Absorption of Gas in Liquid with Corona Discharge

著者	UCHIGASAKI Kin'ichi, ASANO Kiro, SUGAWARA Minoru, TAKAMATSU Toshifumi
journal or publication title	Science reports of the Research Institutes, Tohoku University. Ser. A, Physics, chemistry and metallurgy
volume	19
page range	254-269
year	1967
URL	http://hdl.handle.net/10097/27386

Absorption of Gas in Liquid with Corona Discharge*

Kin'ichi UCHIGASAKI, Kiro ASANO, Minoru SUGAWARA
and Toshifumi TAKAMATSU

Chemical Research Institute of Non-Aqueous Solutions

(Received November 1, 1967)

Synopsis

The absorption rate of gases in liquid in wetted-wall columns is strongly accelerated by a corona discharge. The phenomenon occurs when the main resistance is in the gas phase. It is recognized that the acceleration of the absorption rate is caused by the turbulence of the gas stream, in wetted-wall columns, produced by the corona discharge.

I. Introduction

The increasing amount of energy consumed has made it more and more necessary to remove sulfur dioxide from the gaseous effluent of chemical factories, refineries, electric power stations, etc. These factories are coming under increasing public pressure to reduce this atmospheric pollutatnt.

The following data report studies dealing with the absorption of gases in liquids with a corona discharge which is a method of removing sulfur dioxide from effluent gases. Furthermore, the mechanism of the acceleration of the absorption rate with a corona discharge was discussed. When the gas phase resistance controlled the absorption rate, experimentations were carried out in the following systems, SO_2-H_2O, NH_3-H_2O, SO_2-NaOH, H_2S-NaOH, Cl_2-NaOH and CO_2-NaOH. The systems in which the liquid phase resistance was controlling the absorption rate were absorption of H_2S and Cl_2 in water.

II. Apparatus and Procedure

The wetted-wall columns, one of them is shown in Fig. 1 are made of polymetacrylic resin, and their inner diameters and lengths of columns are as follows: $d=2.5$ cm, $l=30.3$, 60.3 and 120.3 cm; $d=5.0$ cm, $l=30.3$ cm. The liquid is fed by overflow from the top of a column along the wall uniformly, and the gas and the liquid are seperated at the bottom of the column. A corona discharge occurs around a Pt wire elelctrode, diam. 0.5 mm being set as a high potential electrode along the axis of the column and the falling water along the wall is grounded. The gas is exhausted from the top of the tower after passing through a calming section and is absorbed in the wetted-wall column. The flow rates of the gas and the liquid were

---

* Reproted in Japanese in Chem. Eng., Japan, **31** (1967), 878.

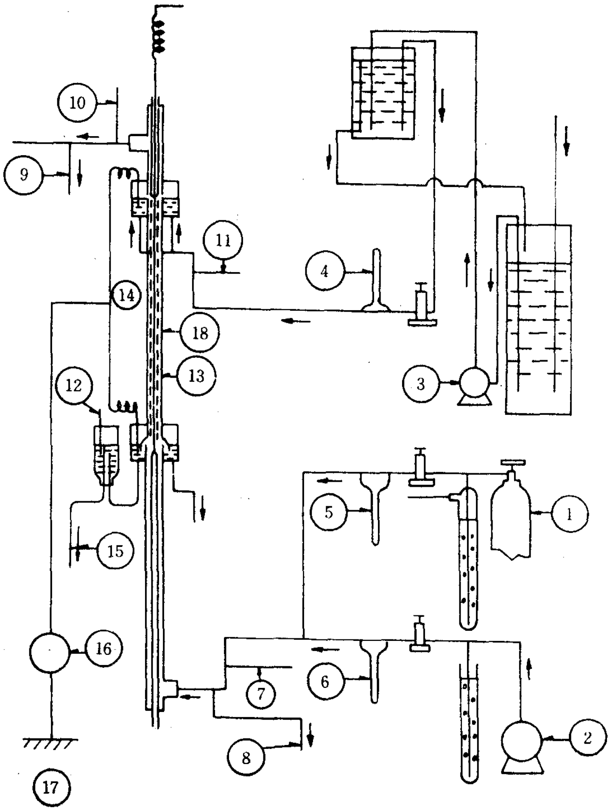

Fig. 1. Schematic diagram of apparatus.
1. SO_2 cylinder 2. air-blower 3. water pump 4.∼6. orifice flow meter 7, 10.∼12. thermometer 8. inlet gas sampling pipe 9. outlet gas sampling pipe 13. wetted-wall tower 14. central wire electrode 15. outlet liquid sampling tube 16. milli-ampare meter 17. earth 18. cylindrical net

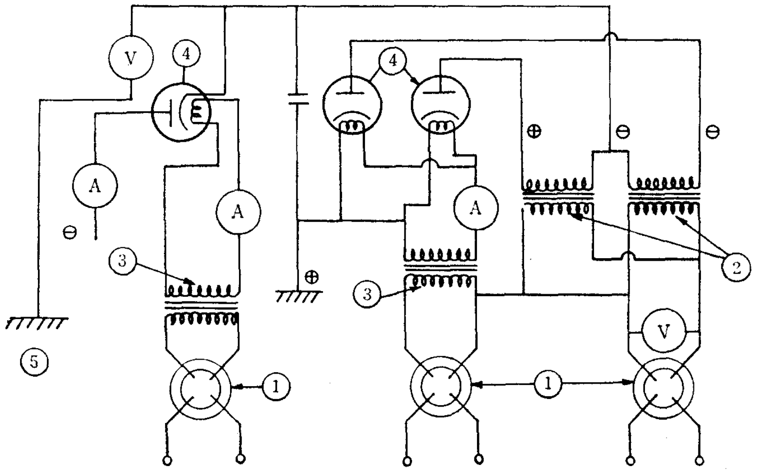

Fig. 2. High voltage apparatus.
1. aut-transformer 2. high voltage transformer 3. filament transformer 4. rectifying tube 5. earth

measured by glass orifice meters. A corona discharge was energized by a high tension taken from a wall outlet which was transformed and rectified by electric valves. The schematic wiring diagram is shown in Fig. 2. The Pt wire should be set in the center of the tower, and be tightened slightly to avoid the vibration of the Pt electrode and break of the water film inside of the column.

In another series of experiments, a control grid which captured ions was used to determine the mechanism of acceleration of the rate of absorption by a corona discharge. A control grid is a stainless steel cylindrical wire net, and a mesh of the net is 1×1 mm. It was set concentrically in the wetted-wall column, diam. 5.0 cm, length 30.3 cm. The potential was applied to the Pt wire electrode and the cylindrical net and water electrode were grounded.

III. Numerical Data

1. Partial pressure and solubility coefficient

Partial pressures and solubility coefficients of many sorts of gases in dilute aqueous solutions are obtained by extrapolation from the following data: SO_2–H_2O system by Yui and Saito(1), NH_3-H_2O system by Sherwood(2), H_2S-H_2O system by Wright(3), Cl_2-H_2O system by Whitney and Vivian(4). Solubility coefficient of CO_2 in NaOH solution was calculated using the equation by Nijsing and Kramers(5). Partial pressures of SO_2, Cl_2, H_2S and CO_2 in the gas phase dissolved in NaOH solution were neglected, when the values of K_{OG} were calculated.

2. Mass transfer coefficient of gas and liquid phase

Mass transfer coefficient in the gas phase was calculated by Ramm's equation(6) in order to compare the experimental results of gas absorption in water with the calculated values and k_l mass transfer coefficient for liquid phase, was calculated by Hikita's equation(7).

$$k_g = 0.027 \times \frac{D}{d}\left(\frac{d\,u\,\rho}{\mu}\right)^{0.8}\left(\frac{\mu}{\rho D}\right)^{0.33} \times \frac{1}{RT} \tag{1}$$

$$H_L\left(\frac{\rho^2 g}{\mu^2}\right)^{1/3} = 2.36 \times Re^{1.0}\left(\frac{\mu}{\rho D_l}\right)^{1/2} \tag{2}$$

3. Diffusion coefficient of gas

The diffusion coefficients of gas were calculated by Arnold's equation.

---

(1) S. Saito and N. Yui J. Soc. Jap., Pure Chem. Sec., **80** (1958), 139.

(2) T.K. Sherwood, Ind. Eng. Chem., **17** (1925), 745.

(3) R.H. Wright and O. Mass, Canad. J. Res., **6** (1932), 94.

(4) Roy P. Whitney and J.E. Vivian, Ind. Eng. Chem., **33** (1941), 741.

(5) R.A.T.O. Nijsing and H. Kramers, Chem. Reaction Eng., Meeting Europ. Federation Chem. Eng. 12th Amsterdam (1957), 81.

(6) W.M. Ramm, Absorptionprozesse in der chemischen Technik p. 197 VEB Verlag Technik (1953).

(7) H. Hikita, H. Nakanishi and K. Katoka, Chem. Eng. Japan, **23** (1959), 459.

Diffusion coefficients in a liquid for SO_2 and Cl_2 by Peaceman(8), for H_2S by Wilke(9), for CO_2 by Nijsing(10) and for NH_3 by Anrold's equation(11) were used. Diffusion coefficient for CO_2 in NaOH solution was calculated by following equations $D_l = D_{H_2O}/\eta$, $\eta = \mu_{NaOH}/\mu_{H_2O}$

4. Reaction coefficient

The reaction coefficient for CO_2 in NaOH solution was calculated by Hatta's equation(12).

$$\beta = \gamma/\tanh\gamma \qquad (3)$$

where

$$\gamma = \sqrt{k[\mathrm{OH}]D_l}/k_l \qquad (4)$$

The second order rate constant, k, for $CO_2 + OH^- \rightarrow HCO_3^-$ was obtained by interpolating Pinsent's results(13). The values of β are given in Table 1.

Table 1. Calculated value of β.

Run No.	Temp. of liquid [°C]	k_g Calc. by Eq. (9)	k_l Calc. by Eq. (10)	H [kg mole /m³·atm]	β [−]
1	25.0	0.372	0.356	0.269	40.2
2	22.0	0.375	0.338	0.293	36.3
3	24.5	—	0.353	0.273	39.3
4	24.8	—	0.355	0.270	39.8

IV. Results

There is a following relation between the rate of absorption and the overall coefficient of mass transfer based on the pressure.

$$w = K_{OG}\,(p_g - p^*)_{lm} \qquad (5)$$

where w is an absorption velocity per unit area. p_g and p^* are the partial pressure of bulk of gas and the equilibrium partial pressure with the solution with the concentration of C_l. $(p_g - p^*)_{lm}$ is a logarithmic mean value between the inlet and the outlet.

1. Effect of electric current

The effect of the current density, i, on K_{OG} with the constant flow rates of the gas and the liquid is shown in Figs. 3, 4 and Table 2. K_{OG} increases with i and are

---

(8) D.W. Peaceman, Sc. D. thesis, Mass. Inst. Tech. (1951).

(9) C.R. Wilke, Chem. Eng. Progress, **45** (1949), 218.

(10) R.A.T.O. Nijsing, R.H. Hendriksz and H. Kramers, Chem. Eng. Sci., **10** (1959), 88.

(11) J.H. Arnold, Ind. Eng. Chem. **22** (1930), 1091.

(12) S. Hatta, J. Chem. Soc. Japan, Ind. Chem. Sec., **35** (1932), 1389.

(13) B.R.W. Pinsent, L. Pearson and F.J.W. Roughton, Trans. Faraday Soc., **52** (1956), 263.

saturated gradually in the following systems, SO_2-H_2O, NH_3-H_2O, SO_2-NaOH Cl_2-NaOH, H_2S-NaOH and CO_2-NaOH. In the system SO_2-H_2O, K_{OG} has the maximum value with the increase of i, when the concentration is large. Fig. 5 shows the corona discharge in air-SO_2 mixture in a wetted-wall column. On the contrary, it seems that there is no acceleration of the absorption rate in the systems H_2S-H_2O and Cl_2-H_2O with a corona discharge. There appears to be a trend of apparent increase of K_{OG} with i in the absorption of H_2S in water, probably because of the decomposition of H_2S to S at a negative electrode.

2. Effect of concentration of gas

K_{OG} decreases with the increase of the concentration of SO_2 in a corona discharge, as shown in Fig. 6. Fig. 7 shows the characteristic current vs. voltage curves, which has the definite relation between voltage and current at the constant composition. Thus, the higher voltage is needed to maintain the same current density, in accordance with the increase of concentration of SO_2 in air-SO_2 and N_2-SO_2 mixture as shown in Fig. 7.

3. Effects of voltage and polarity of an electrode

Fig. 8 shows the correlations between K_{OG} and voltage. K_{OG} with a corona (her-

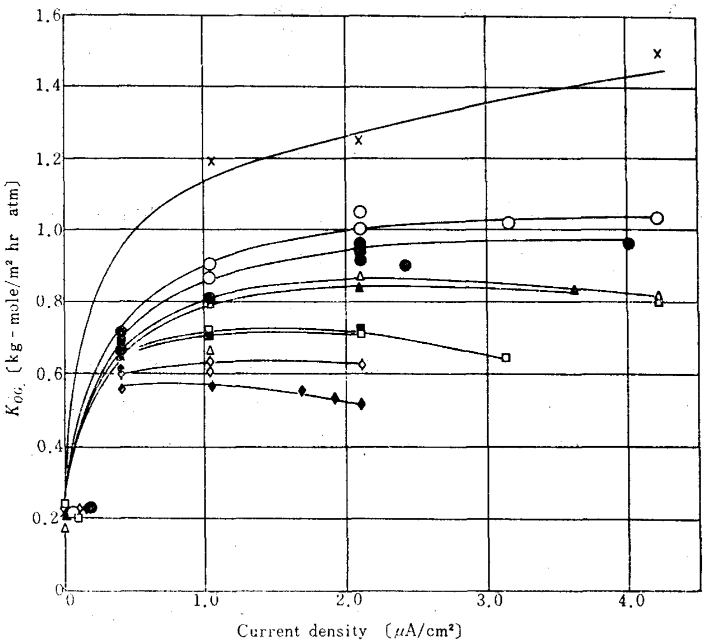

Fig. 3. Correlation of K_{OG} with current density.

N_2-SO_2

SO_2 %	• 3.1	▴ 5.7	▪ 11.6	◆ 20.4
Re_g	500∼550	460∼570	480∼580	520∼710
Re_L	770∼720	540∼670	560∼680	550∼670

Air-SO_2

SO_2 %	× 1.7	○ 3.2	△ 5.6	□ 11.9	◇ 23.4
Re_g	480∼500	520∼540	540∼550	590∼600	720∼730
Re_L	490∼570	510∼580	510∼540	520∼540	540∼570

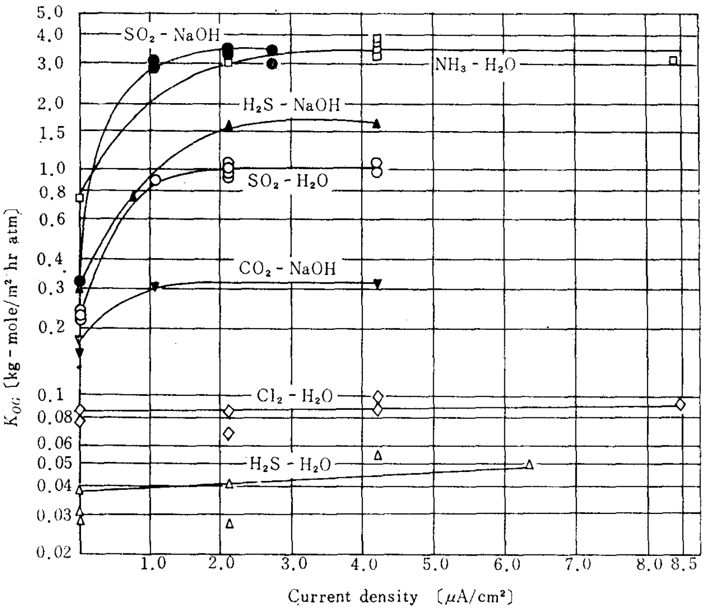

Fig. 4. Absorption of gas in water and NaOH solution with corona discharge.

Absorption by H_2O

	conc. of gas	Re_g	Re_L
□ NH_3	4.4～5.7%	680～760	490～710
○ SO_2	2.9～3.4%	490～540	440～610
△ H_2S	2.6～2.7%	490～500	620～640
◇ Cl_2	3.7～4.1%	580～590	510～540

Absorption by NaOH (0.95～1.07 N)

	conc. of gas	Re_g	Re_L
▼ CO_2	2.4～2.6%	490	370～470
● SO_2	2.7～2.9%	500～510	380～390
▲ H_2S	2.6～2.8%	490～500	350～390

Table 2. Absorption of Cl_2 in NaOH solution with corona discharge.

Run No.	Conc. of NaOH solution [N]	Conc. of Cl_2 [mole fraction]		Temp. [°C]		Re_g [−]	Re_L [−]	Voltage [kV]	Electric current density [μA/cm²]	K_{OG} [kg mole/ m²·hr·atm]
		Inlet	Outlet	Gas	Liquid					
1	1.05	0.0274	0.0165	21.3	20.5	515	353	0	0	0.235
2	1.05	0.0285	0.0014	21.0	20.6	518	355	8.8	2.11	1.37

eafter abbr. to K_{OG}, c.d.) has the same value as K_{OG} without a corona (hereafter abbr. to K_{OG}, n.) until 7.5 and 9.5 kV with a positive and a negative corona, respectively. K_{OG} increased rapidly beyond 10kV with a negative corona, which produces a corona current of 0.42 μA/cm², and then the increase of K_{OG} continues until 11kV, but K_{OG} does not increase beyond 11kV, and current density increases. It is assumed that there will be the same trend as a negative corona in the case of positive corona. Experimentation is not carried out for the higher voltage, because the characteristic relation between electric potential and current can not be maintained by unstable electric field which is produced by dropping water along the electrode.

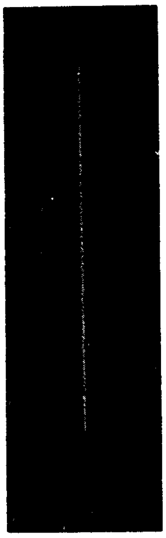

Fig. 5. Corona discharge in air-SO_2 mixture, in a wetted-wall column.
Diameter of column 2.5 cm;height of column 60.3 cm; air-SO_2 mixture, SO_2 2.85%; Re_g 500; the flow rate of water 800cc/min; current density 2.11μA/cm^2; voltage 10.8kV; F2, time 1 sec.

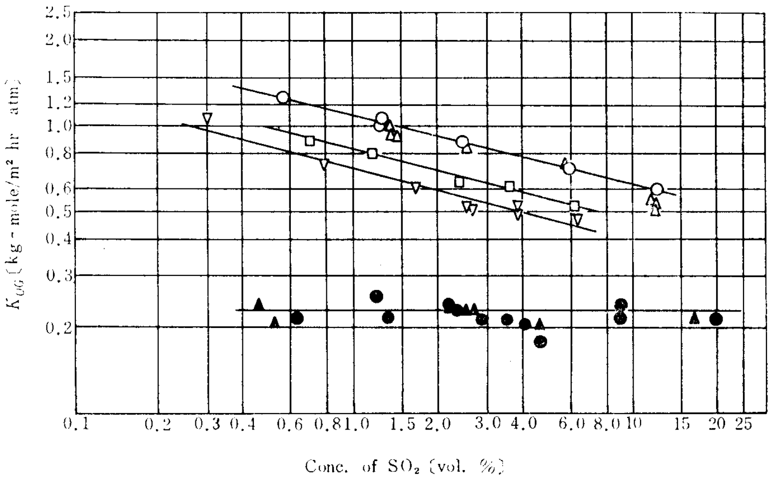

Fig. 6. Correlation of K_{OG} with SO_2 concentration.
with corona; Re_L470~680:
negative corona, ○ air-SO_2, 2.11μA/cm^2, Re_g 490~730,
▽ air-SO_2, 0.42μA/cm^2, Re_g 490~530,
△ N_2-SO_2, 2.11μA/cm^2, Re_g 540~690,
□ air-SO_2, 0.42μA/cm^2, Re_g 500~530, A. C. corona
without corona
● air-SO_2, Re_g 500~740, Re_L 500~600
▲ N_2-SO_2, Re_g 460~520, Re_L 610~720

Therefore it is considered that the acceleration of the absorption rate depends rather on the electric current than on the voltage because the acceleration begins with the flow of electric current. Fig. 6 shows that an A.C. corona has the same trend as the positive and the negative corona.

4. Effect of column length

SO_2 was absorbed by water, using wetted-wall columns diam. 2.5 cm and lengths 30.3, 60.3 and 120.3 cm. K_{OG} decreases with the increase of column length

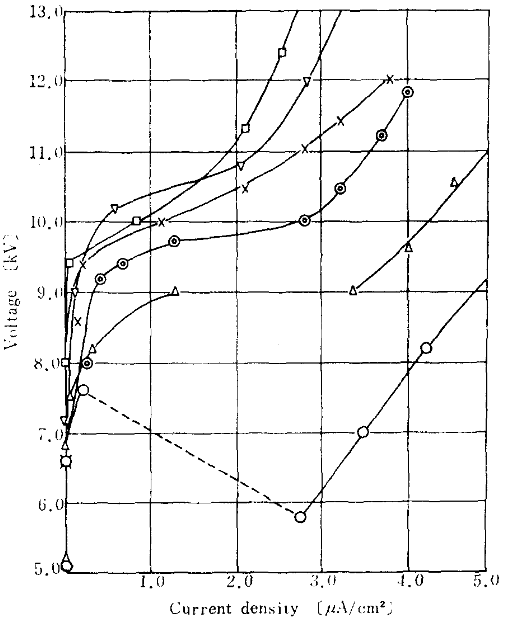

Fig. 7.

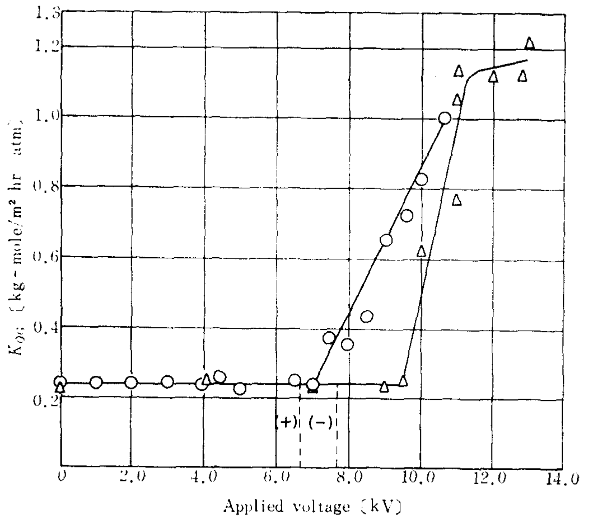

Fig. 8.

Fig. 7. Characteristics between current density and voltage.
Re_g 500, Re_L 500~570
○ pure N_2; N_2-SO_2, △ SO_2 1%, ▽ SO_2 3%;
◉ air; air-SO_2, × SO_2 1%, □ SO_2 3%

Fig. 8. Correlation of applied voltage (potential differenee between the electrodes) with K_{OG}
SO_2, 2.8~3.2%; Re_g, 500~540; Re_L, 530~640:
△ negative corona, ○ positive corona
(+), (−) positive and negative corona onset voltage

with and without a corona. Fig. 9 shows the correlation between the number of transfer unit, N_{OG} and the column length. The relation is plotted as a straight line, but when it is extrapolated, it does not pass through the origin because of end effects. But these values need not be corrected considering that their deviations are small for the purpose of observing the effect of the corona discharge.

5. Effect of gas flow rate

The experimental results of the absorption of SO_2 and NH_3 in water in the range of $Re_g=500\sim6000$, are shown in Fig. 10. With the corona discharge, K_{OG} in SO_2-H_2O system decreases gradually with Re_g, and K_{OG} becomes constant at the range from 2000 to 3000 in Re_g. However, K_{OG}, n. increases with Re_g, and coincides with K_{OG}, c.d. at $Re_g=6000$, on the absorption of SO_2. On the absorption of NH_3 in water, the trend of curves is almost similar to that of the absorption of SO_2, and the curves of K_{OG}, n and K_{OG}, c.d. coincide at $Re_g=10000$. The increase of K_{OG}, n. with Re_g is considered to be caused by the decrease of the gas phase resistance, and the increase of K_{OG}, c.d. is also considered to be caused by the decrease of the gas resistance which is given by the vortex of gas in the wetted-wall column.

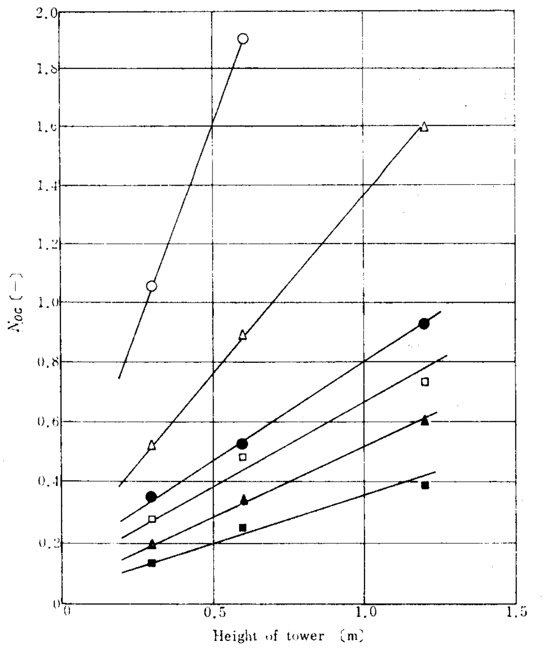

Fig. 9. Correlation of N_{OG} with height of tower.
SO_2 3%, Re_L 570~690;
with corona, 2.11μA/cm^2
Re_g, ○ 500, △ 1000, □ 2000
SO_2 3%, Re_L 570~660;
without corona
Re_g ● 500, ▲ 1000, ■ 2000

6. Effect of liquid flow rate and temperature of liquid and gas

Fig. 11 shows the correlation of K_{OG} and Re_L. K_{OG}, c.d. decreases with the increase of Re_g. As shown in Fig. 12, K_{OG} decreases with the rise of the liquid temperature with and without the corona discharge, and the effect of the temperature on K_{OG}, c.d. is larger than K_{OG}, n. There is no effect of the gas temperature on K_{OG}, n. and K_{OG}, c.d. as shown by the data in Fig. 13.

7. Effect of the concentration of oxygen

The correlation between K_{OG} and the concentration of oxygen is shown in Fig. 14. When the concentration of SO_2 in nitrogen is very small, the state of the corona becomes unstable and the effectiveness of the corona is very slight. However, the corona discharge becomes stable and has the larger effect on the absorption, when the oxygen concentration in N_2-O_2-SO_2 mixture exceeds more than 5%, even if the SO_2 concentration is very dilute.

8. Effect of cylindrical wire net

Fig. 1 shows the apparatus which has a stainless steel cylindrical wire net between the wetted-wall column and the Pt electrode. Experimental results obtained by the above apparatus are presented in Table 3. The electric current

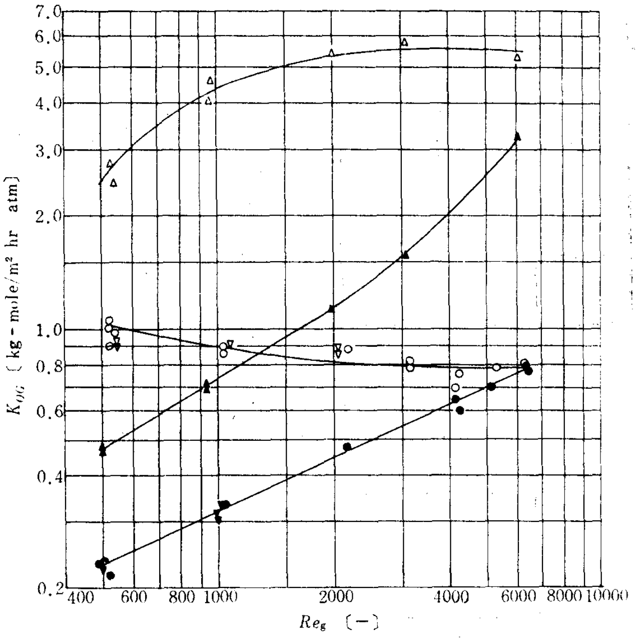

Fig. 10. Correlation of K_{OG} with Re_g.
NH_3, 2.0~2.7%; Re_L 520~630:
▲ without corona △ with corona 4.2μA/cm²
SO_2, 2.83~3.38%:
without corona ● air-SO_2, Re_L 490~610; ▼ N_2-SO_2, Re_L 670~730:
with corona, 2.11μA/cm²,
○ air-SO_2, Re_L 510~570; ▽ N_2-SO_2, Re_L, 540~580

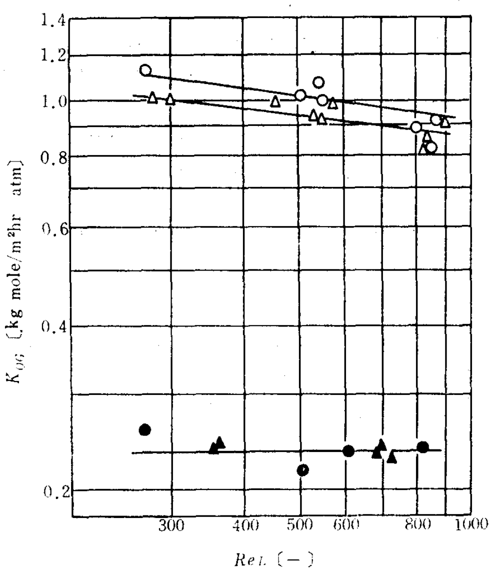

Fig. 11. Effect of the flow rate of water
with corona, SO_2 3.0~3.3%,
○ air-SO_2, Re_g 540
△ N_2-SO_2, Re_g 550
without corona SO_2 2.8~3.4%,
● air-SO_2, Re_g 520
▲ N_2-SO_2, Re_g 500

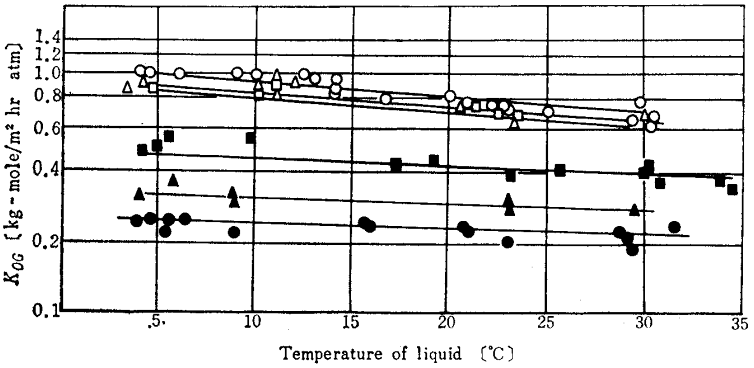

Fig. 12. Effect of liquid temperature.
the flow rate of water 800cc/min; SO_2, 2.5~3.4%
without corona Re_g • 500 ▲ 1000, ■ 2000
with corona 2.11. μ A/cm², Re_g ○ 500, △ 1000, □ 2000

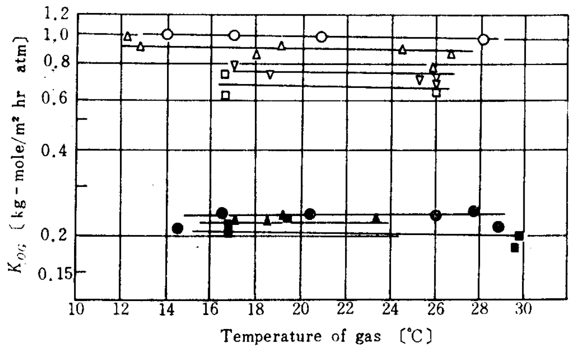

Fig. 13. Effect of gas temperature.
with corona 2.11μA/cm², SO_2, 2.5~3.3%, Re_g 490~540, water 800cc/min; temp. of liquid
○ 4.1~9.0°C △ 10.0~16.7°C, ▽ 20.0~22.8°C, □ 29.3~30.5°C.
without corona, SO_2, 2.8~3.4%, Re_g 490~520. water 800cc/min; temp. of liquid
• 3.9~9.0°C, ▲ 15.8~21.5°C, ■ 23.0~29.4°C

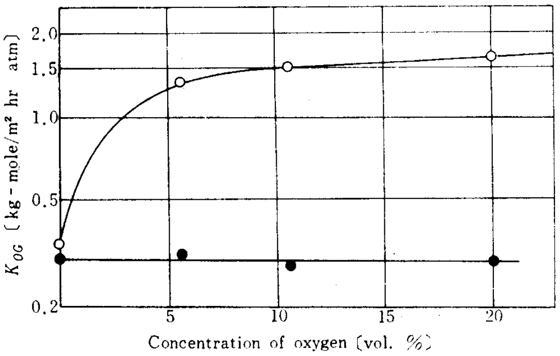

Fig. 14. Effects of concentration of oxygen.
○ with corona, 2.11μA/cm², SO_2, 0.66~0.76%, Re_g 750 Re_L 480~530;
• without corona SO_2, 0.66~0.79%, Re_g 750. Re_L 520~570,

Table 3. Absorption of SO_2 in a wetted-wall column with cylindrical net.

Run No.	Conc. of SO_2 [mole fraction]	Temp. of H_2O [°C]	Re_g [−]	Re_L [−]	Voltage [kV]	Electric current		K_{OG} [kg. mole /m²·hr·atm]
						Betw. net and Pt-wire [mA/30.3cm]	Betw. net and water [μA/30.3cm]	
1	0.0280	14.8	502	297	0	0	0	0.228
2	0.0290	14.9	504	298	10.4	0.3	4	0.777
3	0.0263	15.1	500	298	10.7	0.5	4	0.793

Table 4. Absorption of SO_2 in wetted-wall columns without cylindrical net.

Run No.	Conc. of SO_2 [mole fraction]	Temp. of H_2O [°C]	Re_g [−]	Re_L [−]	Voltage [kV]	Electric current [mA/30.3cm]	K_{OG} [kg·mole/m²hr·atm]	Diam. of tower [m]
1	0.0232	12.5	498	278	0	0	0.207	0.05
2	0.0317	12.3	516	277	16.2	0.09	0.666	0.05
3	0.0242	13.0	501	282	16.2	0.30	0.965	0.05
4	0.0308	14.3	516	593	0	0	0.306	0.025
5	0.0425	15.0	542	595	10.5	0.2	0.777	0.025
6	0.0309	14.3	516	591	10.8	0.5	0.973	0.025
7	0.0296	17.0	502	627	12.0	1.0	0.986	0.025

Table 5. Amount of O_3 produced in the air with corona discharge.

Run No.	Flow rate of gas [l/min]	Flow rate of water [cc/min]	Voltage [kV]	Electric current density [μA/cm²]	Temp. of gas [°C]	Temp. of liquid [°C]	Conc. of ozone produced in the air [%]
1	4	802	9.8	2.11	12.0	10.0	0.034
2	8	802	9.8	2.11	12.0	10.0	0.032
3	16	802	9.8	2.11	12.0	10.0	0.008

Table 6. Oxidized SO_2 in a wetted-wall column with corona discharge.

Run No.		289	287
Conc. of SO_2 in raw gas	[mole fraction]	0.0307	0.0307
Voltage	[kV]	10.8	12.0
Current density	[μA/cm²]	2.11	4.22
Re_g	[−]	515	527
Re_L	[−]	581	561
Temperature of gas	[°C]	18.0	12.8
Temperature of water	[°C]	14.0	13.0
$SO_4^=$ in solution	[H_2SO_4/total S in H_2O 100mole%]	3.36	9.83
SO_3 in exhaust gas	[SO_3, H_2SO_4/total S in gas × 100mole%]	0	1.8

between the Pt electrode and the cylindrical net is 300μA and that between the cylindrical net and falling water is 4μA, and therefore most of the ions and the electrons which migrate to the water electrode are captured by the cylindrical net. Table 4 shows the experimental results of K_{OG} without the cylindrical net using wetted-wall columns diam. 5.0 and 2.5 cm. Comparing with the K_{OG} of Table 3, K_{OG} with the cylindrical net is a little smaller than the one without the net, but the effect of the corona is clearly confirmed.

9. Formation of ozone and sulfur trioxide

The amount of ozone which was produced by the electric discharge in the air is very slight as shown in Table 5. As shown in Table 6 the amount of H_2SO_4 produced in water, when i is 4.22 μA/cm², will be three times as great as when i is 2.11 μA/cm². In the outlet gas, the oxidation efficiency of SO_2 to SO_3 is very small, and its values are zero and 1.8 mole%, when i is 2.11 and 4.22μA/cm² respectively. Very small amount of SO_2 is oxidized in higher current density.

V. Mechanism of acceleration of the rate of absorption

The current of electricity is produced with the migration of electrons and ions which are produced by the corona discharge between two electrodes. Electrons and ions collide violently with neutral molecules, and are accelerated by the electric filed at the interval of each collision, Therefore, it will be considered that the accelerated SO_2 ions will reach rapidly to the water surface and the rate of absorption will be accelerated by the corona discharge. We compared the actual corona current with the ion current and found that all the SO_2 molecules absorbed were ionized. The amount of absorbed SO_2 by the corona discharge means the difference between the amount of absorbed SO_2 with and without the corona discharges. When the concentration of SO_2 is 1%, the rate of absorption of SO_2 is 2.48 cc/min, as shown in Fig. 15. Assuming that the absorbed SO_2 was transproted from the Pt-wire electrode to the water electrode as ions, the numbers of SO_2 ions

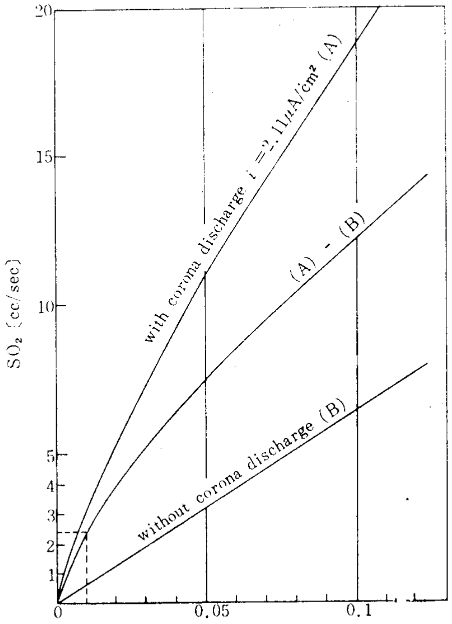

Fig. 15. Correlation of concentration of SO_2 with absorbed SO_2 without corona discharge and with corona discharge.

can be converted into the electric current equivalent, by the equation (5).

$$i = e N_{SO_2^-} \tag{5}$$

When the column diameter is 2.5 cm and the length is 60.3 cm, the current density is as follows.

$$i = e N_{SO_2^-} = 2.25 \times^{-2} \text{A/cm}^2$$

The experimental current density is as follows.

$$i = 2.11 \times 10^{-6} \text{A/cm}^2$$

The former is 10 thousand times as large as the measured one.

The effect of the corona on the absorption of SO_2 is clearly recognized, even when the current of electricity between the cylindrical net and the water electrode hardly flows.

From these results, the absorption of SO_2 by the corona is not only dependent on the acceleration of the velocity of SO_2 ions. According to the experiment by Wilson(14), the top of a flame of a coal gas or a candle was extremely pulled to a negative plate. According to the experiments by Payne(15) et al, the gas was burned with the corona discharge in the cylindrical metal jacket heat exchanger which had a wire electrode along its axis. In the column, it was observed that ions moved radially from the center, the flame was pushed to the wall and gas flowed upward from the bottom producing a vortex. It is assumed that the gas flows through the column in the same way as Payne's experiment, though it was not confirmed experimentally. From the correlation between Re_g and K_{OG} in the absorption of SO_2 in water, the effect of the corona discharge is very large even in the range of laminar flow, Re_g from 500 to 2300. It will be considered that the turbulence of the gas stream occurs in the column, when those ions produced by the corona violently collide with the unionized neutral molecules and are drifted to the wetted-wall under the influence of the electric field. The gas flows passing through the column with turbulence at the range of Re_g from 2300 to 6000, without a corona. And the acceleration of the absorption rate by the corona is seen at that range. But the effect of the corona can not be seen at Re_g more than 6000, for the turbulence by the corona in a column becomes relatively small by decreasing a gas phase resistance by the turbulnet flow of gas in a column. In spite of the violent trubulnece of a gas flow by the corona, the increase of K_{OG}, c.d. is not seen when the absorption rate of resistance. This fact shows that the corona does not affect Cl_2 and H_2S in water is mainly controlled by the liquid phase resistance. This fact shows that the corona does not affect practically on the liquid phase resistance. Though almost all ions are captured by the cylindrical net in the absorption of SO_2 in water with the corona, the rate of absorption is accelerated by a violent turbulence of the gas which was transferred to the outside through the meshes of the net. The rate of

---

(14) H.A. Wilson, Rev. Mod. Phys., **3** (1931), 156.

(15) K.G. Payne and F.J. Weinberg, Proc. Roy. Soc., **A250** (1959), 316.

absorption is accelerate by a negative, a positive and an A.C. corona, inspite of their different polarities and characteristics of the corona discharges. All these results clearly show that the acceleration of the rate of absorption is dependent on the decrease of the gas phase resistance by the turbulence of the gas which is induced by collision of gas with the corona discharge.

Summary

(1) K_{OG}, c.d. in different conditions were measured and examined. The values of K_{OG} were largely affected by the flow rate of the gas and the concentration of SO_2. And, the temperature of the liquid gave a little change to K_{OG}, c.d.

(2) On the absorption of the gas in the liquid, the rates of the absorption were accelerated by the corona discharge in the following systems, which had the main resistance in the gas phase, SO_2-H_2O, NH_3-H_2O, H_2S-NaOH, Cl_2-NaOH and CO_2-NaOH. On the contrary, the rate of absorption of H_2S and Cl_2 in water which was mainly controlled by the liquid phase resistance is not accelerated by the corona discharge.

(3) It was considered that the acceleration of the rate of the absorption with the corona was caused by decrease of the gas phase resistance. At that time the stream of the gas was turbulent, because ions produced by the corona discharge repeated violent collisions with neutral molecules and moved toward the wetted-wall, and the neutral molecules were pushed toward the direction of ion movement.

Nomenclature

A: electric current [ampere]
D, D_l: diffusion coefficient for gas phase and for liquid phase, respectively [m^2/hr] or [cm^2/sec]
d: inside diameter of wetted-wall column [m] or [cm]
e: electronic charge ($=1.602\times10^{-19}$) [A·sec]
g: acceleration by gravity [m/hr^2]
H: Henry's constant [kg-mole/m^3·atm]
H_L: (H.T.U.) height of transfer unit in liquid phase [m]
i: electric current density [μA/cm^2] or [A/cm^2]
k: second-order reaction rate constant [l/mole·sec]
k_g: mass transfer coefficient for gas phase [kg-mole/m^2·hr·atm]
k_e: mass transfer coefficient for liquid phase [m/hr]
K_{OG}: overall mass transfer coefficient [kg-mole/m^2 hr atm]
L: superfical molar velocity of liquid [kg-mole/hr·m^2]
N_{OG}: number of transfer unit [—]
$N_{SO_2^-}$: number of SO_2 ions absorbed per unit area per unit time [SO_2^-/cm^2·sec]
p_g: partial pressure of solute gas in inlet stream [atm]

p^*: partial pressure of solute gas in equilibrium with liquid phase concentration [atm]

R: gas constant (0.08024) [m^{3}atm/kg-mole·°C]

Re_L: Reynolds number of liquid ($4\Gamma/\mu$) [—]

Re_g: Rynolds number of gas ($du\rho/\mu$) [—]

T: absolute temperature [°K]

u: volumetric flow rate of gas divided by the conduit cross section [m/hr]

w: mass transfer rate [kg-mole/hr]

β: Hatta Number ($\gamma/\tanh\gamma$) [—]

γ: dimenssionless parameter ($\sqrt{kD_e/k_e}$) [—]

Γ: mass flow rate of liquid per unit perimeter [kg/m·hr]

μ: viscosity of gas [kg/m·hr] or [C.P.]

ρ: gas density [kg/m^3]