Photoelectric Efficiencies in the Extreme Ultraviolet

Measurements of the photoelectric efficiencies of the extreme ultraviolet radiations of Ne and A have been carried out which confirm earlier results[1] that these efficiencies are considerably higher than the known efficiencies in the nearer ultraviolet.

Photoelectric and energy measurements were made in a side arm to a tube carrying a positive column discharge. A quartz filter, movable magnetically, permitted the separation, in the case of each rare gas, of the effects of the extreme ultraviolet radiations from the effects of the rest of the spectrum. The spectral regions so isolated are: $\lambda744A-\lambda575A$ for Ne, and $\lambda1050A-\lambda790A$ for A, approximately.

For the energy measurements a thermopile was used of the absolute type devised by Coblentz and Emerson.[2] The receiver of this instrument as constructed was a constantan sheet 2.3 cm$\times$1.8 cm$\times$0.00063 cm mounted 1 mm in front of the 19 hot junctions of an iron-constantan thermopile. A known calibrating current could be passed through the receiver. Photoelectric currents were measured either from the receiver itself, in which case all questions of reflection are eliminated, or from a Ni plate of the same size which could be moved magnetically to a position close in front of the receiver. In the latter case it can be assumed that the extreme ultraviolet energy absorbed by the Ni surface is approximately the same as that absorbed by the receiver since O'Brien[3] has shown that reflection coefficients are very small in the wave-length region here considered. The Ni plate could be withdrawn into a side arm for degassing purposes. An open mesh grid placed about 1 cm in front of the receiver served as an anode to collect the electrons. The receiver of the thermopile was left bright in order to decrease, relatively, the sensitivity to the visible and infrared rays. The thermopile, except for the front face of the receiver was completely surrounded by a Ni housing which prevented any radiation from entering the interior. The sensitivity of the instrument, with the galvanometer used, was of the order of 1 mm for a few microwatts, varying considerably, with the nature and pressure of the gas used.

Experiments, showing that the emission of electrons by metastable atoms under circumstances like the present is small compared with the photoelectric effect, have already been reported.[1] The details of these experiments will be given in a later paper, but it may be stated here that electron currents obtained from a micabacked Mo disk, mounted some centimeters in front of the thermopile of the present apparatus so that it could be rotated magnetically were about six times as great when the disk was perpendicular to the direction of the radiation as when the disk was parallel to the radiation. This showed that at least the main part of the currents involved were caused by an agent having directional properties and which therefore must have been radiation rather than metastable atoms, or ions and electrons diffusing in from the discharge.

Gas pressures of the order of 0.1 mm were used. The gases were purified by the action of a mischmetal arc, and also in the case of Ne by circulation over charcoal in liquid air.

In each case, energy measurements were made with and without the quartz filter, and the difference, making allowance for reflection at the quartz surface, was taken to be the energy in the extreme ultraviolet. This difference amounted to from 20 percent to 50 percent of the total energy absorbed. The arc was left on in each case only long enough (10 seconds) for the thermopile reading to reach an approximate equilibrium value. The effects of heat rays from the glass, warmed by the discharge, were found to be relatively small and were allowed for. Approximate saturation photoelectric currents were measured at the same time as the energy. Photoelectric currents were undetectable when the quartz filter was in place.

The values found for the photoelectric efficiencies for a Ni surface degassed by heating in a vacuum until considerable evaporation had taken place were of the order of 2 percent for Ne (2 electrons per hundred quanta) and 1 percent for A. The wave-lengths of the resonance radiations were used in the calculations.

It was found with the present and other apparatus that the photoelectric currents from Ni, Fe, constantan and graphite were all of the same order of magnitude and that in the cases of Ni, Fe, and constantan a non-degassed surface gave two to three times as

[1] Carl Kenty, Phys. Rev. **38**, 377 (1931).

[2] W. W. Coblentz and W. B. Emerson, Bulletin of the Bureau of Standards **12**, 503 (1915–16).

[3] H. M. O'Bryan, Phys. Rev. **38**, 32 (1931).

much current as a surface which had been well degassed. Thus the efficiencies found for such surfaces were of the order of 5 percent and 2 percent for Ne and A respectively.

Photoelectric currents obtained with Hg discharges were relatively very small and sufficiently in accord with the known values of the efficiency of the normal photoelectric effect in the general region of λ2500A (taken to be of the order of 0.1 percent or 0.2 percent for metals like Ni.) The present results may also be compared with the maximum efficiencies reported for the total currents in the selective effect in the case of sensitive films of the order of 1 percent or 2 percent.

Preliminary experiments with He have yielded values of the efficiency comparable with those in Ne. The experimental conditions were not, however, as favorable in He as in the other cases and the evidence was not as clear that the action of metastable atoms was unimportant.

The experiments are being continued and extended to surfaces of different work functions. Details will be given in a later paper.

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Zeeman Effect in Solids

J. Becquerel,[1] Freed and Spedding,[2] and others have reported that the absorption lines of the rare earth spectra split into doublets of enormous separation when a magnetic field is applied. Both Becquerel and ourselves have stated that some lines under certain conditions resolve into more components; however, both emphasized that the doublets were the most striking facts observed. In a letter to the Physical Review of March 15, 1931, I announced that all lines of the Gd^{+++} ion spectra were complex in a magnetic field and that the doublets really consisted of several components, and that they appeared as doublets only on account of the low resolving power of the instrument used.*

Since that time I have combined the prism from a Hilger E2 spectrograph with a large three-meter Hilger (*L* mounting) and obtained in effect a three-prism instrument which gives a dispersion of 1.3A per mm at the 2700A band of the Gd^{+++} ion.

While unfortunately only three plates were obtained at this dispersion before it became necessary to have the magnet rebuilt, nevertheless the results were so interesting that a report of them now seems advisable. In all three cases the bands between 2700A and 2800A were photographed, the light passing through the crystal parallel to the *b* axis of the monoclinic $GdCl_3 \cdot 6H_2O$ crystal. In plates 1 and 2 the field was parallel to the *a* axis, the fields being 17.5 and 18.5 kilograms, respectively. In plate 3 the field of 18.5 kilograms was parallel to the *c* axis.

All the lines of the bands, which were separated from each other so that they did not overlap when the field was applied, split into nine lines of approximately equal spacing with an overall separation of 16 times the normal Larmor precession.

The intensities of these lines varied greatly; In some cases the outer components were very intense while the inner three or five were barely visible, thus giving rise to an apparent doublet under low dispersion. In other instances the inner components were the more intense giving the appearance of a single, unaffected or slightly widened line under low dispersion. Frequently the intense components in plates 1 and 2 were the faint ones in plate 3. For a few lines the nine components were intense in all three plates.

A Paschen-Back effect was clearly discernible in most of the lines, being small in plate 1 and fairly pronounced in plates 2 and 3. With increased Paschen-Back effect the lines tended to widen and blur and the dissymmetries in intensities became very pronounced. The dissymmetries in position were not so great, especially in overall separation. They did tend to make the intervals between the lines more irregular. These irregularities in the intervals, with two exceptions where the lines in question were close together, were never greater

* Note: J. Becquerel for some time has stated that many of the doublets in the case of other rare earths are actually quartets. It appears, however, from the following work they are really even more complex.

[1] Many papers. Leiden Comm. 1906–1931.

[2] Freed and Spedding. Phys. Rev. **35**, 1408 (1930); ibid. **38**, 670 (1931).