THE IONIZATION OF ARGON AND NEON BY NEUTRAL ARGON BEAMS

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As a result of the discovery of Kallmann and Rosen[1,2] that the probability of charge transfer is very great for gas ions moving in a gas of their own molecular or atomic species, the possibility of obtaining an atomic beam of high intensity is at once indicated. Since the charge transfer itself takes place without altering the translatory energy of the moving ion, the translatory energy of the formed neutrals will equal that of the ions in case the ion is not scattered, or only slightly scattered. This fact has been utilized to produce beams of neutral argon atoms for the purpose of this investigation.

The apparatus consists of 3 parts. In part I argon ions are formed by electron impact. These argon ions pass through an aperture in a diaphragm of part I and are accelerated between parts I and II by means of a field to give them the desired velocity. By means of an aperture in a diaphragm in part II they pass through the field-free chamber of part II in which argon gas is maintained at a suitable pressure. Between parts I and II the space is evacuated by a high speed pump. In space II the argon ions encounter atoms of argon and neutralize themselves by transfer of charge. From part II the neutral argon beam passes by means of a diaphragm and an aperture into an evacuated space in which a strong retarding field allows only the neutral atoms to pass through a diaphragm into space III. Electrons which might be formed between parts II and III are deflected away by an appropriate transverse field. Thus only neutral atoms of known velocity enter part III.[3] This part constitutes the ionization chamber in which the interaction of the argon beams with argon and neon is investigated at a suitable gas pressure.

In the case of both gases used an exceptionally intense ionization was observed in part III. Both the positive and negative saturation currents were measured. Saturation was obtained in both cases for potentials of ± 4 volts between electrodes in space III lying parallel to the beam and protected by a sort of guard ring from secondary electrons. No measurement of the intensity of the primary atomic beam was undertaken in these preliminary experiments.

The results obtained were as follows.

Neutral Argon Atoms in Argon.—The number of positive and negative carriers produced by the neutral beams was nearly the same (negative carriers being slightly predominant). This fact indicates that in general only slow argon ions had been formed in part III. Had the atoms of the beams been ionized they would have left the space as positive ions subsequently leaving the region of part III. Thus the positive ion current would have been much smaller than the negative current in part III.

This result and the general result given later on might allow the conjecture that the newly formed neutral atom-beam is not in its normal state, a point which has still to be proved and which might vary the following theoretical considerations.

Neutral Argon Atoms in Neon.—In this case the positive charges collected in part III were relatively feeble in comparison with the negative charges collected. This finds its most natural explanation in the assumption that it is the larger argon atom of lower ionizing potential (which constitutes the beams) that is ionized. They escape from the measuring field of part III leaving only their electrons behind. Thus the currents measured are predominantly due to the electrons generated.

General Result and Conclusions.—A most important common factor underlies the results described in the two cases above. In both cases (argon in argon and argon in neon) it appears that in the region of velocities from 50 to 120 volts equivalent velocity of the neutral argon atoms the intensity of the ionization is practically constant, and decreases but slowly at the lower velocities. This suggests that even at an equivalent velocity of thirty volts the course of the curves will be practically unaltered, the value of about 30 volts being the ionizing potential for argon atoms in argon as it would follow from the law of conservation of momentum.

If one compares the observed sharp inset of ionization of argon-like K^+ ions in argon which occurs at 96 volts with these new results for argon atoms in argon one sees the enormous difference between the ionization potentials which are to be ascribed to the difference in nuclear charge since the electron configurations as well as the masses of K^+ and A are practically the same.

This new phenomenon suggests the following explanation of the ionization experiments. When the potassium ion has approached close enough to the argon atom the two together might be regarded for a short time as a pseudo molecule. The ionization potential of such a pseudo molecular-ion is higher than that of the pseudo molecule itself.[4]

It thus appears possible through a consideration of these experiments to explain the results found in the ionization of the inert gases by slow alkali ions.[5] The high values of the inset of ionization in this case[5] are to be ascribed to the nuclear charge while the maximal effect might be ascribed to the law of conservation of momentum since the transfer of impulse (and thereby the degree of interpenetration) must be greatest for individuals of equal mass. Further fine details of the process must in all probability be sought in the effect of polarization of the neutral atom and the electron configurations of the atoms involved.

But the independent conclusions we might draw from these experiments reach much further than giving us only the possibility of explaining the results on the ionization of the noble gases by positive alkali ions.[5]

Since the experiments indicate that ionization by neutral beams takes place with large efficiency even at low energies, a new field of investigating thermo-ionization is opened by this method. Results in this line might, later on, gain importance in the question of chemical reactions. The possibility is also suggested of selecting from Maxwell's distribution curve of velocities in gases a certain desired velocity.

Furthermore, these results are of the greatest importance for the phenomena of discharge in gases. The rôle which in the past has been ascribed to the positive ion but which seems inconsistent with the high value recently[5] found for the energy required to enable a positive ion to begin to ionize at all may now easily be transferred to the neutral atoms. For the positive ion may very readily transform itself to a neutral atom which may then easily ionize atoms or molecules even at very low velocities.

These investigations will be published in detail when quantitative data resulting from the measurement of the intensity of the neutral beams has been obtained.

In conclusion, I wish to acknowledge that Prof. Fritz Zwicky, to whom I owe in the course of the last year many interesting and helpful discussions on theoretical questions of the ionization of the inert gases by positive alkali ions, has originally suggested this experiment in order to prove the correctness of his considerations given in the following paper.

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[1] H. Kallmann and B. Rosen, *Zeits. Physik*, **61**, 61 (1930); **64**, 806 (1930).

[2] H. Kallmann and B. Rosen, *Naturwissenschaften*, **18**, 867 (1930).

[3] The possibility of neutral argon beams obtained by neutralization of double ionized argon, which would have twice the energy is only very low.

[4] See the following paper of Fritz Zwicky.

[5] The maximum yield, the lowest ionization potentials and the steepest rise of the ionization curve has been shown to occur for that ion that lies nearest the inert gas to be ionized in the periodic table. Otto Beeck, *Annalen Physik*, [5] **6**, 1001 (1930); Otto Beeck and J. C. Mouzon, **11**, 737 (1931); **11**, 858 (1931), and other places to be found there.