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RESONANCES IN THE PHOTOIONIZATION CONTINUUM OF LITHIUM I (55 TO 70 eV)

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Abstract. — Resonances in the photoionization continuum of lithium have been observed by absorption spectroscopy in the region of 55 to 70 eV. These resonances are associated with configurations of the type $(1s\ 2s\ n'l)$ and $(1s\ n'l\ n'1)$ and lie more than 50 eV above the ionization potential; the lowest lying most prominent of these can be identified with configurations of the type $(1s\ 2s\ n\ p)^2P$. A multiconfiguration calculation for the first five members of the series (performed by A. Weiss) has yielded values for the energies which agree with experimental results to within 2 eV.

The design of the lithium vapor absorption furnace was based on the heat-pipe principle. Argon, which has very little structure in the region from 55 to 70 eV, was used as a buffer gas and was contained inside the furnace by thin film aluminum windows. The light source was the 180 MeV NBS synchrotron.

1. The Heat-Pipe Oven. An Absorption Furnace for Far U. V. Spectroscopy.

1.1 THE CONTAINMENT PROBLEM. — Before the work described in this report, the use of the NBS 180 MeV synchrotron as a continuum light source for far ultraviolet absorption spectroscopy had been limited to such gases as the noble gases helium through xenon, oxygen, carbon monoxide and nitrogen. For proper operation of the synchrotron a vacuum of about 10^{-5} torr must be maintained inside the toroid. This required that the gas or vapor under investigation be contained either by thin film windows or narrow slits. Because the amount of light entering the spectrograph is dependent on the solid angle subtended by the toroidal collecting mirror focussed on the spectrograph entrance slit, sufficiently narrow slits could not be placed between the spectrograph and the synchrotron without considerable loss of signal. To overcome this difficulty in the experiments on the rare gases, the spectrograph itself was used as an absorption cell with the spectrograph entrance slit serving to contain the gas; obviously, only a nonreactive gas at room temperature could be studied in this manner. With the use of thin film windows, large apertures could be used and a separate absorption cell could be inserted between the spectrograph and the synchrotron. However, only gases and vapors which would not react with the windows could be studied.

For substances which are solid or liquid at room temperature, an oven having many sets of cooled baffles with small apertures or slits offered a possible solution. Some difficulties with this type of oven are :

- 1) the attenuation of signal due to the slits,
- 2) the need for frequent replenishment of the material being evaporated and for frequent cleaning of the baffles which tend to clog with the condensate,
- 3) the need for a buffer gas which insures effective operation of the baffles, but which can cause considerable attenuation of signal and pumping problems,
- 4) the problem of determining the optical density of the vapor component of the poorly defined vapor-buffer gas mixture.

1.2 THE HEAT-PIPE. — The heat-pipe oven which has been developed quite recently offered a solution to the containment problem. Interest in the heat-

pipe as a high-heat conductivity device has been sparked by the high-heat transfer requirements of nuclear power stations and space-flight packages. Essentially, a heat-pipe utilizes the evaporation and condensation of a working fluid to transfer heat; the working fluid is returned from the region of condensation to the region of evaporation by means of a wick, and a continuous closed cycle is developed. Typical conductivity is about three orders of magnitude greater than that of pure copper of the same cross section.

The use of the heat-pipe principle in an absorption oven was developed by C. R. Vidal and J. Cooper [1] at the NBS, Boulder Laboratories. The essential ingredient necessary for making a heat-pipe into a spectroscopic absorption oven is the addition of a buffer gas.

For our experiment we use argon as the buffer and thin film aluminum windows to separate the inside of the heat-pipe furnace from the vacuum of the synchrotron and spectrograph (see Fig. 1). Heat is

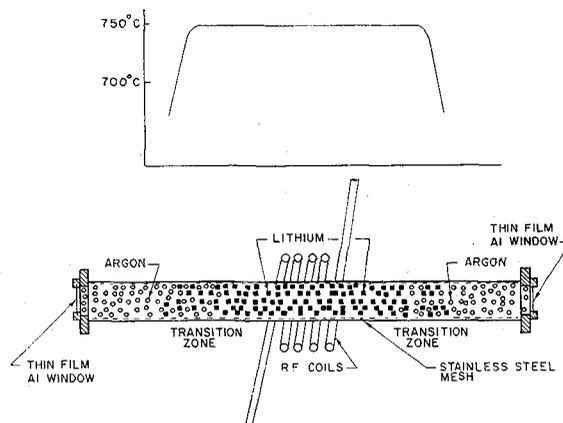


FIG. 1. — Schematic of heat-pipe oven showing typical temperature profile.

applied to the center of the furnace tube through the action of currents induced by a short solenoid connected to a radio-frequency generator. Lithium evaporates from the heated region and condenses in the slightly cooler adjacent regions, creating an almost isothermal section of pipe. The resultant mass motion of the lithium vapor away from the heated region

states assignments are shown in figure 3. However, it is presently felt that the structure of the broad absorption feature may indicate the presence of another resonance overlapping the $(1s\ 2s\ ^1S)3p$ resonance, and a full explanation for the spectrum in this region awaits further clarification by more detailed calculations. The broad increases in absorption directly below the 2^3S and 2^1S limits are probably attributable to the limit effect — a crowding of series members approaching the limit. In the region starting immediately below the 2^3P limit and extending to the 2^1P limit there exists a well-defined Rydberg series, $(1s\ 2p\ ^1P)ns$ ($n = 4, 5, \dots$), with an almost constant quantum defect of 0.6.

3. Future Plans. — These results are of a preliminary nature, and much work remains to give a

more complete account of the lithium spectrum. Data will be taken at higher pressures and longer path-lengths to bring out the weaker lines and to measure the continuum absorption. More extensive use of the three-meter monochrometer should provide information on line profiles and absolute cross section data. The wavelength region below 170 Å will be studied by using thin film windows of plastic, carbon or beryllium instead of the present ones of aluminum.

Finally, efforts will be made to separate the molecular lines from the atomic lines by varying the optical density of the molecules while keeping the optical density of the atoms constant. This variation can be achieved easily in a heat-pipe by varying the pressure and thereby the molecular concentration while, at the same time, adjusting the path-length to keep the atomic optical density constant.

DISCUSSION

JØRGENSEN (Geneva). — I'm sorry but I am not familiar with that work.

M. O. KRAUSE. — The length of time before the windows cloud over depends on the pressure and the length of buffer gas separating the lithium from the windows. We are rather conservative and have a five-cm buffer zone (tube diameter 2 cm, approximate transition zone length 2 cm, pressure 2 torr). We have not noticed any appreciable clouding in twenty or so hours of operation. I've also heard of others who have used heat-pipe ovens with slightly longer buffer zones and higher pressures for months without replacing windows.

Mc GUIRE. — This is a question of finding oven materials which can withstand the molten element of interest at elevated temperatures and finding mesh material for the wick which will be wetted by the element. It seems that all of the alkalis can be used in a stainless oven such as ours. I know of an oven operating with barium, and I think the alkaline earths should not be too difficult.

WEISSLER. — *a*) It is reasonable to assume that the constitution of the transition zone where the lithium and buffer gas are mixed does not depend on the length of the almost isothermal hot zone containing the lithium vapor. Since there is a sharp falloff in temperature marking the end of the hot zone, it is fairly easy to determine the differences in the length of this zone (with the aid of a pyrometer) for two different power inputs. If data is taken at two different lengths but at the same pressure, and the diffe-

rence in the lengths is known, the effects of the transition zones can be subtracted out.

b) The percentage molecular concentration varies with the pressure. For instance, at 1 torr the molecular concentration is about 3 %, while at 20 torr it is about 7 %. By taking data at 1 torr at a given path-length and at 20 torr at one-twentieth of that path-length, we should be able to see a factor of two change in the molecular absorption while the atomic absorption remains constant.

JØRGENSEN (Geneva). — Do you happen to know the positions of the absorption bands due to primary ionization of 1 s of lithium in crystalline lithium fluoride studied by A. Milgram and M. P. Givens: *Phys. Rev.* 1962, **125**, 1506? It would be interesting to compare the influence of the Madelung potential with your data for neutral lithium and the atomic spectra of Li^+ .

KRAUSE M. O. — How long can you operate the heat pipe oven before you need to replace the windows due to deposition of Li metal.

Mc GUIRE. — Question—What materials besides Li can be used in the heat pipe?

WEISSLER. — The heat-pipe reminds me of Prof. Ditchburns earlier work.

Question *a*: How do you propose to take into account the end effects where the buffer gas, argon, is mixed with Li, in order to determine number densities necessary to get cross sections?

Question *b*: How do you propose to separate the effects of molecules from atoms?

References

- [1] VIDAL (C. R.) and COOPER (J.), *J. Appl. Phys.*, 1969, **40**, 3370.
- [2] WEISS (A.), to be published.
- [3] COOPER (J. W.), CONNEELY (M. J.), SMITH (K.) and ORMONDE (S.), *Phys. Rev. Letters*, **25**, 1540.