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

[1] R. W. Wood, Phys. Rev. [1] **5**, 1 (1897).

[2] Hull and Burger, Phys. Rev. **31**, 1121 (1928).

[3] L. B. Snoddy, Phys. Rev. **37**, 1678 (1931).

[4] Street and Beams, Phys. Rev. **38**, 416 (1931).

constant throughout all the experiments here described. This resistance (a portion of which was shunted by a neon tube) served to protect the point when the discharge was once initiated, yet was low enough to allow a small luminous spot to form on the point when the discharge occurred. The point was either measured or photographed after each discharge so that the form factor could always be obtained. If the point and plane were untreated, i.e., merely mounted in the tube and the air pumped out, it was found that the discharge would take place when the field at the point reached only from five to ten million volts per cm. However if the point and plane were baked out and several discharges allowed to take place the field at the anode necessary to produce discharge was increased many times and exceeded fifty million volts per cm for tunsten points. If then the point and plane were allowed to stand over night in 0.01 mm of air pressure with the solid CO_2 removed from the traps, the next morning, upon pumping, out, the positive field at the point necessary to produce discharge was usually lowered by a large amount. Caesium distilled into the tube also reduced the fields at the point necessary to produce discharges. A one mil tungsten wire was then mounted along the axis of a polished steel cylinder of 8 mm internal diameter. The wire was grounded and negative surge potentials were applied to the cylinder. The electrical connections were the same as in the case of the point and plane. The results were similar to those obtained with tungsten points. If the wire was heated almost to the melting point for a few seconds in the presence of commercial hydrogen at a pressure of about one cm, then allowed to cool and the hydrogen pumped out, the field at the surface of the wire necessary to produce discharge was definitely lowered. In the case of a one mil thoriated tungsten wire mounted along the axis of an 8 mm steel cylinder and treated to bring thorium to its surface the field necessary to produce discharges was lower than in the case of the treated pure tungsten wire first mentioned.

As the electrodes were in high vacua and the potential applied for only about 10^{-6} sec. the residual gas could not have been effective in starting the discharge. The discharge must then have been initiated by electrons pulled out of the plane (or cylinder), electrons, negative ions or positive ions pulled off the glass surface, or positive ions pulled off the surface of the point (or wire) by the electric field, or else a combination of these. In the case of the wire and cylinder, discharges occurred when the field at the surface of the cylinder (assuming the surface of the cylinder smooth) was less than twenty-five thousand volts per cm so that electrons pulled out of the cathode could not have started the discharge. Hence the discharges must have been initiated either by ions and electrons pulled off of the glass surface or positive ions pulled off of the surface of the anode by the electric field. Several attempts were made to separate these two effects but always without complete success. However, in some of the experiments the complete initiation of the discharge by ions and electrons coming from the glass surface was rendered unlikely by the arrangement of the electrode potentials by shielding and by the geometry of the glass tube. Therefore, it is believed that in these cases the discharge was started by the positive ions pulled off the surface of the positive point or wire by the field. This explanation is also supported by the fact that the magnitude of the fields necessary to start the discharge depended upon the previous treatment of the wire anode. It is believed by several investigators[5] that adsorbed alkali ions (Becker's "adions" for example) can exist on the surface of tungsten since the work function of tungsten is greater than the ionization potential of many of the alkalis. Also, it is thought that these adsorbed ions can exist on tungsten oxide. Hence the positive ions that are believed to be pulled off of the anode by the field in the above experiments are probably alkali ions. The experiments are being continued and it is hoped that a detailed paper can be published later.

J. W. Beams
University of Virginia,
August 6, 1932.

[5] Compton and Langmuir, Rev. Mod. Phys. **2**, 124 (1930); Dushman, Rev. Mod. Phys. **2**, 381 (1930).

The Reflecting and Resolving Power of Calcite for X-Rays

The writer has recently published the results of a research in which experimental values of the coefficient of reflection of calcite in a range from 0.2 to 2.3A, as obtained in the