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Spectral analysis of the fifth spectrum of indium: In V

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ABSTRACT

The fifth spectrum of indium (In V) has been investigated in the grazing and normal incidence wavelength regions. In^{4+} is a Rh-like ion with the ground configuration $4p^64d^9$ and first excited configurations of the type $4p^64d^8n\ell$ ($n \geq 4$). The theoretical predications for this ion were made by Cowan's quasi-relativistic Hartree–Fock code with superposition of configurations involving $4p^64d^8$(5p+6p+7p+4f+5f+6f), $4p^54d^{10}$, $4p^64d^75s$(5p+4f) for the odd parity matrix and $4p^64d^8$ (5s+6s+7s+5d+6d), $4p^64d^7(5s^2+5p^2)$ for the even parity system. The spectra used for this work were recorded on 10.7 m grazing and normal incidence spectrographs at the National Institute of Standards and Technology, Gaithersburg, Maryland (USA) and also on a 3-m normal incidence vacuum spectrograph at Antigonish (Canada). The sources used were a sliding spark and a triggered spark respectively. Two hundred and thirty two energy levels based on the identification of 873 spectral lines have been established, forty six being new. Least squares fitted parametric calculations were used to interpret the observed level structure. The energy levels were optimized using a level optimization computer program (LOPT). Our wavelength accuracy for sharp and unblended lines is estimated to be within ±0.005 Å for λ below 400 Å and ±0.006 Å up to 1200 Å.

1. Introduction

The importance of atomic data of indium spectra has acknowledged as one of the most valuable sources to understand the atomic structure and properties of atom/ions [1]. The emissions of open-shell atomic ions are also used in astrophysics and fusion research and in the development of EUV light source [2,3]. The fifth spectrum of indium (In V) investigated here is a member of the Rh I isoelectronic sequence. It has the ground configuration $4p^64d^9$ and the lowest excited configurations are of the type of $4p^64d^8n\ell$ ($n \geq 4, \ell \geq 0$). The core excitation leads to $4p^54d^{10}$ and further excitations are $4p^64d^75s$(5p+4f), $4p^64d^7(5s^2+5p^2)$ etc. The first work on In V was carried out by Green [4], followed by others [5–8]. The levels of the $4p^64d^9$, $4p^64d^85p$ and $4p^64d^85s$ configurations were established by Joshi et al. [5] and van Kleef et al. [6]. The analysis was further extended by Srivastava et al. [7]. They reported 45 out of 83 energy levels of the $4p^64d^8$(5d+6s) configurations. Recently, Ryabtsev et al. [8] investigated the $4p^64d^9$-$4p^64d^8$(4f+6p) transition array. In the present analysis, we have been incorporated all the previously reported levels of In V and have added 46 new energy levels belonging to the $4p^64d^8$ (5d+6s) and $4p^64d^8$(5f+7p) configurations.

2. Experimental details

The spectrum of indium was recorded on both normal and grazing incidence spectrographs. The grazing incidence spectrum covers the wavelength region 190–575 Å

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Table 1
Classified lines of In V.

I_{obs}[a]	Char[b]	λ^{c}_{obs}(Å)	σ_{obs} (cm^{-1})	λ^{d} Ritz	$\delta\lambda^{e}_{O\text{-}Ritz}$ (Å)	Classification[f]	E_{low} (cm^{-1})	E_{upper} (cm^{-1})	gA[g] (s^{-1})	C. F[h]	Ref[i]
120		204.808 (5)	488261			4d^9 (^{1}S)^{2}D$_{5/2}$ – 7p (^{3}P)^{2}P$_{3/2}$	0.0	488261	6.72E+09	#	TW
110		205.249 (5)	487213			4d^9 (^{1}S)^{2}D$_{3/2}$ – 7p (^{1}D)^{2}F$_{5/2}$	7171.8	494384	2.98E+10	#	TW
45		206.462 (5)	484351			4d^9 (^{1}S)^{2}D$_{5/2}$ – 5f (^{1}G)^{2}F$_{7/2}$	0.0	484351	1.64E+10	#	TW
80		206.829 (5)	483492			4d^9 (^{1}S)^{2}D$_{5/2}$ – 5f (^{3}P)^{4}D$_{7/2}$	0.0	483492	1.36E+10	#	TW
70		207.323 (5)	482340			4d^9 (^{1}S)^{2}D$_{5/2}$ – 5f (^{3}P)^{2}G$_{7/2}$	0.0	482340	5.55E+09	#	TW
15		209.595 (5)	477111			4d^9 (^{1}S)^{2}D$_{5/2}$ – 7p (^{3}F)^{4}D$_{5/2}$	0.0	477111	4.37E+09	#	TW
80		209.779 (5)	476692	209.781 (3)	−0.002	4d^9 (^{1}S)^{2}D$_{5/2}$ – 5f (^{3}P)^{2}F$_{5/2}$	0.0	476688	5.96E+10	#	TW
15		210.925 (5)	474102			4d^9 (^{1}S)^{2}D$_{5/2}$ – 5f (^{3}P)^{4}F$_{7/2}$	0.0	474102	1.76E+09	#	TW
35		211.129 (5)	473644	211.125(3)	0.004	4d^9 (^{1}S)^{2}D$_{5/2}$ – 5f (^{3}F)^{2}D$_{5/2}$	0.0	473653	4.32E+10	#	TW
35		211.523 (5)	472762			4d^9 (^{1}S)^{2}D$_{5/2}$ – 7p (^{3}F)^{2}F$_{7/2}$	0.0	472762	2.33E+10	#	TW
10		212.987 (5)	469512	212.985 (4)	0.002	4d^9 (^{1}S)^{2}D$_{3/2}$ – 5f (^{3}P)^{2}F$_{5/2}$	7171.8	476688	5.94E+09	#	TW
110		213.717 (5)	467909			4d^9 (^{1}S)^{2}D$_{3/2}$ – 5f (^{3}P)^{4}F$_{5/2}$	7171.8	475081	1.75E+10	#	TW
25		214.266 (5)	466709			4d^9 (^{1}S)^{2}D$_{5/2}$ – 5f (^{3}F)^{2}P$_{3/2}$	0.0	466709	3.47E+10	#	TW
75		214.357 (5)	466512			4d^9 (^{1}S)^{2}D$_{5/2}$ – 5f (^{3}F)^{4}H$_{7/2}$	0.0	466512	8.83E+08	#	TW
55		214.367 (5)	466489	214.371(4)	−0.004	4d^9 (^{1}S)^{2}D$_{3/2}$ – 5f (^{3}F)^{2}D$_{5/2}$	7171.8	473653	1.04E+10	#	TW
15		215.486 (5)	464068			4d^9 (^{1}S)^{2}D$_{5/2}$ – 5f (^{3}F)^{2}G$_{7/2}$	0.0	464068	5.96E+09		TW
45		216.713 (5)	461440			4d^9 (^{1}S)^{2}D$_{5/2}$ – 5f (^{3}F)^{4}P$_{5/2}$	0.0	461440	1.86E+10		TW
50		216.950 (5)	460936			4d^9 (^{1}S)^{2}D$_{5/2}$ – 5f (^{3}F)^{4}F$_{7/2}$	0.0	460936	2.23E+10	#	TW
70		216.967 (5)	460900			4d^9 (^{1}S)^{2}D$_{5/2}$ – 5f (^{3}F)^{4}D$_{3/2}$	0.0	460900	1.25E+10		TW
30		218.655 (5)	457343			4d^9 (^{1}S)^{2}D$_{5/2}$ – 5f (^{3}F)^{4}D$_{7/2}$	0.0	457342.5	7.87E+08		TW
3		223.467 (5)	447493	223.468 (3)	−0.001	4d^9 (^{1}S)^{2}D$_{5/2}$ – 4f (^{1}S)^{2}F$_{5/2}$	0.0	447491	9.50E+08	#	Ry
150	w	223.995 (5)	446439			4d^9 (^{1}S)^{2}D$_{5/2}$ – 4f (^{1}S)^{2}F$_{7/2}$	0.0	446439	4.73E+10		Ry
160	w	227.109 (5)	440317	227.108(4)	0.001	4d^9 (^{1}S)^{2}D$_{3/2}$ – 4f (^{1}S)^{2}F$_{5/2}$	7171.8	447491	9.42E+10		Ry
50		231.070 (5)	432769			4d^9 (^{1}S)^{2}D$_{5/2}$ – 6p (^{1}G)^{2}G$_{7/2}$	0.0	432769	4.15E+09		Ry
10		231.950 (5)	431127	231.951(3)	−0.001	4d^9 (^{1}S)^{2}D$_{5/2}$ – 6p (^{1}G)^{2}F$_{5/2}$	0.0	431126	5.84E+08		Ry
75		232.306 (5)	430467	232.305 (5)	0.001	4d^9 (^{1}S)^{2}D$_{5/2}$ – 4f (^{3}F)^{2}D$_{3/2}$	0.0	430469	1.60E+10	#	Ry
190	w	232.788 (5)	429575			4d^9 (^{1}S)^{2}D$_{5/2}$ – 6p (^{1}D)^{2}F$_{7/2}$	0.0	429575	1.02E+10		Ry
40		233.005 (5)	429175	233.005 (3)	0.000	4d^9 (^{1}S)^{2}D$_{5/2}$ – 4f (^{3}P)^{2}F$_{5/2}$	0.0	429175	3.13E+09		Ry
10		233.514 (5)	428240	233.514(3)	0.000	4d^9 (^{1}S)^{2}D$_{5/2}$ – 6p (^{1}D)^{2}D$_{5/2}$	0.0	428240	3.02E+09	#	Ry
200		233.797 (5)	427721			4d^9 (^{1}S)^{2}D$_{5/2}$ – 6p (^{1}G)^{2}F$_{7/2}$	0.0	427721	2.37E+11	#	Ry
40		234.083 (5)	427199	234.083 (3)	0.000	4d^9 (^{1}S)^{2}D$_{5/2}$ – 6p (^{3}P)^{2}D$_{3/2}$	0.0	427199	1.84E+09		Ry
90		234.177 (5)	427027	234.177(3)	0.000	4d^9 (^{1}S)^{2}D$_{5/2}$ – 6p (^{1}D)^{2}D$_{3/2}$	0.0	427028	2.26E+10	#	Ry
110		234.416 (5)	426592	234.416(3)	0.000	4d^9 (^{1}S)^{2}D$_{5/2}$ – 6p (^{3}P)^{2}D$_{5/2}$	0.0	426592	1.20E+11		Ry
150		234.770 (5)	425949	234.770 (3)	0.000	4d^9 (^{1}S)^{2}D$_{5/2}$ – 6p (^{1}D)^{2}F$_{5/2}$	0.0	425949	5.59E+10		Ry