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Additions to the Spectra LiI^a, LiI^b and LiII^a

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Abstract

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Six new spectral lines have been observed in the lithium spectrum between 200 nm and 600 nm. Possible classifications are given and discussed.

1. Introduction

In a beam-foil experiment in which low energy $^7Li^+$ ions were sent through thin carbon foils, spectral lines which did not correspond to previously published transitions in lithium were observed in the wavelength region 200–600 nm. The photon spectra of lithium have been studied extensively with high resolution spectroscopy [1–4]. However, several transitions between highly excited LiI^a levels and LiII^a levels are not known. Because of this, and since the level structure of doubly excited, neutral lithium (LiI^b) is only partly known [5], it was felt worthwhile to study the above-mentioned new spectral lines, though the beam-foil source is known to be hampered by a relatively broad linewidth and a consequently poor wavelength determination.

2. Experimental procedure and spectrum analysis

A 700 nA beam of $^7Li^+$ ions, accelerated to energies between 20 keV and 70 keV, has been sent through thin (3–4 μg/cm^2) foils of carbon. The radiating beam immediately after the foil was viewed with a scanning monochromator. The accelerator and detecting system have been described previously [6].

The spectra were studied in the wavelength region of 200–600 nm; second order lines were eliminated by using two filters which absorbed radiation below 390 nm and 500 nm.

In order to make proper identifications of the new lines, spectrograms were recorded at observation angles of 45° and 90° with respect to the beam propagation direction. At 45° the projectile lines are noticeably Doppler shifted. In this way, lines emitted from species sputtered from the foil, which have a very small Doppler shift, can be identified [7]. By applying this procedure, one line (observed at $\lambda = 486.1$ nm) was found to be emitted from sputtered particles, most probably hydrogen (H_β, $\lambda = 486.13$ nm). The remaining unknown lines were found to Doppler shift like the known projectile lines.

As an attempt to classify the new lines, excitation functions were measured in the wavelength range 20 keV–70 keV. This technique for charge state assignment has been discussed recently [8], and the similarity between excitation functions for LiI^b levels and LiII^a levels has been pointed out. Some uncertainty in the excitation function measurements was caused partly by the low intensities of the new lines, and because of near lying strong transitions and a continuous radiation from the foil. Therefore it was not in this way possible to differentiate between new LiI^b lines and LiII^a lines, whereas transitions between LiI^a levels could be classified with no ambiguities.

As a further help in the identification a computer program [9] was used to calculate wavelengths from known and extrapolated LiI^a levels and LiII^a levels. Energy levels of Moore [10] were used except for cases discussed later. Wavelengths for allowed, forbidden and intercombination lines were calculated and compared to the new lines.

The new lines are listed in Table I. The wavelengths are those measured in air. The estimated uncertainty of the wavelength determinations is 0.05 nm.

3. Discussion

3.1. *λ 357.98 nm.* From the excitation function, this spectral line is classified as a LiI^a transition. In Table II are listed $2p\,^2P$–$nd\,^2D$ LiI^a transitions ($n = 10$, 11, and 12) taken from Werner [2]. These transitions are not given in standard wavelength tables [11]. The energy levels in Table II were taken from ref. [2]. The λ 357.98 nm line may be identified as the $2p\,^2P$–$13d\,^2D$ LiI^a transition.

3.2. *λ 484.30 nm.* The LiII^a $3d\,^3D$–$4p\,^3P^0$ transition has a computed wavelength of 484.30 nm, using the energy levels of Herzberg and Moore [3], but it has never been reported in the literature. The calculated value compares well with the measured one.

3.3. *λ 217.34 nm and λ 246.02 nm.* These two spectral lines are assigned to the LiI^b spectrum. They agree with the theoretical predictions by Holøien and Geltman [12] for the transitions LiI^b $1s2s2p\,^4P^0$–$1s2s4s\,^4S$ ($\Delta E_{\text{theory}} = 5.71$ eV, $\Delta E_{\text{exp}} = 5.71$ eV)

Table I. *New lines in lithium*

Measured wavelength (in nm$\pm$0.05 nm)	Excitation function	Possible identification
203.96	LiI^b or LiII^a	
217.34	LiI^b or LiII^a	LiI^b $1s2s2p\,^4P^0$–$1s2s4s\,^4S$
246.02	LiI^b or LiII^a	LiI^b $1s23sp$–$^4P^0$–$1s2p6p\,^4P$
357.98	LiI^a	LiI^a $2p\,^2P^0$–$13d\,^2D$
484.30	LiI^b or LiII^a	LiII^a $3d\,^3D$–$4p\,^3P^0$
531.54	LiI^b or LiII^a	

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Table II. $2p\,^2P^0$–$nd\,^2D$ LiI[a] *Transitions* (n=*10–13*)

Upper level	Energy level (cm^{-1})	Wavelength from Werner [2] (in nm ± 0.03 nm)	Wavelength this work (in nm)
$10d\,^2D$	42 389.[a]	363.72	363.68(±0.05)
$11d\,^2D$	42 578.[a]	361.23	Blended
$12d\,^2D$	42 725.[a]	359.33	359.33(±0.05)
$13d\,^2D$	42 837.68(±0.02)[b]		357.887(±0.001)[b]
	42 830.(±4.00)[c]		357.98(±0.05)[c]

[a] Values from Werner [2].
[b] Calculated from polarization formula [4] and corresponding wavelength.
[c] Measured wavelength and corresponding energy level.

and LiI[b] $1s23sp$–$^4P^0$–$1s2p6p\,^4P$ ($\Delta E_{\text{theory}}=5.05$ eV, $\Delta E_{\text{exp}}=5.04$ eV). It may be argued that the transition LiI[b] $1s23sp$–$^4P^0$–$1s2p4p\,^4P$ ($\lambda_{\text{theory}}\cong 412$ nm) has not been observed. This transition may, however, be masked by the strong λ 413.26 nm LiI[a] $2p\,^2P^0$–$5d\,^2D$ transition. An earlier reported line (λ 366.2 nm) has tentatively been identified [5] as the transition LiI[b] $1s23sp$–$^4P^0$ – $1s2p5p\,^4P$, but it may also be a transition between doubly excited doublet levels in neutral Li [13].

3.4. *λ 203.96 nm and λ 531.54 nm.* These two spectral lines are also assigned to the LiI[b] spectrum, since they do not fit into the LiII[a] level scheme. They are not predicted from the present theoretical LiI[b] level calculations.

The wavelength of a LiI[b] line earlier observed at 527.1 nm ±0.3 nm [13] has, in this work, been determined to be 526.72 nm ±0.05 nm.

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