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

Subject: Biochemical Engineering (1 sheet)

1. (25 points)

Answer the following questions.

(1.1) ***D*-value in Heat Sterilization**

Explain the meaning of the *D*-value in heat sterilization and describe its significance in sterilization process design.

(1.2) **Monod Equation and Its Limitations**

Explain the Monod equation describing microbial growth kinetics. In addition, discuss the limitations of the Monod model in practical bioprocesses.

(1.3) **Respiratory Quotient and Its Significance**

Define the respiratory quotient (*RQ*) and explain its physiological and engineering significance in bioprocess monitoring and control.

(1.4) **Shear Stress in Animal Cell Culture**

Explain the mechanism of shear stress generation in animal cell culture systems and discuss its effects on cell growth, viability, and product quality.

(1.5) **Significance of $k_L a$ in Bioprocess Scale-Up**

Explain the meaning of the oxygen transfer coefficient ($k_L a$) in bioreactor scale-up. Discuss its relationship to oxygen transfer, mixing, and cell damage in large-scale bioprocesses.

2. (25 points)

A certain type of cell was cultured using a stirred-tank bioreactor. Answer the following questions.

(2.1) Cells were cultured in suspension under batch operation, during which the cells exhibited good proliferation, yielding the data shown in the table below. Determine the specific growth rate and the doubling time of these cells.

Culture time [h]	0	100
Cell density $[\text{cells} \cdot \text{L}^{-1}]$	1.0×10^8	1.0×10^9

(2.2) In the culture described in (2.1), the cell density reached $1.0 \times 10^{10}\ \text{cells} \cdot \text{L}^{-1}$, and this density required a dissolved oxygen concentration of $4.0 \times 10^{-5}\ \text{mol} \cdot \text{L}^{-1}$. Determine the oxygen consumption rate per cell. Assume that the volumetric oxygen transfer coefficient of the bioreactor is $k_L a = 50\ \text{h}^{-1}$, and that the dissolved oxygen concentration in equilibrium with the oxygen partial pressure of the gas phase is $2.4 \times 10^{-4}\ \text{mol} \cdot \text{h}^{-1}$.

(2.3) When continuous culture operation is carried out at a dilution rate of $0.050\ \text{h}^{-1}$, describe what kind of trouble may be of concern and explain the reason.