International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2024: 7.101

Comprehensive Analysis of Four-Times Ionized Antimony Atoms (Sb V) Using Spectrographic Techniques

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Abstract: ***The spectrum of Four– times ionized antimony (Sb V) was recorded using a 3-meter normal – incidence vacuum spectrograph within the wavelength range of 300A^0 to 2080A^0. Various configurations for both odd and even parity systems were analyzed, and energy levels were categorized. The Cowan Code was utilized for Hartree- Fock calculations with relativistic corrections, along side least squares ftted parametric calculations. A total of 15 energy levels within the 4d95s6p configuration were identified and verified against isoelectronic plots.***

Keywords: Spectroscopy, Isoelectronic Sequence, Ionized Antimony, Atomic Structure, Energy Levels

1. Introduction

The ground state electronic configuration of Sb V is as follows:
$1s^2$, $2s^2$ $2p^6$, $3s^2$ $3p^6$ $3d^{10}$, $4s^2$ $4p^6$ $4d^{10}$

It is a simple one electron doublet spectrum with ground configuration $4d^{10}$ 5s. Work on Sb V was started by Lang [1], then by Gibbs, Vieweg, and Gartlein [2], and lastly by Badami [3]. Chan [4] confirmed all the reported levels in AEL [5] though the level values were revised by as much as 27 cm^{-1} and extended to include the $4d^{10}$ 4f, 6d, 7d, 7s, 7p and $4d^9 5s^2$. Andersen et al [6] measured the life time of some multiplets of Sb IV. Kaufman, Sugar, Van Kleef and Joshi [7] identified 10 transition arising out of the core excitation to $4d^9$5s5p configuration.

The one electron part of the spectrum was investigated without much problem .The levels were also verified on isoelectronic plots. All the levels reported in AEL [5] were confirmed with considerable improvements in their level values. The scaling for these levels were estimated from a least squares fit of Cd II, In III, and Sn IV levels [5, 7]. The analysis was further extended to include $4d^{10}$ 8s, $4d^{10}$ 8p, $4d^{10}$ (5f + 6f + 5g and 6g) levels by author's previous work [11]. The lines used to establish them are showing very clear Sb V characteristics. We see no doubt in its level values as the fitted parameters are in accordance with Cd II and In III [5, 7].

Core excitation results in a more complex spectral structure. While the $4d^9$ 5s 4f offers 39 energy levels, the 4d9 5s 5p only offers 23. Only 10 transitions to this array were identified by Kaufman et al [7] establishing 10 levels of $4d^9$ 5s 5p. Other 4d95s5p levels were identified by author in previous paper [11]. **The analysis was further extended to include configuration $4d^{10}$5s6p and 15 energy levels has been established**. This Study enhances the understanding of Sb V energy levels, contributing to atomic spectroscopy by refining existing spectral data through modern computational techniques.

This study aims to analyze and classify the energy levels of four- times ionized antimony (Sb V) through spectrographic techniques, utilizing Hartree- Fock calculations and least-squares fitting to verify level values. Since $4d^{10}$5s - $4d^9$5s4f transitions lie in a very short wavelength region (grazing incidence) is out of our region of investigation, therefore, could not established.

<u>The Term Structure</u>:

Ground Configuration: $4d^{10}$ 5s: ^{2}S
Only J=1/2 and 3/2 levels of this configuration could be established since ground level is ^{2}S1/2.

Excited Configurations:
(i) **One electron part**
$4d^{10}$ np (n $\geq$ 5): ^{2}P
$4d^{10}$ nd (n $\geq$ 5): ^{2}D
$4d^{10}$ nf (n $\geq$ 4): ^{2}F
$4d^{10}$ ns (n $\geq$ 6): ^{2}S
$4d^{10}$ ng (n $\geq$ 5): ^{2}G
or in general $4d^{10}$nl: ^{2}L

(ii**) Core Excited Configurations**:
$4d^9$ 5s5p: (^{3}D) ^{4}D, (^{3}D) ^{4}P, (^{3}D) ^{4}F, (^{3}D) ^{2}D, (^{3}D) ^{2}F, (^{1}D) ^{2}P, (^{1}D) ^{2}D, (^{1}D) ^{2}F, (^{1}D) ^{2}F,
$4d^9$ 5s4f : (^{3}H) ^{4}H, (^{3}H) ^{2}H, (^{3}G) ^{4}G, (^{3}G) ^{2}G, (^{3}F) ^{4}F, (^{3}F) ^{2}F, (^{3}D) ^{4}D, (^{3}D) ^{2}D, (^{3}P)
^{4}P, (^{3}P) ^{2}P, (^{1}H) ^{2}H, (^{1}G) ^{2}G, (^{1}F) ^{2}F, (^{1}D) ^{2}D, (^{1}P) ^{2}P,
$4d^9$ 5s5d: (^{3}D) ^{4}G, (^{3}D) ^{4}F, (^{3}D) ^{4}D, (^{3}D) ^{4}P, (^{3}D) ^{4}S, (^{3}D) ^{2}G, (^{3}D) ^{2}F, (^{3}D) ^{2}D,
(^{3}D) ^{2}P, (^{3}D) ^{2}S, (^{1}D) ^{2}G, (^{1}D) ^{2}F, (^{1}D) ^{2}D, (^{1}D) ^{2}P, (^{1}D) ^{2}S
$4d^9$5s6s: (^{3}D) ^{4}D, (^{3}D) ^{2}D, (^{1}D) ^{2}D,

2. Experimental Procedures

The spectrograph is an effective instrument for analyzing the characteristics and nature of the substance that emits radiation as well as for figuring out the structure of the atoms or molecules. Most of the data used in this study were obtained from plates recorded using a 3-meter normal- incidence vacuum spectrograph at the Department of Physics, Saint Francis Xavier University, Antigonish, Nova Scotia, Canada. A 3-meter osmium-coated holographic concave grating with 2400 lines/mm is part of the spectrograph. At 1200 Å, it is blazed. The spectrograph's first-order inverse dispersion is 1.385 Å/mm. From 250Å to 2100 Å, the dispersion varies by less than 0.5 percent, remaining nearly constant across the range. Two plates that are 15 inches long can fit in the 76-cm-long plate holder. One can take pictures of a wavelength range of about 1000Å in a single setting.

Light Source:

Triggered Spark, a customized Spark source, was the light source used for the current spectral recordings. The source is somewhat comparable to a vacuum spark source. The only difference is that a 30 KV trigger module TM -11A pulsed transformer may provide a considerably better regulated spark for extremely low voltages (~ 2kV) as well as even for very high voltages (~ 15 – 20 KV). A 14μF quick charging low inductance capacitor that can be charged up to 20 KV makes up the charging condenser bank. To achieve a very high degree of ionization, a large condenser bank of 120 μF (an assembly of three capacitors) and a parallel combination of 14 μF capacitors are also utilized, depending on the situation.

3. Results and Discussion

The 4d95s(5p+6p) – 4d95s (5d + 6s) transitions are located in a very favorable wavelength region on our plate, where ionization separation was reasonably good, it should be noted. However, there were several classified Sb VI [8–11] and Sb VII [10, 12, 13] lines that overlapped practically the whole transition array, making this region extremely crowded. This is problematic because these lines were mixed with a number of anticipated transitions.

Finally, a large number of configurations were included into the least squares fit to incorporate all the possible interactions for the even parity system $4d^{10}$ (5s + 6s + 7s + 8s + 5d + 6d + 7d + 5g + 6g) + $4d^9 5s^2$ + $4d^9$5s5d and $4d^9$5s6s configurations were included, while $4d^{10}$ (5p + 6p + 7p + 8p + 4f + 5f + 6f) + $4d^9$5s5p, and $4d^9$5s4f were run together for odd parity matrix [11]. The study was expanded with configuration $4d^{10}$5s6p, and 15 energy levels were determined listed in table 1**.**

Table 1 aggregates the observed and Least Squares Fitted (LSF) Energy Levels in cm^{-1} for odd parity while Table 2 displays the least squares fitted parameters in (cm^{-1}) for each level of odd parity configuration.

Table 1: Observed and Least Squares Fitted (LSF) Energy Levels in cm^{-1} for Odd Parity Configurations of Sb V

J	E(obs)	E(LSF)	diff.	LS-composition.
1/2	81568.0	81568.0	0.0	100% 4d10 5p 2P
	254406.0	254406.0	0.0	100% 4d10 6p 2P
	307801.0	307736.0	65.0	83% 4d9 5s 5p (3D)4P + 9% 4d9 5s 5p (3D)4D
				+ 7% 4d9 5s 5p (1D)2P
	316429.0	316213.0	216.0	70% 4d9 5s 5p (1D)2P + 22% 4d9 5s 5p (3D)2P
				+ 7% 4d9 5s 5p (3D)4P
	316922.0	317000.0	-78.0	88% 4d9 5s 5p (3D)4D + 10% 4d9 5s 5p (3D)4P
	323316.0	323316.0	0.0	99% 4d10 7p 2P
	-	342384.0	-	75% 4d9 5s 5p (3D)2P + 22% 4d9 5s 5p (1D)2P
	357434.0	357434.0	0.0	100% 4d10 8p 2P
	-	466011.0	-	98% 4d9 4f 5s (3P)4P
	-	474468.0	-	60% 4d9 4f 5s (1P)2P + 21% 4d9 4f 5s (3D)4D
				+ 18% 4d9 4f 5s (3P)2P
	-	480137.0	-	77% 4d9 4f 5s (3D)4D + 12% 4d9 4f 5s (1P)2P
				+ 9% 4d9 4f 5s (3P)2P
	496526.4	**496619.0**	**-92.6**	**38% 4d9 5s 6p (1D)2P + 32% 4d9 5s 6p (3D)4P**
				+ 16% 4d9 5s 6p (3D)2P + 13% 4d9 5s 6p (3D)4D
	502552.8	**502497.0**	**55.8**	**49% 4d9 5s 6p (3D)4P + 34% 4d9 5s 6p (3D)2P**
				+ 13% 4d9 5s 6p (1D)2P
	503585.0	**503679.0**	**-94.0**	**73% 4d9 5s 6p (3D)4D + 18% 4d9 5s 6p (3D)4P**
				+ 8% 4d9 5s 6p (3D)2P
	507815.8	**507802.0**	**13.8**	**48% 4d9 5s 6p (1D)2P + 39% 4d9 5s 6p (3D)2P**
				+ 11% 4d9 5s 6p (3D)4D
	-	530316.0	-	71% 4d9 4f 5s (3P)2P + 26% 4d9 4f 5s (1P)2P
	-	569610.0	-	39% 4d9 5s 7p (1D)2P + 23% 4d9 5s 7p (3D)2P
				+ 23% 4d9 5s 7p (3D)4P + 15% 4d9 5s 7p (3D)4D
	576334.8	576196.0	138.8	48% 4d9 5s 7p (3D)2P + 30% 4d9 5s 7p (3D)4P
				+ 19% 4d9 5s 7p (3D)4D
	576674.0	576688.0	-14.0	54% 4d9 5s 7p (3D)4D + 44% 4d9 5s 7p (3D)4P
	579633.6	579641.0	-7.4	58% 4d9 5s 7p (1D)2P + 28% 4d9 5s 7p (3D)2P
				+ 11% 4d9 5s 7p (3D)4D
3/2	90560.0	90560.0	0.0	100% 4d10 5p 2P
	257605.0	257605.0	0.0	100% 4d10 6p 2P
	301188.0	301481.0	293.0	70% 4d9 5s 5p (3D)4P + 15% 4d9 5s 5p (3D)4D
				+ 8% 4d9 5s 5p (1D)2P + 4% 4d9 5s 5p (3D)4F
		306326.0	-	86% 4d9 5s 5p (3D)4F + 10% 4d9 5s 5p (3D)4P
	311835.0	312134.0	299.0	42% 4d9 5s 5p (1D)2D + 16% 4d9 5s 5p (3D)2D
				+ 13% 4d9 5s 5p (3D)4P + 12% 4d9 5s 5p (1D)2P

	315644.0	315633.0	11.0	60% 4d9 5s 5p (1D)2P + 23% 4d9 5s 5p (3D)4D
				+ 12% 4d9 5s 5p (3D)2P
	320856.0	320624.0	232.0	48% 4d9 5s 5p (3D)4D + 24% 4d9 5s 5p (1D)2D
				+ 11% 4d9 5s 5p (3D)2D + 8% 4d9 5s 5p (1D)2P
	324893.0	324887.0	6.0	98% 4d10 7p 2P
	333472.0	333830.0	-358.0	84% 4d9 5s 5p (3D)2P + 9% 4d9 5s 5p (1D)2P
	349574.0	349603.0	-29.0	66% 4d9 5s 5p (3D)2D + 29% 4d9 5s 5p (1D)2D
	-	358241.0	-	100% 4d10 8p 2P
	-	467289.0	-	94% 4d9 4f 5s (3P)4P + 5% 4d9 4f 5s (3D)4D
	-	476382.0	-	44% 4d9 4f 5s (1P)2P + 33% 4d9 4f 5s (3D)4D
				+ 10% 4d9 4f 5s (3P)2P + 8% 4d9 4f 5s (3D)2D
	-	476827.0	-	40% 4d9 4f 5s (3F)4F + 25% 4d9 4f 5s (3D)2D
				+ 16% 4d9 4f 5s (1D)2D + 11% 4d9 4f 5s (3D)4D
	-	481814.0	-	48% 4d9 4f 5s (3D)4D + 18% 4d9 4f 5s (1D)2D
				+ 11% 4d9 4f 5s (1P)2P + 10% 4d9 4f 5s (3F)4F
	-	486427.0	-	40% 4d9 4f 5s (3F)4F + 39% 4d9 4f 5s (3D)2D
				+ 12% 4d9 4f 5s (1D)2D + 6% 4d9 4f 5s (1P)2P
	-	489342.0	-	52% 4d9 4f 5s (1D)2D + 28% 4d9 4f 5s (3D)2D
				+ 10% 4d9 4f 5s (1P)2P + 6% 4d9 4f 5s (3F)4F
	493475.0	**493445.0**	**30.0**	**53% 4d9 5s 6p (3D)4P + 20% 4d9 5s 6p (1D)2P**
				+ 20% 4d9 5s 6p (3D)4D
	496526.0	**496459.0**	**67.0**	**35% 4d9 5s 6p (3D)2P + 24% 4d9 5s 6p (1D)2D**
				+ 14% 4d9 5s 6p (3D)4P + 13% 4d9 5s 6p (3D)4F
	497549.4	**497557.0**	**-7.6**	**47% 4d9 5s 6p (3D)2P + 17% 4d9 5s 6p (3D)2D**
				+ 14% 4d9 5s 6p (1D)2P + 9% 4d9 5s 6p (3D)4F
	501346.7	**501373.0**	**-26.3**	**72% 4d9 5s 6p (3D)4F + 16% 4d9 5s 6p (3D)2D**
				+ 7% 4d9 5s 6p (1D)2D
	504112.3	**504010.0**	**-102.3**	**57% 4d9 5s 6p (1D)2P + 24% 4d9 5s 6p (3D)4P**
				+ 14% 4d9 5s 6p (3D)2P
	505409.0	**505311.0**	**98.0**	**63% 4d9 5s 6p (3D)4D + 15% 4d9 5s 6p (1D)2D**
				+ 13% 4d9 5s 6p (3D)2D + 6% 4d9 5s 6p (3D)4P
	510553.0	**510581.0**	**-28.0**	**46% 4d9 5s 6p (3D)2D + 44% 4d9 5s 6p (1D)2D**
				+ 6% 4d9 5s 6p (1D)2P
	-	530502.0	-	76% 4d9 4f 5s (3P)2P + 20% 4d9 4f 5s (1P)2P
	567366.8	567424.0	-57.2	45% 4d9 5s 7p (3D)4P + 23% 4d9 5s 7p (3D)4D
				+ 13% 4d9 5s 7p (1D)2P + 10% 4d9 5s 7p (3D)2P
	568346.9	568464.0	-117.1	73% 4d9 5s 7p (3D)2P + 13% 4d9 5s 7p (1D)2P+ 8% 4d9 5s 7p (1D)2D
	-	569497.0	-	28% 4d9 5s 7p (3D)2D + 25% 4d9 5s 7p (1D)2D
				+ 17% 4d9 5s 7p (3D)4P + 10% 4d9 5s 7p (1D)2P
	575572.8	575464.0	108.8	81% 4d9 5s 7p (3D)4F + 14% 4d9 5s 7p (3D)2D
	577342.3	577434.0	-91.7	41% 4d9 5s 7p (3D)4D + 26% 4d9 5s 7p (3D)4P
				+ 20% 4d9 5s 7p (3D)2D + 5% 4d9 5s 7p (1D)2P
	578232.0	578254.0	-22.0	48% 4d9 5s 7p (1D)2P + 21% 4d9 5s 7p (3D)4D
				+ 12% 4d9 5s 7p (1D)2D + 9% 4d9 5s 7p (3D)2P
	580765.4	580702.0	63.4	49% 4d9 5s 7p (1D)2D + 33% 4d9 5s 7p (3D)2D
				+ 10% 4d9 5s 7p (1D)2P
5/2	247129.0	247280.0	-151.0	100% 4d10 4f 2F
	295895.0	295507.0	388.0	88% 4d9 5s 5p (3D)4P + 10% 4d9 5s 5p (3D)4D
	301324.0	301147.0	177.0	57% 4d9 5s 5p (3D)4F + 24% 4d9 5s 5p (1D)2F
				+ 10% 4d9 5s 5p (3D)2F
	310971.0	311078.0	-107.0	41% 4d9 5s 5p (1D)2F + 30% 4d9 5s 5p (3D)4D
				+ 10% 4d9 5s 5p (3D)4F + 8% 4d9 5s 5p (3D)2F
	-	313851.0	-	25% 4d9 5s 5p (3D)4D + 24% 4d9 5s 5p (3D)4F
				+ 21% 4d9 5s 5p (1D)2D + 12% 4d9 5s 5p (3D)2D
	-	316167.0	-	93% 4d10 5f 2F
	322412.0	322693.0	-281.0	37% 4d9 5s 5p (1D)2D + 31% 4d9 5s 5p (3D)4D
				+ 23% 4d9 5s 5p (3D)2D + 4% 4d9 5s 5p (3D)4F
	339316.0	339352.0	-36.0	45% 4d9 5s 5p (3D)2D + 28% 4d9 5s 5p (3D)2F
				+ 22% 4d9 5s 5p (1D)2D + 4% 4d9 5s 5p (1D)2F
	345621.0	345183.0	438.0	49% 4d9 5s 5p (3D)2F + 16% 4d9 5s 5p (1D)2F
				+ 16% 4d9 5s 5p (3D)2D + 16% 4d9 5s 5p (1D)2D
	356047.0	356020.0	27.0	99% 4d10 6f 2F
	-	469531.0	-	83% 4d9 4f 5s (3P)4P + 11% 4d9 4f 5s (3D)4D
	-	476323.0	-	44% 4d9 4f 5s (3F)4F + 36% 4d9 4f 5s (3D)4D
				+ 9% 4d9 4f 5s (1D)2D + 8% 4d9 4f 5s (3D)2D
		481020.0	-	26% 4d9 4f 5s (1F)2F + 25% 4d9 4f 5s (3G)4G
				+ 21% 4d9 4f 5s (3D)4D + 20% 4d9 4f 5s (3F)4F

	-	482269.0	-	57% 4d9 4f 5s (3D)2D + 19% 4d9 4f 5s (3D)4D
				+ 10% 4d9 4f 5s (3P)4P + 5% 4d9 4f 5s (1F)2F
	-	484992.0	-	42% 4d9 4f 5s (1D)2D + 24% 4d9 4f 5s (3F)2F
				+ 9% 4d9 4f 5s (3D)2D + 9% 4d9 4f 5s (3G)4G
	-	487547.0	-	31% 4d9 4f 5s (3F)4F + 27% 4d9 4f 5s (3G)4G
				+ 26% 4d9 4f 5s (1D)2D + 9% 4d9 4f 5s (1F)2F
	490153.o	**490359.0**	**-206.0**	**84% 4d9 5s 6p (3D)4P + 13% 4d9 5s 6p (3D)4D**
	-	491224.0	-	52% 4d9 4f 5s (1F)2F + 36% 4d9 4f 5s (3G)4G
				+ 7% 4d9 4f 5s (3F)2F
	493431.0	**493349.0**	**82.0**	**45% 4d9 5s 6p (3D)4F + 25% 4d9 5s 6p (1D)2F**
				+ 15% 4d9 5s 6p (3D)2F + 5% 4d9 5s 6p (3D)4D
	-	494734.0	-	60% 4d9 4f 5s (3F)2F + 16% 4d9 4f 5s (3D)2D
				+ 15% 4d9 4f 5s (1D)2D + 8% 4d9 4f 5s (1F)2F
	496277.9	**496304.0**	**26.1**	**36% 4d9 5s 6p (3D)4D + 31% 4d9 5s 6p (3D)2D**
				+ 14% 4d9 5s 6p (1D)2F + 8% 4d9 5s 6p (3D)4P
	499929.0	**499928.0**	**1.0**	**56% 4d9 5s 6p (3D)2D + 16% 4d9 5s 6p (3D)2F**
				+ 15% 4d9 5s 6p (1D)2D + 11% 4d9 5s 6p (3D)4D
	503651.7	503691.0	-39.3	50% 4d9 5s 6p (3D)4F + 31% 4d9 5s 6p (1D)2F
				+ 8% 4d9 5s 6p (1D)2D + 7% 4d9 5s 6p (3D)4D
	-	**506382.0**	**-**	**30% 4d9 5s 6p (3D)2F + 26% 4d9 5s 6p (1D)2D**
				+ 19% 4d9 5s 6p (3D)4D + 11% 4d9 5s 6p (3D)2D
	-	**509209.0**	**-**	**41% 4d9 5s 6p (1D)2D + 30% 4d9 5s 6p (3D)2F**
				+ 19% 4d9 5s 6p (1D)2F + 8% 4d9 5s 6p (3D)4D
	565121.4	565123.0	-1.6	78% 4d9 5s 7p (3D)4P + 18% 4d9 5s 7p (3D)4D
	-	567249.0	-	35% 4d9 5s 7p (3D)4F + 15% 4d9 5s 7p (3D)2F
				+ 14% 4d9 5s 7p (1D)2F + 11% 4d9 5s 7p (3D)2D
	568511.8	568368.0	143.8	49% 4d9 5s 7p (3D)2D + 22% 4d9 5s 7p (1D)2F
				+ 12% 4d9 5s 7p (3D)4D + 7% 4d9 5s 7p (3D)4F
	-	570285.0	-	29% 4d9 5s 7p (1D)2D + 26% 4d9 5s 7p (3D)2D
				+ 26% 4d9 5s 7p (3D)4D + 15% 4d9 5s 7p (3D)2F
	577006.7	577094.0	-87.3	53% 4d9 5s 7p (3D)4F + 24% 4d9 5s 7p (3D)2F
				+ 11% 4d9 5s 7p (1D)2F + 10% 4d9 5s 7p (3D)4D
	578489.5	578509.0	-19.5	35% 4d9 5s 7p (1D)2F + 24% 4d9 5s 7p (3D)2F
				+ 17% 4d9 5s 7p (1D)2D + 11% 4d9 5s 7p (3D)2D
	580110.0	580294.0	-184.0	48% 4d9 5s 7p (1D)2D + 17% 4d9 5s 7p (3D)2F
				+ 16% 4d9 5s 7p (1D)2F + 15% 4d9 5s 7p (3D)4D
7/2	247530.0	247379.0	151	100% 4d10 4f 2F
	300868.0	300980.0	-112.0	72% 4d9 5s 5p (3D)4F +13% 4d9 5s 5p (3D)4D
				+ 9% 4d9 5s 5p 3D)2F + 6% 4d9 5s 5p (1D)2F
	312193.0	311791.0	402.0	80% 4d9 5s 5p(3D)4D +12% 4d9 5s 5p (1D)2F
				+ 5% 4d9 5s 5p (3D)4F
	315907.0	315906.0	1.0	96% 4d10 5f 2F
	319673.0	319824.0	-151.0	43% 4d9 5s 5p (1D)2F +28% 4d9 5s 5p (3D)2F
				+ 22% 4d9 5s 5p (3D)4F + 5% 4d9 5s 5p (3D)4D
	334667.0	334674.0	-7.0	60% 4d9 5s 5p (3D)2F + 37% 4d9 5s 5p (1D)2F
	356002.0	356031.0	-29.0	100% 4d10 6f 2F
	-	475922.0	-	53% 4d9 4f 5s (3D)4D + 43% 4d9 4f 5s (3F)4F
	-	477927.0	-	67% 4d9 4f 5s (3H)4H + 14% 4d9 4f 5s (3G)4G
				+ 10% 4d9 4f 5s (1G)2G + 6% 4d9 4f 5s (3G)2G
	-	479671.0	-	33% 4d9 4f 5s (3F)4F + 29% 4d9 4f 5s (3D)4D
				+ 16% 4d9 4f 5s (1F)2F + 10% 4d9 4f 5s (3G)4G
	-	484644.0	-	26% 4d9 4f 5s (3H)4H + 25% 4d9 4f 5s (3G)2G
				+ 24% 4d9 4f 5s (3G)4G + 13% 4d9 4f 5s (1G)2G
	-	486022.0	-	44% 4d9 4f 5s (3F)2F + 22% 4d9 4f 5s (1F)2F
				+ 11% 4d9 4f 5s (3G)4G + 9% 4d9 4f 5s (1G)2G
	-	488898.0	-	23% 4d9 4f 5s (1G)2G + 22% 4d9 4f 5s (3G)4G
				+ 18% 4d9 4f 5s (3F)4F + 17% 4d9 4f 5s (3F)2F
	-	491811.0	-	48% 4d9 4f 5s (1F)2F + 14% 4d9 4f 5s (3G)4G
				+ 12% 4d9 4f 5s (3F)2F + 7% 4d9 4f 5s (3G)2G
	-	**491962.0**	**-**	**50% 4d9 5s 6p (3D)4F + 23% 4d9 5s 6p (3D)2F**
				+ 15% 4d9 5s 6p (3D)4D
	-	**495739.0**	**-**	**77% 4d9 5s 6p (3D)4D + 16% 4d9 5s 6p (3D)2F**
				+ 5% 4d9 5s 6p (1D)2F
	-	497077.0	-	42% 4d9 4f 5s (3G)2G + 36% 4d9 4f 5s (1G)2G
				+ 14% 4d9 4f 5s (3F)2F
	-	**498354.0**	**-**	**51% 4d9 5s 6p (3D)2F + 22% 4d9 5s 6p (1D)2F**
				+ 19% 4d9 5s 6p (3D)4F

		506516.0		**68% 4d9 5s 6p (1D)2F + 21% 4d9 5s 6p (3D)4F**
				+ 5% 4d9 5s 6p (3D)2F + 5% 4d9 5s 6p (3D)4D
	565543.1	565695.0	-151.9	45% 4d9 5s 7p (3D)4F + 35% 4d9 5s 7p (3D)2F
				+ 19% 4d9 5s 7p (3D)4D
	567680.0	567647.0	33.0	70% 4d9 5s 7p (3D)4D + 29% 4d9 5s 7p (3D)2F
	569855.0	569692.0	163.0	34% 4d9 5s 7p (1D)2F + 31% 4d9 5s 7p (3D)4F
				+ 29% 4d9 5s 7p (3D)2F + 6% 4d9 5s 7p (3D)4D
	579416.0	579312.0	104.0	65% 4d9 5s 7p (1D)2F + 23% 4d9 5s 7p (3D)4F
				+ 7% 4d9 5s 7p (3D)2F + 5% 4d9 5s 7p (3D)4D
9/2	304848.0	305031.0	-183.0	100% 4d9 5s 5p (3D)4F
		474460.0	-	66% 4d9 4f 5s (3H)4H + 21% 4d9 4f 5s (1H)2H
				+ 9% 4d9 4f 5s (3H)2H
		477024.0	-	84% 4d9 4f 5s (3F)4F + 11% 4d9 4f 5s (3G)4G
		479462.0	-	32% 4d9 4f 5s (3G)4G + 28% 4d9 4f 5s (1H)2H
				+ 10% 4d9 4f 5s (1G)2G + 10% 4d9 4f 5s (3H)2H
		484538.0	-	37% 4d9 4f 5s (3G)2G + 15% 4d9 4f 5s (3H)4H
				+ 9% 4d9 4f 5s (3G)4G
		485888.0	-	31% 4d9 4f 5s (1H)2H + 29% 4d9 4f 5s (3G)4G
				+ 13% 4d9 4f 5s (3G)2G + 11% 4d9 4f 5s (3H)4H
		490306.0	-	32% 4d9 4f 5s (3G)2G + 21% 4d9 4f 5s (3H)2H
				+ 16% 4d9 4f 5s (1G)2G + 13% 4d9 4f 5s (1H)2H
		492778.0	-	58% 4d9 4f 5s (1G)2G + 17% 4d9 4f 5s (3H)2H
				+ 7% 4d9 4f 5s (3G)2G + 6% 4d9 5s 6p (3D)4F
		493426.0	**-**	**93% 4d9 5s 6p (3D)4F + 4% 4d9 4f 5s (1G)2G**
		566645.0	-	100% 4d9 5s 7p (3D)4F
11/2	-	472869.0	-	84% 4d9 4f 5s (3H)4H + 9% 4d9 4f 5s (1H)2H
				+ 5% 4d9 4f 5s (3H)2H
	-	479012.0	-	63% 4d9 4f 5s (3G)4G + 30% 4d9 4f 5s (3H)2H
				+ 6% 4d9 4f 5s (1H)2H
	-	480095.0	-	55% 4d9 4f 5s (3H)2H + 33% 4d9 4f 5s (1H)2H
				+ 12% 4d9 4f 5s (3G)4G
	-	486362.0	-	53% 4d9 4f 5s (1H)2H + 23% 4d9 4f 5s (3G)4G
				+ 14% 4d9 4f 5s (3H)4H + 10% 4d9 4f 5s (3H)2H
13/2		471515.0	-	100% 4d9 4f 5s (3H)4H

Table 2: Least Squares Fitted (LSF) Parameters in cm^{-1} for odd Parity Configurations of Sb V

Configuration	parameter	LSF	accuracy	HF	LSF/HF
4d10 5p	E0(4d10 5p)	89045.9	163.0	87076.3	1.023
	zeta(5p)	6018.2	207.0	5366.0	1.122
4d10 6p	E0(4d10 6p)	256895.6	163.0	253668.5	1.013
	zeta(6p)	2139.0	206.0	1977.4	1.082
4d10 7p	E0(4d10 7p)	324618.9	165.0	323274.9	1.004
	zeta(7p)	1109.1	208.0	964.3	1.150
4d10 8p	E0(4d10 8p)	358022.1	219.0	359641.8	0.996
	zeta(8p)	546.1	(fixed)	546.2	1.000
4d9 5s 5p	E0(4d9 5s 5p)	317514.2	50.0	317623.4	1.000
	zeta(4d)	3922.9	63.0	3939.3	0.996
	zeta(5p)	6091.6	138.0	5985.0	1.018
	F2(4d, 5p)	28130.4	607.0	32734.6	0.859
	G2(4d, 5s)	15022.9	902.0	16001.2	0.939
	G1(4d, 5p)	9178.0	352.0	10377.4	0.884
	G3(4d, 5p)	9542.4	1092.0	9726.3	0.981
	G1(5s, 5p)	44031.2	187.0	64396.7	0.684
4d9 5s 6p	E0(4d9 5s 6p)	499278.9	89.0	499315.5	1.000
	zeta(4d)	3980.9	66.0	3963.3	1.004
	zeta(6p)	1937.5	252.0	2046.5	0.947
	F2(4d, 6p)	9321.0	787.0	10259.3	0.909
	G2(4d, 5s)	12954.1	1406.0	16566.7	0.782
	G1(4d, 6p)	2488.7	487.0	2677.8	0.929
	G3(4d, 6p)	1684.0	2136.0	2718.4	0.619
	G1(5s, 6p)	5558.1	378.0	7237.7	0.768
4d9 5s 7p	E0(4d9 5s 7p)	571945.2	60.0	571961.6	1.000
	zeta(4d)	4000.3	53.0	3969.1	1.008
	zeta(7p)	1048.7	108.0	984.1	1.066
	F2(4d, 7p)	3911.1	685.0	4628.3	0.845
	G2(4d, 5s)	12167.5	652.0	16602.0	0.733
	G1(4d, 7p)	1056.9	336.0	1178.4	0.897

International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2024: 7.101

	G3(4d, 7p)	425.9	1196.0	1224.6	0.348
	G1(5s, 7p)	1948.7	340.0	2639.9	0.738
4d9 4f 5s	E0(4d9 4f 5s)	483036.0	(fixed)	483030.5	1.000
	zeta(4d)	3933.4	(fixed)	3933.4	1.000
	zeta(4f)	45.1	(fixed)	45.2	0.998
	F2(4d, 4f)	31348.4	(fixed)	36880.5	0.850
	F4(4d, 4f)	17417.2	(fixed)	20490.9	0.850
	G1(4d, 4f)	12074.9	(fixed)	16099.9	0.750
	G3(4d, 4f)	27741.8	(fixed)	36989.1	0.750
	G5(4d, 4f)	16379.3	(fixed)	21839.1	0.750
	G2(4d, 5s)	11309.7	(fixed)	15079.6	0.750
	G3(4f, 5s)	22976.3	(fixed)	30635.1	0.750
4d10 4f	E0(4d10 4f)	247609.8	155.0	244395.7	1.013
	zeta(4f)	27.7	(fixed)	27.7	1.000
4d10 5f	E0(4d10 5f)	316151.8	226.0	313201.0	1.010
	zeta(5f)	21.6	(fixed)	21.7	0.995
4d10 6f	E0(4d10 6f)	355966.9	155.0	352465.0	1.010
	zeta(6f)	13.7	(fixed)	13.7	1.000

Table 2 : continued

4d10 8p -4d9 5s 7p	R2(4d, 4d; 4d, 5s)	0.0	(fixed)	0.0	
	R2(4d, 8p; 5s, 7p)	-1467.5	(fixed)	-1834.3	0.800
	R1(4d, 8p; 7p, 5s)	-568.9	(fixed)	-711.1	0.800
4d10 8p -4d9 4f 5s	R1(4d, 8p; 4f, 5s)	1768.7	(fixed)	2210.8	0.800
	R2(4d, 8p; 5s, 4f)	4782.1	(fixed)	5977.6	0.800
4d9 5s 5p -4d9 5s 6p	R0(4d, 5p; 4d, 6p)	0.0	(fixed)	0.0	
	R2(4d, 5p; 4d, 6p)	10157.8	(fixed)	12697.2	0.800
	R1(4d, 5p; 6p, 4d)	4112.4	(fixed)	5140.5	0.800
	R3(4d, 5p; 6p, 4d)	4011.5	(fixed)	5014.3	0.800
	R0(5s, 5p; 5s, 6p)	0.0	(fixed)	0.0	
	R1(5s, 5p; 6p, 5s)	13508.3	(fixed)	16885.4	0.800
4d9 5s 5p -4d9 5s 7p	R0(4d, 5p; 4d, 7p)	0.0	(fixed)	0.0	
	R2(4d, 5p; 4d, 7p)	6202.7	(fixed)	7753.4	0.800
	R1(4d, 5p; 7p, 4d)	2680.3	(fixed)	3350.4	0.800
	R3(4d, 5p; 7p, 4d)	2640.4	(fixed)	3300.5	0.800
	R0(5s, 5p; 5s, 7p)	0.0	(fixed)	0.0	
	R1(5s, 5p; 7p, 5s)	7064.2	(fixed)	8830.2	0.800
4d9 5s 5p -4d9 4f5s	R2(4d, 5p; 4d, 4f)	-14585.9	(fixed)	-18232.4	0.800
	R4(4d, 5p; 4d, 4f)	-5963.9	(fixed)	-7454.8	0.800
	R1(4d, 5p; 4f, 4d)	-5225.0	(fixed)	-6531.2	0.800
	R3(4d, 5p; 4f, 4d)	-3295.7	(fixed)	-4119.6	0.800
4d9 5s 5p -4d10 4f	R2(5s, 5p; 4d, 4f)	14796.1	(fixed)	18495.1	0.800
	R3(5s, 5p; 4f, 4d)	10852.3	(fixed)	13565.4	0.800
4d9 5s 5p -4d10 5f	R2(5s, 5p; 4d, 5f)	7451.0	(fixed)	9313.8	0.800
	R3(5s, 5p; 5f, 4d)	6244.2	(fixed)	7805.3	0.800
4d9 5s 5p -4d10 6f	R2(5s, 5p; 4d, 6f)	4121.5	(fixed)	5151.8	0.800
	R3(5s, 5p; 6f, 4d)	3776.6	(fixed)	4720.8	0.800
4d9 5s 6p -4d9 5s 7p	R0(4d, 6p; 4d, 7p)	0.0	(fixed)	0.0	
	R2(4d, 6p; 4d, 7p)	4681.2	(fixed)	5851.5	0.800
	R1(4d, 6p; 7p, 4d)	1417.5	(fixed)	1771.9	0.800
	R3(4d, 6p; 7p, 4d)	1455.4	(fixed)	1819.3	0.800
	R0(5s, 6p; 5s, 7p)	0.0	(fixed)	0.0	
	R1(5s, 6p; 7p, 5s)	3435.2	(fixed)	4294.0	0.800
4d9 5s 6p -4d9 4f 5s	R2(4d, 6p; 4d, 4f)	-4107.7	(fixed)	-5134.6	0.800
	R4(4d, 6p; 4d, 4f)	-2614.5	(fixed)	-3268.1	0.800
	R1(4d, 6p; 4f, 4d)	-2662.9	(fixed)	-3328.7	0.800
	R3(4d, 6p; 4f, 4d)	-1933.0	(fixed)	-2416.2	0.800
4d9 5s 6p -4d10 4f	R2(5s, 6p; 4d, 4f)	3149.0	(fixed)	3936.3	0.800
	R3(5s, 6p; 4f, 4d)	4973.5	(fixed)	6216.9	0.800
4d9 5s 6p -4d10 5f	R2(5s, 6p; 4d, 5f)	4916.8	(fixed)	6145.9	0.800
	R3(5s, 6p; 5f, 4d)	3183.5	(fixed)	3979.3	0.800
4d9 5s 6p -4d10 6f	R2(5s, 6p; 4d, 6f)	3390.5	(fixed)	4238.2	0.800
	R3(5s, 6p; 6f, 4d)	2054.8	(fixed)	2568.5	0.800

4d9 5s 7p -4d9 4f 5s	R2(4d, 7p; 4d, 4f)	-2541.1	(fixed)	-3176.4	0.800
	R4(4d, 7p; 4d, 4f)	-1683.0	(fixed)	-2103.8	0.800
	R1(4d, 7p; 4f, 4d)	-1770.3	(fixed)	-2212.9	0.800
	R3(4d, 7p; 4f, 4d)	-1339.1	(fixed)	-1673.9	0.800
4d9 5s 6p -4d10 5f	R2(5s, 6p; 4d, 5f)	4916.8	(fixed)	6145.9	0.800
	R3(5s, 6p; 5f, 4d)	3183.5	(fixed)	3979.3	0.800
4d9 5s 6p -4d10 6f	R2(5s, 6p; 4d, 6f)	3390.5	(fixed)	4238.2	0.800
	R3(5s, 6p; 6f, 4d)	2054.8	(fixed)	2568.5	0.800
4d9 5s 7p -4d9 4f 5s	R2(4d, 7p; 4d, 4f)	-2541.1	(fixed)	-3176.4	0.800
	R4(4d, 7p; 4d, 4f)	-1683.0	(fixed)	-2103.8	0.800
	R1(4d, 7p; 4f, 4d)	-1770.3	(fixed)	-2212.9	0.800
	R3(4d, 7p; 4f, 4d)	-1339.1	(fixed)	-1673.9	0.800
4d9 5s 7p -4d10 4f	R2(5s, 7p; 4d, 4f)	1876.3	(fixed)	2345.4	0.800
	R3(5s, 7p; 4f, 4d)	3131.2	(fixed)	3914.0	0.800
4d9 5s 7p -4d10 5f	R2(5s, 7p; 4d, 5f)	2085.0	(fixed)	2606.3	0.800
	R3(5s, 7p; 5f, 4d)	2067.3	(fixed)	2584.1	0.800
4d9 5s 7p -4d10 6f	R2(5s, 7p; 4d, 6f)	2239.6	(fixed)	2799.5	0.800
	R3(5s, 7p; 6f, 4d)	1359.9	(fixed)	1699.9	0.800
4d9 4f 5s -4d10 4f	R2(4d, 5s; 4d, 4d)	-8799.1	(fixed)	-10998.9	0.800
	R3(4f, 5s; 4d, 4f)	-13563.9	(fixed)	-16954.8	0.800
	R2(4f, 5s; 4f, 4d)	-11717.1	(fixed)	-14646.4	0.800
4d9 4f 5s -4d10 5f	R3(4f, 5s; 4d, 5f)	0.0	(fixed)	0.0	
	R2(4f, 5s; 5f, 4d)	-6322.8	(fixed)	-7903.5	0.800
	R3(4f, 5s; 4d, 6f)	-6718.9	(fixed)	-8398.7	0.800
4d9 4f 5s -4d10 6f	R2(4f, 5s; 6f, 4d)	0.0	(fixed)	0.0	

4. Conclusion

This study expands previous research by analyzing Sb V energy levels, identifying 15 new energy levels within the 4d9 5s 6p configuration. The results were validated using isoelectronic plots and least- squares fitting techniques. These findings contribute to the ongoing refinement of atomic spectral data and provide a basis for further computational and experimental studies.

Acknowledgement

I would like to thank the Deanship of Graduate Studies and Scientific Research at Qassim University for Financial support.

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