TABLE 10.3 Some Time Constants (Equations)[a]

Transport process	Equation
Flow	L/v or V/Q
Diffusion	L^2/D
Oxygen transfer	$1/k_La$
Heat transfer	$V\rho C_p/UA$
Mixing	$t_m = 4V/(1.5ND^3)$, stirred vessel
Conversion processes:	
Growth	$1/\mu$
Chemical reaction	C/r
Substrate consumption	$C_s/r_{\max}$ ($C_s >> K_s$)
	$K_s/r_{\max}$ ($C_s << K_s$)
Heat production	$\rho C_p\, \Delta_k T/r\Delta H$

[a]With permission, from N. W. F. Kossen, in T. K. Ghose, ed., *Biotechnology and Bioprocess Engineering*, United India Press Link House, New Delhi, 1985, pp. 365–380.

One approach to predicting possible reactor limitations is the use of characteristic time constants for conversion and transport processes. Table 10.3 defines some of the important time constants, and Table 10.4 shows the application of these time constants to a 20 m^3 fermenter for the production of gluconic acid.

Processes with time constants that are small compared to the main processes appear to be essentially at equilibrium. If, for example, $1/k_La << t_{O_2}$ conversion (t_{O_2} conversion is the time constant for O_2 consumption), then the broth would be saturated with oxygen, because oxygen supply is much more rapid than conversion. If, on the other hand, consumption is of the same order of magnitude as oxygen supply (e.g., $1/k_La \approx t_{O_2}$ conversion), the dissolved oxygen concentration may be very low. This is precisely the case in Table 10.4 and Fig. 10.6. The resulting experimental measurements of dissolved oxygen show the

TABLE 10.4 Time Constants, 20-m^3 Fermenter[a]

Transport phenomenon	Time constant(s)
Oxygen transfer	5.5 (noncoal.)–11.2 (coal.)[b]
Circulation of the liquid	12.3
Gas residence	20.6
Transfer of oxygen from a gas bubble	290 (noncoal.)–593 (coal.)
Heat transfer	330–650
Conversion	
Oxygen consumption, zero order	16
First order	0.7
Substrate consumption	$5.5 * 10^4$
Growth	$1.2 * 10^4$
Heat production	350

[a]With permission, from N. W. F. Kossen, in T. K. Ghose, ed., *Biotechnology and Bioprocess Engineering*, United Press Link House, New Delhi, 1985, pp. 365–380.

[b]Coal. = coalescing air bubbles.