Equilibrium between Positive Ions and Neutral Atoms in Positive Rays of the Rare Gases

It has been shown by several experimenters that the particles in a positive ray beam may gain or lose electrons in passage through a gas at low pressure without appreciable change of velocity or direction. Rutherford[1] and Henderson[2] have found that in an α-ray beam an equilibrium is established between doubly charged and singly charged particles at high velocities but that at lower velocities the equilibrium shifts to one between singly charged and neutral particles with the fraction of neutral atoms increasing with decreasing velocity. Friedersdorff[3] found that the arc lines of argon do not show a Doppler shift in an end on spectrogram of the positive ray beam, at least, for accelerating voltages less than 30,000 volts; Romig[4] got the same result with neon. Miss McPherson,[5] using quite a different method of excitation, obtains agreement with this conclusion. It has been suggested that this indicates that at the voltages used (of the order of 20,000 volts) the moving particles are predominantly positive, as in high velocity α-rays, rarely becoming neutral and, therefore, emitting the shifted arc lines with inappreciable intensity. In order to check this suggestion directly, Rudnick's work[6] with helium has been extended to neon, argon, and krypton over the velocity range from 10,000 to 22,000 volts. Contrary to expectations, with neon the equilibrium was established with the beam approximately 87 percent neutral at 13,000 volts, this value changing to 85 percent at 22,000 volts. In argon the fraction of neutral atoms changed from 94 to 92 percent as the accelerating potential was increased from 10,000 to 22,000 volts. At all velocities in the range from 13,000 to 22,000 volts the krypton beam was approximately 95 percent neutral. Readings as low as 7000 and as high as 25,000 volts indicated no large changes in the neutral fraction. In agreement with Henderson's and Rudnick's work, the percentage of neutral atoms in the beam in the equilibrium condition decreased with increasing velocity in the case of neon and argon. The behavior of krypton was peculiar in this respect, the fraction of neutral atoms apparently increasing with increasing velocity, but the change was so small (about half of one percent) as to be uncertain.

It might be pointed out that in the present work the velocity of the ions was smaller than in Henderson's experiments so that at higher velocities it is quite possible that the beam might remain predominantly positive since the equilibrium shifted in that direction but the results obtained do appear to rule out the suggested explanation of the absence of arc lines in the Doppler effect observations since the same velocity range was investigated in the two cases.

Complete results, including measurements of the free paths of the positive ions and neutral atoms, will be published shortly.

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[1] E. Rutherford, Phil. Mag. **47**, 277 (1924).

[2] G. H. Henderson, Proc. Roy. Soc. **A109**, 157 (1925).

[3] K. Friedersdorff, Ann. d. Physik **47**, 737 (1915).

[4] W. Romig, Phys. Rev. **38**, 1709 (1931).

[5] A. I. McPherson, Phys. Rev. **41**, 686 (1932).

[6] P. Rudnick, Phys. Rev. **38**, 1342 (1931).

Radiation from Moving Helium, Neon and Argon Ions

Dempster and Batho[1] report obtaining a beam of hydrogen ions of homogenous velocity; the ions were formed in a low-voltage arc, and were accelerated in passage through perforated electrodes maintained at a high-potential difference, of the order of 20,000 volts.

This method has been extended to study some of the rare gases. In the spectrum of such a beam of positive rays observed end on, some lines show the Doppler effect; that is, each such line is accompanied by an additional sharp line displaced toward the higher frequencies by an amount agreeing well with that expected from the velocity of a singly charged ion which had fallen through the applied field.

In argon, only the spark (blue) lines showed

[1] Dempster and Batho, Astrophysical Journal, January, 1932.

the Doppler effect, the displaced lines emitted by the moving ions being in intensity and sharpness comparable to the undisplaced lines excited in the gas at rest. The arc (red) lines were relatively weak, and showed no Doppler effect; the neutral particles in the beam were evidently not excited to emission by collisions. Experiments by Batho[2] indicate such a beam in argon to consist of at least 90 percent neutrals. The single sharp displaced Doppler line does not bear out the observation of earlier workers, who found in their diffuse displaced Doppler strip several maxima, apparently corresponding to ions with multiple charges, in some cases in the red spectrum as well as the blue.

In neon, the arc spectrum was not excited, the lines of the first spark spectrum were intense and showed the Doppler effect strongly. In the recent experiments of Romig[3] the manner of excitation was different; the arc lines appeared but with no Doppler effect. Batho finds such a beam of neon particles to consist of at least 85 percent neutrals.

In helium, lines of the arc spectrum and the spark line 4686 show a Doppler effect. Most of the displaced lines are relatively less intense than those of argon or neon, and vary more in intensity relative to the undisplaced line. The displaced and the undisplaced spark line 4686 are of approximately equal intensity. The spark line 4541 of the "Pickering" series is excited in the gas at rest, but as it shows no displaced line, is evidently not emitted by the moving helium particles in the beam.

It is of interest to give a preliminary restatement in terms of the atomic phenomena at a collision. At these velocities a collision involves the complete interpenetration of the electron systems. During the process electron transitions to other molecular states may occur so that when the two nuclei separate, they are accompanied by new electron arrangements. In neon, neutral atoms emerge from a collision always in an unexcited state, the neutrals left behind are also unexcited, while positive atoms emerge or are left in an excited state. With the velocity used the positive helium atom may emerge from a collision in the 4-quantum excited state but not in the 9-quantum excited state.

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[2] Batho, Phys. Rev. **41,** 686 (1932).

[3] Romig, Phys. Rev. **38,** 1709–1715 (1931).

Some Evidence Indicating a Removal of Positive Ions from Cold Surfaces by Electric Fields

It has been clearly demonstrated that the discharge produced between two plane or spherical electrodes in high vacua, when a sudden electrical potential is applied across them is started by the field electron current from the cold cathode.[1,2,3] The electric field necessary to produce a field current from the cathode of sufficient magnitude to start the discharge in a few microseconds, although found to be somewhat variable and to depend upon the metal and its previous treatment, is of the order of magnitude of a half million volts per cm. For some time, as an auxiliary to an investigation of the initiation of discharges in ion free gases,[4] the writer has been experimenting in high vacua with point and plane (as well as wire and cylinder) electrodes. It was hoped that by making the point (or wire) positive, to increase the applied potential for a given electrode spacing until electrons were pulled out of the plane or cylindrical cathode by the field in sufficient number to start the discharge. This was found, probably to be the case when the point (or wire) is of properly treated tungsten, for example, and free from impurities on its surface. However, when the point (or wire) is not free from impurities (especially the alkali metals) it is believed that this is no longer always true.

In the first experiments a tungsten point was placed opposite a polished nickel plane in a high vacuum. The plane was grounded through a variable non-inductive resistance, and positive electrical surge potentials were applied to the point for a time whose order of magnitude was 10^{-6} sec. (time constant of circuit was 1.5×10^{-6} sec.). This time was held

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