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CONVECTION IN CORONA DISCHARGE*

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Convection of gas in a corona discharge with cylindrical geometry and vertical axis has been experimentally proved. Mixing of A and N_2 at atmospherical pressure in a 1 m long discharge tube has been studied by mass spectrometry. From the time dependence of the mixing of the two gases the effective coefficient of diffusion has been determined, which in the case of the switched on corona discharge increases 21 times. The axial separation effect in argon has also been proved, however, with a negative result.

КОНВЕНКЦИЯ В КОРОННОМ РАЗРЯДЕ

Экспериментально доказана конвекция газа в коронном разряде с цилиндрической геометрией и вертикальной осью. Смешивание A и N_2 в разрядной рубке длиной 1 м при атмосферном давлении изучалось с помощью масс-спектроскопии. Из временной зависимости смешивания этих двух газов определён эффективный коэффициент диффузии, который в случае наличия коронного разряда увеличился в 21 раз. Сделана также попытка обнаружить явление аксиального разделения, однако эксперименты дали отрицательный результат.

I. INTRODUCTION

In the application of an electric discharge to chemical or technological problems the neutral gas is a mixture of two or more gases. In such cases we must necessarily consider the influence of the discharge plasma on the local composition of the gas mixture. In low pressure discharges the effects of cataphoresis are already well known. At high pressures there is besides the influence of the convection of gas, which occurs owing to the nonhomogeneous heating of gas in the discharge.

In this contribution we will study experimentally the mixing of gas components by convection in a corona discharge. To enhance the effect of mixing as much as possible, we have chosen a long discharge tube, vertically placed, with a coaxial arrangement of electrodes in which the positive corona discharge occurs. We suppose the mechanism of the mixing of gases to be the following. The gas in the

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Table 1

time from the introduction of gases	slope of the straight line determining the velocity of convection	discharge	relation of N_2/A above the discharge tube	relation of N_2/A below the discharge tube
0 – 1/2 hour	tg $\alpha = 0.03$	no	—	—
1/2 – 2 hours[1]	tg $\alpha = 0.66$	$U = 8.3$ mkV $I = 2.2$ mA	3.85	1.19
18 hours	—	no	2.80	2.06
18 – 19 hours[1]	—	$U = 8.3$ kV $I = 2.2$ mA	2.65	2.31
19 – 19 1/2 hours[1]	—	$U = 9.6$ kV $I = 5$ mA	2.30	2.27

above mentioned stage stable. The proportion of N_2/A according to the introduced pressures was 2.3. Comparing this with the apparent[2] proportion, which was measured gave the correction factor 1.4, which enabled to determine the composition of the gas mixture at any time.

III. DISCUSSION

The measurement of the mixing of argon with nitrogen in the corona discharge disclosed that the transport in the axial direction during the burning corona discharge was considerable. The axial transport can be assessed best by comparing the reciprocal diffusion of the two components in the tube during the absence of the discharge. The velocity of the reciprocal diffusion in the tube without discharge can be determined from the law of conservation of the particle quantity. If n' is the concentration of argon in the lower vessel and n'' the concentration of argon in the upper vessel (after introducing the gases we have $n' > n''$), we can write the equation

$$V\frac{\mathrm{d}n''}{\mathrm{d}t} = jS \tag{1}$$

$$V\frac{\mathrm{d}n'}{\mathrm{d}t} = -jS \tag{2}$$

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[1] measured immediately after the discharge

[2] the apparent proportion was caused by a different probability of ionization in the ion source of the mass spectrometer.

where j is the density of the diffuse flow, S the cross section of the tube, V the volume of the upper and of the lower vessel.

When we express the density of the diffuse flow with the help of the gradient of concentration we obtain

$$j = -D\frac{n'' - n'}{d}, \tag{3}$$

where d is the length of the discharge tube. After substituting (3) into (1) and (2) we obtain

$$V\frac{\mathrm{d}n''}{\mathrm{d}t} = -SD\frac{n'' - n'}{d} \tag{4}$$

$$V\frac{\mathrm{d}n'}{\mathrm{d}t} = SD\frac{n'' - n'}{d}. \tag{5}$$

From the law of the conservation of the particle quantity there results

$$\frac{\mathrm{d}n''}{\mathrm{d}t} = -\frac{\mathrm{d}n'}{\mathrm{d}t} = n'' + n' = n_0, \tag{6}$$

where n_0 is the average concentration of argon in the discharge tube and the entire apparatus. By elimination with the help of the relation $n' = n_0 - n''$ we obtain from (4)

$$V\frac{\mathrm{d}n''}{\mathrm{d}t} = -SD\frac{2n'' - n_0}{d}. \tag{7}$$

All the considerations so far assume that the volume of the discharge tube is considerably smaller than the volume of the collecting vessels. By the separation of the variables, by integration and by antilogarithmation we obtain

$$n'' = \frac{n_0}{2} + A\,\mathrm{e}^{-(2SD/Vd)t}, \tag{8}$$

where A is the integrating constant. If $t = 0$, there is $n'' = n_0^{'}$, where $n_0^{'}$ is the initial concentration of argon in the upper vessel $A = n_0^{'} - n_0/2$. There holds

$$n'' = \frac{n_0}{2} + \left(n_0^{'} - \frac{n_0}{2}\right)\mathrm{e}^{-(2SD/Vd)t}, \tag{9}$$

which discribes the time development of diffusion. In our experiments the initial concentration of argon in the upper vessel was negligible. Then

$$n'' = \frac{n_0}{2}\left(1 - \mathrm{e}^{-(2SD/Vd\,t)}\right). \tag{10}$$

When we neglect the influence of the change in the composition of the gas mixture on the flow through the leaks we can assume that the current of the argon ions $I(t)$ in the mass analyser is proportional to the concentration of argon in the upper vessel $n'' \sim I(t)$. Then $n''/n_0 = I(t)/I_0$, is the stable value of the collector curent of the argon ions in the mass analyser.

Under our conditions there are $d = 1\text{m} = 100$ cm, $S = 4.908$ cm^2, $V = 500$ cm^3.

By arrangement of equation (10) we obtain

$$\ln(I_0/2 - I(t)) = \ln I_0/2 - \frac{2SD}{Vd}t, \tag{11}$$

which in the semilogarithmic representation is the linear dependence illustrated in Fig. 4. The linear dependences in Fig. 4 prove at the same time that the transport processes can be described by a diffusion equation and characterised by diffusion coefficients. The acceleration of transport during the burning of the discharge is evidence of the existence of axial convection. The diffusion coefficients determined from the plot in Fig. 4 are as follows: $D = 0.115$ cm^{2}s^{-1} without discharge; the effective value of the diffusion coefficient during the discharge $D_{ef} = 2.439$ cm^{2}s^{-1}, which represents a 21-fold accelerated transport. From these values it results that in chemical reactions in the corona discharge the processes of convencion play and important part.

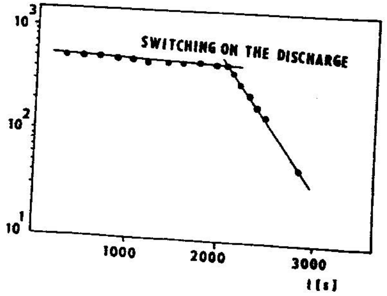

Fig. 4. Dependence of lg $(I_0/2 - I(t))$ as a function of time.

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