

Note on the Analysis of Photoelectric Data

ROBERT J. CASHMAN AND NOEL C. JAMISON, *Department of Physics, Northwestern University, Evanston, Illinois*

(Received July 6, 1936)

IN the development of Fowler's¹ method for the determination of photoelectric work functions, the assumption is made that "the photoelectric current I per quantum of light absorbed is proportional to N_B " where N_B is the number of available electrons. It has been customary, however, to plot current per unit intensity of incident radiation assuming a constant optical reflection coefficient; also the term $(W_a - h\nu)^{-\frac{1}{2}}$ has been assumed constant.

We have made comparisons of different methods of plotting, using data on Ba taken in this laboratory for the purpose of determining the temperature coefficient of the work function. Assuming the constancy of the terms mentioned above, a plot of current per unit intensity is shown in Fig. 1, curve A ; curve B shows electrons/incident quantum plotted as ordinate. In curve C the quantity $(W_a - h\nu)^{\frac{1}{2}} \times$ electrons per incident quantum is plotted as ordinate. The optical reflection coefficient varies so little over the range of frequencies used that one cannot distinguish between the fits to the theoretical curve in plots of electrons per incident quantum and electrons per absorbed quantum. It would appear from the figure that the experimental data fit the theoretical curve about equally well in the three cases. However, careful examination of large scale plots for different sets of data indicates that the least accurate fit is obtained for the plots of electrons per quantum.

According to Fowler's theory, curve C would yield the true work function. The restriction that W_a be known is not a serious one, since a change as large as 25 percent affects appreciably neither the fit nor the value of ϕ obtained. The value of W_a used for curve C was computed on the basis of two free electrons per atom. Waterman and Henshaw's² extension to Fowler's analysis was applied to the problem. Plotting electrons per quantum, the fit to their theoretical curve was as good as for curve C and the work function so obtained was the same as that found from curve C .

The values of the work functions obtained from the three curves given would necessarily be slightly different. In spite of the excellent fit to curve A , the accurate determination of work functions from such plots is not justified by existing theories. Curve B has, as a theoretical basis, DuBridge's³ modification of Fowler's theory since his development does not yield the factor $(W_a - h\nu)^{-\frac{1}{2}}$. Should further work show conclusively that electron-per-quantum plots do not fit Fowler's curve accurately, the deviations might well be absorbed by the proportionality constant α , which DuBridge assumed to be essentially constant.

DuBridge has interpreted the proportionality factor α as "the fraction of the number of electrons which come up to unit area of surface in one second which absorb a quantum of energy when the incident light intensity is unity,"³ or "the probability that an electron at the surface of the metal will absorb a quantum and appear outside as a photoelectron."⁴ The experimental value of α for Ba based on this interpretation is 4.3×10^{-33} cm² sec. quantum⁻¹. Simple theoretical considerations³ show that the optimum value of α , assuming two electrons per atom is 1.4×10^{-30} . The ratio of the α 's $1/325$, equals the ratio of experimental to maximum current possible according to this theory.

Fowler attached no significance to the constant of proportionality appearing in the expression for the current; however, it may be interpreted in a manner analogous to the interpretation of α . Writing Fowler's equation as

$$I = \beta \frac{\text{constant}}{(W_a - h\nu)^{\frac{1}{2}}} T^2 \varphi(x),$$

where I is in electrons per quantum, β may be defined as the fraction of the number of available electrons per unit volume which will be emitted due to one incident quantum, or the probability that an available electron in unit volume of the

³ L. A. DuBridge, *Actualités Scientifiques et Industrielles*, No. 268 (Paris, 1935).

⁴ Marvin M. Mann and Lee A. DuBridge, *Bull. Am. Phys. Soc.* **11**, No. 4, Paper 24.

¹ R. H. Fowler, *Phys. Rev.* **38**, 45 (1931).

² Waterman and Henshaw, *Phys. Rev.* **44**, 59 (1933).

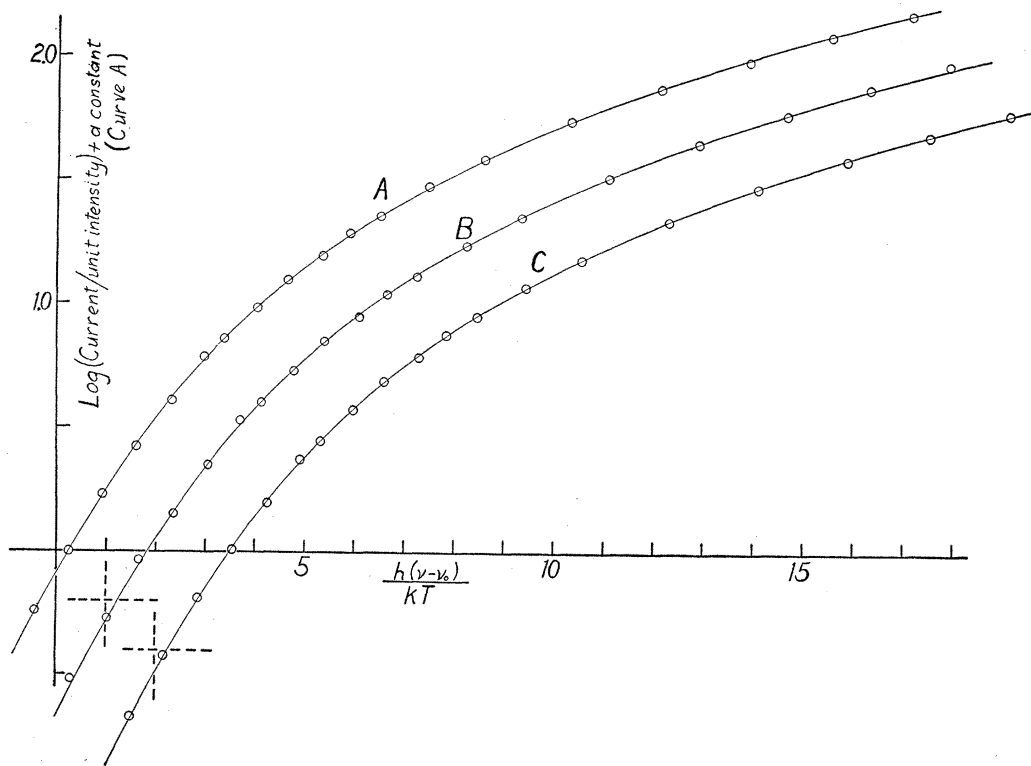


FIG. 1. Curve A: ordinates, current/unit intensity; horizontal shift, 98.58; $\phi = 2.508$ volts. Curve B: ordinates, electrons/quantum; horizontal shift 98.85; $\phi = 2.515$ v. Curve C: ordinates $(W_a - h\nu)^{1/2} \times$ electrons/quantum; horizontal shift, 98.65; $\phi = 2.510$ v. Full lines, Fowler's theoretical curve.

metal will absorb a quantum and appear outside as a photoelectron. The experimental value of the constant β obtained for Ba was 5.0×10^{-25} $\text{cm}^3 \text{ quantum}^{-1}$. The value of β computed on the basis of Waterman and Henshaw's analysis differs inappreciably.

A theoretical limiting value of β may be found by assuming that one electron is emitted per quantum and that the number of available electrons is equal to $1/2$ the total number n of free electrons. The latter assumption is made because, according to Fowler's theory, all the energy of the absorbed quantum is added to the kinetic energy normal to the surface and but

half the electrons have outward normal components. Hence

$$1 \text{ electron/quantum} = \beta n / 2.$$

Assuming two electrons per atom β becomes 6.0×10^{-23} $\text{cm}^3 \text{ quantum}^{-1}$. The ratio of the β 's $1/120$, is the ratio of experimental to theoretical maximum current. Since the probability β (or α) depends on the probability of absorption, the probability of electron transmission and on the number of available electrons, at least a part of this discrepancy may be attributed to a lack of total absorption of light in that region in which photoelectrons originate.