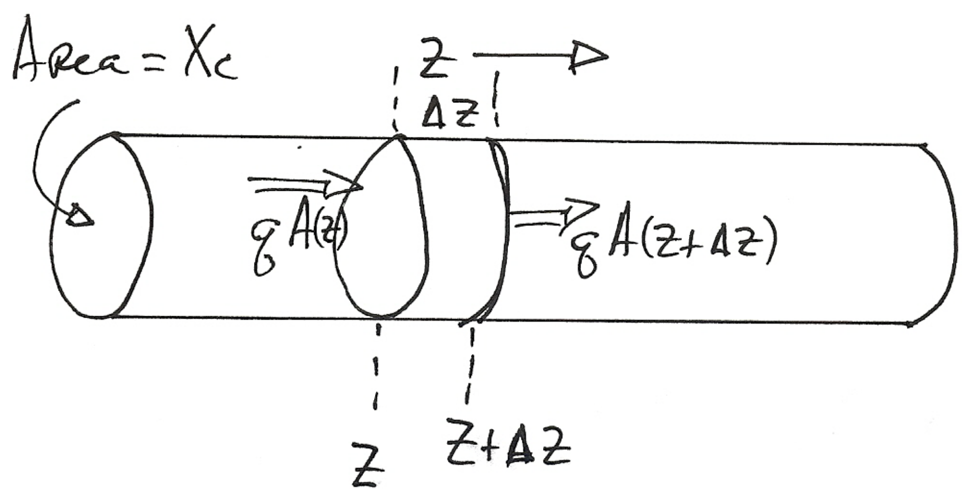
The volumetric flow rate is constant along the whole reactor: q - m^3/min. That is, q is independent of z.

Steady State, first order kinetics

The reaction rate is $r_a = k_f A$. The units of k_f are sec^{-1}

The PFR is not so kind as the other two reactor types. The problem is that the concentrations change along the reactor but we don't know how they change.

We are going to have to do a little calculus to get the material balance. Let's look at a cross sectional slice in the reactor. The slice is Δz long.



We'll just step through the analysis and it won't hurt too much. First, write an expression to compute the volume of the slice:

Volume of slice =

Here, we have to fudge a little until get it exactly right. Assume that the concentration of A with the slice is everywhere equal to the entering concentration, which is A at point z, or A(z). With that, and the volume, write an expression for the rate of reaction of A within the slice. This should have units of something like mol/hr, or similar.

Net rate of reaction within the slice =

Did you notice how, assuming the same concentration throughout the slice, it's just like a little CSTR! How convenient. You already know how to write a balance on that! So do it! Write a CSTR type balance on the slice on A. (Remember, we're considering steady state, so the accumulation term is zero):

Now… chin up! Remember how I showed you how we derive the space derivative?

$$\frac{\mathrm{A}(\mathrm{z}+\Delta \mathrm{z})-\ \mathrm{A}(\mathrm{z})}{\Delta \mathrm{z}} \rightarrow \frac{dA}{dz}$$

Can you rearrange your balance to give this on one side? (Hint, yes):

[Change in A over Δz] = [flow,area constants]*[Rate expression]

And now, you can let Δz go to zero, and then it does become the derivative with respect to z:

[derivative of A wrt z] = [flow,area constants]*[Rate expression]

Go back to your batch exercise. Does anything look similar here? Yes, it's exactly the same *form*, just some different constants.

The PFR is a batch reactor where the reaction proceeds along distance. In fact, since q is constant, there is a simple linear relationship between space and time. The mathematics are ***THE SAME.***

Now…. About the fudge. Remember we fudged that the concentration was the same throughout the slice. When we let Δz go to zero, what does that mean about our fudge?

Don't ask me why the math forgives this. I can't explain.