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REVISED AND EXTENDED ANALYSIS IN FOUR TIMES IONIZED XENON XE V

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Abstract—The atomic-emission spectrum of four times ionized xenon (Xe V) has been observed in the region 500–6700 Å; 233 lines were classified as transition between $5s5p^3$, $5s^25p5d$, $5s^25p6s$ with $5s^25p^2$, $5s^25p6p$ and $5s^25p4f$ configurations. Ninty-seven of these lines are reported for the first time. Two new energy level values corresponding to the $5s^25p4f$ configuration have been determined, and we proposed two new values for the previously reported $^3D_1$ and $^3G_5$ energy levels of this configuration. The value of the $5s^25p6p$ $^1S_0$ energy level has also been determined, and we propose a new value for the previously reported $5s^25p5d$ $^3F_4$ energy level. New adjusted values for the previously known levels of the studied configurations are included. Least-squares fitted parametric calculations involving configuration interactions have been carried out to interpret the observed spectrum. © 1998 Elsevier Scince Ltd. All rights reserved.

1. INTRODUCTION

There is great interest in spectroscopy data from xenon due to applications in collision physics, high-temperature plasmas and laser physics. In this last point, the understanding of the population mechanisms that affect the laser action for this element, require a knowledge of the spectral analysis corresponding to the different ions involved.

The spectrum of four times ionized xenon (Xe V) has the ground configuration $5s^25p^2$, the same as Sn I. Spectra of Sb II,[1] I IV,[2] Cs VI[3] and Ba VII[4] in this sequence were previously analysed by other authors. Several ionic UV-visible Xe lines were charge-state assigned to Xe V by Duchowicz et al[5] but not classifications. Gallardo et al[6] obtained nine new levels of the $5s^25p6p$ configuration, the first established energy levels of an even excited configuration. Pinnington et al[7] have presented a study of the beam-foil spectrum of Xe V. Recently, Tauheed et al[8] made the analysis of several configurations of this ion using a gas-triggered spark as a light source. Very recently, a work concerning $5s^25p5d$–$5s^25p4f$ and $5s5p^3$–$5s^25p4f$ transitions, establishing 10 new levels of the $5s^25p4f$ configuration, the remaining $^3F_4$ level of $5s^25p5d$ and the classification of several known Xe V laser lines, was reported by Larsson et al,[9] using collision-based spectroscopy.

With the final goal of completing the classification of the most prominent UV-visible Xe laser lines, we have continued an investigation of the Xe V spectrum that concerns the study of the energy levels in the configuration $5s^25p4f$, and the transitions $5s5p^3$–$5s^25p4f$, $5s^25p5d$–$5s^25p4f$, $5s^25p6s$–$5s^25p4f$, and the classification of lines belonging to transitions between the $5s^25p6p$ configuration with odd parity configurations.

2. EXPERIMENT

The experimental set-up is similar to that described in the work of Gallardo et al[6] SWR plates were used to record the new spectra in the vacuum ultraviolet region, where known lines of C, N, O, Xe II and Xe III were used as internal standards. In the UV-visible region new spectra were recorded using a water-cooled Pyrex tube 1.3 m long and 3 mm internal bore. The indium-coated tungsten

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electrodes were placed in side arms 1 m apart. Using a 140 nF capacitor, peak current pulses of 3.5 kA and 1 μs (FWHM) were obtained. In certain cases, larger capacitances up to 280 nF were used. Thorium lines from an electrodless discharge were superimposed on the spectrograms and served as reference lines.[10]

The spectrograms were measured with a photoelectric automatic Grant comparator, and the accuracy of the wavelength values is estimated to be ± 0.01 Å in the first diffraction order. The intensities of the lines were based on visual estimates. To distinguish among different states of ionization, we studied the behaviour of the spectral lines intensities as a function of pressure.

3. RESULT AND DISCUSSION

The lines observed in the present work, are listed in Table 1. The total number of observed lines is 233, of which 97 correspond to new classified lines. Table 1 also contains almost all the lines previously reported in the work of Duchowicz et al[5] as laser lines. It is interesting to note that most of these laser lines correspond, in spontaneous emission, to high intensity transitions between the

Table 1. Classified lines in the Xe V spectrum

Intensity	λ [Å] (vac.)	σ [cm⁻¹]		Ref.	Classification		
		Obs	Calc				
10	543.05	184145.1	7.6	6	$5s^25p^2$	$^3P_0$–$5s^25p5d$	$^3P_1$
11	566.57	176500.7	3.2	6	$5s^25p^2$	$^3P_1$–$5s^25p5d$	$^1D_2$
8	571.90	174855.7	5.8	7,8	$5s^25p^2$	$^3P_1$–$5s^25p5d$	$^3P_1$
7	575.59	173734.7	3.4	8	$5s^25p^2$	$^3P_1$–$5s^25p5d$	$^3P_0$
6	577.79	173073.3	1.7	8	$5s^25p^2$	$^3P_0$–$5s^25p5d$	$^3D_1$
7	582.52	171667.9	8.3	8	$5s^25p^2$	$^3P_2$–$5s^25p5d$	$^1D_2$
6	582.93	171547.2	7.8	8	$5s^25p^2$	$^1D_2$–$5s^25p5d$	$^1P_1$
5	588.16	170021.8	0.9	8	$5s^25p^2$	$^3P_2$–$5s^25p5d$	$^3P_1$
4	593.22	168571.5	69.8	7,8	$5s^25p^2$	$^1S_0$–$5s^25p6s$	$^1P_1$
8	595.09	168040.9	0.5	7,8	$5s^25p^2$	$^3P_2$–$5s^25p5d$	$^3D_3$
1	599.24	166878.0	7.6	8	$5s^25p^2$	$^3P_2$–$5s^25p5d$	$^3D_2$
7	603.40	165727.5	6.8	7,8	$5s^25p^2$	$^1D_2$–$5s^25p5d$	$^1F_3$
6	610.57	163781.4	79.9	8	$5s^25p^2$	$^3P_1$–$5s^25p5d$	$^3D_1$
9	635.39	157383.7	3.8	7,8	$5s^25p^2$	$^1D_2$–$5s^25p5d$	$^1D_2$
8	637.51	156860.2	0.9	7,8	$5s^25p^2$	$^3P_2$–$5s^25p5d$	$^3D_2$
6	662.10	151034.5	3.7	6	$5s^25p^3$	$^5S_2$–$5s^25p6p$	$^1P_1$
7	679.28	147214.7	5.0	7,8	$5s^25p^2$	$^3P_1$–$5s^25p5d$	$^3F_2$
7	691.27	144661.3	0.5	8	$5s^25p^2$	$^1D_2$–$5s^25p5d$	$^3D_1$
6	701.38	142576.1	6.4	8	$5s^25p^2$	$^1D_2$–$5s^25p5d$	$^3P_2$
12	702.34	142381.2	0.1	8	$5s^25p^2$	$^3P_2$–$5s^25p5d$	$^3F_2$
12A	702.87	142273.8	2.8	6	$5s5p^3$	$^5S_2$–$5s^25p6p$	$^3P_1$
10	707.26	141390.7	1.4	7,8	$5s^25p^2$	$^3P_2$–$5s5p^3$	$^3S_1$
6	707.90	141263.0	1.4	8	$5s^25p^2$	$^1D_2$–$5s5p^3$	$^1P_1$
3	735.94	135880.6	2.1	6	$5s5p^3$	$^5S_2$–$5s^25p6p$	$^3D_1$
2	765.47	130638.7	8.2		$5s5p^3$	$^3D_3$–$5s^25p6p$	$^1D_2$
3	768.58	130110.1	1.0		$5s5p^3$	$^3D_2$–$5s^25p6p$	$^3D_3$
7	772.00	129533.7	5.0	6	$5s5p^3$	$^3D_1$–$5s^25p6p$	$^3P_2$
6 bl	776.87	128721.7	4.3	6	$5s5p^3$	$^3D_2$–$5s^25p6p$	$^3P_2$
6	777.61	128599.2	601.3	8	$5s^25p^2$	$^1S_0$–$5s^25p5d$	$^3D_1$
7	780.67	128095.1	5.6	7,8	$5s^25p^2$	$^1D_2$–$5s^25p5d$	$^3F_2$
3	786.66	127119.7	9.5		$5s5p^3$	$^3D_2$–$5s^25p6p$	$^1P_1$
8	791.84	126288.1	9.0	6	$5s5p^3$	$^3D_3$–$5s^25p6p$	$^3D_3$
5	797.38	125410.7	0.9	8	$5s^25p^2$	$^3P_1$–$5s5p^3$	$^3P_2$
7	798.19	125283.5	3.4	8	$5s^25p^2$	$^3P_1$–$5s5p^3$	$^3P_1$
5	798.71	125201.9	2.2	8	$5s^25p^2$	$^1S_0$–$5s5p^3$	$^1P_1$

continued

Table 1—*continued*

Intensity	λ [Å] (vac.)	σ [cm⁻¹] Obs	Calc	Ref.	Classification		
7	805.70	124115.7	6.3	8	$5s^25p^2$	$^3P_1$–$5s5p^3$	$^3P_0$
9	829.35	120576.4	6.0	7,8	$5s^25p^2$	$^3P_2$–$5s5p^3$	$^3P_2$
6	830.23	120448.6	8.5	8	$5s^25p^2$	$^3P_2$–$5s5p^3$	$^3P_1$
1	834.08	119892.6	2.6	6	$5s5p^3$	$^3D_1$–$5s^25p6p$	$^3D_2$
2	839.15	119168.2	9.3		$5s5p^3$	$^3D_1$–$5s^25p6p$	$^3P_1$
6	844.89	118358.6	8.6	6	$5s5p^3$	$^3D_2$–$5s^25p6p$	$^3P_1$
7	851.82	117395.7	5.8	7,8	$5s^25p^2$	$^1D_2$–$5s5p^3$	$^1D_2$
6	862.20	115982.4	2.0	6	$5s5p^3$	$^3P_1$–$5s^25p6p$	$^1D_2$
3	863.15	115854.7	4.5		$5s5p^3$	$^3P_2$–$5s^25p6p$	$^1D_2$
8	867.40	115287.1	6.3	7,8	$5s^25p^2$	$^3P_0$–$5s5p^3$	$^3D_1$
9A	886.68	112780.3	78.6	6	$5s5p^3$	$^5S_2$–$5s^25p6p$	$^3D_1$
1	893.12	111967.0	7.9	6	$5s5p^3$	$^3D_2$–$5s^25p6p$	$^3D_1$
10	896.82	111505.1	5.3	6	$5s5p^3$	$^3P_2$–$5s^25p6p$	$^3D_3$
6	900.51	111048.2	7.7	8	$5s^25p^2$	$^1S_0$–$5s5p^3$	$^3S_1$
9	907.06	110246.3	6.1	6	$5s5p^3$	$^3P_1$–$5s^25p6p$	$^3P_2$
6	908.11	110118.8	8.6	6	$5s5p^3$	$^3P_2$–$5s^25p6p$	$^3P_2$
7	921.54	108514.0	3.8	6	$5s5p^3$	$^3P_2$–$5s^25p6p$	$^1P_1$
13	936.29	106804.5	5.2	7,8	$5s^25p^2$	$^3P_1$–$5s5p^3$	$^3D_2$
8	940.81	106291.4	1.5	7,8	$5s^25p^2$	$^1D_2$–$5s5p^3$	$^3P_2$
5	941.95	106162.7	4.0	6	$5s^25p^2$	$^1D_2$–$5s5p^3$	$^3P_1$
7	943.44	105995.1	4.5	8	$5s^25p^2$	$^3P_1$–$5s5p^3$	$^3D_1$
7	954.66	104749.3	50.2	6	$5s5p^3$	$^1D_2$–$5s^25p6p$	$^1D_2$
12	980.68	101970.1	0.3	6	$5s^25p^2$	$^3P_2$–$5s5p^3$	$^3D_2$
10	988.55	101158.3	9.6	7,8	$5s^25p^2$	$^3P_2$–$5s5p^3$	$^3D_1$
3	989.63	101047.9	7.5		$5s5p^3$	$^3P_0$–$5s^25p6p$	$^3P_1$
5	995.26	100476.3	6.2		$5s5p^3$	$^3P_2$–$5s^25p6p$	$^3D_2$
10	1002.48	99752.6	2.9		$5s5p^3$	$^3P_2$–$5s^25p6p$	$^3P_1$
9	1026.60	97408.9	9.5	6	$5s5p^3$	$^1D_2$–$5s^25p6p$	$^1P_1$
3	1056.47	94654.8	6.8	6	$5s5p^3$	$^3P_0$–$5s^25p6p$	$^3D_1$
6	1059.34	94398.4	8.7		$5s5p^3$	$^3D_3$–$5s^25p4f$	$^1G_4$
4	1063.26	94050.4	0.4	6	$5s^25p5d$	$^3F_2$–$5s^25p6p$	$^1D_2$
7	1063.55	94024.7	4.4		$5s5p^3$	$^3D_1$–$5s^25p4f$	$^3D_1$
8	1071.10	93362.0	2.2		$5s5p^3$	$^3P_2$–$5s^25p6p$	$^3D_1$
6	1072.81	93213.2	3.7		$5s5p^3$	$^3D_2$–$5s^25p4f$	$^3D_1$
3	1083.53	92290.9	2.3	6	$5s5p^3$	$^3S_1$–$5s^25p6p$	$^3S_1$
4	1086.01	92080.1	0.4		$5s5p^3$	$^3D_1$–$5s^25p4f$	$^3D_2$
6	1092.79	91508.9	7.8	7,8	$5s5p^2$	$^1D_2$–$5s5p^3$	$^3D_3$
8	1095.65	91270.0	69.7		$5s5p^3$	$^3D_2$–$5s^25p4f$	$^3D_2$
6	1109.81	90105.5	4.8	8	$5s^25p^2$	$^1S_0$–$5s5p^3$	$^3P_1$
5	1111.49	89969.3	9.7		$5s5p^3$	$^1P_1$–$5s^25p6p$	$^1S_0$
3	1114.82	89700.6	1.2	6	$5s^25p5d$	$^3F_2$–$5s^25p6p$	$^3D_3$
1	1115.28	89663.6	1.8		$5s5p^3$	$^3D_2$–$5s^25p4f$	$^3D_3$
6	1118.92	89371.9	1.9	6	$5s5p^3$	$^1D_2$–$5s^25p6p$	$^3D_2$
4	1119.77	89304.1	3.2	6	$5s5p^3$	$^3S_1$–$5s^25p6p$	$^3P_2$
3	1128.06	88647.8	8.6	6	$5s5p^3$	$^1D_2$–$5s^25p6p$	$^3P_1$
5	1132.32	88314.3	4.5	6	$5s^25p5d$	$^3F_2$–$5s^25p6p$	$^3P_2$
6	1140.28	87697.8	8.4	6	$5s5p^3$	$^3S_1$–$5s^25p6p$	$^1P_1$
8	1143.53	87448.5	7.7		$5s5p^3$	$^3D_3$–$5s^25p4f$	$^3D_2$
6	1153.27	86710.0	9.7	6	$5s^25p5d$	$^3F_2$–$5s^25p6p$	$^1P_1$
4	1155.13	86570.3	0.6		$5s^25p5d$	$^3F_2$–$5s^25p6p$	$^1S_0$
11	1164.96	85839.9	9.8	9	$5s5p^3$	$^3D_3$–$5s^25p4f$	$^3D_3$
9	1168.52	85578.3	7.6		$5s^25p5d$	$^3F_3$–$5s^25p6p$	$^3D_3$
10	1191.69	83914.4	3.2	9	$5s5p^3$	$^3D_2$–$5s^25p4f$	$^1F_3$
7	1218.88	82042.5	2.9		$5s5p^3$	$^3P_2$–$5s^25p4f$	$^1D_2$
12	1225.10	81626.0	6.2	9	$5s5p^3$	$^3D_3$–$5s^25p4f$	$^3F_4$
4	1236.34	80883.9	4.6	6	$5s5p^3$	$^1P_1$–$5s^25p6p$	$^1D_2$
7	1248.58	80091.0	1.2		$5s5p^3$	$^3D_3$–$5s^25p4f$	$^1F_3$
5	1255.32	79661.0	0.8	6	$5s5p^3$	$^3S_1$–$5s^25p6p$	$^3D_2$

continued

Table 1—*continued*

Intensity	λ [Å] (vac.)	σ [cm^{-1}]		Ref.	Classification		
		Obs	Calc				
6	1256.75	79570.3	69.6	6	$5s^25p5d$	$^3P_2$–$5s^25p6p$	$^1D_2$
6	1271.10	78672.0	2.1	6	$5s^25p5d$	$^3F_2$–$5s^25p6p$	$^3D_2$
12	1281.13	78056.1	6.1	7,8	$5s^25p^2$	$^3P_2$–$5s5p^3$	$^5S_2$
12	1282.89	77949.0	8.8	6	$5s^25p5d$	$^3F_2$–$5s^25p6p$	$^3P_1$
3	1290.57	77485.1	5.5	6	$5s^25p5d$	$^3D_1$–$5s^25p6p$	$^1D_2$
4	1301.69	76823.2	2.8	6	$5s^25p5d$	$^3P_2$–$5s^25p6p$	$^3S_1$
12	1317.46	75903.6	26		$5s5p^3$	$^3P_0$–$5s^25p4f$	$^3D_1$
9	1324.38	75507.0	6.5	9	$5s5p^3$	$^3D_2$–$5s^25p4f$	$^3F_2$
4	1324.58	75495.6	4.7		$5s^25p5d$	$^3P_1$–$5s^25p6p$	$^1S_0$
4	1329.44	75219.6	20.4	6	$5s^25p5d$	$^3P_2$–$5s^25p6p$	$^3D_3$
3	1330.70	75148.4	8.7	6	$5s5p^3$	$^1P_1$–$5s^25p6p$	$^3P_2$
10	1338.05	74735.6	5.5		$5s5p^3$	$^3P_1$–$5s^25p4f$	$^3D_1$
5	1340.34	74607.9	8.0		$5s5p^3$	$^3P_2$–$5s^25p4f$	$^3D_1$
12	1341.42	74547.9	8.5	6	$5s^25p5d$	$^3F_3$–$5s^25p6p$	$^3D_2$
7	1354.40	73833.4	3.7	6	$5s^25p5d$	$^3P_2$–$5s^25p6p$	$^3P_2$
13	1359.31	73566.7	6.8	9	$5s5p^3$	$^3D_2$–$5s^25p4f$	$^3F_3$
4	1359.74	73543.5	3.9	6	$5s5p^3$	$^1P_1$–$5s^25p6p$	$^1P_1$
11	1373.79	72791.3	1.5		$5s5p^3$	$^3P_1$–$5s^25p4f$	$^3D_2$
10	1376.20	72663.9	4.0		$5s5p^3$	$^3P_2$–$5s^25p4f$	$^3D_2$
6	1393.73	71749.9	9.6	6	$5s^25p5d$	$^3D_1$–$5s^25p6p$	$^3P_2$
9A	1397.45	71558.9	8.1	6	$5s^25p5d$	$^3F_2$–$5s^25p6p$	$^3D_1$
9	1407.34	71056.0	6.1	9	$5s5p^3$	$^3P_2$–$5s^25p4f$	$^3D_3$
7	1409.67	70938.6	8.6		$5s5p^3$	$^1D_2$–$5s^25p4f$	$^1D_2$
10	1412.12	70815.5	5.9	6	$5s^25p^2$	$^1S_0$–$5s5p^3$	$^3D_1$
12	1413.91	70725.9	5.6	9	$5s5p^3$	$^3D_3$–$5s^25p4f$	$^3G_4$
3	1425.61	70145.4	4.8	6	$5s^25p5d$	$^3D_1$–$5s^25p6p$	$^1P_1$
1	1433.80	69744.7	4.8		$5s5p^3$	$^3D_3$–$5s^25p4f$	$^3F_3$
1	1437.75	69553.1	2.9	6	$5s^25p5d$	$^3D_2$–$5s^25p6p$	$^1D_2$
8	1496.38	66827.9	7.7	9	$5s5p^3$	$^3D_3$–$5s^25p4f$	$^3G_3$
9	1505.80	66409.9	9.6	6	$5s^25p5d$	$^3P_1$–$5s^25p6p$	$^1D_2$
12	1531.22	65307.4	7.5	9	$5s5p^3$	$^3P_2$–$5s^25p4f$	$^1F_3$
4	1533.66	65203.5	3.7	6	$5s^25p5d$	$^3D_2$–$5s^25p6p$	$^3D_3$
6	1543.61	64783.2	3.0	6	$5s5p^3$	$^1P_1$–$5s^25p6p$	$^3P_1$
9	1544.11	64762.2	2.2	6	$5s^25p5d$	$^1D_2$–$5s^25p6p$	$^1D_2$
6	1557.84	64191.4	1.3	6	$5s^25p5d$	$^3P_2$–$5s^25p6p$	$^3D_2$
14	1561.47	64042.2	0.8		$5s^25p5d$	$^3D_3$–$5s^25p6p$	$^3D_3$
7	1566.96	63817.8	7.0	6	$5s^25p5d$	$^3D_2$–$5s^25p6p$	$^3P_2$
5	1568.10	63771.4	1.6	6,7	$5s^25p^2$	$^1D_2$–$5s5p^3$	$^5S_2$
7	1574.73	63502.9	3.7		$5s5p^3$	$^1D_2$–$5s^25p4f$	$^3D_1$
8	1575.59	64468.3	8.0	6	$5s^25p5d$	$^3P_2$–$5s^25p6p$	$^3P_1$
7	1607.41	62211.9	2.2	6	$5s^25p5d$	$^3D_2$–$5s^25p6p$	$^1P_1$
3	1610.11	62107.6	7.2	6	$5s^25p5d$	$^3D_1$–$5s^25p6p$	$^3D_2$
8	1624.41	61560.8	59.7		$5s5p^3$	$^1D_2$–$5s^25p4f$	$^3D_2$
2	1629.08	61384.3	3.9	6	$5s^25p5d$	$^3D_1$–$5s^25p6p$	$^3P_1$
6	1648.14	60674.5	3.7	6	$5s^25p5d$	$^3P_1$–$5s^25p6p$	$^3P_2$
8	1655.26	60413.5	3.0		$5s^25p5d$	$^1D_2$–$5s^25p6p$	$^3D_3$
12	1668.00	59952.0	1.8	9	$5s5p^3$	$^1D_2$–$5s^25p4f$	$^3D_3$
10	1675.51	59683.3	3.3		$5s^25p5d$	$^1P_1$–$5s^25p6p$	$^1S_0$
7	1692.91	59069.9	8.9		$5s^25p5d$	$^3P_1$–$5s^25p6p$	$^1P_1$
10	1712.52	58393.5	2.3		$5s5p^3$	$^1P_1$–$5s^25p6p$	$^3D_1$
3	1741.50	57421.8	1.5		$5s^25p5d$	$^1D_2$–$5s^25p6p$	$^1P_1$
6	1753.52	57028.1	8.3		$5s5p^3$	$^3P_1$–$5s^25p4f$	$^3F_2$
6	1775.44	56324.1	4.5		$5s^25p6s$	$^3P_1$–$5s^25p6p$	$^1D_2$
8	1782.05	56115.1	5.2		$5s^25p5d$	$^3F_3$–$5s^25p4f$	$^1D_2$
5	1818.40	54993.4	3.2		$5s^25p5d$	$^3D_1$–$5s^25p6p$	$^3D_1$
9	1844.91	54203.2	3.2	9	$5s5p^3$	$^1D_2$–$5s^25p4f$	$^1F_3$
5	1845.87	54175.0	4.6		$5s^25p5d$	$^3D_2$–$5s^25p6p$	$^3D_2$
6	1862.62	53687.8	7.3	9	$5s^25p5d$	$^3F_3$–$5s^25p4f$	$^1G_4$

continued

Table 1—*continued*

Intensity	λ [Å] (vac.)	σ [cm⁻¹] Obs	Calc	Ref.	Classification		
4	1870.87	53451.1	1.3		$5s^25p5d$	$^3D_2$–$5s^25p6p$	$^3P_1$
3	1893.79	52804.2	3.9		$5s^25p5d$	$^3F_2$–$5s^25p4f$	$^3D_1$
2	1920.49	52070.0	0.0		$5s^25p5d$	$^1F_3$–$5s^25p6p$	$^3D_3$
10	1921.44	52044.3	4.0	9	$5s5p^3$	$^3P_2$–$5s^25p4f$	$^3G_3$
3	1928.68	51848.9	8.6		$5s5p^3$	$^3S_1$–$5s^25p4f$	$^3D_2$
2	1944.34	51431.3	0.4		$5s^25p5d$	$^3P_0$–$5s^25p6p$	$^3P_1$
4	1959.60	51030.8	1.3		$5s^25p5d$	$^3P_1$–$5s^25p6p$	$^3D_2$
6	1976.36	50598.1	8.2		$5s^25p5d$	$^1P_1$–$5s^25p6p$	$^1D_2$
5	1987.79	50307.1	8.0		$5s^25p5d$	$^3P_1$–$5s^25p6p$	$^3P_1$
	λ (Å) (air)						
2	2024.35	49382.7	3.9		$5s^25p5d$	$^1D_2$–$5s^25p6p$	$^3D_2$
8	2029.75	49251.3	2.0		$5s^25p5d$	$^3F_2$–$5s^25p4f$	$^3D_3$
6	2032.56	49183.2	3.4		$5s^25p6s$	$^3P_0$–$5s^25p6p$	$^1P_1$
5	2040.86	48983.2	3.6		$5s^25p6s$	$^3P_1$–$5s^25p6p$	$^3S_1$
1	2089.12	47851.8	1.4		$5s^25p5d$	$^1P_1$–$5s^25p6p$	$^3S_1$
8	2123.69	47073.0	3.0		$5s5p^3$	$^1P_1$–$5s^25p4f$	$^1D_2$
4	2124.25	47060.6	0.6		$5s^25p5d$	$^3D_2$–$5s^25p6p$	$^3D_1$
5	2138.99	46736.3	6.3		$5s^25p5d$	$^3F_3$–$5s^25p4f$	$^3D_2$
9	2145.16	46601.9	2.1		$5s^25p6s$	$^1P_1$–$5s^25p6p$	$^1S_0$
8	2184.69	45758.8	8.0		$5s^25p5d$	$^3P_2$–$5s^25p4f$	$^1D_2$
3	2228.33	44862.7	2.3	6	$5s^25p5d$	$^1P_1$–$5s^25p6p$	$^3P_2$
4	2311.04	43257.3	7.5	6	$5s^25p5d$	$^1P_1$–$5s^25p6p$	$^1P_1$
11	2409.59	41488.3	8.3	6	$5s^25p6s$	$^3P_2$–$5s^25p6p$	$^1D_2$
2	2435.82	41041.5	0.9		$5s^25p5d$	$^1F_3$–$5s^25p6p$	$^3D_2$
14bl	2441.49	40946.2	6.0		$5s^25p6s$	$^3P_1$–$5s^25p6p$	$^3D_2$
15	2441.86	40940.0	39.7		$5s5p^3$	$^1D_2$–$5s^25p4f$	$^3G_3$
10	2443.37	40914.7	4.8	9	$5s^25p5d$	$^3F_3$–$5s^25p4f$	$^3F_4$
12	2473.11	40422.7	2.5	6	$5s^25p6s$	$^3P_0$–$5s^25p6p$	$^3P_1$
9	2485.41	40222.7	2.7	6	$5s^25p6s$	$^3P_1$–$5s^25p6p$	$^3P_1$
5	2513.88	39767.1	6.4	6	$5s^25p6s$	$^3P_1$–$5s^25p6p$	$^3P_0$
1	2522.04	39638.6	8.1		$5s5p^3$	$^1P_1$–$5s^25p4f$	$^3D_1$
11	2538.60	39380.0	79.8	9	$5s^25p5d$	$^3F_3$–$5s^25p4f$	$^1F_3$
6	2664.68	37516.8	7.0	6	$5s^25p6s$	$^1P_1$–$5s^25p6p$	$^1D_2$
15w	2691.74	37139.7	9.1	5,6	$5s^25p6s$	$^3P_2$–$5s^25p6p$	$^3D_3$
3	2780.10	35959.4	9.4		$5s^25p5d$	$^3F_4$–$5s^25p4f$	$^3D_3$
6	2796.17	35752.7	2.4	6	$5s^25p6s$	$^3P_2$–$5s^25p6p$	$^3P_2$
9	2848.43	35096.8	6.7	9	$5s^25p5d$	$^3F_2$–$5s^25p4f$	$^3F_2$
11	2875.15	34770.6	{1.2		$5s^25p5d$	$^1P_2$–$5s^25p4f$	$^3D_3$
			0.2	6	$5s^25p6s$	$^1P_1$–$5s^25p6p$	$^3S_1$
10	2927.64	34147.3	7.6	6	$5s^25p6s$	$^3P_2$–$5s^25p6p$	$^1P_1$
3	2936.86	34040.1	0.3	6	$5s^25p5d$	$^1P_1$–$5s^25p6p$	$^3P_0$
12	2937.57	34031.8	1.8	6	$5s^25p6s$	$^3P_0$–$5s^25p6p$	$^3D_1$
10	2954.93	33831.9	2.0	6	$5s^25p6s$	$^3P_1$–$5s^25p6p$	$^3D_1$
13	3015.09	33156.9	7.0	9	$5s^25p5d$	$^3F_2$–$5s^25p4f$	$^3F_3$
16	3077.71	32485.5	2.4		$5s^25p5d$	$^3F_4$–$5s^25p4f$	$^3G_5$
9	3109.49	32150.3	0.5	9	$5s^25p5d$	$^3D_3$–$5s^25p4f$	$^1G_4$
10	3145.57	31781.6	1.1	6	$5s^25p6s$	$^1P_1$–$5s^25p6p$	$^3P_2$
13	3149.11	31745.8	5.8		$5s^25p5d$	$^3F_4$–$5s^25p4f$	$^3F_4$
5	3227.69	30973.0	3.1		$5s^25p5d$	$^3F_3$–$5s^25p4f$	$^3F_2$
6	3230.04	30950.5	0.6		$5s^25p5d$	$^1D_2$–$5s^25p4f$	$^1D_2$
16	3305.96	30242.5	9.9	5	$5s^25p5d$	$^3F_2$–$5s^25p4f$	$^3G_3$
2	3309.11	30210.9	0.8		$5s^25p5d$	$^3F_4$–$5s^25p4f$	$^1F_3$
9	3312.92	30176.2	6.3	6	$5s^25p6s$	$^1P_1$–$5s^25p6p$	$^1P_1$
16	3330.84	30013.9	4.2	5	$5s^25p5d$	$^3F_3$–$5s^25p4f$	$^3F_4$
9	3443.32	29033.4	3.4		$5s^25p5d$	$^3F_3$–$5s^25p4f$	$^3F_3$
8	3444.70	29021.8	2.6		$5s^25p5d$	$^3P_2$–$5s^25p4f$	$^1F_3$

continued

Table 1—*continued*

Intensity	λ [Å] (vac.)	σ [cm⁻¹] Obs	Calc	Ref.	Classification		
3	3556.98	28105.7	5.9		$5s^25p5d$	$^1P_1$–$5s^25p6p$	$^3D_1$
11	3792.31	26361.7	2.4		$5s^25p5d$	$^3D_2$–$5s^25p4f$	$^3D_2$
12	3803.26	26285.8	5.7	5	$5s^25p5d$	$^3P_0$–$5s^25p4f$	$^3D_1$
14	3827.98	26116.1	6.3		$5s^25p5d$	$^3F_3$–$5s^25p6p$	$^3G_3$
6	3828.89	26109.8	10.0	6	$5s^25p6s$	$^3P_2$–$5s^25p6p$	$^3D_2$
3	3938.04	25386.2	6.7	6	$5s^25p6s$	$^3P_2$–$5s^25p6p$	$^3P_1$
6	3967.25	25199.3	9.5		$5s^25p5d$	$^3D_3$–$5s^25p4f$	$^3D_2$
8	3973.01	25162.7	3.1	5	$5s^25p5d$	$^3P_1$–$5s^25p4f$	$^3D_1$
4	4038.46	24754.9	4.5		$5s^25p5d$	$^3D_2$–$5s^25p4f$	$^3D_3$
10	4237.66	23591.3	1.6		$5s^25p5d$	$^3D_3$–$5s^25p4f$	$^3D_3$
15	4305.69	23218.5	9.1	5	$5s^25p5d$	$^3P_1$–$5s^25p4f$	$^3D_2$
12	4422.08	22607.5	7.6		$5s^25p5d$	$^1F_3$–$5s^25p4f$	$^1D_2$
1	4515.67	22138.9	8.7	6	$5s^25p6s$	$^1P_1$–$5s^25p6p$	$^3D_2$
15	4558.49	21931.0	0.9	12	$5s5p^3$	$^1P_1$–$5s^25p4f$	$^3F_2$
12	4634.49	21571.3	1.7		$5s^25p5d$	$^1D_2$–$5s^25p4f$	$^3D_2$
7	4769.94	20958.8	9.1	6	$5s^25p6s$	$^1P_1$–$5s^25p6p$	$^3P_0$
9	4849.30	20615.8	5.9		$5s^25p5d$	$^3P_2$–$5s^25p4f$	$^3F_3$
15	4954.13	20179.6	9.7	5,9	$5s^25p5d$	$^1F_3$–$5s^25p4f$	$^1G_4$
12	5007.80	19963.3	3.8	5	$5s^25p5d$	$^1D_2$–$5s^25p4f$	$^3D_3$
1	5151.90	19405.0	5.1		$5s^25p6s$	$^3P_2$–$5s^25p4f$	$^3F_3$
15	5159.08	19377.9	8.0	5	$5s^25p5d$	$^3D_3$–$5s^25p4f$	$^3F_4$
15	5260.19	19005.4	5.9	5	$5s^25p5d$	$^3D_2$–$5s^25p4f$	$^1F_3$
16	5352.92	18676.2	6.2	5	$5s^25p5d$	$^3P_2$–$5s^25p4f$	$^3F_3$
15	5394.62	18531.9	1.8	5	$5s^25p5d$	$^3D_1$–$5s^25p4f$	$^3F_2$
9	5602.83	17843.2	3.0		$5s^25p5d$	$^3D_3$–$5s^25p4f$	$^1F_3$
2	5899.11	16947.0	7.3		$5s^25p5d$	$^3F_4$–$5s^25p4f$	$^3G_3$
12	5955.67	16786.1	6.6	5	$5s^25p5d$	$^1P_1$–$5s^25p4f$	$^1D_2$
1	6653.85	15024.7	4.7		$5s^25p6s$	$^1P_1$–$5s^25p6p$	$^3D_1$

Notes: Int. Observed line intensity from visual estimation.
λ (Å): Observed wavelength in Å.
vac. Values of the observed wavelength in vacuum.
air Values of the observed wavelength in air.
σ (cm^{-1}): Wave number in cm^{-1}.
Obs. Observed wave number.
Calc. Calculated wave number from the level values given in Table 2 and the work of Tauheed *et al.*[8] by the Ritz combination principle.
Ref: References of previously published lines.
Classification: Level designations for the transition including configuration, term and total angular momentum.

levels involved. We present in total, 14 classified laser lines, 11 more than were observed in the work of Larsson et al[9] using collision-based spectroscopy.

We present in Table 2 the adjusted energy level values corresponding to the analysed configurations. We have revised the energy values corresponding to the $5s^25p4f$ $^3D_1$ and $^3G_5$ levels reported in the work of Larsson et al,[9] and changed them to 209310.0 and 202281.5 cm^{-1}, respectively. We also present in Table 2 two new energy levels values in 207366.7 and 216745.6 cm^{-1} that correspond to the levels $5s^25p4f$ $^3D_2$ and $^1D_2$, respectively, in order to complete all the energy level of this configuration. Our fitted values for these levels are also in agreement with the predicted values showed in the work of Larsson et al[9] In the same table is presented also the new value in 169799.4 cm^{-1} for the $5s^25p5d$ $^3F_4$ energy level reported in the same reference. This new value is supported by four new classified lines and by the line in 3077.71 Å corresponding to the $5s^25p5d$ $^3F_4$–$5s^25p4f$ $^3G_5$ transition.

Table 2. Energy level values of Xe V

Designation		E_{Obs} (cm^{-1})	E_{Calc} (cm^{-1})	Percentage composition
$5s^25p^2$	$(^3P)^3P_0$	0.0	15.3	89 + 10 $(^1S)^1S$
	$(^3P)^3P_1$	9291.8	9300.8	99
	$(^3P)^3P_2$	14126.7	14150.2	67 + 32 $(^1D)^1D$
	$(^1D)\,^1D_2$	28411.2	28387.8	66 + 32 $(^3P)^3P$
	$(^1S)^1S_0$	44470.4	44476.1	87 + 10 $(^3P)\,^3P$
$5s^25p6p$	$(^2P)^3D_1$	228064.9	228484.3	67 + 30 $(^2P)^1P$
	$(^2P)^3D_2$	235178.9	234968.0	74 + 13 $(^2P)^3P$ + 12 $(^2P)^1D$
	$(^2P)^3D_3$	246208.0	246101.9	100
	$(^2P)^3P_0$	233999.3	233755.0	89 + 11 $(^2P)\,^1S$
	$(^2P)^3P_1$	234459.6	234452.7	45 + 20 $(^2P)^1P$ + 19 $(^2P)^3S$ + 16 $(^2P)^3D$
	$(^2P)^3P_2$	244821.3	244805.1	62 + 24 $(^2P)^3D$ + 14 $(^2P)^1D$
	$(^2P)^3S_1$	247810.4	247814.9	77 + 15 $(^2P)^5P$ + 6 $(^2P)^3P$
	$(^2P)^1D_2$	250557.2	251227.1	73 + 24 $(^3P)^3P$
	$(^2P)^1P_1$	243216.5	242881.6	49 + 34 $(^2P)^1P$ + 16 $(^2P)^3D$
	$(^2P)^1S_0$	259642.3	259465.7	89 + 11 $(^2P)^3P$
$5s^25p4f$	$(^2P)^3G_3$	186746.7	186752.3	57 + 38 $(^2P)^1F$
	$(^2P)^3F_4$	190644.7	190712.6	53 + 39 $(^2P)^3F$ + 8 $(^2P)^1G$
	$(^2P)^3G_5$	202281.8	202517.7	100
	$(^2P)^3F_2$	191603.5	191268.2	81 + 11$(^2P)^3D$ + 7$(^2P)^1D$
	$(^2P)^3F_3$	189663.8	189876.0	47 + 22 $(^2P)^3D$ + 22 $(^2P)^1F$ + 9 $(^2P)^3G$
	$(^2P)^3G_4$	201545.2	201559.1	58 + 42 $(^2P)^3G$
	$(^2P)^3D_1$	209310.7	209139.1	100
	$(^2P)^3D_2$	207366.7	207204.4	80 + 16 $(^2P)^3F$
	$(^2P)^3D_3$	205758.8	205913.2	74 + 18 $(^2P)^3F$ + 7 $(^2P)^5F$
	$(^2P)^1G_4$	214317.7	214683.1	92
	$(^2P)^1F_3$	200010.2	199883.4	33 + 33 $(^2P)^3G$ + 32 $(^2P)^3F$
	$(^2P)^1D_2$	216745.6	216483.3	86 + 9 $(^2P)^3D$
$5s5p^3$	$(^4S)^5S_2$	92182.8	92202.7	93 + 6 $(^2P)^3P$
	$(^2D)^3D_1$	115286.3	115276.0	75 + 11 $(^2P)^3P$ + 8 $5s^25p5d$ $(^2P)^3D$
	$(^2D)^3D_2$	116097.0	116021.0	73 + 14 $(^2P)^3P$ + 8 $5s^25p5d$ $(^2P)^3D$
	$(^2D)^3D_3$	119919.0	119931.7	91 + 9 $5s^25p5d$ $(^2P)^3D$
	$(^2P)^3P_0$	133408.1	133406.5	92 + 8 $5s^25p5d$ $(^2P)^3P$
	$(^2P)^3P_1$	134575.2	134536.5	77 + 7 $5s^25p5d$ $(^2P)^3P$
	$(^2P)^3P_2$	134702.7	134737.0	43 + 21 $(^2D)^1D$ + 11 $5s^25p5d$ $(^2P)^1D$ + 6 $5s^25p5d$ $(^2P)^3P$
	$(^4S)^3S_1$	155518.1	155545.3	62 + 30 $(^2P)^1P$
	$(^2P)^1P_1$	169672.6	169435.1	28 + 23 $5s^25p5d$ $(^2P)^5P$ + 13 $5s^25p5d$ $(^2P)^3P$ + 9 $5s^25p5d$ $(^2P)^3D$ + 5 $5s^25p5d$ $(^2D)^3D$
	$(^2P)^1D_2$	145807.0	145976.2	29 + 27 $(^2P)^3P$ + 32 $5s^25p5d$ $(^2P)^1D$ + 6 $5s^25p5d$ $(^2P)^3F$
$5s^25p5d$	$(^2P)^3F_2$	156506.8	156462.7	89 + 8 $5s5p^3$ $(^2D)^1D$
	$(^2P)^3F_3$	160630.4	160663.5	93
	$(^2P)^3F_4$	169799.4	169759.2	100
	$(^2P)^3D_1$	173071.7	173220.1	57 + 9 $(^2P)^3P$ + 19 $5s5p^3$ $(^2P)^1P$ + 11 $5s5p^3$ $(^4S)^3S$
	$(^2P)^3D_2$	181004.3	181050.6	41 + 31 $(^2P)^1D$ + 19 $5s5p^3$ $(^2D)^1D$
	$(^2P)^3D_3$	182167.2	181959.0	80 + 6 $(^2P)^3F$ + 6 $(^2P)^1F$ + 8 $5s5p^3$ $(^2D)^3D$
	$(^2P)^3P_0$	183025.2	183059.3	92 + 8 $5s5p^3$ $(^2P)^3P$
	$(^2P)^3P_1$	184147.6	184139.3	68 + 18 $(^2P)^3D$ + 7 $5s5p^3$ $(^2P)^3P$

continued

Table 2—*continued*

Designation		E_{Obs} (cm^{-1})	E_{Calc} (cm^{-1})	Percentage composition
	$(^2P)^3P_2$	170987.6	171018.9	$48 + 25\ (^2P)^3D$ $+ 10\ (^2P)^1D$ $+ 12\ 5s5p^3\ (^2D)^1D$
	$(^2P)^1F_3$	194138.0	194190.1	$90 + 8\ (^2P)^3D$
	$(^2P)^1D_2$	185795.0	185803.9	$15 + 43\ (^2P)^3P + 22\ (^2P)^3D$ $+ 10\ 5s5p^3\ (^2D)^1D$ $+ 7\ 5s5p^3\ (^2P)^3P$
	$(^2P)^1P_1$	199959.0	200018.4	$55 + 13\ p^3\ (^2P)^1P$ $+ 24\ 5s^25p6s\ (^2P)^3P$
$5s^25p6s$	$(^2P)^3P_0$	194033.1	194065.0	99
	$(^2P)^3P_1$	194232.9	194182.5	$57 + 26\ (^2P)^1P$ $+ 10\ 5s^25p5d\ (^2P)^1P$
	$(^2P)^3P_2$	209068.9	209045.5	100
	$(^2P)^1P_1$	213040.2	213058.2	$73 + 18\ (^2P)^3P$ $+ 8\ 5s^25p5d\ (^2P)^1P$

Notes:
Designation: Level designation, including configuration, parentage, term and total angular momentum.
E_{Obs}: Experimental energies in cm^{-1}. The energy values for the even parity are based on odd parity levels given in the work of Tauheed *et al.*[8] and wave numbers of Table 1 weighted according to their estimated uncertainties.
E Calc: Values obtained from the least-squares fitting.
Percentage Composition: Percentage composition of the experimental energy level. Percentages lower than 5% are omitted.

In accordance with our wavelength values, we classified the laser line in 3305.96 Å as a $5s^25p5d\ ^3F_2$–$5s^25p4f\ ^3G_3$ transition, rejecting the previous classification reported by Larsson et al[9] We also report in this work a new value in 259642.3 cm^{-1} for the $5s^25p6p\ ^1S_0$ energy level.

The level values were determined in an iterative procedure where the wavenumbers of the observed lines were weighted according to their estimated uncertainties.

Theoretical predictions of the energy levels have been used in our analysis of the spectra. Relativistic Hartree–Fock calculations were used to obtain the energy parameters with the computer code developed by Cowan.[12] Predictions of the energy levels are then made by diagonalizing the energy matrices. A least-squares fit of the parameters to the observed levels was carried out involving configuration interactions.

In Table 3 we present the parameters obtained in the LSF calculations for the $5s^25p^2$, $5s^25p6p$ and $5s^25p4f$ configurations with their corresponding Hartree–Fock values and scaling factors. We have included the $5p^4$ configuration in this calculation because the $5s^25p^2$ configuration structure is affected through the s^2–p^2 interaction and the standard deviation was reduced from 368 to 328 cm^{-1}. The inclusion of the $5s^25p6p\ ^1S_0$ level made possible to let free the G^2 (5p6p) parameter, which was fixed in the table of energy parameters reported by Gallardo et al[6]

All the configuration interaction integrals were fixed at their Hartree–Fock values in the calculation except the $5s^25p^2$–$5p^4$ integral that it was fixed at 85% of its Hartree–Fock value. Hereby we achieved better results in the least-squares fit and the standard deviation was slightly reduced. These configurations structures are also affected by the interaction with the experimental unknown $5s5p^25d$ configuration, but its inclusion in this calculation significantly increases the standard deviation.

The fitted values for the odd configurations were calculated including configuration Rydberg series interaction and the new experimental value for the $5s5p^25d\ ^3F_4$ energy level. The results were in general accordance with the previously published values,[8] except that our calculation shows a small reduction of the standard deviation value, considering that we were using different scaled values for the interaction integrals.

Table 3. Energy parameters for the $5s^25p^2$, $5s^25p6p$, $5s^25p4f$ and $5p^4$ configurations of Xe V

Configuration	Parameter	HFR value (cm^{-1})	Fitted value (cm^{-1})	Fit/HF
$5s^25p^2$	E_{av}		21 403	
	$F^2(5p,5p)$	55 554	50 278 ± 1007	0.905 ± 0.018
	$\alpha(5p,5p)$		− 143 (FIX)[a]	
	ζ_{5p}	9095	9593 ± 202	1.055 ± 0.022
$5s^25p6p$	E_{av}	225 119	242 484 ± 113	1.077 ± 0.001
	ζ_{5p}	9793	8739 ± 167	0.892 ± 0.017
	ζ_{6p}	2586	2594 ± 213	1.003 ± 0.082
	$F^2(5p,6p)$	19 780	17 839 ± 902	0.902 ± 0.046
	$G^0(5p,6p)$	4267	3503 ± 149	0.821 ± 0.035
	$G^2(5p,6p)$	5648	5846 ± 809	1.035 ± 0.143
$5s^25p4f$	E_{av}	187 936	200 751 ± 96	1.068 ± 0.001
	ζ_{5p}	8858	9330 ± 191	1.053 ± 0.021
	ζ_{4f}	168	168 (FIX)	1.000
	$F^2(5p,4f)$	48 022	39 199 ± 1173	0.816 ± 0.024
	$G^2(5p,4f)$	37 402	29 201 ± 825	0.781 ± 0.022
	$G^4(5p,4f)$	26 627	18 663 ± 1123	0.700 ± 0.042
$5p^4$	E_{av}	249 988	249 988 (FIX)	1.000
	$F^2(5p,5p)$	55 559	55 559 (FIX)	1.000
	$\alpha(5p,5p)$		0 (FIX)	
	ζ_{5p}	8994	8994 (FIX)	1.000
Configuration interaction integrals				
$5s^25p^2$–$5s^25p6p$	$R^0(5p5p, 5p6p)$	1851	1851 (FIX)	1.000
$5s^25p^2$–$5s^25p6p$	$R^2(5p5p, 5p6p)$	8658	8658 (FIX)	1.000
$5s^25p^2$–$5s^25p4f$	$R^2(5p5p, 5p4f)$	− 43 668	− 43 668 (FIX)	1.000
$5s^25p^2$–$5p^4$	$R^1(5s5s, 5p5p)$	72 662	55 680 (FIX)	0.766
$5s^25p6p$–$5s^25p4f$	$R^2(5p6p, 5p4f)$	− 5314	− 5314 (FIX)	1.000
$5s^25p6p$–$5s^25p4f$	$R^2(5p6p, 4f5p)$	− 6025	− 6025 (FIX)	1.000
	σ^b		328	

Notes:

Configuration: Configurations involved in the calculation.

Parameter: Energy parameters.

HFR: Hartree–Fock values in cm^{-1} of the energy parameters.

Fitted value: Fitted value of the energy parameters: a, The α value is taken from the work of Tauheed *et al.*[8].

Fit/HF: Rate between fitted and Hartree–Fock energy parameter values.

Configuration interaction integrals: Values of the Configuration interaction integrals for the involved configurations.

b, The rms. deviation of the fit.

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