

THE ABSORPTION COEFFICIENT FOR SLOW
ELECTRONS IN THALLIUM VAPOR

BY ROBERT B. BRODE

DEPARTMENT OF PHYSICS, UNIVERSITY OF CALIFORNIA

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ABSTRACT

The absorption coefficient α has been observed by sending a beam of electrons through thallium vapor and measuring the decrease in intensity of the beam as a function of the pressure of the vapor. α , plotted as a function of the velocity of the electrons, decreases rapidly to a minimum of 15 at 1.4 volts, rises less rapidly to a maximum of 51 at 4.5 volts, and then slopes off gradually to 20 at 100 volts.

IN THE study of the absorption coefficients of the monatomic elements of the periodic system, all of the noble gases,^{1,2} four of the alkali metals³ and three of the elements of the second column, i.e., Hg,⁴ Cd and Zn,⁵ have been investigated. Thallium has been chosen for the extension of these observations to the third column of the periodic table. In the vapor state thallium is monatomic but it differs from all of the elements previously investigated in the nature of its normal spectroscopic state. The thallium normal state is of a *P* type while all of the other elements mentioned above have normal states of the *S* type.

For the range of pressure (5×10^{-3} to 5×10^{-2} mm of Hg) necessary for satisfactory measurements, thallium requires temperatures from 550 to 630° C. The apparatus was therefore enclosed in a quartz tube. The electric connections to the apparatus were made by fusing molybdenum wires into quartz capillaries. This was not a vacuum tight seal but it was sufficient to prevent the rapid diffusion of the metal vapor out of the quartz tube. The molybdenum wires were continued in quartz tubes to the outside of the furnace. Quartz to Pyrex graded seals enabled vacuum tight connections to be made by tungsten seals through the Pyrex.

The metal parts of the apparatus were made of tantalum as shown in the cross-sectional view of the apparatus in Fig. 1. The tungsten filament, *F*, was the source of electrons which were bent in a circle through the slit *S* and into the collecting box *B* at the end of the path. The mean radius of the path was 7.0 mm and the widths of the slits at *F*, *S*, and *B* were 0.5, 1.0, and 0.5 mm respectively.

In the preparation of the tube the spaces on both sides of the quartz capillaries were connected to the vacuum pumps. The apparatus was baked

¹ C. Ramsauer, Ann. d. Physik **72**, 345 (1923).

² C. E. Normand, Phys. Rev. **35**, 1217 (1930).

³ R. B. Brode, Phys. Rev. **34**, 673 (1929).

⁴ R. B. Brode, Roy. Soc. Proc. **A125**, 134 (1929).

⁵ R. B. Brode, Phys. Rev. **35**, 504 (1930).

out to 800°C and the metal parts glowed to a bright yellow by an induction furnace. A small amount of thallium metal was then slowly distilled into the lower end of the apparatus. The vacuum connections to the quartz tube and to the Pyrex seals were sealed off.

The main portion of the tube was enclosed in a non-inductively wound electric furnace. The small tube containing the metal was enclosed in a heavy copper tube in a separate furnace directly below the main furnace. The temperatures in the two furnaces were measured by chromel-alumel thermocouples. From the vapor pressure equation and the temperature of the lower furnace the pressure of the thallium vapor could be calculated. This pressure was corrected for the difference in pressure caused by the difference in temperatures of the upper and lower furnaces.

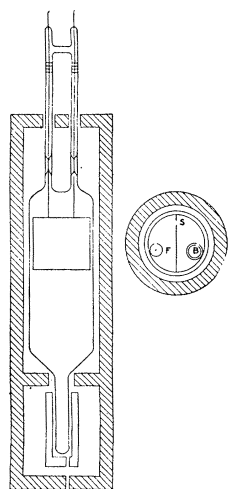


Fig. 1. Diagram of apparatus and furnaces.

The measurements of the absorption coefficient were made in the same way as those previously described for mercury.⁴ The total emission from the filament was assumed to be proportional to the initial current I_0 that would have reached the end of the path if there had been no collisions. The current I at the end of the path was measured by a galvanometer connected to the box B . The currents I and I_0 are related by the equation, $I = I_0 e^{-\alpha xp}$, where α is the absorption coefficient, x the path length and p the pressure of the absorbing vapor. From this equation the logarithm of the ratio of I/I_0 should be a linear function of the pressure. Measurements were made at from 3 to 5 pressures for every velocity studied and the value of α computed from this linear relation.

The results of the measurements are shown in Fig. 2, where the absorption coefficients in cm^2 per cm^3 of the thallium vapor at 1 mm pressure at 0°C are plotted as a function of the velocity of the electrons which is expressed in square root of volts. The first two resonance potentials, 3.3 and 4.5 volts, and

the ionization potential, 6.1 volts, are indicated by the letters *R*, *R*, and *I*. The curve is characterized by a sharp minimum at 1.4 volts and a maximum at 4.5 volts.

The magnitude of the absorption coefficient depends on the constants chosen for the equation relating the vapor pressure and the temperature. Measurements of the vapor pressure of thallium have been made by Gibson⁶ and von Wartenberg.⁷ Professor Gibson has advised me to use the data of von Wartenberg instead of his own. He suggested that his own data for thallium vapor pressures might be somewhat uncertain because of the effect of the high temperatures, 1000 to 1600°C, on the elastic properties of the quartz of which his manometer was constructed. The vapor pressure of thallium measured by Gibson at 970°C, his lowest temperature, agrees well with the value from von Wartenberg's data for the same temperature. For the vapor pressure equation, $\log p_{mm} = B - A/T$, the International Critical Tables⁸ give the values $A = 6,280$, and $B = 6.14$, based on Gibson's high temperature data.

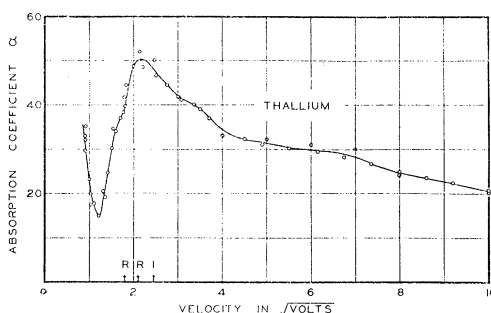


Fig. 2. The absorption coefficient α for electrons in thallium vapor as a function of the velocity of the electrons.

The data of von Wartenberg give for the constants the values $A = 8,890$, and $B = 8.55$, which are the values used in this experiment to calculate the vapor pressure. At the temperatures used in this experiment, the I. C. T. values of the pressure are about five times those of von Wartenberg for the same temperature. If the I. C. T. values of the constants were used, the values of α shown in Fig. 2 should be reduced to about 1/5 of their value or at 4.5 volts, the maximum, $\alpha = 10$ and at 100 volts $\alpha = 4$. These values seem improbably small as helium has a value of $\alpha = 15$ at 4.5 volts and $\alpha = 3.5$ at 100 volts.

In the curves for thallium vapor, the alkali metal vapors and the heavier noble gases, the maximums are at about the resonance potentials while the minimums are at definitely lower velocities. This means that the probability of an elastic collision between an electron and an atom increases as the energy of the electron approaches the critical potential of the atom.

⁶ G. E. Gibson, Dissertation, Breslau (1911).

⁷ H. von Wartenberg, *Zeit. f. Electrochemie* **19**, 482 (1913).

⁸ International Critical Tables, Vol *III*, 205.

Because of the maxima and minima in the absorption coefficient curves, the relative magnitude of the curves of different elements is somewhat uncertain. By taking the value of the absorption coefficient for a velocity well beyond the region of maxima and minima, a definite order of arrangement for the elements can be obtained. Choosing arbitrarily 100 volts as the velocity for comparison of the curves, the order of arrangement of the absorption coefficients for the 13 monatomic elements that have been measured is, with the exception of thallium, inversely proportional to the ionization potential. To fit into this arrangement, thallium with an ionization potential of 6.1 volts should have an absorption coefficient at 100 volts of about 100 instead of 20. Further experimental observations will be necessary to determine whether this deviation of thallium from the general order is really a property of the thallium atom or is due to the inaccuracies in the vapor pressure. Since the normal state of the thallium atom is a *P* state as compared with *S* states for the other atoms, it would not be unexpected to find a real difference.