

1918

On the Coefficient of Absorption of Photoelectrons in Silver and Platinum

Otto Stuhlman Jr.
The State University

Let us know how access to this document benefits you

Copyright ©1918 Iowa Academy of Science, Inc.

Follow this and additional works at: <https://scholarworks.uni.edu/pias>

Recommended Citation

Stuhlman, Otto Jr. (1918) "On the Coefficient of Absorption of Photoelectrons in Silver and Platinum," *Proceedings of the Iowa Academy of Science*, 25(1), 61-65.

Available at: <https://scholarworks.uni.edu/pias/vol25/iss1/10>

This Research is brought to you for free and open access by the Iowa Academy of Science at UNI ScholarWorks. It has been accepted for inclusion in Proceedings of the Iowa Academy of Science by an authorized editor of UNI ScholarWorks. For more information, please contact scholarworks@uni.edu.

ON THE COEFFICIENT OF ABSORPTION OF PHOTO-ELECTRONS IN SILVER AND PLATINUM.

OTTO STUHLMAN, JR.

The coefficient of absorption can be defined by the constant α in the exponential relation $N=N_0e^{-\alpha t}$. The precise physical interpretation of such an exponential law when applied to a beam of electrons moving through a metal plate of thickness "t" is not so simple as its mathematical expression would lead one to suppose. It may, however, be interpreted if we assume that there exists no "scattering" or energy transformation as the beam of electrons passes through the metal. If αx is taken as that fraction of the number which is absorbed when the beam of electrons passes normally through a very thin screen of thickness x (cm), then for a plate of thickness t (cm), $N=N_0e^{-\alpha t}$, in which N_0 is the intensity of the beam when it enters, and N that of the beam when it emerges from the slab of material in which the absorption has taken place.

A more convenient form for experimental use is, however, the following. $\alpha = 2.3 (\log N_0 - \log N) / t$ where the logarithms are taken to the base 10. Hence given a set of observations with homogeneous (i. e. electrons of the same initial velocity) rays, if $\log N$ is plotted as ordinate against t , the thickness of the slab through which the electrons pass, the graph is then a straight line and α is 2.3 times the slope of this line. If large values of α are obtained, this is an indication of easily absorbed electrons (velocity small) while if α is found to be small it indicates the presence of penetrating rays or fast moving electrons.

In some cases it is, however, easier to think of the absorption coefficient in terms of the thickness t which reduces the number of electrons to half value. Since $\frac{1}{2}$ represents the distance to which the electrons penetrate before their number is reduced $\frac{1}{2}$ of the original value, then α may be written in the form, $\alpha = \frac{0.693}{t}$ where $e^{-0.693} = 0.500$. In the following observations this expression was used in determining the coefficient of absorption of electrons liberated in a metal by monochromatic ultra violet light.

A Cooper-Hewitt, quartz, 110 volt, mercury vapour lamp served as a source of ultra violet light. This passed through a

Hilger monochromatic illuminator with a quartz optical system.

The image of the particular wave length under investigation was reduced to 8×0.23 mm and focused on the metal under examination. The metal in the form of a wedge, semi-transparent at one end and opaque at the other, was deposited by distillation from an incandescent wire in vacuo. The technique of obtaining the metal in the form of a wedge was described in a recent article by the writer.¹ The method consists essentially of a wire heated to incandescence by means of an electric current, while a quartz plate upon which the wedge is to be deposited is placed below and to one side of it. If the whole is now placed in vacuo, the metal will vaporize and condense upon the quartz surface. Since there is no reflection of metal from the walls of the inclosure it can be shown that under these circumstances a section of the surface thus developed upon the quartz plate is of the form $y = \frac{8a^2}{x^2 + 4a^2}$ where $2a$ is the height of the wire above the plane, y being the thickness of the deposit at any distance x out from the perpendicular dropped from the wire to the plane containing the plate. The section of the metal thus deposited, forms a surface at a distance of four centimeters from the wire ($2a=2\text{cm.}$), which approaches a right triangular wedge with a variation of five per cent at either end.

This wedge ($1 \times 2.5\text{cm}$) was placed, metal side facing the light, along the axis of a Faraday Cylinder, having slits cut in its opposite sides to allow for the unobstructed passage of the light. This cylinder was electrostatically shielded and connected to an electrometer. The wedge was clamped at its thick end to an indicator which slid over an engraved scale. The rod carrying the indicator and the wedge could be moved so that successively thicker layers of the metal could be photoelectrically examined as it passed in front of the illumination. The wedge was thus exposed at millimeter intervals through its entire length with the result that successive increases in thickness of the metal exposed, gave the required in photoelectric current desired.

Plotting the resulting photoelectric current against thickness of the metal thus exposed, developed an exponential curve, which saturated at a point where further increase in thickness produced no further decrease in current. This gave a true

¹Stuhlman. Journal of the Optical Society, vol. 1, p. 78, 1917. On the Preparation of Metallic Mirrors, Semi-transparent and Transparent Metallic Films and Prisms by Distillation.

absorption curve between the limits of thickness investigated. A secondary phenomenon occurring for thicknesses of less than 10^{-6} cm does not make its appearance in the region investigated here. The absorption coefficients were then computed from the half value relations by means of the equation $a = \frac{2.522}{t}$. Sample results are given in the accompanying table and show samples of the values which the limitations of the method allow.

VALUES OF a IN $uu^{-1}cm^{-1}$ FOR λ 2536

Silver Thickness in $\mu\mu$.0133 55	.0137 60	.0137 65	.0133 70			
Platinum Thickness in $\mu\mu$.0331 40	.0301 50	.0346 55	.0333 60	.0331 65	.0331 70	.0347 75

Lenard² investigating the properties of cathode rays showed that their coefficient of absorption was very nearly proportional to the density " ρ " of the material. The maximum variation in his results for $\frac{a}{\rho}$ were 2070 and 5610, although the densities of the absorbing material varied between 3.6×10^{-7} and 19.3. Rutherford³ found that a similar relation held approximately for the faster B rays from Uranium X. Though the elements of large atomic weight were found to possess a mass absorption coefficient ($\frac{a}{\rho}$) nearly twice as large as the lighter elements, Crowther⁴ who extended these latter observations for thirty-two elements, found that the mass absorption coefficient exhibited a progressive increase from the lighter to the heavier elements. The following values of $\frac{a}{\rho}$ for B rays of platinum and silver quoted from his paper will give some idea of the magnitude of his results.

Metal	Atomic Weight	Atomic Number	Density	Brays $\frac{a}{\rho}$	Photo-electrons	
					$\frac{a}{\rho}$	a
Platinum	195.2	78	21.5	9.4	15400	331000
Silver	107.9	47	10.5	8.3	12850	135000
Ratio	1.81	1.66	2.00	1.13	1.19	2.45

For comparison the values of $\frac{a}{\rho}$ for photoelectrons (λ 2536) are given and it is seen that the ratio of the mass absorption

²Lenard, Ann. d. Phys. 56 p. 275, 1895.

³Rutherford, Phil. Mag. 47, p. 109, 1899.

⁴Crowther, Phil. Mag. 49 p. 379, 1906.

coefficients for the two metals is nearly equal to the ratio of this same quantity as quoted from Crowther's paper, although the velocities of the B rays are a thousand times greater than the maximum velocity of the photoelectrons.

The values of ν as tabulated are constant through quite a range in thickness. The constancy of the coefficient of absorption has been found to hold up to thicknesses limited by the depth of penetration of the incident energy. This indicates that the mean distribution of velocity of the electrons is the same whether they come from sheets of metal less than or equal to the depth of penetration of the light. ($t > 10^{-6}$ cm.)

The coefficient of absorption of silver ($\alpha = .0135 \mu\mu^{-1}$) is less than that for platinum ($\alpha = .0331 \mu\mu^{-1}$) which indicates that the velocity of the electrons, although excited by the same frequency, and hence starting initially from their respective atoms with the same velocity, do not in appearing at the surface of the metal, although coming from the same depth, give up on the average the same amount of energy in reaching that surface. Since a large value of α corresponds to a small velocity it follows that electrons originating from the same depths in the two metals, appear at the surface of silver with greater velocities than those originating from the correspondingly placed platinum atom. This would imply that the distribution of velocity amongst the electrons would be totally different in these two metals and that the "distribution of velocity curve" for silver would lie to the left of that for platinum and hence would have a greater slope than the latter.

If it is the mass of the material alone that effects absorption then $\frac{\alpha}{\rho}$ should be constant for all metals, since this so-called mass absorption coefficient gives a measure of the absorption per unit mass of the screen per unit cross section for a normally incident beam of electrons. The values of $\frac{\alpha}{\rho}$ are, however, only superficially constant, so that it might be worth while giving some evidence for the argument that atomic structure and not density exclusively influences the absorption of the electrons as they move through the material. Unfortunately we are here confronted with a most difficult problem, because no allowance has been made for any scattering of the electrons. We know that scattering increases in amount with the thickness of the metal traversed. Just what contribution scattering has made towards the above data cannot be determined from them. An

analysis of the behaviour of thin transparent metals of the thickness less than 10^{-6} cm just completed will, it is hoped, furnish the necessary data.

In a subsequent paper it will be shown that α varies very nearly as the cube of the thickness of the metal through which the electron passes when the value of α is small. The exact experimental relation between α and t is, however, given by the expression $\alpha - \alpha_0 = mt^3$, where $\frac{1}{\alpha}$ represents the distance to which a homogeneous beam of electrons can penetrate before its intensity is reduced to $\frac{1}{2}$ of the original incident value. The data also showed that heavy atoms are not so effective in stopping an electron as light atoms.

DEPARTMENT OF PHYSICS,
THE STATE UNIVERSITY.