Lifetime Measurements of All Excited States of the $4d^95p$ Configuration in the Pd-I Spectrum

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Z. Naturforsch. **36a**, 778–779 (1981);
received May 19, 1981

The lifetimes for the $4d^95p$ configuration have been determined by zero field level crossing technique. The results are (in nsec):

$\tau(^3P_1{}^0) = 7.5\ (4)$
$\tau(^3P_2{}^0) = 6.9\ (8)$
$\tau(^1P_1{}^0) = 5.0\ (4)$
$\tau(^3D_1{}^0) = 4.9\ (4)$
$\tau(^3D_2{}^0) = 8.1\ (5)$
$\tau(^3D_3{}^0) = 7.0\ (5)$
$\tau(^1D_2{}^0) = 7.2\ (5)$
$\tau(^3F_2{}^0) = 9.0\ (6)$
$\tau(^3F_3{}^0) = 7.9\ (5)$
$\tau(^3F_4{}^0) = 7.1\ (5)$
$\tau(^1F_3{}^0) = 8.4\ (6)$

An atomic beam of natural Palladium, produced in an oven of coaxial construction, was irradiated by the light of a hollow cathode lamp [1]. By absorption of the corresponding resonance lines (Fig. 1) the atoms were raised from the ground state $4d^{10}\ ^1S_0$ and from the metastable D-states of the configuration $4d^95s$ to the excited states of the $4d^95p$ configuration. (At an oven temperature of about 1850 K the metastable D-states are noticeably populated.)

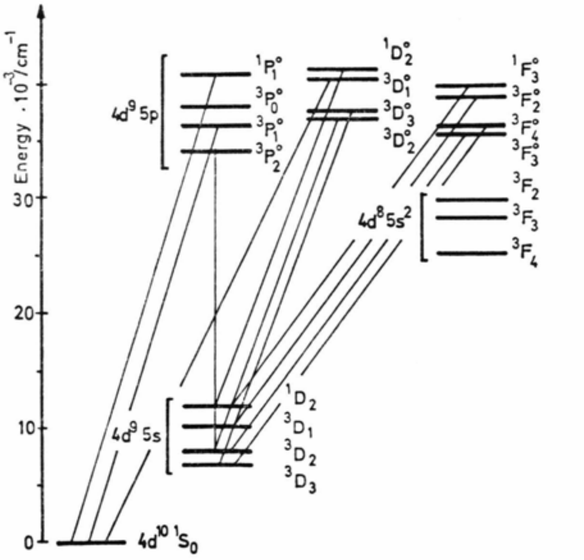

Fig. 1. Part of the level scheme of the Pd I spectrum (the wavelength are indicated in Table 1).

The lifetimes of all excited states except the $^3P_0{}^0$-state were determined by measuring the depolarization of the fluorescence light in a magnetic field (Hanle-effect) [2]. The $^3P_0{}^0$-state gives no Hanle-signal because $J=0$ for the even isotopes; the half width of the Hanle-signal of the odd isotope $^{105}\text{Pd}\,(I=5/2)$ is very large ($g_F = g_I'$), therefore this signal is not detectable.

The $\Delta m = 2$ zero field level crossing signals were detected by an experimental arrangement similar to that described in an earlier paper [3]. The spectral lines under study, which partially are close together in wavelength, were selected by a monochromator, hence a considerable decrease of the detectable intensities. A further reduction in the signal-to-noise ratio may be given due to the different possibilities of excitation of the states under study. As may be seen from the Breit-formula [4] the signal amplitudes of the Hanle-effect changes in sign whether the excitation is via a $J \to J$ transition or a $J \pm 1 \to J$ transition. Therefore if the excitation is achieved by all corresponding lines in the spectrum of a hollow cathode lamp, the Hanle signal in some special cases nearly cancels. This explains the very poor signal-to-noise ratio of the Hanle effect we measured in some excited states of the $4d^95p$-configuration. In order to overcome this difficulty signal processing up to ten hours had to be employed.

For the geometry chosen in our experiment the signal curve of the even isotopes of the field dependent part of the observed fluorescence intensity plotted against the magnetic field is lorentzian shaped with a half width ΔB related to the coherence time by $\Delta B = 1/\gamma \cdot T$, where γ is the gyromagnetic factor of the excited state. Only for small particle density the coherence time is equal to the lifetime of the excited state [5]. Therefore in all measurements the particle density has been varied over a range of one order of magnitude in order to get rid of the coherence narrowing [5].

But because of the different gyromagnetic factors for the hfs levels of the odd isotope ^{105}Pd (22%) the resulting signal is a superposition of Lorentzian curves with different half widths. In addition the broad band excitation, which is supposed in the Breit formula is no longer valid as may be seen from relative isotope shifts in the Pd I spectrum

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Table 1.

Term	λ/AE	$\Delta H_{1/2}$	g_J	τ/nsec without hfs	τ/nsec with hfs	τ/nsec Corliss & Bozman
$4d^95p$ $^3P_1^0$	2763	10.9 ± 0.5	1.396	7.5	7.5 ± 0.4	3.8
$^3P_2^0$	3635	11.1 ± 1.3	1.482	6.9	6.9 ± 0.8	7.4
$^1P_1^0$	2448	29.7 ± 2.1	0.768	4.9	5.0 ± 0.4	1.9
$^3D_1^0$	2476	28.0 ± 2.3	0.831	4.8	4.9 ± 0.4	2.5
$^3D_2^0$	3421	14.2 ± 0.8	0.988	7.9	8.1 ± 0.5	6.0
$^3D_3^0$	3243	12.8 ± 0.9	1.276	6.9	7.0 ± 0.5	5.3
$^1D_2^0$	3442	14.2 ± 0.9	1.114	7.2	7.2 ± 0.5	2.5
$^3F_2^0$	3482	16.8 ± 1.0	0.752	8.8	9.0 ± 0.6	2.9
$^3F_3^0$	3610	13.5 ± 0.9	1.063	7.7	7.9 ± 0.5	5.7
$^3F_4^0$	3405	12.8 ± 0.9	1.25	7.0	7.1 ± 0.5	7.5
$^1F_3^0$	3553	12.5 ± 0.9	1.081	8.3	8.4 ± 0.6	3.4

recently become available [6]. Taking into account approximately the spectral distribution of the incident light the resulting shapes of the signals were calculated due to the Breit formula and fitted to the measured values with the aid of a mini-computer (PDP 11/45) making use of the experimental g_J-values [7, 8]. The results are given in column 6 of Table 1. The errors include uncertainties made by fitting as well as systematic errors.

If the measured Hanle signals are fitted simply with one Lorentzian curve without regard of the lamp profile we get lifetimes that are at most 2.5% smaller. This seems to be a little surprising in view of the odd-even isotope shift [6] and the large hfs-splitting in the D-states of the $4d^95s$ configuration [9] and the states of the configuration $4d^95p$ [10]. (Table 1 also includes the results of earlier measurements of lifetimes in the Pd I spectrum [11, 12].) The lifetime of the $^3P_1^0$-state has already been measured by Budick [13]. His result was $\tau(^3P_1^0) = 8.7(9)$ nsec. Another measurement was performed by Hese and Weise [14]. In the last column in Table 1 we calculated the τ-values from the transition probabilities of Corliss and Bozman [15]. As can be seen, there is no systematic trend in the deviation.

We like to thank Prof. H. Krüger for his continuous support of this work.

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