Separation Science and Technology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713708471

A Separation Factor Method for the Analysis of Ideal Binary Mixtures in Gas-Solid Adsorption

T. Victor Lee[a]; Jan-Chan Huang[ab]; Richard Madey[a]
[a] DEPARTMENT OF PHYSICS, KENT STATE UNIVERSITY, KENT, OHIO [b] General Electric Co., Schenectady, New York

To cite this Article Lee, T. Victor , Huang, Jan-Chan and Madey, Richard(1984) 'A Separation Factor Method for the Analysis of Ideal Binary Mixtures in Gas-Solid Adsorption', Separation Science and Technology, 19: 2, 157 — 172
To link to this Article: DOI: 10.1080/01496398408060652
URL: http://dx.doi.org/10.1080/01496398408060652

SEPARATION SCIENCE AND TECHNOLOGY, 19(2 & 3), pp. 157-172, 1984

A Separation Factor Method for the Analysis of Ideal Binary Mixtures in Gas–Solid Adsorption

T. VICTOR LEE, JAN-CHAN HUANG,* and RICHARD MADEY

DEPARTMENT OF PHYSICS
KENT STATE UNIVERSITY
KENT, OHIO 44242

Abstract

A correlation formula based on the separation factor is proposed for the mixture concentration in the adsorbed phase of an ideal binary solution in gas–solid adsorption. This formula is shown to apply to two binary systems (viz., 1,3-butadiene and *n*-butane on cross-linked polystyrene at 25°C, and acetylene and ethane on activated carbon at 25°C) with similar molecular and thermodynamic properties in the two components for each system. Comparison between the calculated and experimental values of the separation factor showed that the assumption of an ideal mixture is justified for each of these two binary systems. Mixture isotherms for the two ideal binary systems are calculated by the proposed correlation formula from the corresponding single-component isotherms. Good agreement between the calculated and experimental mixture isotherm data confirms that a binary system of two components with similar molecular properties (viz., molecular weight, normal boiling point, vapor pressure, number of carbon atoms in molecules, etc.) tends to form an ideal mixture (i.e., one with a constant separation factor).

INTRODUCTION

Dynamic studies (*1, 2*) on the transport of binary gaseous mixtures through solid adsorbents revealed interference and displacement phenomena as a result of the interactions between the two components in the adsorbed phase. From the point of view of chemical equilibrium, these molecular interactions affect the adsorption isotherms of binary gas mixtures. An indication of the degree of the molecular interactions in the adsorbed phase is

*Present address: General Electric Co., Schenectady, New York 12308.

 0149-6395/84/1902-0157$3.50/0

also provided by a parameter called the separation factor, which was used (*3, 4*) in the analysis of adsorption equilibrium data of binary mixtures. The separation factor in adsorption equilibrium is analogous to that commonly used in vapor–liquid equilibria.

In this paper we make use of the separation factor to analyze adsorption isotherms of ideal binary mixtures. In gas–solid adsorption, an ideal binary mixture is one with a constant value of the separation factor. Also, we develop and verify a correlation formula, which involves the separation factor, for the prediction of binary isotherms of an ideal mixture from single-component isotherms. Verification of the proposed correlation formula is made by comparison with experimental data for two ideal binary systems (viz., 1,3-butadiene and *n*-butane on cross-linked polystyrene at 25°C, and acetylene and ethane on activated carbon at 25°C). Comparisons are made between the experimental binary isotherms and those calculated from the corresponding single-component isotherm data for the two binary systems. Effects of the similarity in molecular properties between two hydrocarbon gases on the possibility of forming an ideal mixture are also discussed.

THE SEPARATION FACTOR METHOD FOR IDEAL BINARY MIXTURES

Binary gas adsorption on solid adsorbents is a separation process based upon the equilibration of two immiscible phases (viz., the gas and adsorbed phases). The separation factor α_{AB} (*5, 6*) is a parameter used to measure the degree of separation between a weakly adsorbed (more volatile) Component A and a strongly adsorbed (less volatile) Component B:

$$\alpha_{AB} \equiv \frac{K_A}{K_B} \equiv \frac{Y_A/X_A}{Y_B/X_B} \tag{1}$$

Here Y and X denote mole fractions in the gas and adsorbed phases, respectively; and the adsorption equilibrium ratio K is the ratio of gas-phase mole fraction Y to adsorbed-phase mole fraction X. The separation factor is a measure of the distribution of two components between the gas phase and the adsorbed phase. According to the definition in Eq. (1), the separation factor is always greater than or equal to unity because $Y_A > X_A$ for the more volatile component and $Y_B < X_B$ for the less volatile component in the binary mixture. When $\alpha_{AB} > 1$, Component A is more volatile than Component B in the gas phase and less concentrated than Component B in the adsorbed phase. When $\alpha_{AB} = 1$, Components A and B are equally volatile in the gas

phase and the gas- and adsorbed-phase mole fractions are identical for both components.

In vapor–liquid equilibration processes, a binary mixture is an ideal mixture if the two components obey Raoult's law (*7*):

$$P_i = P_T Y_i = P_i^0 X_i \tag{2}$$

where Y_i and X_i are the mole fractions of Component i in the vapor and liquid phases, respectively, P_T is the total pressure, P_i is the partial pressure of Component i in the vapor, and P_i^0 is the vapor pressure of pure Component i. In such a case,

$$K_i \equiv Y_i/X_i = P_i^0/P_T \tag{3}$$

and

$$\alpha_{AB} = P_A^0/P_B^0 \tag{4}$$

According to Eq. (4), the separation factor becomes the ratio of the vapor pressure of Component A to that of Component B, and has a constant value under isothermal conditions. Analogously, in the gas–solid equilibration processes, a statistical mechanical treatment for the adsorption of mixtures at a very low surface coverage (*8*) gives

$$n_i = k_i P_i, \qquad i = A, B \tag{5}$$

According to Eq. (5), each component obeys a linear isotherm, where n_i, k_i, and P_i are the adsorbed-phase concentration, adsorption capacity, and partial pressure for Component i, respectively. The partial pressure P and the adsorbed-phase concentration n are related to the gas-phase mole fraction Y and adsorbed-phase mole fraction X by

$$n_T = n_A + n_B \tag{6}$$

$$n_A = X_A n_T \tag{7}$$

$$n_B = X_B n_T \tag{8}$$

and

$$P_T = P_A + P_B \tag{9}$$

$$P_A = Y_A P_T \tag{10}$$

$$P_B = Y_B P_T \tag{11}$$

Here the subscript T on n_T and P_T denotes the total concentration in the adsorbed phase and the total pressure in the gas phase of Components A and B. Rearrangement of Eqs. (1), (2), and (5) through (11) yields

$$\alpha \equiv \frac{Y_A/X_A}{Y_B/X_B} = \frac{P_A/n_A}{P_B/n_B} = \frac{k_B}{k_A} (= \text{constant}) \tag{12}$$

Most binary systems encountered in gas–solid adsorption do not have linear isotherms for each individual component even for a fairly narrow range of gas pressure. In this paper, binary mixtures with constant values of the separation factor under isothermal and isobaric conditions will be classified as ideal binary mixtures.

Prior studies, based on empirical observations (*3, 5*) or on ideal adsorbed-phase thermodynamics (*6*), reported that the total concentration n_T of Components A and B in the adsorbed phase can be expressed as functions of the mole fractions X_i in the adsorbed phase and of the single-component isotherms:

$$n_T = f[X_i,\ n_A^0(\theta, P_T),\ n_B^0(\theta, P_T)] \tag{13}$$

Here n_A^0 and n_B^0 are the isotherms for pure Components A and B at a temperature θ and a total pressure P_T. Two typical formulas commonly used (*3, 5, 6*) are

$$\frac{1}{n_T} = \frac{X_A}{n_A^0} + \frac{X_B}{n_B^0} \tag{14}$$

and

$$n_T = X_A n_A^0 + X_B n_B^0 \tag{15}$$

These formulas have not been successful in correlating the binary mixture data (*4, 5, 9, 10*).

In binary gas adsorption, the separation factor depends on the temperature (*10*), the total pressure (*4*), and the compositions of the components in the mixture (*4, 10*). For ideal binary mixtures, variations in separation factor occur because the molecular properties of the components vary from one

mixture to another, and the separation factor is an index of the difference between the two components in an ideal binary mixture. We propose to modify the functional relationship Eq. (13) for the total adsorbed-phase concentration n_T by introducing the separation factor as an additional parameter:

$$n_T = f[X_i,\ \alpha_{AB}(\theta,P_T),\ n_A^0(\theta,P_T),\ n_B^0(\theta,P_T)] \tag{16}$$

Using Eq. (1) plus the mass balance equations (viz., $Y_A + Y_B = 1$ and $X_A + X_B = 1$) to express α as a function of Y_A and X_A, and then solving for the ratio $Y_A/X_A \equiv K_A$, we obtain

$$K_A = \frac{Y_A}{X_A} = \frac{\alpha}{1 + X_A(\alpha - 1)} \tag{17}$$

Thus, the adsorption equilibrium ratio K_A is a function of the separation factor α and the adsorbed-phase mole fraction X_A.

Equation (15) is a linear relationship between the total adsorbed-phase concentration n_T of both components in a binary mixture and the adsorbed-phase mole fraction X_i of either component. Measurements (*10–19*) of binary mixtures at constant temperature and pressure reveal that plots of n_T versus X_i exhibit negative deviations from the linear relationship expressed by Eq. (15). To represent the actual behavior of these binary mixture isotherms, we use a linear function of the natural logarithm of adsorption equilibrium ratio ($\ln K_A$) for the correlation of the total adsorbed-phase concentration n_T at a temperature of θ and a constant total pressure P_T:

$$n_T = a(\ln K_A) + b \tag{18}$$

where a and b are coefficients to be determined. For an ideal binary mixture with a constant value of separation factor α, the boundary conditions are as follows: When

$$n_T = n_A^0 \qquad \text{(i.e., when } X_A \to 1\text{)}, \qquad K_A = 1 \tag{19}$$

and when

$$n_T = n_B^0 \qquad \text{(i.e., when } X_A \to 0\text{)}, \qquad K_A = \alpha \tag{20}$$

Substitution of Eqs. (19) and (20) into Eq. (18) gives n_T as a function of K_A:

$$n_T = \left(\frac{n_B^0 - n_A^0}{\ln \alpha} \right) \ln K_A + n_A^0 \tag{21}$$

Finally, substitution of Eq. (17) into Eq. (21) gives

$$n_T = \frac{(n_A^0 - n_B^0) \ln [1 + X_A(\alpha - 1)]}{\ln \alpha} + n_B^0 \tag{22}$$

In a similar manner, we find another equation which is identical to Eq. (22):

$$n_T = \frac{(n_A^0 - n_B^0) \ln [\alpha - X_B(\alpha - 1)]}{\ln \alpha} + n_B^0 \tag{23}$$

Equation (22) or (23) is the basis for calculating the binary isotherms of ideal mixture systems with a constant value of separation factor. When the gas-phase mole fraction Y_A and the separation factor α are known, the adsorbed-phase mole fraction X_A can be calculated from the following equation:

$$X_A = \frac{Y_A}{Y_A + \alpha(1 - Y_A)} \tag{24}$$

Equation (24) is obtained from the rearrangement of Eq. (17). The mole fraction X_B in Eq. (23) is equal to $(1 - X_A)$. The single-component isotherms for Components A and B should give n_A^0 and n_B^0. In this study, the method of Lewis et al. (5) is employed to calculate the separation factor α of a binary mixture from the integration of the corresponding single-component isotherms.

RESULTS AND DISCUSSION

Binary Mixtures of 1,3-Butadiene and *n*-Butane on Polystyrene

Experimental data of pure-gas isotherms of 1,3-butadiene and *n*-butane and of binary mixture isotherms of these gases adsorbed on polystyrene at

25°C were reported in a previous paper (*20*). We calculate the adsorption isotherms for the binary mixtures of 1,3-butadiene and *n*-butane from the corresponding single-component isotherms by the separation factor method proposed here. In Table 1 the calculated values of the separation factor and the adsorbed-phase concentrations are compared with the experimental values. The fact that the calculated values of the separation factor have a nearly constant value with an average of 1.047 confirms that this binary mixture system is an ideal binary mixture. In Table 2 the calculated adsorbed-phase concentrations for the binary mixtures are compared with the experimental values. The largest deviation in the adsorbed-phase concentration is 5.4%; however, most data points are within a 2% deviation of that obtained from experiments. Absolute deviations between the experimental and calculated mole fractions in the adsorbed phase, which are shown in Table 1, range from 0.001 to 0.009.

Binary Mixtures of Acetylene and Ethane on Activated Carbon

Experimental data of pure-gas isotherms of acetylene (*11*) and ethane (*21*) and of binary-mixture isotherms (*11*) of these gases adsorbed on (Columbia 4LXC 12/28) activated carbon were reported in our previous papers. In Table 3 the calculated values of the separation factor and the adsorbed-phase mole fractions are compared with the experimental values. Because the total pressures for the five binary mixtures are close, the calculated separation factors are almost identical (viz., $\alpha = 3.33$). The experimental separation factors range from 3.12 to 3.50 with an average value of 3.29 and appear to be slightly dependent on the compositions. In Table 4 the calculated adsorbed-phase concentrations for the binary mixtures are compared with the experimental values. The calculated adsorbed-phase concentrations are within a 3% deviation of that obtained from experiments except the last data point. Absolute deviations between the experimental and calculated mole fractions, as shown in Table 3, are smaller than 0.011.

Effects of Molecular Properties on the Formation of Ideal Binary Mixtures

The molecular properties (viz., chemical formula, molecular weight, and normal boiling points) of 1,3-butadiene and *n*-butane (Mixture System 1) and that of acetylene and ethane (Mixture System 2) are listed in Table 5. The molecular weights and formulas indicate the size and shape of the compounds, and the normal boiling points are reasonable indices of

TABLE 1

Comparison of Experimental and Calculated[a] Values of Separation Factors and Adsorbed-Phase Mole Fractions of Binary Mixtures of 1,3-Butadiene (Component A) and n-Butane (Component B) on Cross-Linked Polystyrene at 25°C

Gas-phase pressure (mmHg), P_T	Gas-phase mole fraction		Adsorbed-phase mole fraction			Separation factor, α_{AB}
	1,3-Butadiene, Y_A	n-Butane, Y_B	1,3-Butadiene, X_A	n-Butane, X_B	Absolute deviation[b] Δ	
9.47	0.483	0.517	0.477 (0.474)	0.523 (0.526)	0.003	1.026 (1.036)
7.95	0.385	0.615	0.381 (0.376)	0.619 (0.624)	0.005	1.023 (1.040)
7.91	0.583	0.417	0.573 (0.574)	0.427 (0.426)	0.001	1.042 (1.040)
6.43	0.238	0.762	0.239 (0.230)	0.761 (0.770)	0.009	0.994 (1.045)
6.33	0.482	0.518	0.474 (0.471)	0.526 (0.529)	0.003	1.034 (1.046)
6.24	0.737	0.263	0.723 (0.728)	0.277 (0.272)	0.005	1.074 (1.046)
4.81	0.320	0.680	0.318 (0.309)	0.682 (0.691)	0.009	1.010 (1.053)
4.70	0.651	0.349	0.637 (0.639)	0.363 (0.361)	0.002	1.062 (1.054)
3.17	0.484	0.516	0.474 (0.469)	0.526 (0.531)	0.005	1.043 (1.064)

[a] Numbers in parentheses are calculated values.

[b] Absolute deviation $\Delta \equiv |(X_i)_{expt} - (X_i)_{calc}|$.

TABLE 2

Comparison of Experimental and Calculated[a] Adsorbed-Phase Concentrations of Binary Mixtures of 1,3-Butadiene (Component A) and *n*-Butane (Component B) on Cross-Linked Polystyrene at 25°C

Gas-phase pressure (mmHg), P_T	Gas-phase concentration (10^{-7} mol/cm^3)		Adsorbed-phase concentration (10^{-4} mol/cm^3)			Percentage deviation[b] Δ
	1,3-Butadiene, C_A	*n*-Butane, C_B	1,3-Butadiene n_A	*n*-Butane n_B	Total n_T	
9.47	2.459	2.633	1.029 (1.037)	1.130 (1.150)	2.159 (2.186)	1.3
7.95	1.644	2.631	0.7470 (0.7321)	1.215 (1.218)	1.962 (1.950)	0.6
6.43	0.822	2.636	0.4094 (0.3892)	1.304 (1.305)	1.713 (1.694)	1.1
4.81	0.8271	1.759	0.4643 (0.4312)	0.9972 (0.9660)	1.462 (1.397)	4.4
6.33	1.640	1.762	0.8123 (0.7898)	0.9022 (0.8875)	1.714 (1.677)	2.2
7.91	2.480	1.773	1.119 (1.115)	0.8337 (0.8291)	1.953 (1.944)	0.4
6.24	2.472	0.8808	1.214 (1.212)	0.4644 (0.4517)	1.678 (1.664)	0.9
4.70	1.644	0.8823	0.9117 (0.8814)	0.5198 (0.4986)	1.432 (1.380)	3.6
3.17	0.8246	0.8785	0.5318 (0.4976)	0.5911 (0.5642)	1.123 (1.062)	5.4

[a] Numbers in parentheses are calculated values.

[b] Percentage deviation $\Delta \equiv 100|(n_T)_{\text{exptl}} - (n_T)_{\text{calc}}|/(n_T)_{\text{exptl}}$.

TABLE 3

Comparison of Experimental and Calculated[a] Values of Separation Factors and Adsorbed-Phase Mole Fractions of Binary Mixtures of Acetylene (Component A) and Ethane (Component B) on Columbia 4LXC 12/28 Activated Carbon at 25°C

Gas-phase pressure (mmHg), P_T	Gas-phase mole fraction		Adsorbed-phase mole fraction			
	Acetylene, Y_A	Ethane, Y_B	Acetylene, X_A	Ethane, X_B	Absolute deviation[b] Δ	Separation Factor, α_{AB}
7.30	0.151	0.849	0.054 (0.051)	0.946 (0.949)	0.003	3.116 (3.330)
7.64	0.355	0.645	0.148 (0.142)	0.852 (0.858)	0.006	3.168 (3.335)
7.30	0.496	0.504	0.235 (0.228)	0.765 (0.772)	0.007	3.197 (3.330)
7.30	0.711	0.289	0.417 (0.425)	0.583 (0.575)	0.008	3.440 (3.330)
7.44	0.860	0.140	0.637 (0.648)	0.363 (0.352)	0.011	3.500 (3.332)

[a] Numbers in parentheses are calculated values.

[b] Absolute deviation $\Delta \equiv |(X_i)_{\text{exptl}} - (X_i)_{\text{calc}}|$.

TABLE 4

Comparison of Experimental and Calculated[a] Adsorbed-Phase Concentration of Binary Mixtures of Acetylene (Component A) and Ethane (Component B) on Columbia 4LXC 12/28 Activated Carbon at 25°C

Gas-phase pressure (mmHg), P_T	Gas-phase concentration (10^{-7} mol/cm^3)		Adsorbed-phase concentration (10^{-4} mol/cm^3)			Percentage Deviation[b] Δ
	Acetylene, C_A	Ethane, C_B	Acetylene n_A	Ethane n_B	Total n_T	
7.30	0.59	3.34	0.30 (0.28)	5.20 (5.25)	5.50 (5.53)	0.5
7.64	1.46	2.65	0.78 (0.74)	4.50 (4.46)	5.28 (5.20)	1.5
7.30	1.95	1.98	1.10 (1.06)	3.57 (3.59)	4.67 (4.65)	0.4
7.30	2.79	1.14	1.59 (1.67)	2.22 (2.25)	3.81 (3.92)	2.9
7.44	3.45	0.56	1.95 (2.11)	1.12 (1.16)	3.07 (3.27)	6.5

[a] Numbers in parentheses are calculated values.

[b] Percentage deviation $\Delta \equiv 100|(n_T)_{\text{exptl}} - (n_T)_{\text{calc}}|/(n_T)_{\text{exptl}}$.

TABLE 5
Molecular Properties for Individual Components of Two Binary Mixture Systems (*22*)

Substance	Binary Mixture System 1		Binary Mixture System 2	
	1,3-Butadiene (Component *A*)	*n*-Butane (Component *B*)	Acetylene (Component *A*)	Ethane (Component *B*)
Formula	C_4H_6	C_4H_{10}	C_2H_2	C_2H_6
Normal boiling point (°K)	268.7	272.7	189.2	184.5
Molecular weight	54.092	58.124	26.028	30.085
Ratio of molecular weights	54.092/58.124 = 0.931		26.028/30.085 = 0.865	

differences in volatility. As shown in Table 5, the molecular weights and the normal boiling points for the two hydrocarbon compounds in Mixture System 1 are very close, and the number of carbon atoms in each compound are identical. Also, the molecular properties of the two hydrocarbon compounds in Mixture System 2 are similar. The distinct difference in the average value of the separation factors in Tables 1 and 3 for Systems 1 and 2 could be attributed to the difference in the ratios of molecular weights. The similarities in the molecular properties for both Systems 1 and 2 provide a physical basis for forming ideal binary mixtures. This expectation is supported by results shown in Tables 1 through 4.

CONCLUSIONS

In this paper a useful equation (viz., Eq. 22 or 23) is developed for analyzing ideal binary mixtures in gas–solid adsorption. This formula correlates the total adsorbed-phase concentration n_T as a function of the separation factor α and the mole fraction X_i of one of the binary components. This formula is shown to apply to two binary mixture systems (viz., 1,3-butadiene and *n*-butane on polystyrene at 25°C, and acetylene and ethane on activated carbon at 25°C). Physically, the two binary systems are considered to have the capability of forming ideal binary mixtures because the two components in each system have similar molecular properties. Comparison between the calculated and experimental adsorption data (viz., the adsorbed-phase mole fractions and concentrations) shows that the proposed formula is useful for predicting these properties for the two binary systems studied here. The agreement between the calculated and experimental separation factors confirms that these two systems are ideal binary mixtures. This result also demonstrates that the inclusion of a new parameter (viz., the separation factor α) in the correlation formula offers an accurate method for the prediction of adsorption data for ideal binary mixtures. Adsorption isotherms for the ideal binary systems can then be constructed from the predicted adsorption data. This separation factor method of analysis has an additional advantage over prior methods (*6, 23, 24*) in that the calculational procedure is simpler.

According to the definition of ideal binary mixtures, the method proposed in the present work is applicable only to a binary system with a constant value of the separation factor. For other binary systems that do not exhibit this kind of ideal behavior, further investigations on the modification of the present method seem necessary.

SYMBOLS

a slope in Eq. (18)
b intercept in Eq. (18)
C_A gas-phase concentration for Component A (moles of A/cm^3 gas mixture)
C_B gas-phase concentration for Component B (moles of B/cm^3 gas mixture)
k_A adsorption capacity for pure Component A (moles of A/cm^3 adsorbent-mmHg A)
k_B adsorption capacity for pure Component B (moles of B/cm^3 adsorbent-mmHg B)
k_i adsorption capacity for pure Component i (moles of i/cm^3 adsorbent-mmHg i)
K_A adsorption equilibrium ratio for Component A ($\equiv Y_A/X_A$) (dimensionless)
K_B adsorption equilibrium ratio for Component B ($\equiv Y_B/X_B$) (dimensionless)
n_A adsorbed-phase concentration for Component A in mixtures (moles of A/cm^3 adsorbent)
n_A^0 adsorbed-phase concentration for pure Component A (moles of A/cm^3 adsorbent)
n_B adsorbed-phase concentration for Component B in mixture (moles of B/cm^3 adsorbent)
n_B^0 adsorbed-phase concentration for pure Component B (moles of B/cm^3 adsorbent)
n_T total adsorbed-phase concentration (moles of A and B/cm^3 adsorbent)
P_A partial pressure of Component A in binary gas mixtures (mmHg)
P_A^0 vapor pressure for Component A (mmHg)
P_B partial pressure of Component B in binary gas mixtures (mmHg)
P_B^0 vapor pressure for Component B (mmHg)
P_i^0 vapor pressure for Component i (mmHg)
P_T total gas pressure (mmHg)
X_A mole fraction of Component A in the adsorbed phase (dimensionless)
X_B mole fraction of Component B in the adsorbed phase (dimensionless)
Y_A mole fraction of Component A in the gas phase (dimensionless)
Y_B mole fraction of Component B in the gas phase (dimensionless)

Greek Letters

$\alpha_{AB}(\alpha) \equiv \dfrac{K_A}{K_B} \equiv \dfrac{Y_A/X_A}{Y_B/X_B}$ separation factor of a binary mixture containing weakly adsorbed Component A and strongly adsorbed Component B (dimensionless)

θ absolute temperature (°K)

Subscripts

A weakly adsorbed component
B strongly adsorbed component
i either A or B
T binary mixture

Acknowledgment

This work was supported in part by the U.S. Department of Energy.

REFERENCES

1. R. Madey, R. Forsythe, and J.-C. Huang, *Proceedings of the IX Meeting on Flow through Proous Media*, Salvador, Brazil, October 1981.
2. J.-C. Huang and R. Madey, *Carbon, 20*, 118 (1982).
3. D. Basmadjian, *Can. J. Chem., 38*, 149 (1960).
4. J. D. Kaser, L. D. Rutz, and K. Kammermeyer, *J. Chem. Eng. Data, 7*, 211 (1962).
5. W. K. Lewis, E. R. Gilliland, B. Chertow, and W. P. Cadogan, *Ind. Eng. Chem., 42*, 1319 (1950).
6. A. L. Myers and J. M. Prausnitz, *AIChE J., 11*, 121 (1965).
7. K. G. Denbigh, *The Principle of Chemical Equilibrium*, Oxford University Press, 1981, Chap. 8.
8. T. L. Hill, *An Introduction to Statistical Mechanics* Addison-Wesley, Reading, Massachusetts, 1960.
9. R. P. Danner and L. A. Wenzel, *AIChE J., 15*, 515 (1969).
10. R. V. Jelinek, PhD Dissertation, Columbia University, 1953.
11. T. V. Lee, J.-C. Huang, D. P. Rothstein, and R. Madey, *Sep. Sci. Technol., 19*, 1 (1984).
12. K. Chandrasekharan, PhD Dissertation, Rhode Island University, 1963.
13. R. O. Friederich and J. C. Mullins, *Ind. Eng. Chem., Fundam., 11*, 439 (1972).
14. A. J. Kidnay and A. L. Myers, *AIChE J., 12*, 981 (1966).
15. O. K. Crosser and B. V. Hang, *J. Chem. Eng. Data, 25*, 339 (1980).
16. R. P. Danner and E. C. F. Choi, *Ind. Eng. Chem., Fundam., 17*, 248 (1978).

17. S. H. Hyun and R. P. Danner, *J. Chem. Eng. Data, 27*, 196 (1982).
18. T. Nakahara, M. Hirata, and H. Mori, *Ibid.*, 27, 317 (1982).
19. T. Nakahara, M. Hirata, and S. Kamatsu, *Ibid., 26*, 161 (1981).
20. J.-C. Huang, D. Rothstein, and R. Madey, *J. Chromatogr., 256*, 213 (1983).
21. J.-C. Huang, R. Forsythe, and R. Madey, *Ibid., 214*, 269 (1981).
22. R. C. Reid, J. M. Prausnitz, and T. K. Sherwood, *The Properties of Gases and Liquids*, 3rd ed., McGraw-Hill, New York, 1977.
23. S. Suwanayuen and R. P. Danner, *AIChE J., 26*, 76 (1980).
24. E. Costa, J. L. Sotelo, G. Calleja, and C. Marron, *Ibid., 27*, 5 (1981).

Received by editor August 9, 1983