Journal of Natural Sciences and Mathematics
Qassim University, Vol. 8, No. 1, PP 29-47 (January 2015/Rabi I 1436H.)

Revised and Extended Analysis of Silver like Sb V ion

Tazeen Rana

Physics Department, Deanship of Educational services, Qassim University, Al Qassim, Saudi Arabia

Abstract. The Spectrum of Antimony was recorded in the 300Ǻ- 2080 Ǻ wavelength range using a 3m normal incidence vacuum Spectrograph. Large number of configurations were investigated first time for odd parity and even parity system. Sixty-seven lines have been classified in this spectrum. The Hartree–Fock calculations with relativistic correction and least squares fitted parametric calculations were carried out using Cowan Code in order to interpret the spectrum satisfactorily”

Introduction

The ground state configuration of four- times ionized antimony (SbV) is $4d^{10}$ 5s. Lang [1] initiated the work on Sb V, followed by Gibbs, Vieweg and Gartlein [2] and finally by Badami [3]. There were 9 lines classified in the range 699 Å - 3363 Å region to establish the levels of $4d^{10}5p$, $4d^{10}6p$, $4d^{10}5d$ and $4d^{10}6s$ configurations. Chan [4] confirmed all the reported levels in Atomic Energy Level , AEL [5] though the level values were revised by as much as 27 cm^{-1} and extended to include the $4d^{10}$ 4f, $4d^{10}$ 6d, $4d^{10}7d$, $4d^{10}7s$, $4d^{10}7p$ and $4d^9 5s^2$. Andersen et al [6] measured the life time of some multiplets of Sb V. Kaufman, Sugar, Van Kleef and Joshi [7] identified 10 transitions arising out of the core excitation to $4d^9 5s5p$ configuration. Since ground level is $^2S_{1/2}$, therefore only J=1/2 and 3/2 levels of this configuration could be established. Out of possible 11 levels of J=1/2 and J=3/2, 10 levels were reported. The highest J=3/2 level was not found. The present work was undertaken to extend our knowledge on Ag I sequence and to confirm all the levels reported in AEL [5] with considerable improvements in their level values.

Experimental Procedures

The Spectrum of antimony was recorded in the 300Å - 2080Å wavelength region on a 3m normal incidence vacuum Spectrograph at the Antigonish laboratory. The data obtained from the 3-m spectrograph were supplemented by line list from a hollow cathode source exposures taken at the 6.65m normal incidence spectrograph at the Zeeman Laboratory, University of Amsterdam, which existed at the Antigonish laboratory as well as National Institute of Standard and Technology (NIST) Plates, recorded by using a Sliding spark source. This Spectrograph is equipped with a 2400 lines/mm holographic grating giving an inverse dispersion of 1.385Å in the first order. The source used was a triggered spark with charging potential of 2-5KV across a low inductance (few nanohenry) capacitor of value 14.7 microfarad.

Pure antimony powder was packed into the cavity of aluminium electrodes. The ionization discrimination among antimony lines belonging to different ionization stages was achieved by studying the line aspect (principally its length polarity) or its intensity when series inductance was introduced. The position and intensity of each spectral line on the plate was measured using Zeiss Abbe Comparator at the Antigonish laboratory or at the Aligarh University Laboratory. This comparator can measure the line list position of sharp lines to 0.0005 mm (equivalent to 0.001 Å) and a few times larger for wide lines and asymmetric lines. The line intensities are the relative visual darkening of the lines. These relative values are valid over a short distance on the plate. The other parameters also recorded for each line is the line shape and character viz, whether it is a normal line, diffused line, wide line, shoulder line, asymmetric line, or line with polarity, it is indicated by a numeric value 1-9. Often more than one track on a plate has been measured. The lines of oxygen, carbon, nitrogen, and aluminium also appear on the plate due to the air present in the evacuated source chamber and due to the Al electrodes. They are identified on the plate as well as on the measurement list.

All exposures were taken on Kodak SWR plates and the spectrograms were measured on a grant comparator at the Antigonish laboratory in Canada and on an abbe comparator in Aligarh. The wavelengths were calculated by using internal standards of C, N, O, and Al [8]. The wavelength accuracy for the symmetric lines are ± 0.005Å in the wavelength region reported here.

Results and Discussion

Hartree - Fock calculations are performed with relativistic correction and correlation effects with complex system like three electrons or even four electrons system.. The atomic energy structure expressed in Hartree- Fock Slater theory in the form of complicated integro- differential equation. Which have been simplified so as to divide the whole complex into smaller manageable integrals, called "Slater Parameters" written in the form of F^k, G^k, R^k and ζ_{nl} and E_{av} including approximate relativistic and correlation energy corrections as explained , these integrals can be evaluated on rigorous treated simply as adjustable parameters in application to observed spectra.

The integral F^k (n_l,n_1) represent that part of the electrostatic energy which depends on the orientation of the l- vectors and is responsible for the separation of terms with different L- values in LS coupling notation those denoted by G^k (nl, nl) are the exchange integrals that give energies due to the exchange forces which depends on the spin orientations; they cause the splitting of terms with equal L but different total spin S, for instance the separation of singlet term from the triplet etc. In case of equivalent electrons like p^2, p^3, d^2 the G^k parameters vanish. ζ_{nl} is the magnetic spin orbit interaction responsible for fine structure splitting. E_{av} including approximate relativistic and correlation energy corrections. Relativistic Hartree-Fock Multi Configuration Interaction method have been utilized to predict the structure of the ions.

In the given analysis of SbV, first carried out Hartree – Fock calculations with relativistic corrections using Cowan Codes [9] for SbV to get ab-initio energy parameters. The parameters used in the level fitting calculations (LSF) were estimated by extrapolating the parameters scaling factor. (the ratio of the LSF and HF parameter values) from Te VI to Cs IX only 10 levels of $4d^95s5p$ were identified by Kaufman et al [7] . With the help of 10 levels of $4d^95s5p$, I have investigated $4d^95s5d$ configuration. Since only J=1/2 and 3/2 levels of $4d^95s5p$ were previously known, therefore, using J=3/2 levels, I established sufficient levels of $4d^95s5d$ with J=5/2 and returning back to $4d^95s5p$, I established J=5/2 and J=7/2 levels of $4d^95s5p$. Two levels of $4d^95s^2$ were also quite useful to locate some of the J=5/2 and 7/2 levels of $4d^95s5p$ configuration. The configurations $4d^{10}$ 8p, $4d^{10}$ 5f, and $4d^{10}$ 6f of odd parity matrix were investigated first time. Sixty-seven lines are now classified in SbV in the 446Ǻ- 2076Å region and are given in table1.

In the odd parity system, I have established 35 levels out of which 17 levels are new. Fitted and HFR (Hartree Fock Relativistic Calculation) energy parameter values in cm^{-1} and scaling factors for odd parity configurations are given in table II The odd parity levels their calculated values and LS percentage compositions are given in table III . In even parity configuration, 5 new levels have been established. The experimental and fitted energy level values (cm^{-1}) and their LS percentage of the levels of even parity configuration are given in table IV. The energy parameters used in the present calculations for even parity configurations, along with the HFR values and scaling factors are given in table V.

Table (1). Classified lines of SbV.

λ(Ǻ)	ν (cm^{-1})	Int.	Classifications	Diff.
299.875	333472.0	91	$d^9sp(^3D)$ $^2P_{3/2}$ - $4d^{10}5s$ $^2S_{1/2}$	0.000
311.666	320856.0	45	$d^9sp(^3D)$ $^4D_{3/2}$ - $4d^{10}5s$ $^2S_{1/2}$	0.000
316.027	316429.0	78	$d^9sp(^1D)$ $^2P_{1/2}$ - $4d^{10}5s$ $^2S_{1/2}$	0.000
316.813	315644.0	70	$d^9sp(^1D)$ $^2P_{3/2}$ - $4d^{10}5s$ $^2S_{1/2}$	0.000
324.885	307801.0	81	$d^9sp(^3D)$ $^4P_{1/2}$ - $4d^{10}5s$ $^2S_{1/2}$	0.000
326.835	305965.0	85	$d^9sp(^3D)$ $^4F_{3/2}$ - $4d^{10}5s$ $^2S_{1/2}$	0.000
388.190	257605.6	45	$4d^{10}5s$ $^2S_{1/2}$ - $6p$ $^2P_{3/2}$	0.000
393.072	254406.0	45	$4d^{10}5s$ $^2S_{1/2}$ - $6p$ $^2P_{1/2}$	0.000
470.245	212655.1	27	$4d^{10}5p$ $^2P_{3/2}$ - $6d$ $^2D_{5/2}$	0.000
631.933	158244.6	22	$d^95s6s(^3D)$ $^4D_{3/2}$ - $d^9sp(^3D)^4F_{5/2}$	0.008
637.889	156767.2	20	d^9sd (^3D) $^2S_{1/2}$ - $d^9sp(^1D)^2P_{3/2}$	0.007
641.085	155985.5	12	d^9sd (^3D) $^2S_{1/2}$ - $d^9sp(^1D)^2P_{1/2}$	-0.007
651.635	153460.1	37	$d^95s6s(^3D)$ $^2D_{5/2}$ - $d^9sp(^1D)^2F_{5/2}$	-0.003
692.332	144439.3	33	d^9sd (^3D) $^4D_{5/2}$ - $d^9sp(^3D)^4D_{5/2}$	0.000
695.327	143817.3	21	$d^9sd(^3D)$ $^4F_{3/2}$ - $d^9sp(^3D)^4F_{5/2}$	-0.007
698.750	143112.6	40	$4d^{10}5p$ $^2P_{1/2}$ - $6s$ $^2S_{1/2}$	0.003
718.512	139176.5	35	$d^9sd(^3D)$ $^4F_{3/2}$ - $d^9sp(^3D)^4F_{3/2}$	-0.006
728.986	137176.8	7	$d^9sd(^3D)$ $^4D_{3/2}$ - $d^9sp(^3D)^4F_{3/2}$	-0.010
733.154	136397.0	53	$d^9sd(^3D)$ $^4G_{5/2}$ - $d^9sp(^3D)^4F_{3/2}$	0.004
735.189	136019.5	12	$d^9sd(^3D)$ $^4D_{1/2}$ - $d^9sp(^3D)^4P_{1/2}$	0.000

Continue Table (1).

λ(Ǻ)	ν (cm^{-1})	Int.	Classifications	Diff.
738.876	135340.7	15	$d^9sd(^3D)$ $^4D_{3/2}$ - $d^9sp(^3D)^4P_{1/2}$	-0.010
743.715	134460.1	60	$d^9sd(^3D)$ $^2F_{5/2}$ - $d^9sp(^3D)^4D_{3/2}$	-0.002
744.377	134340.5	47	$d^9sd(^1D)$ $^2D_{3/2}$ - $d^9sp(^1D)^2D_{3/2}$	-0.007
745.594	134121.2	35	$4d^{10}5p$ $^2P_{3/2}$ - 6s $^2S_{1/2}$	-0.003
747.318	133811.9	26	$d^9sd(^3D)$ $^4P_{1/2}$ - $d^9sp(^3D)^4P_{1/2}$	-0.001
750.249	133289.0	30	$d^9sd(^3D)$ $^4P_{1/2}$ - $d^9sp(^3D)^4P_{3/2}$	0.000
772.217	129497.2	8	$d^9sd(^3D)$ $^4F_{3/2}$ - $d^9sp(^1D)^2P_{3/2}$	-0.005
782.405	127811.0	41	$d^9sd(^3D)$ $^4S_{3/2}$ - $d^9sp(^3D)^4P_{3/2}$	0.000
789.146	126719.2	28	$d^9sd(^3D)$ $^4G_{5/2}$ - $d^9sp(^1D)^2P_{3/2}$	-0.003
816.425	122485.2	28	7P $^2P_{1/2}$ - 5d $^2D_{3/2}$	0.000
817.760	122285.3	36	$d^9sd(^3D)$ $^4D_{3/2}$ - $d^9sp(^3D)^4D_{3/2}$	-0.010
820.763	121837.8	34	7P $^2P_{3/2}$ - 5d $^2D_{5/2}$	0.012
821.272	121762.3	13	$d^9sd(^3D)$ $^4F_{5/2}$ - $d^9sp(^3D)^4D_{5/2}$	0.001
			$d^9sd(^3D)$ $^4G_{7/2}$ - $d^9sp(^3D)^4D_{7/2}$	-0.003
828.363	120720.0	26	7P $^2P_{3/2}$ - 5d $^2D_{3/2}$	0.012
830.700	120380.4	78	$4d^{10}5p$ $^2P_{1/2}$ - 5d $^2D_{3/2}$	-0.004
832.678	120094.5	22	d^9sd (^1D) $^2S_{1/2}$ - $d^9sp(^1D)$ $^2P_{1/2}$	0.000
840.911	118918.6	25	d^9s^2 $^2D_{5/2}$ - $d^9sp(^3D)$ $^2F_{5/2}$	0.000
841.633	118816.7	12	$d^9sd(^3D)$ $^2D_{5/2}$ - $d^9sp(^3D)$ $^2F_{5/2}$	0.000
862.062	116001.0	48	$d^9sd(^3D)$ $^2F_{5/2}$ - $d^9sp(^3D)$ $^2D_{5/2}$	0.001
888.887	112500.2	80	$4d^{10}5p$ $^2P_{3/2}$ - 5d $^2D_{5/2}$	0.010
890.212	112332.8	11	$d^9sd(^3D)$ $^4F_{5/2}$ - $d^9sp(^3D)$ $^2P_{3/2}$	0.005
896.768	111511.6	55	$d^9sd(^3D)$ $^2D_{3/2}$ - $d^9sp(^3D)$ $^2P_{1/2}$	-0.001
897.763	111388.0	74	$4d^{10}5p$ $^2P_{3/2}$ - 5d $^2D_{3/2}$	-0.006
898.863	111251.7	35	$d^9sd(^3D)$ $^2D_{5/2}$ - $d^9sp(^3D)$ $^2P_{3/2}$	0.004
920.487	108638.2	44	d^9sd (^3D) $^2P_{1/2}$ - $d^9sp(^3D)$ $^2P_{1/2}$	0.000
920.487	108638.2	44	d^9sd (^3D) $^2P_{1/2}$ - $d^9sp(^3D)$ $^2P_{1/2}$	0.000
922.893	108354.9	9	$d^9sd(^3D)$ $^2D_{3/2}$ - $d^9sp(^3D)^2F_{5/2}$	0.001
935.813	106859.0	16	$d^9sd(^1D)$ $^2D_{3/2}$ - $d^9sp(^3D)^2D_{5/2}$	0.005

Continue Table (1).

λ(Å)	ν (cm^{-1})	Int.	Classifications	Diff.
944.959	105824.7	49	$d^9sd(^3D)$ $^4F_{3/2}$ - $d^9sp(^3D)^2D_{5/2}$	0.010
948.681	105409.5	47	$d^9sd(^3D)$ $^2D_{5/2}$ - $d^9sp(^3D)^2D_{5/2}$	0.001
993.305	100674.0	17	$d^9sd(^3D)$ $^4D_{3/2}$ - $d^9sp(^3D)$ $^2P_{1/2}$	0.018
995.923	100409.4	13	6p $^2P_{1/2}$ - 8s $^2S_{1/2}$	0.006
998.142	100186.1	7	$d^9sd(^3D)$ $^4F_{5/2}$ - $d^9sp(^3D)$ $^2F_{5/2}$	-0.012
1009.039	99104.2	60	$d^9sd(^3D)$ $^2D_{5/2}$ - $d^9sp(^3D)^2F_{5/2}$	-0.004
1056.796	94625.6	75	6p $^2P_{1/2}$ - 7d $^2D_{3/2}$	-0.005
1086.522	92036.8	48	$d^9sd(^3D)$ $^2P_{3/2}$ - $d^9sp(^3D)$ $^2D_{3/2}$	-0.002
1092.466	91536.0	71	6p $^2P_{3/2}$ -7d $^2D_{5/2}$	0.000
1093.795	91424.8	36	6p $^2P_{3/2}$ - 7d $^2D_{3/2}$	0.005
1104.233	90560.6	80	$4d^{10}5s$ $^2S_{1/2}$ - $4d^{10}5p$ $^2P_{3/2}$	0.001
1225.968	81568.2	80	$4d^{10}5s$ $^2S_{1/2}$ - $4d^{10}5p$ $^2P_{1/2}$	-0.001
1253.273	79791.1	32	5g $^2G_{7/2}$ - 4f $^2F_{5/2}$	0.000
1332.745	75033.1	52	d^9s^2 $^2D_{3/2}$ - $d^9sp(^1D)^2D_{3/2}$	0.000
1752.167	57072.2	65	6p $^2P_{1/2}$ - 7s $^2S_{1/2}$	0.000
1795.574	55692.5	75	4f $^2F_{7/2}$ - 6d $^2D_{5/2}$	0.000
1800.264	55547.4	72	4f $^2F_{5/2}$ - 6d $^2D_{3/2}$	0.000
2070.136	48306.0	75	6p $^2P_{1/2}$ - 6d $^2D_{3/2}$	0.000

Table (2). Fitted and HFR energy parameters values (cm^{-1}) and scaling factors for the odd parity configurations of SbV

parameter	LSF	Accu.	HF	LSF/HF
$E_{av}(4d^{10}\ 5p)$	88673	211	85518	1.037
ζ_{5p}	6012	267	5366	1.120
$E_{av}(4d^{10}\ 6p)$	256804	210	252111	1.019
ζ_{6p}	2137	266	1977	1.081
$E_{av}(4d^{10}\ 7p)$	324561	213	321717	1.009
ζ_{7p}	1098	268	964	1.139
$E_{av}(4d^{10}\ 8p)$	357970	200	358084	1.000

Continue Table (2).

parameter	LSF	Accu.	HF	LSF/HF
ζ_{8p}	546	(fixed)	546	1.000
$E_{av}(4d^{10}\ 4f)$	247543	200	242838	1.019
ζ_{4f}	28	(fixed)	28	1.000
$E_{av}(4d^{10}\ 5f)$	316108	207	311643	1.014
ζ_{5f}	22	(fixed)	22	0.995
$E_{av}(4d^{10}\ 6f)$	355973	200	350907	1.014
ζ_{6f}	14	(fixed)	14	1.000
$E_{av}(4d^{9}\ 4f\ 5s)$	481478	(fixed)	481472	1.000
ζ_{4d}	3933	(fixed)	3933	1.000
ζ_{4f}	45	(fixed)	45	0.998
F^1(4d, 4f)	0	(fixed)	0	
F^2(4d, 4f)	31348	(fixed)	36881	0.850
F^3(4d, 4f)	0	(fixed)	0	
F^4(4d, 4f)	17417	(fixed)	20491	0.850
G^1(4d, 4f)	27742	(fixed)	36989	0.750
G^2(4d, 4f)	0	(fixed)	0	
G^3(4d, 4f)	16379	(fixed)	21839	0.750
G^4(4d, 4f)	0	(fixed)	0	
G^5(4d, 4f)	11310	(fixed)	15080	0.750
G^2(4d, 5s)	12075	(fixed)	16100	0.750
G^3(4f, 5s)	22976	(fixed)	30635	0.750
$E_{av}(4d^{9}\ 5s\ 5p)$	317364	61	316065	1.004
ζ 4d	3897	68	3939	0.989
ζ 5p	6177	165	5985	1.032
F^1(4d, 5p)	0	(fixed)	0	
F^2(4d, 5p)	28495	565	32735	0.870
G^2(4d, 5s)	14652	329	16001	0.916
G^1(4d, 5p)	9502	213	10377	0.916
G^2(4d, 5p)	0	(fixed)	0	

Continue Table (2).

parameter	LSF	Accu.	HF	LSF/HF
G^3(4d, 5p)	8906	200	9726	0.916
G^1(5s, 5p)	43619	221	64397	0.677
R^1(4d, 5p; 4f, 5s)	26928	(fixed)	38469	0.700
R^2(4d, 5p; 5s, 4f)	13456	(fixed)	19223	0.700
R^2(4d, 4d; 4d, 5s)	-7737	(fixed)	-11052	0.700
R^2(4d, 5p; 5s, 5p)	-1429	(fixed)	-20424	0.700
R^1(4d, 5p; 5p, 5s)	-13141	(fixed)	-18773	0.700
R^1(4d, 6p; 4f, 5s)	10087	(fixed)	14410	0.700
R^2(4d, 6p; 5s, 4f)	3767	(fixed)	5381	0.700
R^2(4d, 6p; 5s, 5p)	0	(fixed)		
R^1(4d, 6p; 5p, 5s)	-4253	(fixed)	-6075	0.700
R^1(4d, 7p; 4f, 5s)	-3815	(fixed)	-5450	0.700
R^2(4d, 7p; 5s, 4f)	6008	(fixed)	8582	0.700
R^2(4d, 7p; 5s, 5p)	2232	(fixed)	3188	0.700
R^1(4d, 7p; 5p, 5s)	0	(fixed)	0	
R^1(4d, 8p; 4f, 5s)	-2256	(fixed)	-3222	0.700
R^2(4d, 8p; 5s, 4f)	-2001	(fixed)	-2859	0.700
R^2(4d, 8p; 5s, 5p)	4184	(fixed)	5978	0.700
R^1(4d, 8p; 5p, 5s)	1548	(fixed)	2211	0.700
R^2(4d, 4d; 4d, 5s)	0	(fixed)	0	
R^3(4d, 4f; 4f, 5s)	-1467	(fixed)	-2096	0.700
R^2(4d, 4f; 5s, 4f)	-1294	(fixed)	-1849	0.700
R^2(4d, 4f; 5s, 5p)	-7699	(fixed)	-10999	0.700
R^3(4d, 4f; 5p, 5s)	-10253	(fixed)	-14646	0.700
R^3(4d, 5f; 4f, 5s)	-11868	(fixed)	-16955	0.700
R^2(4d, 5f; 5s, 4f)	12947	(fixed)	18495	0.700
R^2(4d, 5f; 5s, 5p)	9496	(fixed)	13565	0.700
R^3(4d, 5f; 5p, 5s)	-5879	(fixed)	-8399	0.700
R^3(4d, 6f; 4f, 5s)	-5533	(fixed)	-7904	0.700
R^2(4d, 6f; 5s, 4f)	6520	(fixed)	9314	0.700

Continue Table (2).

parameter	LSF	Accu.	HF	LSF/HF
R^2(4d, 6f; 5s, 5p)	5464	(fixed)	7805	0.700
R^3(4d, 6f; 5p, 5s)	-3518	(fixed)	-5026	0.700
λ(Å) = wave length in Angstrom, ν (cm^{-1}) = wave number in cm^{-1} σ (Mean Error) = 282				

Table (3). The experimental and fitted energy level values (cm^{-1}) and their LS percentage of the levels of odd parity configurations of Sb V.

E(obs)	E(LSF)	Diff.	LS –Composition
J=1/2 81568.0	81568.0	0.0	100% $4d^{10}5p$ ^2P
254406.0	254406.0	0.0	100% $4d^{10}6p$ ^2P
307801.0	307783.0	18.0	83% $4d^95s5p$ (^3D) ^4P + 10% $4d^95s5p$ (^3D) ^4D+ 7%$4d^95s5p$ (^1D) ^2P
316429.0	316383.0	46.0	71%$4d^95s5p$ (^1D) ^2P + 21% $4d^95s$ 5p (^3D) ^2P+ 7%$4d^95s5p$ (^3D) ^4P
316922.0	316992.0	-70.0	88% $4d^95s5p$ (^3D) ^4D + 10% $4d^95s$ 5p (^3D) ^4P
323316.0	323316.0	0.0	99% $4d^{10}7p$ ^2P
342464.0	342297.	167.0	76% $4d^95s5p$ (^3D) ^2P + 21% $4d^95s5p$ (^1D) ^2P
357434.n	357397.0	37.0	100% $4d^{10}8p$ ^2P
	464468.0	-	98% $4d^94f5s$ (^3P) ^4P
	472905.0	-	79% $4d^94f5s$ (3P) ^2P + 21% $4d^94f5s$ (^3D) ^4D
	478574.0	-	77% $4d^94f5s$ (^3D) ^4D + 20% $4d^94f5s$ (^3P) ^2P
	528057.0	-	99% $4d^94f5s$ (^1P) ^2P
J=3/2			
90560.0	90559.0	1.0	100% $4d^{10}5p$ ^2P
257605.0	257605.0	0.0	100% $4d^{10}6p$ ^2P
301188.0	301482.0	-294.0	69% $4d^95s5p$ (^3D) ^4P + 15% $4d^95s5p$ (^3D) ^4D + 9%$4d^95s5p$ (^1D) ^2P+ 4% $4d^95s$ 5p (^3D) ^4F
305965.0	306276.0	-311.0	86% $4d^95s5p$ (^3D) ^4F + 10% $4d^95s5p$ (^3D) ^4P
311835.0	312050.0	-215.0	43% $4d^95s5p$ (^1D) ^2D + 15% $4d^95s$ 5p (^3D) ^2D +14%$4d^95s5p$(^3D) ^4P + 12% $4d^95s$ 5p (^1D) ^2P
315644.0	315662.0	-18.0	60% $4d^95s5p$ (^1D) ^2P + 24% $4d^95s5p$ (^3D) ^4D 11%$4d^95s5p$(^3D) ^2P
320856.0	320632.0	224.0	47% $4d^95s5p$ (^3D) ^4D + 24% $4d^95s5p$ (^1D) ^2D +11%$4d^95s5p$(^3D) ^2D + 8% $4d^95s$ 5p (^1D) ^2P

Continue Table (3).

E(obs)	E(LSF)	Diff.	LS –Composition
324893.0	324887.0	6.0	99% $4d^{10}7p$ ^2P
333472.0	333916.0	-444.0	86% $4d^9 5s5p$ (^3D) ^2P + 8% $4d^9 5s5p$ (^1D) ^2P
349574.0	349796.0	-222.0	67%$4d^9 5s5p$ (^3D) ^2D + 29% $4d^9 5s$ 5p (^1D) ^2D
358170.n	358206.0	-36.0	100% $4d^{10}8p$ ^2P
	465749.0	-	94% $4d^9 4f5s$ (^3P) ^4P + 5% $4d^9 4f5s$ (^3D) ^4D
	474838.0	-	55% $4d^9 4f5s$ (^3P) ^2P + 32% $4d^9 4f5s$ (^3D) ^4D + 5% $4d^9 4f5s$ (^3D) ^2D
	475283.0	-	40% $4d^9 4f5s$ (^1D) ^2D + 40% $4d^9 4f5s$ (^3F) ^4F + 11%$4d^9 4f5s$ (^3D) ^4D + 8% $4d^9 4f$ 5s (^3P) ^2P
	480261.0	-	48% $4d^9 4f$ 5s (^3D) ^4D + 17% $4d^9 4f5s$ (^3P) ^2P + 14%$4d^9 4f5s$ (^3D) ^2D + 10% $4d^9 4f$ 5s (^3F) ^4F
	484897.0	-	51% $4d^9 4f5s$ (^1D) ^2D + 40% $4d^9 4f5s$ (^3F) ^4F + 8% $4d^9 4f5s$ (^3P) ^2P
	487808.0	-	79% $4d^9 4f5s$ (^3D) ^2D + 11% $4d^9 4f5s$ (^3P) ^2P + 6% $4d^9 4f5s$ (^3F) ^4F
	528243.0		98% $4d^9 4f5s$ (^1P) ^2P
<u>J=5/2</u>			
247129.0	247281.0	-152.0	100% $4d^{10}4f$ ^2F
295895.n	295515.0	380.0	88% $4d^9 5s5p$ (^3D) ^4P + 10% $4d^9 5s5p$ (^3D) ^4D
301324.n	301007.0	317.0	56% $4d^9 5s5p$ (^3D) ^4F + 25% $4d^9 5s$ 5p (^1D) ^2F + 10%$4d^9 5s5p$ (^3D) ^2F
310971.n	310962.0	9.0	42% $4d^9 5s5p$ (^1D) ^2F + 28% $4d^9 5s5p$ (^3D) ^4D + 13%$4d^9 5s5p$ (^3D) ^4F + 8% $4d^9 5s5p$ (^3D) ^2F
313903.n	313814.0	89.0	27% $4d^9$ 5s 5p (^3D) ^4D+ 23% $4d^9 5s5p$ (^3D) ^4F +22%$4d^9 5s5p$ (^1D) ^2D + 13% $4d^9 5s5p$ (^3D) ^2D
316117.n	316102.0	15.0	95% $4d^{10}5f$ ^2F
322412.n	322668.0	-256.0	37% $4d^9 5s5p$ (^1D) ^2D + 32% $4d^9 5s5p$ (^3D) ^4D +22%$4d^9 5s5p$ (^3D) ^2D + 4% $4d^9 5s$ 5p (^3D) ^4F
339316.n	339468.0	-152.0	44% $4d^9 5s5p$ (^3D) ^2D + 31% $4d^9 5s5p$ (^3D) ^2F +20%$4d^9 5s5p$ (^1D) ^2D + 5% $4d^9 5s$ 5p (^1D) ^2F
345621.n	345125.0	496.0	46% $4d^9 5s5p$ (^3D) ^2F + 18% $4d^9 5s5p$ (^3D) ^2D +17%$4d^9 5s5p$ (^1D) ^2D + 16% $4d^9 5s$ 5p (^1D) ^2F
356047.n	356016.0	31.0	99% $4d^{10}6f$ ^2F
	467997.0	-	84% $4d^9 4f5s$ (^3P) ^4P + 11% $4d^9 4f5s$ (^3D) ^4D + 5% $4d^9 4f5s$ $(^1D)^2D$
	474782.0	-	44% $4d^9 4f5s$ (^3F) ^4F + 36% $4d^9 4f5s$ (^3D) ^4D + 16% $4d^9 4f5s$ (^1D) ^2D
	479476.0	-	25% $4d^9 4f5s$ $(^3G)^4G$ + 20% $4d^9 4f5s$ $(^3D)^4D$ + 20% $4d^9 4f5s$ (^3F) ^4F + 17% $4d^9 4f5s$ (^1F) ^2F
	480725.0	-	57% $4d^9 4f5s$ $(^1D)^2D$ + 19% 4d 4f5s $(^3D)^4D$ + 10% $4d^9 4f5s$ (^3P) ^4P + 9% $4d^9 4f5s$ (^3F) ^2F

Continue Table (3).

E(obs)	E(LSF)	Diff.	LS –Composition
	483445.0	-	51% $4d^94f5s\ (^3D)^2D$ + 19% $4d^94f5s\ (^1F)\ ^2F$ + 9% $4d^94f5s\ (^3G)^4G$ + 8% $4d^94f5s\ (^3D)^4D$
	486013.0	-	31% $4d^94f5s\ (^3F)\ ^4F$ + 27% $4d^94f5s\ (^3G)^4G$ + 14% $4d^94f5s\ (^1D)\ ^2D$+ 14% $4d^94f5s\ (^3D)\ ^2D$
	489687.0	-	37% $4d^94f5s\ (^3G)\ ^4G$+ 34% $4d^94f5s\ (^1F)\ ^2F$ + 25% $4d^94f5s\ (^3F)\ ^2F$
	493198.0	-	41% $4d^94f5s\ (^3F)\ ^2F$ + 28% $4d^94f5s\ (^3D)^2D$ + 28% $4d^94f5s\ (^1F)\ ^2F$
J=7/2			
247530.0	247379.0	151.0	100% $4d^{10}4f\ ^2F$
300868.n	300928.0	-60.0	71% $4d^95s5p\ (^3D)\ ^4F$ + 13% $4d^95s5p\ (^3D\ ^4D$ + 9% $4d^95s5p\ (^3D)\ ^2F$ + 6% $4d^95s5p\ (^1D)\ ^2F$
312193.n	311851.0	342.0	79% $4d^95s5p\ (^3D)\ ^4D$ + 12% $4d^95s5p\ (^1D)\ ^2F$ + 5% $4d^95s5p\ (^3D)\ ^4F$
315907.n	315930.0	-23.0	97% $4d^{10}5f\ ^2F$
319673.n	319595.0	78.0	43% $4d^95s5p\ (^1D)\ ^2F$ + 27% $4d^95s5p\ (^3D)\ ^2F$ + 23% $4d^95s5p(^3D)\ ^4F$ + 5% $4d^95s5p\ (^3D)\ ^4D$
334667.n	334511.0	156.0	60% $4d^95s5p\ (^3D)\ ^2F$ + 37% $4d^95s5p\ (^1D)\ ^2F$
356002.n	356035.0	-33.0	100% $4d^{10}6f\ ^2F$
	474383.0		- 53% $4d^94f5s\ (^3D)\ ^4D$ + 43% $4d^94f5s\ (^3F)\ ^4F$
	476369.0	-	67% $4d^94f5s\ (^3H)\ ^4H$ + 14% $4d^94f5s\ (^3G)\ ^4G$
	478130.0	-	33% $4d^94f5s\ (^3F)\ ^4F$ + 29% $4d^94f5s\ (^3D)\ ^4D$ + 12% $4d^94f5s\ (^1F)\ ^2F$ + 10% $4d^94f5s\ (^3G)\ ^4G$
	483090.0	-	38% $4d^94f5s\ (^1G)\ ^2G$ + 26% $4d^94f5s\ (^3H)\ ^4H$ + 24% $4d^94f5s\ (^3G)\ ^4G$ + 8% $4d^94f5s\ (^3F)\ ^2F$
	484495.0	-	54% $4d^94f5s\ (^3F)\ ^2F$ + 15% $4d^94f5s\ (^3G)\ ^2G$+ 12% $4d^94f5s\ (^1F)\ ^2F$ + 11% $4d^94f5s\ (^3G)\ ^4G$
	487361.0	-	24% $4d^94f5s\ (^1G)\ ^2G$ + 22% $4d^94f5s\ (^3G)\ ^4G$ + 20% $4d^94f5s\ (^1F)\ ^2F$ + 18% $4d^94f5s\ (^3F)\ ^4F$
	490279.0	-	45% $4d^94f5s\ (^1F)\ ^2F$ + 20% $4d^94f5s\ (^3F)\ ^2F$ + 16% $4d^94f5s(^3G)\ ^4G$ + 12% $4d^94f5s\ (^1G)\ ^2G$
	495586.0	-	74% $4d^94f5s\ (^3G)\ ^2G$ + 10% $4d^94f5s\ (^3F)\ ^2F$ + 7% $4d^94f5s\ (^1F)\ ^2F$
J=9/2	305126.0	-	100% $4d^95s5p\ (^3D)^4F$
	472902.0	-	66% $4d^94f5s\ (^3H)\ ^4H$ + 24% $4d^94f5s\ (^1H)\ ^2H$ + 6% $4d^94f5s\ (^3H)\ ^2H$
	475500.0	-	84% $4d^94f5s\ (^3F)\ ^4F$ + 12% $4d^94f5s\ (^3G)\ ^4G$
	477906.0	-	32% $4d^94f5s\ (^3G)\ ^4G$ + 29% $4d^94f5s\ (^1H)\ ^2H$ + 18% $4d^94f5s\ (^1G)\ ^2G$ + 9% $4d^94f5s\ (^3H)\ ^2H$

Continue Table (3).

E(obs)	E(LSF)	Diff.	LS –Composition
	482980.0	-	33% 4d^{9}4f5s (^{1}H) ^{2}H + 26% 4d^{9}4f5s (^{1}G) ^{2}G + 15% 4d^{9}4f5s (^{3}H) ^{4}H + 11% 4d^{9}4f5s (^{3}G) ^{2}G
	484332.0	-	34% 4d^{9}4f5s (^{3}H) ^{2}H + 29% 4d^{9}4f5s (^{3}G) ^{4}G + 20% 4d^{9}4f5s (^{3}G) ^{2}G + 11% 4d^{9}4f5s (^{3}H) ^{4}H
	488765.0	-	47% 4d^{9}4f5s(1G)^{2}G + 29% 4d^{9}4f5s (^{3}H) ^{2}H + 12% 4d^{9}4f5s (^{3}G) ^{4}G + 7% 4d^{9}4f5s (^{3}F) ^{4}F
	491259.0	-	67% 4d^{9}4f5s (^{3}G) ^{2}G + 17% 4d^{9}4f5s (^{3}H) ^{2}H + 6% 4d^{9}4f5s (^{1}H) ^{2}H + 5% 4d^{9}4f5s (^{3}G) ^{4}G
<u>J=11/2</u>			
	471311.0	-	84% 4d^{9}4f5s (^{3}H) ^{4}H + 12% 4d^{9}4f5s (^{1}H) ^{2}H
	477453.0	-	63% 4d^{9}4f5s (^{3}G) ^{4}G + 35% 4d^{9}4f5s (^{1}H) ^{2}H
	478537.0	-	75% 4d^{9}4f5s (^{3}H) ^{2}H + 13% 4d^{9}4f5s (^{1}H) ^{2}H + 12% 4d^{9}4f5s (^{3}G) ^{4}G
	484804.0	-	40% 4d^{9}4f5s (^{1}H) ^{2}H + 23% 4d^{9}4f5s (^{3}G) ^{4}G+ 22% 4d^{9}4f5s (^{3}H) ^{2}H + 14% 4d^{9}4f5s (^{3}H) ^{4}H
	469957.0	-	100% 4d^{9}4f5s (^{3}H) ^{4}H

Table (4). The experimental and fitted energy level values (cm^{-1}) and their L-S percentage of the levels of Even parity configuration of SbV.

E(obs.)	E(LSF)	Diff.	LS- Composition
<u>J=1/2</u> 0.0	0.0	0.0	100% 4d^{10} 5s ^{2}S
224681.0	224681.0	0.0	100% 4d^{10} 6s ^{2}S
311478.0	311478.0	0.0	100% 4d^{10} 7s ^{2}S
	354814.0	0.0	100% 4d^{10} 8s ^{2}S
434477.0	434392.0	85.0	40% 4d^{9}5s5d (^{3}D) ^{4}P + 29% 4d^{9}5s5d (^{3}D) ^{4}D + 20% 4d^{9}5s5d (^{1}D) ^{2}P + 8% 4d^{9}5s5d (^{3}D) ^{2}P
436524.0	436823.0	-299.0	33% 4d^{9}5s5d (^{3}D) ^{4}P + 23% 4d^{9}5s5d (^{3}D) ^{2}P + 21% 4d^{9}5s5d (^{1}D) ^{2}S + 11% 4d^{9}5s5d (^{1}D) ^{2}P
441613.0	441608.0	5.0	27% 4d^{9}5s5d (^{1}D) ^{2}S + 25% 4d^{9}5s5d (^{3}D) ^{4}P + 15% 4d^{9}5s5d (^{3}D) ^{4}D +15% 4d^{9}5s5d (^{3}D) ^{2}P
443820.0	443632.0	188.0	45% 4d^{9}5s5d (^{3}D) ^{4}D + 29% 4d^9 5s5d (^{1}D) ^{2}P + 11% 4d^{9}5s5d (^{3}D) ^{2}P + 10% 4d^{9}5s5d (^{1}D) ^{2}S
451102.0	450874.0	228.0	43% 4d^{9}5s5d (^{3}D) ^{2}P + 33% 4d^{9}5s5d (^{1}D) ^{2}P + 19% 4d^{9}5s5d (^{1}D) ^{2}S
	465670.0	-397.0	100% 4d^{9}5s6s (^{3}D) ^{4}D

Continue Table (4).

E(obs.)	E(LSF)	Diff.	LS- Composition
472413.0	472418.0	-5.0	77% $4d^95s5d$ (^3D) 2S + 20% $4d^95s5d$ (^1D) ^2S
J=3/2			
201949.0	201949.0	0.0	100% $4d^{10}5d$ ^2D
236805.0	236805.0	0.0	100% $4d^95s2$ ^2D
302677.0	302745.0	-68.0	100% $4d^{10}6d$ ^2D
349031.0	348974.0	57.0	100% $4d^{10}7d$ ^2D
428999.0	429124.0	-125.0	75% $4d^95s5d$ (^3D) ^4S + 22% $4d^95s5d$ (^3D) ^4P
433428.0	433882.0	-454.0	37% $4d^95s5d$ (^3D) ^4D + 26% 4d95s5d (^3D) 4P + 15% 4d95s5d (1D) 2P + 11% 4d95s5d (3D) 2P
	437492.0		31% $4d^95s5d$ (^1D) ^2D + 26% 4d95s5d (3D) 4F + 13% 4d95s5d (3D) 4D + 11% 4d95s5d (3D) 4P
441613.0	441438.0	175.0	58% 4d95s5d (3D) 2P + 22% 4d95s5d (3D) 4P
			+ 11% 4d95s5d (3D) 4S + 4% 4d95s5d (3D) 2D
443142.0	443313.0	-171.0	30% 4d95s5d (3D) 4D + 18% 4d95s5d (3D) 4P
			+ 15% 4d95s5d (3D) 2D + 11% 4d95s5d (3D) 4F
445141.0	444873.0	268.0	36% 4d95s5d (3D) 4F + 34% 4d95s5d (1D) 2P + 16% 4d95s5d (3D) 2D + 13% 4d95s5d (3D)4D
446175.0	446296.0	-121.0	40% 4d95s5d (1D) 2D +25% 4d95s5d (3D) 4F + 23% 4d95s5d (1D) 2P + 6% 4d95s5d (3D) 4D
453976.0	454159.0	-183.0	49% 4d9 5s 5d(3D) 2D + 26% 4d95s5d (1D)2D + 13% 4d95s5d (3D) 2P + 11% 4d95s5d (1D) 2P
	459624.0	-	42% 4d95s6s (3D) 4D + 37% 4d95s6s (1D) 2D + 21% 4d95s6s (3D)2D
	466884.0	-	58% 4d95s6s (3D) 4D + 22% 4d95s6s (1D) 2D + 20% 4d95s6s (3D) 2D
	474488.0	-	59% 4d95s6s (3D) 2D + 40% 4d95s6s (1D) 2D
J=5/2			
203060.0	203060.0	0.0	99% $4d^{10}5d$ ^2D
226692.0	226692.0	0.0	99% $4d^95s2$ ^2D
303222.0	303154.0	68.0	100% $4d^{10}6d$ ^2D
349141.0	349197.0	-56.0	100% $4d^{10}7d$ ^2D
435662.0n	435775.0	-113.0	33% $4d^95s5d$ (^3D) ^4F + 16% 4d95s5d (3D)4P + 14% 4d95s5d (3D)4D +13% 4d95s5d (3D)4G

Continue Table (4).

E(obs.)	E(LSF)	Diff.	LS- Composition
	437301.0	-	26% 4d95s5d (3D)4G +22% 4d95s5d (3D)4D + 21% 4d95s5d (1D)2F + 10% 4d95s5d (3D)2F
442363.0n	442334.0	29.0	60% 4d95s5d (3D) 4G + 16% 4d95s5d (3D)4F + 11% 4d95s5d (3D) 2F + 11% 4d95s5d(1D)2F
444726.0n	444544.0	182.0	77% 4d95s5d (3D) 2D + 13% 4d95s5d (3D)2F + 5% 4d95s5d (3D) 4F
445803.0n	445593.0	210.0	28% 4d95s5d (3D) 4F +26% 4d95s5d (3D)4D + 14% 4d95s5d (1D) 2F + 12% 4d95s5d (3D)2F
	447768.0		65% 4d95s5d (1D) 2D + 15% 4d95s5d $(^1D)^2F$+ 14% 4d95s5d (3D)4F + 4% 4d95s5d (3D)4P
455322.0n	455787.0	465.0	50%4d95s5d (3D) 2F + 33% 4d95s5d $(1D)^2F$
	458083.0	-	72% 4d9 5s 6s (3D) 4D + 15% 4d95s6s (1D)2D + 13% 4d95s6s (3D) 2D
	464681.0	-	85% 4d95s6s (3D) 2D + 8% 4d95s6s (3D)4D + 7% 4d95s6s (1D) 2D
	469152.	-	79%4d95s6s (1D) 2D + 20% 4d95s6s (3D)4D
<u>J=7/2</u>			
	326997.0	-	100% 4d105g 2G
	361301.0	-	100% 4d106g ^2G
	433814.0	-	38% $4d^95s5d$ (^3D) ^4G+24% $4d^95s5d$ (^3D) ^4D +21% $4d^95s5d$ (^3D) ^4F +10% $4d^95s5d(^1D)$ ^2G
	434566.0	-	54% $4d^95s5d$ (^3D) ^4D +19% $4d^95s5d$ (^3D) + 13% $4d^95s5d$ (^1D) ^2G +7% $4d^95s5d$ (^3D) ^2G
	437147.0	-	37% $4d^95s5d$ (^3D) ^4F + 17% $4d^95s5d$ (^1D) ^2G
	443480.0	-	38% $4d^95s5d$ (^3D) ^4G + 22% $4d^95s5d$ (^3D) ^2G + 20% $4d^95s5d$ (^3D) ^2F+16% $4d^95s5d$ (^1D) ^2G
	445054.0	-	55% $4d^95s5d$ (^3D) ^2F + 23% $4d^95s5d$ (^3D) ^4F + 11% $4d^95s5d$ (^1D) ^2G + 5% $4d^95s5d$ (^3D) ^4G
	448617.0	-	66% $4d^95s5d$ (^1D) ^2F + 9% $4d^95s5d$ (^3D) ^4F + 9% $4d^95s5d$ (^3D) ^2G + 9% $4d^95s5d$ (^1D) ^2G
	453247.0	-	48% $4d^95s5d$ (^3D) ^2G +25% $4d^95s5d$ (^1D) ^2G +17% $4d^95s5d$ (^1D) ^2F+10% $4d^95s5d(^3D)$ ^2F ^2F
	456592.0		100% $4d^95s6s$ (^3D) ^4D
<u>J=9/2</u>			
	327002.0	-	100% $4d^{10}5g$ ^2G
	361303.0	-	100% $4d^{10}6g$ ^2G

Continue Table (4).

E(obs.)	E(LSF)	Diff.	LS- Composition
	433047.0	-	76% $4d^95s5d$ (^3D) ^4G +10% $4d^95s5d$ (^3D) ^2G +7% $4d^95s5d$ (^1D) ^2G +7% $4d^95s5d$ (^3D) ^4F
	436386.0	-	83% $4d^9$ 5s 5d (^3D) ^4F + 9% $4d^9$ 5s 5d (^1D) ^2G
	442253.0	-	82% $4d^95s5d$ (^3D)^2G + 10% $4d^95s5d$ (^3D)^4G + 4% $4d^95s5d$ (^1D) ^2G
	446454.0	-	80% $4d^95s5d$ (1D) ^2G + 13% 4d95s5d (3D)4G + 7% $4d^95s5d$ (^3D) 4F
J=11/2			
	432705.0	-	100% $4d^95s5d$ (^3D) ^4G
n = new level			

Table (5).Fitted and HFR energy parameters values (cm^{-1}) and scaling factors for the even parity configurations of SbV.

Parameter	LSF	Accu.	H F	LSF/HF
$E_{av}(4d^{10}\,5s)$	1001	266	1009	
$E_{av}(4d^{10}\,6s)$	224778	266	221362	1.016
$E_{av}(4d^{10}\,7s)$	311544	266	307363	1.014
$E_{av}(4d^{10}\,8s)$	354862	266	350457	1.013
$E_{av}(4d^{10}\,5d)$	202796	193	198657	1.021
ζ_{5d}	466	151	366	1.274
$E_{av}(4d^{10}\,6d)$	302982	188	298880	1.014
ζ_{6d}	165	(fixed)	165	1.000
$E_{av}(4d^{10}\,7d)$	349108	188	346188	1.008
ζ_{7d}	90	(fixed)	90	1.000
$E_{av}(4d^{10}\,5g)$	327011	188	327840	0.997
ζ_{7d}	1	(fixed)	1	1.000
$E_{av}(4d^{10}\,6g)$	361313	188	361694	0.999
ζ_{6g}	1	(fixed)	1	1.000
$E_{av}(4d^9\,5s\,5d)$	441348	56	441286	1.000
ζ_{4d}	3840	64	3961	0.969
ζ_{5d}	504	74	404	1.248

Continue Table (5).

Parameter	LSF	Accu.	H F	LSF/HF
$F^{1(}$ 4d, 5d)	0	0	(fixed)	0
F^{2}(4d, 5d)	14048	529	18594	0.756
F^{3}(4d, 5d)	0	(fixed)	0	
F^{4}(4d, 5d)	5157	941	8008	0.644
G^{2}(4d, 5s)	13318	139	16183	0.823
G^{0}(4d, 5d)	3538	37	4300	0.823
G^{1}(4d, 5d)	0	(fixed)	0	
G^{2}(4d, 5d)	4310	45	5238	0.823
G^{3}(4d, 5d)	0	(fixed)	0	
G^{4}(4d, 5d)	3527	37	4286	0.823
G^{2}(5s, 5d)	22393	234	27211	0.823
E_{av}($4d^{9}$ 5s 6s)	463466	114	465198	0.996
ζ_{4d}	3631	97	3961	0.917
G^{2}(4d, 5s)	12526	(fixed)	16701	0.750
G^{2}(4d, 6s)	2498	(fixed)	3330	0.750
G^{0}(5s, 6s)	34861	27	4212	
E_{av}($4d^{9}$ $5s^{2}$)	230783	193	238448	0.968
ζ_{4d}	4070	151	3926	1.036

Continue Table (5).

configurations	parameters	LSF	Accu.	HF	LSF/HF
$4d^{10}5s$ -$4d^{9}5s5d$	R^{0}(4d, 4d; 4d,5d)	1263	(fixed)	1684	0.750
	R^{2}(4d, 4d; 4d,5d)	9575	(fixed)	12766	0.750
	R^{4}(4d, 4d; 4d,5d)	7312	(fixed)	9749	0.750
	R^{2}(4d, 5s; 5s, 5d)	-10865	(fixed)	-14487	0.750
	R^{0}(4d, 5s; 5d, 5s)	-1057	(fixed)	-1409	0.750
$4d^{10}5s$ -$4d^{9}5s6s$	R^{2}(4d, 4d; 4d, 6s)	-4219	(fixed)	-5626	0.750
$4d^{10}5s$ -$4d^{9}5s^{2}$	R^{2}(4d, 4d; 4d, 5s)	-8366	(fixed)	-11154	0.750
$4d^{10}6s$ -$4d^{9}5s5d$	R^{2}(4d, 6s; 5s, 5d)	1257	(fixed)	1675	0.750
	R^{0}(4d, 6s; 5d, 5s)	1659	(fixed)	2212	0.750

Continue Table (5).

configurations	parameters	LSF	Accu.	HF	LSF/HF
$4d^{10}5s$ -$4d^95s5d$	R^0(4d, 4d; 4d,5d)	1263	(fixed)	1684	0.750
$4d^{10}6s$ -$4d^95s6s$	R^2(4d, 4d; 4d, 5s)	-8450	(fixed)	-11267	0.750
$4d^{10}7s$ -$4d^95s5d$	R^2(4d, 7s; 5s, 5d)	993	(fixed)	1324	0.750
	R^0(4d, 7s; 5d, 5s)	1111	(fixed)	1481	0.750
$4d^{10}8s$ -$4d^95s5d$	R^2(4d, 8s; 5s, 5d)	0	(fixed)	0	
$4d^{10}8s$ -$4d^95s5d$	R^0(4d, 8s; 5d, 5s)	779	(fixed)	1038	0.750
	R^2(4d, 4d; 4d, 5s)	812	(fixed)	1082	0.750
$4d^{10}5d$ -$4d^95s5d$	R^2(4d, 5d; 5s, 5d)	0	(fixed)	0	
$4d^{10}5d$ -$4d^95s5d$	R^2(4d, 5d; 5d, 5s)	-8243	(fixed)	-10991	0.750
	R^2(4d, 5d; 5s, 6s)	-9236	(fixed)	-12315	0.750
	R^2(4d, 5d; 6s, 5s)	-3369	(fixed)	-4491	0.750
$4d^{10}5d$ -$4d^95s^2$	R^2(4d, 5d; 5s, 5s)	2325	(fixed)	3100	0.750
	R^2(4d, 6d; 5s, 5d)	-2707	(fixed)	-3609	0.750
$4d^{10}6d$ -$4d^95s5d$	R^2(4d, 6d; 5d, 5s)	-9667	(fixed)	-12890	0.750
$4d^{10}6d$ -$4d^95s6s$	R^2(4d, 6d; 5s, 6s)	0	(fixed)	0	
	R^2(4d, 6d; 6s, 5s)	-3616	(fixed)	-4821	0.750
	R^2(4d, 6d; 5s, 5s)	-1625	(fixed)	-2166	0.750
$4d^{10}7d$ -$4d^95s5d$	R^2(4d, 7d; 5s, 5d)	-1439	(fixed)	-1918	0.750
	R^2(4d, 7d; 5d, 5s)	-1793	(fixed)	-2391	0.750
$4d^{10}7d$ -$4d^95s6s$	R^2(4d, 7d; 5s, 6s)	-5535	(fixed)	-7380	0.750
$4d^{10}7d$ -$4d^95s6s$	R^2(4d, 7d; 6s, 5s)	0	(fixed)	0	
	R^2(4d, 7d; 5s, 5s)	-2143	(fixed)	-2857	0.750
	R^2(4d, 5g; 5s, 5d)	-1009	(fixed)	-1345	0.750
$4d^{10}5g$ -$4d^95s5d$	R^4(4d, 5g; 5d, 5s)	-1356	(fixed)	-1808	0.750
	R^2(4d, 6g; 5s, 5d)	-1296	(fixed)	-1728	0.750
$4d^{10}6g$ -$4d^95s5d$	R^4(4d, 6g; 5d, 5s)	-3781	(fixed)	-5041	0.750
$4d^95s5d$ -$4d^95s6s$	R^2(4d, 5d; 4d, 6s)	-3579	(fixed)	-4772	0.750
	R^2(4d, 5d; 6s, 4d)	-949	(fixed)	-1266	0.750
$4d^95s5d$ -$4d^95s^2$	R^2(4d, 5d; 4d, 5s)	-2977	(fixed)	-3970	0.750
	R^2(4d, 5d; 5s, 4d)	-883	(fixed)	-1177	0.750

Continue Table (5).

configurations	parameters	LSF	Accu.	HF	LSF/HF
$4d^{10}5s$ - $4d^95s5d$	R^0(4d, 4d; 4d,5d)	1263	(fixed)	1684	0.750
$4d^95s6s$ - $4d^95s^2$	R^0(4d, 6s; 4d, 5s)	961	(fixed)	1282	0.750
	R^2(4d, 6s; 5s, 4d)	1482	(fixed)	1976	0.750
$4d^95s6s$ - $4d^95s^2$	R^0(5s, 6s; 5s, 5s)	15889	(fixed)	21185	0.750
σ = 265					

Conclusion

With the help of 10 levels of $4d^95s5p$, I have investigated $4d^95s5d$ configuration. Since only J=1/2 and 3/2 levels of $4d^95s5p$ were previously known, therefore, using J=3/2 levels, I established sufficient levels of $4d^95s5d$ with J=5/2 and returning back to $4d^95s5p$, I established J=5/2 and J=7/2 levels of $4d^95s5p$. Two levels of $4d^95s^2$ were also quite useful to locate some of the J=5/2 and 7/2 levels of $4d^95s5p$ configuration. The configurations $4d^{10}$ 8p, $4d^{10}5f$, and $4d^{10}6f$ of odd parity matrix were investigated first time. Sixty-seven lines are now classified in SbV . spectrum.

The Hartree–Fock calculations with relativistic correction and least squares fitted parametric calculations were carried out using Cowan code in order to interpret the spectrum satisfactorily"

ACKNOWLEDGMENT

To the light, our Allah who guided me through the way, I am thankful to the Natural Sciences and Engineering Research Council of Canada (NSERC) for the financial assistance which made my stay possible in Antigonish laboratory in 2002. I also wish to thank the Aligarh Muslim University for their continued support to the research program on atomic spectra.The author gratefully acknowledge to the Dean, Dr. Faisal Mohammad Al Jassir for services and facilities provided in Qassim university, KSA. Finally. I would like to express my deepest appreciation to Prof. Rahimullah Khan and Prof. Tauheed Ahmad of Aligarh Muslim University (India) for his valuable discussion and suggestions.

References

[1] R.J. Lang, Phys. Rev.**35**, (1930).
[2] R. C. Gibbs, A.M. Vieweg and C.W. Gartlein, Phys. Rev. **34**, 406 (1929).
[3] Badami, J.S. Proc. Phys. Soc. London. **43**, 538 (1931).
[4] Chan, C, Phd. Thesis University of British Columbia, Vancouver B.C, Canada (1966).

[5] C. E. Moore, Atomic energy levels, **3**, N.B.S Circular 467 (U.S. Government Printing Bureau, Washington, D.C) (1957).
[6] T. Andersen, A. Kirkegard Nielsen and G. Sorensen, Phys. Scr. **6**, 122, (1972).
[7] V. Kaufman and J. Sugar, th.A.M Vankleef and Y.Joshi, J.opt. Soc. Am. B/Vol.2, No.3/March (1985).
[8] R.L; Kelly Atomic and ionic lines below 2000Å; J. Phys. Chem. Ref. Data, **16** **[**Suppl 1] (1987).
[9] R.D. Cowan, "Theory of Atomic Structure and Spectra, Berkeley ,CA, University of California Press (1981) and Cowan code programs.

[10] J Migdalek and M Garmulewicz 2000 *J. Phys. B: At. Mol. Opt. Phys.* **33** 1735

[11] Ryabtsev, S. S. Churilov, and É. Ya. Kononov, Opt. Spektrosk. 102(3), 396–404) (Russ.) [Opt. Spectrosc. 102(3), 354–362 (2007)]

[12] Relativistic configuration-interaction oscillator strengths for lowest E1 transitions in silver and gold isoelectronic sequences Phys. Rev. A 80, 42505 – Published 14 October 2009 Leszek Głowacki and Jacek Migdałek

[13] Transitions from Autoionized States of Sb, Te and I in the 100-260 Å Region, S. S. Churilov and Y. N. Joshi, Phys. Scr. 57, 500–502 (1998)