Physica Scripta. Vol. 45, 584–589, 1992.

Revised and Extended Analysis of Five Times Ionized Argon (Ar VI)

M. Raineri, F. Bredice, M. Gallardo and J. G. Reyna Almandos

Centro de Investigaciones Opticas, (CIOp), Casilla de Correo 124, 1900 La Plata, Argentina

C. J. B. Pagan

Instituto de Física "Gleb Wataghin", Universidade Estadual de Campinas (UNICAMP), C.P. 6165, 13081 Campinas, São Paulo, Brasil

and

A. G. Trigueiros*

Department of Physics, University of Lund, S-223 62 Lund, Sweden

Received September 20, 1991; accepted November 22, 1991

Abstract

The spectrum of five times ionized argon, (Ar VI), has been observed in the 280–2100 Å wavelength range. Eighty-seven lines have been identified as transitions between levels of the $3s^23p$, $3s3p^2$, $3s^23d$, $3p^3$, $3s3p3d$, $3s^24s$, $3s^24d$ and $3s3p4s$ configurations. For 33 of the lines the classification is new. Forty-one energy level values belonging to these configurations were analyzed and we propose 9 new energy level values for levels corresponding to odd parity configurations. The configurations are interpreted by fitting the theoretical energy expressions to the observed energy levels using least-squares techniques. The parameter values are compared with results from Hartree–Fock calculations.

1. Introduction

The ground-state configuration of five times ionized argon, (Ar^{5+}), is $3s^23p$ with the term ^2P. Ar VI belongs to the Al I isoelectronic sequence. Excited states either belong to simple one-electron configuration of the type $3s^2nl$ or to three-electron configurations such as $3s3p^2$, $3p^3$ and $3s3p(^{1,3}P)nl$ etc., giving both doublets and quartets.

The spectra of the first, second and third elements in this sequence are presented in Atomic Energy Levels (AEL), Ref. [1]. Subsequent to this tabulation, the Al I spectrum was investigated by Eriksson and Isberg [2]. Results about Si II were published by Shenstone [3] and the P III spectrum was studied by Magnusson and Zetterberg [4]. Early results on the spectra of S IV and Cl V have been published in AEL but later results of S IV were compiled by Martin *et al.*, see Ref. [5] and references therein. The first results about the spectrum of Ar VI in the vacuum ultraviolet were published by Phillips and Parker [6]. Fawcett *et al.* [7] studied the spectra of multiple ionized inert gases, including Ar, and Schönheit [8] made a similar study finding a large quantity of new lines. Lines corresponding to the spin-forbidden resonance multiplet $3s^23p\,^2P$–$3s3p^2\,^4P$ were reported by Ekberg and Svensson [9]. Using a Theta-Pinch light source Fawcet *et al.* [10] classified some lines of Ar VI. Using the beam-foil technique Livingston *et al.* [11] have studied the argon spectra from Ar V to Ar VIII and using the same technique Buchet–Poulizac *et al.* [12] have studied the argon spectra from Ar VI to Ar VIII. A few lines of Ar VI were classified in the work of De-Ye *et al.* [13].

Theoretical calculations for the Al I isoelectronic sequence were made by Fawcett [14]. Computed *ab-initio* transition probabilities and energy levels for Al I-like ions were made by Huang [15] and data about highly ionized copper and zinc, belonging to this sequence, were published by Sugar and Kaufman [16–17].

Recently, Träbert *et al.* [18–19] have studied the spectrum of argon and other ions in the vacuum ultraviolet. They searched for lines of Mg-, Al- and Si-like ions. Recoil ion spectroscopy was used by Lesteven–Vaïsse *et al.* [20] who have studied all argon spectra from Ar I to Ar IX. Some anomalies in resonance transitions in the Al I isoelectronic sequence were observed by Engström *et al.* [21] and a new work about energy levels and lifetimes of Ar VI was recently published by Pinnington *et al.* [22]. An extended analysis of spectra and term systems in Al-like Ca VIII to Ni XVI was published by Redfors and Litzén [23] and lifetimes of the $3s^24s\,^2S$ states for Al-like ions from S IV to Fe XIV were published by Thornbury *et al.* [24]. Transitions in spectra of highly ionized Kr and Mo belonging to the Al I isoelectronic sequence were recently reported by Jupén *et al.* [25]. In the present work we report a revised and extended analysis of Ar VI that includes 33 newly classified lines and 9 new energy level values.

Experiment

The light source used in the present work is a discharge tube built at the Centro de Invesitgaciones Opticas, (CIOp), to study highly ionized gases [26]. It is a 30 cm long Pyrex tube with an inner diameter of 3 mm. Gas excitation was produced by discharging a bank of low inductance capacitors varying between 2.5 and 100 nF and charged up to 19 kV through the tube. Light radiation emitted axially was analyzed using a 3 m normal incidence vacuum spectro-

* *Permanent address:* Instituto de Fisica "Gleb Wataghin", Universidade Estadual de Campinas (UNICAMP), C.P. 6165, 13081 Campinas, São Paulo, Brasil.

graph with a concave diffraction grating of 1200 lines/mm, blazed for 1200 Å. The plate factor in the first order is 2.77 Å/mm. Ilford Q-2 plates were used to record the spectra between 280–2100 Å. C III and N II [27], O III [28] and lines of Ar III–Ar V [27] were recorded as internal wavelength standards. Exposing the plates with 10^4 shots we were able to obtain good spectra of argon below 300 Å. The lines were observed in the first, second, and in some cases, third order of diffraction.

The gas pressure, the discharge voltage, and the capacitance were varied to distinguish between different stages of ionization. A well developed Ar VI spectrum was obtained with the following parameters: 120 mTorr, 18 kV and 20 nF. The positions of spectral lines on the plates were determined with a rotating prism photoelectric automatic Grant comparator whose precision is 1 μm. The uncertainty in determining the wavelength of unperturbed lines by this procedure is estimated to be ± 0.01 Å in the first diffraction order.

Analysis

The Ar VI lines observed in the present work are given in Table I, 33 of them being without previous classification. The intensities of the lines given in the table are based on visual estimates and the values given in the calculated column are deduced from the optimized level values. The optimized energy values derived from the observed lines are given in Table II and the general structure of the term system is shown in Fig. 1. The level values were determined in an iterative procedure where the wavenumbers of the observed lines are weighted according to their estimated uncertainties. Theoretical predictions of the structure of the configurations made at the Department of Physics, University of Lund, were also used in the analysis. The predictions were obtained by diagonalizing the energy matrices with appropriately scaled Hartree–Fock (HF) values for the energy parameters. The computer code developed by Cowan [29] was used. All levels designations in Table II are in *LS* notation, and in the same table we present the percentage composition of the levels.

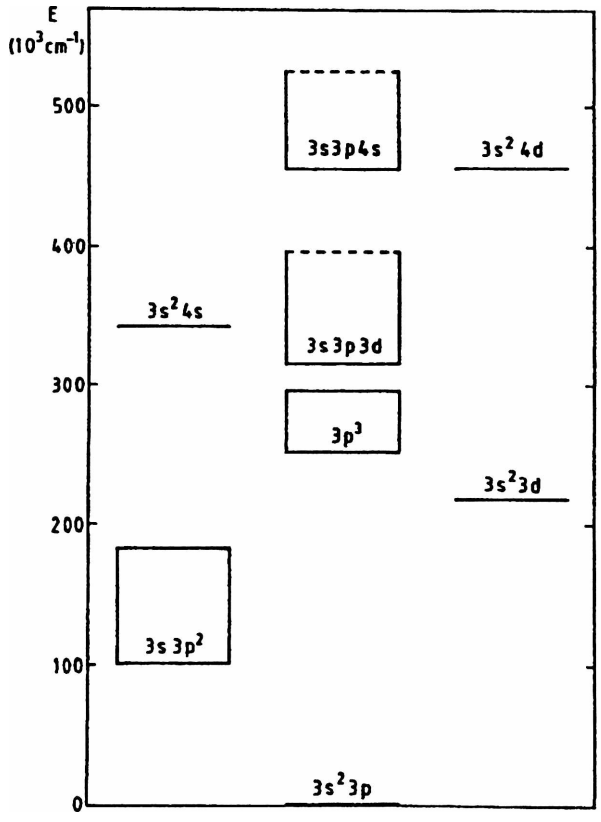

Fig. 1. Gross structure of the observed Ar VI configurations

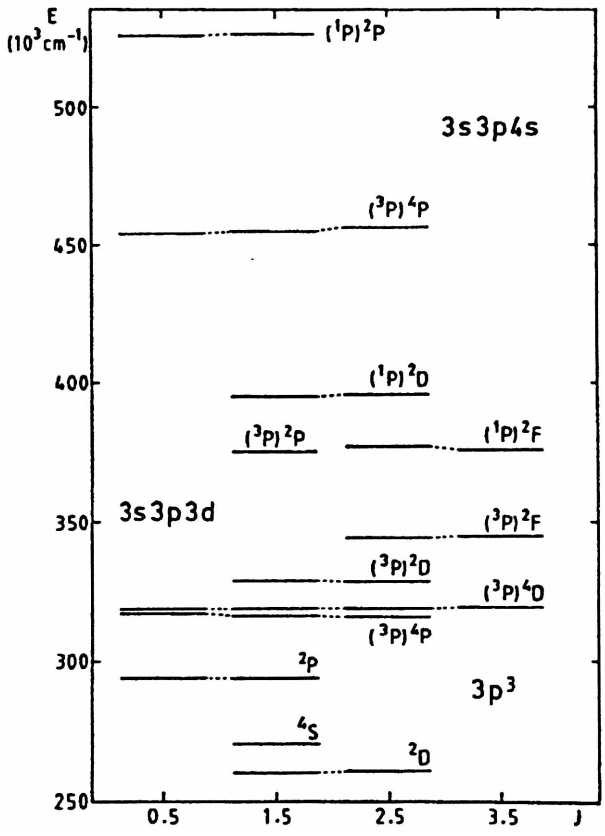

Fig. 2. Level structure of the observed $3p^3$, $3s3p3d$ and $3s3p4s$ configurations in Ar VI

A comparison with the level system given by Pinnington *et al.* [22] shows that six of their level values have been confirmed, although the accuracy has been considerably improved. However, for seven levels we propose new identifications as discussed below.

The observed structure of the configurations $3p^3$, $3s3p3d$ and $3s3p4s$ is shown in Fig. 2. For the level $3s3p(^3P)3d\,^2F_{5/2}$ we propose the new value 344 307.9 cm^{-1}. The level is established by five new lines that are given in Table I.

For the level $3s3p(^3P)3d\,^2F_{7/2}$ we propose the new value 346 073.4 cm^{-1} determined by two new lines, see Table I. Both level values fit well with the extrapolation that can be done from the isoelectronic data published in Ref. [23].

For the level $3s3p(^3P)3d\,^2P_{3/2}$ we propose the new value 375 657.6 cm^{-1}. This level is determined by four new lines, see Table I. The level value fits very well with the isoelectronic trend from Ref. [23]. The isoelectronic graph gives for the $3s3p(^3P)3d\,^2P_{1/2}$ level a probable value near 376 300 cm^{-1}. We were not able to find the transitions establishing this level, but according to the extrapolated values mentioned above and our theoretical predictions we reject the experimental value published in the work of Pinnington *et al.* [22] for this level.

Table I. *Classified lines in the Ar VI spectrum*

Int.	λ (Å)	σ (cm⁻¹) Observed	Calculated	Transition
4	219.91[c,d]	454 736.6	45.6	$3s^23p\,^2P_{1/2} - 3s^24d\,^2D_{3/2}$
6bl	220.93[c,d]	452 622.7	591.7	$3s^23p\,^2P_{3/2} - 3s^24d\,^2D_{5/2}$
1	281.43[c,d]	355 321.2	16.8	$3s3p^2\,^4P_{3/2} - 3s3p(^3P)4s\,^4P_{5/2}$
1	281.91[c,d]	354 723.8	14.3	$3s3p^2\,^4P_{1/2} - 3s3p(^3P)4s\,^4P_{3/2}$
2	282.42[c,d]	354 077.9	82.2	$3s3p^2\,^4P_{5/2} - 3s3p(^3P)4s\,^4P_{5/2}$
1	282.55[c,d]	353 917.7	7.7	$3s3p^2\,^4P_{3/2} - 3s3p(^3P)4s\,^4P_{3/2}$
1	283.16[c,d]	353 155.0	5.0	$3s3p^2\,^4P_{3/2} - 3s3p(^3P)4s\,^4P_{1/2}$
1	283.55[b]	352 676.0	83.1	$3s3p^2\,^4P_{5/2} - 3s3p(^3P)4s\,^4P_{3/2}$
2	294.03[c,d]	340 095.7	5.7	$3s^23p\,^2P_{3/2} - 3s^24s\,^2S_{1/2}$
2bl	326.15[a,c]	306 609.2	598.3	$3s^23d\,^2D_{3/2} - 3s3p(^1P)4s\,^2P_{3/2}$
4	326.22[a,c]	306 537.4	8.5	$3s^23d\,^2D_{5/2} - 3s3p(^1P)4s\,^2P_{3/2}$
4	326.32[a,c]	306 448.7	50.6	$3s^23d\,^2D_{3/2} - 3s3p(^1P)4s\,^2P_{1/2}$
6	409.10[a]	244 440.4	0.1	$3s3p^2\,^2D_{3/2} - 3s3p(^1P)3d\,^2F_{5/2}$
2	409.28[a,c]	244 328.9	7.4	$3s3p^2\,^2D_{5/2} - 3s3p(^1P)3d\,^2F_{5/2}$
6bl	410.10[a,c]	243 842.4	3.1	$3s3p^2\,^2D_{5/2} - 3s3p(^1P)3d\,^2F_{7/2}$
6A	455.83[c,d]	219 379.6	8.3	$3s3p^2\,^4P_{1/2} - 3s3p(^3P)3d\,^4D_{3/2}$
6	456.38[c,d]	219 113.5	3.8	$3s3p^2\,^4P_{1/2} - 3s3p(^3P)3d\,^4D_{1/2}$
8	457.01[c,d]	218 812.2	2.2	$3s3p^2\,^4P_{3/2} - 3s3p(^3P)3d\,^4D_{5/2}$
8bl	457.46[c,d]	218.598.3	3.0	$3s^23p\,^2P_{1/2} - 3s^23d\,^2D_{3/2}$
4bl	457.51[a,c]	218 574.5	81.7	$3s3p^2\,^4P_{3/2} - 3s3p(^3P)3d\,^4D_{3/2}$
8bl	458.05[c,d]	218 318.6	7.2	$3s3p^2\,^4P_{3/2} - 3s3p(^3P)3d\,^4D_{1/2}$
8w	459.32[c,d]	217 714.5	4.5	$3s3p^2\,^4P_{5/2} - 3s3p(^3P)3d\,^4D_{7/2}$
6	460.09[c,d]	217 346.0	7.1	$3s3p^2\,^4P_{5/2} - 3s3p(^3P)3d\,^4D_{3/2}$
6	460.19[c,d]	217 300.7	0.6	$3s3p^2\,^4P_{1/2} - 3s3p(^3P)3d\,^4P_{1/2}$
8w	461.23[c,d]	216 811.3	2.3	$3s3p^2\,^4P_{1/2} - 3s3p(^3P)3d\,^4P_{3/2}$
4	461.89[d]	216 501.8	504.0	$3s3p^2\,^4P_{3/2} - 3s3p(^3P)3d\,^4P_{1/2}$
6	462.01[d]	216 445.3	5.7	$3s^23p\,^2P_{3/2} - 3s^23d\,^2D_{5/2}$
6	462.13[d]	216 386.7	5.9	$3s^23p\,^2P_{3/2} - 3s^23d\,^2D_{3/2}$
2	462.93[c]	216 013.8	5.7	$3s3p^2\,^4P_{3/2} - 3s3p(^3P)3d\,^4P_{3/2}$
8	464.26[c,d]	215 397.0	6.8	$3s3p^2\,^4P_{3/2} - 3s3p(^3P)3d\,^4P_{5/2}$
6	465.58[c,d]	214 783.2	1.1	$3s3p^2\,^4P_{5/2} - 3s3p(^3P)3d\,^4P_{3/2}$
8	466.94[c,d]	214 161.5	2.2	$3s3p^2\,^4P_{5/2} - 3s3p(^3P)3d\,^4P_{5/2}$
4	468.39[a]	213 498.6	9.3	$3s3p^2\,^2D_{5/2} - 3s3p(^3P)3d\,^2F_{7/2}$
6	468.80[a,c]	213 310.3	0.9	$3s3p^2\,^2P_{1/2} - 3s3p(^1P)3d\,^2D_{3/2}$
8	471.19[a,c]	212 227.8	7.9	$3s3p^2\,^2P_{3/2} - 3s3p(^1P)3d\,^2D_{5/2}$
4A	471.87[a]	211 922.6	15.9	$3s3p^2\,^2P_{3/2} - 3s3p(^1P)3d\,^2D_{3/2}$
6	472.04[a,c]	211 844.4	6.5	$3s3p^2\,^2D_{3/2} - 3s3p(^3P)3d\,^2F_{5/2}$
4	472.29[a,c]	211 735.2	3.8	$3s3p^2\,^2D_{5/2} - 3s3p(^3P)3d\,^2F_{5/2}$
6	485.78[a,c]	205 853.5	3.9	$3s3p^2\,^2S_{1/2} - 3s3p(^3P)3d\,^2P_{3/2}$
8	508.83[a,c]	196 528.6	8.5	$3s3p^2\,^2D_{3/2} - 3s3p(^3P)3d\,^2D_{3/2}$
8	508.91[a,c]	196 496.9	7.4	$3s3p^2\,^2D_{3/2} - 3s3p(^3P)3d\,^2D_{5/2}$
4bl	509.12[a]	196 417.0	5.8	$3s3p^2\,^2D_{5/2} - 3s3p(^3P)3d\,^2D_{3/2}$
8	509.20[a,c]	196 385.3	4.7	$3s3p^2\,^2D_{5/2} - 3s3p(^3P)3d\,^2D_{5/2}$
4	516.86[a,c]	193 476.2	6.5	$3s3p^2\,^2P_{1/2} - 3s3p(^3P)3d\,^2P_{3/2}$
4	520.61[a,c]	192 082.7	1.5	$3s3p^2\,^2P_{3/2} - 3s3p(^3P)3d\,^2P_{3/2}$
10	544.73[c,d]	183 576.3	6.1	$3s^23p\,^2P_{1/2} - 3s3p^2\,^2P_{3/2}$
10	548.91[c,d]	182 179.2	81.1	$3s^23p\,^2P_{1/2} - 3s3p^2\,^2P_{1/2}$
6bl	551.35[d]	181 373.6	69.0	$3s^23p\,^2P_{3/2} - 3s3p^2\,^2P_{3/2}$
8	555.63[c,d]	179 975.5	4.0	$3s^23p\,^2P_{3/2} - 3s3p^2\,^2P_{1/2}$
4	564.30[a]	177 209.9	11.1	$3s^23d\,^2D_{3/2} - 3s3p(^1P)3d\,^2D_{5/2}$
6	564.49[a,c]	177 151.9	0.3	$3s^23d\,^2D_{5/2} - 3s3p(^1P)3d\,^2D_{5/2}$
6bl	565.29[a]	176 901.4	899.0	$3s^23d\,^2D_{3/2} - 3s3p(^1P)3d\,^2D_{3/2}$
4	565.49[a,c]	176 838.4	9.2	$3s^23d\,^2D_{5/2} - 3s3p(^1P)3d\,^2D_{3/2}$
8	587.02[c,d]	170 351.5	2.2	$3s3p^2\,^4P_{1/2} - 3p^3\,^4S_{3/2}$
8w	588.91[c,d]	169 803.9	3.7	$3s^23p\,^2P_{1/2} - 3s3p^2\,^2S_{1/2}$
8	589.78[c,d]	169 555.4	5.6	$3s3p^2\,^4P_{3/2} - 3p^3\,^4S_{3/2}$
8	594.10[c,d]	168 322.2	1.0	$3s3p^2\,^4P_{5/2} - 3p^3\,^4S_{3/2}$
6w	596.67[d]	167 596.8	6.6	$3s^23p\,^2P_{3/2} - 3s3p^2\,^2S_{1/2}$
8bl	618.67[c,f]	161 637.5	8.1	$3s3p^2\,^2D_{3/2} - 3p^3\,^2P_{1/2}$
6bl	618.72[a,c]	161 624.0	3.4	$3s3p^2\,^2D_{3/2} - 3p^3\,^2P_{3/2}$
8	619.16[c,f]	161 508.7	10.7	$3s3p^2\,^2D_{5/2} - 3p^3\,^2P_{3/2}$
6	622.15[a,c]	160 732.1	1.8	$3s3p^2\,^2P_{3/2} - 3s3p(^3P)3d\,^2F_{5/2}$
6	631.68[a]	158 307.9	8.5	$3s^23d\,^2D_{3/2} - 3s3p(^1P)3d\,^2F_{5/2}$
4	631.91[a,c]	158 248.9	8.7	$3s^23d\,^2D_{5/2} - 3s3p(^1P)3d\,^2D_{3/2}$
6A	633.85[b]	157 765.0	4.4	$3s^23d\,^2D_{5/2} - 3s3p(^1P)3d\,^2F_{7/2}$
4	636.94[a,c]	157 001.5	4.8	$3s^23d\,^2D_{5/2} - 3s3p(^3P)3d\,^2P_{3/2}$
6	687.84[f]	145 382.8	2.7	$3s3p^2\,^2P_{3/2} - 3s3p(^3P)3d\,^2D_{5/2}$
10w	754.93[c,d]	132 462.1	1.4	$3s^23p\,^2P_{1/2} - 3s3p^2\,^2D_{3/2}$
6A	767.07[c,d]	130 366.3	7.0	$3s^23p\,^2P_{3/2} - 3s3p^2\,^2D_{5/2}$
10	767.73[c,d]	130 253.2	4.3	$3s^23p\,^2P_{3/2} - 3s3p^2\,^2D_{3/2}$
6	782.41[f]	127 810.7	0.0	$3s3p^2\,^2D_{3/2} - 3p^3\,^2D_{5/2}$
8A	783.07[f]	127 702.5	697.3	$3s3p^2\,^2D_{5/2} - 3p^3\,^2D_{5/2}$
8A	783.66[f]	127 606.2	5.5	$3s3p^2\,^2D_{3/2} - 3p^3\,^2D_{3/2}$
6	784.35[f]	127 494.0	2.8	$3s3p^2\,^2D_{5/2} - 3p^3\,^2D_{3/2}$
6	784.80[a]	127 420.9	0.6	$3s^23d\,^2D_{5/2} - 3s3p(^3P)3d\,^2F_{7/2}$
6A	795.44[a]	125 716.8	4.9	$3s^23d\,^2D_{3/2} - 3s3p(^3P)3d\,^2F_{5/2}$
6bl	795.85[a]	125 651.8	5.1	$3s^23d\,^2D_{5/2} - 3s3p(^3P)3d\,^2F_{5/2}$
8	804.62[f]	124 282.3	1.1	$3s3p^2\,^2S_{1/2} - 3p^3\,^2P_{3/2}$
8	893.50[f]	111 919.3	8.4	$3s3p^2\,^2P_{1/2} - 3p^3\,^2P_{1/2}$
6bl	893.63[f]	111 903.3	3.7	$3s3p^2\,^2P_{1/2} - 3p^3\,^2P_{3/2}$
6	904.90[f]	110 509.0	8.7	$3s3p^2\,^2P_{3/2} - 3p^3\,^2P_{3/2}$
8	998.43[d]	100 157.6	8.2	$3s3p^2\,^2P_{1/2} - 3p^3\,^4P_{1/2}$
1	1000.16[c,d]	99 983.8	2.3	$3s3p^2\,^2P_{3/2} - 3p^3\,^4P_{5/2}$
6	1012.66[d]	98 749.4	7.7	$3s3p^2\,^2P_{3/2} - 3p^3\,^4P_{3/2}$
10w	1303.87[f]	76 694.6	5.3	$3s3p^2\,^2P_{3/2} - 3p^3\,^2D_{5/2}$
4	1420.60[a]	70 392.5	2.5	$3s^24d\,^2D_{5/2} - 3s3p(^1P)4s\,^2P_{3/2}$
4	1422.51[a]	70 298.0	8.0	$3s^24d\,^2D_{3/2} - 3s3p(^1P)4s\,^2P_{1/2}$

[a] New line
[b] Previously identified by Lesteven–Vaïsse (Ref. [20])
[c] Measured in second order
[d] Previously identified according to Ref. [27]
[e] Previously identified by De-Ye *et al.* (Ref. [13])
[f] Previously identified by Pinnington *et al.* (Ref. [22])
A = Asimetric line
w = Wide line
bl = Blended line

For the levels $3s3p(^1P)3d\,^2D_{3/2}$ and $3s3p(^1P)3d\,^2D_{5/2}$ we propose the new values 395 492.0 cm^{-1} and 395 804.1 cm^{-1} respectively. These level values are in accordance with the values obtained along the isoelectronic sequence using data of Ref. [23] and with our theoretical predictions. The $3s3p(^1P)3d\,^2D_{3/2}$ level is determined by four new lines, see Table I. For the other level of the same multiplet we classified three lines that are given in the same table.

For the $3s3p(^1P)3d\,^2F_{7/2}$ level we propose the new value 376 417.2 cm^{-1}. This level is determined by a new line at 410.10 Å, classified as $3s3p^2\,^2D_{5/2}$–$3s3p(^1P)3d\,^2F_{7/2}$ and another new line at 633.85 Å, classified as $3s^23d\,^2D_{5/2}$–$3s3p(^1P)3d\,^2F_{7/2}$. For the $3s3p(^1P)3d\,^2F_{5/2}$ level we propose the new value 376 901.5 cm^{-1}. The level is determined by four new lines that are classified in Table I. Both level values of this multiplet are in good agreement with our theoretical predictions and with the graphic extrapolation along the isoelectronic sequence based on the work of Ref. [23].

For the level $3s3p(^1P)4s\,^2P_{1/2}$ we propose the new value 525 043.6 cm^{-1}. The level is determined by a new line at 326.32 Å, classified as $3s^23d\,^2D_{3/2}$–$3s3p(^1P)4s\,^2P_{1/2}$, and

Table II. *Energy levels of Ar VI*

Designation	Energy (cm^{-1})		Percentage composition[a]
$3s^23p\ ^2P_{1/2}$	0.0	97	
$3s^23p\ ^2P_{3/2}$	2 207.1	97	
$3s3p^2\ ^4P_{1/2}$	100 158.2	99	
$3s3p^2\ ^4P_{3/2}$	100 954.8	99	
$3s3p^2\ ^4P_{5/2}$	102 189.2	99	
$3s3p^2\ ^2D_{3/2}$	132 461.4	87	$3s3p^2\ ^2D$ + 12 $3s^23d\ ^2D$
$3s3p^2\ ^2D_{5/2}$	132 574.1	87	$3s3p^2\ ^2D$ + 12 $3s^23d\ ^2D$
$3s3p^2\ ^2S_{1/2}$	169 803.7	99	
$3s3p^2\ ^2P_{1/2}$	182 181.1	99	
$3s3p^2\ ^2P_{3/2}$	183 576.1	99	
$3s^23d\ ^2D_{3/2}$	218 593.0	87	$3s^23d\ ^2D$ + 12 $3s3p^2\ ^2D$
$3s^23d\ ^2D_{5/2}$	218 652.8	87	$3s^23d\ ^2D$ + 12 $3s3p^2\ ^2D$
$3p^3\ ^2D_{3/2}$	260 066.9	64	$3p^3\ ^2D$ + 35 $3s3p(^3P)3d\ ^2D$
$3p^3\ ^2D_{5/2}$	260 271.4	64	$3p^3\ ^2D$ + 35 $3s3p(^3P)3d\ ^2D$
$3p^3\ ^4S_{3/2}$	270 510.4	99	
$3p^3\ ^2P_{3/2}$	294 084.8	73	$3p^3\ ^2P$ + 19 $3s3p(^3P)3d\ ^2P$ + 6 $3s3p(^1P)3d\ ^2P$
$3p^3\ ^2P_{1/2}$	294 099.5	74	$3p^3\ ^2P$ + 19 $3s3p(^3P)3d\ ^2P$ + 6 $3s3p(^1P)3d\ ^2P$
$3s3p(^3P)3d\ ^4P_{5/2}$	316 351.6	98	
$3s3p(^3P)3d\ ^4P_{3/2}$	316 970.5	97	
$3s3p(^3P)3d\ ^4P_{1/2}$	317 458.8	98	
$3s3p(^3P)3d\ ^4D_{1/2}$	319 272.0	98	
$3s3p(^3P)3d\ ^4D_{3/2}$	319 536.5	97	
$3s3p(^3P)3d\ ^4D_{5/2}$	319 767.0	98	
$3s3p(^3P)3d\ ^4D_{7/2}$	319 903.9	99	
$3s3p(^3P)3d\ ^2D_{5/2}$	328 958.8	47	$3s3p3d(^3P)\ ^2D$ + 32 $3s3p(^1P)3d\ ^2D$ + 20 $3p^3\ ^2D$
$3s3p(^3P)3d\ ^2D_{3/2}$	328 989.9	47	$3s3p3d(^3P)\ ^2D$ + 32 $3s3p(^1P)3d\ ^2D$ + 20 $3p^3\ ^2D$
$3s^24s\ ^2S_{1/2}$	342 302.8	99	
$3s3p(^3P)3d\ ^2F_{5/2}$	344 307.9[n]	71	$3s3p3d(^3P)\ ^2F$ + 28 $3s3p(^1P)3d\ ^2F$
$3s3p(^3P)3d\ ^2F_{7/2}$	346 073.4[n]	71	$3s3p3d(^3P)\ ^2F$ + 28 $3s3p(^1P)3d\ ^2F$
$3s3p(^3P)3d\ ^2P_{3/2}$	375 657.6[n]	78	$3s3p3d(^3P)\ ^2P$ + 16 $3p^3\ ^2P$
$3s3p(^1P)3d\ ^2F_{7/2}$	376 417.2[n]	71	$3s3p3d(^1P)\ ^2F$ + 28 $3s3p(^3P)3d\ ^2F$
$3s3p(^1P)3d\ ^2F_{5/2}$	376 901.5[n]	71	$3s3p3d(^1P)\ ^2F$ + 28 $3s3p(^3P)3d\ ^2F$
$3s3p(^1P)3d\ ^2D_{3/2}$	395 492.0[n]	66	$3s3p3d(^1P)\ ^2D$ + 17 $3s3p(^3P)3d\ ^2D$ + 15 $3p^3\ ^2D$
$3s3p(^1P)3d\ ^2D_{5/2}$	395 804.1[n]	67	$3s3p3d(^1P)\ ^2D$ + 17 $3s3p(^3P)3d\ ^2D$ + 15 $3p^3\ ^2D$
$3s3p(^3P)4s\ ^4P_{1/2}$	454 109.8	99	
$3s^24d\ ^2D_{3/2}$	454 745.6	99	
$3s^24d\ ^2D_{5/2}$	454 798.8	99	
$3s3p(^3P)4s\ ^4P_{3/2}$	454 872.5	99	
$3s3p(^3P)4s\ ^4P_{5/2}$	456 271.6	99	
$3s3p(^1P)4s\ ^2P_{1/2}$	525 043.6[n]	99	
$3s3p(^1P)4s\ ^2P_{3/2}$	525 191.3[n]	98	

[a] Percentages lower than 5% are omitted
[n] New level

another new line at 1422.51 Å, classified as $3s^24d\ ^2D_{3/2}$–$3s3p(^1P)4s\ ^2P_{1/2}$.

For the level $3s3p(^1P)4s\ ^2P_{3/2}$ we propose the new value 525 191.3 cm^{-1}. This level is supported by three new lines that are classified in Table I.

We report a new line at 618.72 Å, classified as $3s3p^2\ ^2D_{3/2}$–$3p^3\ ^2P_{3/2}$ transition. For us, the line at 804.62 Å, corresponds to the $3s3p^2\ ^2S_{1/2}$–$3p^3\ ^2P_{3/2}$ transition. This line has a double classification in the previous work of Ref. [22]. In the same work, some other lines also appear with double classification, but for us, the lines at 893.50 Å, 893.63 Å and 904.90 Å correspond to the $3s3p^2\ ^2P$–$3p^3\ ^2P$ multiplet. These transitions confirm (fairly well) the previously observed values of the $3p^3\ ^2P_{1/2}$ and $^2P_{3/2}$ levels, see Ref. [22].

We report two new lines at 508.91 Å and 509.12 Å, classified as $3s3p^2\ ^2D_{3/2}$–$3s3p(^3P)3d\ ^2D_{5/2}$ and $3s3p^2\ ^2D_{5/2}$–$3s3p(^3P)3d\ ^2D_{3/2}$ transitions. These lines confirm the previously observed values of the $3s3p(^3P)3d\ ^2D$ doublet, see Ref. [22].

Theoretical Interpretation

The level structure was theoretically interpreted by a least-squares fit of the energy parameters to the experimental level values. For this purpose the computer code developed by Cowan [29] was used.

The scaled Hartree–Fock factor was 0.85 for all parameters, except for ζ_{nl} where the scaled factor was 0.95 and for E_{av} where the scaled factor was 1.00. These scaled factors were taken in this form because the computed energy-level intervals agree better with the experimental ones.

In order to obtain a better interpretation of the levels it was necessary to introduce the $3s^24p$ configuration. The results of the parametric calculations are presented in Table III.

The α parameter was kept free because all the levels of the $3p^3$ configuration are known. The first three configuration interaction integrals were held fixed in the calculation scaled at 0.75, 0.95 and 0.95 of their Hartree–Fock values. The rest of the configuration interaction integrals were held fixed at

Table III. *Energy parameters (cm^{-1}) for the $3s^23p$, $3s^24p$, $3p^3$, $3s3p3d$, $3s3p4s$ configurations of Ar VI*

Configuration	Parameter	Scaled Hf Value	Fitted Value[a]	Ratio Fitted Value SHF Value
$3s^23p$	E_{av}	0	13738	
$3s^23p$	ζ_{3p}	1307	1512	1.157
$3s^24p$	E_{av}	391438	393887	1.006
$3s^24p$	ζ_{4p}	394	394 (FIX)	
$3p^3$	E_{av}	287614	294987	1.026
$3p^3$	$F^2(3p,3p)$	66962	68868	1.028
$3p^3$	$\alpha(3p,3p)$		−112	
$3p^3$	ζ_{3p}	1306	1610	1.233
$3s3p3d$	E_{av}	323495	332094	1.027
$3s3p3d$	$F^2(3p,3d)$	63506	63334	0.997
$3s3p3d$	$G^1(3s,3p)$	90341	70384	0.779
$3s3p3d$	$G^2(3s,3d)$	61497	66186	1.076
$3s3p3d$	$G^1(3p,3d)$	78310	76869	0.982
$3s3p3d$	$G^3(3p,3d)$	48916	44557	0.911
$3s3p3d$	ζ_{3p}	1319	1797	1.362
$3s3p3d$	ζ_{3d}	60	60 (FIX)	
$3s3p4s$	E_{av}	463784	475779	1.026
$3s3p4s$	$G^1(3s,3p)$	82900	95501	1.152
$3s3p4s$	$G^0(3s,4s)$	5896	6137	1.041
$3s3p4s$	$G^1(3p,4s)$	7775	7775 (FIX)	
$3s3p4s$	ζ_{3p}	1405	1420	1.011
Configuration Interaction Integrals				
$3s^23p - 3p^3$	$R^1(3s3s,3p3p)$	79351	79351 (FIX)	
$3s^23p - 3s3p3d$	$R^1(3s3p,3p3d)$	92765	92765 (FIX)	
$3s^23p - 3s3p3d$	$R^2(3s3p,3d3p)$	70775	70775 (FIX)	
$3s^23p - 3s3p4s$	$R^0(3s3s,3s4s)$	4725	4725 (FIX)	
$3s^23p - 3s3p4s$	$R^1(3s3p,3p4s)$	7557	7557 (FIX)	
$3s^23p - 3s3p4s$	$R^0(3s3p,4s3p)$	1368	1368 (FIX)	
$3s^24p - 3s3p3d$	$R^1(3s4p,3p3d)$	8998	8998 (FIX)	
$3s^24p - 3s3p3d$	$R^2(3s4p,3d3p)$	10777	10777 (FIX)	
$3s^24p - 3s3p4s$	$R^1(3s4p,3p4s)$	38098	38098 (FIX)	
$3s^24p - 3s3p4s$	$R^0(3s4p,4s3p)$	6074	6074 (FIX)	
$3p^3 - 3s3p3d$	$R^1(3p3p,3s3d)$	82900	82900 (FIX)	
$3p^3 - 3s3p4s$	$R^1(3p3p,3s4s)$	7384	7384 (FIX)	
$3s3p3d - 3s3p4s$	$R^2(3p3d,3p4s)$	2974	2974 (FIX)	
$3s3p3d - 3s3p4s$	$R^1(3p3d,4s3p)$	5010	5010 (FIX)	

[a] The RMS deviation of the fit is 210 cm^{-1} for 28 observed levels

the standard 85% of the Hartree–Fock values. The standard-deviation for the 28 observed levels was 210 cm^{-1}.

Acknowledgements

Support from Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Brasil, Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP), Brasil, Comisión de Investigaciones Científicas de la Provincia de Buenos Aires (CIC), Argentina, where J. G. Reyna Almandos and F. Bredice belong as researchers and M. Raineri as fellow, and Consejo Nacional de Investigaciones Científicas e Técnicas (CONICET), Argentina is gratefully acknowledged.

References

1. Moore, C. E., Atomic Energy Levels, Vol. I. Nat. Bur. Stand., Ref. Data Ser. Circ. N: 467 (U.S. GPO, Washington D.C. 1971).
2. Eriksson, K. B. S. and Isberg, H. B. S., Ark. Fys. 23, 527 (1963).
3. Shenstone, A. G., Proc. Roy. Soc. A261, 153 (1961).
4. Magnusson, C. E. and Zetterberg, P. O., Phys. Scr. 15, 237 (1977).
5. Martin, W. C., Zalubas, R. and Musgrove, A. J., J. Phys. Chem. Ref. Data 19, 821 (1990).
6. Phillips, L. W. and Parker, W. L., Phys. Rev. 60, 301 (1941).
7. Fawcett, B. C., Jones, B. B. and Wilson, R., Proc. Phys. Soc. 78, 1223 (1961).
8. Schönheit, E., Optik 23, 409 (1966).
9. Ekberg, J. O. and Svensson, L. A., Phys. Scr. 2, 283 (1970).
10. Fawcett, B. C., Ridgeley, A. and Bromage, G. E., Phys. Scr. 18, 315 (1978).
11. Livingston, A. E., Pinnington, E. H., Irwin, J. G., Kernahan, J. A. and Brooks, R. L., J. Opt. Soc. Am. 71, 442 (1981).
12. Buchet-Poulizac, M. C., Buchet, J. P. and Ceyzeriat, P., Nucl. Instr. and Meth. 202, 13 (1982).
13. De-Ye, J., Li-Kang, S., Li-Zeng, Z. and Wen-Shu, W., Chin. J. Phys. 33, 508 (1984).
14. Fawcett, B. C., At. Data and Nucl. Data Tables 28, 557 (1983).
15. Huang, K.-N., At. Data and Nucl. Data Tables 34, 1 (1986).
16. Sugar, J. and Kaufman, V., J. Opt. Soc. Am. B3, 704 (1986).
17. Sugar, J. and Kaufman, V., Phys. Scr. 34, 797 (1986).
18. Träbert, E., Hutton, R., Engström, L., Bliman, S. L., Berry, H. G. and Kurtz, C., Phys. Lett. A129, 381 (1988).
19. Träbert, E., Heckmann, P. M., Hutton, R. and Martinson, I., J. Opt. Soc. Am. B5, 2173 (1988).
20. Lesteven-Vaïsse, I., Folkmann, F., Ben Sitel, A., Chantepie, M. and Lecler, D., Phys. Scr. 38, 45 (1988).

21. Engström, L., Reistad, N., Jupén, C. and Westerlind, M., Phys. Scr. **39**, 66 (1989).
22. Pinnington, E. H., Ge, Z.-Q., Ansbacher, W., Kernahan, J. A. and Goselin, R. N., Phys. Scr. **39**, 321 (1989).
23. Redfors, A. and Litzén, U., J. Opt. Soc. Am. **B6**, 1447 (1989).
24. Thornbury, J. F., Hibbert, A. and Träbert, E., Phys. Scr. **40**, 472 (1989).
25. Jupén, C., Denne, B. and Martinson, I., Phys. Scr. **41**, 669 (1990).
26. Gallardo, M., Bredice, F., Raineri, M. and Reyna Almandos, J. G., Appl. Opt. **28**, 4513 (1989).
27. Kelly, R. L., J. Phys. Chem. Ref. Data **16**, Suppl. 1 (1987).
28. Pettersson, S.-G., Phys. Scr. **26**, 296 (1982).
29. Cowan, R. D., "The Theory of Atomic Structure and Spectra" (University of California Press, Berkeley, U.S.A. 1981).