10.37 Chemical and Biological Reaction Engineering, Spring 2007
Prof. William H. Green
Lecture 22: Combined Internal & External Transport Resistances

Packed Bed Reactor → use PFR equation

$$\frac{dF_i}{dz} = Ar_i^{eff}$$

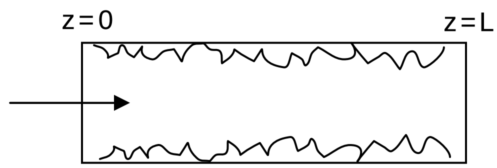

Figure 1. Packed Bed Reactor

$r_i^{eff} \neq r_i^{chem}$ → $r_i^{eff} = \Omega r_i^{chem}$

if $\Omega \approx 1$?
if $\Omega \ll 1$?
($\Omega > 1$) –weird

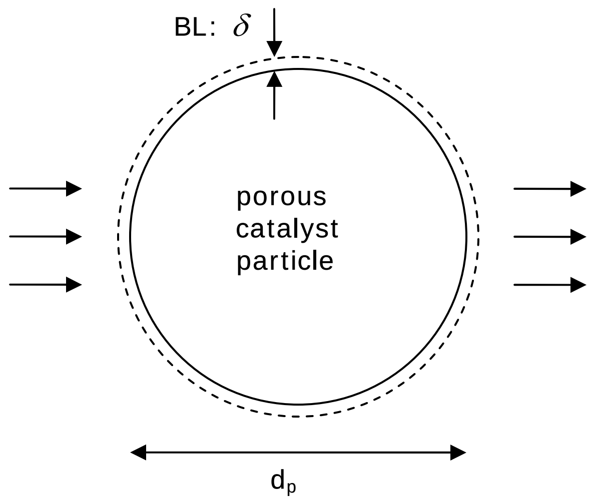

Figure 2. Porous Catalyst Particle

Biot Number:

$$B_i \sim \frac{\text{external heat transfer resistance}}{\text{internal heat transfer resistance}}$$

Mass transfer Biot Number:

$$B_{i_m} = \frac{k_c d_p}{D_{inside}^{eff}} \quad \text{where } k_c \sim \frac{D_{fluid}}{\delta}$$

$$B_{i_m} = \frac{D_{fluid}}{D_{inside}^{eff}} \frac{\text{diameter}}{\delta}$$

Mears' Test:

$$\text{if } \left| \frac{r_A'(\text{observed})\rho_b R_p n}{k_c C_{A\,bulk}} \right| < 0.15 \qquad \text{where } n \equiv \text{order of rxn}$$

then $C_{Ab} \approx C_{As}$ (no external diffusion limitation) → i.e. no changing concentration across the boundary layer

Similarly,

$$\text{if } \left| \frac{\Delta H_{rxn} r_A''(\text{observed or theory})\rho_b R_p E_a}{h_{fluid} RT^2} \right| < 0.15 \text{ then } T_b \approx T_s \text{ (text: Eqn. 12-63)}$$

$$\left| r_A^{\text{no external diff. limit}} \right| \text{ vs. } \left| r_A^{\text{observed}} \right|$$

[>]

Weisz-Prater:

$$\text{if } \left| \frac{r_A'(\text{observed})\rho_c R_p^2}{D_{inside}^{eff} C_{A\,bulk}} \right| \ll 1 \quad \text{(text: Eqn. 12-61)}$$

then you can neglect internal diffusion limitations, i.e. $C_{As} \approx C_{Ab} \approx C_A(r=0)$

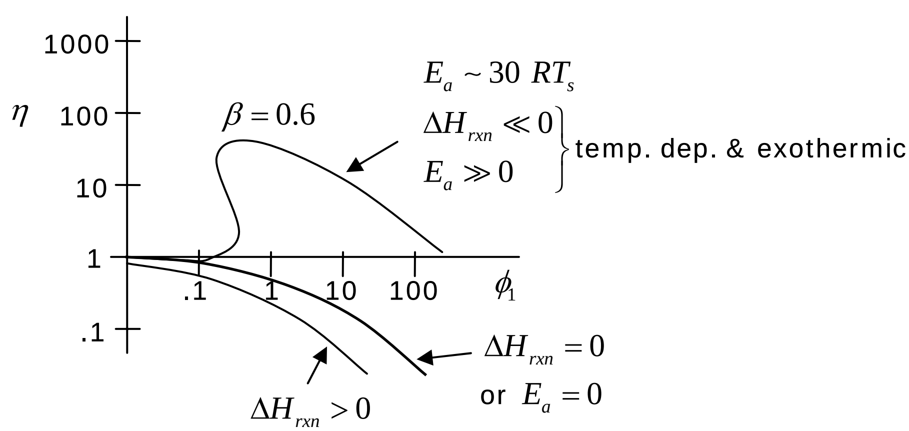

Figure 3. (text: Figure 12-7)

$\beta = \dfrac{-\Delta H_{rxn} D_e C_{As}}{k_t T_s}$ **where** $D_e \equiv D_{inside}^{eff}$ **and** $k_t \equiv$ **heat conductivity**

$$k_c \left(C_{i,b} - C_{i,s} \right) = -D_{inside}^{eff} \left(\frac{\partial C_i}{\partial r} \right) \bigg|_{r=R}$$

$$= \int r_i dV \, .$$

$$k_c \, C_i \big|_{r=R} - D_{inside}^{eff} \left(\frac{\partial C_i}{\partial r} \right) \bigg|_{r=R} = k_c C_{i,\, bulk}$$

$$\left(\frac{\partial C_i}{\partial r} \right) \bigg|_{r=0} = 0$$

if no significant external diffusion limit: $C_i \big|_{r=R} \approx C_{i,\, bulk}$

$$r_A \approx -k C_A$$

$$e^{-E_a/RT}$$

$$r_A^{eff} \approx f(k) C_A$$

fit to: $A_{eff} e^{-E_a^{eff}/RT}$. (text: Table 12-1)