Name: ______________________________ Entry no: ______________________________

QUIZ-04

ENZYME SCIENCE AND ENGINEERING

DEPARTMENT OF BIOCHEMICAL ENGG AND BIOTECHNOLOGY-IIT DELHI

22/3/2023 5 x 1 marks

1. A system is being developed to remove urea from the blood of patients with renal failure. A prototype fixed-bed reactor is set up with urease immobilised in 2-mm gel beads; buffered urea solution is recycled rapidly through the bed so that the system is well mixed. The urease reaction is:

$$(NH_2)_2CO + 3\,H_2O \rightarrow 2\,NH_4^+ + HCO_3^- + OH^-$$

K_m for the immobilised urease is 0.54 g/L. The volume of beads in the reactor is 250 cm^3, the total amount of urease is 10^{-4}g, and the turnover number is 11 000 g $NH4^+$ per g enzyme per second. The effective diffusivity of urease in the gel is 7 x 10^{-6} cm $^2s^{-1}$; external mass-transfer effects are negligible. The reactor is operated continuously with a liquid volume of 1 litre. The feed stream contains 0.42 g/L urea; the desired urea concentration is 0.02 g/L. Ignoring enzyme deactivation, what volume of urea solution can be treated in 30 min?

Table 12.2 Generalised Thiele moduli

First-order reaction: $r_A = k_1\, C_A$

$$\phi_1 = \frac{V_p}{S_x}\sqrt{\frac{k_1}{\mathscr{D}_{Ae}}}$$

Sphere $\quad \phi_1 = \frac{R}{3}\sqrt{\frac{k_1}{\mathscr{D}_{Ae}}}$

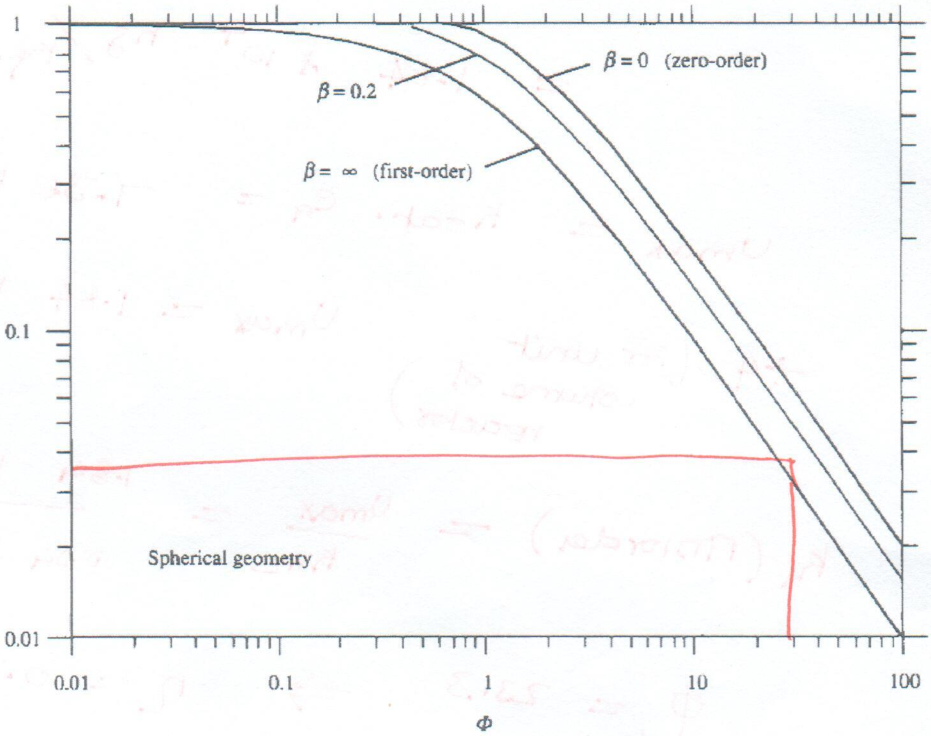
Flat plate $\quad \phi_1 = b\sqrt{\frac{k_1}{\mathscr{D}_{Ae}}}$

Zero-order reaction: $r_A = k_0$

$$\phi_0 = \frac{1}{\sqrt{2}}\frac{V_p}{S_x}\sqrt{\frac{k_0}{\mathscr{D}_{Ae}\, C_{As}}}$$

Sphere $\quad \phi_0 = \frac{R}{3\sqrt{2}}\sqrt{\frac{k_0}{\mathscr{D}_{Ae}\, C_{As}}}$

Flat plate $\quad \phi_0 = \frac{b}{\sqrt{2}}\sqrt{\frac{k_0}{\mathscr{D}_{Ae}\, C_{As}}}$



$\beta = k_m/C_{AS}$

Kcat = 11000 g $NH4^+$/g/sec

R = 1mm = 10^{-3} m

S_o = 0.42g/L

K_m = 0.54 g/L = 0.54 Kg/m^3

S_f = 0.02g/L

V = 1L

First order:

$$\phi_1 = \frac{R}{3}\sqrt{\frac{K_1}{Deff}}$$

Enzyme loading / unit volume:

$$e_a = \frac{10^{-4}\,g}{250\ cm^3} = 4\times10^{-4}\ kg/m^3$$ (unit volume of enzyme)

$$D_{eff} = 7\times10^{-10}\ m^2/s$$

60.1 g Urea $\longrightarrow$ 36 g NH_4^+

$$k_{cat} = 11000\ g\ NH_4/g.\ enzyme/s \times \frac{60.1}{36}$$

$$= 1.84\times10^{4}\ kg/kg.(enz)/sec.$$

$$U_{max} = k_{cat}.\ e_a = 7.36\ kg/m^3/s$$

$\div 4$ (for unit volume of reactor) $U_{max} = 1.84\ kg/m^3/s$

$$k_1\ (\text{First order}) = \frac{U_{max}}{k_m} = \frac{1.84\ kg/m^3/s}{0.54\ kg/m^3} = 3.41\ s^{-1}$$

$$\phi_1 = 23.3 \Rightarrow \eta = 0.03$$

$$D = \eta \cdot \frac{U_{max}.S}{k_m + S\ (S_i - S)} = 7.06\times10^{-3}\ s^{-1}$$

$$F = D.v = 7.06\times10^{-3}\ 1/s$$

in 30 minutes

volume treated = $\underline{\underline{12.7\ L}}$