Tl as three electron atom.

Mikhail Kozlov

March 12, 2001. Updated: April 7, 2001

Spectrum of Tl for Coulomb and Coulomb-Gaunt potentials (1/cm).

	CI+MBPT		Exper.
	C	C-G	
$6p_{1/2}{}^{*}$	*2.0742*	*2.0720*	*2.0722*
$6p_{3/2}$	7925	7836	7793
$7p_{1/2}$	34193	34087	34160
$7p_{3/2}$	35215	35098	35161
$7s_{1/2}$	26583	26455	26478
$6d_{3/2}$	36363	36208	36118
$6d_{5/2}$	36469	36321	36200

(*) The three electron valence energy in a.u.

Hyperfine constants for ^{205}Tl (MHz).

	$A_{6p_{1/2}}$	$A_{6p_{3/2}}$	$A_{7p_{1/2}}$	$A_{7p_{3/2}}$	$A_{7s_{1/2}}$	$A_{6d_{3/2}}$
DF	17339	1291	1940	187	7579	21
CI	924	−1369	−102	112	3799	−185
H_{eff}	3428	−45	331	−56	765	114
RPA	959	359	103	73	1031	5
A_σ	−1071	−31	−92	−9	−269	3
A_{sbt}	−1389	−161	−113	−19	−75	−19
A_{tp}	1731	120	133	4	−22	21
SR	209	88	14	6	−29	−1
Norm.	−467	−4	−20	−3	−113	0
Total	21663	248	2193	295	12666	−41
Exper.	21311	265	2155	309	12297	−43

E1 amplitudes for Tl in L-gauge (a.u.).

		DF	CI	Tot.	Exper.
$6p_{1/2} \rightarrow$	$7s_{1/2}$	2.049	1.863	1.77	1.81(2)
$\rightarrow$	$6d_{3/2}$	2.722	2.454	2.30	2.30(9)
$6p_{3/2} \rightarrow$	$7s_{1/2}$	3.966	3.466	3.35	3.28(4)
$\rightarrow$	$6d_{3/2}$	1.633	1.472	1.40	1.36(7)
$\rightarrow$	$6d_{5/2}$	4.840	4.292	4.08	3.8(2)
$7p_{1/2} \rightarrow$	$7s_{1/2}$	6.618	6.152	5.96	5.94(6)
$\rightarrow$	$6d_{3/2}$	11.980	10.874	10.86	
$7p_{3/2} \rightarrow$	$7s_{1/2}$	8.794	8.252	7.98	7.90(8)
$\rightarrow$	$6d_{3/2}$	5.395	4.887	4.90	
$\rightarrow$	$6d_{5/2}$	16.300	14.799	14.88	

Polarizabilities for Tl (a.u.).

	Valence	Core	δCore	Total	Exper.
$\alpha_0(6p_{1/2})$	43.47	6.23	−0.51	49.2	
$\alpha_0(6p_{3/2})$	73.79	6.23	−0.48	79.6	
$\alpha_2(6p_{3/2})$	−25.04	0	0.06	−25.0	−24.2(3)

$E1_{\text{PNC}}$ amplitude for $6p_{1/2} \to 6p_{3/2}$ transition in ^{205}Tl ($i \cdot 10^{-10}(-Q_w/N)$ a.u.).

	(H_P)	$(E1)$
CI	-3.420	-2.988
H_{eff} & RPA	-0.726	$+0.001$
A_σ	$+0.129$	$+0.112$
A_{sbt}	$+0.103$	$+0.077$
A_{tp}	-0.029	-0.053
SR	-0.004	-0.002
Subtotal	-6.81	
Normalization	$+0.14$	
Total	-6.67	
$M1$ amplitude (10^{-3} a.u.)		
CI+MBPT-II	4.145	
MBPT-III(1e)	4.149	
$\mathcal{R} = 10^8 \times \text{Im}\frac{E1_{\text{PNC}}}{M1}$ $(Q_w = Q_w^{\text{SM}} = -116.8)$		
	$-15.2(4)$	

Theoretical results for $E1_{\mathrm{PNC}}$ for $6p_{1/2} \rightarrow 6p_{3/2}$ transition in ^{205}Tl ($i \cdot 10^{-10}(-Q_w/N)$ a.u.).

Novikov *et al* (76)	−7.0 (20%)
Henley & Wilets (76)	−9.0
Henley *et al* (77)	−6.2
Neuffer & Commins (77)	−8.8
Dzuba *et al* (87)	−6.6 (3%)
Hartley *et al* (90)	−6.4 (10%)
Hartley & Sandars (90)	−7.7 (9%)
Liu & Johnson (96)	−7.1 (6%)
Kozlov, Porsev, & Johnson (01)	−6.7 (2.5%)

Experimental and theoretical values of $\mathcal{R} = 10^8 \times \frac{\mathrm{Im}E1_{\mathrm{PNC}}}{M1}$ for $6p_{1/2} \rightarrow 6p_{3/2}$ transition in ^{205}Tl

Experiment

Oxford	Edwards *et al* (1995)	−15.68 (0.45)
	Majumder & Tsai (1999)[1]	−14.71 (0.45)
Seattle	Vetter *et al* (1995)	−14.68 (0.17)

Theory

(Standard model value $Q_W = -116.8$ assumed)

Novosibirsk	Dzuba *et al* (1987)	−15.1 (0.5)
Notre Dame	Liu *et al* (1996)	−16.1 (1.0)
Gatchina	Kozlov *et al* (1997)	−15.0 (0.6)
Gatchina-ND	Kozlov *et al* (2001)	−15.2 (0.4)

[1] scaling of Oxford result

Calculation of the PNC amplitude in Cs

Hyperfine constants for ^{133}Cs (MHz).

	DF	MBPT	Breit	Theory	Exper.
$6s_{1/2}$	1424	2298	+5.0	2302	2298
$6p_{1/2}$	160.9	293.3	-0.2	293.5	292
$6p_{3/2}$	23.9	51.2	-0.0	51.2	50.3
$7s_{1/2}$	391.4	546.0	+0.8	546.8	546
$7p_{1/2}$	57.6	94.0	-0.0	94.0	94.3
$7p_{3/2}$	8.6	17.1	-0.0	17.1	

Stark shift $\delta\nu_{6s,7s}$ for the $6s \rightarrow 7s$ transition (Hz/(V/cm)^2) and Stark-induced vector amplitude $\beta_{6s,7s}$ (a.u.).

$$\delta\nu_{6s,7s} = \begin{cases} .7259 & \text{theory,} \\ .7262 & \text{experiment (Bennett } et\ al\text{).} \end{cases}$$

$$\beta_{6s,7s} = \begin{cases} 26.89 & \text{theory,} \\ 27.02(8) & \text{experiment (Bennett } et\ al\text{).} \end{cases}$$

Theoretical results for $E1_{\mathrm{PNC}}(6s, 7s)$ for ^{133}Cs in the units $i \cdot 10^{-11} Q_W/(-N)$ a.u.

	MBPT	Breit	Total
[1]	−.908	—	−.908
[2]	−.907	.002	−.905
[3]		.008	
[4]	−.907	.005	−.902
[5]	−.905	.004	−.901

[1] Dzuba, Flambaum, and Sushkov. Phys.Lett.A **141**, 147 (89).

[2] Blundell, Sapirstein, and Johnson. Phys.Rev.D **45**, 1602 (92).

[3] Derevianko. Phys.Rev.Lett. **85**, 1618 (00).

[4] Dzuba, Harabati, Johnson, and Safronova. Phys.Rev.A **63**, 044103 (01).

[5] Kozlov, Porsev, and Tupitsyn. Phys.Rev.Lett. **86**, 3260 (01).

Theoretical uncertainties

1.	Electron correlations	$\sim 0.5\%$
2.	QED (vacuum polarization, etc.)	$0.2 - 0.4\%$
3.	Nuclear structure	$0.1 - 0.3\%$

Atomic tests of standard model.

Weak charges of ^{133}Cs and ^{205}Tl

	SM	Exper.
$Q_{\mathrm{W}}(^{133}\mathrm{Cs})$	$-73.09(3)$	$-72.5(3)_{\mathrm{exp.}}(7)_{\mathrm{theor.}}$
$Q_{\mathrm{W}}(^{205}\mathrm{Tl})$	$-116.8(2)$	$-113(1)_{\mathrm{exp.}}(3)_{\mathrm{theor.}}$