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GAS ABSORPTION BY SINGLE CHARGED DROPS DURING THEIR FORMATION IN A UNIFORM ELECTRIC FIELD

MANABU YAMAGUCHI, YOSHIKI HASHIMOTO, TORU TAKAMATSU and TAKASHI KATAYAMA
Department of Chemical Engineering, Faculty of Engineering Science, Osaka University, Toyonaka, Osaka 560, Japan

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Abstract—A new technique for measuring gas absorption rates during the formation of liquid drops was devised. By the technique, the amount of carbon dioxide absorbed during the formation of single charged drops was measured in the presence of a uniform electric field. Also the relationships between the surface area of the drop, its volume, and the time for one cycle of the growth of the drop were obtained using a TV system. The mass transfer rates are discussed by taking account of the surface area of the drop being formed in the electric field. It is clarified that the mechanism of gas absorption during drop formation is explained satisfactorily by the surface-stretch penetration model of Angelo *et al.*, not only for uncharged drops but also for charged drops formed in the electric field.

NOMENCLATURE

C,	concentration of CO_2 in the dispersed phase [mol dm^{-3}];
C_0,	initial concentration of CO_2 in the dispersed phase [mol dm^{-3}];
C^*,	equilibrium concentration of CO_2 in the dispersed phase [mol dm^{-3}];
D,	diffusion coefficient of CO_2 in water [m^2 s^{-1}];
D_n,	outside diameter of a nozzle [m];
E_0,	uniform electric field strength [V m^{-1}];
F,	saturation efficiency of CO_2 absorbed during drop formation;
Fe,	electrostatic force acting on a pendent drop [N];
k_{ave},	average mass transfer coefficient in the dispersed phase [m s^{-1}];
l,	nozzle length extended from electrode [m];
r,	radius of a pendent drop on a nozzle [m];
S,	surface area of a pendent drop on a nozzle [m^2];
S_0,	surface area of a rest drop on a nozzle [m^2];
S_f,	surface area of a drop formed by liquid supplied [m^2];
t,	time during growth of a pendent drop [s];
t_f,	formation time of a drop [s];
v_f,	liquid volume supplied during one cycle of growth [m^3];
v,	volume of a pendent drop on a nozzle [m^3].

Greek symbols

α,	$(l + r)/r$;
ε,	permittivity of continuous phase [F m^{-1}];
η,	constant dependent on the mechanism of drop formation;
ζ,	constant dependent on the mechanism of drop formation [m$^{2-3\eta}$];
$\Delta\rho$,	density difference [kg m^{-3}];
σ,	surface tension [N m^{-1}];
τ,	dimensionless time variable, t/t_f;
Φ,	Harkins correction factor;
Φ_v,	volumetric flow rate of dispersed phase [m^3 s^{-1}].

1. INTRODUCTION

IN SEPARATION processes dealing with liquid drops, various attempts have been made to enhance their mass transfer efficiencies. Generally, the enhancement can be obtained by producing a larger interfacial area for diffusion and a higher degree of turbulence within and around drops for eddy diffusion. The requirement for making turbulence coupled with a large interfacial area is difficult because these features are incompatible in the sense that small drops do not have high relative velocities nor do they exhibit marked internal circulation patterns. The application of an electric field as a technique to overcome these problems has been proposed by some investigators [1–5]. This technique has some advantages in that small charged drops can be produced easily by using an electrostatic force [1–6] and the charged drops can move through a continuous phase with higher velocity due to the Coulomb force [1–3], which in consequence induces a high degree of fluid turbulence around and within the drops. Thus it is useful for mass transfer operations to produce high interfacial areas coupled with enhanced transfer coefficients. Furthermore, the direct utilization of electrical energy to processes dealing with liquid drops will obtain higher energy efficiency than energy supplied in the form of thermal or mechanical energy. Several investigators [1, 2, 4, 7–9] have studied the effects of an electric field on mass transfer rates in liquid–liquid systems and have suggested that the application produced significant increases in the mass transfer coefficients. Austin *et al.* [7] indicated in their experiment of liquid–liquid extraction that the presence of an electrical charge on a plane interface could result in interfacial turbulence induced by the local variation of the effective interfacial tension. This turbulence gave rise to a remarkable increase in the mass transfer coefficient.

On the other hand, for the system of liquid drops in a gas stream, Harker and Ahmadzadeh [10] reported that the rate of evaporation of acetone from falling drops of 50% acetone–water solution into a nitrogen stream increased by up to 50% by applying an electric field of up to 3.5 kV cm^{-1}. Uchigasaki *et al.* [11] measured the rate of gas absorption in a liquid film under an influence of corona-discharge and demonstrated that the discharge worked effectively on the rate when the resistance was controlled on the gas-film side. In the various investigations mentioned above, although they showed the effects of the electric field on mass transfer rates, no quantitative studies of the mechanism were made. Neither experimental nor theoretical investigations have been made for mass transfer during drop formation in the presence of an electric field in gas–liquid or liquid–liquid systems.

In our previous paper [6], theoretical studies were made for the drop volume and the charge characteristics of a single charged drop formed in a uniform electric field, and corresponding experimental studies were performed in the atmosphere. The experimental results showed good agreement with the theoretical predictions. This work is an extension of our previous study and is aimed at measuring mass transfer rates during the formation of single drops in a uniform electric field and clarifying the mechanism. The experimental work was performed on the system of water drops in carbon dioxide under the conditions that (i) charged drops of constant volume were formed in a wide range of formation times under a constant electric field strength, and (ii) charged drops were formed for increasing electric field strengths up to 5 kV cm^{-1} under a constant flow rate of the dispersed phase.

2. EXPERIMENTAL APPARATUS AND PROCEDURE

Since the absorption of carbon dioxide by water drops was reported [12], the mechanism of the mass transfer has been subjected to numerous experimental and theoretical studies. The information on mass transfer rates during drop formation is very important because successive mass transfer processes are influenced by the rates. However, there are very few reliable experimental data for the rates. This is due to the experimental difficulty in removing the drop from the solute–gas atmosphere without any additional absorption or desorption. Groothius and Kramers [13] developed an excellent technique for obtaining the amount of gas absorbed during the period of drop formation directly by measuring the pressure change or volume change of the solute gas atmosphere in a mass transfer cell occurring during the growth of the drop. Whitman *et al.* [12] presented a technique in which a layer of kerosene oil was applied to eliminate the end effect during drop coalescence. Since then other investigators [14–17] have also used the technique. Application of their techniques to the present study was tried but was not successful. A new technique was developed in the present study to obtain mass transfer rates during the formation of drops.

The experimental apparatus developed to satisfy the requirements of present study is shown in Fig. 1(a). The apparatus consists of a mass transfer cell equipped with electric plates, a temperature-control system, a gas-supply system, a system for liquid-supply and drop-formation, a drop-collection device, and a TV system.

Mass transfer cell equipped with electric plates

The cell (1) was made of transparent acrylic resin to enable the observation and photography of liquid drops. It had a square cross-section and was fabricated from four sections each 1 cm thick, 3 cm high and 11 cm wide. The top and bottom of the cell were sealed with the same resin plates. Upper and lower electrodes (3), copper disks of 7.5 cm dia and 0.2 cm thick, were fixed at each of the top and bottom plates and were kept 2.0 cm apart. A stainless steel nozzle (0.1 or 0.26 cm O.D.) (4) was extended 0.2 cm into the electric field from the center of the upper electrode. High d.c. voltage was supplied to the nozzle and the upper electrode by means of a Brandenburg generator (model 2807R, 0-30 kV, 1 mA, reversible polarity) (13). The lower earthed electrode was drilled with a 1.3 cm dia hole just under the nozzle to facilitate the passage both of drops detached from the nozzle and carbon dioxide gas.

Drop-collection devices

A special drop-collection method was devised to eliminate the mass transfer quantity during the free movement and coalescence periods of the drops as much as possible. That is, the former was negligible as discussed later and the latter was perfectly eliminated by creating a nitrogen gas curtain between the continuous carbon dioxide phase and the coalescing liquid phase.

The drops, after detaching from the nozzle, fell a short distance in the cell and passed out of it via a hole together with carbon dioxide flowing out of the cell. The drops were then collected in a beaker (2) through the nitrogen curtain. Aqueous barium hydroxide solution of known volume was prepared in the beaker and was agitated by a stirrer (6) driven from below in such a way as to produce a vortex into which the drops fell. The carbon dioxide dissolved in the drops reacted rapidly with the barium hydroxide under a nitrogen gas atmosphere and barium carbonate was produced. Penetration of the carbon dioxide from air and the cell into the barium hydroxide solution were perfectly prevented by covering the beaker with aluminum foil and flushing the beaker with nitrogen gas (gas curtain)

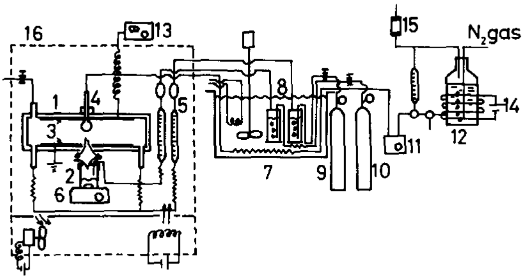

Fig. 1(a). Schematic diagram of experimental apparatus.

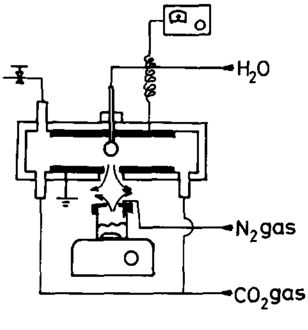

Fig. 1(b). Drop-collection device.

which was continuously supplied from a cylinder (10). An illustration of the drop-collection device is shown in Fig. 1(b). Flow rates of carbon dioxide and nitrogen were determined with a blank test: the carbon dioxide and the nitrogen gases flowing, respectively, from the cell and the beaker, meet midway between the cell and the beaker, and each gas spreads radially at that place. The flow rate of nitrogen gas from the beaker prevented carbon dioxide gas flowing out of the cell through the hole and penetrating into the beaker. The flow rate of carbon dioxide gas was controlled as for the nitrogen gas-stream so as not to penetrate into the cell. It was confirmed in the test that the amount of evaporation of the drops during formation and of the barium hydroxide solution could be neglected within the experimental accuracy by supplying the gases saturated with water.

Liquid-supply system and drop-formation

Water used as a dispersed phase was purified by distillation in the presence of potassium permanganate and stored in a dispersed-phase bottle (12). It was kept decarbonated by the bubbling through of nitrogen gas. The water was also kept at about 25°C using a ribbon-heater (14) and a temperature regulator. The flow system of the dispersed phase did not have any control valves and the flow rate was accurately adjusted by a micro-tube pump (Gilson minipulse 2) (11). The water flowed through a water bath of constant temperature (7) to an electrified nozzle (4) and formed charged drops at the nozzle tip in the mass transfer cell under an electric field. The drop volume was calculated from the formation frequency and the water flow rate at the nozzle.

Gas-supply system

Pure carbon dioxide and nitrogen gases were respectively supplied to each section through humidifiers (8) in a water bath of constant temperature (7) and flowmeters (5). Carbon dioxide then entered the cell from the bottom at the rate of 500 $\mathrm{cm^3\,min^{-1}}$ and escaped through the hole of the lower electrode to the atmosphere. Nitrogen gas (1700 $\mathrm{cm^3\,min^{-1}}$) was supplied to the beaker for drop-collection. Gas flow behavior in each compartment was observed by smoke to be ideal for the mass transfer experiment. Physical properties of the fluids used are shown in Table 1.

TV system

The profile of a forming drop (uncharged or charged) which is determined by the force balance acting on the drop is a very important factor for investigating the mass transfer mechanism during formation. In the present study, the drop-profile during one cycle of the growth was investigated by employing a system of telescopic camera, video-recorder, and television monitor fitted with a digital timer. Analysis of the profile was carried out directly using a X–Y tracker and by using a film analyzer for enlarged profiles.

Analysis procedure

Quantitative analysis for dissolved carbon dioxide was performed by reaction of the sample with an excess of barium hydroxide to precipitate the carbonate and subsequent back titration with standard hydrochloric acid. The titration curve has two equivalent points for the reaction. The first point is that of the acid–base reaction occurring at pH = 9.3, and the second point is the one of dissociated product of the carbonate with the acid at pH = 4.9. The amount of carbon dioxide absorbed during the formation of the drops was evaluated by the acid–base analysis of the first equiva-

Table 1. Physical properties of the fluids used at 25°C

Fluid	Density [19] ($\mathrm{g\,cm^{-3}}$)	Surface tension [19] ($\mathrm{dyne\,cm^{-1}}$)	Dielectric constant [19]	Diffusion coefficient [20] ($\mathrm{cm^2\,s^{-1}}$)
Water	0.998	72.0	80.4	1.85×10^{-5}
Carbon dioxide	0.001		1.00	

lent point of the sample. Prior to each run the content of carbon dioxide in the dispersed phase was checked and confirmed to be zero. The sample beaker, containing about 15 cm^3 0.05 N barium hydroxide, was weighed on an analytical balance. After collecting the sample, its quantity was obtained by the weight difference. The sample was analyzed with 0.05 N hydrochloric acid. The measurement for each run was carried out four times and only the average was used. In each run the reproducibility of the absorbed quantity proved to be better than ±5%. The analysis was carried out under a nitrogen gas stream by employing an auto-titrator with a computer control system (model Comtite-7, Hiranuma). The experimental runs were performed in a constant temperature chamber controlled at 25 ± 1°C.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Prior to the absorption experiment, test runs were made for volumes of charged drops formed in the electric fields and their charges by the present apparatus. The results showed good agreement with the previous work [6].

3.1. *Relation between surface area and volume of forming drops*

In order to investigate the mechanism of mass transfer during the formation of liquid drops, the relation between the surface area of the drop and its volume has to be known. The drop-profile (uncharged or charged drop) in each growth-time was analyzed using TV system and reflection analyzer described above. Because the drop profile had a revolving shape, the length of the drop along its axis of revolution was divided into 12 equal distances and the radius of each section perpendicular to the axis was measured from a sequence of photographs. The profile was approximated as a 7th degree polynominal and the surface area and the volume of a drop were calculated using the polynominal. Figure 2 shows the relationships between the surface area and the volume of a drop being formed during one cycle of the growth. Triangular symbols in the figure show experimental results for uncharged drops during one cycle of the growth and circular ones show those for charged drops. Consequently, empirical correlations for both cases were obtained as follows:

$$S = 5.30\,v^{0.690} \text{ for } D_n = 0.10\,\text{cm}, \quad \text{uncharged drop,} \qquad (1a)$$

$$S = 13.8\,v + 0.112 \text{ for } D_n = 0.26\,\text{cm}, \quad \text{charged drop.} \qquad (1b)$$

The equations are valid only for the system described in this study.

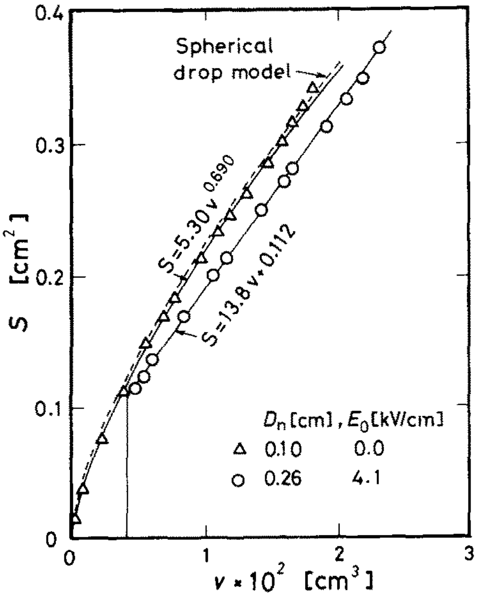

FIG. 2. The relationship between the surface area of uncharged or charged drops and their volume during one cycle of drop formation.

3.2. *Evaluation of mass transfer during free movement of falling drops and drop coalescence period*

From the drop-collection method described in the previous section, it was concluded that the mass transfer quantity during the process of drop-coalescence was almost eliminated. Evaluation of the mass transfer quantity during the free movement of falling drops was considered as follows: drops after detaching from the nozzle travel some distance in the cell in an atmosphere of carbon dioxide flowing from the cell towards the beaker, then in an atmosphere of nitrogen gas flowing from the beaker towards the cell and finally in the nitrogen gas-phase of the beaker. The distance travelled in each gas atmosphere is about 5 cm and each residence time for the drop is estimated as roughly 0.07 s. The falling drop absorbs carbon dioxide during the residence time in the carbon dioxide atmosphere and desorbs the gas during the residence time in the following atmosphere of nitrogen. Even if the absorption quantity during free movement is larger than that of desorption, the longer the time of drop formation the less influence the mass transfer quantity during free movement has on the total mass transfer quantity for the drop. That is, it was considered that the contribution of the mass transfer quantity during free movement of the drop to the total was negligibly small in the present experiment.

3.3. *Absorption rates during formation of uncharged and charged drops*

Application of the penetration theory to the mass transfer rate during drop formation has been tried by many investigators. However, consistencies between experimental and theoretical results are not always satisfied. This may be probably due to rather fantastic models, because in addition to the complexity of flow behavior within a forming drop due to the jet flow of the liquid issuing from a nozzle, the surface area of the

Table 2. Experimental data of carbon dioxide absorption during drop formation with or without electric field

Experiment 1

t_f (s)	$\Phi_v \times 10^3$ ($cm^3 s^{-1}$)	$v \times 10^2$ (cm^3)	$C \times 10^6$ ($mol\,cm^{-3}$)	F	
0.992	19.0	1.88	2.62	0.080	
2.27	8.18	1.86	2.50	0.076	
3.98	4.60	1.83	3.63	0.110	$E_0 = 0.0\ V\,m^{-1}$
6.20	2.95	1.83	4.78	0.145	$D_n = 0.10\ cm$
9.02	2.01	1.81	6.55	0.199	$l = 0.20\ cm$
15.95	1.13	1.81	9.31	0.283	
1.00	18.7	1.88	1.50	0.046	
2.26	8.20	1.86	2.65	0.081	
4.00	4.60	1.84	3.73	0.113	$E_0 = 4.15 \times 10^5\ V\,m^{-1}$
6.24	2.93	1.83	5.10	0.155	$D_n = 0.26\ cm$
8.97	2.03	1.82	5.93	0.180	$l = 0.20\ cm$
16.05	1.13	1.81	7.49	0.228	

Experiment 2

$E_0 \times 10^{-5}$ ($V\,m^{-1}$)	t_f (s)	$v \times 10^2$ (cm^3)	$C \times 10^6$ ($mol\,cm^{-3}$)	F	
0.0	3.98	1.83	3.63	0.110	
2.0	3.15	1.42	3.63	0.110	
3.0	2.38	1.07	3.44	0.104	$D_n = 0.10\ cm$
4.0	1.55	0.70	2.98	0.091	$l = 0.20\ cm$
4.0*	1.54	0.70	3.03	0.092	$\Phi_v = 4.52 \times 10^{-3}\ cm^3 s^{-1}$
5.0	0.87	0.40	3.04	0.092	

* Negative polarity.

drop varies with time. Therefore, various modified penetration models taking into account the flow patterns within a drop have been proposed. Angelo *et al.* [18] extended the penetration theory by including the velocity component perpendicular to the interface caused by the stretching motion of the surface. They applied the model to the mass transfer during drop formation in a liquid–liquid system. According to their model, the saturation efficiency is given as

$$F = \frac{C - C_0}{C^* - C_0} = \frac{2}{\tau}\left[\int_0^{\tau}\left(\frac{S}{S_f}\right)^2 dt\right]^{1/2}\left(\frac{D}{\pi t_f}\right)^{1/2}\frac{S_f}{v}\,t. \quad (2)$$

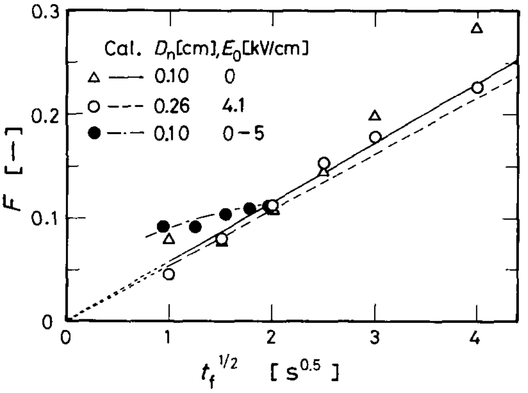

FIG. 3. Comparison of the experimental saturation degree of CO_2 absorbed during drop formation with those predicted by the model of Angelo *et al.*

When the relationship between the surface and the volume during formation of a drop is expressed as

$$S = S_0 + S_f\left(\frac{t}{t_f}\right)^{\eta}, \quad S_f = \zeta(v_f)^{\eta} \quad (3)$$

the efficiency of drop formation is obtained by substituting equation (3) into equation (2) as follows:

$$F = 2\left[\left(\frac{S_0}{S_f}\right)^2 + \frac{2}{\eta + 1}\left(\frac{S_0}{S_f}\right) + \frac{1}{2\eta + 1}\right]^{1/2}\left(\frac{D}{\pi t_f}\right)^{1/2}\frac{S_f}{v}\,t_f. \quad (4)$$

Experiment 1. In the present experiment, to clarify the mass transfer mechanism, uncharged and charged drops were formed to be of constant and equal volume ($0.0184\ cm^3$) independently of the frequency of the drop formation. Uncharged drops were formed by a steel nozzle of 0.1 cm O.D. Charged drops were obtained using a steel nozzle of 0.26 cm O.D. and applying a constant electric field strength (E_0 = $4.1\ kV\,cm^{-1}$). These conditions were determined previously [6]. Experimental mass transfer data for positively charged and uncharged drops are given in Table 2. Experimental values for the absorption efficiency (F) are plotted against values of the square-root of the formation time ($t_f^{1/2}$) with the electric field strength as a parameter in Fig. 3. Solid and dotted lines in the figure also show the results calculated by equations (3) and (4). Values of η in the equations are 0.69 (solid line) and 1.0 (dotted line), which correspond respectively to small and large nozzle sizes in equation (1). The results shown with triangular symbols in the figure are for uncharged drops without the electric field. At a high flow rate of the dispersed phase ($t_f = 1.0$), the efficiency is greater than the one calculated by equations (3) and (4). This effect may be caused by the greater circulation within the drop due to the jet flow of the liquid issuing from the nozzle. On the other hand, efficiencies in the region of low flow rates ($t_f > 9$) have a tendency to be higher than the values calculated by the equations. It is considered that, as Groothius and Kramers [13] pointed out, this may be due to free convection flow of liquid along the inside of the surface which is induced by the density gradient. As shown in Fig. 3, the mass transfer mechanism of a forming drop in the region of intermediate frequency of drop-formation is satisfactorily explained by the penetration theory of the surface-stretch model of Angelo *et al.*

Circular symbols show the experimental efficiencies of charged drops. Although they are the results obtained at lower flow rates of the dispersed phase than those of uncharged drops, the relationship between the results for charged drops and the formation time apparently differs from those of uncharged drops in the region of low drop formation frequency. It appears that the free convection flow which was presumed to contribute to mass transfer for uncharged drops was not induced for charged drops. That is, because the growth behavior of the surface of a charged drop is controlled by the electrostatic force, which is produced by the electric field and is everywhere directed normally outward from the drop surface, the stretching behavior of the drop might satisfy very well the model of Angelo *et al.*

Experiment 2. In this experiment, the flow rate of the dispersed phase was kept constant independently of the electric field strength and the strength of the latter was increased up to 5.0 kV cm^{-1} in 1.0 kV cm^{-1} intervals. Consequently, volumes of forming charged drops varied with the electric field strength. Absorption rates of carbon dioxide to the charged drops being formed under above conditions were measured. The experimental results are given in Table 2. Experimental solid circles in Fig. 3 show how the efficiencies for the charged drops are influenced with an increase in the electric field strength though the scale of the field strength is not directly expressed in Fig. 3. As shown in the Fig. 3 and Table 2, the efficiencies decreased slightly with an increase in the electric field strength. Although the flow rate for the solid circles was lower than those for the triangles, the former efficiencies were considerably higher than the latter.

Apparently, the results of the solid circles show a highly different tendency than those of the triangles and circles. It is not clear, at the present time, what kind of the mass transfer mechanism is controlling these efficiencies. So, the experimental mass transfer data were evaluated using an average mass transfer coefficient during the formation frequency which is defined as follows:

$$k_{\mathrm{ave}} = \frac{(C - C_0)v}{(C^* - C_0)\,S_{\mathrm{ave}} \times t_{\mathrm{f}}} \qquad (5)$$

where the S_{ave} is the average surface area during one cycle of drop formation, assuming the drop is spherical. Therefore, the theoretical mass transfer coefficient is derived from equation (4) as

$$k_{\mathrm{ave}} = \frac{10}{3}\left[\left(\frac{S_0}{S_{\mathrm{f}}}\right)^2 + \frac{2}{\eta + 1}\left(\frac{S_0}{S_{\mathrm{f}}}\right) + \frac{1}{2\eta + 1}\right]^{1/2}\left(\frac{D}{\pi t_{\mathrm{f}}}\right)^{1/2} \qquad (6)$$

where the value of S_0 is zero and the value of η is 2/3 when the drop is spherical.

The volume of a charged drop detached at the nozzle is calculated theoretically as follows [6]:

$$\left.\begin{aligned} \pi D_{\mathrm{n}}\sigma &= \Phi\Delta\rho g v_{\mathrm{f}} + Fe, \\ Fe\dagger &= 4\pi\varepsilon(1.7\alpha + 0.578)r^2E_0^2, \\ \alpha &= \frac{(l + r)}{r}. \end{aligned}\right\} \qquad (7)$$

The drop formation time (t_f) in equation (6) is calculated from the relationship between the drop-volume and the flow rate at the nozzle as follows:

$$t_{\mathrm{f}} = \frac{v_{\mathrm{f}}}{\Phi_{\mathrm{v}}}. \qquad (8)$$

Figure 4 shows plots of experimental k_{ave} values together with theoretical ones calculated by equations (6)–(8) (solid line) against applied electric field strength. As shown in the figure, the experimental data agree satisfactorily with the theoretical values. One experimental value given by a solid circle in the figure represents the result obtained with negatively charged drops. It shows that the mass transfer mechanism is not influenced by the polarity of electric field. Experimental data for the volumes of charged drops for which measurements of mass transfer were carried out are also shown in the figure together with the theoretical line calculated by equation (7). Both the experimental k_{ave} values and drop volumes are in good agreement with the theoretical predictions which are shown as solid lines. When the drop shape of the experimental data shown by solid circles in Fig. 3 is assumed to be spherical, the saturation efficiency is evaluated by equations (4), (7) and (8). The calculated values given as a chain line in the figure show successful agreement with the experimental data. The reason for the higher efficiencies of the solid circles as compared with those of the triangles is evidently due to an increase in the total surface area of drops per unit liquid volume supplied.

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†In our previous study, electrostatic force (Fe) acting on the pendent drop was derived by assuming that the drop is a sphere.

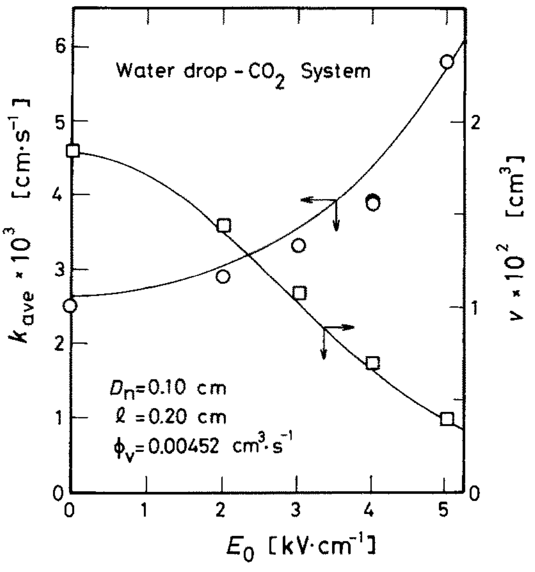

FIG. 4. Average mass transfer coefficient during drop formation (○) and drop volume (□) vs electric field strength.

4. CONCLUSIONS

The effect of the electric field on the gas absorption rate to charged drops during the formation of drops was investigated by the use of a new experimental technique. It was clarified that the mass transfer mechanism for single charged drops being formed in a uniform electric field is explained satisfactorily over a wide range of drop formation frequencies by the surface-stretch penetration model of Angelo *et al.*

The experimental data for uncharged drops showed that the mass transfer rates are also explained well with the same model in the region of intermediate drop formation frequency.

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ABSORPTION DE GAZ PAR UNE GOUTTE CHARGEE PENDANT SA FORMATION DANS UN CHAMP ELECTRIQUE UNIFORME

Résumé—On a imaginé une technique nouvelle pour mesurer l'absorption de gaz pendant la formation de gouttes liquides. Par cette technique est déterminée la quantité de gaz carbonique absorbée en présence d'un champ éléctrique. Les relations entre l'aire de la goutte, le volume et le temps du cycle de croissance de la goutte sont obtenues par un système TV. Les flux massiques transférés sont discutés en tenant compte de l'aire de la goutte formée dans le champ électrique.

Le mécanisme de l'apsortion du gaz pendant la formation de la goutte est expliqué de façon satisfaisante par le modèle d'Angelo *et al.*, non seulement pour les gouttes non chargées mais aussi pour les gouttes chargées dans un champ électrique.

GASABSORPTION DURCH ELEKTRISCH GELADENE EINZELTROPFEN WÄHREND IHRES ENTSTEHENS IN EINEM GLEICHFÖRMIGEN ELEKTRISCHEN FELD

Zusammenfassung—Ein neues Verfahren zur Messung der Gasabsorptionsgeschwindigkeiten während der Bildung von Flüssigkeitstropfen wurde entwickelt. Bei diesem Verfahren wurde die Menge an Kohlendioxid, die bei der Bildung von elektrisch geladenen Einzeltropfen absorbiert wurde, in einem gleichförmigen elektrischen Feld gemessen. Auch wurde der Zusammenhang zwischen der Oberfläche des Tropfens, seinem Volumen und der Dauer eines Wachstumszyklusses mit Hilfe einer Fernsehkamera festgestellt. Die Stoffübergangsgeschwindigkeiten werden unter Berücksichtigung der Tropfenoberfläche, die im elektrischen Feld gebildet wird, erörtert.

Es wird gezeigt, daß der Mechanismus der Gasabsorption während der Tropfenformation zufriedenstellend durch das Modell von Angelo u.a. erklärt wird, nicht nur für ungeladene, sondern auch für geladene Tropfen, die im elektrischen Feld entstanden sind.

ПОГЛОЩЕНИЕ ГАЗА ЕДИНИЧНЫМИ ЗАРЯЖЕННЫМИ КАПЛЯМИ, ОБРАЗУЮЩИМИСЯ В ОДНОРОДНОМ ЭЛЕКТРИЧЕСКОМ ПОЛЕ

Аннотация—С помощью предложенного нового метода измерено количество двуокиси углерода, поглощаемого при образовании единичных заряженных капель в однородном электрическом поле. Получены соотношения между площадью поверхности капли, ее объемом и временем одного цикла роста капли. Определение скорости переноса массы проводилось с учетом изменения площади поверхности капли, образующейся в электрическом поле. Механизм поглощения газа при образовании капли удовлетворительно объяснен на основе пенетрационной модели поверхностного натяжения Анжело и др. не только для незаряженных, но и заряженных частиц, образующихся в электрическом поле.