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IONIZATION AND EXCITATION OF RADIATION BY ELECTRON IMPACT IN NITROGEN.

By Bergen Davis and F. S. Goucher.

THE purpose of the present paper is to present some of the experimental results obtained in further experiments of the writers on ionization and excitation of radiation by electron impact in various gases.

The method of experimentation employed was in principle that used in connection with our experiments on mercury vapor and hydrogen and the reader is referred to our paper for a detailed description of the same.[1]

This method is simply a modification of that applied by Frank and Hertz and others for the determination of the ionizing potentials of various gases, with the end in view of differentiating between the effects due to radiation from the bombarded atoms and those due to ionization.

This modified method may be summarized by reference to the schematic diagram Fig. 1 as follows. Electrons from a source A are accel-

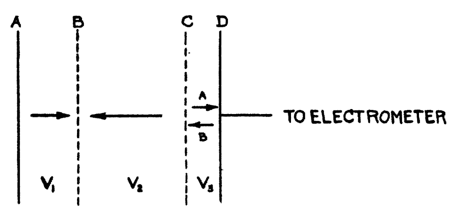

Fig. 1.

erated by an applied potential V_1 through a gauze B into a region BCD, C being a second gauze and D a collecting plate connected to an electrometer. V_2 is a retarding field applied between B and C, and V_2 is maintained at a constant amount greater than V_1 to prevent the original electrons from A reaching the plane of the gauze C. V_3 is small as compared with V_1 and V_2 and determines the direction of the field in the

[1] Physical Review, August, 1917.

neighborhood of C and D. The original electrons from A will be capable of making impacts with atoms or molecules in the space between A and C; and, depending on the energy imparted to them by V_1, may result in either the production of radiation from some of the impacted atoms or ionization or both. If the gauze C were not present and D in the place of C either of these results might cause a positive charging up of D due to the direction of V_2; if the cause were radiation alone it might cause a photoelectric emission of electrons from D, and if it were ionization alone the positive ions formed would travel to D. But with the small controlling field V_3 present the effects arising from these two causes can be differentiated, for if the cause be radiation alone it would produce a photo electric emission of electrons from either C or D dependent on the direction of V_3 and a consequent charging up of D—negatively if V_3 is in direction (*a*), and positively if in direction (*b*), if however the cause be ionization alone the positive ions formed in the region BC will be capable of reaching D in either case—V_3 being small as compared with V_2. As however both of these causes may occur simultaneously we may have a combination of these effects. Consequently the method consists in varying the applied potential V_1 maintaining $V_2—V_1$ at a constant small value, and obtaining two current curves as against V_1. One for V_3 being in direction (*a*); and the other for V_3 being in the direction (*b*). The shape of these curves and position of the intercept on the V_1 axis indicates the energy required to produce the different effects for any given gas.

The apparatus and experimental details were essentially the same as those used for mercury vapor and hydrogen. Certain improvements in design of the tube in which the measurements were made are worthy of note however. The same platinum thimble equipotential surface electron source was used, but the amount of metal in the tube was reduced considerably by using spiral wire grids wound on pyrex glass supports in place of the gauzes, with their heavy metal end supports. The grid B was of fine platinum wire about no. 30 and about 10 turns to the inch. The grid C was of nickel no. 20 and about 5 turns to the inch. The collecting electrode D was also of nickel and supported on a glass tube insulated by two grounding rings. All the seals were of glass, thus eliminating the use of cemented joints. This design made it possible to get rid of a much larger portion of the residual gases in the tube both on account of the reduction of the amount of metal and because the tube could be baked out as a whole and the grids glowed by means of current furnished from the outside.

The nitrogen used was prepared by the usual chemical method and was purified by washing with H_2SO_4 and NaOH and then passing over hot copper. It was collected over distilled water and before being introduced into the measuring system was dried by passing through a phosphorus pentoxide tube.

The streaming method was employed; the pumps were kept running and the gas was allowed to pass through a porous plug inserted in the bore of a stopcock. By exposing more or less of the surface of the plug and regulating the speed of the pump desirable pressures could be maintained at a constant value as measured by a McLeod gauge.

Experimental Results.—From a large number of curves obtained under varying conditions of pressure and intensity of electron emission from the source, the curves shown in Figs. 2–5 were selected as being typical.

Fig. 2 shows that by reversing V_3 which was of the order of 2 volts in

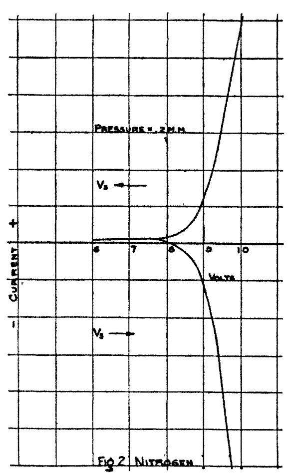

Fig. 2.

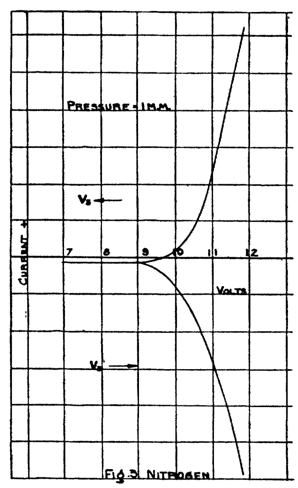

Fig. 3.

all these experiments the current curve could be made to reverse, indicating that the effect is produced largely if not entirely by radiation from the bombarded atoms. It is to be noticed that the curves have a horizontal portion in common. This is due to a very slight leak to the electrometer possibly from the glass. This could not seem to be avoided within small limits and was sometimes positive and sometimes negative. But the essential thing is that the two curves break away from this natural leak line at the same point which is about 7.5 volts, a result consistent with the results obtained by one of us and also as found by other experimenters.

There seems to be quite a marked increase in this radiation at about

9 volts; the curves being very steep after 9 volts. This is better shown in Fig. 3 where the electron emission was much less intense, here the curves do not separate until 9 volts had been reached. The current curve, Fig. 4, was obtained with a very small emission from the source and at low pressure a condition which is most favorable for ionization effects with this type of apparatus. This shows the effect to be radiation largely up to a value of about 17.5 to 18 volts. At this value the curve rises rapidly in spite of the opposing field V_3 showing that ionization has set in.

This then shows that the ionization potential of nitrogen is about 18 volts a value considerably higher than that heretofore supposed. This

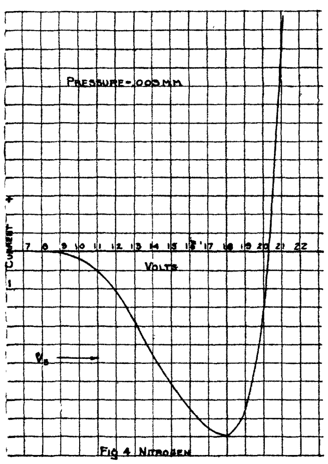

Fig. 4.

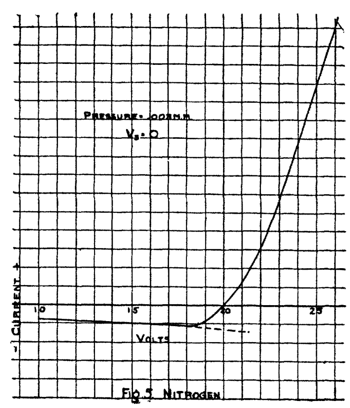

Fig. 5.

result however is more in accord with the work of Johnson on the total ionization by slow electrons. His straight line relation between total ionization and volts points more nearly to 20 than to 10 volts, though this method could not be expected to give an accurate value for the minimum ionization potential.

The intense radiation produced at about 9 volts is of interest in connection with the work of Meyer[1] who found that the wave-length about 1300 $A°$ stimulated the fluorescent band 3064 $A°$ in nitrogen. The value 1300 $A°$ from the quantum relation $Ve = hn$ would correspond to a voltage of the order of 9 applied to an electron.

Fig. 5 shows the current curve obtained when $V_3 = 0$. There is evidently not a complete neutralization of the radiation effect but the ionization effect is shown to set in strongly at about 18 volts.

[1] PHYSICAL REVIEW, November, 1917.

Summary.

These experiments show.

(*a*) Radiation can be stimulated in nitrogen molecules by electron bombardment without any appreciable ionization of the same.

(*b*) The value 7.5 volts heretofore accepted as the value of the ionizing potential really corresponds to the least energy an electron must have in order that it may excite radiation by the bombarded molecule.

(*c*) There is an indication of a more intense type of radiation setting in at about 9 volts.

(*d*) That ionization sets in at about 18 volts.

These experiments were completed more than a year ago, but stress of circumstance has delayed their publication to the present time.

Phœnix Physical Laboratory,
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