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THE POSITIVE COLUMN IN THE THREE-COMPONENT MIXTURE $Ne/H/H_2$- EXPERIMENTAL RESULTS IN COMPARISON WITH AN APPROXIMATIVE DIFFUSION THEORY

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INTRODUCTION: During the last years the kinetic description of electrical discharges in multi-component gas mixtures had shown considerable progress. This was the consequence of an already high degree of perfection in solving the BOLTZMANN equation for electrons. Especially multi-component gas mixtures are important in LASERs and plasma chemical reactors. Typical for such devices is a more or less marked interaction between the composition of the mixture and the properties of the discharge. Analysing the dissociation of H_2 recently a first example of the influence of chemical changes (produced by the discharge itself) on the electrical characteristic was given /1/. It could be shown that the negative differential resistance of the positive column follows from increasing dissociation, which reached a considerable extent (about 100%) at high currents and low pressures. Unfortunately in pure hydrogen discharges the space and time behaviour is often complicated by standing or moving striations, fluctuations etc. More silent operation conditions are possible in mixtures of hydrogen and inert gases.
In this paper a neon/hydrogen mixture is investigated by measuring the electric characteristic and the degree of dissociation. Based on a simple theoretical model the experimental results are compared with calculated ones.

EXPERIMENTAL ARRANGEMENT: The axial electric field strength of the positive column (length: 1m, radius: 1cm) was measured via two usual static probes. To reduce the large influence of the electrodes on the degree of dissociation (effective recombination at the metallic surface) two narrow capillaries were attached in front of the electrodes. The degree of dissociation was determined using a WREDE-HARTECK-probe. In all cases the discharge tube was connected with a large dead space.

THEORETIC MODEL: Till now no solution of the BOLTZMANN equation is known for electrons in the three-component mixture $Ne/H/H_2$. But the discussion of this equation shows that generally the contribution of not too large Ne constituents only plays a rather small role in the electron kinetics compared with the other terms (resulting from H and H_2) because of the small cross-sections and the large atomic mass of Ne. Neglecting all the Ne terms, the BOLTZMANN equation for electrons in the $Ne/H/H_2$ mixture changes to that in the H/H_2 mixture with the only difference that the actual (reduced) fieldstrength E/p_o is replaced by a effective one $(E/p_o)_{eff} = E/p_o(1-x_o)$; x_o: relative concentration of Ne. In the framework of this approximation the Ne admixture in a molecular gas discharge mainly plays the role of a buffer gas. Some calculations and experiments have shown this very clearly in the Ne/N_2-mixture /2/. It could be estimated that up to $x_o \lesssim 0,5$ and $(E/p_o)_{eff} \lesssim 20$ V/cmTorr the explicit influence of Ne in the H/H_2 mixture is very small. At higher Ne content the influence is noticeable, especially in the H/H_2 ionization range of the electron energy distribution function.
Taking into account Ne only as a buffer gas the diffusion theory of the positive column in the $Ne/H/H_2$ mixture can be formulated using the electron energy distribution functions of H/H_2, mentioned in /1/. Then the balance equations of the charge carriers, of the H atoms and of the discharge current give the basis for calculating the column characteristic, the degree of dissociation etc. With some further simplifications these equations read:

$$(\lambda/r_o)^2(D_e/b_e)(b^+/N_o) = x_1 z_1 + x_2 z_2$$

$$x_I x_2 z_D - x_1^2(x_o z_{RO} N_o + x_1 z_{R1} N_o + x_2 z_{R2} N_o) + - \gamma x_1 \bar{c}/4 r_o N_o = 0$$

$$i = \pi e_o r_o^2 N_o x_I b_e E$$

(λ=2,405; D_e, b_e: diffusion coefficient and mobility of electrons; b^+: mobility of ions; N_o: total concentration of neutral particles; x_o, x_1, x_2: relative concentrations of

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Ne, H, and H_2 particles; z_1, z_2: ionization rate of H and H_2; z_D: rate of H_2 dissoziation by electron collisions; z_R: recombination rate by three body collisions of H atoms; γ: wall recombination coefficient of H atoms; $\bar{c}$: thermal velocity; r_o: column radius; x_I: degree of ionization).
The simplifications mentioned are: Use of only one value for the mobility of the different ions H^+, H_2^+, H_3^+ (BLANCs law shows that this is correct within a failure of about 20%; $b^+ \approx 1,3\ m^2/Vs$ at 1 Torr); neglect of the ionization of Ne and neglect of the PENNING ionization of H and H_2 via metastable Ne atoms.

RESULTS: Fig.1 shows that with increasing Ne content x_o the degree of dissociation $x_D = x_1/(x_1+x_2)$ is increased too. This is the consequence of the increase of the effective field strength. Although the hydrogen component decreases by this change of the mixture ratio the absolute value of the H atom concentration remains nearly constant in the beginning (Fig.2). Fig.3 shows the degree of ionization and dissociation in dependence on the discharge current. The measured values x_D agree quite well with the theory. Finally Fig.4 compares the measured and calculated electric characteristic. The two dashed lines correspond to the limiting cases of constant chemical constitution: Ne/H_2 (upper curve), Ne/H (lower curve). An explicit consideration of Ne in the BOLTZMANN equation of the mixture would increase these limits which roughly correspond to the experimental values. But the transit from the upper to the lower level differs considerably. Mainly this must be attributed to the neglect of the gas heating at higher currents. As a boundary condition we used N_o=const (together with n_1+n_2=const). But actually N_o will decrease with increasing current, giving higher experimental reduced electrical field strengths than shown in Fig.4.

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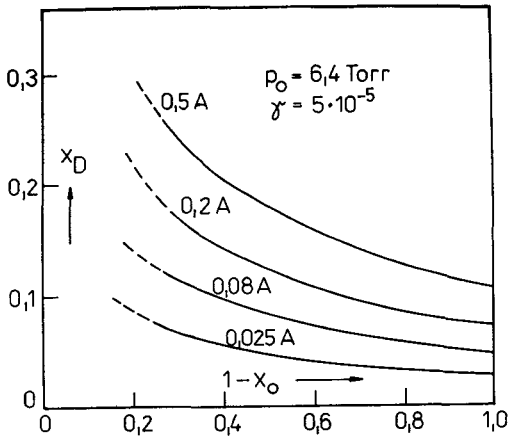

Fig.1

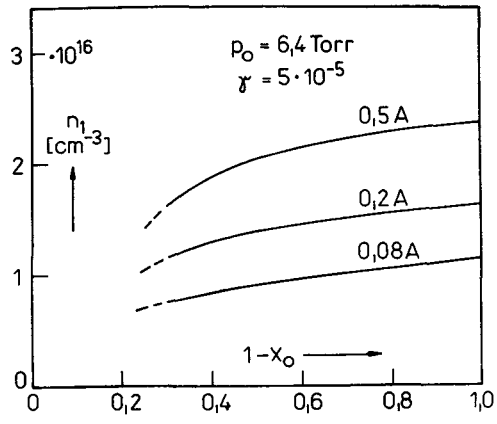

Fig.2

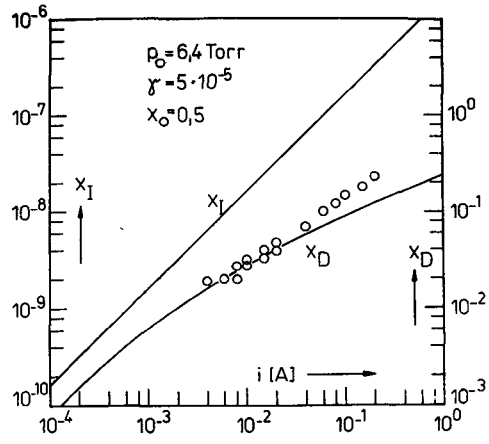

Fig.3

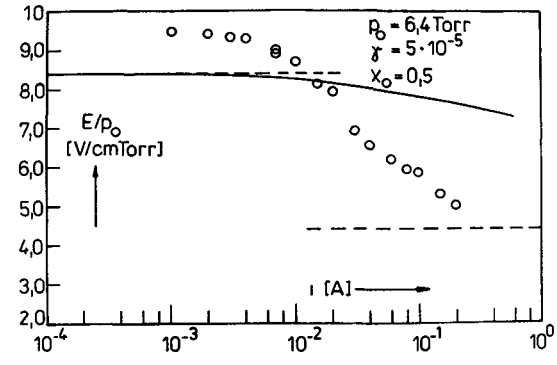

Fig.4