element of Ω is the negative of the sum of the first-class parts of S_{f0} and $\bar{S}_{0f}$, and so is equal to

$$\text{M.E.}=[7(\tfrac{3}{2})^{\frac{1}{2}}MCR(B^2R^3)^2/90\pi\hbar^2\beta^7]\times\int_0^\beta j_1{}^3(x)\{\ \}dx, \quad (24)$$

where { } denotes the curly bracket in Eq. (23).

V. NUMERICAL RESULT AND DISCUSSION

The x integral in Eq. (24) can be evaluated analytically, but is much easier to do numerically; it is equal to -1.98. From Eq. (18), the normalization constant B is given by $B^2R^3=6\beta/\sin2\beta$. Substitution of $\beta=4.493$ gives finally

$$\text{M.E.}=-1.58\times10^{22}CR\ \text{cm}^2,$$

where R is measured in cm and C in Mev-cm^3. If now we set $|\text{M.E.}|=3.8\times10^{-26}$ cm^2, as in Sec. I, and $R=3.0\times10^{-13}$ cm, we obtain $C=8.0\times10^{-36}$ Mev-cm^3. This is about six times as large as the volume integral of the triplet neutron-proton interaction, when it is assumed to be of Gaussian form.[18] Conversely, even if C were chosen to correspond to the free-space neutron-proton interaction, in which case the first-order perturbation theory used here would not be reliable, M.E. would have only about one-sixth the experimental value.

This result, together with those of Sec. II, suggests that a model that is more collective than the independent-particle model with pair interactions and less collective than the alpha-particle or elastic-fluid models, is required to account for the experimental observations. The suggestion of Christy and Fowler,[19] that low-lying excited states in the p shell nuclei arise from excitation of four nucleons, may be promising in this connection.

The writer is indebted to Dr. D. R. Yennie and Dr. M. G. Redlich for stimulating conversations, and to Professor R. Hofstadter for discussion of the experimental situation.

[18] J. M. Blatt and J. D. Jackson, Phys. Rev. **76**, 18 (1949); other forms for the interaction have roughly similar volume integrals.

[19] R. F. Christy and W. A. Fowler, Phys. Rev. **96**, 851(A) (1954), and private communication from W. A. Fowler. With the Hamiltonian (5) and this model for the excited state, it would be necessary to go at least to second order in H' in order for the matrix element not to vanish; it would probably then be desirable for the calculation to stress the collective rather than the perturbation aspects of the situation.

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Nuclear Moments of Nb^{93}, La^{139}, Os^{187}, and Hg^{201}

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The effective charge Z^* for a d-electron was studied by means of a hyperfine structure (hfs) investigation; the screening correction $(Z-Z^*)$ was found to range from 15 to about 19 for the charge number Z ranging from 27 to 78. Investigation of the hfs of the spectra of Nb I and La I yielded the result that $Q(\text{Nb}^{93})=(-0.2\pm0.1)\times10^{-24}$ cm^2 and $Q(\text{La}^{139})=(+0.6\pm0.2)\times10^{-24}$ cm^2, respectively, in which the polarization correction (due to Sternheimer) is taken into account. In the hfs of the spectrum of Os I the components due to the rarer odd isotope Os^{187} were detected and it was found that Os^{187} has a spin 1/2 and a magnetic moment most probably equal to $+0.12$ nm (possible range being from $+0.16$ nm to $+0.09$ nm). The quadrupole moment of Hg^{201} was calculated from the hfs of $6s6p\ {}^1P_1$ and $6s6p\ {}^3P_2$ of the spectrum of Hg I, taking the configuration interaction into account, and $Q(\text{Hg}^{201})=(+0.45\pm0.04)\times10^{-24}$ cm^2 was obtained.

I. SCREENING CORRECTION FOR A d-ELECTRON

IN the hyperfine structure (hfs) formulas for both the interval factor (A) and the quadrupole coupling constant (B) of a configuration containing d-electrons, the effective charge $Z_d{}^*$ for a d-electron frequently enters. It is usual to put $Z_d{}^*=Z-\sigma_d$, where σ_d is the screening correction for a d-electron. Casimir[1] assumed that $\sigma_d=10$, and this value has been adopted by many investigators. However, as far as the author is aware, this has no sound experimental basis. In order to fill this gap, an experimental investigation of the hfs of several atomic spectra was undertaken. A liquid-air-cooled hollow-cathode discharge tube described previously[2] was used, and a Fabry-Pérot etalon was used to resolve the hfs.

We begin with the analysis of the configuration $4d^3$ of Nb I.[3] Nb is known to consist of only one isotope Nb^{93} with spin 9/2.[4] The hfs was previously measured by Meeks and Fisher,[5] using a water-cooled hollow

[1] H. Casimir, Verhandel. Teylers Tweede Genootschap, Haarlem (1936), p. 11.

[2] K. Murakawa, J. Phys. Soc. (Japan) **9**, 391 (1954).

[3] The notation of the level symbol of the spectrum of Nb I was taken from W. F. Meggers and B. F. Scribner, J. Research Natl. Bur. Standards **14**, 629 (1935).

[4] J. E. Mack, Revs. Modern Phys. **22**, 64 (1950). P. F. A. Klinkenberg, Revs. Modern Phys. **24**, 63 (1952). K. Murakawa and T. Kamei, Rept. Inst. Sci. Technol. Univ. Tokyo **7**, 219 (1953).

[5] W. W. Meeks and R. A. Fisher, Phys. Rev. **72**, 451 (1947).

TABLE I. Hfs of Nb I.

$4d^35s^2$	A (cm^{-1}) K.M.[a]	A (cm^{-1}) M and F[b]	$4d^45s$	A (cm^{-1}) K.M.[a]	A (cm^{-1}) M and F[b]
$^4F_{9/2}$	0.0109	0.005	$^6D_{9/2}$	0.0250	0.021
$^4F_{7/2}$	0.0101	0.004	$^6D_{7/2}$	0.0249	0.022
$^4F_{5/2}$	0.0129	0.013	$^6D_{5/2}$	0.0255	0.024
$^4F_{3/2}$	0.02190	0.021	$^6D_{3/2}$	0.02863	0.028
			$^6D_{1/2}$	0.06264	0.060

[a] Our value.
[b] Value given in reference 5.

cathode. In the present work using an improved technique, more accurate results were obtained, as shown in Table I. The $4d^3$ configuration of Nb I is of fairly good LS coupling, so the values of $A(^4F)$ can be described by the formulas[6]:

$$\begin{aligned} A(d^3\,^4F_{9/2}) &= (8a_d'+a_d''+8a_d''')/9, \\ A(d^3\,^4F_{7/2}) &= (281a_d'+34a_d''+128a_d''')/315, \\ A(d^3\,^4F_{5/2}) &= (712a_d'+163a_d''-424a_d''')/875, \\ A(d^3\,^4F_{3/2}) &= (59a_d'+66a_d''-368a_d''')/125, \\ a_d' &= a(d_{5/2}), \quad a'' = a(d_{3/2}), \quad a''' = a(d_{5/2,\,3/2}). \end{aligned} \tag{1}$$

Of the levels arising from the configuration $4d^45s$ of Nb I, only ^6D and ^4D are available to the author and it is impossible to calculate accurate percentage of mixing[7] of $4d^35s^2\,^4F$ and $4d^4(_4^3F)5s\,^4F$. However, a calculation based on the interpolation between neighboring elements shows that within the accuracy of about six percent the mixing of $4d^4(_4^3F)5s\,^4F$ will not influence $A(4d^3\,^4F)$. The values of $A(4d^3\,^4F)$ listed in Table I can be fitted fairly well into the aforementioned formulas by choosing $a(d_{5/2})=0.0234$ cm^{-1}. Putting this and $\zeta_d=450$ and $\mu/I=1.3701$ in the well-known formula (the notations are the same as reference 1)

$$a(d_{\frac{5}{2}}) = \frac{8}{5}\frac{\zeta_d}{Z_d^*}\frac{F_2''}{H_2}\frac{1}{1836}\frac{\mu}{I}, \tag{2}$$

TABLE II. Screening correction for d-electrons.

Spectrum	Z	$a(d_{3/2})$	Z_d^*	σ_d	Data
Co^{59} I	27	0.0382	11.8	15.2	[a]
Nb^{93} I	41	0.0234 0.0222	23.5	17.5	
La^{139} I	57	0.00696	39.7	17.3	[b]
Lu^{175} I	71	0.01120	51.0	20.0	[c]
Pt^{195} I	78	0.0744	60.3	17.7	[d]

[a] See reference 8.
[b] See references 9 and 10, and some unpublished data of the present author.
[c] See reference 11. Gollnow found $a^{175}(6s)=0.320$ cm^{-1} in the spectrum of Lu II. Putting this and F (relativity correction) $=1.465$, $1-\delta$ (nuclear finite volume correction) $=0.917$, $(dn^*/dn)/n^{*3}=0.125$, $I=7/2$ in the modified Goudsmit-Fermi-Segrè formula, we get $\mu=2.77\pm0.3$ nm instead of Gollnow's $\mu=2.6\pm0.5$ nm. The new value of μ was used in deriving the value of Z_d^*.
[d] See reference 12.

[6] When the relativity correction is neglected, these formulas go over to those that are calculated by the formulas given by S. Goudsmit [Phys. Rev. **37**, 663 (1931)] and by R. E. Trees [Phys. Rev. **92**, 308 (1953)].
[7] The lower index attached to ^3F is the seniority number defined by G. Racah, Phys. Rev. **63**, 367 (1943).

we get $Z_d^*=23.0$. Since $Z(\mathrm{Nb})=41$, we obtain $\sigma_d=18.0$.

Similarly from the configuration $4d^35s\,^6D$ (Table I), we get $a(d_{3/2})=0.0222$ cm^{-1}, $a(5s)=0.217$ cm^{-1} [Meeks and Fisher[5] obtained $a(5s)=0.155$ cm^{-1}]. Putting this $a(d_{3/2})$ and $\zeta_d=450$ cm^{-1} in the formula (2), we get $Z_d^*=24.1$ and therefore $\sigma_d=16.9$. The mean of the two values of σ_d obtained from the $4d^3$ and $4d^45s$ configurations is $\sigma_d=17.5$.

In an analogous way we can derive the values of σ_d for other arc spectra, using spectroscopic data given in the literature[8–12] and the values of μ^4. They are listed in Table II. In the practical use for the present work, Table II was represented by a graph plotting σ_d *versus* Z.

II. QUADRUPOLE MOMENT OF Nb^{93}

The hfs of Nb I that are suited for deriving the value of Q are shown in Figs. 1 and 2. From these measurements we get the constants: $A=0.02190$, $B=0.0021\times10^{-3}$ cm^{-1} for $4d^35s^2\,^4F_{3/2}$, and $A=0.02864$, $B=-0.0036\times10^{-3}$ cm^{-1} for $4d^45s\,^6D_{3/2}$. Two lines lie close to λ4195, and the measurement is therefore difficult, so the accuracy of $B(4d^45s\,^6D_{3/2})$ is inferior to $B(4d^35s^2\,^4F_{3/2})$. For the former level we can use the formula derived by Schmidt[13]:

$$(d^3\,^4F_{3/2}{}^{3/2}|\omega|d^3\,^4F_{3/2}{}^{3/2}) = (13R_2'+14R_2''-12S_2)8/875, \tag{3}$$

in which we have put $\omega=3\cos^2\theta-1$ for brevity. Putting $R_2'\doteqdot S_2=1.00_5$, $R_2''=1.03$ in (3) and then putting the value of B and $Z_d^*=23.5$, $\zeta_d=450$ in modified Casimir's formula

$$Q=-BZ^*HI(2I-1)J(2J-1)(1+\Delta)1.988\times10^{-21}/[\zeta\langle\textstyle\sum\omega\rangle_{\mathrm{Av}}], \tag{4}$$

we get $Q=-0.20\times10^{-24}$ cm^2 from the level $4d^35s^2\,^4F_{3/2}$. In the formula (4), Δ is the polarization correction due to Sternheimer,[14] and we have assumed $\Delta_d=0.196$ for Nb.

Similarly for the level $4d^45s\,^6D_{3/2}$ the formula

$$(d^4s\,^6D_{3/2}{}^{3/2}|\omega|d^4s\,^6D_{3/2}{}^{3/2}) = -(2/175)\times[(3128/175)R_2'+(29/25)R_2''+(1044/175)S_2] \tag{5}$$

was derived and $Q=-0.15\times10^{-24}$ cm^2 was obtained.

The value of Q derived from $4d^3\,^4F_{3/2}$ is more trustworthy, and taking the possible effect of the configuration interaction as well as the experimental error into account, we might consider

$$Q(\mathrm{Nb}^{93}) = (-0.20\pm0.10)\times10^{-24}\ \mathrm{cm}^2$$

as the final value. Cotts and Knight[15] have observed

[8] E. Rasmussen, Z. Physik **102**, 229 (1936).
[9] O. E. Anderson, Phys. Rev. **46**, 473 (1934).
[10] M. F. Crawford, Phys. Rev. **47**, 768 (1935).
[11] H. Gollnow, Z. Physik **103**, 443 (1936).
[12] T. Schmidt, Z. Physik **101**, 486 (1936).
[13] T. Schmidt, Z. Physik **121**, 63 (1943).
[14] R. Sternheimer, Phys. Rev. **84**, 244 (1951); **86**, 316 (1952).
[15] R. M. Cotts and W. D. Knight, Phys. Rev. **93**, 940 (1954).

nuclear resonance of Nb^{93} in $KNbO_3$ and found definite evidence of the existence of a quadrupole moment[16] in Nb^{93}.

III. QUADRUPOLE MOMENT OF La^{139}

In a previous work[17] the hfs of the line La I λ5106 $[5d^26s\ ^4F_{3/2}-5d^2(^3F)6p\ ^4D_{1/2}]$ was studied. In the present work this line and other lines involving the same final level were studied, and $A=-0.01615$ cm^{-1}, $B=0.0062\times10^{-3}$ cm^{-1} were obtained for the level $5d^26s\ ^4F_{3/2}$. This value of B is somewhat smaller than that of the previous work. Putting $Z_d^*=39.7$ (instead of $57-10=47$ of the previous work) and $(d^2s\ ^4F_{3/2}'|\omega|d^2s\ ^4F_{3/2}')=-0.1352$ (calculated in reference 2) and $\Delta_d=0.164$, $\zeta_d=420$ (instead of Crawford's[10] 400), $H_2=1.01$ in the formula (4), we get

$$Q(La^{139})=(0.6\pm0.2)\times10^{-24}\ \text{cm}^2.$$

This is more accurate than the previous value.[17]

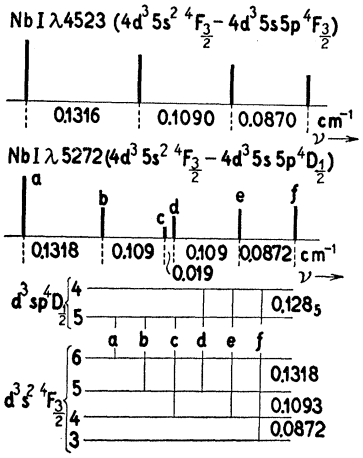

FIG. 1. Hfs of Nb I, λ4523 and λ5272.

IV. NUCLEAR SPIN OF Os^{187}

Osmium is known[18] to consist of seven isotopes: 184 (0.018), 186 (1.59), 187 (1.64), 188 (13.3), 189 (16.1), 190 (26.4), and 192 (41.0). The abundance in percent is in parentheses. The isotope 184 is too weak to be detected in hfs patterns, but 187 could be detected in the line Os I λ4447 as shown in Fig. 3.[19] Since another strong line lies close, the measurement of the positions of 187 and 186 in λ4447 was difficult and has no great accuracy. The component 187 was found to be relatively sharp, so $\mu(Os^{187})$ must be small. The hfs of λ4260 which had been studied in detail previously[20] was again studied, and indeed a component α due to Os^{187} was detected (see Fig. 3). Assuming the intensity of the 186-component to be 15.9, the intensity of α was measured to be 8.9 ± 0.9. This can be interpreted only by the assumption that Os^{187} has a spin 1/2 and that $\mu(Os^{187})$ is positive. The hfs of Os I λ4420 and λ4135 were then examined, and it was found that they support the above-mentioned assumption for Os^{187}.

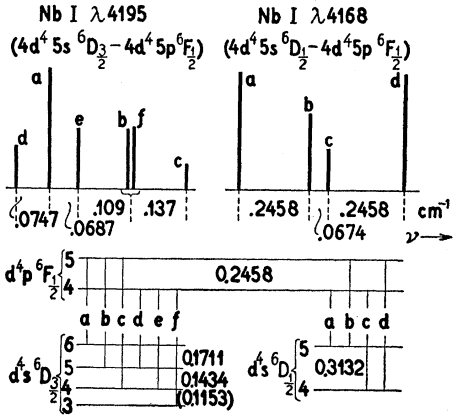

FIG. 2. Hfs of Nb I, λ4195 and λ4168.

The value of $\mu(Os^{187})$ can be determined relative to $\mu(Os^{189})=+0.65065$ nm that has been determined by Loeliger and Sarles[21] by the nuclear induction method.

Let A, B and A', B' denote the interval factor and quadrupole coupling constant of the initial and the final level of λ4260, respectively, for the isotope Os^{189} with spin 3/2.[20] Since the $5d^66s^2$ configuration of Os I is of jj coupling, we can put $A(5d^66s^2\ ^5D_4')=a(d_{5/2})=0.008$ cm^{-1}, in which we have assumed that $Z_d^*=76-19=57$. The wave function for the initial level was first expressed as a linear combination of jj-coupling wave functions and then transformed into a linear combination of LS-coupling wave functions, and electrostatic interaction with other configurations was

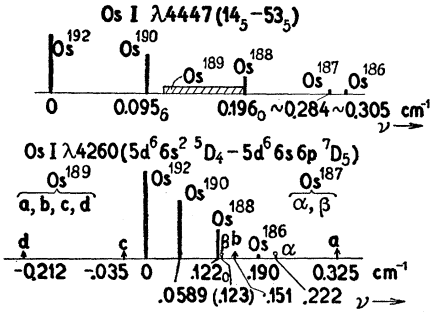

FIG. 3. Hfs of Os I, λ4447 and λ4260.

[16] Just before submitting the present paper, we received the short note of D. R. Speck and F. A. Jenkins, Bull. Am. Phys. Soc. **29**, No. 8, 34 (1954). They measured the hfs of the level $4d^35s^2\ ^4F_{3/2}$ of Nb I and obtained $Q(Nb^{93})=(-0.4\pm0.3)\times10^{-24}$ cm^2.

[17] K. Murakawa and T. Kamei, Phys. Rev. **92**, 325 (1953). See also reference 2.

[18] O. Nier, Phys. Rev. **52**, 885 (1937).

[19] The classification of the Os I spectrum was given by W. Albertson, Phys. Rev. **45**, 304 (1934).

[20] K. Murakawa and S. Suwa, Phys. Rev. **87**, 1048 (1952).

[21] H. R. Loeliger and L. R. Sarles, Phys. Rev. **95**, 291 (1954).

roughly taken into account. In this way the approximate relation $B'\approx 3.0B$ was obtained. Keeping this in mind, A, B, and B' were determined so as to fit the observation, and $A=0.0383$ cm^{-1}, $B=0.10\times10^{-13}$ cm^{-1}, $B'=0.34\times10^{-3}$ cm^{-1} were obtained.[22]

Assuming that the center of gravity of Os^{187} is such that the ratio $(Os^{186}-Os^{187})/(Os^{187}-Os^{188})$ is the same for λ4447 and λ4260, we can estimate the total splitting of Os^{187} in λ4260 to be 0.099 cm^{-1}. This gives, when compared with the interval factors of the initial and final levels of Os^{189} and $\mu(Os^{189})$, the magnetic moment of Os^{187} as $+0.12\{^{+0.04}_{-0.03}\}$ nm.

V. QUADRUPOLE MOMENT OF Hg^{201}

As a continuation of the study of the hfs of the spectrum of mercury by means of a high-frequency electrodeless discharge tube[23] which is better than a hollow cathode, the hfs of the lines Hg I λ5790 ($6p\,^1P_1-6d\,^1D_2$) and λ4916 ($6p\,^1P_1-8s\,^1S_0$) was studied, and data concerning $6p\,^1P_1$ that are more accurate than before[24] were obtained: the splitting of Hg^{201} ($I=3/2$) in $6p\,^1P_1$ was found to be $F_{5/2}-F_{3/2}=0.124_2$ cm^{-1}, $F_{3/2}-F_{1/2}=0.042_8$ cm^{-1} and that of Hg^{199} ($I=1/2$) $F_{3/2}-F_{1/2}=-0.179_9$ cm^{-1}, from which we get $A=0.0443$ cm^{-1}, $B=1.32_2\times10^{-3}$ cm^{-1} for $6p\,^1P_1(Hg^{201})$. The wave function of $6s6p\,^1P_1$ can be obtained by the procedure published by Hume and Crawford[25] in treating the analogous spectrum of Pb III. In the case of Hg I, the mixing of the configuration $5d^96s^26p$ is essential. Expressing the wave function in the present case as a linear combination of LS-coupling wave functions, we have

$$6s6p\,^1P_1'=K_1\,^3P_1(6s6p)+K_2\,^1P_1(6s6p)+K_3\,^1P_1(6s7p)+K_4\,^1P_1(5d^9\,6s^26p), \quad (6)$$

$$K_1=-0.158,\quad K_2=0.883,\quad K_3=0.286,\quad K_4=0.336,$$

where the prime denotes that the wave function is actually of intermediate coupling and also perturbed. The quadrupole moment of Hg^{201} can be calculated by the equation:

$$Q=-BI(2I-1)J(2J-1)1.988\times10^{-21}\Big/\Big[\frac{\zeta_{6p}}{Z_p^*H_1(1+\Delta_p)}\Big\{K_1^2(sp\,^1P_1|\omega|sp\,^1P_1)+K_2^2(sp\,^3P_1|\omega|sp\,^3P_1)+2K_1K_2(sp\,^1P_1|\omega|sp\,^3P_1)\Big\}+\frac{\zeta_{7p}}{Z_p^*H_1(1+\Delta_p)}K_3^2(sp\,^1P_1|\omega|sp\,^1P_1)+K_4^2\Big\{\frac{\zeta_{6p}}{Z_p^*H_1(1+\Delta_p)}(dp\,^1P_1|\omega|dp\,^1P_1)_p-\frac{\zeta_{5d}}{Z_d^*H_2(1+\Delta_d)}(dp\,^1P_1|\omega|dp\,^1P_1)_d\Big\}\Big], \quad (7)$$

where $(dp\,^1P_1|\omega|dp\,^1P_1)_l$ means the angular part (including R', R'' and S) of $(dp\,^1P_1|\omega/r^3|dp\,^1P_1)$ contributed by the l-electron. The matrix elements of ω are $(sp\,^3P_1|\omega|sp\,^3P_1)=(-R'+4S)/15$, $(sp\,^1P_1|\omega|sp\,^1P_1)=-(2/15)(R'+2S)$, $(sp\,^3P_1|\omega|sp\,^1P_1)=(2^{1/2}/15)\times(R'-S)$, and $(dp\,^1P_1|\omega/r^3|dp)\,^1P_1=-(1/75)(R'+2S)\times\langle1/r_p^3\rangle_{Av}-(1/125)(12R_2'+7R_2''+6S_2)\langle1/r_d^3\rangle_{Av}$.

Putting the aforementioned value of B and $\zeta_{5p}=4300$, $\zeta_{7p}=460$, $\zeta_{5d}=6150$, $Z_p^*=80-4=76$, $Z_d^*=80-20=60$, $\Delta_p=0.019$, and $\Delta_d=0.085$ in Eqs. (6), (7), and (4), we get $Q(Hg^{201})=0.42\times10^{-24}$ cm^2.

Similarly for $6s6p\,^3P_2$ we get

$$6s6p\,^3P_2'=K_1\,^3P_2(6s6p)+K_2\,^3P_2(5d^96p), \quad (8)$$

$$K_1=0.958,\quad K_2=0.287,$$

$$(sp\,^3P_2|\omega|sp\,^3P_2)=-(2/5)R',\quad (dp\,^3P_2|\omega/r^3|dp\,^3P_2)=(-1/125)(36R_2'+R_2''-12S_2)\langle1/r_d^3\rangle_{Av}+(1/25)(3R'-4S)\langle1/r_p^3\rangle_{Av}. \quad (9)$$

The constants that were obtained for this level previously[24] are $A=-0.1119_0$ cm^{-1} and $B=0.278\times10^{-3}$ cm^{-1} for Hg^{201}. Putting (8) and (9) in an expression similar to (7) and then in (4), we get $Q(Hg^{201})=0.46\times10^{-24}$ cm^2.

Because of the insufficient number of equations for determining the composition of $6s6p\,^1P_1$ the mixing of $6s8p\,^1P_1$ was tentatively neglected. Inclusion of this will slightly increase the value of Q obtained from $6s6p\,^1P_1$. We might thus consider

$$Q(Hg^{201})=(0.45\pm0.04)\times10^{-24}\text{ cm}^2$$

as the best value available at present. Schüler and Schmidt[26] obtained 0.5×10^{-24} cm^2, without taking configuration interaction into account, and Dehmelt, Robinson, and Gordy[27] obtained 0.6×10^{-24} cm^2 by a nuclear quadrupole resonance experiment.

[22] Since the final level is of jj-coupling, we have $(d^4\,^5D_4'|\omega|d^4\,^5D_4')=(16/35)R_2'$. Putting $B=0.34\times10^{-3}$ cm^{-1}, $\Delta_d=0.10$, $\zeta_d=2700$, $R_2'=1.05$ and $H_2=1.02_2$ in the formula (4), and reversing the sign, we get $Q(Os^{189})=(2.7\pm1.3)\times10^{-24}$ cm^2. The uncertainty comes mainly from the fact that the splitting of the final level cannot be deduced from the observed hfs by a purely empirical method.

[23] K. Murakawa, Phys. Rev. **93**, 1232 (1954).

[24] K. Murakawa, Phys. Rev. **78**, 480 (1950). K. Murakawa and S. Suwa, J. Phys. Soc. (Japan) **5**, 429 (1950).

[25] J. N. P. Hume and M. F. Crawford, Phys. Rev. **84**, 486 (1951).

[26] H. Schüler and T. Schmidt, Z. Physik **98**, 239 (1935).

[27] Dehmelt, Robinson, and Gordy, Phys. Rev. **93**, 480 (1954).