Int. J. Heat Mass Transfer. Vol. 25, No. 2, pp. 223-229, 1982
Printed in Great Britain

0017-9310/82/020223-07 $03.00/0

CORRELATION OF THE EFFECTS OF VISCOSITY AND SURFACE TENSION ON GAS ABSORPTION RATES INTO FREELY FALLING TURBULENT LIQUID FILMS

Y. S. WON and A. F. MILLS
University of California, Los Angeles, CA 90024, U.S.A.

(*Received* 20 *December* 1980 *and in revised form* 7 *July* 1981)

Abstract—Experimental data for gas absorption into freely falling turbulent liquid films are presented. Carbon dioxide was absorbed into methanol and aqueous propanol solutions at 25°C to obtain a surface tension range of 22.2–72 $\times$ 10^{-3} N/m. Hydrogen, oxygen and CO_2 were absorbed into ethanol at 25°C to obtain a diffusion coefficient range of 3.88–17.6 $\times$ 10^{-9} m^2/s in a low surface tension liquid. The data obtained, together with earlier data of Lamourelle and Sandall, and Chung and Mills, was used to develop a correlation of the mass transfer coefficient which properly accounts for the effects of liquid phase properties.

NOMENCLATURE

c,	molar concentration;
Cb,	'capillary-buoyancy' number, $\nu(\rho^3 g/\sigma^3)^{1/4}$; same as Kapitsa number to the one-quarter power;
$\mathscr{D}$,	diffusion coefficient;
g,	gravitation acceleration;
K_L,	mass transfer coefficient [m/s];
L,	exchanger length;
$\dot{M}_L$,	molar flow rate [kmol/s];
N_{tu},	number of transfer units, $K_L cPL/\dot{M}_L$;
P,	wetted perimeter;
R,	tube radius;
Re_L,	film Reynolds number, $4\Gamma/\rho\nu$;
Sc,	Schmidt number;
x,	mole fraction solute.

Greek symbols

Γ,	liquid flow rate/unit width perimeter [kg/ms];
δ,	film thickness;
ν,	kinematic viscosity;
ρ,	liquid density;
σ,	surface tension.

INTRODUCTION

WETTED wall tubes or plates, with turbulent falling liquid films are in wide industrial use, for example, as gas scrubbers, evaporators or condensers. A large scale application of current interest is for open cycle ocean thermal energy conversion, in which air desorption rates determine the amount of gas to be pumped out of the condenser. In such equipment the mass transfer coefficient, K_L, characterizing gas absorption into a freely falling turbulent film, can reasonably be postulated to have the following parameter dependence:

$$K_L = f(\Gamma, g, \nu, \rho, \mathscr{D}, \sigma) \qquad (1)$$

for which a complete set of dimensionless groups is

$$\frac{K_L}{(g\nu)^{1/3}};\ Re_L = \frac{4\Gamma}{\rho\nu};\ Sc = \frac{\nu}{\mathscr{D}};\ Cb = \nu\left(\frac{\rho^3 g}{\sigma^3}\right)^{1/4}. \qquad (2)$$

For engineering purposes we desire the functional relationship among these groups, i.e. we should develop a correlation of the form

$$\frac{K_L}{(g\nu)^{1/3}} = f(Re_L, Sc, Cb) \qquad (3)$$

which will be valid over the parameter range of engineering interest.

Dimensionless correlations of convective heat and mass transfer coefficients usually have been developed using both experimental data and elements of theoretical analysis, such as asymptotic limits etc. Unfortunately, theory relevant to the problem under consideration is in a very primitive state, mainly due to the complex nature of the underlying fluid mechanics, which involves the interaction between a wavy free interface and a turbulent base flow. The available theory gives little guidance to developing an appropriate correlation: perhaps the only useful prediction is that $K_L \propto \mathscr{D}^{1/2}$ which is given by both surface renewal models, e.g., Higbie [1] and by eddy diffusivity models with $\varepsilon \propto y^2$, e.g. Levich [2].

Since adequate theoretical guidance is lacking, a comprehensive experimental data base is required to develop a generally valid correlation for K_L. In principle each of the independent parameters in eqn. (1) should be varied over the range of concern. However we can reasonably restrict our attention to normal gravity, and also we observe that density varies but slightly compared to the other liquid properties. Thus we are primarily interested in the parameters Γ, ν, $\mathscr{D}$ and σ.

Significant prior work

Kamei and Oishi [3] absorbed CO_2 into water at temperature from 8.5 to 50°C in the Reynolds number range 55–11,000. In the turbulent flow regime ($Re \gtrsim 1000$) the data were correlated as

$$K_L \propto Re_L^{0.7} \mathscr{D}^{0.556}. \qquad (4)$$

Although Kamei and Oishi took the Reynolds number exponent to be constant at 0.7, a careful examination of their data shows a clear dependence of the exponent on water temperature, and hence, most probably, on viscosity. They also assumed that the effect of surface tension on K_L was negligible: however the surface tension of water varied only 9% in their temperature range, so that the conclusion is unwarranted.

Lamourelle and Sandall [4] absorbed He, H_2,O_2, and CO_2 into water at 25°C over a Reynolds number range of 1300–8300. Their data were well correlated by

$$K_L \propto Re_L^{0.837} \mathscr{D}^{0.537}. \tag{5}$$

In a later investigation using the same rig, Menez and Sandall [5] absorbed CO_2 into water at 25°C over a Reynolds number range of 2300–10,500 to obtain values of K_L which showed a mean deviation of 3.1% from equation (5).

Chung and Mills [6] investigation the effect of liquid viscosity by absorbing CO_2 into tap water at three different temperatures, and aqueous ethylene glycol solutions at four mixture ratios, giving a viscosity range from 0.661×10^{-6} to 2.75×10^{-6} m^2/s: complete property data for these liquids are given in Table 1. In the turbulent flow regime it was found that the data could be well correlated as

$$K_L = aRe_L^n. \tag{6}$$

A two-fold variation of n was found, from 0.57 to 1.14, and since it appeared to be primarily a function of viscosity, n was correlated as

$$n = 6.95 \times 10^{-2} (\nu m^2/s)^{1/2}. \tag{7}$$

Assuming a one-half power dependence of K_L upon $\mathscr{D}$, the data for K_L was correlated as

$$\frac{K_L}{(g\nu)^{1/3}} = Re_L^n Sc^{-1/2} f(Cb) \tag{8}$$

where $f(Cb)$ is a graphed function. For these liquids the surface tension varied over too small a range (57.5–73.5×10^{-3} N/m) to allow a conclusive determination of its effect. Chung [7] tested one low surface tension liquid, ethanol at 25°C ($\sigma = 22.7 \times 10^{-3}$ N/m) and found that although n was well correlated by equation (7), equation (8) gave too low a value of K_L. Thus further studies of the effect of surface tension were indicated.

Objectives

The objectives of the work reported here were to experimentally determine the effect of surface tension on the liquid side mass transfer coefficient for gas absorption into freely falling turbulent films, and subsequently attempt a correlation of K_L which would properly account for the effects of Γ, $\mathscr{D}$, ν and σ. Two sets of experiments were carried out:

(i) Methanol, and aqueous propanol solutions of varying concentration were used to obtain a wide range of surface tension (22.2–72×10^{-3} N/m). Propanol was chosen from candidate primary alcohols because its vapor pressure at 25°C is close to that of water, which facilitated the operation of an existing test rig built by Chung [7]. Use of a higher or lower vapor pressure alcohol leads to difficulties in maintaining the mixture composition substantially constant during a test. Carbon dioxide was absorbed into each of the solutions at 25°C.

(ii) In order to determine the effect of $\mathscr{D}$ on K_L in an unambiguous manner it is desirable, for a given test liquid, to vary $\mathscr{D}$ by absorbing different solute gases (as was done by Lamourelle and Sandall [4] for water at 25°C). To obtain the corresponding data for a low surface tension liquid, H_2,O_2 and CO_2 were absorbed into pure ethanol giving a range of $\mathscr{D}$ from 3.88 to 17.6 $\times 10^{-9}$ m^2/s.

EXPERIMENTAL EQUIPMENT AND PROCEDURES

A detailed description is given by Won [8]. Briefly the liquid loop components were: circulating pump, rotameter, activated carbon filter, absorption column, liquid receiver, desorption tower, and various valves and connecting pipes. The liquid film was formed on the inside wall of a 20.5 mm inside diameter, 2 m long vertical glass tube. A machined slot-shaped distributor ensure a uniform inlet film thickness while, to minimize splashing where the liquid film met the liquid in the collector, the column exit was made in the form of a bell-mouth. The end effect due to increased absorption area in the collector was estimated to give a 2% increase in effective column height. The desorption tower was maintained at about 5 cmHg absolute pressure by a vacuum pump. The solute gas supply was saturated with the test liquid in a bubbler before entering the column, and the pressure in the column was maintained at about 10 cm H_2O above ambient pressure. The temperature of the test liquid was maintained at 25°C ± 0.5°C. Sample solutions were drawn from inlet and outlet sampling ports. For CO_2 a common wet chemistry method was used to determine concentration, as described by Chung [7]. For H_2 and O_2 a vacuum extractor in the form of a modified van Slyke gas blood apparatus, and a gas chromatograph were used.

The test liquids were methanol, ethanol and aqueous propanol solutions of mole fraction propanol x = 0, 0.02, 0.05, 0.10, 0.20, 0.50 and 1.00. Table 1 lists ν, σ, Sc and Cb for each of the liquids. These physical properties of the liquids, as well as the solute gas solubilities, were measured independently in our laboratory, and where comparison with prior data was possible, the agreement was found to be satisfactory. The mass transfer coefficient was calculated using the equation for a single stream mass exchanger,

$$K_L = \frac{\Gamma}{\rho L} \frac{R}{R - \delta} \ln \frac{c_i - c_{in}}{c_i - c_{out}} \tag{9}$$

where c_i is the interfacial concentration of solute gas, and c_{in}, c_{out} are the bulk concentration at the inlet and outlet of the column, respectively. Equation (9) assumes that K_L is independent of distance along the

Table 1. Summary of liquid properties (at 25°C unless otherwise stated)

Liquid	ρ (kg/m^3)	ν (m^2/s) × 10^6	σ (N/m) × 10^3	c_{sat,CO_2} kg-mol/m^3 atm	Cb × 10^3	Sc_{CO_2}
Methanol	786.6	0.695	22.2	0.159	3.17	83
Ethanol	785.0	1.400	22.7	0.125	6.28	360
		Aqueous propanol solutions				
$x = 0.0$	997.0	0.893	72.2	0.0346	2.02	458
$x = 0.02$	987.2	1.169	41.8	0.0332	3.90	683
$x = 0.05$	975.6	1.613	30.5	0.0318	6.84	1128
$x = 0.10$	954.2	2.178	26.3	0.0334	10.14	1534
$x = 0.20$	916.8	2.790	25.9	0.0429	12.75	1777
$x = 0.50$	849.4	2.884	24.9	0.0685	12.79	1494
$x = 1.00$	800.0	2.428	23.4	0.0963	10.79	889
		Ethylene glycol–water mixtures				
$x = 0.00$	997	0.898	72	0.0346	2.02	458
$x = 0.052$	1015	1.30	65	0.0302	3.20	822
$x = 0.12$	1036	1.88	61	0.0279	4.95	1540
$x = 0.20$	1053	2.75	57.5	0.0270	7.66	2700
		Tap water at different temperatures				
40°C	992	0.661	69.6	0.0240	1.53	236
25°C	997	0.898	72	0.343	2.03	458
14°C	999	1.171	73.5	0.0472	2.61	813

column, i.e. entrance effects are negligible, and that δ is constant, i.e. K_L is based on the superficial area of the falling film. The mean film thickness was calculated from the Brötz formula [9].

$$\delta = 0.068\left(\frac{\nu^2}{g}\right)^{1/3} Re_L^{2/3}. \qquad (10)$$

EXPERIMENTAL RESULTS

Figures 1, 2 and 3 show K_L as a function of Re_L for CO_2 absorption into the test liquids. The transition from wavy laminar to turbulent flow is in clear evidence. For the higher viscosity liquids the highest attainable Reynolds numbers were limited by the capacity of the rotameter. The turbulent regime data was fitted as $K_L = aRe_L^n$; values of a and n are given in Table 1. Figure 4 shows K_L as a function of Re_L for

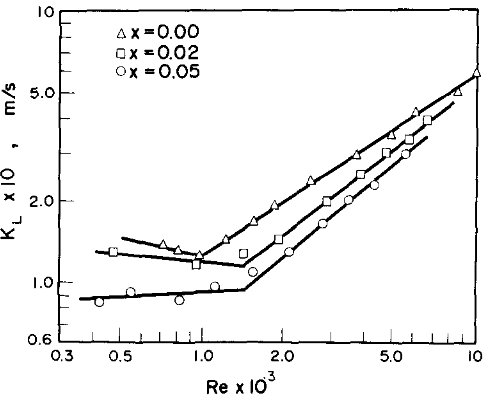

FIG. 2. Mass transfer coefficient vs. Reynolds number for CO_2 absorption in aqueous propanol solutions at 25°C.

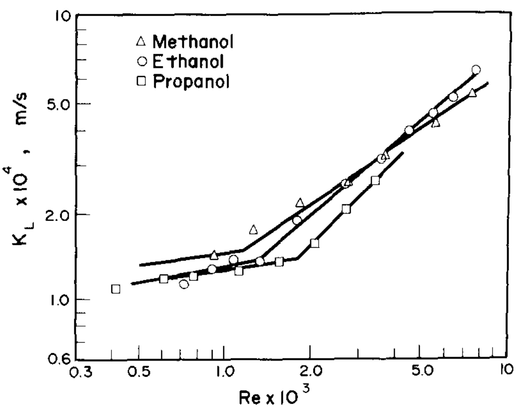

FIG. 1. Mass transfer coefficient vs. Reynolds number for CO_2 absorption into three alcohols at 25°C.

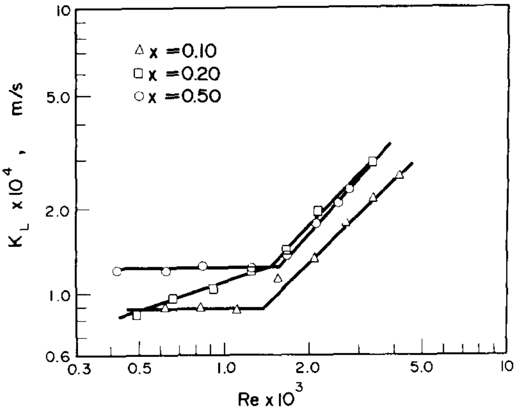

FIG. 3. Mass transfer coefficient vs. Reynolds number for CO_2 absorption into aqueous propanol solutions at 25°C.

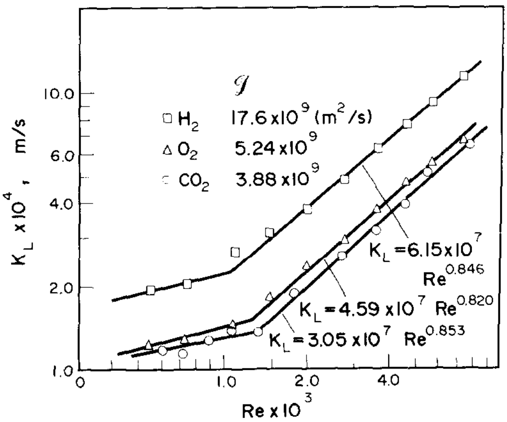

FIG. 4. Mass transfer coefficient vs. Reynolds number for CO_2, O_2 and H_2 absorption by ethanol at 25°C.

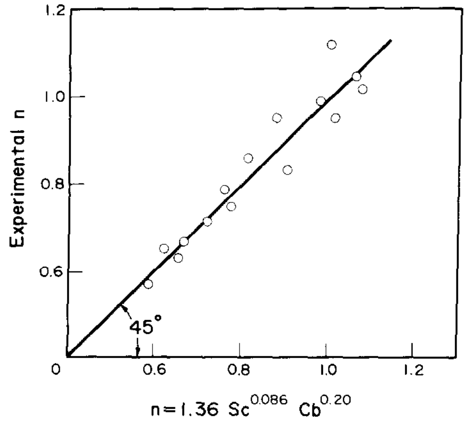

FIG. 5. Correlation of Reynolds number exponent as a function of Schmidt number and capillary-buoyancy number.

H_2,O_2 and CO_2 into ethanol; values of a and n are also shown in Fig. 4. Within experimental error the value of n is seen to be independent of $\mathscr{D}$.

DISCUSSION

Development of a correlation

As mentioned in the Introduction, dimensional analysis suggests a correlation of the form $K_L/(g\nu)^{1/3} = f(Re,Sc,Cb)$. Since experiment suggests $K_L \propto Re^n$, and $K_L \propto \mathscr{D}^\alpha$, the correlation can be reduced to

$$\frac{K_L}{(g\nu)^{1/3}} = Re_L^n Sc^{-\alpha} f(Cb). \qquad (11)$$

Since n was observed to be independent of Re_L within the Reynolds number range considered (to the precision of the data), n is at most a function of the remaining dimensionless groups Sc and Cb, and we can attempt a correlation of the form $n = bSc^\beta Cb^\gamma$. The constants b and exponents β and γ were determined by least squares regression analysis for the set of 15 liquids listed in Table 1 to give

$$n = 1.36\, Sc^{0.086}\, Cb^{0.20}. \qquad (12)$$

Table 2. Values of a and n in the curve fits $K_L = a\, Re_L^n$ for CO_2 absorption

X	$a \times 10^7$ (m/s)	$S_a^* \times 10^7$	n	$S_n^\dagger$
Propanol aqueous solutions at 25°C				
0.00 [6]	14.1	1.28	0.651	0.011
0.02	5.28	1.064	0.748	0.025
0.05	2.31	0.559	0.829	0.030
0.10	0.964	0.333	0.948	0.043
0.20	0.758	0.213	1.018	0.036
0.50	0.589	0.227	1.046	0.050
1.00	0.826	0.343	0.991	0.053
Ethyl alcohol at 25°C [6]				
	3.05	0.56	0.853	0.022
Methyl alcohol at 25°C				
	15.91	5.93	0.546	0.045

$$* \; S_a = \sqrt{\mathrm{var}(a)}\sqrt{\frac{a^2\,\mathrm{var}\,(y_i)\Sigma x_i{}^2}{N\Sigma(x_i - \bar{x})^2}}.$$

$$\dagger \; S_n = \sqrt{\mathrm{var}(n)} = \sqrt{\frac{\mathrm{var}\,(y_i)}{\Sigma(x_i - \bar{x})^2}}$$

where $x_i = \ln Re,i$; $y_i = \ln K_L,i$; $\bar{x} = \Sigma x_i/N$.

A comparison between the experimental values and the calculated values according to equation (12) is shown in Fig. 5.

On the other hand, the results in Fig. 3 for absorption of H_2,O_2 and CO_2 into ethanol show no discernible effect of Sc on n, whereas equation (12) indicates a 14% variation should be expected. Likewise Lamourelle discerned no effect of Sc on n in their results for water. Thus the Sc effect in equation (12) could be at least partly due to lack of precision in the data. A simpler alternative correlation as a function of Cb alone was attempted, as shown in Fig. 6. The result is

$$n = 3.49\, Cb^{0.27}. \qquad (13)$$

Since the Schmidt number is the only dimensionless group in the attempted correlation that contains the molecular diffusion coefficient, its exponent α in equa-

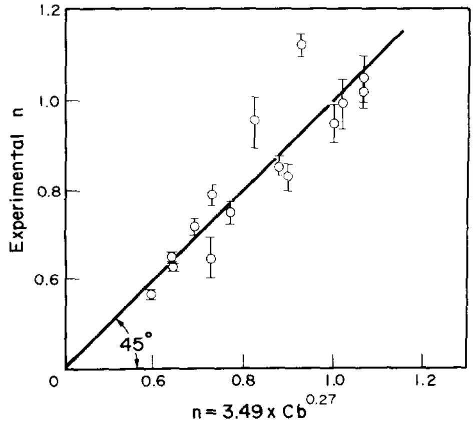

FIG. 6. Correlation of Reynolds number exponent as a function of capillary-buoyancy number.

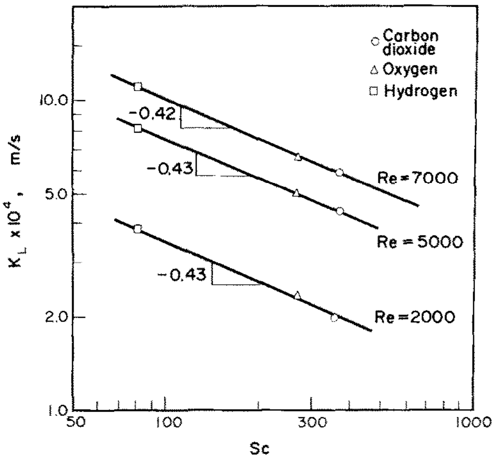

FIG. 7. Mass transfer coefficient as a function of Schmidt number at three different Reynolds numbers.

tion (11) can be determined from the observed dependence of K_L on $\mathscr{D}$. Unfortunately there are only two test liquids available for this purpose, water at 25°C from the study by Lamourelle, and ethanol at 25°C from the present study. Ethanol was chosen in the present study so as to have a value of σ very different to the value for water, 22.2 vs 72.2 × 10^{-3} N/m. Originally we had hoped to be able to construct a statistically significant empirical correlation based on a number of test liquids covering both the viscosity and surface tension range. However at the present time there are available only the two test liquids, and no theoretical model which could give insight into the dependence of α. Nevertheless, it does seem reasonable to assume that α is independent of Re and Sc (at least in the relatively narrow range of high Sc values characterizing gas absorption): Fig. 7 supports such an assumption. Thus at most $\alpha = \alpha(Cb)$, and assuming $\alpha = cCb^{\delta}$ gives

$$\alpha = 0.137\,Cb^{-0.22}. \tag{14}$$

On the other hand we note that for the two test liquids ν varied over a relatively small range (0.9–1.4 × 10^{-6} m^2/s) compared with σ (22.7–72.2 × 10^{-3} N/m). Thus it could be argued that the limited data do not justify characterization of the dependence of α by properties other than surface tension. A simple linear interpolation gives

$$\alpha = 0.36 + 2.43\,(\sigma \mathrm{N/m}). \tag{15}$$

It remains to determine the function $f(Cb)$ in equation (11). Figure 8 shows $(K_L/g\nu)^{1/3}/Re^n Sc^{-\alpha}$ plotted vs. Cb, with α calculated from equation (15). It can be seen that the data points collapse to a single curve quite well, and can be correlated as

$$\frac{K_L}{(g\nu)^{1/3}} = 6.97 \times 10^{-9} Re^n Sc^{-\alpha} Cb^{-2}. \tag{16}$$

The worst discrepancy is for aqueous ethylene glycol solution with $x = 0.2$. However this is not surprising as the highest Reynolds number which could be tested for this liquid was only 3800, and thus the value of n obtained is particularly suspect. We also note that if a correlation is attempted with a constant value of α, the correlation is markedly inferior to eqn. (16): Won shows such a plot for $\alpha = 1/2$.

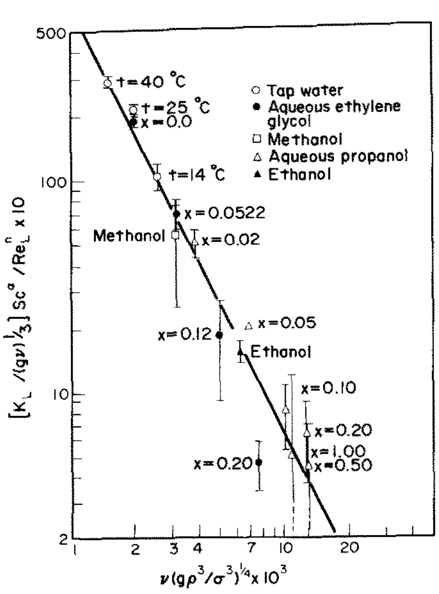

FIG. 8. Attempt to correlate K_L as $K_L/(g\nu)^{1/3}\,Sc^{\alpha}/Re^n$ vs. $Cb = \nu(g\rho^3/\sigma^3)^{1/4}$ for tap water at various temperatures, aqueous ethylene glycol solutions, methanol ethanol and aqueous propanol solutions.

Validity of the data

Figure 9 shows all the turbulent film data taken during this study, plotted as $K_L Sc^{1/2}/(\nu g)^{1/3}$ vs. Re_L. The relatively narrow data spread in an equivalent plot lead Henstock and Hanratty [10] to conclude that there is no significant effect of viscosity variation in our data. Yet Table 1 shows a nearly two-fold variation in Reynolds number exponent, with liquid viscosity apparently having the dominant influence on its value. The possible variation of Reynolds number exponent is of considerable importance in the development of a proper theoretical model of the mass transfer process. Also the Reynolds number exponent impacts strongly on the optimization of liquid side controlled mass exchangers: the number of transfer units $N_{tu} = K_L cPL/\dot{M}_L$ is proportional to flow rate raised to the $(n - 1)$ power: for $n < 1$ the N_{tu} decreases with increasing $\dot{M}_L$ while for $n > 1$ the opposite is true. Since the observed range of n is 0.57–1.12 the effect of process liquid viscosity on choice of liquid flow rate is considerable. Thus it is in order to give an assessment of the validity of our data.

The only other study in which liquid viscosity was varied systematically is that of Kamei and Oishi [3] for water in the temperature range 8.5–50°C. Although they assumed $K_L \sim Re^{0.7}$ in their correlation, the original data clearly shows an effect of water temperature on the Reynolds number exponent. By replotting Fig. 3 of [3] and performing a least squares regression analysis at the four temperatures for which there were

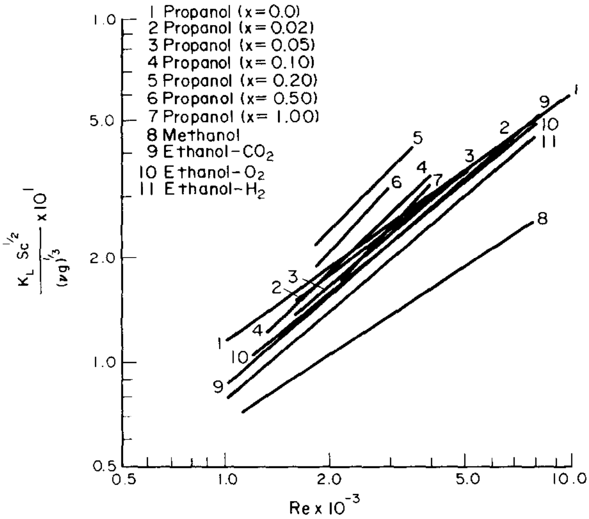

FIG. 9. Attempt to correlate K_L with fixed Re and Sc exponents for eleven test liquids.

sufficient data points, values of n were obtained. These values, together with those obtained by Chung and Mills [6] for water are shown in Fig. 10, where the agreement is seen to be quite good. We also note that recently Koziol *et al.* [11] presented considerable data for CO_2 absorption into water at 8.6–12.8°C, and found $n = 0.71$, a value in reasonable accord with Fig. 10. Thus there seems to be little reason to doubt the essential validity of the correlation for n developed in the present study.

The validity of our correlation for α depends heavily on the accuracy of our measurement of the diffusion coefficient of H_2 in ethanol. Yet the fact that a value of α that increases with surface tension is needed to collapse the data to a single curve in Fig. 9, does confirm that the observed trend of α is appropriate. The validity of our correlation of $f(Cb)$ is more difficult to assess. As a benchmark one would like to use water at 25°C, for which many investigators have obtained correlations for K_L. However as the plots presented by both Henstock [10] and Koziol [11] show, there is considerable disagreement amongst the correlations. As noted by Chung and Mills [6], perhaps the most important consideration is the effect of surface contamination: particular care was taken in this regard in both that study, and in the present investigation. Orridge [12] demonstrated the marked effect of small concentrations of surfactant, causing a decrease of K_L, particularly at lower Reynolds numbers. Since our values of K_L for water at 25°C are amongst the highest obtained at low Re_L, the possibility of a surfactant effect is remote. Furthermore our data taken with the alcohols should be free of any effects of organic contaminants. Nevertheless it is clear that further experimental data should be obtained, particularly for pure organic liquids, in order to confirm the behavior of K_L determined in the present work.

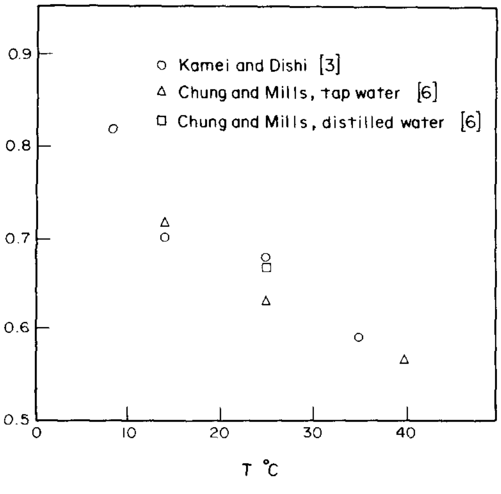

FIG. 10. Reynolds number exponent vs. water temperature: comparison of values calculated from data of Kamei and Oishi [3] and Chung and Mills [6].

CONCLUSION

Our recommended correlation of the liquid side mass transfer coefficient for gas absorption into a freely falling turbulent liquid film is

$$\frac{K_L}{(gv)^{1/3}} = 6.97 \times 10^{-9} Re_L^n Sc^{-\alpha} Cb^{-2},$$

$$n = 3.49\ Cb^{0.27}$$

$$\alpha = 0.137\,Cb^{-0.22}, \text{ or } 0.36 + 2.43\,(\sigma \text{N/m})$$

and is based on data for which the ranges of the dimensionless parameters are $1000 < Re_L < 10{,}000$; $80 < Sc < 2700$; $1.5 \times 10^{-3} < Cb < 10.8 \times 10^{-3}$.

Acknowledgements—This work was initiated on Grant GK 40180 from the National Science Foundation, and completed with a grant from the School of Engineering and Applied Science, University of California, Los Angeles.

REFERENCES

1. R. Higbie, The rate of absorption of a pure gas into a still liquid during short periods of exposure, *Trans. A.I.Ch.E.* **31**, 365–375 (1935).
2. V. G. Levich, *Physicochemical Hydrodynamics*, Prentice Hall, Englewood Cliffs, NJ (1962).
3. S. Kamei and J. Oishi, Mass and heat transfer in a falling liquid film of wetted tower, *Mem. Fac. Kyoto Univ.* **17**, 229–289 (1955).
4. A. P. Lamourelle and O. C. Sandall, Gas absorption into a turbulent liquid, *Chem. Engng. Sci.* **27**, 1035–1042 (1972).
5. G. D. Menez and O. C. Sandall, Gas absorption accompanied by first-order chemical reaction in turbulent liquids, *Ind. Engng. Chem. Fundam.* **13**, 72–76 (1974).
6. D. K. Chung and A. F. Mills, Experimental study of gas absorption into turbulent falling films of water and ethylene glycol–water mixtures, *Int. J. Heat Mass Transfer* **19**, 51–59 (1976).
7. D. K. Chung, An experimental investigation of gas absorption into a turbulent liquid film with interfacial shear. Ph.D. dissertation, School of Engineering and Applied Science, Univ. of California, Los Angeles (1974).
8. Y. Won, Experimental study of gas absorption into turbulent falling films of low surface tension liquids. Ph.D. dissertation, School of Engineering and Applied Science, Univ. of California, Los Angeles (1977).
9. W. Brötz, Über die Vorausberechung der Absorptions geschwindigkeit von Gasen in Stramen der Fussigkeitsschichten, *Chem. Engng Tech.* **26**, 470–478 (1966).
10. W. H. Henstock and T. J. Hanratty, Gas absorption by a liquid layer flowing on the wall of a pipe, *A.I.Ch.E. Jl* **25**, 122–131 (1979).
11. K. Koziòl, L. Broniarz and T. Nowicka, Transfer processes in film apparatus. I. Mass transfer during flow of a film of liquid down smooth pipes, *Int. chem. Engng* **20**, 136–142 (1980).
12. J. T. Davies, *Turbulence Phenomena* p. 260. Academic Press, New York (1972).

EFFETS DE LA VISCOSITE ET DE LA TENSION INTERFACIALE SUR L'ABSORPTION DES GAZ PAR UN FILM LIQUIDE TURBULENT, TOMBANT LIBREMENT

Résumé—On présente des résultats expérimentaux sur l'absorption des gaz par des films liquides turbulents qui tombent librement. CO_2 est absorbé par du méthanol et des solutions aqueuses de propanol à 25°C pour obtenir un domaine de tension interfaciale égal à $22{,}2–72 \times 10^{-3}$ N/m. H_2, O_2 et CO_2 sont absorbés par l'éthanol à 25°C pour obtenir un coefficient de diffusion dans le domaine $3{,}88–17{,}6 \times 10^{-9} m^2/s$ dans un liquide à faible tension interfaciale. Les données obtenues et les données antérieures de Lamourelle et Sandal, de Chung et Mills, sont utilisées pour établir une formule du coefficient de transfert massique qui tient compte correctement des propriétés de la phase liquide.

KORRELATION DER VISKOSITÄTS- UND OBERFLÄCHENSPANNUNGS-EINFLÜSSE AUF DIE GAS-ABSORPTION IN FREI FALLENDE TURBULENTE FLÜSSIGKEITSFILME

Zusammenfassung—Es werden Versuchsdaten für die Gas-Absorption in frei fallende turbulente Flüssigkeitsfilme wiedergegeben. CO_2 wurde in Methanol und in wäßrige Propanol-Lösungen bei 25°C absorbiert, wobei sich ein Oberflächenspannungsbereich von $22{,}2–72 \cdot 10^{-3}$ N/m ergab. H_2, O_2 und CO_2 wurden in Äthanol bei 25°C absorbiert; man erhält damit einen Bereich der Diffusionskoeffizienten von $3{,}88–17{,}6 \cdot 10^{-9}$ m^2/s in einer Flüssigkeit geringer Oberflächenspannung. Die gemessenen Daten wurden zusammen mit früheren Daten von Lamouvelle und Sandall sowie von Chung und Mills dazu verwendet, eine Korrelation für den Stoffübergangs-Koeffizienten zu entwickeln, welche die Stoffwert-Einflüsse der Flüssigphase richtig berücksichtigt.

КОРРЕЛЯЦИЯ ВЛИЯНИЯ ВЯЗКОСТИ И ПОВЕРХНОСТНОГО НАТЯЖЕНИЯ НА ИНТЕНСИВНОСТЬ ПОГЛОЩЕНИЯ ГАЗА СВОБОДНО СТЕКАЮЩИМИ ТУРБУЛЕНТНЫМИ ПЛЕНКАМИ ЖИДКОСТИ

Аннотация — Представлены результаты экспериментального исследования поглощения газа свободно стекающими турбулентными пленками жидкости. Для получения поверхностного натяжения в диапазоне $22{,}2–72 \cdot 10^{-3}$ Н/м использовались процессы поглощения углекислого газа метанолом и водными растворами пропанола при температуре 25°C. Для получения коэффициента диффузии в диапазоне $3{,}88–17{,}6 \cdot 10^{-9}$ $м^2/сек$ в жидкости с малым поверхностным натяжением использовалось поглощение H_2, O_2 и CO_2 этанолом при температуре 25°C. Эти данные, вместе с данными Ламурелля и Санделла, а также Чанга и Миллза, использованы для вывода обобщенного соотношения для коэффициента массопереноса, в котором надлежащим образом учитываются свойства жидкой фазы.