ABSORPTION OF POTASSIUM IONS IN VARIOUS GASES

By F. M. Durbin

Abstract

Loss by scattering, retardation or neutralization suffered by a beam of positive potassium ions in traversing helium, argon, hydrogen, nitrogen, air and oxygen. —The absorption of potassium ions accelerated by 8.5 to 350 volts has been measured in helium, argon, hydrogen, nitrogen, air and oxygen. A magnetic deflection apparatus was used in which the metal parts were entirely enclosed in glass. The rays were observed that traversed a fixed distance at various pressures without being deflected from a semicircular path by scattering, retardation, or neutralization. A free path for absorption may be deduced which varies with the gas and velocity of the ions; it is larger than the value given by the kinetic theory for an argon atom in the gases used, varying from 10 times in the case of fast rays in helium to 1.4 times for slow rays in oxygen. At low velocity the free path decreases rapidly and approaches the kinetic theory value.

IT IS well known that positive rays with high velocity are able to capture electrons from the gas molecules through which they pass and become neutralized. Very slow positive ions were investigated by Dempster[1] and were found to show great differences in the rate at which they became neutralized in passing through helium. The present paper describes experi-

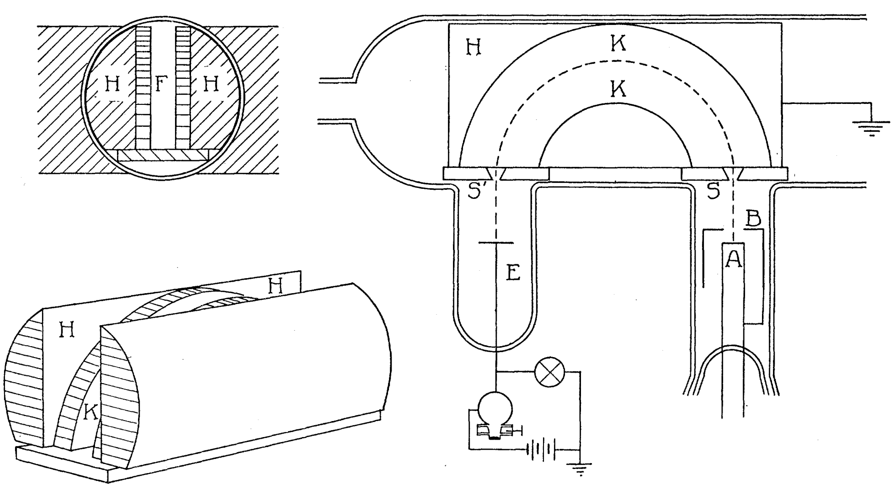

Fig. 1. Diagram of apparatus.

ments in which ions of one kind, positively charged potassium, were allowed to pass through air, hydrogen, nitrogen, helium, oxygen, and argon and the decrease in the intensity of the rays observed in each case.

[1] A. J. Dempster, Phil. Mag., 3, p. 115 (1927).

The apparatus used is illustrated in Fig. 1. It is similar to that described in the paper just referred to but modified so that the metal parts may be completely enclosed in glass tubes. The rays were obtained by heating a potassium catalyst on the platinum strip A. The material was kindly supplied by Mr. Kunsman and was found to give a very steady emission of potassium ions.[2] After passing the opening in the brass cylinder B, the ions were accelerated to the first slit S by potential differences varying from 9 to 350 volts. The ions were then deflected magnetically in a circular path of 7 cm diameter so as to pass the second slit S'. Those completing the path as charged particles were measured by the charge given to the electrode E. The initial emission was kept constant by means of a galvanometer connected in the circuit between A and S. The electromagnet had pole pieces closely fitting the outside of the glass tube as shown in the cross section, and inside the tube were placed two iron pole pieces H separated by a narrow slot about 3 mm wide shown at F. By cutting back the pole faces as indicated at H the field was concentrated to a narrow area K on either side of the path of the ions. Fields as high as 4750 gauss were used.

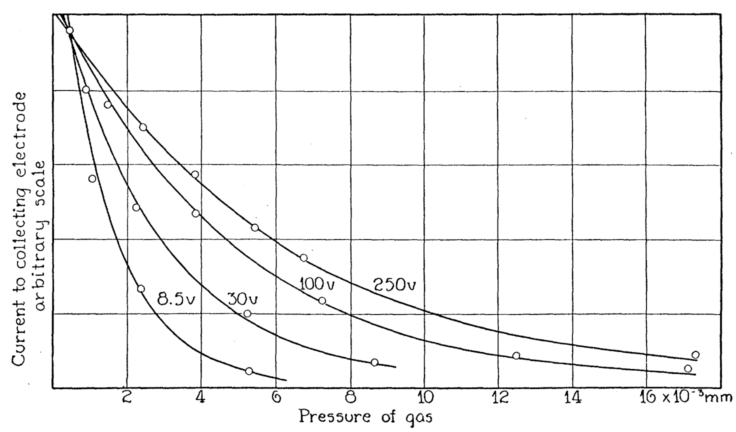

Fig. 2. Variation with the pressure of helium of the number of positive ions reaching the collecting electrode.

Gas was kept flowing into the apparatus through a small capillary from a reservoir whose pressure was varied. The pressures in the apparatus were measured by means of a MacLeod gauge. The number of ions reaching the electrode with various pressures of gas was observed, the initial intensity and the magnetic field being kept constant.

The decrease in the rays with increasing pressure is shown in Fig. 2 for helium gas. The ordinates are the currents observed and the abscissas the pressures of the helium. The curves as drawn are exponential curves passing through the first point, and the observations as indicated lie very close to the exponential curves. The slow rays are much more weakened than the faster rays. From the curves the constant of the exponential factor may be

[2] C. H. Kunsman, Journal of Industrial and Engineering Chemistry, **17**, 971 (1925).

found and interpreted as a mean free path for the removal of the ion from its original path by scattering, retardation or neutralization. If L is this free path reduced to atmospheric pressure, $N = N_0 e^{-xp/760L}$, where p is the pressure in millimeters and x is the distance covered by the rays. This free path may be compared with that given by the kinetic theory if we suppose the potassium ion to have the same diameter as the argon atom. In all cases the ions have velocities greater than the gas molecules through which they are moving so that the simple kinetic theory formula for a rapidly moving particle gives a value that is within 5 percent of the correct value. In helium the curves shown give a free path 9.8; 7.5; 4.5 and 2.3 times the kinetic theory free path at 0°C, for the 250, 100, 30 and 8.5 volt rays respectively. Thus disturbances sufficient to remove an ion from the original bundle occur less frequently than the collisions with the helium atoms. The velocity

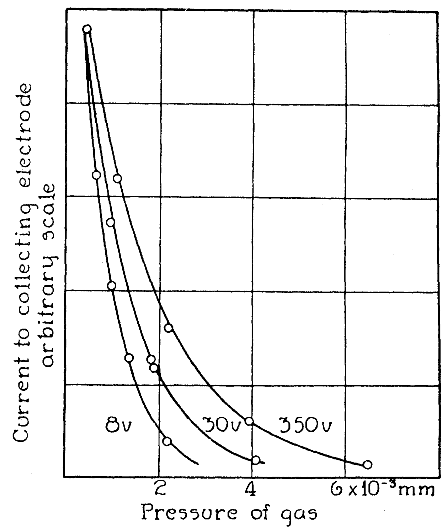

Fig. 3. Variation with the pressure of nitrogen of the number of positive ions reaching the collecting electrode.

of the 8.5 volt ions is 3.24×10^5 cm per sec. while the average velocity of the helium atoms is 1.2×10^5 cm per sec. Thus with velocities only slightly greater than those of the kinetic theory, many of the potassium ions pass through the helium atoms at a collision, without neutralization and without appreciable changes in direction or velocity.

With other gases similar results were obtained. Fig. 3 shows the decrease of the positive ion current with pressure in nitrogen. A collision with a nitrogen molecule is much more effective in throwing the potassium ion out of the original beam than a collision with a helium atom. However the mean free paths deduced from the three curves in Fig. 3 are 4.13, 2.81 and 2.07 times the kinetic theory free path for an argon atom in nitrogen, showing that even here not every collision is effective in removing the ion from the original group.

In hydrogen, oxygen, air and argon similar observations were made and the decrease with pressure was found to agree well with exponential curves from which a mean free path for absorption could be deduced. These mean free paths are plotted in Fig. 4 for rays of different speed in the various gases used. The ordinate is the ratio of this mean free path to the kinetic theory mean free path for an argon atom in the gas used. There is a decided decrease in the free path at low velocities and the curves suggest an extrapolation to the ratio unity at very low speeds. Oxygen is most and helium least

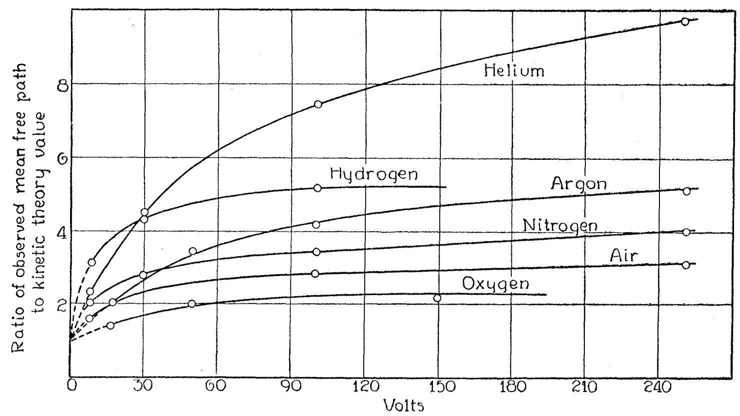

Fig. 4. Ratio of the mean free path for absorption to the kinetic theory value of the mean free path as a function of the velocity of the potassium ions in various gases.

effective in weakening the rays. In the case of oxygen the effect is probably due to neutralization of the potassium ion, and accompanying this process there is in all probability ionization of the oxygen molecule. Thus if it should prove possible to separate the effects due to scattering and retardation of the rays and examine the weakening due to neutralization by itself, we may hope to investigate the question of ionization of gases by ions of different kinds and its dependence on the velocity of the moving particles.

The author is indebted to Professor Dempster for assistance in designing the apparatus used and in preparing this paper.

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