Advanced Transport Phenomena 1

ChE 862 **May 8, 2019** **Spring 2019**

Final Exercise, due May 17, 2019 by 11:50 AM, and independent effort is expected.

Flow of species "A" through an annular reactor; the inner wall is catalytic and "A" is very rapidly consumed at that surface ($r=R_1$). The outer wall ($r=R_2$) is impermeable. Our main goal is to determine the length of reactor required to reduce the average concentration of "A" by 90%. We will examine two cases: plug flow with $V_{plug} = 60D/(R_2 - R_1)$ *, and laminar flow in which* $V_{max}=V_{plug}$.

The model we are going to employ is:

$$V\frac{\partial C_A}{\partial z} = D\left[\frac{\partial^2 C_A}{\partial r^2} + \frac{1}{r}\frac{\partial C_A}{\partial r}\right].$$

We will take R_1=2 cm, R_2=5 cm, and D=1/8 cm^2/s. For the plug flow case, the velocity (as given above) is $\frac{(60)(1/8)}{(5-2)} = 2.5$ cm/s. Since the reaction at the inner wall is rapid and irreversible, the concentration of species "A" at $r=R_1$ is effectively zero. For laminar flow, you may recall that the maximum velocity occurs at a position given by

$$R_{\max} = \sqrt{\frac{R_2^2 - R_1^2}{2\ln(R_2/R_1)}}.$$

Since the average velocity for the laminar flow will be significantly *lower* than 2.5 cm/s, we should expect the conversion (with respect to *z*-position) to be enhanced. Assume that "A" enters the annular reactor with a uniform (dimensionless) concentration of 1. Use your results to prepare a figure that shows how the *average* concentration of "A" diminishes with *z*-position for the two cases. How long must the two reactors be in order to reduce the average concentration of "A" by 90%?

Exactly how would your model for this problem change if the reaction occurring at the catalytic surface at R_1 was not instantaneous?