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CVI. *The Occurrence of Ionization by Cumulative Effects.*

By FRANK HORTON and ANN CATHERINE DAVIES*.

IN the *Philosophical Magazine* for March 1922, Professor K. T. Compton replies to criticisms we made† of the experiments by which he claims to have demonstrated the ionization of helium below its normal ionizing voltage, as the result of electron impacts against atoms which have absorbed resonance radiation from neighbouring atoms‡. In this reply Prof. Compton produces evidence which he states “proves these criticisms to be unfounded.”

The experiments which we criticized as giving inconclusive results were made with an apparatus in which the collecting electrode was in the form of a hollow cylindrical box having one plane end of platinum gauze and the other plane end of platinum foil, arranged so that each end in turn could be faced towards the glowing filament. The ratio R of the

currents measured in the two cases is $\frac{i+r}{i+cr}$, where i is the

part of the measured current which is due to ionization (which is the same whichever end of the box faces the filament), and r and cr are the parts of the measured current which are due to the photoelectric effects of radiation when the foil end and the gauze end, respectively, face the filament. Hence, if the constant c is known, the ratio of i/r can be calculated from the ratio R of the two measured currents. For pure radiation the value of R is $1/c$, and for pure ionization it is unity. Prof. Compton assumed that the value of c was given by the ratio of the area covered by the wires of the gauze end to the total area of the plane end, and checked his calculation of this by comparing the photoelectric currents measured when using radiation from a quartz-mercury arc outside the apparatus. The value used by him in estimating i/r was 0.5. The following table, which is taken from Prof. Compton's paper, gives the values of R and i/r obtained for electron energies between 20 and 25 volts, at different pressures of helium:—

* Communicated by the Authors.

† F. Horton and A. C. Davies, *Phil. Mag.* vol. xlii. p. 746 (1921).

‡ K. T. Compton, *Phil. Mag.* vol. xl. p. 553 (1920).

p (mm.).	R.	i/r .
0.0005	1.90	0.055
0.001	1.81	0.116
0.003	1.74	0.176
0.012	1.60	0.333
0.015	1.57	0.378
0.044	1.55	0.410
0.17	1.40	0.75
1.00	1.19	2.22
8.00	1.07	6.3
25.00	1.04	11.4

In considering the origin of any ionization obtained below the normal ionizing voltage of helium under the conditions of his experiments, Prof. Compton dismisses the possibility of its being due to electron impacts against helium atoms in such rapid succession that the energies of the impacts are additive in their effect, for reasons given by him in another paper *. He explains the ionization by supposing that part of the necessary energy is acquired from the radiation produced at the minimum radiation voltage, which is assumed to be absorbed and re-emitted by other atoms and thus passed on from atom to atom. That this assumption is justified has been shown by recent experiments of the writers †. It is, however, upon this very property of the radiation (which is so essential to Prof. Compton's interpretation of his results) that the writers based their main criticism of his deduction that ionization of helium was occurring at all the pressures given in the table, and that the ratio of the ionization current to the radiation current at each pressure in his experiments is that stated in the third column.

Prof. Compton's criterion for the presence of ionization was the deviation of the experimentally determined value of the ratio R from the value which he took to be the standard one for a pure radiation effect, viz. $R=1/c=2$. Any error in the value taken as the standard seriously affects the interpretation of the experimental results, and it was pointed out in our criticism of these experiments that the occurrence of the process of the handing on of the helium radiation from atom to atom of necessity means that the area of the collecting electrode acted upon by the radiation in any given case is not simply the area of the covered part of the particular plane end of this electrode which is facing the filament, but may include also the area of the curved surface of the cylinder and possibly even the area of the plane end

* K. T. Compton, Phys. Rev. vol. xv. p. 476 (1920).

† F. Horton and A. C. Davies, Phil. Mag. vol. xlii. p. 746 (1921).

remote from the filament. In his reply to this point Prof. Compton admits that some uncertainty exists in the value of R which can be taken as denoting a pure radiation effect, but asserts that the observed variation in R with variation of the pressure of helium is entirely too large to be accounted for in this way, quoting as an instance the result he obtained at 25 mm. pressure. It follows, from the additional data now given by Prof. Compton, that in the case of eight out of the ten results in his table (quoted above) the observed variation in R is not such as to justify the statement that it cannot be adequately accounted for without assuming the presence of ionization.

The area of the cylindrical surface of the collecting electrode is stated to have been equal to four times the area of the plane end of this electrode. Hence the limiting value of R for pure radiation, a value to which R will approximate when the radiation is so scattered by repeated absorption and re-emission that it is as likely to fall on the curved surface as upon the front plane end, would be $\frac{4r+r}{4r+0.5r}=1.11$,

where r is, as before, the photoelectric current from the foil-covered plane end of the collecting electrode. In deducing this limiting value of R for pure radiation we have neglected the photoelectric effect from the plane end of the collecting electrode remote from the filament, as this is unfavourably situated in regard to the electric field, whereas the cylindrical surface is, according to the diagram of the apparatus, in a situation comparable with that of the front plane end so far as this field is concerned.

At very low pressures the radiation cannot suffer much deviation from its original direction through absorption and re-emission by helium atoms, and hence the front plane end of the collecting electrode will, in these cases, receive nearly all of the radiation which falls on the outside of this electrode, and the value of R will approximate to the value 2 assumed by Prof. Compton. At higher pressures, however, the curved surface receives a larger proportion of the total radiation falling on the collecting electrode, and hence, as the pressure is increased, R decreases from the value 2 and approaches more and more nearly to the limiting value 1.11. From the table already quoted, it will be seen that the decrease in the experimental value of R with increase of the pressure of helium is such as might be anticipated for a pure radiation effect, and that only in the two cases in which the pressure was very considerable do the experimental values of R fall below the limiting value for pure radiation. Thus in eight out of the ten instances the experiments do

not give conclusive evidence of the presence of ionization below the normal ionizing voltage of helium.

There is, of course, ample evidence from spectroscopic observations * that when the pressure of the gas is considerable, ionization, which is presumably produced by cumulative action, occurs below the normal ionizing voltage, but this does not show, as Prof. Compton implies in his recent paper, that the results of the experiments we have criticized are reliable.

In regard to our criticism of Prof. Compton's original contention that the neon which was present in the helium used in his earlier experiments would be incapable of causing the effects he obtained at different pressures, it must be pointed out that the interesting new evidence of the purity of the helium used in the later experiments does not affect our objection to his original contention.

CVII. On the Buckling of Deep Beams.

To the Editors of the *Philosophical Magazine*.

GENTLEMEN,—

IN connexion with the two papers on the Buckling of Deep Beams published in your periodical (see Dr. J. Prescott, xxxvi. p. 297 and xxxix. p. 194), I beg to communicate the following:—

The question of the buckling of beams can be regarded as solved for a long time already. The first paper on this subject was published in your periodical by A. G. M. Michell, 1899, vol. xlviii. The same problem was investigated with more details by Prof. L. Prandtl, 1899 (*Munich Dissert.*). In both these papers, as also in the paper of Dr. J. Prescott, the bending of the flanges of girders by sideways buckling is neglected, and in consequence of that the results cannot be applied to the calculation of I girders.

The influence of the flexion of flanges of the girder was studied by me, and the results were published in Russia, 1905 (Bulletins of the Polytechnical Institute, Petersburg).

The translation of this paper in German can be found in *Zeitschr. f. Math. u. Phys.*, Bd. lviii. (1910). Other manner of

* O. W. Richardson and C. B. Bazzoni, *Phil. Mag.* vol. xxxiv. p. 285 (1917); K. T. Compton, E. G. Lilly, and P. S. Olmstead, *Phys. Rev.* vol. xvi. p. 282 (1920); A. C. Davies, *Proc. Roy. Soc. A*, vol. c. p. 599 (1922).