Effect of Residual Gases on Contact E.M.F.'s and Photo- Currents.[1]

By R. A. Millikan and W. H. Souder.

Curves representing both the variation of contact E.M.F.'s and saturation photo currents with time have been taken on freshly cut sodium surfaces both in the best vacuum obtainable with a Gaede molecular pump and in vessels containing residual gases.

The most striking characteristics of the photo-current-time curves is that they are of altogether different form according as the frequency of the light with which they are taken is that of the extreme ultra-violet or that of the visible spectrum. Thus, when tested with light of wave-length 5,461 Å. the photo-sensitiveness of a *freshly cut* sodium surface is zero. It rises with time to a considerable value and finally falls again to zero When tested, however, with light of wave-length 2,535 Å., this same surface shows a large initial photo-sensitiveness which falls off steadily with time to zero.

These photo current-time curves taken in connection with the contact E.M.F.-time curves are interpreted as follows:

A freshly cut sodium surface is not sufficiently electro-positive to respond photo-electrically to light of wave-length 5,461 Å., but under the influence of an active gas, the sodium forms a new substance which is more electro-positive than the freshly cut sodium and hence is photo-sensitive to longer waves. The photo-curve taken with wave-length 5,461 Å. represents then merely the growth and decay of this substance. For sufficiently short waves, however, the freshly cut surface is itself so photo-electrically active that its own decay curve completely masks the rise and fall curve due to the growth and decay of the more electro-positive substance resulting from the action of gas upon the sodium.

In view of these results the authors raise a question as to the correctness of the conclusions of Wiedmann and Hallwachs[2] that photo currents are only obtainable in the presence of gas. We suggest that if the Wiedmann and Hallwachs experiments are repeated with light of sufficiently short wave-lengths instead of with visible light, it is not likely that the photo-sensitiveness will be found to vanish in the way in which it did in the experiments reported by these authors. Further experiments on potassium and lithium are in progress.

A Direct Determination of "*h*."[1]

By R. A. Millikan.

The experiments herewith reported were undertaken for the sake of subjecting to rigorous experimental test the three assertions contained in Einstein's photo-electric equation[3]

$$\frac{1}{2}mv^2 = PDe = h\nu - P.$$

These assertions are

[1] Abstract of a paper presented at the Washington meeting of the Physical Society, April 24, 1914.

[2] Ber. d. D. Phys. Ges., 16, 107, January 30, 1914.

[3] A. Einstein, Ann. d. Phys. (4), 20, 199, 1905.

1. That there is a linear relation between the frequency of the impressed light and the maximum energy of emission of the electrons ejected by it.

2. That the slope of the line representing the linear relation between PD and ν is h/e, *i. e.*, that this slope times e is Planck's "h."

3. That the intercept of the PD line on the ν axis gives the frequency ν_0 at which the metal in question first begins to be photo-electrically active.

The second and third of these assertions have not heretofore been made the subject of accurate test nor can they be so made without simultaneous measurement *in vacuo* of both contact potentials and photo-potentials in the case of metals which are sensitive throughout a long range of frequencies. The spectral lines used in the test must further be strictly monochromatic and of frequency determinable with a high degree of precision.

The first of the assertions of Einstein's equation has previously been tested with widely varying results by Ladenburg,[1] Kunz,[2] Hughes,[3] Richardson and Compton,[4] and Cornelius.[5] The most satisfactory of these measurements are probably those of Richardson and Compton, though Pohl and Pringsheim[6] do not regard even these as sufficient to distinguish between $PD \propto \nu$ and $PD \propto \nu^2$, much less to test between any closer relations such as $PD \propto \nu$ and $PD \propto \nu^{\frac{3}{2}}$, the latter being the relation implied by Lindemann's theory. Very recent measurements made in the Ryerson Laboratory by Kadesch[8] between $\lambda = 3{,}900$ and $\lambda = 2{,}300$ seem however to speak positively in favor of a proportionality between PD and ν. The present measurements made on sodium from $\nu = 6{,}800$ to $\lambda = 2{,}300$ fully confirm Kadesch's linear relationship and further, they fix the value of the slope, *i. e.*, of h/e at 4.123×10^{-15} volt/frequency with an error of not more than $\frac{1}{2}$ per cent.

Inserting the author's value of e, viz., 4.774×10^{-10} which is thought to be correct to within .2 per cent., there results from this value of h/e

$$h = 6.561 \times 10^{-27}.$$

This value of "h" combined with the author's value of e gives with the aid of Planck's equation the following value for the constant of total radiation

$$\sigma = 5.688 \times 10^{-5},$$

which is very close to the value obtained by Coblentz[9] from a study of all the data at present available.

When this value of σ is combined with the author's value of e and substitution made in Planck's equation, the Planck-Wien constant of spectral radiation

[1] E. Ladenburg, Verh. d. D. Phys. Ges., 9, 504, 1907.

[2] J. Kunz, PHYS. REV., 29, 212, 1909; also 33, 208, 1911.

[3] A. L. L. Hughes, Phil. Trans., 212, 205, 1912.

[4] O. Richardson and R. T. Compton, Phil. Mag., 24, 575, 1912.

[5] D. W. Cornelius, PHYS. REV., 1, 16, 1913.

[6] R. Pohl u. P. Pringsheim, Verh. d. D. Phys. Ges., 15, p. 637, 1913.

[7] F. A. Linderman, Verh d. D. Phys. Ges., 13, 1107, 1911.

[8] W. H. Kadesch, PHYS. REV., May, 1914.

is found to be

$$c_2 = 1.434$$

which is within one part in 700 of the latest Reichsanstalt value of this constant.

The value of ν_0 obtained for sodium, the metal upon which all of these experiments have been made, is $.439 \times 10^{15}$, which corresponds to $\lambda = 6,800$.

Planck's constant "h" is thus found to stand out in connection with photoelectric measurements, perhaps more sharply, more exactly, and more certainly than in connection with any other type of measurements thus far made.

ERRATUM.

Page 486, Vol. III., No. 6, Second Series, lines 13 and 12 from the bottom of the page, in the abstract of a paper by G. W. Middlekauff and J. F. Skogland, entitled "Characteristic Curves of Tungsten Filament Incandescent Lamps and Their Application in Heterochromatic Precision Photometry," should read as follows: x = log per cent. voltage and y = log per cent. candlepower, log per cent. watts, log per cent. current, or log actual watts per candle."

Through typographical error, in the printed text, "cent." after "per" was omitted in four places.