An Attempt to Observe the Spectrum of Doubly Excited Helium

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(Received July 1, 1937)

In this paper is described an electron-impact discharge tube which was designed to give excitation conditions favorable to the production of doubly excited helium. The tube furnished a concentrated 1000 ma beam of 300 to 500 volt electrons which passed through purified helium gas at a pressure of approximately 0.01 mm Hg. The comparatively feeble glow produced was photographed with a high speed two-prism glass spectrograph. Long exposures yielded only very much over-exposed He_{I} lines and rather strong He_{II} lines. This result is consistent with certain approximate theoretical calculations of Kreisler which show that the lifetimes of the doubly excited states of helium are limited by autoionization to approximately 10^{-14} sec., so that any spectral "lines" would be far too broad to be observable. This result tends to weaken the argument that the far ultraviolet helium lines, λλ320.4 and 357.5A, found by Kruger, and by Compton and Boyce, are due to transitions from doubly excited states to singly excited ones; and that the 60-volt energy losses of electrons passing through helium, observed by Whiddington, are due to a transition from the ground state to a doubly excited state.

INTRODUCTION

ATTEMPTS have been made by Rosenthal,[1] by Kiang, Ma, and Wu,[2] and by others to observe the visible spectrum of doubly excited helium. In this paper is described a discharge tube which is of the same general type as that used by Kiang, Ma, and Wu, but twenty-five times more powerful in regard to the magnitude of the electron current available for excitation. This experiment, which was near completion when Kiang, Ma, and Wu reported their work, merely strengthens their conclusion that in such a tube no visible spectrum attributable to doubly excited helium is observable. We do not give a detailed discussion of the general problem since an ample treatment has been given by Kiang, Ma, and Wu in their report.

It has been suggested by several people[3, 4] that the bright lines of the solar corona may be due to doubly excited helium. This suggestion was strengthened by the fact that Kruger,[5] and Compton and Boyce,[6] had observed two lines, λλ320.4 and 357.5A, in the far ultraviolet spectrum of helium which were attributed to transitions from doubly excited states to singly excited ones; and by the fact that Whiddington[7–9] and collaborators found energy losses in beams of electrons through helium gas which corresponded well with calculated energies[10–13] of the doubly excited states of helium. These, and other considerations, pointed out that the most favorable conditions for exciting the spectrum of doubly excited helium would be to have a heavy stream of 300 to 500 volt electrons[14] pass through the gas at very low pressure.

EXPERIMENTAL

The essentials of the discharge tube are shown in Fig. 1. The hollow cylinder bearing the grids, G, is 45 mm in diameter and 65 mm in length. Electrons from the flat spiral filaments, F, are accelerated by the grids, G, and stream through the region, R, exciting the gas to a glow. The grids were held at potentials of 300 to 500 volts positive to the filaments. Electron currents up to 1200 ma could be maintained for many hours. The gas pressure was kept at about 0.01 mm Hg in all the experiments. The entire tube was sub-

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[3] Rosenthal, Zeits. f. Astrophys. **1**, 115 (1930).
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[14] Massey and Mohr, Proc. Camb. Phil. Soc. **31**, 604 (1935).

merged in a water bath for cooling. The feeble glow in the region, R, was observed through the window W, against the dark background afforded by the blackened absorption horn, H. This horn was required in order to absorb the brilliant filament light, which if scattered into the spectrograph would fog the plate with continuous spectrum.

Tank helium, 96 percent pure, was purified by passing it very slowly through a hot tube containing successively, copper pellets, magnesium ribbon, and black copper oxide; then over P_2O_5; then through activated charcoal at liquid-air temperature. The purified gas was stored in a 12 liter reservoir flask. During operation of the discharge tube, fresh helium from the reservoir was continuously pumped through the tube. It was necessary to operate the tube for a few hours in order to "clean it up." The tube was considered "clean" when the bands of CO and NO no longer appeared in the spectrum.

A high speed two-prism glass spectrograph was employed. Long exposures of 15 hours revealed only over-exposed He_{I} lines, fairly strong He_{II} lines, and very faintly the auroral bands of N_2^+ at λλ3914 and 4278A. There were no indications of lines at λλ5303 and 4231A (the positions of the strongest solar corona lines suggested to be due to doubly excited helium). The lines reported by Rosenthal,[1] λλ5058.9, 5028.8, 4958.9, 4269.5 and 4258.5A, were not present.

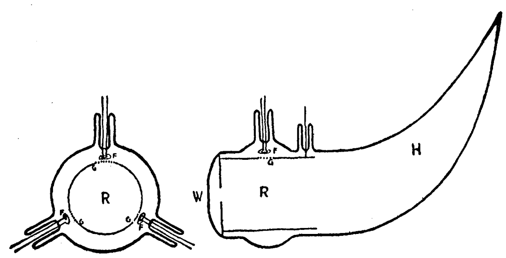

FIG. 1. Discharge tube.

DISCUSSION

The results of this experiment and that of Kiang, Ma and Wu may be interpreted in two ways. First, that helium cannot give a spectrum from its doubly excited states due to the nature of these states or, second, that the proper discharge conditions and technique have not yet been attained.

The first alternative would be consistent with the approximate theoretical calculations of Kreisler[15] which show the lifetimes of these states to be limited by autoionization to about 10^{-14} sec. Under these conditions all spectral "lines" would be far too broad to observe. This would not, however, be consistent with the experimental observations of Whiddington, and Kruger, and Compton and Boyce, because the line in Whiddington's electron spectrum is comparatively sharp and the far ultraviolet lines, λλ320.4 and 357.5A, are very sharp.

The second alternative is not consistent with the calculations of Kreisler but stands in accord with the electron energy loss experiments and the sharp far ultraviolet lines, λλ320.4 and 357.5A, of helium, as well as the tentative explanation of the solar corona bright lines.

In conclusion, the author wishes to express his most sincere appreciation for the valuable discussions and suggestions of Dr. M. L. Pool, Dr. H. A. Robinson, and Dr. G. H. Shortley during the progress of this experiment.

[15] Kreisler, Physica Acta Polonica **4**, 15 (1935).