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AN ANALYSIS OF THE CONFIGURATIONS $5d^8 6s^2$ IN Pt I THROUGH
Hg III AND $5d^9 6p$ IN Pt I THROUGH Bi VI*

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ABSTRACT

The levels of the configurations $5d^8 6s^2$ in Pt I through Hg III and $5d^9 6p$ in Pt I through Bi VI were calculated and compared with experiment. It is shown that the experimental levels of $5d^9 6p$ in Pt I and $5d^8 6s^2$ in Au II do not agree with calculation. Some minor corrections are suggested for the other ions. It is also shown that the published g factors of Au II are rather doubtful.

*Work performed under the auspices of U. S. Energy Research and Development Administration.

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INTRODUCTION

Our attention to some irregularities in the level assignment of the configuration $5d^8 6s^2$ in Au II was drawn by a comparison we made between these levels and predicted Au IV levels corresponding to $5d^8$. These two configurations not only have the same structure of levels but should also have about the same splitting between the corresponding levels. The irregularities in the $5d^8 6s^2$ were such that a theoretical analysis of the spectra was needed to check the present analysis presented by Moore¹ and more recently by Ehrhardt and Davis.² In order to obtain a further assessment and a better understanding of the level structure the analysis was carried a step further to include a study of $5d^8 6s^2$ and $5d^9 6p$ in Pt I through Hg III. The configuration $5d^9 6p$ was also studied in Tl IV, Pb V and Bi VI as this was important for the understanding of the even configuration.

The results show evident disagreement between the theoretical calculations and some of the previous classification in all ions. These disagreements were particularly serious in the case of $5d^9 6p$ in Pt I and $5d^8 6s^2$ in Au II. We present here in addition to the results of the analysis some suggestion for reclassification.

THE CONFIGURATION $5d^8 6s^2$

This configuration has nine levels. The compilation of Moore¹ reports seven levels of this configuration in Pt I and all nine levels in Au II and Hg III. Ehrhardt and Davis² published corrected values for six Au II levels, differing only slightly from the values given by Moore.¹ The parameters used in the analysis are the d electron parameters A, B,

C, ζ_d and α . A, B, and C are the electrostatic parameters as defined by Racah,³ ζ_d is the spin-orbit interaction and α is the parameter of the $L(L+1)$ correction. The configuration $5d^8 6s^2$ was calculated by itself, because by analogy to Shadmi's work in Au III⁴ it's interaction with $5d^9 6s$ is negligible. The results of the calculations for Pt I and Hg III are presented in Tables I and II. We list in Table I under Diag. the values of the parameters used to diagonalize the matrices and under L.S. the parameters obtained after a least-square fit of calculated and observed levels. In all the tables Δ designates the r.m.s. error of the level energy fit. As in the case of $5d^8 6s$ calculated in Au III by Shadmi,⁴ α obtains negative values by the least-square fit and was fixed to be zero in the final least-square calculations. The calculation of Pt I shows that the classification compiled by Moore¹ is in agreement with the calculations, except for the level with $J=4$ which is deviating by more than Δ . Yet the small number of experimental levels does not allow the exclusion of this level. The calculated levels of Pt I are presented in Table II. Except for the level with $J=2$ at 15502 cm^{-1} the agreement in the g factor values is satisfactory. The calculation in Hg III gave by the first least-square fit with all published levels $\Delta = 1620 \text{ cm}^{-1}$. However, after the level $8_0 (J=0)$ at 122661 is excluded from the calculation a good agreement between the calculated and observed levels is obtained. We believe that the 8_0 level is not correct despite the fact that Foster⁵ classified three transitions ending on this level. The calculated and observed levels together with the calculated and observed g factors are listed in Table II. To calculate the configuration $5d^8 6s^2$ in Au II we have interpolated the various parameters of Pt I and Hg III. A linear interpolation of B and C should give rather

good estimates, as these parameters depend linearly on the degree of ionization. ζ_d was estimated by a linear interpolation of $(\zeta_d)^{1/4}$. The estimation can be assessed by a Hartree-Fock calculation made by Cowan⁶ of ζ_d for $5d^8$ in Au IV. His value of 5492 cm^{-1} is slightly larger than our extrapolation giving $\zeta_d = 5450 \text{ cm}^{-1}$ for $5d^8 6s^2$. It is impossible to obtain a good initial estimate for the parameter A in Au II by knowing A only in Pt I and Hg III. We estimate A to be $60,000 \pm 3000 \text{ cm}^{-1}$. For the other parameters we had as initial values $B = 610$, $C = 3590$, and $\alpha \equiv 0$ (cm^{-1}). Using these parameters a very bad fit was obtained with the experimental levels of Moore. No shift of A could improve the agreement with the observed levels. The work of Platt and Sawyer¹⁰ shows an analysis based on a rather well established table of differences, however no least-square fit with various changes of labeling or omission of levels could make the published classification agree with theory. To further study the classification of levels in Au II the upper odd configuration $5d^9 6p$ was analyzed. This configuration is important in the determination of the $5d^8 6s^2$ classification.

THE CONFIGURATION $5d^9 6p$

We first studied this configuration in Hg III, as we had indications to believe that the analysis of the energy levels in this ion is well established. The parameters used in the first diagonalization are those of $5d^8 6p$ in Au III as found by Shadmi.⁴ The parameters obtained by the least-square fit after the convergence of the iterations are given in Table III. The r.m.s. of the fit is rather good confirming the analysis of Foster.⁵ We next examined $5d^9 6p$ in the spectra of Tl IV. The analysis

of Tl IV is due to Goble⁷ and Mack and Fromer.⁸ They have classified all twelve levels of this configuration. The Δ obtained in the first least-squares fit (L.S.1) when all the levels were included was not satisfactory. The level with $J=0$ had the greatest deviation of 674 cm^{-1} . In L.S.2 this level was excluded and this reduced markedly the error of the fit. The parameters obtained for Tl IV are also listed in Table III. A similar situation occurs in the spectra of Pb V. The first calculation, L.S.1, which was done with all levels had $\Delta = 448 \text{ cm}^{-1}$. Two levels were deviating markedly — the level with $J=0$ (by 573 cm^{-1}) and the level with $J=4$ (by 625 cm^{-1}). The exclusion of the level with $J=4$ (in L.S.2) reduced Δ to 300 cm^{-1} but still left the other level with a large deviation between experimental and calculated values. Furthermore, the parameters $F_2(\text{pd})$, $G_1(\text{pd})$, and $G_3(\text{pd})$ which were obtained by this least-square fit are too large compared to the linearly extrapolated parameters predicted from Hg III and Tl IV. We have attempted in our fits to obtain not only small r.m.s. values but also reasonable parameters. L.S.3 fit was then made with eleven levels, $J=0$ excluded. This calculation gave a reasonable fit with $\Delta = 239 \text{ cm}^{-1}$ and the level with $J=4$ agreeing well with the calculation. More important is to note that the parameters we obtain now, except for F_0 , agree with the expected linear dependence on the ionization. F_0 should depend quadratically on the degree of ionization, and we shall deal with its extrapolation later. The analysis of Bi VI was started with extrapolated parameters which we found to be very close to their final values obtained later. Unexpectedly the level with $J=0$ agreed well with the calculations. The level with $J=1$ at 274158 cm^{-1} was found to be deviating strongly from the calculations. When this level

was excluded we got a rather good agreement between experiment and theory. Only the level with $J=4$ is still deviating markedly. The calculation of $5d^9 6p$ in Au II was undertaken with extrapolated parameters based on those found for Hg III through Bi VI. We expected to obtain not only a good fit with the experimental levels, but we also tried to obtain parameters not deviating markedly from their predicted values. The parameter F_0 as used in our calculations includes, in addition to Slater's parameters, the separation between the configurations $5d^{10}$ and $5d^9 6p$. This separation depends quadratically on ξ , where ξ is the core charge. ($\xi - 1$ is the degree of ionization.) We fitted F_0 to an expression of the form $F_0 = A\xi^2 + B\xi + C + \frac{D}{\xi}$. The last member of this expression, D/ξ , represents the contribution of configuration interaction. Actually, the expression of F_0 should include more terms of ξ^{-n} , where $n \geq 2$, but we had no experimental data to base such calculations. If the energy centers, E , of these configurations can be represented by a formula of the form

$$E = R \left(\frac{\xi - \sigma}{n^2} \right)^2$$

where σ is a screening factor, and R is Rydberg constant, then the theoretical coefficient A in the expression of F_0 should be 1341 cm^{-1} . We find for it the value of 1370 cm^{-1} . This is a good indication of the accuracy of F_0 in Hg III through Bi VI. The complete expression of F_0 is,

$$F_0 = 1370 \xi^2 + 41741 \xi - 25519 + 24240/\xi.$$

However, this expression for F_0 is less accurate for $\xi=1,2$ because of the lack of terms with higher powers of $1/\xi$, and the screening approxi-

mation for E is less valid. Thus we find that the extrapolated F_0 for Au II is lower by 1.3% than its fitted value.

The analysis of the levels of $5d^9 6p$ in Au II turned out to be very different from that of $5d^8 6s^2$ in the sense that most of the experimental levels agreed with the calculations. We obtain in L.S.1, $\Delta = 369 \text{ cm}^{-1}$ and significant deviation of the level with $J=4$ at 72495 cm^{-1} . In L.S.2 this level was excluded and a satisfactory fit is obtained. Except for F_0 the other parameters are predicted very well along the isoelectronic sequence of Pt I. In Table II we compare not only experimental and observed energy levels, but also g factors of Au II. In the next section we discuss this comparison together with the observed and calculated g factors in $5d^8 6s^2$. To conclude this section about the analysis of $5d^9 6p$ we shall comment on the classification of $5d^9 6p$ in Pt I. It is to be expected that in Pt I the configurations $5d^9 6p$ and $5d^8 6s 6p$ will strongly interact and perturb each other. Yet we have tried to compare the levels of $5d^9 6p$ as classified by Shenstone (Moore¹) with calculated levels based on extrapolated parameters, without taking into account of the interaction. The following parameters were used: $F_0 = 44000$ (relative to the ground state $6s, {}^3D_3$), $F_2 = 240 \text{ cm}^{-1}$, $G_1 = 421 \text{ cm}^{-1}$, $G_3 = 30 \text{ cm}^{-1}$, $\zeta_{5d} = 4000 \text{ cm}^{-1}$, and $\zeta_{6p} = 2080 \text{ cm}^{-1}$. The extrapolation of F_0 is rather uncertain and we estimate it to be at least $\pm 2000 \text{ cm}^{-1}$. ζ_{6p} was obtained by calculating the screening parameter S in the expression $\zeta_p = A(Z - S)^4$. S calculated for Au II through Bi VI fitted very well to the formula $S = a + b/(\xi + 2)$ with $a = 35.838$ and $b = 60.737$. This formula is according to Edlén⁹ (p. 184). The r.m.s. of this fit for ζ_{6p} is 180 cm^{-1} . ζ_{5d} was determined by a linear extrapolation of $S(\zeta_{5d})$. The extrapolated value, 4000 cm^{-1} , agrees very well with ζ_{5d} of $5d^9 6s$.

No agreement was obtained between the calculated energy levels and those classified previously, though F_0 was changed over a wide range. With all the parameters free to change, they converge to unaccepted values. It is to be expected that a simultaneous analysis of $5d^8 6s 6p$ and $5d^9 6p$ may clarify the situation.

DISCUSSION

We shall first discuss the classification of the levels belonging to $5d^8 6s^2$ in Au II. Most of the transitions that determine these levels belong mainly to the transition-array $5d^9 6p - 5d^8 6s^2$. Platt and Sawyer¹⁰ list 35 transitions in this array at wavelength region $2210\text{\AA} - 7457\text{\AA}$. Ehrhardt and Davis² found only ten of these. As we have shown above, eleven levels of $5d^9 6p$ in Au II are correctly classified, and this should suffice to determine the levels of $5d^8 6s^2$ if the transition-array $5d^9 6p - 5d^8 6s^2$ was indeed observed accurately. An examination of a frequency table generated by Platt and Sawyer data shows in some cases inconsistencies as large as a few wave numbers. The more accurate measurement of Ehrhardt and Davis corrects some of these discrepancies yet less lines are observed. In the analysis of $5d^8 6s^2$ the least accurately interpolated parameter is F_0 . Hence if we consider only the intervals between the levels, then four levels of $5d^8 6s^2$ listed by Ehrhardt and Davis have intervals in rough agreement with the theoretical prediction, with F_0 about 60000 cm^{-1} . However, the other four levels of Platt and Sawyer ($9_0, 14_0, 11_1, 13_2$) have also a good fit to the predicted splitting but with $F_0 \approx 57100\text{ cm}^{-1}$. As the data stands now we could not explain the discrepancy. A further comparison between theory and experiment is made

by comparing the theoretical and experimental g factor. It is important to note that the calculated g factors are independent of F_0 and hence we would expect that our calculated g factors for the levels of $5d^8 6s^2$ to be significant, as the relevant parameters are rather well established by interpolation. Green and Maxwell¹¹ who measured g factors in Au II reported that only a few Zeeman patterns were resolved. From unresolved Zeeman patterns we cannot usually find the g 's of both upper and lower levels, but if one of the g 's is known the other can be calculated. We find that in some cases a wrong choice or a wrong estimate was made of the g factor supposed to be known. Thus for example, because the levels $5d^9 7s^3 D_3$ (15_3) and $5d^9 6p^3 F_4$ (3_4) are the only levels with such J 's in their configurations, their g factor is given by the Landé formula. Yet Green and Maxwell determine an inaccurate g factor of 15_3 from a doubtful pattern and continue to use this to determine other g factors, and so on. Hence, we suggest that the g factors reported by Green and Maxwell,¹¹ which are also reported by Moore,¹ are of low accuracy. In order to have any comparison between the experimental and calculated g factors, we chose to recalculate expected unresolved Zeeman patterns for the transition arrays $5d^9 6p - 5d^8 6s^2$, $5d^9 6p - 5d^9 6s$ and $5d^9 6p - 5d^9 7s$. The coupling scheme of $5d^9 6s$ and $5d^9 7s$ is very close to Jj coupling, enabling a good estimate of the g factor. The theoretical formula of Shenstone and Blair¹² were used in this calculation. Calculated and observed Zeeman patterns are presented in Table V. In four transitions the differences between the calculated and observed Zeeman patterns are significant. One of them, $26_2 - 12_2^0$, is described by Green and Maxwell as inconsistent. Another one, $13_2 - 11_1^0$, is very doubtful as it is a

superposition with strong Au I line. In the transition $10_2 - 7_2^0$, while the σ components differ markedly, the π components are in agreement. We conclude that higher resolution of the Zeeman pattern is needed to confirm both J and g factors of levels.

CONCLUSION

The spectrum of Au II is far from being studied satisfactorily. The existing lists of wavelength of Platt and Sawyer¹⁰ (and see also earlier references given there), Green and Maxwell,¹¹ the M.I.T. Au II lines,¹³ and Ehrhardt and Davis² differ seriously from one to another. There is a need of an experimental work which will explain all of these differences. In addition to this we have shown that the levels of the configuration $5d^8 6s^2$ in Au II as listed by Moore¹ are in serious disagreement with theory. It is to be expected that the majority of transitions to $5d^8 6s^2$ will come from $5d^8 6s 6p$, yet only one level of $5d^8 6s 6p$ has been identified. As for the situation of $5d^9 6p$, we find that it is theoretically well established in Au II through Bi VI except for the few levels mentioned above. On the other hand, we tend to reject the assignment of $5d^9 6p$ levels in Pt I as presented by Moore.¹

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FOOTNOTES AND REFERENCES

*Work performed under the auspices of the U. S. Energy Research and Development Administration.

†On sabbatical leave from Tel-Aviv University, Tel-Aviv, Israel.

1. C. E. Moore, Atomic Energy Levels, National Bureau of Standards (U.S.) Cir. #467, Vol. III (1958).
2. J. Ehrhardt and S. P. Davis, J. Opt. Soc. Am. 61, 1342 (1971).
3. A. Racah, Phys. Rev. 62, 438 (1942).
4. Y. Shadmi, J. Res. Natl. Bur. Std. (U.S.), 69A (Phys. & Chem.), 511 (1965).
5. E. W. Foster, Proc. Roy. Soc. (London) A200, 429 (1950).
6. R. D. Cowan, private communication (1975).
7. A. T. Goble, Phys. Rev. 48, 346 (1935).
8. J. E. Mack and M. Fromer, Phys. Rev. 48, 357 (1935).
9. B. Édlen, Atomic Spectra in: Encyclopedia of Physics, Vol. XXVII, (Springer, Berlin, 1964).
10. J. R. Platt and R. A. Sawyer, Phys. Rev. 60, 866 (1941).
11. J. B. Green and H. N. Maxwell, J. Opt. Soc. Am. 45, 98 (1955).
12. A. G. Shenstone and H. A. Blair, Phil. Mag. 8, 765 (1929).
13. G. R. Harrison, Massachusetts Institute of Technology Wavelength Tables, 1969 Edition.

TABLE I. Parameters of the configuration $5d^8 6s^2$ in Pt I, Hg III (in cm^{-1}).

	----- Pt I -----		----- Hg III -----		
	Diag.	L.S.	Diag.	L.S.1 ^b	L.S.2 ^c
A	6500	$6454^a \pm 700$	115000	115283 ± 749	114635 ± 72
B	500	521 ± 71	700	829 ± 106	697 ± 12
C	3200	3324 ± 377	3750	3626 ± 453	3681 ± 48
ζ_d	4500	4539 ± 123	6300	6104 ± 400	6407 ± 42
α	40	0 - FIX	--	0 - FIX	0 - FIX
Δ		456		1620	161

^aRelative to the level $5d^{10} \ ^1S_0$.^bAll levels listed by Moore are used.^cThe level 8_0 is excluded.

TABLE II. Observed and calculated levels of the configuration $5d^8 6s^2$ in Pt I and Hg III.

----- Pt I -----						----- Hg III -----			
J	Observed level (cm ⁻¹)	Calculated level (cm ⁻¹)	C - O	g Obs.	g Calc.	Observed level (cm ⁻¹)	Calculated level (cm ⁻¹)	C - O	g Calc.
4	824	413	-411	1.25	1.239	97894	97941	47	1.237
2	6567	6803	236	1.12	1.12	106028	105863	-165	1.123
3	10117	10491	-374	--	1.084	112226	112263	37	1.084
2	15502	15568	66	0.92	1.079	118927	118961	36	1.091
0	--	16166	--	--	--	(122661) ^a	118450	--	--
1	18567	18476	-91	--	1.501	122735	122717	-18	1.501
4	21967	21987	20	1 + ?	1.012	126468	126654	186	1.013
2	26639	26443	-196	0.97	0.968	133732	133626	-106	0.953
0	--	47736	--	--	--	158909	158891	-18	--

^aThis level was excluded from the parameters least-squares fit.

TABLE III. Energy parameters of the configuration $5d^9 6p$ in Au II through Bi VI.

	----- Au II -----		Hg III	Tl IV	----- Pb V -----		Bi VI
	L.S.1	L.S.2 ^a	L.S.1	L.S.2 ^b	L.S.2 ^c	L.S.3 ^b	L.S.2 ^d
F_0	74679 ± 140	74571 ± 108	120114 ± 86	169425 ± 88	221919 ± 131	222284 ± 99	278287 ± 72
$F_2(dp)$	348 ± 33	361 ± 24	486 ± 21	601 ± 29	842 ± 31	209 ± 34	828 ± 18
$G_1(dp)$	489 ± 32	491 ± 23	564 ± 17	607 ± 17	714 ± 22	647 ± 21	700 ± 15
$G_3(dp)$	32 ± 8	35 ± 6	34 ± 5	37 ± 5	50 ± 7	41 ± 5	47 ± 4
ζ_d	4920 ± 104	5011 ± 81	6114 ± 83	7407 ± 68	8902 ± 111	8765 ± 68	10174 ± 51
ζ_p	5759 ± 184	5622 ± 140	9501 ± 151	13350 ± 141	17040 ± 200	17622 ± 145	22351 ± 96
Δ	369	264	233	219	300	239	185

^aThe level of $J = 4$ excluded from the least-square calculations.

^bThe level $J = 0$ excluded.

^cThe level at 27415 cm^{-1} is excluded.

^dThe level with $J = 1$ is excluded.

TABLE IV. Observed and calculated levels of the configuration $5d^9 6p$ in Au II through Bi VI.

J	Au II					Hg III			Tl IV			Pb V			Bi VI		
	Obsv. (cm^{-1})	Calc. (cm^{-1})	C-O	$\bar{g}$ Obsv.	$\bar{g}$ Calc.	Obsv. (cm^{-1})	Calc. (cm^{-1})	C-O	Obsv. (cm^{-1})	Calc. (cm^{-1})	C-O	Obsv. (cm^{-1})	Calc. (cm^{-1})	C-O	Obsv. (cm^{-1})	Calc. (cm^{-1})	C-O
2	63053	63351	298	1.45	1.384	103549	103837	288	147635	147935	300	194803	195111	308	244721	244911	190
3	65003	64861	-142	1.04	1.102	105628	105389	-239	149841	149638	-203	197131	196952	-179	247165	246991	-174
4	(72495) ^a	71650	--	1.15	1.251	117995	117777	-218	167672	167491	-181	221069	220911	-158	277866	277632	-234
2	73178	72903	-275	1.12	1.089	118548	118410	-138	166425	166340	-85	217069	217133	64	270603	270579	-24
1	73403	73524	121	1.04	1.254	118607	118767	160	167499	167427	-72	219488	219200	-288	(274158) ^a	273537	--
3	74791	74806	15	1.30	1.253	121602	121752	150	172272	172292	20	226511	226494	-17	284058	284133	75
2	76659	76611	-48	1.38	0.776	120928	120932	4	170334	170472	138	223909	224048	139	280930	281075	145
1	81659	81539	-120	--	0.824	126556	126506	-50	175290	175274	-16	227835	227830	-5	284036	284049	13
0	82613	82375	-238	--	--	130702	130631	-71	(181083) ^a	183002	--	(237660) ^a	239276	--	298862	298925	63
3	85699	85781	82	--	1.062	134588	134680	92	187667	187809	142	244661	244811	150	305272	305363	91
1	85707	85966	-259	1.11	0.922	134999	135176	177	188233	188318	85	245277	245325	48	305903	305824	-79
2	86565	86611	46	1.29	1.085	136479	136322	-157	190144	190016	-128	247595	247533	-62	308613	308548	-65

^aThis level excluded from the least-square fit.

TABLE V. Comparison between observed and calculated Zeeman pattern in Au II. (Calculated center of gravity of π and σ components with respect to the place of the unsplit line.)

Transition	Observed Zeeman Pattern		Calculated Zeeman Pattern	
	π	σ	π	σ
$15_3 - 3_4^0$	0	1.07	0	1.13
$16_2 - 4_2^0$	0	1.03	0	1.10
$26_2 - 10_3^0$	0	1.01	0	1.07
$5_2 - 2_3^0$	0	1.08	0	1.13
$16_2 - 5_1^0$	0	0.93	0	1.02
$26_2 - 12_2^0$	0	0.94	0	1.08
$8_3 - 12_2^0$	0	1.01	0	1.08
$6_4 - 6_3^0$	0	1.17	0	1.22
$5_2 - 1_2^0$	0.69	1.26	0.56	1.23
$15_3 - 6_3^0$	0	1.25	0.21	1.29
$10_2 - 11_1^0$	0	1.14	0	1.15
$7_2 - 5_1^0$	0	1.01	0	1.06
$7_2 - 4_2^0$	0	1.07	0	1.11
$8_3 - 6_3^0$	0.47	1.23	0.43	1.17
$8_3 - 4_2^0$	0	1.08	0	1.08
$10_2 - 7_2^0$	0.63	1.36	0.54	0.93
$13_2 - 11_1^0$	0	1.32	0	0.98
$7_2 - 2_3^0$	0	1.07	0	1.10

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