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face. Thus, for a reaction of arbitrary order n

$$\text{reaction rate} = k\,C_w^n = \beta(C - C_w) \qquad (1)$$

In accordance with Frank-Kamenetskii (2), $\zeta = C_w/C$. Then

$$\text{reaction rate} = kC^n\,\zeta^n = \beta C(1 - \zeta) \qquad (2)$$

The dimensionless concentration ratio ζ is found by solving Equation (2)

$$\lambda\,\zeta^n = 1 - \zeta,\ \lambda = \frac{kC^{n-1}}{\beta} \qquad (3)$$

Equations (2) and (3) are easily applied to an experimentally interesting case: a differential tubular reactor with reaction occurring along the tube wall, reactant supplied to the wall by diffusion from fluid passing through the tube. For fully developed laminar flow, $\beta = \gamma N_{Re}{}^{1/3}$, where γ is a constant for a given diffusing species, fixed tube diameter and length (5). Because a differential reaction is occurring, reactant concentration C is essentially constant along the length of the reactor and may be closely approximated by C_o, the inlet reactant concentration. Then

$$\text{reaction rate} = kC_o^n\zeta^n = \gamma N_{Re}{}^{1/3}C_o(1 - \zeta) \qquad (4)$$

where ζ is given by

$$\lambda\zeta^n = 1 - \zeta,\ \lambda = \frac{kC_o^{n-1}}{\gamma N_{Re}{}^{1/3}} \qquad (5)$$

The usual differential reactor rate expression, Fx/SAL, where x is reactant conversion, may be cast into a more useful form for our purpose. Because the feed rate is essentially constant everywhere along the tube for a differential reactor (even for the case where reaction stoichiometry indicates a change in total moles), the apparent contact time for fixed L is inversely proportional to N_{Re} (that is, $F/C_oAL = \dfrac{\mu}{DL\rho}\,N_{Re}$). Furthermore, reactant conversion for a differential reactor is usually too small to measure experimentally and is best expressed as the measured product concentration at the reactor exit normalized on reactant concentration, C_o (that is, $x = C_{\text{prod}}/\nu C_o$ for $A \rightarrow \nu B$ and product free feed). The net result is a rate of reaction for this differential system of the form $aC_{\text{prod}}\,N_{Re}$ where a is a dimensional constant ($a = \mu/\nu SDL\rho$) incorporating terms resulting from the transformation of the usual rate expression.

Finally

$$aC_{\text{prod}}N_{Re} = kC_o^n\zeta^n = \gamma N_{Re}{}^{1/3}C_o(1 - \zeta) \qquad (6)$$

or

$$\frac{C_{\text{prod}}}{C_o} = \frac{kC_o^{n-1}\,\zeta^n}{aN_{Re}} = \frac{\gamma(1 - \zeta)}{aN_{Re}{}^{2/3}} \qquad (7)$$

and ζ is found from Equation (5) for particular values of $\lambda = kC_o^{n-1}/\gamma N_{Re}{}^{1/3}$. Equation (7) has two limiting forms:

Complete diffusion control

$$\frac{C_{\text{prod}}}{C_o} = \frac{\gamma}{a}\,N_{Re}{}^{-2/3}\ \text{for}\quad kC_o^{n-1} >> \gamma N_{Re}{}^{1/3}$$

Complete activation control

$$\frac{C_{\text{prod}}}{C_o} = \frac{kC_o^{n-1}}{a}\,N_{Re}{}^{-1}\ \text{for}\quad kC_o^{n-1} << \gamma N_{Re}{}^{1/3}$$

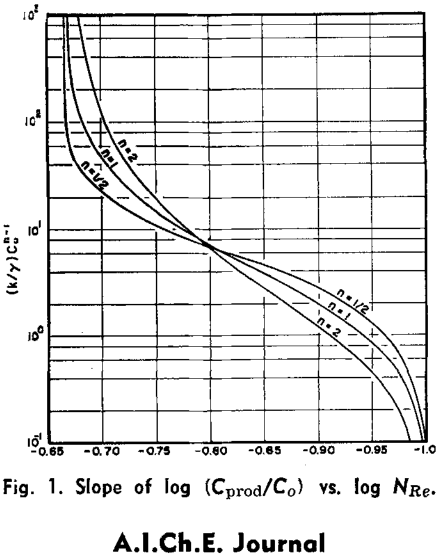

Fig. 1. Slope of log (C_{prod}/C_o) vs. log N_{Re}.

Plots of log (C_{prod}/C_o) vs log N_{Re} will be straight lines of indicated slopes for these two extreme cases. For intermediate control, Equation (7) applies, and a linear relationship between log (C_{prod}/C_o) and log N_{Re} would not be expected. Actually, essentially straight lines do result when Equation (7) is solved for pairs of values of C_{prod}/C_o and N_{Re} at fixed values of kC_o^{n-1}/γ. With a N_{Re} range of 10 to 1,000, deviation from linear behavior is less than 4% for $n = 1/2$, 1, 2, and is certainly within the usual experimental error. The result of measuring the slopes of plots of log (C_{prod}/C_o) vs log N_{Re} for fixed kC_o^{n-1}/γ is shown in Figure 1 for reaction orders, $n = 1/2$, 1, 2. The asymptotic behavior of the slopes for the two limiting cases is evident.

With this method it is possible, for differential tube-wall reactions, to estimate wall reactant concentrations. One need only measure product concentrations at various flow rates for a tube of fixed length and inlet reactant concentration. The slope of a plot of log (C_{prod}/C_o) vs log N_{Re} fixes kC_o^{n-1}/γ and then, provided n is known, ζ or C_w/C_o may be found using Equation (5).

Of particular interest is the accuracy one might expect in estimating C_w/C_o for systems operating under true diffusional control. Although the following analysis may be performed for any reaction order it will be simpler to treat $n = 1$. In any case the conclusions to be drawn will be equally valid for any order reaction simply because

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Chemical Engineers' Handbook, 4th Edition, Edited by R. H. Perry, C. H. Chilton, S. D. Kirkpatrick, McGraw-Hill, New York (1963). 1,915 pages. $29.50.

The first edition of the Chemical Engineers' Handbook, edited by the late John H. Perry, was published in 1934. It was intended to present, in convenient form, many of the equations and data that a practicing engineer needed for the design of chemical-plant equipment. Perry's Handbook, as it became known, was soon regarded as the chemical engineer's "bible."

The rapid growth of chemical engineering literature and changes in design techniques have been evidenced in the subsequent editions of 1941 and 1950 and particularly in the present edition. Although the concept of unit operations is still used for defining the sections of the handbook, emphasis has been shifted toward the more fundamental engineering sciences of thermodynamics, reaction kinetics, solid and fluid mechanics, and mass and energy transfer. There is considerably less in the way of empiricism and more in the use of statistical and mathematical analysis.

Unfortunately, the expansion in the number of topics covered has necessitated an accompanying decrease in detail. In many areas the handbook serves only as a guide to the literature, with a profusion of bibliographical references. In view of the obvious difficulty, or impossibility, of giving adequate coverage to so many topics in one handbook, this reviewer wonders if some of the sections, such as the one on physical and chemical data, should not be published as separate volumes.

Among the new topics presented in the fourth edition are dynamics of falling films and fluidized beds, electromagnetic pumps, jet pulverizers, the use of computers in designing multicomponent distillation units, and unsteady state diffusion.

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