International Master's Programs of Chemical Engineering in the Graduate School of Engineering, Kyushu University (Academic Year from October, 2026)

Subject: Chemical Engineering II: Mass transfer (1 sheet)

1. (25 points)

A liquid flows downward as a laminar liquid film along the inner wall of a vertical tube, absorbing a solute component from a gas stream rising inside the tube. The tube diameter is 0.050 m, the average gas velocity is 1.0 m/s, the kinematic viscosity of the gas is 15.0×10^{-6} $\mathrm{m^2/s}$, and the diffusion coefficient of the solute components is 1.0×10^{-5} $\mathrm{m^2/s}$. The Sherwood number Sh, Reynolds number Re, and Schmidt number Sc are assumed to follow the correlation $Sh = 0.023Re^{0.83}Sc^{0.44}$.

(1.1) Calculate the Reynolds number.

(1.2) Calculate the Schmidt number.

(1.3) Calculate the Sherwood number.

(1.4) Calculate the mass transfer coefficient.

2. (25 points)

Consider a binary fluid composed of species A and B, which has a one-dimensional concentration distribution in the y direction. The molar flux of species A is given by

$$N_A = x_A\left(N_A + N_B\right) - cD_{AB}\frac{\mathrm{d}x_A}{\mathrm{d}y}, \tag{1}$$

where x_i, c_i, N_i $(i = \mathrm{A, B})$ represent the mole fraction, molar concentration, and molar flux of component i, respectively; D_{AB} represents the diffusivity of the component A in B; $c = c_A + c_B$. The boundary conditions are given as $x_A = x_0$ at $y = 0$ and $x_A = x_\delta$ at $y = \delta$. In addition, $\frac{\mathrm{d}N_A}{\mathrm{d}y} = 0$ at $0 \leq y \leq \delta$. Fill in the blanks X1-X6 with the appropriate expressions or numerical values.

(2.1) For equimolar counterdiffusion, $N_A + N_B = \boxed{\text{X1}}$ holds. In this case, integrating Eq. (1) over the interval $[0, \delta]$ yields $N_A = \boxed{\text{X2}}$. Accordingly, the mass transfer coefficient under this condition is given by $k' = \boxed{\text{X3}}$.

(2.2) For one-directional diffusion of component A through stagnant B, $N_A + N_B = \boxed{\text{X4}}$ holds. In this case, integrating Eq. (1) over the interval $[0, \delta]$ yields $N_A = \boxed{\text{X5}}$. Accordingly, the mass transfer coefficient under this condition is given by $k = \boxed{\text{X6}}$.