PROCEEDINGS

OF THE

AMERICAN PHYSICAL SOCIETY.

Extreme Ultra-Violet Spectra of Hot Sparks in High Vacua.[1]

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In 1905, while working upon the spark potentials between metal electrodes in very high vacua, one of us observed that when the electrodes were a millimeter or less apart it was possible to obtain from condensers charged with a static machine, hot metallic sparks when the vacuum was so high that gases apparently, played no rôle in the discharge. The potentials required to produce these hot sparks, amounting to 150,000 volts per millimeter under certain conditions, were altogether independent of the pressure of the residual gas, provided this was sufficiently low, for example, between 10^{-5} and 10^{-8} millimeters of mercury. The potential measurements were made with a specially designed electrostatic voltmeter of a construction similar to that used by Müller.

Sparks of this kind in highly exhausted tubes have been observed by others. but we are not aware of any prior attempts to determine the potentials required to produce them. These were found to show interesting fatigue effects, the initial discharge potential rising from, say 30,000 volts per millimeter to 100,000 with continued sparking, as though the spark potential depended upon a surface condition. After the spark potentials had been increased by continuous sparking from say 30,000 to 120,000 volts per millimeter, if the electrodes were allowed to stand, the spark potential would fall in the course of twenty-four hours to about the initial value. Reversal of the electrodes would also produce a large change in the spark potential.

In connection with this study of spark potentials it occurred ot one of us that since the difficulties in the pushing of the spectra into the extreme regions of the ultra-violet arose in practically all cases from the absorption of very short wave-length radiations either in fluorite windows or in the residual gases of the vacuum spectrometer,[2] it might be possible by building a vacuum spectrometer designed specially for the study of the spectra of these hot sparks in the extreme ultra-violet, to increase considerably our knowledge of the spectra

[1] Abstract of paper presented at the New York meeting, American Physical Society, April 27, 1918.

[2] Lyman, Spectroscopy of the Ultra Violet, Astrophysical Journal, 43, 89, 1916.

emitted by different metals in this region. Accordingly, in 1915 one of the writers designed and had built in the Ryerson Laboratory a vacuum spectrometer, as shown in Fig. 1. The grating was specially constructed for the purpose by Mr. Fred Pearson at Professor Michelson's request. It was a 4-inch concave, 512 lines per millimeter, focal-length of 89 cm. The exhaustion was accomplished at first by a Gaede molecular pump and later and more successfully by a mercury vapor pump of the kind designed by Dr. H. D. Arnold and used by the Western Electric Company in the exhaustion of their audion bulbs. The first photographs which were taken revealed many lines in the fine spectrum which had not been discovered before, some of them below 1000 Ångströms.

On account of the absorption of one of the writers in war duties, the later work upon the problem and the overcoming of the difficulties arising from the fogging of the photographic plate have been the task of the other of the writers. This fogging of the plate was due to the brilliancy of the spark and the leaking of the light past the diaphragm which had been arranged to intercept it. (See Fig. 1.). This diaphragm completely filled the brass cylinder 15 cm. in

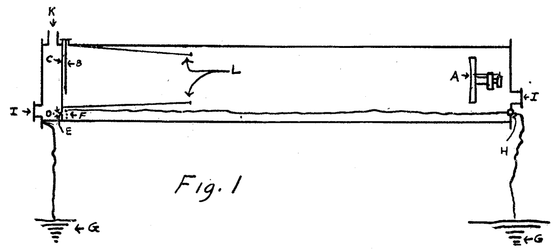

Fig. 1

A, Grating; *B*, Plate; *C*, Diaphragm; *D*, Electrodes, represented symbolically; *E*, Slit; *F*, Gauze; *G*, Separate Grounds; *H*, Insulation for leak from gauze to Ground; *I*, Windows in end Plates; *K*, Connection to pump; *L*, Sleeve to keep scattered light from plates; Shutter not shown in figure was between slit and Gauze.

diameter and 10 cm. long, which constituted the case of the spectrometer. The slit was in one side of this diaphragm and the spark gap just behind it. The plate holder was carried on the diaphragm, the grating of course being at the other end of the tube. (See Fig. 1.) The vacuum was so high that sparks would at first pass without producing a glow, but with continued sparking the glow would appear and the plate become fogged. Various diaphragms and shields failed to reduce it sufficiently. It was suggested by Dr. A. J. Dempster, of the University of Chicago, that he had seen similar glow effects in vacua checked by two gauzes close together and grounded separately. In accordance with this suggestion, it was arranged to use the diaphragm containing the slit as one screen and a gauze about a millimeter from it and grounded by a separate connection, as the other. (See Fig. 1.) A very great diminution of glow resulted and the desired spectrum became at once obtainable.

While a complete investigation of the spectra of this type of source has not

Zinc.

Distance from Image of Slit.	Wave-length.	Comparison.
91.0 mm.	2138	Standard Ames
89.1	2099	Standard Cornu
88.6	2082	
88.4	2077	2073.7 Cornu
87.8	2064	2061.3 Cornu
86.6	2035	
86.3	2025	Standard Cornu
85.0	1998	
84.3	1981	1982.7 Handke
83.5	1962	1965.3 Handke
83.0	1950	1953.1 Handke
82.0	1927	1931.2 Handke
81.5	1915	1919.9; 1915.9 Handke
80.4	1889	1886.1 Handke
79.5	1868	1868.5; 1866.9; 1864.6 Handke
79.0	1856	
78.0	1833	1836.6; 1834; 1832 Handke
76.3	1793	1795.5; 1794; 1791.3 Handke
75.0	1763	
74.2	1745	1748.3; 1746.3; 1743.6 Handke
73.7	1734	1736.5 Handke
72.5	1704	1707 Handke
71.6	1683	
70.8	1665	
70.0	1645	1647 Handke
69.7	1640	1642 Handke
69.5	1633	
69.0	1621	
67.8	1593	1589.8 Wolff
67.0	1574	
66.0	1551	
64.4	1513	
63.4	1490	1486 Wolff
62.5	1469	
61.8	1452	
61.2	1438	
60.8	1429	
59.0	1386	
58.5	1375	1376.9 Wolff
57.5	1351	
56.8	1335	
56.1	1318	
55.4	1302	
54.5	1281	
53.5	1257	
53.0	1246	
52.5	1234	
52.0	1222	

Zinc—continued

Distance from Image of Slit.	Wave-length.	Comparison.
50.8 mm.	1194	
50.0	1175	
49.5	1163	
47.2	1109	
43.3	1018	
42.5	999	
42.0	987	
41.2	968	
39.5	928	

yet been made, it seems advisable to present a preliminary report. Zinc spectra have been obtained which show about 50 lines in the region between 2,100 and 900 Ångström units, the shortest wave-length obtained being 928 Ångström units. The lines recorded in the table have all been measured on at least two plates. There is some indication of even shorter wave-lengths, though no positive proof as yet. It is impossible to get the whole plate in focus at once and the shortest lines are so blurred that exact measurements upon them have thus far been difficult. As shown in the accompanying table the measurements which have been made on lines heretofore published check as closely as could be expected with the zinc wave-lengths given by Handke and extending down to 1,632.9 Ångström units and those published by Wolff extending to 1,376.87. The shortest line ever published on the zinc spectrum was 1,099.6 by Saunders,[1] and the shortest for any metal was 977.9 by Saunders for calcium. Incomplete experiments with aluminum and iron as electrodes give promise of results as good as those with zinc. Comparison of the spectra of different metals seems to show that the shorter lines are not due to occluded gases in the metals, but are rather characteristic of the metals themselves.

[1] Astrophysical Journal 43, 234, 1916.