The Infrared Spectrum of Argon

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A hot cathode discharge tube permitting a discharge current of up to 10 amperes is described. This tube was used as the source for an investigation of the infrared spectrum of argon. Forty-six lines between 0.69μ and 1.80μ are listed. Twenty of these lines have never been observed before.

BEYOND the wave-length of about 1μ very little is known of the infrared spectrum of argon. Meggers and Humphreys[1] with the new Eastman infrared-sensitive plates extended the spectrum to 1.2μ. Beyond that wave-length only three other lines are known and they were discovered by Paschen.[2] Much of the difficulty in obtaining the infrared spectra of the gases has been due to the lack of a sufficiently intense and steady source, and a sensitive detecting instrument.

The source of the argon radiation was a hot cathode discharge tube shown in Fig. 1. The tube was made entirely of Pyrex with a clear Pyrex window *W*. Since the Pyrex glass cuts off radiation beyond 2μ for the thickness used, the long wave limit of the spectrum was limited to that value. The cathode *K* consisted of a sheet nickel cylinder about 1.2 cm in diameter and about 4.0 cm long. Connected to one end of this cylinder was a heavy coiled tungsten filament running along the axis of the cylinder. The cylinder was given a coat of a mixture of Zapon varnish, amylacetate, and barium carbonate. After the tube was assembled the cathode was formed in vacuum by heating with an induction furnace.

The anode *A* was a cylinder of either sheet iron or sheet nickel. A constriction *C* was made

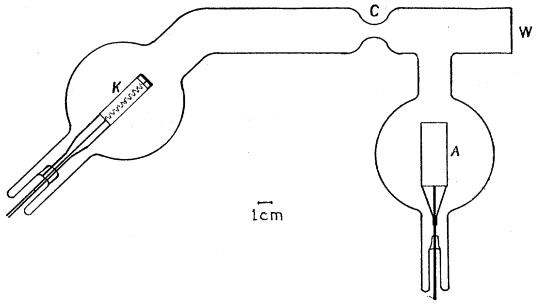

FIG. 1. Diagram of discharge tube.

in the tube to intensify the discharge and this was in turn focussed on the slit of the spectrometer. The assembled tube was put through the customary pumping and baking processes to clean up impurities and finally filled with argon to a pressure of about 6 mm of mercury. To operate the tube the cathode filament was heated sufficiently to heat to a dull red the cathode cylinder. The tube was connected to a source of potential of about 250 volts with a suitable ballast resistance in series to operate the tube at a current of about 6 amperes. It was usually necessary to touch off the tube with a 5000 volt transformer. The voltage drop across the tube at 6 amperes was about 35 volts. As a source of radiation it was very intense and exceedingly steady.

The spectrometer has been described by Spence[3] and in this experiment a plane grating having 14,400 lines to the inch was used. The

[1] W. F. Meggers and C. J. Humphreys, *Infrared Spectra of Neon, Argon and Krypton*, Bur. Standards J. Research **10**, 427 (1933).

[2] F. Paschen, *Infrared Line Spectra*, Ann. d. Physik **27**, 537 (1908).

[3] B. J. Spence, *A Spectrometer Table*, J. O. S. A. and R. S. I. **7**, 853 (1923).

receiving instrument was a radiometer already described by Spence[4] with a scale two meters distant. The deflection of the instrument for the intense argon lines with a 0.3 mm slit was about 100 mm. With care deflections of about 1.0 mm could be observed; we thus had a possible range of intensities from 1 to 100. The instrument was calibrated by means of visible lines of helium, neon and mercury out to the seventh order. The precision of the measurements was not better than an average of 1A largely because of the presence of very intense ghosts associated with the line under observation.

[4] B. J. Spence, *An Improved Form of Nichols Radiometer*, J. O. S. A. and R. S. I. **6**, 625 (1922).

Results

The results are shown in Table I. The column labelled intensity shows the deflections of the radiometer in millimeters for the lines of the first order which are therefore only roughly proportional to the absolute intensities. The table shows a comparison of the observed and computed frequency. In some cases two computed values are given for a particular observed line, the resolution of the spectrometer not being sufficient to determine the wave-lengths sufficiently accurately. The observed values followed by an asterisk have been observed by others[1] principally by photography.

TABLE I. *Argon.*

Intensity	λ obs.	ν obs.	ν calc.	Combination
20	6966	14351	14352.66	$1s_5 - 2p_2$
20	7068	14144	14145.94	$1s_5 - 2p_3$
10	7278	13736		
40	7384	13539	13539.10	$1s_4 - 2p_3$
55	7505	13321	13322.79	$1s_2 - 2p_1$
55	7515	13303	13303.69	$1s_4 - 2p_3$
60	7634	13096*	13093.79	$1s_5 - 2p_6$
75	7668	13038	13039.24	$3d_5 - 7X$
35	7725	12941*	12942.74	$1s_3 - 2p_2$
30	7950	12575*	12578.03	$1s_3 - 2p_4$
45	8015	12473*	12473.57	$1s_5 - 2p_8$
50	8107	12332*	12336.66	$1s_4 - 2p_7$
85	8117	12316*	12319.00	$1s_5 - 2p_9$
			12319.18	$3d_5 - 5Z$
25	8266	12094*	12096.58	$1s_2 - 2p_2$
40	8409	11889*	11889.86	$1s_2 - 2p_3$
65	8425	11866*	11866.73	$1s_4 - 2p_8$
25	8522	11731*	11731.87	$1s_2 - 2p_4$
80	9126	10955*	10958.28	$1s_5 - 2p_{10}$
27	9227	10835*	10837.71	$1s_2 - 2p_6$
40	9657	10352*	10351.44	$1s_4 - 2p_{10}$
10	9783	10219*	10217.49	$1s_2 - 2p_8$
15	10474	9545	9544.91	$3d_1' - 5p_6$
15	10677	9363*	9366.37	$2p_{10} - 2s_5$
			9359.36	$2p_9 - 3s_1'''$
10	11674	8564	8564.81	$3s_1'''' - 5p_9$
20	12116	8251	8250.55	$3d_4 - 4p_6$
10	12384	8096	8099.49	$2p_8 - 3d_1'$
15	12408	8057	8060.36	$2p_7 - 3d_2$
25	12431	8042	8045.37	$2s_1'''' - 5X$
			8037.00	$2p_{10} - 3d_3$
20	12448	8031		
25	12495	8001†	8005.65	$2p_9 - 2s_5$
			7994.22	$3s_1'''' - 4p_3$
10	12709	7866	7870.44	$2p_2 - 3s_1'$
20	12805	7807	7808.71	$2p_8 - 3d_1''$
35	12960	7714	7716.02	$2p_{10} - 3d_5$
20	13012	7683	7685.35	$2p_3 - 2s_2$
30	13230	7556	7557.69	$2p_9 - 3d_4$
			7555.81	$2p_7 - 2s_4$
50	13275	7531	7535.32	$2p_3 - 3s_1'''$
35	13317	7507	7509.29	$2p_4 - 3s_1''''$
60	13365	7480	7479.27	$2p_6 - 3d_1'$
80	13505	7403†	7403.12	$2p_8 - 3d_4$
30	13630	7335	7338.78	$2p_7 - 3d_1''$
20	13685	7305	7308.69	$2p_2 - 3s_1''$
90	13725	7284†	7287.60	$2p_9 - 3d_4'$
20	14100	7090	7093.33	$2p_5 - 3d_2$
10	14635	6831	6827.47	$3p_8 - 6d_1''$
30	16975	5889	5890.41	$3s_1' - 4p_7$
10	17920	5579	5580.70	$2p_7 - 3d_6$
			5580.51	$2p_6 - 3d_5$

† These lines observed by Paschen.[2]