

nosity of the vapor travels away from the anode at the rate of $1.7 (10^6)$ cm per second during the first $2 (10^{-7})$ sec after breakdown. We also have obtained actual photographs of the initial stages of single sparks with exposure times as short as $4 (10^{-8})$ sec. These snapshots of the beginnings of single sparks show that a current of 1600 amperes is carried by a filament of cross-section $5 (10^{-4})$ sq. cm at the anode which gradually widens out to a cross-section of $2 (10^{-3})$ cm at the cathode. Thus the current density in the discharge attains the enormous magnitude of $3 (10^6)$ amps per sq. cm. This great current density produced the great brilliance of the spark as a light source which made possible the photography of the spark with the short exposures mentioned above.

It seems probable that the above recorded velocity of spreading of the spark luminosity from the anode really measures the velocity of the positive ions. Assuming this to be the case and that the positive ions carry one half the discharge current, it is calculated from the cross-section of the discharge that about 30 percent of the molecules and atoms in the discharge are ionized. This result is in striking agreement with the above estimate of the ionic density evaluated from the broadening of the spectrum lines. These calculations have

not taken into account certain factors and therefore are approximate but certainly right in order of magnitude. Perhaps it does not seem valid to assume that the positive ions carry as much of the discharge current as the electrons because of the greater speeds of the latter carriers. This objection appears less serious when it is pointed out that the magnetic field produced by the discharge itself reaches the magnitude of 40,000 Gauss and therefore that the electrons are confined to spiral paths of very small radii in such a manner that their velocity of migration to the anode is diminished considerably.

Finally, we should like to mention that two of our photographs of early stages of sparks show off-shoots from the main filament of the discharge which remind one of Wilson cloud photographs of alpha-particle tracks. Because the off-shoots in both cases are bent towards the cathode the possibility is suggested that they are due to regions of ionization initiated by high velocity positive ions ejected from the main filament of the discharge.

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December 11, 1929.

The Effect of Second Order Zeeman Terms on Magnetic Susceptibilities: Errata.

Due to a previous arithmetical error, the theoretical Bohr magneton numbers given in Table I of our note in the preceding (December 1) issue should read 3.68, 2.83, 1.66 and 3.53 for Nd^{+++} , III^{+++} , Sm^{+++} , and Eu^{+++} respectively instead of 3.69, 2.87, 1.83 and 3.56. There is no change in the balance of this Table or in Table II. This revision is seen to be appreciable only for Sm^{+++} , and here improves the agreement with

experimental values (1.54, Cabrera, or 1.32, St. Meyer) so that the situation for the whole rare earth group is now quite satisfactory. The first sentence of the last paragraph in our previous note obviously relates to the iron rather than rare earth group.

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December 13, 1929.

Electron Emission by Metastable Atoms

It has been shown recently by Oliphant [Proc. Roy. Soc. **A124**, 793 (1919)] that helium metastable atoms cause a secondary electron emission when they strike a negatively charged target. Uytterhoeven [Proc. Nat. Acad. Sci. **15**, 32-37, (1929)] has observed that the currents to a negative probe in neon are greater than those calculated from the observed sheath thickness. This could be accounted for by the assumption that a portion of the current measured was due to

secondary emission by metastable neon atoms. The writer (Science **68**, 598, 1928) has also reported observations with a negative probe in neon which can be accounted for by a secondary electron emission from the probe. More recent experiments in this laboratory (which will be reported shortly by Found and Lowe) indicate this secondary emission is due to metastable atoms.

There is considerable difficulty in separating the currents due to positive ions from that

due to secondary electrons. In the course of some experiments on sputtering by positive ions of neon, it was observed that the energy delivered to a sputtered wire target was much less than that calculated from the current and the voltage drop at the electrode.

This was ascribed to the fact that part of the measured current was due to secondary emission by metastable atoms. As Oliphant's results show that the difference in energy between the metastable state and the work function of the metal is taken up by the emitted electron, we may assume that the total energy to the target is carried by positive ions. Thus the positive ion current may be calculated from measurement of energy delivered to the target and the relation between secondary electron current and positive ion current determined.

A second method of calculating the contribution of secondary electrons to collector currents is the space charge equation developed by Langmuir and Mott Smith (G. E. Rev. 1924). If the secondary emission is due to metastable atoms, it will be proportional to the collector area, whereas the positive ion current is proportional to the sheath area. It has been proved by Langmuir that the secondary electron emission from a negatively charged collector does not vary by more than 0.1 percent per volt. A change of this magnitude can be neglected when dealing with a cylindrical collector of small diameter. If, with such a collector, we

choose conditions such that the sheath area is large (i.e., low discharge currents and high voltages) we may assume as a first approximation that the current is due entirely to positive ions. On this basis an approximate value of sheath thickness can be calculated. By comparing the rate of change of collector current to the rate of change of sheath area, the random positive ion current density can be determined by a series of approximations. From this value, the contributions of secondary electrons to collector current is readily computed. Calculation by this method shows that in the positive column of a neon tube of 5 cm diameter at 300 baryes pressure and operating at 0.4 amperes discharge current, the secondary electron emission from a tungsten wire is 7.5 m.a./cm² compared to a random positive ion current density in the discharge of 0.82 m.a./cm². This means that a wire collector of 0.005 cm diameter and 3.5 cm long, 100 volts negative to the discharge, receives a positive ion current of 0.91 m.a. and emits a secondary electron current of 0.42 m.a. Results giving the secondary electron current as a function of discharge current and pressure will be given in a future publication.

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Frequency Distribution in Raman Spectra

If we grant that most of the lines in the Raman spectra of organic compounds correspond to fundamental frequencies in the molecule, it is possible to explain the distribution of the frequencies in the spectra by assuming that the non-polar chemical bond always has about the same elastic constants independent of the atoms which it joins or their position in the molecule. In other words variations in frequency appear to be due in most part to the variations in the masses of the particles vibrating rather than to variations in bond strength when the bonds involved are non-polar single bonds.

We have taken the following values as representing the average state of the non-polar single bond: $k_1 = 4 \times 10^5$ dynes per cm for stretching the bond; $k_2 = 0.66$ dynes per

cm for bending the bond. In other words k_1 is the restoring force on an atom when it is moved unit distance along the line in which we think the bond to act, and k_2 is the restoring force when the atom is moved perpendicular to this line, the rest of the molecule being held still. This implies; (1) that the bond is a definite localized force closely analogous to a spring, at least for the small displacements involved in thermal vibration which are of the order of 0.2A; (2) that all bonds have a common mechanism as was first suggested by G. N. Lewis when he proposed the electron pair theory.

These assumptions lead us to expect the following groups of frequencies in the Raman spectra of typical organic molecules. (Values are in cm⁻¹.)