BT 302: Biochemical Engineering
Tutorial-1 Date: 14/03/2106

1. An enzyme is immobilized in agarose beads of diameter 8 mm. The concentration of enzyme in the beads is 0.018 kg of protein per m^3 of gel. Ten beads are immersed in a well-mixed solution containing substrate at a concentration of 5.0×10^{-3} kg /m^3. The effective diffusivity of substrate in the agarose gel is 2.13×10^{-9} m^2 /s. The kinetics of the enzyme reaction can be approximated as first-order with specific rate constant 3.11×10^5 s^{-1} per kg of protein. Mass transfer effects outside the particles are negligible. Calculate the steady-state substrate concentration inside the beads at different values of r = (a) 4 mm, (b) 2 mm, (c) 1 mm and (d) 0.01 mm.

2. Nonviable yeast cells are immobilised in alginate beads. The beads are stirred in glucose medium under anaerobic conditions. The effective diffusivity of glucose in the beads depends on cell density according to the relationship: $D_{es} = 6.33 - 7.17\, y$
   where D_{es} is the effective diffusivity x 10^{10} m^2 /s and y is the weight fraction of yeast in the gel. The rate of glucose consumption can be assumed to be zero-order; the reaction rate constant at a yeast density in the beads of 15 wt% is 0.5 g /min-l. For the catalyst to be utilized effectively, the concentration of glucose inside the particles should remain above zero.
   (a) Calculate the maximum allowable particle size as a function of the bulk glucose concentrations of 5 g/ l and 50 g /l.
   (b) For medium containing 30 g /l glucose, calculate R_{max} at cell loading of 5 and 30 wt%.

3. An enzyme which hydrolyzes the cellobiose to glucose, β-glucosidase is immobilized in a sodium alginate gel sphere 2.5 mm in diameter). Assume that the zero-order reaction occurs at every point within the sphere with k_0 = 0.0795 mol/sm^3 and cellobiose moves through the sphere by molecular diffusion with D_{es} =0.6 x 10^{-5} cm^2/s (cellobiose in gel). Calculate the effectiveness factor of the immobilized enzyme when the cellobiose concentration in bulk solution is 10 mol/m^3.

4. The values of K_M and v_{max} for an enzyme (21°C and pH 7.1) are 0.004 kmol/m^3 and 10 kmol/m^3s, respectively. We immobilized this enzyme by attaching it covalently to acrylamide-based polymers that can be assumed to have spherical shape (diameter = 1 mm). The effectiveness of the immobilized enzyme was found to be 70 percent of the free enzyme when the concentration of the substrate was 0.5 kmol/m^3 .The reaction was carried out in a stirred reactor with an agitation speed of 50 rpm.
   (a) Estimate the concentration of the substrate at the surface of the immobilized enzyme,
   (b) Estimate *ks a.*

5. Consider a system where a flat sheet of polymer coated with enzyme is placed in a stirred beaker. The intrinsic maximum reaction rate (v_{max}) of the enzyme is 6 x 10^{-6} mol/s-mg enzyme. The amount of enzyme bound to the surface has been determined to be 1 x 10^{-4} mg enzyme/cm^2 of support. In solution, the value of K_M has been determined to be 2 x10^{-3} mol/l. The mass-transfer coefficient can be estimated from standard correlations for stirred vessels. We assume in this case a very poorly mixed system where k_s = 4.3 x 10^{-5} cm/s. What is the reaction rate when (a) the bulk concentration of the substrate is 7 x 10^{-3} mol/l? (b) Sb = 5 x 10^{-2} mol/l?