

**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.

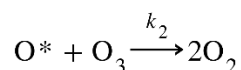
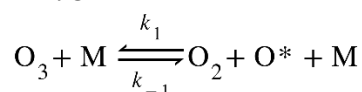
The liquid-phase reaction, $A \rightarrow P$ proceeds at a steady state in a constant temperature with Plug Flow Reactor (PFR). The reaction rate is $-r_A = kC_A$, where r_A , k , and C_A are reaction rate, reaction rate constant and concentration of A, respectively. The reactor has a total volume V , 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^* :



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, $-r_{O_3}$, 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 .