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ABSORPTION STRUCTURE NEAR THE $L_{\mathrm{II,III}}$ EDGE OF ARGON GAS

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We have studied the absorption spectrum of argon in the 50-Å region. The discrete structure observed near the $L_{\mathrm{II,III}}$ edge is attributed to the excitations of a $2p$ electron to the high-lying Rydberg states which converge to the $^2P_{3/2}$ (L_{III}) and $^2P_{1/2}$ (L_{II}) states of the argon ion. The energy values of the L_{II} and L_{III} levels of the argon atom are found to be 250.55 ± 0.05 and 248.52 ± 0.05 eV, respectively.

Absorption measurements of gases in the extreme uv and soft x-ray regions have been conducted by the INS-SOR group (Institute for Nuclear Study–Synchrotron Orbital Radiation) with the 1.3-BeV electron synchrotron at the Institute for Nuclear Study, University of Tokyo, as a continuum light source for the last few years.

Madden and Codling[1] have recently made an extensive study of the absorption spectra of the rare gases in the extreme uv region using the synchrotron at the National Bureau of Standards. However, in regard to the L absorption of gaseous argon, only a few measurements have been carried out to date, probably because of the difficulty in obtaining an appropriate continuum light source in the region concerned. Lukirskii and Zimkina[2] reported a structure in the L absorption of argon which shows a rather broad line followed by a continuum absorption. Deslattes[3] also obtained almost the same structure in the argon L absorption as did Lukirskii and Zimkina.

The present Letter shows the preliminary result of absorption measurements on the structure near the $L_{\mathrm{II,III}}$ absorption edge of argon gas in the 50-Å region, obtained by means of continuum light emitted from the electron synchrotron and photographic detection with a vacuum spectrograph.[4]

The electron synchrotron was mostly operated in an energy range between 850 MeV and 1.2 BeV during this experiment. The intensity maximum of the continuum lies in a wavelength range between 5 and 20 Å for this energy range. The spectrograph used is a 2-m grazing-incidence vacuum type equipped with a glass grating having 1080 lines/mm, and it is placed at a distance of about 8 m away from the synchrotron doughnut. The resolution obtained is somewhat better than 0.03 Å in the 50-Å region with a slit width of about 10 μ.

In the absorption experiment, prepurified tank argon gas is introduced into the main chamber of the spectrograph at a pressure range of between 0.1 and 2.0 Torr, and the argon gas leaking out through the entrance slit is evacuated with a differential pumping system to maintain the synchrotron doughnut pressure below 5×10^{-6} Torr. Eastman S.W.R. plates are chiefly used to photograph the absorption spectrum. A line spectrum produced by a sliding spark is used as a comparison for the determination of the wavelengths of the absorption spectrum. A special mechanism is provided in the sliding spark discharge tube so as to obtain comparison spectrum

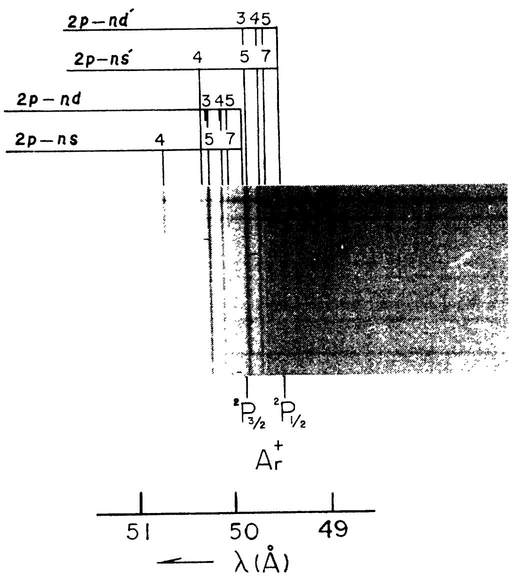

FIG. 1. Absorption spectrum of Ar in the 50-Å region. Experimental conditions: Energy of the synchrotron, 850 MeV; Ar pressure, 0.5 Torr; exposure time, 1 min.

without breaking the vacuum. The electrodes of the discharge tube are vertically supported and they can easily be moved, by simple rotation, onto and away from the optical axis joining the spectrograph and the synchrotron doughnut.

In Fig. 1 is shown the absorption spectrum of argon obtained in the 50-Å region. This spectrum was taken in the first order with argon pressure of 0.5 Torr and a 1-min exposure. Figure 2 shows a densitometer trace of the absorption spectrum in Fig. 1. Since no appropriate comparison lines were available in the 50-Å region, the wavelengths of some strong absorption lines were determined by comparing the fourth-order spectrum of the absorption lines with the line spectrum of the sliding spark, which was superimposed on the argon absorption spectrum. The wavelengths of the absorption lines which did not show up in the fourth-order spectrum were determined by means of the grating formula, in which the wavelengths of the strong absorption lines determined above were used as reference lines.

In Figs. 1 and 2, it is obvious that the absorption structure near 50 Å is due to transitions of a $2p$ electron over to the Rydberg series of high-lying atom energy levels followed by the photoionization continuum level. There are two groups of Rydberg series converging to the $^2P_{3/2}$ and $^2P_{1/2}$ states of the argon ion with a $2p$ electron being removed. In the absorption due to optically allowed transitions with excitation of a $2p$ electron, one group of Rydberg series converging to the $^2P_{3/2}$ state of the argon ion consists of one series with the configuration $(^2P_{3/2})ns$ $(^2n \geq 4)$, and two series with the configuration $(^2P_{3/2})nd$

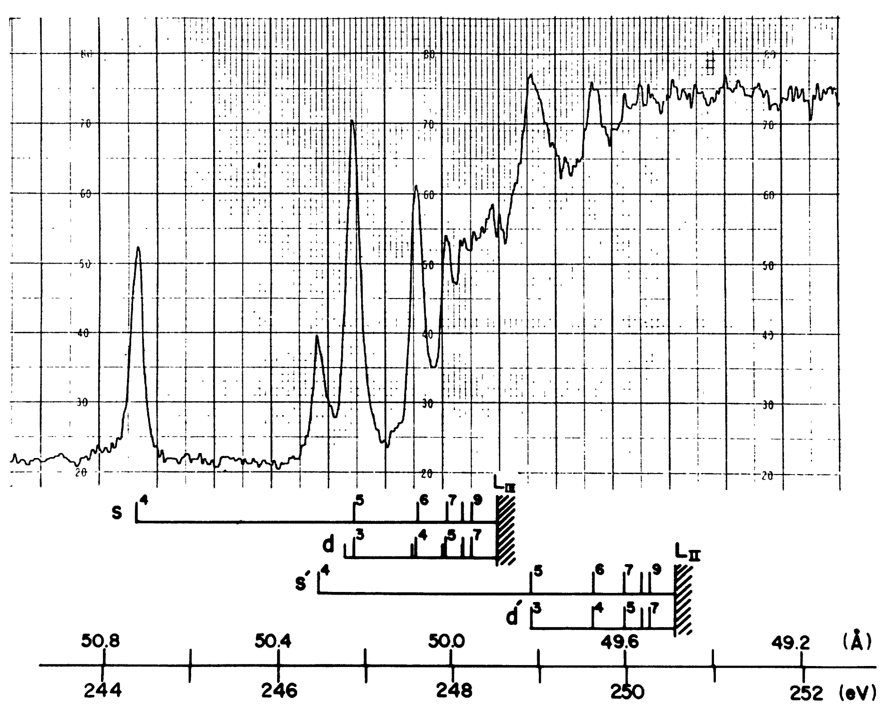

FIG. 2. Densitometer trace of Ar L absorption spectrum. This trace is of the spectrum shown in Fig. 1.

Table I. Values of L_{II} and L_{III} energy levels of argon.

	Wave number (cm^{-1})	Energy (eV)	Wavelength (Å)
L_{III}	2 004 500 ± 500	248.52 ± 0.05	49.887 ± 0.01
L_{II}	2 020 900 ± 500	250.55 ± 0.05	49.480 ± 0.01

($n \geq 3$). The other group of Rydberg series converging to the $^2P_{1/2}$ state of the argon ion consists of two series with the configurations $(^2P_{1/2})ns'$ ($n \geq 4$) and $(^2P_{1/2})nd'$ ($n \geq 3$). The absorption lines obtained in the present experiment have been assigned tentatively on the basis of optical absorption data[5] and on the assumption that the coupling between nd and $2p$ electrons is weak. Such an assignment is shown in Figs. 1 and 2. In the present absorption spectrum, each pair with same quantum number m in the members of two series, $(^2P_{3/2})ms$ levels and $(^2P_{3/2})(m-2)d$ doublet levels, is not resolved. This insufficient resolution may be attributed to the fact that either the linewidth itself is broad because of the short lifetime of such a highly excited state or these lines lie too close beyond the resolution of the spectrograph used.

The levels with configurations $(^2P_{1/2})ns'$ ($n \geq 5$) and $(^2P_{1/2})nd'$ ($n \geq 3$) lie in the photoionization continuum following the $^2P_{3/2}$ state of the ion, i.e., the L_{III} edge. Therefore, it is expected that the absorption lines corresponding to excitation to these levels will show an anomaly of the Beutler-Fano type due to autoionization as found first by Beutler[6] in the case of optical absorption resulting from excitation of a $3p$ electron in the 780-Å region and studied later in detail by Huffman, Tanaka, and Larrabee.[7] It can actually be seen in Fig. 2 that the lines lying in the L_{III} ionization continuum are apparently broadened and show asymmetric shapes.

The wave numbers of the L_{II} and L_{III} absorption edges were calculated by means of a simple Rydberg formula using the wave numbers of observed members. The preliminary values thus obtained are listed in Table I together with the corresponding wavelengths and energies in eV. From the values thus obtained for the L_{II} and L_{III} edges, it is found that the spin-orbit splitting of L_{II} and L_{III} levels of the free argon atom is 2.03 ± 0.01 eV. This value is quite reasonable for argon and is in good agreement with the value 2.07 eV obtained from the K_α emission.[8]

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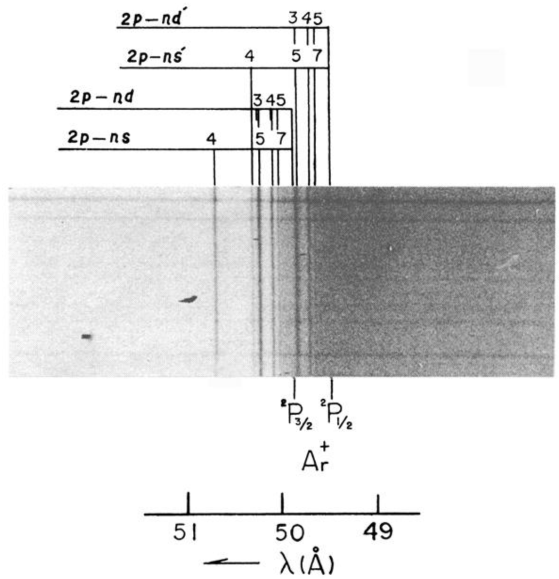

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