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

Subject: Biochemical Engineering

(1.1) The *D*-value is the time required at a specific temperature to reduce the microbial population by 90% (1/10 reduction rate).
A smaller *D*-value indicates lower heat resistance. *D*-values are used in sterilization process design for food and pharmaceutical applications.

(1.2) The Monod equation describes the relationship between substrate concentration and microbial growth rate.
The growth rate increases with substrate concentration and approaches μ_{max}.
Limitations include inability to describe substrate inhibition, product inhibition, multiple substrates, and intracellular metabolic regulation.

(1.3) The respiratory quotient (*RQ*) is the ratio of carbon dioxide production to oxygen consumption.
RQ indicates cellular metabolic state. *RQ* monitoring is useful for process control.

(1.4) Shear stress is mechanical stress caused by fluid flow and agitation.
It occurs near impellers, bubbles, and pumps. Animal cells are sensitive because they lack cell walls.
Excessive shear stress causes cell damage, reduced viability, lower productivity, altered product quality, etc.
Low-shear agitation and protective additives are commonly used.

(1.5) $k_L a$ represents oxygen transfer capacity from gas to liquid phases.
Maintaining sufficient $k_L a$ is important because oxygen is often limiting in aerobic cultures.
During scale-up, oxygen transfer becomes more difficult due to poor mixing and oxygen gradients. Increasing agitation improves $k_L a$, but may also increase shear stress and energy consumption.

(2.1) Specific growth rate: $0.023\ \mathrm{h^{-1}}$, Doubling time: 30 h

(2.2) $1.0 \times 10^{-12}\ \mathrm{mol \cdot h^{-1} \cdot cell^{-1}}$

(2.3) Wash out, $\because$ Dilution rate $\gg$ Specific growth rate in (2.1)