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mass transfer calculations than the practical diffusion coefficient form.

ACKNOWLEDGMENT

Acknowledgment is made to the donors of the Petroleum Research Fund, administered by the American Chemical Society, for support of this research.

NOTATION

C = total molar concentration
C_i = concentration of species i
$\mathcal{D}_{ij}$ = binary diffusion coefficient
D_{ij} = multicomponent diffusion coefficient
$[D]$ = multicomponent diffusion coefficient matrix with elements D_{ij}
$[k]$ = multicomponent mass transfer coefficient matrix
k_i = binary mass transfer coefficients
$\lceil k_i \rfloor$ = diagonal matrix whose elements are k_i
n = one less than the number of components
$[t]$ = modal matrix of $[D]$
(u) = column vector defined by $\beta(y)$
$\lceil u \rfloor$ = diagonal matrix with elements of (u)
y_i = mole fraction of component i
(y) = column vector with elements y_i
$\lceil y \rfloor$ = diagonal matrix with elements of y_i
α_{ij} = $1/\mathcal{D}_{ij}$
(α_{n+1}) = column vector with elements $\alpha_{i,n+1}$
$\lceil \alpha_{n+1} \rfloor$ = diagonal matrix with elements $\alpha_{i,n+1}$
β_{ij} = defined by Equation (5)
$[\beta]$ = matrix whose elements are β_{ij}
$\underline{\theta}_i$ = molar flux of species i with respect to molar average velocity, a three vector
(θ) = column vector with elements θ
$\lceil \underline{\theta} \rfloor$ = diagonal matrix with elements $\underline{\theta}_i$
∇ = gradient operator

Subscripts

i, j, k = indices

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the surface, and a (horizontal) force, acting between the molecule and other adsorbed molecules in the immediate vicinity. The first of these forces depends upon the potential energy function between the surface and a single gas molecule, whereas the second can be characterized by a two-dimensional equation of state for the adsorbed layer. For an idealized homogeneous adsorbent, the characteristic potential energy between the surface and a single gaseous molecule is uniform over the surface, but for a real, heterogeneous adsorbent the potential energy is not the same for all parts of the surface since some sites are more active than others. To characterize the heterogeneity of the solid surface, the authors use a Gaussian distribution function $\Phi(U_o)$ for the characteristic adsorption potential energy U_o. For the equation of state of the adsorbed layer they use a two-dimensional analogue of the van der Waals equation which, through the Gibbs adsorption isotherm, may be integrated to give a fractional coverage θ at equilibrium pressure P having the form $\psi(P, U_o)$. It is then shown that the experimentally obtained adsorption isotherm, up to monolayer coverage, has the general form

$$\theta = \int \Phi\,(U_o)\;\Psi\,(P, U_o)\;dU_o.$$

Perhaps the most important contribution of the book is concerned with a discussion of this integral equation. The equation has four temperature-independent molecular parameters having clear physical significance. The function Φ involves the mean characteristic potential energy of adsorption and its (Gaussian) variance, and the function ψ involves the two van der Waals constants α and β which are two-dimensional analogues of the familiar a and b in the van der Waals equation for nonideal gases. For this particular model numerical integrations are presented in tabular form at the end of the book; the calculated isotherms are matched with experimental results to yield the desired molecular parameters. This type of data reduction enables interpretation of adsorption data along rational molecular lines. According to this simple but reasonable model the variance of the adsorption energy is independent of the adsorbate but depends only on the heterogeneity of the adsorbent, and the van der Waals constants depend only on the nature of the adsorbate, being independent of the adsorbent. Only the mean characteristic potential energy of adsorption is a function of the adsorbent-adsorbate pair. Molecular parameters are presented for various gases and solids, and it is reasonable to expect that at least some of these may be correlated in terms of more readily available macroscopic properties.

In addition to a detailed analysis of the heterogeneous solid-mobile gas model, the authors devote a chapter to a lucid discussion of the various heats of adsorption and their interrelation, and another chapter to a generous treatment of intermolecular potentials between solids and adsorbed gases. The latter, unfortunately, does not include any mention of the effect of nonadditivity which, as Sinanoglu and Pitzer have shown, is by no means negligible.

Dr. Ross, Professor of Colloid Science at Rensselaer Polytechnic Institute, and his former student and associate, Dr. Olivier, have performed a valuable service to the chemical profession in summarizing the present state of monolayer physical adsorption, a subject to which Professor Ross and his co-workers have contributed much original material. As pointed out in the foreword by Professor de Boer, the complex subject of the physical adsorption of gases on solids, which has for so long been known only empirically, is now at last beginning to stand on a sound theoretical foundation, one on which future research workers may build with confidence. This well-written monograph will serve admirably to introduce interested chemical engineers to one of the fascinating frontiers of current research in molecular thermodynamics.

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Process Systems Analysis and Control, Donald R. Coughanowr and Lowell B. Koppel, McGraw-Hill Book Company, Inc., New York (1965), 491 pages, $15.50.

Although it has become apparent in recent years that one of the major areas of application of control systems is the chemical and petroleum industries, there has been a decided lack of textbooks written for the chemical engineer and the chemist that deal with this type of analysis. The current book is therefore welcome as an attempt to familiarize the chemical engineer with available process control techniques from both an analytical and a simulation point of view.

The first half of the book is devoted to linear-systems analysis of such topics as open- and closed-loop systems, root

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$$U_s = k\,U \qquad (15)$$

where k is a proportionality constant greater than unity which accounts for local slip. Equation (15) is integrated over the flow cross section as in Equation (1), using the distribution parameter as defined by Equation (8), to give

$$\frac{\overline{U}_s}{\overline{U}_w} = \left[\frac{1-\alpha}{\dfrac{K}{k}-\alpha}\right] \qquad (16)$$

This author (*4*) analyzed slug flow where the local gas velocity has two components; it is rising through the liquid with a velocity given by the Taylor relationship (*5*) and, at the same time, it is being carried along at the stream velocity. Thus

$$U_s = U + C\sqrt{gD} \qquad (17)$$

where g is the acceleration due to gravity and D is the diameter of the enclosing channel. Again, integrating Equation (17) over the cross section of the stream as in Equation (1), using Equation (8) and noting that the buoyant component of the slug velocity is constant, we obtain

$$\overline{U}_s = \frac{1}{K}\overline{U} + C\sqrt{gD} \qquad (18)$$

Using Equation (3) in Equation (18) gives

$$\frac{\overline{U}_s}{\overline{U}_w} = \left[\frac{1-\alpha}{K-\alpha}\right]\left[1 + KC\frac{\sqrt{gD}}{<U_w>}\right] \qquad (19)$$

where $<U_w> = (1-\alpha)\,\overline{U}_w$ is the superficial liquid velocity.

Equation (18) was used previously, although not derived analytically, by Nicklin et al. (*6*), to correlate results of an experimental slug flow study.

Zuber (*7*) made a more general derivation than that of reference (*4*) by defining a local drift velocity V as

$$V = U_s - U \qquad (20)$$

which is again integrated to obtain the cross-sectional average gas velocity

$$\overline{U}_s = \frac{1}{K}\overline{U} + \frac{\int_A pV\,dA}{\int_A p\,dA} \qquad (21)$$

For slug flow, V is equal to the Taylor rise velocity and Equation (18) is valid. For the bubble flow regimes, Zuber gave other rise velocity rela-

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locus methods, and frequency-response methods. The development is a standard one and, except for some of the examples, is not too different from that found in many electrical engineering texts. The next quarter of the book, however, does apply this linear theory to more complex systems which are of direct interest to the chemical engineer.

The final quarter of the book discusses such nonlinear techniques as phase-plane analysis and the describing-function method and then moves to analog simulation techniques as applied to control systems. This portion of the book is the most interesting; it is unfortunate that a greater percentage of the material covered in the entire book was not devoted to these nonlinear systems.

In general, the book is well written and the examples are clearly detailed. The main drawback is the large amount of linear analysis, but for an undergraduate text this may prove quite valuable.

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Industrial Wastewater Control, C. Fred Gurnham, Editor, Academic Press, New York (1965), 476 pages, $16.00.

Control of water pollution is a subject of high current interest. For several years newspapers and popular magazines have been recounting the ravages of uncontrolled discharge of domestic sewage and industrial wastes into surface water; and public demands for abatement of pollution have been reflected in a great deal of legislative activity at both state and federal levels. Publication of a text and reference work on wastewater control is therefore quite timely.

The editor's introduction defines the various parameters of pollution control and briefly describes the common types of wastewater treatment and management. Each of the contributing authors followed a definite outline consisting of a broad review of his industry, a description of the characteristics and volume of the resulting waste water, a discussion of wastewater treatment processes, and a projection of trends in water quality management. This procedure avoided all needless repetition.

Each of the twenty-four chapters has a brief preface that refers the reader to related material in other chapters. The chapters, which are arranged in logical groups, are: Meat; Fish and Fish Products; Poultry and Eggs; Canned Foods; Starch and Starch Products; Sugar; Fermentation Products; Coal Mining; Metal Mining; Industrial Mineral Mining; Coke and Gas; Iron and Steel; Nonferrous Metals; Petroleum; Inorganic Chemicals; Organic Chemicals; Metal Finishing Products; Pulp and Paper; Textiles; Leather; Power; Atomic Energy; and Transportation.

The authors have assembled a surprisingly large amount of numerical data that are frequently difficult to locate. Thus this is truly a reference work that will be useful equally to the professional consultant and to the plant manager seeking a solution to his own wastewater problem.

There is a single thread that runs through all the chapters: the emphasis on good housekeeping practices and process changes to reduce or eliminate industrial wastes at their sources. These common-sense expedients are sometimes difficult to achieve in old industrial plants, but new installations have provision for wastewater control built into the design.

This book illustrates the great progress industry has made in pollution abatement, but it shows clearly that much more needs to be accomplished and indicates the direction future developments should take. On the other hand, the complex technical and economic problems that must be overcome are well documented.

The literary style of the contributors is attractive and quite uniform, indicating conscientious editorial supervision. There is a good index.

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ERRATUM

In the papers "Vapor-Liquid Equilibria in Hydrogen-Benzene and Hydrogen-Cyclohexane Mixtures" by Richard E. Thompson and Wayne C. Edmister and "Calorimetric Determination of the Isothermal Pressure Effect on the Enthalpy of the Propane-Benzene System" by Lyman Yarborough and Wayne C. Edmister (Vol. 11, No. 3, pp. 457-461 and 492-497, respectively), the captions for Figures 1 and 2 were interchanged. The caption for Figure 1 on page 457 should be interchanged with that for Figure 1 on page 492 and the caption for Figure 2 on page 458 should be interchanged with that for Figure 2 on page 493.