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

Subject：Reaction Engineering　(1 sheet)

1.　(25 points)

Answer the following questions.

The liquid-phase reaction, A → P proceeds at a steady state in a constant temperature with Plug Flow Reactor (PFR). The reaction rate is $-r_A = kC_A$, where r_A, k, and C_A are reaction rate, reaction rate constant and concentration of A, respectively.　The reactor has a total volume V, and the feed stream is supplied at a constant volumetric flow rate v. The space time is defined as $\tau = V/v$. The feed stream contains only component A , and an initial molar concentration of A is C_{A0}.

(1.1)　Describe the reactor outlet ($C_{A,out}$) in terms of C_{A0}, k, and τ .

(1.2)　Describe the fractional conversion (X_A) of the system as a function of k and τ.

(1.3)　Suppose we have a Continuous Stirred Tank Reactor (CSTR) and a PFR, both having the same space time τ. Which reactor will achieve a higher conversion?　Describe the reason briefly.

2.　(25 points)

Answer the following questions.

The gas-phase decomposition of ozone ($2O_3 \rightarrow 3O_2$) proceeds through the following two-step mechanism involving a highly reactive oxygen intermediate, O*:

$$O_3 + M \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} O_2 + O^* + M$$

$$O^* + O_3 \xrightarrow{k_2} 2O_2$$

where M represents inert gas molecule. The reaction takes place in a steady-state at constant temperature and pressure.

(2.1)　By applying the steady-state approximation to the intermediate species O*, derive the rate expression for the disappearance of ozone, $-r_{O3}$, in terms of [O_3], [O_2], [M], and the rate constants.

(2.2)　Suppose the feed consists of 10 % ozone (O_3) and 90% inert gas (M) by mole fraction. If the conversion of O_3 at the reactor outlet is 50 %, calculate the mole fraction of O_2 at the outlet. Assume the reaction is irreversible and follows the stoichiometry $2O_3 \rightarrow 3O_2$.

(2.3)　Show that if the second step is much faster than the reverse of the first step ($k_2[O_3] \gg k_{-1}[O_2][M]$), the reaction becomes first-order with respect to O_3.