Physica Scripta

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To cite this article: S S Churilov *et al* 2002 *Phys. Scr.* **66** 293

Physica Scripta. Vol. 66, 293–307, 2002

Analysis of the Spectra of Pd-like Ions from Xe IX Through Ce XIII

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Received April 10, 2002; accepted June 12, 2002.

PACS Ref: 31.15.Ct, 32.30-r, 32.70.Cs, 52.25.Qt

Abstract

The VUV spectra of the Pd-like Xe IX, Cs X, Ba XI, La XII and Ce XIII ions were analyzed. The cascade $4d^95s$–$4d^95p$–$4d^95d$–$4d^95f$ transitions were classified in Ba XI, La XII and Ce XIII ions for the first time. The analysis of the $4d^95s$–$4d^95p$ transitions in Cs X ion was revised and the $4d^95p$–$4d^95d$–$4d^95f$ transitions were classified in Xe IX and Cs X ions. The complete energy structures of the $4d^95s$, $4d^95p$ and $4d^95d$ configurations and most of the $4d^95f$ energies were determined in every investigated ion. The energy structures of the $4d^94f$ configurations were established by the analysis of the $4d^94f$–$4d^95d$ transitions in Ba XI, La XII and Ce XIII ions for the first time in a Pd I sequence. The experimental results were confirmed by semi-empirical calculations in the frames of Cowan code and Generalized Least-Squares techniques.

1. Introduction

The Pd-like ions have a closed $4d^{10}$ shell in the ground state and offer the possibilities for a laser effect in the EUV spectral region, as it was demonstrated on the $4d^95p\ ^1P_1$–$4d^95d\ ^1S_0$ transition ($\lambda \sim 418.1$ Å) in the Xe IX ion [1]. The laser effect is also possible on the $4d^95d\ ^1P_1$–$4d^95f\ ^1P_1$ transitions in Pd-like ions as a consequence of the "self-photopumping" effect, in analogy with the Ni-like ions [2]. Furthermore, the $4d^94f$ configuration can influence strongly the energy balance and the kinetics in a plasma containing Pd-like ions, and the $4d^94f\ ^1P_1$–$4d^95d\ ^1S_0$ transition can be interesting for the laser effect in the ions beyond Cs X. Therefore, the energy structures of the $4d^95l$ (l = s,p,d,f) and $4d^94f$ configurations have to be known for the correct modeling and optimization of laser media containing Pd-like ions.

The $4d^95s$, $4d^95p$ and $4d^95d$ configurations were known in the Pd-like Ag II, Cd III, In IV and Sn V ions [3 and references therein, 4,5]. The analyses of the $4d^95s$–$4d^95p$–$4d^95d$–$4d^95f$ transitions in the Sb VI, Te VII and I VIII ions have been revised and significantly extended in [6]. However the spectra of heavier Pd-like ions were known unsatisfactory till the present time. Indeed only the $4d^95s$–$4d^95p$ transitions were classified in the Xe IX [7] and Cs X [8] ions. It should be noted that the Xe IX analysis in [7] was carried out using *beam-gas techniques* with low wavelength accuracy and for Cs X, some energies determined in [8] did not fit the isoelectronic trends of the preceding ions. Recently we improved and extended the analysis of the $4d^95s$–$4d^95p$ transitions and accurately measured the laser $4d^95p\ ^1P_1$–$4d^95d\ ^1S_0$ transition wavelength (418.257 Å) in Xe IX [9]. A number of the $4d^{10}\ ^1S_0$–$4d^9$ (np + mf) ($J = 1$; $n, m \leq$ 7–8) resonance transitions have also been classified in the Pd I sequence from Cd III through Cs X in [10,11]. For Ba XI and heavier ions only several resonance transitions from the $4d^95p(J = 1)$ and $4d^94f(J = 1)$ levels were classified [12–14]. It should be noted that the $4d^94f$ configuration was not known at all in the Pd I sequence except for the $J = 1$ levels mentioned above.

The purpose of the present work is to report detailed results of the analysis of the transitions between $4d^95l$ and $4d^94f$ configurations and the energy structures of these configurations in the Pd-like ions from Xe IX through Ce XIII. Some preliminary results concerned with the Cs X–Ce XIII ion spectra were published in [15].

2. Experimental set-up

In our earlier analysis of the 5-5 transitions in Pd-like ions, the spectra of Sb, Te and I were excited in vacuum spark sources [6]. As the relative intensities of these transitions decrease rapidly along the sequence in the spark spectra, we could not classify the $4d^95d$–$4d^95f$ transitions in I VIII ion with certainty. Therefore a laser-produced plasma (LPP) source was mainly used in the present work. The 2 GW and 20 ns Nd-glass laser pulses were focused onto a target surface with radiation intensities of 10^{12}–10^{13} W/cm^2. The details of this LPP source have been described in a similar study of Ni-like ions [16]. We used polished metallic barium, lanthanum and cerium, BaF_2 crystal and pressed Cs_2CO_3 salt as targets. The xenon spectra were excited in a fast 40 kV capillary discharge with inductive storage which has been used in the analysis of Ne-like Ar IX [17]. The spectra excited in a low-inductance triggered vacuum spark [6] were also obtained in the wavelength regions corresponding to the resonance and 5-5 transitions of the investigated Pd-like ions.

The spectra of LPP and capillary sources were recorded in the 300–800 Å region on a 6.65 m normal incidence spectrograph at the Institute of Spectroscopy (Troitsk, Russia). The spectrograph was equipped with a 1200 l/mm grating and had a plate factor 1.25 Å/mm. The spectra were photographed on Kodak SWR or SC-5 plates, the normal exposures being recorded with 10–20 laser pulses or 100–200 capillary discharges.

The cesium spectrum in the 500–900 Å region was additionally produced in the Meudon Observatory (Paris, France) on a 10.7 m normal incidence spectrograph with a 3600 l/mm grating and a plate factor of 0.25 Å/mm. A 15 kV triggered vacuum spark with 4.82 μF capacitance bank was used as an excitation source, $CsCl_2$ salt being pressed into an aluminum cathode. This spectrum was used for the measurements of the $4d^95s$–$4d^95p$ line wavelengths in the Cs X ion.

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The spectra of resonance transitions in Ba XI, La XII and Ce XIII ions were also photographed at the Troitsk laboratory on a 3 m grazing incidence spectrograph equipped with a holographic 3600 l/mm grating. The incidence angle was 85° corresponding to a plate factor of 0.25–0.30 Å/mm in the 90–150 Å spectral region. A triggered low inductance vacuum spark with a 10 μF capacitance charged to a 4 kV voltage was used as a source in this case.

The spectrograms were measured on an automatic comparator-microdensitometer at Troitsk and on a semi-automatic comparator at Meudon. The lines of lower ionization stages as well as the O III – O V lines were used as standards in the capillary and vacuum spark spectra obtained on the normal incidence spectrographs. The LPP spectra do not contain enough lines that could be used as internal standards, therefore we used external standards in this case. For this purpose the vacuum spark spectra of iron were superimposed on some of the LPP exposures, and the lines of Fe IV – Fe VI were used as standards [18]. The estimated accuracy of the wavelength measurements in the LPP and capillary spectra is 0.007 and 0.010 Å in the 300–800 Å region respectively. The wavelengths of vacuum spark lines were measured with an average error of ±0.005 Å in the same region. The grazing incidence spectrograms were reduced by using external Ti standards [18] with an average accuracy of ±0.003 Å in the 90–150 Å wavelength region. The line intensities (I) were measured from the plate darkening taking into account the photoemulsion response. The intensities are given in a 1–1000 scale, intensity $I = 1000$ being attributed to the strongest line in each spectrum.

3. Methods of spectra analysis

The LPP spectrograms mainly consist of the intense lines of Pd-, Ag-, Cd- and In-like ions. These spectra are spatially resolved at normal direction to the target surface because the 6.65 m spectrograph has an almost stigmatic image in the investigated spectral region. It was observed that the Pd-like ions emit mainly at the hottest plasma region just near the target surface whereas the lower ionization stages radiate also at larger distances from the target. Moreover, the lines of Pd-like ions were completely absent in the spark spectra of Ba, La and Ce, and only weak lines of the $4d^95s$–$4d^95p$ transitions of Cs X were observed in the high voltage spark spectrum. The capillary Xe source is almost uniform in space, but most lines of the lower ionization stages (Xe VIII, Xe VII and Xe VI ions) have been classified earlier in the investigated region of xenon spectrum [19–21]. Therefore we could unambiguously select the lines of Pd-like ions in most of the cases.

The spectra analyses were carried out by using the complex spectra identification program IDEN [22] on the basis of level energies and transition probabilities predicted by the Cowan computer code with relativistic corrections [23]. We included into the calculations the even $4d^{10}$, $4d^9ns$ ($n = 5, 6$), $4d^9nd$ ($n = 5, 6$), $4d^85s^2$, $4d^85s5d$, $4p^54d^{10}5p$ and $4p^54d^{10}4f$ configurations and the odd $4d^9np$ ($n = 5, 6$), $4d^9nf$ ($n = 4$–6), $4d^85s5p$, $4d^85snf$ ($n = 4, 5$), $4p^54d^{10}5s$ and $4p^54d^{10}5d$ configurations. Thus, all the more or less important configuration interactions were taken into account. The energy parameters were extrapolated along the sequence for the $4d^95l$ configurations and were fixed at their *ab initio* Hartree-Fock (HF) values (E_{av} and spin-orbit parameter) or were scaled to 0.85 of their HF values (F^k, G^k and R^k parameters) for the $4d^94f$ and other unknown configurations.

After the first stage of our analyses the results were checked out, partly improved and extended by means of the Generalized-Least-Squares (GLS) techniques. The usual parametric studies in the Racah-Slater approach lead to the determination of radial parameters for a set of configurations in a given ion as it is processed in the RCE code by Cowan [23]. However for many small configurations of multicharged ions, there are less levels than parameters needed to interpret them. Therefore the semi-empirical regularities in the trends of parameters *vs.* $Z_c = Z - N_e + 1$ may be used as constraints in a Generalized-Least-Squares fit of all ions simultaneously. This was done with success in the sequence of Ni I [16] and in the recent work on the Pd-like ions [6]. In the present case, Z_c-expansions similar to those of [16] were applied to $4d^95s$, $4d^95p$ and $4d^95d$ with acceptable deviations $E_{exp} - E_{GLS}$, but they failed to fit the $4d^95f$ levels. As we noticed that the $G^k(4d,5f)$ exchange integrals calculated by the RCN code [23] are inappropriate for a $R^k = A + B \cdot Z_c + C/(Z_c + D)$ simple expansion, since they increase from Ag II to Sb VI, then decrease and increase again after Eu XVIII, we expanded the scaling factors SF according to $P_{fit} = P_{HFR} \times SF(P)$ instead of the parameters themselves.

4. Results and discussion

The classified spectral lines in Xe IX, Cs X, Ba XI, La XII and Ce XIII ions are respectively presented in Tables I–V. The line wavelengths and intensities were taken from the LPP (Cs, Ba, La, Ce) or capillary (Xe) spectrograms, with only exception of the $4d^95s$–$4d^95p$ lines in Cs X for which the more accurate data from the high voltage spark spectrogram were given. In the first columns of the tables the transition probabilities (gA) are given in 10^9 s^{-1} units. The measured line intensities mostly agree with the gA values, especially when taking into account the dependence of population on level energy and the spectrograph efficiency curve. The latter has a maximum in the 500–600 Å region and sharply decreases below 300 Å. The $\Delta\lambda$ values represent the deviations of the measured line wavelengths from the wavelengths calculated with the level energies given in the last columns. It is seen that these deviations mostly do not exceed the wavelength accuracy (0.005–0.010 Å) excluding some disturbed lines.

The lines of resonance and 5-5 transitions classified in the earlier analyses are also included in Tables I–V for the sake of completeness. The data for resonance lines of the Xe IX – La XII ions coincide with the data published earlier in [10–13]. The newly measured wavelengths of resonance lines in Ce XIII are given in Table V. These new wavelengths of the $4d^{10}$–$4d^95p$ transitions coincide with the earlier data in [12] within 0.005 Å, but have better agreement with the wavelengths of the $4d^95s$–$4d^95p$ transitions. Most of the $4d^95s$–$4d^95p$ transitions in Xe IX have been classified in [7], and their improved wavelengths together with three transitions from the $4d^95d$ $^1S_0$ level were already published in [9]. We found that almost half of the 19 lines classified in [8] as the $4d^95s$–$4d^95p$ transitions in Cs X are absent in the LPP cesium spectrum and really belong to the Cs IV, Cs V or ions from the Cs compound. All lines correctly classified in earlier publications are marked in Tables I–V.

Table I. *Classified lines in the Xe IX spectrum.*

gA	I^{a}	λ, Å^{b}	$\Delta\lambda$, Å	ν, cm^{-1}	Transition	E_{low}	E_{up}
1516.0	35	96.449C	0.000	1 036 820	4d $^1S_0$–5f $^1P_1$	0	1 036 820
64.7	10	99.553C	0.000	1 004 493	4d $^1S_0$–5f $^3D_1$	0	1 004 493
4766.0	200	120.133S	0.000	832 414	4d $^1S_0$–4f $^1P_1$	0	832 414
5.9	90	143.614S	0.000	696 312	4d $^1S_0$–4f $^3D_1$	0	696 312
0.7	5?	150.275C	0.000	665 447	4d $^1S_0$–4f $^3P_1$	0	665 447
47.0	650	161.742S	0.000	618 268	4d $^1S_0$–5p$^3D_1$	0	618 269
264.8	950	165.323S	0.000	604 876	4d $^1S_0$–5p $^1P_1$	0	604 877
1.4	26	400.906R	0.008	249 435	5p $^3P_1$–5d$^1S_0$	594 522	843 962
24.5	171	418.257L	−0.004	239 087	5p $^1P_1$–5d $^1S_0$	604 877	843 962
4.3	31	443.080R	0.000	225 693	5p $^3D_1$–5d $^1S_0$	618 269	843 962
29.6	90	457.624	0.002	218 520	5p $^3F_2$–5d $^3F_2$	593 154	811 675
15.0	99	459.407	−0.002	217 672	5p $^3F_2$–5d $^1D_2$	593 154	810 825
49.0	224	460.719	−0.004	217 052	5p $^3P_2$–5d $^3D_3$	575 438	792 488
19.7	102	462.229	0.007	216 343	5p $^3F_3$–5d $^1F_3$	578 986	795 332
17.2	83	462.319	0.005	216 301	5p $^3P_1$–5d $^1D_2$	594 522	810 825
74.3	300 m	466.010	−0.008	214 588	5p $^3P_2$–5d $^3D_2$	575 438	790 022
49.5	223	468.386	0.006	213 499	5p $^3F_3$–5d $^3D_3$	578 986	792 488
102.4	276	471.498	−0.009	212 090	5p $^3F_2$–5d $^3G_3$	593 154	805 240
12.7	66	473.864	0.011	211 031	5p $^3F_3$–5d $^3D_2$	578 986	790 022
2.4	55	474.601	0.006	210 703	5p $^3F_2$–5d $^3P_1$	593 154	803 860
48.4	103	476.892	−0.002	209 691	5d $^3G_5$–5f $^3G_5$	790 742	1 000 432
172.6	374	477.240	−0.005	209 538	5p $^3F_3$–5d $^3G_4$	578 986	788 522
21.4	115	477.685	−0.011	209 343	5p $^3P_1$–5d $^3P_1$	594 522	803 860
78.7	59	480.313	0.001	208 198	5d $^3D_2$–5f $^3F_3$	790 022	998 220
285.4	160	482.068	−0.001	207 439	5d $^3G_4$–5f $^3H_5$	788 522	995 961
58.2	108	482.695	0.000	207 170	5d $^1P_1$–5f $^1D_2$	790 854	998 024
230.0	148	483.367	0.000	206 882	5d $^3G_3$–5f $^3H_4$	805 240	1 012 122
14.1	73	483.556	−0.008	206 801	5p $^1P_1$–5d $^3F_2$	604 877	811 675
87.8	71	484.139	0.000	206 552	5d $^1D_2$–5f $^3G_3$	810 825	1 017 377
107.5	118	484.258	−0.001	206 502	5d $^3D_3$–5f $^3F_4$	792 488	998 989
78.2	142	484.365	0.000	206 456	5d $^3D_1$–5f $^3F_2$	807 691	1 014 147
82.4	57	486.070	0.001	205 732	5d $^3D_3$–5f $^3F_3$	792 488	998 220
44.9	229	486.959	−0.005	205 356	5p $^3P_2$–5d $^3S_1$	575 438	780 792
121.0	123	487.131	0.000	205 284	5d $^3P_2$–5f $^1F_3$	796 070	1 001 354
10.2	64	487.285	0.001	205 219	5d $^3G_5$–5f $^3H_5$	790 742	995 961
338.2	178	488.718	0.000	204 617	5d $^3G_5$–5f $^3H_6$	790 742	995 359
149.4	151	489.110	0.000	204 453	5d $^1F_3$–5f $^1G_4$	795 332	999 785
19.2	85	489.300	0.000	204 374	5p $^3P_1$–5d $^3P_0$	594 522	798 896
281.2	266bl	490.564	0.000	203 847	5d $^1G_4$–5f $^1H_5$	809 314	1 013 161
114.7	73	490.763	0.000	203 376	5d $^3F_2$–5f $^3D_3$	811 675	1 015 439
235.1	232	491.719	0.002	203 368	5d $^3F_4$–5f $^3G_5$	797 063	1 000 432
196.4	144	491.804	0.000	203 333	5d $^3F_3$–5f $^3G_4$	813 696	1 017 029
6.8	71	492.817	0.002	202 915	5p $^3F_2$–5d $^3P_2$	593 154	796 070
31.0	154	493.343	0.001	202 699	5p $^1D_2$–5d $^3G_3$	602 541	805 240
24.6	169	494.614	0.000	202 178	5p $^3F_2$–5d $^1F_3$	593 154	795 332
72.2	70	495.231	0.000	201 926	5d $^3F_4$–5f $^3F_4$	797 063	998 989
16.8	69	496.162	0.002	201 547	5p $^3P_1$–5d $^3P_2$	594 522	796 070
49.1	100	499.478	0.000	200 209	5p $^3F_4$–5d $^3F_4$	596 854	797 063
26.4	79	500.532	−0.006	199 787	5p $^3P_0$–5d $^3D_1$	607 906	807 691
2.3	30	501.679	0.008	199 331	5p $^3F_2$–5d $^3D_3$	593 154	792 488
10.9	46	502.566	0.011	198 979	5p $^1P_1$–5d $^3P_1$	604 877	803 860
0.9	51	505.821	0.004	197 699	5p $^3F_2$–5d $^1P_1$	593 154	790 854
31.3	309	506.230	0.001	197 539	5p $^1F_3$–5d $^3F_3$	616 157	813 696
14.1	133	509.332	−0.009	196 336	5p $^3P_1$–5d $^1P_1$	594 522	790 854
10.0	94	511.159	0.000	195 634	5p $^3F_4$–5d $^3D_3$	596 854	792 488
194.7	457	515.762	0.000	193 888	5p $^3F_4$–5d $^3G_5$	596 854	790 742
44.1	185	516.714	−0.004	193 531	5p $^1D_2$–5d $^3P_2$	602 541	796 070
53.7	350m	517.050	0.003	193 405	5p $^3D_1$–5d $^3F_2$	618 269	811 675
157.0	354	517.714	0.000	193 157	5p $^1F_3$–5d $^1G_4$	616 157	809 314
56.9	346	518.700	0.004	192 790	5p $^1D_2$–5d $^1F_3$	602 541	795 332
90.1	393	519.347	−0.001	192 549	5p $^3D_2$–5d $^3F_3$	621 147	813 696
11.4	150	521.730	−0.005	191 670	5p $^3F_4$–5d $^3G_4$	596 854	788 522
110.1	538	521.783	0.007	191 651	5p $^3D_3$–5d $^3F_4$	605 410	797 063
13.7	173	523.037	0.005	191 191	5p $^1P_1$–5d $^3P_2$	604 877	796 070
29.1	205	526.523	−0.009	189 925	5p $^3D_3$–5d $^1F_3$	605 410	795 332
34.1	183	527.206	−0.003	189 679	5p $^3D_2$–5d $^1D_2$	621 147	810 825
12.7	110	527.929	0.007	189 419	5p $^3D_1$–5d $^3D_1$	618 269	807 691
8.2	119	528.876	0.008	189 080	5p $^1F_3$–5d $^3G_3$	616 157	805 240

Table I. *continued.*

gA	I^{a}	λ, Å^{b}	$\Delta\lambda$, Å	ν, cm^{-1}	Transition	E_{low}	E_{up}
7.3	162	531.040	0.009	188 310	5p $^{1}D_{2}$–5d $^{1}P_{1}$	602 541	790 854
30.0	195	534.528	−0.008	187 081	5p $^{3}D_{3}$–5d $^{3}D_{3}$	605 410	792 488
17.7	160	537.701	0.000	185 977	5p $^{1}P_{1}$–5d $^{1}P_{1}$	604 877	790 854
8.6	114	538.820	0.001	185 591	5p $^{3}D_{1}$–5d $^{3}P_{1}$	618 269	803 860
16.4	100	541.665	−0.011	184 616	5p $^{3}D_{3}$–5d $^{3}D_{2}$	605 410	790 022
8.2	234	546.118	0.004	183 111	5p $^{3}D_{3}$–5d $^{3}G_{4}$	605 410	788 522
8.2	239	547.309	0.003	182 712	5p $^{3}D_{2}$–5d $^{3}P_{1}$	621 147	803 860
4.1	97	561.013	0.006	178 249	5p $^{1}D_{2}$–5d $^{3}S_{1}$	602 541	780 792
0.4	61	596.379R	0.001	167 678	5s $^{3}D_{3}$–5p $^{3}D_{2}$	453 468	621 147
0.6	132	609.050K	0.003	164 190	5s $^{3}D_{2}$–5p $^{3}D_{2}$	456 956	621 147
0.5	80	614.670R	0.000	162 689	5s $^{3}D_{3}$–5p $^{1}F_{3}$	453 468	616 157
1.8	99	619.909R	−0.004	161 314	5s $^{3}D_{2}$–5p $^{3}D_{1}$	456 956	618 269
1.8	100	628.144K	0.007	159 199	5s $^{3}D_{2}$–5p $^{1}F_{3}$	456 956	616 157
25.0	470	658.146K	0.000	151 942	5s $^{3}D_{3}$–5p $^{3}D_{3}$	453 468	605 410
10.5	260	661.812K	−0.006	151 100	5s $^{3}D_{1}$–5p $^{3}D_{2}$	470 048	621 147
1.4	75	670.810R	−0.002	149 073	5s $^{3}D_{3}$–5p $^{1}D_{2}$	453 468	602 541
11.8	239	673.602K	−0.007	148 456	5s $^{3}D_{2}$–5p $^{3}D_{3}$	456 956	605 410
13.2	244	674.673R	0.005	148 220	5s $^{3}D_{1}$–5p $^{3}D_{1}$	470 048	618 269
5.9	200 m	676.040R	0.004	147 920	5s $^{3}D_{2}$–5p $^{1}P_{1}$	456 956	604 877
15.9	300 m	677.280K	0.007	147 649	5s $^{1}D_{2}$–5p $^{3}D_{2}$	473 496	621 147
19.6	256	686.885K	0.001	145 585	5s $^{3}D_{2}$–5p $^{1}D_{2}$	456 956	602 541
1.4	103	690.731K	−0.001	144 774	5s $^{1}D_{2}$–5p $^{3}D_{1}$	473 496	618 269
45.5	494	697.417K	−0.001	143 386	5s $^{3}D_{3}$–5p $^{3}F_{4}$	453 468	596 854
32.3	396	700.962K	0.000	142 661	5s $^{1}D_{2}$–5p $^{1}F_{3}$	473 496	616 157
4.5	107	725.378K	−0.001	137 859	5s $^{3}D_{1}$–5p $^{3}P_{0}$	470 048	607 906
7.7	148	726.923K	−0.001	137 566	5s $^{3}D_{2}$–5p $^{3}P_{1}$	456 956	594 522
3.6	80	734.224K	−0.001	136 198	5s $^{3}D_{2}$–5p $^{3}F_{2}$	456 956	593 154
2.3	152	741.683R	0.003	134 829	5s $^{3}D_{1}$–5p $^{1}P_{1}$	470 048	604 877
1.4	121	754.770K	0.013	132 491	5s $^{3}D_{1}$–5p $^{1}D_{2}$	470 048	602 541
1.4	131	758.066R	−0.004	131 915	5s $^{1}D_{2}$–5p $^{3}D_{3}$	473 496	605 410
5.5	731bl	761.125K	−0.020	131 384	5s $^{1}D_{2}$–5p $^{1}P_{1}$	473 496	604 877
1.8	134	774.916K	−0.007	129 046	5s $^{1}D_{2}$–5p $^{1}D_{2}$	473 496	602 541
7.7	168	796.712K	0.014	125 516	5s $^{3}D_{3}$–5p $^{3}F_{3}$	453 468	578 986
8.6	253	812.297K	−0.011	123 108	5s $^{3}D_{1}$–5p $^{3}F_{2}$	470 048	593 154
14.1	390	819.470R	0.000	122 030	5s $^{3}D_{2}$–5p $^{3}F_{3}$	456 956	578 986
15.0	404	819.875K	0.001	121 970	5s $^{3}D_{3}$–5p $^{3}P_{2}$	453 468	575 438
4.1	258	826.270K	−0.001	121 026	5s $^{1}D_{2}$–5p $^{3}P_{1}$	473 496	594 522
4.1	224	835.729K	0.014	119 656	5s $^{1}D_{2}$–5p $^{3}F_{2}$	473 496	593 154
0.5	149	844.006K	−0.004	118 483	5s $^{3}D_{2}$–5p $^{3}P_{2}$	456 956	575 438

[a] bl – blended line; m – masked line; ? – tentative classification.
[b] line classified earlier in: L – [1]; K – [7]; R – [9]; C – [11]; S – [12].

The measured level energies (E_{obs}) and their deviations from the semi-empirically fitted values (ΔE) are presented in Table VI. The estimated measurement accuracy of the energy splitting between the excited levels is 5 cm^{-1}, but the positions of the measured excited levels relative to the ground state were determined through the short-wavelength resonance transitions with an error of 20–50 cm^{-1} for the Xe IX – Ce XIII ions respectively. The fitted energies are given in brackets for the levels which remain unknown. The levels in Tables I–VI are designated by the first terms of *LS* percentage compositions given in Table VII. It is seen that the first term does not coincide with the leading term for some level compositions due to the intermediate coupling and C.I. mixing effects in heavy ions. Nevertheless we retained the *LS* designations because they were used in all the previous analyses of the Pd-like ions (see, for example, [3–14]). It should be noted that due to the mixing between 4d^{9}5d $^{1}P_{1}$ and $^{3}P_{1}$ states the 4d^{9}5d $^{3}P_{1}$–4d^{9}5f $^{1}P_{1}$ transition has much higher probability than the 4d^{9}5d $^{1}P_{1}$–4d^{9}5f $^{1}P_{1}$ one in the designations used, therefore laser effect should be expected for the first transition.

As a result, the energies of all the 4d^{9}5s, 4d^{9}5p and 4d^{9}5d levels and of most 4d^{9}5f levels were determined in the investigated Pd-like ions. The energies of the 4d^{9}5l configurations, determined in the present and earlier works [3–6] for twelve Pd-like ions from Ag II through Ce XIII, were fitted by means of GLS techniques. The parameters used in this GLS fitting are given in Table VIII. The 48 levels of the 4d^{9}5s configuration in Ag II – Ce XIII were described by using 22 parameters and the 144 4d^{9}5p levels were fitted by 39 parameters. The 199 4d^{9}5d level energies from the possible 216 ones were determined in twelve ions from Ag II to Ce XIII and they were described by means of 41 parameters. The GLS fitting of the 4d^{9}5f configuration was carried out for 110 known levels in seven ions, Sb VI, Te VII and Xe IX – Ce XIII, and 17 parameters (average energies and expansion coefficients for the scaling factors, as explained in Section 3.) were used for the description of these energies. The scaling factors are found to be almost constant within the sequence Sb VI – Ce XIII. The sign of the linear coefficient of Z_c is defined only if the number of coefficients is limited to three (for F^k, G^k and ζ_{4d}). The standard deviations in GLS fittings

Table II. *Classified lines in the Cs X spectrum.*

gA	I^a	λ, Å^b	$\Delta\lambda$, Å	ν, cm^{-1}	Transition	E_{low}	E_{up}
916.8	10	85.052C	0.000	1 175 751	4d $^1S_0$–5f $^1P_1$	0	1 175 751
60.6	20bl	87.337C	0.000	1 144 990	4d $^1S_0$–5f $^3D_1$	0	1 144 990
5992.0	50	109.589S	0.000	912 500	4d $^1S_0$–4f $^1P_1$	0	912 500
8.4	20	132.888S	0.000	752 513	4d $^1S_0$–4f $^3D_1$	0	752 513
1.4	10?	139.534C	0.000	716 673	4d $^1S_0$–4f $^3P_1$	0	716 673
62.4	500	139.670S	0.000	715 973	4d $^1S_0$–5p $^3D_1$	0	715 972
343.3	700	142.890S	−0.001	699 839	4d $^1S_0$–5p $^1P_1$	0	699 833
3.0	50	145.172J	0.001	688 838	4d $^1S_0$–5p $^3P_1$	0	688 845
26.4	149	375.446	0.000	266 350	5p $^1P_1$–5d $^1S_0$	699 833	966 183
58.2	437	414.186	−0.002	241 438	5p $^3P_2$–5d $^3D_3$	666 498	907 934
27.0	324	416.304	0.002	240 209	5p $^3P_1$–5d $^1D_2$	688 845	929 055
85.8	488	418.899	0.007	238 721	5p $^3P_2$–5d $^3D_2$	666 498	905 223
65.4	452	420.549	−0.004	237 785	5p $^3F_3$–5d $^3D_3$	670 152	907 934
64.8	203	422.601	−0.001	236 630	5d $^3S_1$–5f $^3P_1$	895 017	1 131 646
124.2	847	423.753	0.000	235 987	5p $^3F_2$–5d $^3G_3$	686 663	922 650
17.4	126	425.407	0.004	235 069	5p $^3F_3$–5d $^3D_2$	670 152	905 223
200.4	999	428.573	0.001	233 333	5p $^3F_3$–5d $^3G_4$	670 152	903 485
96.6	176	428.930	0.014	233 138	5d $^3P_2$–5f $^3F_3$	905 223	1 138 369
27.0	300	430.152	−0.002	232 476	5p $^3P_1$–5d $^3P_1$	688 845	921 320
360.1	410	430.368	0.000	232 359	5d $^3G_4$–5f $^3H_5$	903 485	1 135 844
289.8	324	430.706	0.000	232 177	5d $^3G_3$–5f $^3H_4$	922 650	1 154 827
75.6	116	431.254	0.000	231 882	5d $^3P_1$–5f $^3D_2$	921 320	1 153 202
73.2	148	431.772	0.000	231 604	5d $^1P_1$–5f $^1D_2$	906 425	1 138 029
149.7	431	431.998	0.005	231 482	5d $^3D_3$–5f $^3F_4$	907 934	1 139 419
140.4	385	432.063	0.000	231 448	5d $^1D_2$–5f $^3G_3$	929 055	1 160 503
96.6	189	433.949	−0.013	230 442	5d $^3D_3$–5f $^3F_3$	907 934	1 138 369
150.6	229	435.971	0.000	229 373	5d $^3P_2$–5f $^1F_3$	912 250	1 141 623
17.4	413	436.254	−0.004	229 224	5p $^1P_1$–5d $^1D_2$	699 833	929 055
424.2	544	436.627	0.000	229 028	5d $^3G_5$–5f $^3H_6$	906 364	1 135 392
202.8	496	437.232	0.000	228 711	5d $^1F_3$–5f $^1G_4$	911 410	1 140 121
55.8	361	437.595	−0.005	228 522	5p $^3P_2$–5d $^3S_1$	666 498	895 017
171.6	379	438.471	0.000	228 065	5d $^3F_2$–5f $^3D_3$	930 209	1 158 274
353.8	392	437.763	0.000	228 434	5d $^1G_4$–5f $^1H_5$	927 704	1 156 138
298.2	566	439.360	0.000	227 604	5d $^3F_4$–5f $^3G_5$	913 420	1 141 024
249.6	566	439.595	0.000	227 482	5d $^3F_3$–5f $^3G_4$	932 529	1 160 011
21.6	304	441.297	0.000	226 605	5p $^3P_1$–5d $^3P_0$	688 845	915 450
28.8	311?	441.655	0.004	226 421	5d $^3P_2$–5f $^3P_1$	905 223	1 131 646
87.6	270	442.472	−0.008	226 003	5d $^3F_4$–5f $^3F_4$	913 420	1 139 419
16.2	188	447.630	0.012	223 399	5p $^3P_1$–5d $^3P_2$	688 845	912 250
53.4	403	451.429	0.005	221 519	5p $^3F_4$–5d $^3F_4$	691 899	913 420
28.8	109	453.210	0.000	220 648	5p $^3P_0$–5d $^3D_1$	705 043	925 691
217.8	818	466.277	0.000	214 465	5p $^3F_4$–5d $^3G_5$	691 899	906 364
50.4			0.007		5p $^1D_2$–5d $^3P_2$	697 782	912 250
63.2	465	466.773	0.000	214 237	5p $^3D_1$–5d $^3F_2$	715 972	930 209
175.2	715	467.769	0.000	213 781	5p $^1F_3$–5d $^1G_4$	713 923	927 704
65.4	447	468.105	0.002	213 627	5p $^1D_2$–5d $^1F_3$	697 782	911 410
100.8	467	468.810	0.000	213 306	5p $^3D_2$–5d $^3F_3$	719 223	932 529
18.1	241	470.756	−0.016	212 424	5p $^1P_1$–5d $^3P_2$	699 833	912 250
123.6	634	471.009	−0.005	212 310	5p $^3D_3$–5d $^3F_4$	701 112	913 420
35.7	218	475.513	−0.003	210 299	5p $^3D_3$–5d $^1F_3$	701 112	911 410
31.2	300m	476.580	0.008	209 828	5p $^3D_2$–5d $^1D_2$	719 223	929 055
29.8	110	483.516	0.008	206 818	5p $^3D_3$–5d $^3D_3$	701 112	907 934
22.3	100	484.070	0.000	206 582	5p $^1P_1$–5d $^1P_1$	699 833	906 425
8.4	127	486.978	0.000	205 349	5p $^3D_1$–5d $^3P_1$	715 972	921 320
17.9	149	489.918	−0.011	204 116	5p $^3D_3$–5d $^3D_2$	701 112	905 223
5.4	145	507.017	0.008	197 232	5p $^1D_2$–5d $^3S_1$	697 782	895 017
1.2	474bl	558.961	0.002	178 903	5s $^3D_2$–5p $^3D_1$	537 068	715 972
1.5	354	565.433	−0.002	176 856	5s $^3D_2$–5p $^1F_3$	537 068	713 923
28.2	448	596.056J	0.002	167 769	5s $^3D_3$–5p $^3D_3$	533 342	701 112
12.6	560	599.580	−0.005	166 783	5s $^3D_1$–5p $^3D_2$	552 441	719 223
1.8	200m	608.130J	0.005	164 439	5s $^3D_3$–5p $^1D_2$	533 342	697 782
14.4	384	609.586J	−0.006	164 046	5s $^3D_2$–5p $^3D_3$	537 068	701 112
14.7	475	611.505	0.000	163 531	5s $^3D_1$–5p $^3D_1$	552 441	715 972
18.3	643	612.640	0.000	163 228	5s $^1D_2$–5p $^3D_2$	555 995	719 223
8.5	429	614.383	0.000	162 765	5s $^3D_2$–5p $^1P_1$	537 068	699 833
22.8	454	622.216J	−0.006	160 716	5s $^3D_2$–5p $^1D_2$	537 068	697 782
1.9	194	625.085	−0.005	159 978	5s $^1D_2$–5p $^3D_1$	555 995	715 972
52.2	645	630.686	−0.002	158 557	5s $^3D_3$–5p $^3F_4$	533 342	691 899
37.8	663	633.205	0.005	157 927	5s $^1D_2$–5p $^1F_3$	555 995	713 923

Table II. *continued.*

gA	I^a	λ, Å^b	$\Delta\lambda$, Å	ν, cm^{-1}	Transition	E_{low}	E_{up}
4.8	328	655.297	−0.002	152 603	5s $^3D_1$–5p $^3P_0$	552 441	705 043
7.8	434	658.865J	0.004	151 776	5s $^3D_2$–5p $^3P_1$	537 068	688 845
3.6	154	668.480	0.007	149 593	5s $^3D_2$–5p $^3F_2$	537 068	686 663
2.4	231m	678.460	−0.003	147 393	5s $^3D_1$–5p $^1P_1$	552 441	699 833
1.3	113	688.040	0.003	145 340	5s $^3D_1$–5p $^1D_2$	552 441	697 782
1.1	91	689.103	0.004	145 116	5s $^1D_2$–5p $^3D_3$	555 995	701 112
1.9	485bl	695.216	−0.011	143 840	5s $^1D_2$–5p $^1P_1$	555 995	699 833
1.7	107	705.280	−0.003	141 788	5s $^1D_2$–5p $^1D_2$	555 995	697 782
9.2	323	730.944J	0.003	136 809	5s $^3D_3$–5p $^3F_3$	533 342	670 152
9.6	447	745.033	−0.001	134 222	5s $^3D_1$–5p $^3F_2$	552 441	686 663
16.2	622	750.993J	−0.006	133 157	5s $^3D_3$–5p $^3P_2$	533 342	666 498
14.8	598	751.405J	0.000	133 084	5s $^3D_2$–5p $^3F_3$	537 068	670 152
4.9	265	752.726J	−0.003	132 850	5s $^1D_2$–5p $^3P_1$	555 995	688 845
4.7	158	765.296J	−0.002	130 668	5s $^1D_2$–5p $^3F_2$	555 995	686 663

[a] see the footnotes to Table I.

[b] line classified earlier in: J – [8]; C – [10]; S – [12].

Table III. *Classified lines in the Ba XI spectrum.*

gA	I^a	λ, Å^b	$\Delta\lambda$, Å	ν, cm^{-1}	Transition	E_{low}	E_{up}
7471.0	70	101.391S	0.000	986 281	4d $^1S_0$–4f $^1P_1$	0	986 281
87.2	70	122.103S	0.000	818 981	4d $^1S_0$–5p $^3D_1$	0	818 983
26.0	50	124.001S	0.000	806 445	4d $^1S_0$–4f $^3D_1$	0	806 445
441.7	100	125.042S	0.000	799 731	4d $^1S_0$–5p $^1P_1$	0	799 729
9.9	30	126.908S	0.000	787 972	4d $^1S_0$–5p $^3P_1$	0	787 972
35.1	64	340.585	0.000	293 613	5p $^1P_1$–5d $^1S_0$	799 729	1 093 342
47.1	68	374.120	0.000	267 294	5p $^3F_2$–5d $^1D_2$	785 014	1 052 308
16.4	35	375.166	0.010	266 549	5p $^3F_3$–5d $^1F_3$	765 841	1 032 397
79.2	150	375.815	0.000	266 088	5p $^3P_2$–5d $^3D_3$	762 099	1 028 187
41.1	53	378.308	0.002	264 335	5p $^3P_1$–5d $^1D_2$	787 972	1 052 308
111.3	266	380.044	−0.003	263 127	5p $^3P_2$–5d $^3D_2$	762 099	1 025 224
88.2	222	381.177	0.001	262 345	5p $^3F_3$–5d $^3D_3$	765 841	1 028 187
53.3	35	381.306	−0.002	262 257	5d $^3G_4$–5f $^1G_4$	1 023 277	1 285 532
33.6	70	382.360	0.009	261 534	5d $^3G_4$–5f $^3F_4$	1 023 277	1 284 817
168.1	458	384.297	0.003	260 215	5p $^3F_2$–5d $^3G_3$	785 014	1 045 231
81.4	48	385.281	0.003	259 551	5d $^3G_5$–5f $^3G_5$	1 026 912	1 286 465
24.7	76	385.542	0.011	259 375	5p $^3F_3$–5d $^3D_2$	765 841	1 025 224
125.5	71	387.057	0.000	258 360	5d $^3D_2$–5f $^3F_3$	1 025 224	1 283 584
264.5	720	388.449	0.003	257 434	5p $^3F_3$–5d $^3G_4$	765 841	1 023 277
470.7	363	388.558	0.000	257 362	5d $^3G_4$–5f $^3H_5$	1 023 277	1 280 639
378.1			0.000		5d $^3G_3$–5f $^3H_4$	1 045 231	1 302 593
50.8	24	388.744	−0.003	257 239	5d $^1G_4$–5f $^3G_4$	1 051 219	1 308 456
90.4	48	389.066	0.000	257 026	5d $^3P_1$–5f $^3D_2$	1 043 843	1 300 869
224.2	121	389.667	0.000	256 629	5d $^3D_3$–5f $^3F_4$	1 028 187	1 284 817
99.4	56	390.079	0.000	256 358	5d $^1P_1$–5f $^1D_2$	1 026 776	1 283 134
118.8	100	390.181	0.000	256 291	5d $^3D_1$–5f $^3F_2$	1 048 878	1 305 169
39.6	134	390.820	−0.002	255 872	5p $^3P_1$–5d $^3P_1$	787 972	1 043 843
189.0	154bl	390.979	0.000	255 768	5d $^1D_2$–5f $^3G_3$	1 052 308	1 308 076
127.0	63	391.547	−0.001	255 397	5d $^3D_3$–5f $^3F_3$	1 028 187	1 283 584
67.2	47	393.332	−0.002	254 238	5d $^3D_2$–5f $^3P_2$	1 025 224	1 279 461
553.7	371	394.514	0.000	253 476	5d $^3G_5$–5f $^3H_6$	1 026 912	1 280 388
192.0			0.000		5d $^3P_2$–5f $^1F_3$	1 033 393	1 286 869
285.4	178	395.049	0.003	253 133	5d $^1F_3$–5f $^1G_4$	1 032 397	1 285 532
460.3	314	395.213	0.000	253 028	5d $^1G_4$–5f $^1H_5$	1 051 219	1 304 247
21.7	125	395.919	0.003	252 577	5p $^1P_1$–5d $^1D_2$	799 729	1 052 308
225.7	353bl	396.078	0.000	252 475	5d $^3F_2$–5f $^3D_3$	1 053 907	1 306 382
74.7	403	396.865	0.000	251 975	5p $^3P_2$–5d $^3S_1$	762 099	1 014 074
322.0	247	396.948	0.003	251 922	5d $^3F_3$–5f $^3G_4$	1 056 532	1 308 456
384.1	270	397.199	−0.001	251 763	5d $^3F_4$–5f $^3G_5$	1 034 703	1 286 465
97.9	81	399.806	−0.012	250 122	5d $^3F_4$–5f $^3F_4$	1 034 703	1 284 817
29.1	99	401.361	−0.001	249 152	5p $^3P_1$–5d $^3P_0$	787 972	1 037 124
6.7	84	402.611	0.000	248 379	5p $^3F_2$–5d $^3P_2$	785 014	1 033 393
27.6	186	404.244	0.013	247 375	5p $^3F_2$–5d $^1F_3$	785 014	1 032 397
13.4	174	404.930	−0.001	246 956	5p $^1D_2$–5d $^3G_3$	798 275	1 045 231

Table III. *continued.*

gA	I^a	λ, Å^b	$\Delta\lambda$, Å	ν, cm^{-1}	Transition	E_{low}	E_{up}
11.1	191	405.172	0.012	246 809	4f $^3H_4$–5d $^3G_3$	798 415	1 045 231
56.8	99	406.394	0.002	246 067	5d $^3P_2$–5f $^3P_2$	1 033 393	1 279 461
17.9	132	407.460	−0.003	245 423	5p $^3P_1$–5d $^3P_2$	787 972	1 033 393
12.7	113	409.651	0.006	244 110	5p $^1P_1$–5d $^3P_1$	799 729	1 043 843
61.2	368	411.807	−0.003	242 832	5p $^3F_4$–5d $^3F_4$	791 873	1 034 703
57.1	333	413.654	0.000	241 748	4f $^3H_6$–5d $^3G_5$	785 164	1 026 912
40.3	213	414.264	0.009	241 392	5p $^3P_0$–5d $^3D_1$	807 481	1 048 878
43.3	245	417.156	−0.006	239 718	5p $^1F_3$–5d $^3F_3$	816 810	1 056 532
59.0	356	425.319	0.001	235 118	5p $^1D_2$–5d $^3P_2$	798 275	1 033 393
279.5	780	425.461	0.000	235039	5p $^3F_4$–5d $^3G_5$	791 873	1 026 912
86.7	373	425.677	0.008	234 929	5p $^3D_1$–5d $^3F_2$	818 983	1 053 907
40.8	298	426.504	−0.001	234 464	4f $^3H_5$–5d $^3G_4$	788 813	1 023 277
224.2	720	426.605	0.000	234 409	5p $^1F_3$–5d $^1G_4$	816 810	1 051 219
50.8	550bl	427.122	−0.006	234 125	5p $^1D_2$–5d $^1F_3$	798 275	1 032 397
11.9			0.023		4f $^3F_2$–5d $^1D_2$	818 170	1 052 308
128.5	472	427.659	0.002	233 831	5p $^3D_2$–5d $^3F_3$	822 700	1 056 532
20.0			0.015		4f $^3F_4$–5d $^3F_4$	800 864	1 034 703
26.2	453m	427.975	0.010	233 659	5p $^1P_1$–5d $^3P_2$	799 729	1 033 393
9.6	145	428.311	0.000	233 475	4f $^3D_2$–5d $^3P_1$	810 368	1 043 843
143.5	616	429.300	0.003	232 937	5p $^3D_3$–5d $^3F_4$	801 764	1 034 703
39.3	451	431.742	0.000	231 620	4f $^3G_5$–5d $^1G_4$	819 599	1 051 219
14.8	172	431.904	0.000	231 533	4f $^3F_4$–5d $^1F_3$	800 864	1 032 397
23.2	154	432.510	−0.003	231 208	5p $^3D_2$–5d $^3F_2$	822 700	1 053 907
10.4	284	433.449	0.001	230 708	4f $^3F_2$–5d $^3D_1$	818 170	1 048 878
47.0	255	433.591	0.002	230 632	5p $^3D_3$–5d $^1F_3$	801 764	1 032 397
24.5	211	434.305	0.001	230 253	4f $^1G_4$–5d $^3G_3$	814 978	1 045 231
21.7	122	434.970	−0.011	229 901	5p $^3D_1$–5d $^3D_1$	818 983	1 048 878
11.1	63	435.201	−0.013	229 779	4f $^3H_4$–5d $^3D_3$	798 415	1 028 187
30.6	131	435.525	0.000	229 608	5p $^3D_2$–5d $^1D_2$	822 700	1 052 308
17.9	129	436.073	0.001	229 319	4f $^1D_2$–5d $^1P_1$	797 456	1 026 776
34.1	238	439.078	0.001	227 750	4f $^1H_5$–5d $^3F_4$	806 953	1 034 703
17.1	215	439.412	0.000	227 557	4f $^3F_3$–5d $^3D_2$	797 647	1 025 224
21.5	79	439.695	−0.001	227 430	4f $^3G_3$–5d $^3F_2$	826 477	1 053 907
32.9	325	440.437	−0.001	227 047	5p $^1P_1$–5d $^1P_1$	799 729	1 026 776
30.4	175	440.786	0.001	226 867	4f $^3G_4$–5d $^3F_3$	829 664	1 056 532
14.2	132	447.505	−0.002	223 461	5p $^3D_3$–5d $^3D_2$	801 764	1 025 224
12.6	147	447.850	−0.005	223 289	4f $^3D_3$–5d $^3P_2$	810 106	1 033 393
8.9	86	449.865	0.004	222 289	4f $^3D_3$–5d $^1F_3$	810 106	1 032 397
11.2	61	452.201	0.005	221 141	5p $^3D_2$–5d $^3P_1$	822 700	1 043 843
13.3	152	467.408	0.000	213 946	4f $^1F_3$–5d $^1D_2$	838 362	1 052 308
2.2	79	512.573	−0.003	195 094	5s $^3D_2$–5p $^1F_3$	621 717	816 810
35.1	749	543.493	0.000	183 995	5s $^3D_3$–5p $^3D_3$	617 769	801 764
16.4	490	546.276	0.002	183 058	5s $^3D_1$–5p $^3D_2$	639 642	822 700
17.9	482	555.396	−0.014	180 052	5s $^3D_2$–5p $^3D_3$	621 717	801 764
22.4	497	557.345	−0.003	179 422	5s $^1D_2$–5p $^3D_2$	643 279	822 700
20.1	517	557.590	−0.007	179 343	5s $^3D_1$–5p $^3D_1$	639 642	818 983
12.7	387	561.757	−0.003	178 013	5s $^3D_2$–5p $^1P_1$	621 717	799 729
18.7	705	566.383	−0.004	176 559	5s $^3D_2$–5p $^1D_2$	621 717	798 275
11.9	491m	569.021	−0.005	175 740	5s $^3D_2$–4f $^1D_2$	621 717	797 456
65.7	570	574.369	−0.001	174 104	5s $^3D_3$–5p $^3F_4$	617 769	791 873
48.6	796	576.268	0.002	173 530	5s $^1D_2$–5p $^1F_3$	643 279	816 810
6.7	232	595.809	0.000	167 839	5s $^3D_1$–5p $^3P_0$	639 642	807 481
8.2	395	601.478	−0.008	166 257	5s $^3D_2$–5p $^3P_1$	621 717	787 972
0.7	79	630.983	0.009	158 483	5s $^1D_2$–5p $^3D_3$	643 279	801 764
5.2	146	639.187	0.005	156 449	5s $^1D_2$–5p $^1P_1$	643 279	799 729
11.2	131	675.341	−0.006	148 073	5s $^3D_3$–5p $^3F_3$	617 769	765 841
11.9	78	687.891	0.001	145 372	5s $^3D_1$–5p $^3F_2$	639 642	785 014
7.5	44	691.126	0.008	144 691	5s $^1D_2$–5p $^3P_1$	643 279	787 972
20.1	110	692.857	0.000	144 330	5s $^3D_3$–5p $^3P_2$	617 769	762 099
18.7	102	693.858	0.011	144 122	5s $^3D_2$–5p $^3F_3$	621 717	765 841

[a,b] see the footnotes to Table I.

of the $4d^95s$, $4d^95p$, $4d^95d$ and $4d^95f$ energies were 31, 68, 66 and 126 cm^{-1} respectively.

It was mentioned above that the $4d^94f$ configuration was not previously analyzed at all in the Pd I sequence. This configuration energy structure can really be established only from the $4d^94f$–$4d^95d$ transitions. The $4d^94f$ levels are located close to the $4d^95d$ ones in the Sb VI – I VIII ions resulting in very long wavelengths of the corresponding transitions,

Table IV. *Classified lines in the La XII spectrum.*

gA	I^a	λ, Å^b	$\Delta\lambda$, Å	ν, cm^{-1}	Transition	E_{low}	E_{up}
8476.0	100	94.764S	0.000	1 055 253	4d $^1S_0$–4f $^1P_1$	0	1 055 253
116.2	30	107.849S	0.000	927 222	4d $^1S_0$–5p $^3D_1$	0	927 222
581.9	70	110.514S	0.001	904 863	4d $^1S_0$–5p $^1P_1$	0	904 867
26.9	20	112.107S	−0.001	892 005	4d $^1S_0$–5p $^3P_1$	0	891 994
8.8	5	116.473K	0.000	858 568	4d $^1S_0$–4f $^3D_1$	0	858 568
40.2	69	311.798	0.000	320 721	5p $^1P_1$–5d $^1S_0$	904 867	1 225 588
98.4	148	315.467	0.000	316 990	4f $^3H_6$–5d $^3G_5$	835 512	1 152 502
71.8	138	323.442	0.000	309 174	4f $^3H_5$–5d $^3G_4$	838 843	1 148 017
11.1	54	323.987	−0.003	308 654	4f $^3H_4$–5d $^1F_3$	849 793	1 158 444
70.1	119	326.562	0.000	306 220	4f $^3G_5$–5d $^1G_4$	873 848	1 180 068
34.2	73	326.901	0.000	305 903	4f $^3F_4$–5d $^1F_3$	852 541	1 158 444
21.4	57	327.476	0.000	305 366	4f $^3F_2$–5d $^3D_1$	871 851	1 177 217
8.5			0.000		4f $^3D_1$ - 5d $^3P_0$	858 568	1 163 934
45.3	111	327.861	−0.005	305 008	4f $^1G_4$–5d $^3G_3$	867 957	1 172 960
17.1	46	328.809	0.000	304 128	4f $^1D_2$–5d $^1P_1$	848 145	1 152 273
26.5	76	329.390	0.001	303 592	4f $^3H_4$–5d $^3D_3$	849 793	1 153 386
39.3	58	331.091	0.000	302 032	4f $^3G_3$–5d $^3F_2$	880 871	1 182 903
61.6	175	331.325	0.000	301 819	4f $^1H_5$–5d $^3F_4$	859 195	1 161 014
22.9	42	331.860	0.000	301 332	4f $^3F_3$–5d $^3D_2$	848 847	1 150 179
53.9	103	332.079	0.000	301 133	4f $^3G_4$–5d $^3F_3$	884 710	1 185 843
32.5	96	336.164	0.000	297 474	4f $^3D_3$–5d $^3P_2$	862 102	1 159 576
16.2	97	339.646	0.002	294 424	5p $^3F_2$–5d $^3F_2$	888 477	1 182 903
65.9	120	342.165	0.004	292 257	5p $^3F_2$–5d $^1D_2$	888 477	1 180 738
20.5	114	342.388	0.009	292 066	5p $^3F_3$–5d $^1F_3$	866 370	1 158 444
93.2	149	343.652	0.007	290 992	5p $^3P_2$–5d $^3D_3$	862 388	1 153 386
53.0	107	346.321	−0.006	288 749	5p $^3P_1$–5d $^1D_2$	891 994	1 180 738
137.7	215	347.475	0.000	287 791	5p $^3P_2$–5d $^3D_2$	862 388	1 150 179
28.2	76	348.165	0.000	287 220	4f $^1F_3$–5d $^1D_2$	893 518	1 180 738
118.0	186	348.413	0.000	287 016	5p $^3F_3$–5d $^3D_3$	866 370	1 153 386
44.5	53	348.805	0.000	286 693	5d $^3P_1$–5f $^3F_2$	1 171 569	1 458 262
206.1	235	351.516	0.001	284 482	5p $^3F_2$–5d $^3G_3$	888 477	1 172 960
99.2	86	351.789	0.000	284 261	5d $^3G_5$–5f $^3G_5$	1 152 502	1 436 763
163.4	88	352.536	−0.002	283 659	5d $^3D_2$–5f $^3F_3$	1 150 179	1 433 836
64.1	93	353.173	−0.005	283 147	5d $^3D_2$–5f $^1D_2$	1 150 179	1 433 322
569.6	197	353.976	0.000	282 505	5d $^3G_4$–5f $^3H_5$	1 148 017	1 430 522
458.5			0.000		5d $^3G_3$–5f $^3H_4$	1 172 960	1 455 465
272.8	143	354.917	0.000	281 756	5d $^3D_3$–5f $^3F_4$	1 153 386	1 435 142
289.9	312	355.053	−0.001	281 648	5p $^3F_3$–5d $^3G_4$	866 370	1 148 017
136.0	93	355.815	0.000	281 045	5d $^3D_1$–5f $^3F_2$	1 177 217	1 458 262
118.9			0.004		5d $^1P_1$–5f $^1D_2$	1 152 273	1 433 322
234.4	92	356.194	0.000	280 746	5d $^1D_2$–5f $^3G_3$	1 180 738	1 461 484
105.2	101	356.574	0.004	280 447	5d $^3D_3$–5f $^3F_3$	1 153 386	1 433 836
53.0	136	357.686	0.000	279 575	5p $^3P_1$–5d $^3P_1$	891 994	1 171 569
124.0	90	358.620	0.000	278 847	5d $^3D_2$–5f $^3P_2$	1 150 179	1 429 026
670.6	186	359.853	0.000	277 891	5d $^3G_5$–5f $^3H_6$	1 152 502	1 430 393
349.0	171	360.286	0.000	277 557	5d $^1F_3$–5f $^1G_4$	1 158 444	1 436 001
235.2	183	360.549	0.000	277 355	5d $^3P_2$–5f $^1F_3$	1 159 576	1 436 931
556.8	111	360.855	0.000	277 120	5d $^1G_4$–5f $^1H_5$	1 180 068	1 457 188
270.3	76	361.340	0.003	276 748	5d $^3F_2$–5f $^3D_3$	1 182 903	1 459 653
389.2	168	362.297	0.000	276 017	5d $^3F_3$–5f $^3G_4$	1 185 843	1 461 860
463.6	185	362.632	−0.017	275 762	5d $^3F_4$–5f $^3G_5$	1 161 014	1 436 763
86.4			0.000		5p $^3P_2$–5d $^3S_1$	862 388	1 138 150
55.6	91	365.214	−0.003	273 812	5d $^3F_3$–5f $^3D_3$	1 185 843	1 459 653
55.6	94	365.304	0.002	273 744	5d $^3P_2$–5f $^1D_2$	1 159 576	1 433 322
31.4	99	367.726	0.000	271 940	5p $^3P_1$–5d $^3P_0$	891 994	1 163 934
28.2	192	370.406	−0.010	269 974	5p $^3F_2$–5d $^1F_3$	888 477	1 158 444
85.5	251	378.974	−0.003	263 870	5p $^3F_4$–5d $^3F_4$	897 146	1 161 014
47.9	251	381.719	0.000	261 973	5p $^3P_0$–5d $^3D_1$	915 244	1 177 217
81.3	331	390.309	0.000	256 207	5p $^1D_2$–5d $^3P_2$	903 369	1 159 576
103.5	326	391.111	−0.001	255 682	5p $^3D_1$–5d $^3F_2$	927 222	1 182 903
328.4	427	391.610	0.000	255 356	5p $^3F_4$–5d $^3G_5$	897 146	1 152 502
105.2	315	392.040	−0.002	255 076	5p $^1D_2$–5d $^1F_3$	903 369	1 158 444
265.1	392	392.692	−0.001	254 652	5p $^1F_3$–5d $^1G_4$	925 416	1 180 068
155.7	371	392.919	0.000	254 505	5p $^3D_2$–5d $^3F_3$	931 338	1 185 843
186.5	386	394.849	0.003	253 262	5p $^3D_3$–5d $^3F_4$	907 751	1 161 014
64.1	414	398.896	0.002	250 692	5p $^3D_3$–5d $^1F_3$	907 751	1 158 444
41.0	391	404.193	−0.001	247 406	5p $^1P_1$–5d $^1P_1$	904 867	1 152 273
39.3	237	407.099	−0.009	245 640	5p $^3D_3$–5d $^3D_3$	907 751	1 153 386
24.8	371	412.488	−0.006	242 431	5p $^3D_3$–5d $^3D_2$	907 751	1 150 179

Table IV. *continued.*

gA	I^a	λ, Å^b	$\Delta\lambda$, Å	ν, cm^{-1}	Transition	E_{low}	E_{up}
14.5	279	416.210	0.005	240 263	5p $^3D_3$–5d $^3G_4$	907 751	1 148 017
43.6	240	497.576	−0.001	200 974	5s $^3D_3$–5p $^3D_3$	706 777	907 751
20.5	132	500.892	−0.007	199 644	5s $^3D_1$–5p $^3D_2$	731 697	931 338
24.0	143	508.145	0.005	196 794	5s $^3D_2$–5p $^3D_3$	710 955	907 751
3.4	66	508.683	0.015	196 586	5s $^3D_3$–5p $^1D_2$	706 777	903 369
27.4	189	510.430	0.005	195 913	5s $^1D_2$–5p $^3D_2$	735 423	931 338
24.0	157	511.443	0.000	195 525	5s $^3D_1$–5p $^3D_1$	731 697	927 222
17.1	163	515.704	0.006	193 910	5s $^3D_2$–5p $^1P_1$	710 955	904 867
36.8	301	519.706	−0.007	192 416	5s $^3D_2$–5p $^1D_2$	710 955	903 369
2.6	175m	521.397	0.016	191 793	5s $^1D_2$–5p $^3D_1$	735 423	927 222
81.3	339	525.296	0.000	190 369	5s $^3D_3$–5p $^3F_4$	706 777	897 146
59.9	298	526.337	0.002	189 992	5s $^1D_2$–5p $^1F_3$	735 423	925 416
8.6	134	544.820	0.000	183 547	5s $^3D_1$–5p $^3P_0$	731 697	915 244
8.7	205m	552.360	−0.007	181 041	5s $^3D_2$–5p $^3P_1$	710 955	891 994
4.3	70	563.319	0.009	177 519	5s $^3D_2$–5p $^3F_2$	710 955	888 477
0.8	55	580.285	−0.004	172 329	5s $^1D_2$–5p $^3D_3$	735 423	907 751
1.7	40	582.515	0.009	171 669	5s $^3D_1$–5p $^1D_2$	731 697	903 369
5.1	80	590.158	−0.007	169 446	5s $^1D_2$–5p $^1P_1$	735 423	904 867
1.7	30	595.433	0.004	167 945	5s $^1D_2$–5p $^1D_2$	735 423	903 369
12.8	126bl	626.589	−0.005	159 594	5s $^3D_3$–5p $^3F_3$	706 777	866 370
9.4	30	638.687	−0.001	156 571	5s $^1D_2$–5p $^3P_1$	735 423	891 994
13.7	34	637.836	0.000	156 780	5s $^3D_1$–5p $^3F_2$	731 697	888 477
22.2	45	642.630	0.002	155 611	5s $^3D_3$–5p $^3P_2$	706 777	862 388
19.7	43	643.439	0.000	155 415	5s $^3D_2$–5p $^3F_3$	710 955	866 370
7.7	45	653.364	0.000	153 054	5s $^1D_2$–5p $^3F_2$	735 423	888 477

[a] see the footnotes to Table I.
[b] line classified earlier in: S – [12]; K – [13].

Table V. *Classified lines in the Ce XIII spectrum.*

gA	I^a	λ, Å^b	$\Delta\lambda$, Å	ν, cm^{-1}	Transition	E_{low}	E_{up}
9434.0	100	89.237S	0.000	1 120 610	4d $^1S_0$–4f $^1P_1$	0	1 120 610
141.2	30	96.091S	−0.001	1 040 680	4d $^1S_0$–5p $^3D_1$	0	1 040 669
787.6	60	98.535S	0.001	1 014 868	4d $^1S_0$–5p $^1P_1$	0	1 014 883
61.8	15	99.936S	0.000	1 000 640	4d $^1S_0$–5p $^3P_1$	0	1 000 641
13.3	10	109.945S	0.000	909 545	4d $^1S_0$–4f $^3D_1$	0	909 545
163.6	11	250.931	0.000	398 516	4f $^3H_6$–5d $^3G_5$	884 523	1 283 039
121.5	21	256.514	0.000	389 842	4f $^3H_5$–5d $^3G_4$	887 732	1 277 574
120.5	39	258.142	0.000	387 383	4f $^3G_5$–5d $^1G_4$	926 708	1 314 091
65.6	29	258.371	0.000	387 040	4f $^3F_4$–5d $^1F_3$	902 449	1 289 489
32.3	29	258.786	0.000	386 420	4f $^3F_2$–5d $^3D_1$	924 529	1 310 949
78.4	38	258.971	0.000	386 144	4f $^1G_4$–5d $^3G_3$	919 636	1 305 780
51.0	33	260.618	0.000	383 704	4f $^3H_4$–5d $^3D_3$	899 707	1 283 411
62.7	33	261.294	0.000	382 710	4f $^3G_3$–5d $^3F_2$	934 451	1 317 161
104.8	49	261.601	0.000	382 262	4f $^1H_5$–5d $^3F_4$	909 973	1 292 235
35.3	42	261.920	0.000	381 796	4f $^3F_3$–5d $^3D_2$	898 158	1 279 954
91.1	33	262.119	0.000	381 507	4f $^3G_4$–5d $^3F_3$	938 735	1 320 242
48.0	36	265.099	0.000	377 217	4f $^3D_3$–5d $^3P_2$	913 579	1 290 796
45.0	46	272.650	0.000	366 770	4f $^1F_3$–5d $^1D_2$	947 456	1 314 226
50.0	34	287.383	0.000	347 967	5p $^1P_1$–5d $^1S_0$	1 014 883	1 362 851
90.1	81	314.592	0.000	317 872	5p $^3F_2$–5d $^1D_2$	996 354	1 314 226
120.5	102	316.097	0.001	316 359	5p $^3P_2$–5d $^3D_3$	967 051	1 283 411
74.4	50	318.896	0.003	313 582	5p $^3P_1$–5d $^1D_2$	1 000 641	1 314 226
175.4	149	319.588	0.000	312 903	5p $^3P_2$–5d $^3D_2$	967 051	1 279 954
150.0	137bl	320.139	–0.001	312 365	5p $^3F_3$–5d $^3D_3$	971 047	1 283 411
267.5	180	323.179	0.000	309 426	5p $^3F_2$–5d $^3G_3$	996 354	1 305 780
189.1	91	323.715	0.001	308 914	5d $^3D_2$–5f $^3F_3$	1 279 954	1 588 869
36.2			–0.006		5p $^3F_3$–5d $^3D_2$	971 047	1 279 954
580.1	69	324.942	0.000	307 747	5d $^3G_3$–5f $^3H_4$	1 305 780	1 613 527
717.3	67	325.143	0.000	307 557	5d $^3G_4$–5f $^3H_5$	1 277 574	1 585 131
366.5	63	325.650	0.000	307 078	5d $^3D_3$–5f $^3F_4$	1 283 411	1 590 489
396.9	118	326.236	0.000	306 527	5p $^3F_3$–5d $^3G_4$	971 047	1 277 574
315.5	57	327.120	0.000	305 699	5d $^1D_2$–5f $^3G_3$	1 314 226	1 619 925
193.1	57	327.377	0.000	305 458	5d $^3D_3$–5f $^3F_3$	1 283 411	1 588 869
168.5	52	327.521	0.000	305 324	5d $^3D_1$–5f $^3F_2$	1 310 949	1 616 273

Table V. *continued.*

gA	I^a	λ, Å^b	$\Delta\lambda$, Å	ν,cm^{-1}	Transition	E_{low}	E_{up}
74.4	60	329.180	0.000	303 785	5p $^3P_1$–5d $^3P_1$	1 000 641	1 304 426
841.8	78	330.932	0.000	302 177	5d $^3G_5$–5f $^3H_6$	1 283 039	1 585 216
449.8	65	331.242	0.000	301 894	5d $^1F_3$ – 5f $^1G_4$	1 289 489	1 591 383
292.0	79	331.610	0.000	301 559	5d $^3P_2$–5f $^1F_3$	1 290 796	1 592 355
700.7	65	331.886	0.000	301 308	5d $^1G_4$–5f $^1H_5$	1 314 091	1 615 399
348.9	61	332.056	0.000	301 154	5d $^3F_2$–5f $^3D_3$	1 317 161	1 618 315
486.1	65	332.804	0.000	300 477	5d $^3F_3$–5f $^3G_4$	1 320 242	1 620 719
582.1	66	333.068	0.000	300 239	5d $^3F_4$–5f $^3G_5$	1 292 235	1 592 474
110.7	95	333.291	0.000	300 038	5p $^3P_2$–5d $^3S_1$	967 051	1 267 089
37.2	95?	338.472	0.000	295 445	5p $^3P_1$–5d $^3P_0$	1 000 641	1 296 086
61.7	68	353.650	0.000	282 765	5p $^3P_0$–5d $^3D_1$	1 028 184	1 310 949
102.9	174bl	360.552	0.001	277 352	5p $^1D_2$–5d $^3P_2$	1 013 443	1 290 796
127.4	384	361.674	0.000	276 492	5p $^3D_1$–5d $^3F_2$	1 040 669	1 317 161
132.3	260	362.258	0.000	276 046	5p $^1D_2$–5d $^1F_3$	1 013 443	1 289 489
410.6	230	362.562	0.000	275 815	5p $^3F_4$–5d $^3G_5$	1 007 224	1 283 039
332.2	168	363.398	0.000	275 181	5p $^1F_3$–5d $^1G_4$	1 038 910	1 314 091
194.0	126	363.595	0.000	275 031	5p $^3D_2$–5d $^3F_3$	1 045 211	1 320 242
235.2	126	365.122	0.000	273 881	5p $^3D_3$–5d $^3F_4$	1 018 354	1 292 235
35.2	49	369.980	−0.007	270 285	5p $^3D_1$–5d $^3D_1$	1 040 669	1 310 949
56.8	117	373.338	0.000	267 854	5p $^1P_1$–5d $^1P_1$	1 014 883	1 282 737
46.0	80	377.277	0.000	265 057	5p $^3D_3$–5d $^3D_3$	1 018 354	1 283 411
54.9	374	458.415	−0.004	218 143	5s $^3D_3$–5p $^3D_3$	800 213	1 018 354
25.6	237	461.297	0.004	216 780	5s $^3D_1$–5p $^3D_2$	828 429	1 045 211
30.4	366	467.855	0.008	213 741	5s $^3D_2$–5p $^3D_3$	804 609	1 018 354
34.3	247	469.566	−0.004	212 963	5s $^1D_2$–5p $^3D_2$	832 250	1 045 211
30.4	206	471.164	0.000	212 240	5s $^3D_1$–5p $^3D_1$	828 429	1 040 669
23.5	450	475.571	0.000	210 274	5s $^3D_2$–5p $^1P_1$	804 609	1 014 883
47.0	455	478.848	0.000	208 834	5s $^3D_2$–5p $^1D_2$	804 609	1 013 443
101.9	677	483.067	0.000	207 011	5s $^3D_3$–5p $^3F_4$	800 213	1 007 224
75.5	629	483.887	0.000	206 660	5s $^1D_2$–5p $^1F_3$	832 250	1 038 910
10.8	629bl	500.613	0.000	199 755	5s $^3D_1$–5p $^3P_0$	828 429	1 028 184
7.8	249	510.120	−0.001	196 032	5s $^3D_2$–5p $^3P_1$	804 609	1 000 641
15.7	499	585.366	0.002	170 833	5s $^3D_3$–5p $^3F_3$	800 213	971 047
12.7	333	593.855	−0.001	168 391	5s $^1D_2$–5p $^3P_1$	832 250	1 000 641
16.6	325	595.504	0.000	167 925	5s $^3D_1$–5p $^3F_2$	828 429	996 354
27.5	561	599.383	−0.001	166 838	5s $^3D_3$–5p $^3P_2$	800 213	967 051
25.5	490	600.826	0.002	166 438	5s $^3D_2$–5p $^3F_3$	804 609	971 047
9.8	325	609.371	0.001	164 104	5s $^1D_2$–5p $^3F_2$	832 250	996 354
1.9	91	615.604	0.000	162 442	5s $^3D_2$–5p $^3P_2$	804 609	967 051

[a,b] see the footnotes to Table I.

therefore falling outside of the previously observed range in [6]. Furthermore the $4d^94f$ configuration falls down rapidly along the sequence and crosses the $4d^95p$ configuration in Ba XI. For La XII and Ce XIII ions the $4d^9$ $4f$–$4d^95d$ transitions already lie at much shorter wavelengths than the $4d^95p$–$4d^95d$–$4d^95f$ ones, creating the clearly distinguished line arrays at 315–335 Å and 250–270 Å regions respectively. As a result, the strongest $4d^94f$–$4d^95d$ transitions were reliably classified in the La XII and Ce XIII ions. The analysis of the $4d^94f$–$4d^95d$ transitions in Ba XI was complicated because a lot of lines of the lower ionization stages lie in the same region. We classified the strongest $4d^94f$–$4d^95d$ transitions in Ba XI by using the accurate extrapolation of $4d^94f$ energy parameters determined for La XII and Ce XIII ions. It is seen from Table VII that the $4d^94f$ $^1D_2$ level in Ba XI is strongly mixed with the $4d^95p$ $^1D_2$ state and has a relatively strong transition to the $4d^95s$ $^3D_2$ level. There was no line with Ba XI character in the predicted region apart from a partly masked feature in the blue wing of the strong Ba IX line at 569.113 Å. We supposed that this 569.021 Å line corresponds to the $4d^95s$ $^3D_2$–$4d^94f$ $^1D_2$ transition in Ba XI (see Table III).

The determined $4d^9$ $4f$ level energies are included in Table VI. We could not carry out the GLS fitting of these energies because they were determined only in three ions, Ba XI - Ce XIII, and furthermore disturbed by the $4d^95p$ levels in Ba XI. Therefore the fitting in the frame of Cowan code [23] was run for the $4d^94f$ levels and the corresponding ΔE values, given in Table VI. The energies of closely lying mixed $4d^94f$ $^1D_2$ (797 456 cm^{-1}) and $4d^95p$ $^1D_2$ (798 275 cm^{-1}) levels deviate significantly from the fitted values, therefore these energies were excluded from the corresponding GLS and Cowan fittings. The Least-Squares-Fitted (LSF) parameters and their ratios to the HF values for the $4d^94f$ configuration in Ba XI, La XII and Ce XIII are presented in Table IX. It is seen that the LSF / HF parameter ratios agree well in all the three ions. The calculated $4d^94f$ energies for the Xe IX and Cs X ions are given in brackets in Table VI. The E_{av} ($4d^94f$) and G^1 (4d,4f) parameters were fitted by using the

Table VI. *The measured energies and their deviations from fitted values (in cm^{-1}) in the Pd-like Xe IX–Ce XIII ions.*

	Xe IX		Cs X		Ba XI		La XII		Ce XIII	
Level	E_{obs}	ΔE	E_{obs}	ΔE	E_{obs}	ΔE	E_{obs}	ΔE	E_{obs}	ΔE
4d^{9}5s										
$^3D_1$	470 048[a]	24	552 441	17	639 642	23	731 697	30	828 429	25
$^3D_2$	456 956[a]	28	537 068[b]	34	621 717	32	710 955	32	804 609	38
$^1D_2$	473 496[a]	−22	555 995	−20	643 279	−26	735 423	−25	832 250	−31
$^3D_3$	453 468[a]	−31	533 342[b]	−31	617 769	−29	706 777	−37	800 213	−32
4d^{9}5p										
$^3P_0$	607 906[a]	37	705 043	52	807 481	104	915 244	52	1 028 184	102
$^3P_1$	594 522[a]	59	688 845[b]	97	787 972[c]	114	891 994[c]	69	1 000 641[c]	88
$^1P_1$	604 877[c]	11	699 833[c]	11	799 729[c]	−61	904 867[c]	−60	1 014 883[c]	11
$^3D_1$	618 269[c]	−21	715 972[c]	−28	818 983[c]	34	927 222[c]	−85	1 040 669[c]	−52
$^3P_2$	575 438[a]	−92	666 498[b]	−103	762 099	−152	862 388	−213	967 051	−197
$^3F_2$	593 154[a]	12	686 663	−49	785 014	−88	888 477	28	996 354	−14
$^1D_2$	602 541[a]	37	697 782[b]	51	798 275*		903 369	20	1 013 443	−82
$^3D_2$	621 147[a]	4	719 223	−20	822 700	109	931 388	32	1 045 211	26
$^3F_3$	578 986[a]	83	670 152[b]	74	765 841	15	866 370	101	971 047	42
$^3D_3$	605 410[a]	23	701 112[b]	23	801 764	−32	907 751	87	1 018 354	31
$^1F_3$	616 157[a]	−129	713 923	−116	816 810	−238	925 416	−67	1 038 910	−76
$^3F_4$	596 854[a]	−25	691 899[b]	8	791 873	−44	897 146	35	1 007 224	122
4d^{9}4f										
$^3P_0$	(662 461)		(714 (373)		(764 244)		(812 438)		(859 176)	
$^3P_1$	665 447[d]?		716 673[e]?		767 861?	−9	(816 404)		(863 966)	
$^3D_1$	696 312[c]		752 513[c]		806 445[c]	141	858 568[c]	263	909 545[c]	154
$^1P_1$	832 414[c]		912 500[c]		986 281[c]	0	1 055 253[c]	−1	1 120 610[c]	0
$^3P_2$	(670 544)		(723 780)		(775 147)		(824 885)		(873 503)	
$^1D_2$	(689 957)		(744 755)		797 456*		848 145	−25	(897 520)	
$^3D_2$	(699 288)		(755 830)		810 368	5	(863 409)		(915 733)	
$^3F_2$	(705 901)		(763 070)		818 170	58	871 851	64	924 529	49
$^3F_3$	(690 460)		(745 343)		797 647	−154	848 847	−50	898 158	−182
$^3D_3$	(699 660)		(755 913)		810 106	112	862 102	−127	913 579	103
$^3G_3$	(712 655)		(770 637)		826 477	20	880 871	−78	934 451	84
$^1F_3$	(722 667)		(781 868)		838 362	−20	893 518	30	947 456	−28
$^3H_4$	(690 311)		(745 424)		798 415	−50	849 793	−41	899 707	48
$^3F_4$	(692 368)		(747 568)		800 864	177	852 541	338	902 449	228
$^1G_4$	(704 102)		(760 750)		814 978	−131	867 957	−165	919 636	−132
$^3G_4$	(715 074)		(773 465)		829 664	−18	884 710	−99	938 735	−84
$^3H_5$	(682 823)		(736 683)		788 813	152	838 843	−43	887 732	117
$^1H_5$	(697 763)		(753 200)		806 953	5	859 195	−75	909 973	−37
$^3G_5$	(707 270)		(764 317)		819 599	−79	873 848	115	926 708	−32
$^3H_6$	(679 525)		(733 387)		785 164	−148	835 512	−162	884 523	−161
4d^{9}5d										
$^3P_0$	798 896	164	915 450	64	1 037 124	95	1 163 934	154	1 296 086?	526
$^1S_0$	843 962[f]	89	966 183	89	1 093 342	45	1 225 588	−19	1 362 851	−103
$^3S_1$	780 792	−59	895 017	−22	1 014 074	−17	1 138 150	39	1 267 089	78
$^1P_1$	790 854	−152	906 425	−114	1 026 776	−201	1 152 273	−162	1 282 737	−95
$^3P_1$	803 860	−56	921 320	−48	1 043 843	−51	1 171 569	−43	1 304 426	−22
$^3D_1$	807 691	13	925 691	20	1 048 878	75	1 177 217	7	1 310 949	112
$^3D_2$	790 022	42	905 223	76	1 025 224	81	1 150 179	104	1 279 954	100
$^3P_2$	796 070	41	912 250	0	1 033 393	−4	1 159 576	−7	1 290 796	64
$^1D_2$	810 825	6	929 055	−2	1 052 308	−24	1 180 738	−31	1 314 226	−79
$^3F_2$	811 675	5	930 209	17	1 053 907	11	1 182 903	−9	1 317 161	−13
$^3D_3$	792 488	−18	907 934	7	1 028 187	4	1 153 386	15	1 283 411	5
$^1F_3$	795 332	−13	911 410	−36	1 032 397	−65	1 158 444	−75	1 289 489	−48
$^3G_3$	805 240	−13	922 650	−57	1 045 231	12	1 172 960	47	1 305 780	60
$^3F_3$	813 696	−22	932 529	−27	1 056 532	−19	1 185 843	8	1 320 242	−105
$^3G_4$	788 522	−50	903 485	−53	1 023 277	−54	1 148 017	−40	1 277 574	−57
$^3F_4$	797 063	50	913 420	71	1 034 703	94	1 161 014	105	1 292 235	66
$^1G_4$	809 314	−2	927 704	28	1 051 219	19	1 180 068	52	1 314 091	26
$^3G_5$	790 742	−23	906 364	−13	1 026 912	−2	1 152 502	11	1 283 039	9
4d^{9}5f										
$^3P_0$	(990 713)		(1 130 216)		(1 274 651)		(1 423 904)		(1 578 093)	
$^3P_1$	(992 190)		1 131 646?	−200	(1 276 464)		(1 425 901)		(1 580 291)	
$^3D_1$	1 004 493[d]	5	1 144 990[e]	128	(1 290 708)		(1 440 815)		(1 595 821)	
$^1P_1$	1 036 821[d]	−58	1 175 751[e]	−55	(1 319 774)		(1 470 092)		(1 626 111)	
$^3P_2$	(994 492)		(1 134 446)		1 279 461	83	1 429 026	−162	(1 583 982)	
$^1D_2$	998 024	106	1 138 029	−75	1 283 134	−181	1 433 322	−93	(1 588 513)	
$^3D_2$	(1 011 201)		1 153 202	−200	1 300 869	−178	(1 453 818)		(1 611 861)	
$^3F_2$	1 014 147	−192	(1 157 038)		1 305 169	167	1 458 262	148	1 616 273?	−214

Table VI. *continued.*

	Xe IX		Cs X		Ba XI		La XII		Ce XIII	
Level	E_{obs}	ΔE	E_{obs}	ΔE	E_{obs}	ΔE	E_{obs}	ΔE	E_{obs}	ΔE
$^3F_3$	998 220	53	1 138 369	−33	1 283 584	−97	1 433 836	12	1 588 869	−93
$^1F_3$	1 001 354	217	1 141 623	165	1 286 869	102	1 436 931	−117	1 592 355	−5
$^3D_3$	1 015 439	−225	1 158 274	−260	1 306 382?	−249	1 459 653	−275	1 618 315	−207
$^3G_3$	1 017 377	−26	(1 160 140)		1 308 076	−215	1 461 484	−96	1 619 925	−229
$^3F_4$	998 989	−62	1 139 419	−31	1 284 817	−37	1 435 142	−28	1 590 489	−10
$^1G_4$	999 785	80	1 140 121	22	1 285 532	−24	1 436 001	83	1 591 383	96
$^3H_4$	1 012 122	−112	1 154 827	133	1 302 593	194	1 455 465	239	1 613 527	226
$^3G_4$	1 017 029	141	1 160 011	95	1 308 456	199	1 461 860	75	1 620 719	99
$^3H_5$	995 961	1	1 135 844	−6	1 280 639	−73	1 430 522	77	1 585 131	−22
$^3G_5$	1 000 432	46	1 141 024	158	1 286 465	54	1 436 763	−123	1 592 474	77
$^1H_5$	1 013 161?	−388	1 156 138	11	1 304 247	250	1 457 188	167	1 615 399	68
$^3H_6$	995 359	26	1 135 392	37	1 280 388	3	1 430 393	94	1 585 216	1

The level energy has been measured earlier in: a – [7,9]; b – [8]; c – [12]; d – [11]; e – [10]; f – [1,9].
* – these Ba XI levels were excluded from the fitting (see the text).
? – tentative energy.

Table VII. *The* LS *percentage compositions of* $4d^95l$ *and* $4d^94f$ *levels in the Xe IX, Ba XI and Ce XIII ions. The first component corresponds to the level designation in Tables I–VI.*

J	Xe IX	Ba XI	Ce XIII
$4d^95s$			
1	100% ^{3}D	100% ^{3}D	100% ^{3}D
2	61% ^{3}D + 39% ^{1}D	57% ^{3}D + 43% ^{1}D	55% ^{3}D + 45% ^{1}D
2	61% ^{1}D + 39% ^{3}D	57% ^{1}D + 43% ^{3}D	55% ^{1}D + 45% ^{3}D
3	100% ^{3}D	100% ^{3}D	100% ^{3}D
$4d^95p$			
0	100% ^{3}P	100% ^{3}P	100% ^{3}P
1	76% ^{3}P + 23% ^{3}D	67% ^{3}P + 31% ^{3}D + 1% ^{1}P	58% ^{3}P + 36% ^{3}D
1	83% ^{1}P + 12% ^{3}D	81% ^{1}P + 11% ^{3}P + 7% ^{3}D	80% ^{1}P + 17% ^{3}P
1	65% ^{3}D + 18% ^{3}P	62% ^{3}D + 21% ^{3}P + 16% ^{1}P	60% ^{3}D + 25% ^{3}P
2	76% ^{3}P + 18% ^{3}D	71% ^{3}P + 20% ^{3}D + 6% ^{1}D	69% ^{3}P + 22% ^{3}D
2	87% ^{3}F + 6% ^{3}D	85% ^{3}F + 5% ^{3}D + 5% ^{3}P	85% ^{3}F + 5% ^{1}D
2	65% ^{1}D + 18% ^{3}D	41% ^{1}D + 14% ^{3}P + 14% 4f ^{3}F	61% ^{1}D + 22% ^{3}P
2	58% ^{3}D + 28% ^{1}D	56% ^{3}D + 26% ^{1}D + 12% ^{3}F	57% ^{3}D + 26% ^{1}D
3	53% ^{3}F + 33% ^{1}F	52% ^{3}F + 34% ^{1}F + 15% ^{3}D	51% ^{3}F + 33% ^{1}F
3	73% ^{3}D + 26% ^{1}F	71% ^{3}D + 24% ^{1}F + 4% 4f ^{3}F	73% ^{3}D + 26% ^{1}F
3	40% ^{1}F + 46% ^{3}F	40% ^{1}F + 47% ^{3}F + 12% ^{3}D	40% ^{1}F + 49% ^{3}F
4	100% ^{3}F	96% ^{3}F + 4% 4f ^{3}F	100% ^{3}F
$4d^94f$			
0	100% ^{3}P	100% ^{3}P	100% ^{3}P
1	97% ^{3}P + 2% ^{3}D	97% ^{3}P + 3% ^{3}D	97% ^{3}P + 3% ^{3}D
1	97% ^{3}D + 2% ^{3}P	96% ^{3}D + 3% ^{3}P + 1% 5p ^{1}P	96% ^{3}D + 3% ^{3}P
1	89% ^{1}P + 9% 5f ^{1}P	96% ^{1}P + 3% 5f ^{1}P	98% ^{1}P + 1% 5f ^{1}P
2	91% ^{3}P + 6% ^{3}D	90% ^{3}P + 7% ^{3}D + 3% ^{1}D	88% ^{3}P + 9% ^{3}D
2	33% ^{1}D + 41% ^{3}F	24% ^{1}D + 26% ^{3}F + 22% 5p ^{1}D	34% ^{1}D + 41% ^{3}F
2	50% ^{3}D + 42% ^{1}D	49% ^{3}D + 41% ^{1}D + 10% ^{3}P	44% ^{3}D + 44% ^{1}D
2	59% ^{3}F + 22% ^{1}D	58% ^{3}F + 22% ^{1}D + 18% ^{3}D	59% ^{3}F + 22% ^{3}D
3	53% ^{3}F + 44% ^{3}D	50% ^{3}F + 44% ^{3}D + 1% ^{3}G	55% ^{3}F + 41% ^{3}D
3	46% ^{3}D + 28% ^{3}F	44% ^{3}D + 25% ^{3}F + 14% ^{1}F	45% ^{3}D + 21% ^{3}F
3	70% ^{3}G + 18% ^{3}F	67% ^{3}G + 19% ^{3}F + 7% ^{3}D	65% ^{3}G + 22% ^{3}F
3	82% ^{1}F + 13% ^{3}G	80% ^{1}F + 14% ^{3}G + 4% ^{3}D	78% ^{1}F + 14% ^{3}G
4	79% ^{3}H + 11% ^{3}G	75% ^{3}H + 13% ^{3}G + 9% ^{1}G	61% ^{3}H + 20% ^{3}G
4	87% ^{3}F + 6% ^{1}G	82% ^{3}F + 7% ^{1}G + 4% ^{3}H	76% ^{3}F + 11% ^{3}H
4	47% ^{1}G + 34% ^{3}G	45% ^{1}G + 33% ^{3}G + 22% ^{3}H	43% ^{1}G + 29% ^{3}G
4	50% ^{3}G + 39% ^{1}G	50% ^{3}G + 39% ^{1}G + 11% ^{3}F	50% ^{3}G + 38% ^{1}G
5	79% ^{3}H + 19% ^{1}H	79% ^{3}H + 20% ^{1}H + 1% ^{3}G	75% ^{3}H + 23% ^{1}H
5	49% ^{1}H + 44% ^{3}G	45% ^{1}H + 49% ^{3}G + 6% ^{3}H	40% ^{1}H + 54% ^{3}G
5	54% ^{3}G + 32% ^{1}H	50% ^{3}G + 35% ^{1}H + 15% ^{3}H	45% ^{3}G + 36% ^{1}H
6	100% ^{3}H	100% ^{3}H	100% ^{3}H
$4d^95d$			
0	98% ^{3}P + 2% ^{1}S	98% ^{3}P + 2% ^{1}S	98% ^{3}P + 2% ^{1}S

Table VII. *continued.*

J	Xe IX	Ba XI	Ce XIII
0	96% ^{1}S + 2% ^{3}P	96% ^{1}S + 2% ^{3}P	96% ^{1}S + 2% ^{3}P
1	81% ^{3}S + 17% ^{3}P	79% ^{3}S + 20% ^{3}P	77% ^{3}S + 22% ^{3}P
1	51% ^{1}P + 25% ^{3}D	51% ^{1}P + 25% ^{3}D	51% ^{1}P + 26% ^{3}D
1	31% ^{3}P + 45% ^{1}P	24% ^{3}P + 47% ^{1}P	23% ^{3}P + 48% ^{1}P
1	63% ^{3}D + 31% ^{3}P	57% ^{3}D + 37% ^{3}P	50% ^{3}D + 43% ^{3}P
2	41% ^{3}D + 54% ^{3}P	44% ^{3}D + 51% ^{3}P	46% ^{3}D + 46% ^{3}P
2	26% ^{3}P + 45% ^{1}D	29% ^{3}P + 46% ^{1}D	32% ^{3}P + 46% ^{1}D
2	54% ^{1}D + 19% ^{3}D	49% ^{1}D + 36% ^{3}F	42% ^{1}D + 50% ^{3}F
2	70% ^{3}F + 25% ^{3}D	46% ^{3}F + 38% ^{3}D	32% ^{3}F + 47% ^{3}D
3	52% ^{3}D + 34% ^{3}F	46% ^{3}D + 37% ^{3}F	41% ^{3}D + 39% ^{3}F
3	41% ^{1}F + 34% ^{3}D	39% ^{1}F + 41% ^{3}D	38% ^{1}F + 45% ^{3}D
3	73% ^{3}G + 21% ^{1}F	74% ^{3}G + 21% ^{1}F	75% ^{3}G + 20% ^{1}F
3	52% ^{3}F + 33% ^{1}F	52% ^{3}F + 33% ^{1}F	53% ^{3}F + 32% ^{1}F
4	56% ^{3}G + 42% ^{1}G	56% ^{3}G + 42% ^{1}G	55% ^{3}G + 41% ^{1}G
4	77% ^{3}F + 19% ^{1}G	78% ^{3}F + 19% ^{1}G	79% ^{3}F + 19% ^{1}G
4	39% ^{1}G + 40% ^{3}G	39% ^{1}G + 41% ^{3}G	40% ^{1}G + 42% ^{3}G
5	100% ^{3}G	100% ^{3}G	100% ^{3}G
4d^{9}5f			
0	100% ^{3}P	100% ^{3}P	100% ^{3}P
1	88% ^{3}P + 11% ^{3}D	72% ^{3}P + 9% ^{3}D	87% ^{3}P + 12% ^{3}D
1	85% ^{3}D + 10% ^{3}P	72% ^{3}D + 13% ^{1}P	63% ^{3}D + 30% ^{1}P
1	84% ^{1}P + 8% 4f ^{1}P	81% ^{1}P + 12% ^{3}D	56% ^{1}P + 22% ^{3}D
2	62% ^{3}P + 25% ^{3}D	54% ^{3}P + 28% ^{3}D	56% ^{3}P + 31% ^{3}D
2	39% ^{1}D + 39% ^{3}F	41% ^{1}D + 38% ^{3}F	42% ^{1}D + 38% ^{3}F
2	36% ^{3}D + 37% ^{3}P	27% ^{3}D + 33% ^{3}P	29% ^{3}D + 42% ^{3}P
2	61% ^{3}F + 22% ^{1}D	62% ^{3}F + 20% ^{1}D	61% ^{3}F + 20% ^{1}D
3	48% ^{3}F + 47% ^{3}D	47% ^{3}F + 49% ^{3}D	49% ^{3}F + 46% ^{3}D
3	49% ^{1}F + 20% ^{3}G	52% ^{1}F + 19% ^{3}G	55% ^{1}F + 19% ^{3}D
3	27% ^{3}D + 40% ^{3}F	30% ^{3}D + 42% ^{3}F	33% ^{3}D + 41% ^{3}F
3	57% ^{3}G + 38% ^{1}F	64% ^{3}G + 31% ^{1}F	69% ^{3}G + 27% ^{1}F
4	78% ^{3}F + 19% ^{3}G	67% ^{3}F + 29% ^{3}G	58% ^{3}F + 36% ^{3}G
4	48% ^{1}G + 26% ^{3}G	52% ^{1}G + 19% ^{3}H	52% ^{1}G + 21% ^{3}F
4	75% ^{3}H + 15% ^{1}G	78% ^{3}H + 13% ^{1}G	79% ^{3}H + 13% ^{1}G
4	45% ^{3}G + 35% ^{1}G	45% ^{3}G + 34% ^{1}G	45% ^{3}G + 34% ^{1}G
5	56% ^{3}H + 43% ^{1}H	54% ^{3}H + 45% ^{1}H	53% ^{3}H + 46% ^{1}H
5	78% ^{3}G + 16% ^{1}H	79% ^{3}G + 15% ^{1}H	80% ^{3}G + 14% ^{1}H
5	41% ^{1}H 38% ^{3}H	40% ^{1}H + 40% ^{3}H	40% ^{1}H + 41% ^{3}H
6	100% ^{3}H	100% ^{3}H	100% ^{3}H

Table VIII. *The Generalized-Least-Squares-Fitted (GLS) parameters used for the description of 4d^{9}5l configurations in Pd-like ions. The standard errors associated with the fitted constants are given in parentheses (R HFR means that the coefficients for Zc^2, Zc^3 and Zc^4 are held in a HFR ratio).*

4d^{9}5s							
	G^2(4d,5s)	11980.6	+718.4 Zc	−11394.2/(Zc+1)			
		(395)	(29)	(1256)			
$\zeta 4^\delta$	1036.58	+339.87 Zc	+24.550 Zc^2	+0.6451 Zc^3	+0.0085 Zc^4		
	(19)	(4.8)	(0.22)	R HFR	R HFR		
4d^{9}5p							
	F^2(4d,5p)	15607	+2864.5 Zc	−24729/(Zc+1)			
		(497)	(37)	(1590)			
	G^1(4d,5p)	6656	+708 Zc	−8118/(Zc+1)			
		(193)	(14)	(645)			
	G^3(4d,5p)	3282	+1087 Zc	−4555/(Zc+1)			
		(1071)	(80)	(3430)			
	ζ_{4d}	1033.15	+344.83 Zc	+24.440 Zc^2	+0.6373 Zc^3	+0.0085 Zc^4	
		(23)	(5.2)	(0.02)		R HFR	R HFR
	ζ_{5p}	−248.72	+745.05 Zc	+80.889 Zc^2	+1.1149 Zc^3	+0.0542 Zc^4	
		(41)	(8.1)	(0.31)		R HFR	R HFR
4d^{9}5d							
	F^2(4d,5d)	1887	+3191 Zc	−16170/(Zc+2)			
		(595)	(41)	(2410)			
	F^4(4d,5d)	−2382	+1962 Zc	+2090/(Zc+2)			
		(886)	(62)	(3691)			
	G^0(4d,5d)	−321	+697.4 Zc	−1830/(Zc+2)			
		(76)	(4)	(424)			

Table VIII. *continued.*

	G^2(4d,5d)	−3490	+1234 Zc	+8911/(Zc+2)		
		(771)	(51)	(3207)		
	G^4(4d,5d)	−3475	+1067 Zc	+10694/(Zc+2)		
		(1438)	(98)	(5751)		
	ζ_{4d}	1031.6	+348.2 Zc	+24.23 Zc^2	+0.632 Zc^3	+0.0084 Zc^4
		(18)	(4.8)	(0.23)	R HFR	R HFR
	ζ_{5d}	−67.7	+33.84 Zc	+12.457 Zc^2	+0.147 Zc^3	+0.0064 Zc^4
		(25.5)	(6.9)	(0.36)	R HFR	R HFR
$4d^9 5f$						
	F^2(4d,5f)	SF= 0.7802	+0.00634 Zc			
		(0.015)	(0.002)			
	F^4(4d,5f)	SF= 0.8841	+0.00634 Zc			
		(0.024)				
	G^1(4d,5f)	SF= 1.10197	−0.00778 Zc			
		(0.040)	(0.004)			
	G^3(4d,5f)	SF= 0.91826	−0.00778 Zc			
		(0.038)				
	G^5(4d,5f)	SF= 0.90826	−0.00778 Zc			
		(0.046)				
	ζ_{4d}	SF= 1.02448	−0.00086 Zc			
		(0.006)	(0.0006)			
	ζ_{5f}	SF= 1.01135				

Table IX. *The Least-Squares-Fitted (LSF) energy parameters (in* cm^{-1}*) and their ratios to the Hartree-Fock parameters (LSF/HF) for the* $4d^9 4f$ *configuration in Pd-like Ba XI, La XII and Ce XIII ions.*

Energy	Ba XI		La XII		Ce XIII	
parameter	LSF	LSF/HF	LSF	LSF/HF	LSF	LSF/HF
$E_{av}(4d^9 4f)$	807942(56)	0.994	860503(63)	0.994	911684(56)	0.994
ζ(4d)	8479(79)	1.020	9608(77)	1.014	10995(72)	1.022
ζ(4f)	546(48)	0.832	745(50)	0.893	987(44)	0.954
F^2(4d,4f)	96183(730)	0.842	104730(1123)	0.856	111237(1057)	0.856
F^4(4d,4f)	66908(1109)	0.907	71043(1481)	0.895	77451(1383)	0.916
G^1(4d,4f)	112692(164)	0.827	120704(225)	0.830	127762(209)	0.832
G^3(4d,4f)	72268(874)	0.841	77582(868)	0.840	83400(768)	0.850
G^5(4d,4f)	53699(1571)	0.882	58051(1634)	0.885	61838(1473)	0.885

known $J = 1$ level energies and the other $4d^9 4f$ parameters were extrapolated along the Ba XI – Ce XIII sequence in these calculations.

5. Conclusion

The VUV spectra of the Pd-like Xe IX – Ce XIII ions have been analysed. Between 65 and 100 lines have been classified in each of the spectra for the first time. The energies of the $4d^9 5s$, $4d^9 5p$, $4d^9 5d$ and $4d^9 5f$ configurations in Xe IX – Ce XIII ions and of the $4d^9 4f$ configuration in Ba XI, La XII and Ce XIII ions were determined. The wavelengths of laser transitions in Pd-like ions from Xe IX through Ce XIII were accurately measured or can be predicted from the level energies given in Table VI. The spectroscopic data obtained give a good basis for the analyses of the heavier Pd-like ions.

Acknowledgements

This work has been supported by a Programme International de Cooperation Scientifique (CNRS-PICS grant No.570) and by a Russian Foundation for Basic Research (RFBR-CNRS grant No.98-05-22027). SSC and ANR are thankful to P.S. Antsiferov and A.V. Nazarenko for their help in operating the capillary source.

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