THE MOTION OF ELECTRONS IN ARGON

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Abstract

The motion of electrons in argon containing 1.53 percent N_2 has been investigated. For low fields the mobility is a constant, but rises rapidly as the field is increased due to the increase of the electron free path with increasing thermal velocity.

The mean free path of electrons in pure argon and in thermal equilibrium with the argon is 0.385 cm at 1 mm pressure.

IN A series of earlier papers[1] results of investigations on the motion of electrons in N_2, H_2, He and CO have been presented. The method used was the alternating potential method of measuring mobilities. Since in the case of the electron motion through a gas the mobility is in general not a constant, this method does not lead to a direct determination of the mobility. It is possible, however, as was done in this earlier work, to make an indirect comparison of the experimental results with the theoretically calculated mobilities. In all the cases presented so far, with the exception of N_2, a good agreement with the theory proposed by K. T. Compton[2] was shown to exist, provided it is assumed that the energy loss of an electron on impact with a molecule is greater than it would be if due to momentum transfer only. In N_2 the variation of the electronic free path with the electron velocity enters into the experimental results to such an extent that a check is impossible. Compton's theory takes no such variation into account.

In the present paper results on argon corresponding as much as possible to those on the other gases, are presented.

The argon used in these experiments contained, after being freed of oxygen, 1.53 percent nitrogen. This was not removed, but instead, as shall be seen, corrections were made for its presence. All the measurements were made at a pressure of 760 mm.

When the mobility is a constant, it may be calculated exactly from the voltage intercept of the mobility curves by the expression

$$K = \pi n d^2/(2)^{1/2}V. \tag{1}$$

If the mobility is a function of V as it will be for electrons, this equation gives an average value determined by the relation

$$\int_0^{1/2n} \frac{V}{d} K \sin 2\pi n t\, dt = \int_0^{1/2n} f(v)\frac{V}{d} \sin 2\pi n t\, dt.$$

Compton's theory gives

$$f(v) = \frac{a}{[1 + (1 + BV^2)^{1/2}]^{1/2}}. \tag{2}$$

[1] H. B. Wahlin, Phys. Rev. **23**, 169 (1924); **27**, 558 (1926); **35**, 1568 (1930).
[2] K. T. Compton, Phys. Rev. **22**, 333, (1923).

In Fig. 1 the average values of K calculated from Eq. (1) are plotted against the field strength (V/d) in which they were determined. For very low values of the field the mobility is a constant, and over this range the values calculated from Eq. (1) are nearly exact. In fields above 2 volts/cm the mobility rises sharply. The values found for this range serve merely to illustrate qualitatively the rapid increase in the mobility.

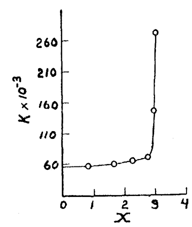

Fig. 1.

An examination of Eq. (2) shows that according to Compton's theory one should expect a decrease in the mobility with increasing voltage due to the increased thermal velocity of the electrons. In order to account for the discrepancy between theory and experiment it is necessary to assume a very rapid increase in the electron free path in argon with increasing thermal velocity. This is in agreement with the free path determinations of Townsend and Bailey[3] and others.

The results shown in Fig. 1 serve in one way as a check on Compton's theory. The equation giving the mobility as a function of the field strength (Eq. (2)) demands that for low field the mobility shall be a constant; i.e. that for low field the electrons shall be in thermal equilibrium with the gas.

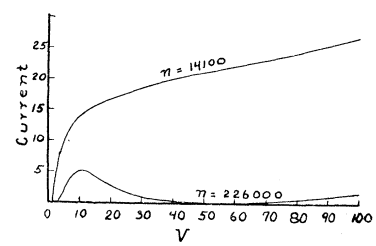

Fig. 2.

The fact that the mobility is nearly a constant as V approaches zero shows that apparently the thermal velocity does not vary sufficiently to produce any appreciable change in the free path.

In Fig. 2 two typical mobility curves are presented. The curve taken at a frequency of 14,100 cycles/sec is of the same character as those found for other gases. The one taken at the higher frequency is characteristic for argon. This frequency gives two values for the mobility. The variation in the shape of the mobility curve is due to the Ramsauer effect which in argon is much more pronounced than in other gases studied.

[3] J. S. Townsend and V. A. Bailey, Phil. Mag. **44**, 1033 (1922).

The limiting electron mobility in argon containing 1.53 percent N_2 is for low fields 59,600 cm/sec/volt/cm. The mean free path calculated from this value assuming

$$K = 0.75e\lambda/mc$$

is 0.363 cm at 1 mm pressure.

To correct for the presence of N_2 the following expression may be used

$$\frac{760}{\lambda_m} = \frac{P_n}{\lambda_n} + \frac{P_a}{\lambda_a}$$

where P_n is partial pressure of N_2, P_a the partial pressure of argon, λ_m the mean free path at 1 mm in mixture, λ_n the mean free path at 1 mm in N_2 and λ_a the mean free path at 1 mm in pure argon. This expression was used by Townsend and Bailey with a mixture of H_2 and A and was justified by them for this case. The corrected value for the mean free path when the electrons are in thermal equilibrium with the argon atoms is (assuming $\lambda_n = 0.0996$ cm) 0.385 cm at 1 mm pressure.

In Fig. 3 the author's value of λ (indicated by X) together with Townsend and Bailey's values are plotted as a function of the thermal velocity $\bar{c}$. This

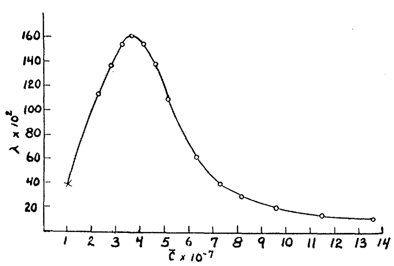

Fig. 3.

curve shows the prominence of the Ramsauer effect in argon, and also serves to explain the shape of the mobility curves obtained at high frequencies.

Summary

The results of the determinations of the mean free paths of electrons in gases, together with the values calculated from kinetic theory, are shown in Table I.

Table I.

	Obs.	KT	Obs./KT
H_2	0.041	0.0741	0.553
He	.066	.117	.565
CO	.069	.0391	1.75
N_2	.0996	.0393	2.53
A	.385	.0417	9.2

As is seen there is no systematic agreement between the observed and the kinetic theory values.