International Master's Programs of Chemical Engineering in the Graduate School of Engineering, Kyushu University (Academic Year from October, 2025)

Subject: Mass Transfer (1 sheet)

1. (25 points)

Consider the diffusion of dilute component A in a stationary fluid in a cylindrical tube of radius R. Let C_A be the concentration of component A, and D be the diffusion coefficient.

(1.1) The rate of change in concentration C_A due to diffusion in cylindrical coordinates is expressed as follows:

$$D\left[r^{B_1}\frac{\partial}{\partial r}+r^{B_2}\frac{\partial^2}{\partial r^2}+r^{B_3}\frac{\partial^2}{\partial \varphi^2}+r^{B_4}\frac{\partial^2}{\partial z^2}\right]C_A.$$

Answer the integers correponding to B_1, B_2, B_3, and B_4. Additionally, provide the rationale for these values.

(1.2) At the inner wall of the tube, component A is decomposed at a rate of kC_AA_w per unit time, where k (>0) is a constant and A_w is the wall surface area. Assuming that C_A is uniform in both the radial and circumferential directions, derive the partial differential equation describing the time variation of C_A.

2. (25 points)

Consider the mass transfer of a protein from a stationary sphere surface of diameter $d = 0.1$ mm into the surrounding flowing water. The diffusion coefficient of the protein in water is $D = 1\times10^{-9}$ m^2/s and the Schmidt number is $Sc = 700$. The concentration the protein on the sphere is $C_s = 100$ mol/m^3, and in flowing water is $C_\infty = 0$. The Sherwood number Sh, Reynolds number Re, and Schmidt number Sc are assumed to follow the correlation $Sh = 2 + 0.6Re^{1/2}Sc^{1/3}$.

(2.1) Calculate the flux of the protein from the sphere surface to the water when the flow velocity of water far from the sphere is U_∞ =3.5 cm/s.

(2.2) When the flow velocity is increased, the flux becomes twice as large as in question (2.1). Answer how many times U_∞ has increased.