

The Absorption Spectrum of the Iodine Atom

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(Received April 9, 1934)

The absorption spectrum of atomic iodine has been investigated in the spectral range $\lambda 2100$ to 1400\AA . The iodine was dissociated by heating to 1000°C . A hydrogen discharge tube or an iodine discharge tube was used as the source of illumination. The former source revealed clearly that $\lambda 1830$ and 1783\AA are absorption lines. When light from a discharge in iodine was passed through the heated iodine the following lines were found to be weakened by absorption, $\lambda 1830$, 1783 , 1642 , 1618 , 1583 , 1515 , 1507 and 1422\AA .

IODINE is one of the few remaining elements whose atomic arc spectrum is not as yet well analyzed. Turner¹ measured the wave-length of the arc lines in the Schumann region and later² identified the fundamental multiplet which arises from electronic transitions to the fundamental $^2P_{1/2, 3/2}$ energy level. In a later paper Turner³ also described experiments on the absorption of iodine emission lines when the light was passed through a column of iodine gas partially dissociated by radiation from a quartz mercury arc. Evans⁴ and Deb⁵ have analyzed some of the lines appearing in the visible and infrared portions of the spectrum.

With a view to getting more information about the spectrum of iodine two experiments were carried out to further investigate the absorption spectrum of iodine in the Schumann spectral region.

In the first experiment the continuous radiation from a hydrogen discharge tube was used as a source. Fig. 1 shows the general arrangement of the apparatus. The hydrogen discharge tube at *H* emitted ultraviolet light. The fluorite lenses L_1 and L_2 directed the light through the quartz absorption cell and on to the slit of the spectrograph.

The absorption cell was 15 cm in length and had very thin windows of quartz. The temperature of the absorption cell could be raised to

1000°C by means of the electric resistance furnace.

Iodine at a partial pressure of approximately 0.3 mm was admitted to the absorption cell from a side tube kept at 26°C . At a temperature of 1000°C practically all of the iodine was in the atomic form.⁶ Pure argon at a pressure of about 55 cm was mixed with the iodine. The purpose of the argon was to broaden the absorption lines of iodine to such a width that they would be recorded as lines on the plate, even with a spectrograph of low resolving power.

Two spectrographs were used. The first was a small Hilger quartz instrument from which all the oxygen was displaced by flowing through it a stream of tank nitrogen. Fig. 2a is a positive print of a spectrogram taken with this instrument. The resonance line at $\lambda 1830\text{\AA}$ is seen to be clearly absorbed by the iodine gas. Attempts were made to observe in absorption other lines in this region namely $\lambda 1844$, 1876 and 2062\AA . No trace of absorption at these wave-lengths was observed. This result agrees with Turner's

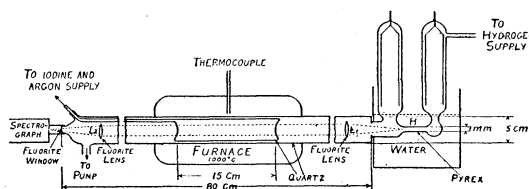


FIG. 1. General arrangement of absorption tube.

¹ Turner, *Phys. Rev.* **27**, 397 (1926).

² Turner, *Phys. Rev.* **31**, 983 (1928).

³ Turner, *Phys. Rev.* **41**, 627 (1932).

⁴ Evans, *Proc. Roy. Soc.* **A133**, 417 (1931).

⁵ Deb, *Proc. Roy. Soc.* **A139**, 380 (1933).

⁶ Starck and Bodenstein, *Zeits. f. Elektrochemie* **16**, 965 (1910).

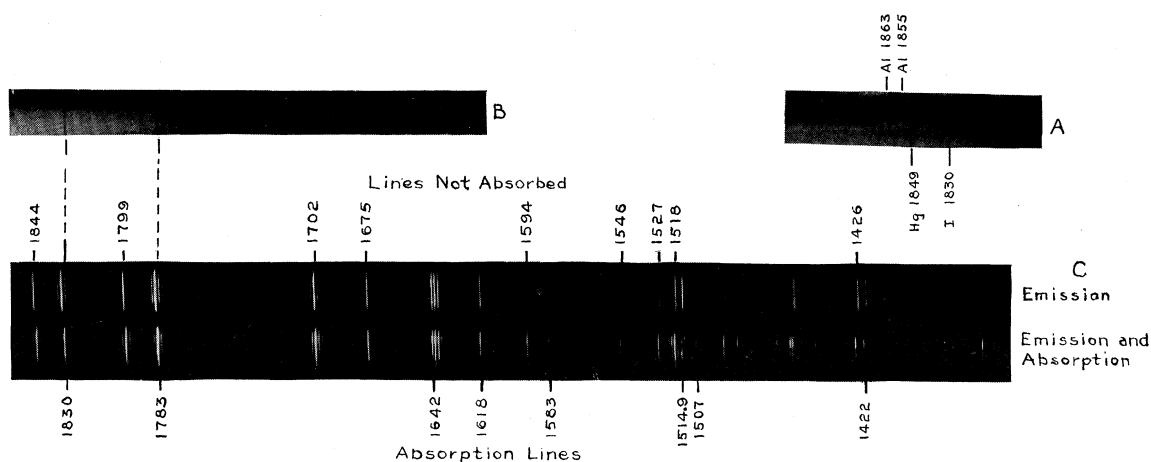


FIG. 2. Spectrograms showing lines which appear in emission and absorption.

analysis since he allotted the lines mentioned to transitions to the upper or metastable ${}^2P_{1/2}$ member of the doublet P low level. The temperature of 1000°C was too low to elevate a sufficient number of atoms into the metastable level which is 7600 cm^{-1} higher up in energy value.

For investigations of shorter wave-lengths a vacuum grating spectrograph was employed. The grating had 30,000 lines per inch and a radius of curvature of one meter. Fig. 2b is a reproduction of the absorption spectrum observed with the grating spectrograph. The lines at $\lambda 1830$ and 1783Å are seen to be absorbed. The iodine was at a pressure of about 0.3 mm and the argon at a pressure of 30 cm.

It will be noted that the hydrogen continuous spectrum did not extend much below $\lambda 1783$. This was because the quartz windows absorbed shorter wave-lengths when the quartz was heated to 1000°C . When the furnace had cooled off, the upper spectrum of Fig. 2b was made by running the hydrogen discharge tube for a short time. The quartz windows then transmitted to below 1630 and the hydrogen lines in the region 1630–1650 were recorded. The position of these lines and the known dispersion of the spectrograph served to identify with certainty the two absorption lines. A trace of the mercury absorption line at $\lambda 1849$ appeared on the original plate and served as an additional check on the wave-length of the absorption lines.

For the investigation of the absorption spectrum below $\lambda 1783$ a different method was necessary. Obviously all quartz in the path of the light had to be eliminated. Below $\lambda 1650$ the continuous spectrum of hydrogen is very weak and to make matters worse a many-line spectrum begins. The hydrogen discharge tube was therefore unsuited for the work.

Fig. 3 shows the arrangement of the new apparatus. It consisted essentially of two tubes, an emission tube to emit the spectrum of iodine and an absorption tube to reabsorb any absorption lines. The emission tube was of Pyrex glass about 8 mm internal diameter. It contained iodine at about 0.04 mm pressure and argon at about 5 mm pressure. A current of 100–140 m.a. a.c. produced a brilliant arc spectrum of atomic iodine. The absorption tube was of quartz and the central portion was surrounded by a furnace to dissociate the iodine molecules. No focussing lenses were used, instead the high reflecting power of quartz and glass for rays at nearly grazing incidence was depended on to produce sufficient light at the slit of the spectrograph in spite of the distance of half a meter between the discharge tube and the slit.

Care was taken to prevent the iodine from coming into contact with wax or stopcock grease. The Kittlack wax used to fasten the fluorite window over the slit was coated with paraffin. Other joints were designed to present a minimum of area of wax to the action of the

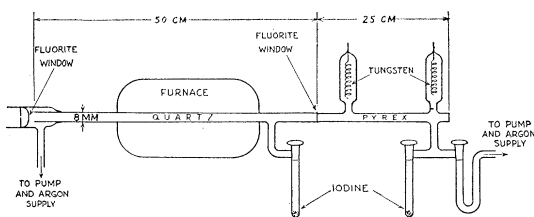


FIG. 3. Arrangement of new apparatus.

iodine. Access of iodine to stopcock grease was reduced to a minimum by having all stopcocks connecting directly with the emission or absorption tube of a "dry" type. They were the right-angle type and had grease only around the outer end. A circular groove ground around the plug of the stopcock prevented the grease from working down to the main portion of the stopcock. The cocks were perfectly tight to the outside atmosphere but of course were not leakproof from one side to the other. However, when closed, they served admirably to prevent the heavy iodine molecules from diffusing through with any great rapidity. Other stopcocks, fully greased, were placed between the "dry" cocks and the pump as shown in the diagram.

The absorption tube contained a mixture of about 0.3 mm iodine and 20 cm of argon. The temperature of the furnace was raised to about 900° and an exposure of 35 hours gave a spectrum extending to about $\lambda 1400\text{\AA}$.

Another exposure was then made with the furnace cold. The gas pressures in the absorption tube were suitably reduced so as to have approximately the same number of atoms of argon and molecules of iodine in the path of the light as there were when the furnace was hot. In this way a spectrum was photographed under conditions that were similar to the first one except that there were no iodine atoms in the light path.

Fig. 2c shows a pair of spectrograms taken as described above. It will be noticed that some lines are relatively weaker in the spectrogram taken with absorbing atoms in the path. They are undoubtedly absorption lines. A careful examination of the plates showed that the lines $\lambda 1830.4$, 1782.9 , 1642.5 , 1617.9 and 1514.9 are

absorbed. In addition there is good evidence that the lines $\lambda 1582.8$, 1507.3 , and 1421.6 are absorption lines.

In this spectral region the following lines are long wave-length members of doublets having the frequency difference 7600 cm^{-1} ; $\lambda 1782.9$, 1642.5 , 1617.9 , 1582.8 , 1507.3 , 1486.1 , 1459.0 , 1458.2 and 1421.6 . Since 7600 cm^{-1} is the frequency difference of the inverted low levels $^2P_{1/2}$ and $^2P_{3/2}$ of the iodine atom it would be expected that the long wave-length members of lines having this frequency difference would be absorbed. It is seen that this is so except for the lines $\lambda 1486.1$, 1459.0 and 1458.2 . It may be that more accurate measurements of wave-lengths will show that the lines $\lambda 1486.1$, 1459.0 and 1458.2 are not associated with the frequency difference of the two low levels. On the other hand it may be that uncertainties associated with very long exposures in the extreme ultraviolet were such as to mask slight absorptions for these lines.

The line $\lambda 1514.9$ was absorbed but is not associated with the frequency difference 7600 cm^{-1} . This would indicate that it must be due, in emission, to a transition from an upper state having $j=5/2$ to the lowest state $^2P_{3/2}$.

The experiment indicated that the following lines were not absorbed, $\lambda 1844.5$, 1799.2 , 1702.3 , 1675.4 , 1593.8 , 1545.9 , 1526.6 , 1518.3 and 1425.7 . This would suggest that the lines are due to transitions to the upper or $^2P_{1/2}$ low metastable energy level of atomic iodine. It follows that each should be the short wave-length member of a doublet, $\Delta\nu=7600\text{ cm}^{-1}$. This is the case except for $\lambda 1526.6$.

Other lines in the region were too weak or presented conflicting evidence so could not be safely classified either as absorbed or non-absorbed lines.

A new measurement of the arc and spark wave-lengths of atomic iodine in the Schumann spectral region is now in progress.

It is with great pleasure that I take this opportunity to thank Professor O. Oldenberg for his interest and numerous suggestions during the course of this research.

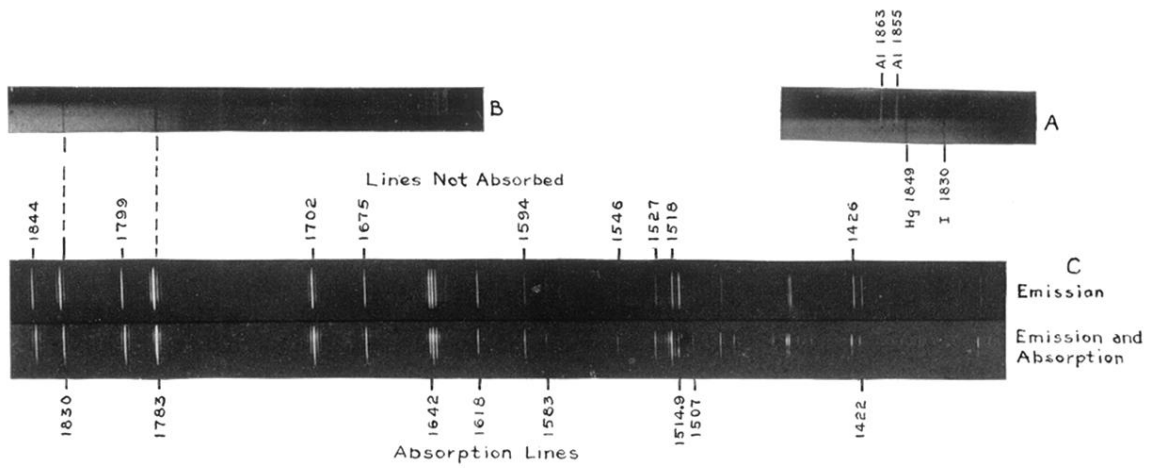


FIG. 2. Spectrograms showing lines which appear in emission and absorption.