THE ABSORPTION SPECTRA OF COPPER, SILVER AND GOLD VAPORS IN THE ULTRA-VIOLET

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Abstract

Using a carbon tube heated to between 1600°C and 2000°C with an oxy-acetylene torch, the absorption spectrum has been studied in the ultra-violet to 2000 A. With copper, besides strong absorption at the first pair of the principal series 3273.9 and 3247, in agreement with Grotrian, lines were found at 2225, 2182, 2178.9, 2165, 2024.3 and, with 2000°C, at 2244. The second pair of the principal series has been calculated by Randall to come at 2024.4 and 2025.7, but the absence of any trace of the second line makes this identification still uncertain. With silver very strong absorption was obtained at 3382 and 3280 (as by Grotrian) and also at 2070.0 and 2061.2. These are the first two pairs of the principal series. With gold there was distinct absorption only at 2675.9 and 2427.9 indicating that these lines are the first pair of the principal series.

Introduction

THE absorption spectra of copper and silver vapors have been investigated by Grotrian.[1] The absorption cell which he used was an evacuated quartz tube 30 cm long. With this tube heated to about 1200°C he obtained sufficient vapor to show absorption at the first members of the principal series of doublets for copper and silver. According to Fowler[2] there is some doubt concerning the position of the higher members of both these principal series. The lines observed in absorption by Grotrian are of very great intensity in the arc and strongly reversed. It had been long suspected that they were the first members of the principal series of doublets. The position of the next higher members of this series has been calculated to be in the region of 2000 A. In the arc spectrum of copper and silver there is no intense doublet in this region. The following remarks are taken from Fowler's Report, p. 110: " . . . it is doubtful whether the second pair is really represented in the spectrum. In any case, there would seem to be an unusually rapid fall in intensity in the principal series." It therefore appeared desirable to study the absorption spectra of copper and silver vapors in the region of 2000 A to see if the second pair could be identified with certainty.

[1] W. Grotrian, Zeit. f. Phys. **18**, 169 (1923)

[2] Fowler, Report on Series in Line Spectra, p. 111.

Apparatus

In Grotrian's work the windows of clear fused quartz which were sealed to the ends of his absorption cell frequently became opaque and had to be renewed. Since quartz begins to absorb radiation below 2000 A and also cannot be heated above 1200°C for any length of time, an attempt was made to design an absorption cell without windows and without using quartz.

The method used is indicated in Fig. 1. A carbon tube C 15 cm long, has a hole of 1 cm diameter drilled through the center with a small pocket to hold the metal. The source of light S is a condensed spark between electrodes of zinc, cadmium or aluminium. Through the side tube H hydrogen enters when necessary to prevent oxidation of the heated metal. The central portion of the carbon tube is heated from the out-

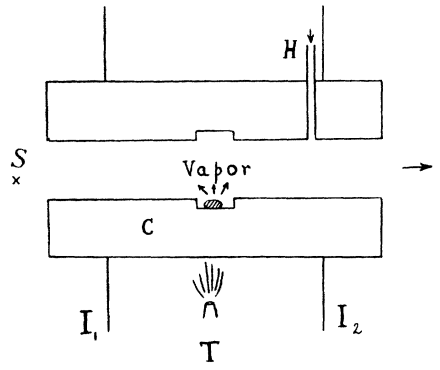

Fig. 1

side by an oxy-acetylene torch T. Iron shields I_1 and I_2 protect the source of light and the slit of the spectroscope from the spreading of the flame. The temperature of the drop of molten metal was between 1200°C and 2000°C as measured by an optical pyrometer.

Experimental Results

Silver. As the carbon tube heated up the silver melted and the central part of the tube became filled with vapor which was visible. Strong absorption was observed at 3280 and 3382 as first observed by Grotrian. The absorption at 3280 was stronger than at 3382. Using a small quartz spectroscope the region of 2000 A was examined. No absorption was observed in this region below a temperature at which the lines at 3280 and 3382 showed a considerable broadening, when lines appeared at 2061.2 and, at higher temperatures, at 2070.0. The absorption was stronger at 2061.2 than at 2070.0.

The position of the second pair of the principal series of doublets was first calculated by Randall[3] at 2070.0 and 2061.3. Rubies[4] has photographed two lines in the silver spark at 2070.05 and 2061.55 which Catalan[5] considers are the second pair. Shenstone[6] has obtained a low voltage arc in silver vapor showing only the first two pairs of the principal series. He states that the wave-lengths of the second pair as given by Rubies are not correct.

In taking the absorption spectra, the arc in air between pure silver electrodes was always photographed for comparison. Two lines, 2061.2 and 2070.0 are distinctly present in the arc. These wave-lengths were determined using Hasbach's[7] values of the copper spark as standard. From these results it seems certain that the second pair of the principal series of doublets of silver are 2061.2 and 2070.0, in close agreement with the values predicted by Randall.

Copper. A similar procedure was followed for copper. It was very noticeable that in order to secure copper vapor the carbon tube had to be heated to considerably higher temperatures than for silver. As the temperature was increased the lines 3274 and 3247 first appeared in absorption. When the copper drop was at 1600°C additional absorption lines were observed corresponding to the emission lines 2225.6, 2181.6, 2178.9, 2165.0, 2024.3, and at the highest temperatures a line also appeared at 2244.2. It was only at the highest temperatures (2000°C) that the two main absorption lines showed considerable broadening. The component of shorter wave-length being always the more intense. The observations regarding this pair are in agreement with Grotrian's. Absorption was also observed at 2833, 2170 and 2139. The first two are due to lead and the last one to zinc. The copper used was among Baker's Analyzed Chemicals, certified to contain no lead. After the copper had been kept about 10 minutes at 1600°C, no trace of absorption at 2833 and 2170 could be obtained. The lead had apparently evaporated.

There seems little doubt that the first members of the principal series of doublets are 3247 and 3274. The second pair has been calculated by Randall[3] at 2024.42 and 2025.73. At that time only one line had been observed by Kayser and Runge at 2025.08. Rubies[8] has observed two

[3] Randall, Astrophys. J. **34,** 1 (1911)

[4] Kayser and Konen, Spektroskopie, **7,** p. 42

[5] Hicks, Analysis of Spectra, p. 258

[6] Shenstone, Nature, Oct. 4, (1924), p. 501

[7] Kayser and Konen, op. cit.[4] p. 350

[8] Kayser and Konen, op. cit.[4] p. 351

lines in the arc at 2024.05 and 2023.64. Fowler[9] states that Rubies has observed two lines at 2025.1 and 2024.11 (international normals). Shenstone[6] has photographed the low voltage arc in copper vapor in this region. In place of a pair he obtained a single line at 2025. Using the arc in air between copper electrodes I get a strong line at 2025.36 and a faint line at 2024.3. The wave-length 2024.3 was obtained as before, using Hasbach's values of the copper spark as standards. If, however, the arc is obtained from one electrode of copper and the other of silver, 2024.3 is much stronger than 2025.3, which is observed to fall off rapidly in intensity with distance from the copper electrode. It would appear that 2025.36 is a spark line and 2024.3 an arc line. It is to be noted especially that instead of a doublet at the position calculated for the second pair, absorption was only observed at a single line, 2024.3. From this work one cannot be certain of the second pair of the principal series. The absorption at 2244 appears to be due to copper atoms in an excited state since it only occurs on three plates taken at the highest temperatures, about 2000°C.

Gold. The gold was observed to melt readily, but at very high temperatures the quantity of vapor present in the tube was small as judged by the eye. However the absorption at 2427.9 and 2675.9 was well marked, the absorption at 2427.9 being the stronger. Absorption was also observed at 3280, 3382 and 3303. The first two are due to silver but the origin of the third line is uncertain. This affords good evidence that the first members of the principal series of doublets are 2427.9 and 2675.9. No other absorption lines were observed of wave-length greater than 2000 A, the higher members of this series being in the Schumann region.

In the absorption spectra of these three elements the component of the doublet having the shorter wave-length is always the stronger. In this respect the spectra are similar to those of the alkali metals. Similar also is the increase in the separation of the doublets with increasing atomic weight. The rapid falling off in intensity of the higher members of the principal series as noted by Fowler is very remarkable.

National Research Fellowship,
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November 22, 1924

[9] Fowler, op. cit.[2] p. 109