THE ABSORPTION COEFFICIENT FOR SLOW ELECTRONS IN CADMIUM AND ZINC VAPORS

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Abstract

The variation with the electron velocity of the absorption coefficient, α, or the effective collision cross-section has been measured in the vapors of cadmium and zinc and found to follow a curve of the type previously found for mercury. The cadmium curve has a maximum at about 40 volts, $\alpha=130$, and a minimum at about 25 volts, $\alpha=126$, followed by a steady rise with decreasing velocity to the limit of accurate measurements, 1 volt, $\alpha=700$. The zinc curve has a very flat maximum at about 50 volts, $\alpha=76$, a minimum at about 36 volts, $\alpha=74$, followed by a steady rise to $\alpha=500$ at 1 volt. The magnitudes of the maximums are in the order: Cd, $\alpha=130$; Zn, $\alpha=75$; and Hg, $\alpha=60$. Other related properties of these atoms, such as the molar refractivity and the critical potentials, show this same irregularity in order.

THE measurement of the absorption coefficient for electrons in the noble gases, Ar, Kr and Xe,[1] has shown that the shape of the curves obtained is the same for all three of these. Similar measurements in the vapors of the alkali metals[2] have shown that these elements also have a characteristic type of curve. Mercury has been studied by Brode,[3,7] Maxwell,[4] Beuthe,[5] and Jones.[6] All of these observers except Beuthe have found a curve with values of the absorption coefficient in excellent agreement. Cadmium and zinc were also studied at the same time with the first measurements of mercury.[3] These observations were shown by subsequent experiments[7] to be unreliable, due to secondary and reflected electrons which were present in the form of apparatus used for the first measurements.

The apparatus, Fig. 1, used for the measurements of cadmium and zinc was of the same design as that described in the measurements of mercury.[7] About half of the measurements in cadmium vapor were made with the apparatus used for the mercury measurements. The mean radius of the path was 15 mm and the final slit was 0.5 mm wide. The rest of the observations in cadmium were made with an apparatus in which the mean radius of the path was 10 mm and the width of the final slit 1.0 mm. All of the measurements in zinc were made with this same apparatus.

[1] C. Ramsauer, Ann. d. Physik **72,** 345 (1923).
[2] R. B. Brode, Phys. Rev. **34,** 673 (1929).
[3] R. B. Brode, Roy. Soc. Proc. **A109,** 397 (1925).
[4] L. R. Maxwell, Proc. Nat. Acad. Sci. **12,** 509 (1926).
[5] H. Beuthe, Ann. d. Physik **84,** 949 (1927).
[6] T. J. Jones, Phys. Rev. **32,** 459 (1928).
[7] R. B. Brode, Roy. Soc. Proc. **A125,** 134 (1929).

The control of the temperatures, the neutralization of the earth's field, the deflecting magnetic field, and the arrangement of the electrical circuits was the same as previously described in the mercury[7] and alkali[2] metal

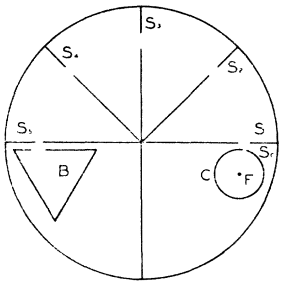

Fig. 1. Diagram of apparatus.

papers. The pressure of the gas was obtained from the vapor pressure at the temperature of the lower furnace which contained the supply of metal. This pressure was corrected for thermal effusion and the observations were

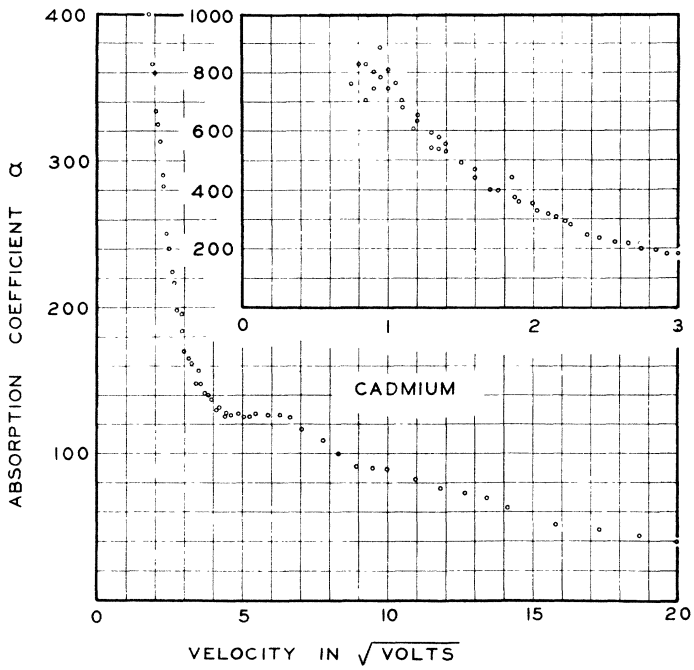

Fig. 2. The absorption coefficient α for electrons in cadmium vapor as a function of the velocity of the electrons.

reduced to 0°C and 1 mm of Hg pressure. The constants of the vapor pressure equation were taken from those given in the International Critical Tables.[8]

[8] International Critical Tables, Vol. III, p. 205.

These constants for zinc and cadmium are much more accurately determined than those for the alkali metals. The principle source of uncertainty in the values of the absorption coefficients is not due to the vapor pressure constants in this case but to the determination of the temperature. From the uncertainty in the temperature, not over 2°C, the resulting absorption coefficients might be in error by about 5 percent. Small differences in the temperature could be measured to 0.1°C.

Samples of the metals were used which were over 99 percent pure. These were distilled several times in vacuum and finally into the apparatus, which had previously been baked at 500°C for several hours, and the metal

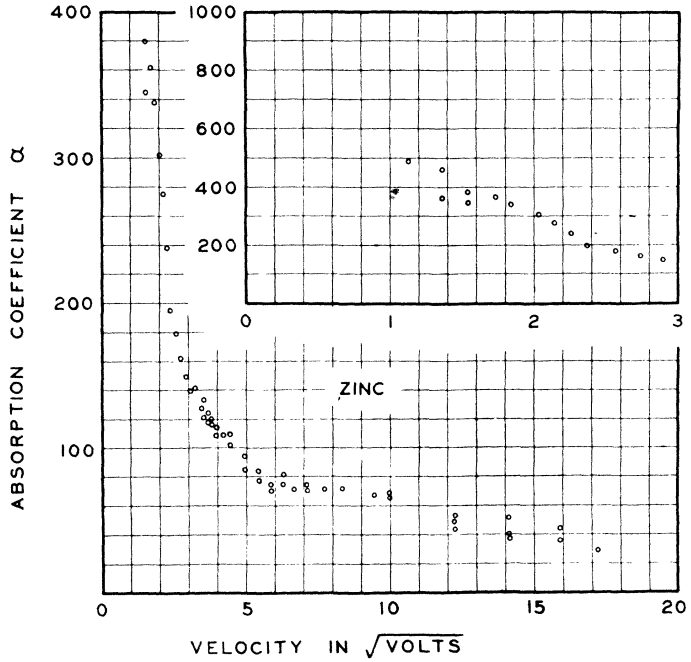

Fig. 3. The absorption coefficient α for electrons in zinc vapor as a function of the velocity of the electrons.

parts glowed by an induction furnace. This treatment was effective in removing the gases absorbed in the cadmium and zinc as measurements of the absorption coefficient were constant over a period of two months in a closed apparatus.

By plotting the log of the ratio of the current at the end of the path to the current from the slit in the cylinder, S_c, against the pressure, a straight line was obtained. The slope of the line gave the value of the absorption coefficient for unit pressure. Figs. 2 and 3 show the resulting values of the absorption coefficient for cadmium and zinc. Each point is the result of measurements at from 3 to 5 different pressures. Due to increasing leakage currents above 300°C, the data obtained with zinc were not as consistent as

those obtained with cadmium. The data taken with the two different experimental arrangements in cadmium are shown on the graph and are seen to be in excellent agreement. In the upper right portion of each graph the low velocity measurements are plotted. In cadmium the measurements were taken to 0.5 volts but, due to the leakage currents at the higher temperature used with zinc, the measurements could not be extended to 1.0 volt in zinc. There is an indication that the absorption coefficient in cadmium ceases to rise as rapidly below one volt as above one volt.

The opening of the final slit determines the maximum angle through which an electron may be deflected without being measured as absorbed. In

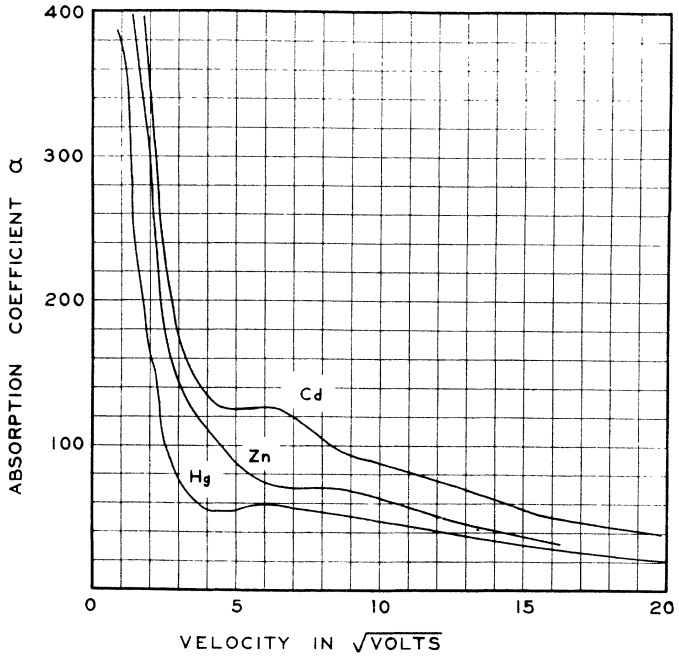

Fig. 4. The absorption coefficient α for electrons in cadmium, zinc and mercury vapors as a function of the velocities of the electrons.

cadmium two systems of slits and chambers were used with different limiting angles but the values of the absorption coefficient were not changed. Measurements by several observers on mercury[7] gave results that are quite consistent although the chambers used were geometrically quite different. This would indicate that the number of electrons scattered through small angles is only a small fraction of the total number of scattered electrons. These results are not in agreement with the measurements of Arnot[9] which indicate that a large fraction of the electrons of 82 volts velocity in mercury vapor are scattered in small angles. An apparatus with an adjustable aperture is being constructed to test this point.

[9] Arnot, Roy. Soc. Proc. **A125,** 660 (1929).

In Fig. 4 the curves for cadmium and zinc are compared with that for mercury. The values of α for mercury[7] have been changed from those due to vapor pressure data in Landolt and Börnstein's tables used in the original report to the data given in the International Critical Tables[10] from which the vapor pressure data for cadmium and zinc were also taken. This involves an increase of about 10 percent in the values of α. The character of all the three curves is the same; a very large effective cross-section for slow electrons which decreases rapidly with increasing velocity to a minimum, then rises slightly to a faint maximum followed by a steady decrease with further increase in velocity.

The curves indicate that cadmium is the largest of the three, zinc is next, and mercury is the smallest. This is the order of size to be expected rather than that of increasing atomic weight. The classical scattering of electrons due to the polarization of the atom by a passing electron was shown by Zwicky[11] to give the right order of magnitude for the absorption coefficients in the noble gases at velocities above the maximum in the curves. The absorption coefficient was proportional to the molar refractivity. The molar refractivities for these elements are Cd = 20.0 Zn = 14.6, and Hg = 13.7. This same agreement between the absorption coefficients and molar refractivity is found in the alkali vapors. The effective size of an atom is also indicated by its ionization potential. Helium, with the highest ionization potential, has one of the smallest effective cross-sections of any observed atom while caesium, with the lowest ionization potential, has the largest effective cross-section. The ionization potentials of the elements studied in this paper are Cd 8.9 volts, Zn 9.4 volts and Hg 10.4 volts. In the curves of elements not in the same row of the periodic table and therefore of different shape, it is not always easy to designate one as larger than the other. In general, however, it seems to be true that the magnitude of the absorption coefficient or the effective collision cross-section of an atom is proportional to the molar refractivity and inversely proportional to the ionization potential.

[10] International Critical Tables, Vol. III, p. 206.
[11] F. Zwicky, Phys. Zeits. **24,** 171 (1923).