

$^{10}\text{B}(^{40}\text{Ca},2\text{p}\gamma), ^{40}\text{Ca}(^{10}\text{B},2\text{p}\gamma)$ [1994Ca04,1973Hu08](#)

Type	Author	History Citation	Literature Cutoff Date
Full Evaluation	Jun Chen	NDS 179, 1 (2022)	30-Nov-2021

Also includes $^{40}\text{Ca}(^{12}\text{C},3\text{pn}\gamma)$ from [1973Hu08](#).

[1994Ca04](#): $^{10}\text{B}(^{40}\text{Ca},2\text{p}\gamma)$ E=150 MeV ^{40}Ca beam was produced from the Daresbury Nuclear Structure Facility. Target was ^{10}B .

Fragments were separated with the Daresbury 0° recoil separator. γ rays were detected with the escape-suppressed HPGe detector array (19 detectors in 4 rings at 40° , 101° , 117° , and 143° to the beam direction). Measured $E\gamma$, $I\gamma$, $\gamma\gamma$ -coin, γ anisotropies.

Deduced levels, J, π , band structures, γ -ray multiplicities.

[1973Hu08](#) (also [1972BiZG](#)): $^{40}\text{Ca}(^{10}\text{B},2\text{p}\gamma)$ E=19, 22.5 and 25 MeV ^{10}B beams were produced from the MP Tandem Van de Graaff of Technische Universitat Munchen. Target was $100\text{ }\mu\text{g}/\text{cm}^2$ metallic calcium layer sandwiched between a $1\text{ mg}/\text{cm}^2$ gold backing and a $150\text{ }\mu\text{g}/\text{cm}^2$ gold cover. γ rays were detected with two Ge(Li) detectors. Charged particles were detected with an annular silicon counter. Measured $E\gamma$, $I\gamma$, $\gamma\gamma$ -coin, $\text{p}\gamma$ -coin, $\gamma(\theta)$, recoil distance. Deduced levels, J, π , $T_{1/2}$, γ -ray multiplicities, transitions strengths. Comparisons with shell model calculations. [1973Hu08](#) also report $\gamma\gamma$ -coin and γ excitation functions from $^{40}\text{Ca}(^{12}\text{C},3\text{pn}\gamma)$ with E(^{12}C)=41-62 MeV, but most data are from the $^{40}\text{Ca}+^{10}\text{B}$ reaction.

other:

[2005ChZY](#): $^{10}\text{B}(^{40}\text{Ca},2\text{p}\gamma)$ E=110 MeV at ANL. Measured $E\gamma$, $I\gamma$, $\gamma\gamma$ -coin.

 ^{48}V Levels

A $J\geq 7$ state at 1651 keV proposed by [1973Hu08](#) was not confirmed by [1994Ca04](#) or in other studies by [1978MoZZ](#), [1991Ca30](#), and [2002Br42](#). The 396γ assigned to the 1651 level in [1973Hu08](#) is found to deexcite the 2626 level in [1994Ca04](#) and other studies.

E(level) [†]	J π [@]	$T_{1/2}$ [#]	Comments
0.0 ^{&}	4 ⁺		
308.8 ⁵	2 ⁺		
420.9 ⁷	1 ⁺		
428.3 ^{& 4}	5 ⁺	<14 ps	J π : spin=5 suggested by $\gamma(\theta)$ in 1973Hu08 .
519.6 ^{b 6}	1 ⁻	3.8 ns ³¹	J π : spin=1 supported by $\gamma(\theta)$ and γ decay pattern in 1973Hu08 . $T_{1/2}$: deduced by the evaluator from $0.7\text{ ns}<T_{1/2}<6.9\text{ ns}$ given in 1973Hu08 .
613.9 ⁶	4 ⁺		
627.6 ^{& 4}	6 ⁺	90 ps ⁴²	
745.9 ^{b 7}	2 ⁻	16 ps ¹³	$T_{1/2}$: deduced by the evaluator from $2.8\text{ ps}<T_{1/2}<29\text{ ps}$ given in 1973Hu08 .
775.8 ⁵	3,5		
1055.6 ^{b 8}	3 ⁻		
1099.8 ^{a 7}	4 ⁻		
1254.8 ^{& 6}	7 ⁺	<6.9 ps	
1557.7 ^{b 8}	4 ⁻		
1685.7 ^{a 9}	5 ⁽⁻⁾		
2062.7 ^{b 9}	5 ⁽⁻⁾		
2231.8 ^{& 8}	8 ⁺		
2397.6 ^{a 7}	6 ⁻		
2626.8 ^{& 10}	9 ⁺		
3173.6 ^{a 9}	(7 ⁻)		
3978.6 ^{a 12}	(8 ⁻)		
4307.8 ^{& 14}	(11 ⁺)		
4394.6 ^{a 12}	(9 ⁻)		
6244.9 ^{& 17}	(13 ⁺)		

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$^{10}\text{B}(^{40}\text{Ca},2\text{p}\gamma), ^{40}\text{Ca}(^{10}\text{B},2\text{p}\gamma)$ 1994Ca04,1973Hu08 (continued) ^{48}V Levels (continued)

E(level) [†]	J ^π @	Comments
8289.9? [‡] & 20	(15,13)	E(level): level not adopted in Adopted Levels. See comment for 2045γ.
8589.0? [‡] & 20	(14)	E(level): level not adopted in Adopted Levels. See comment for 2344γ.

[†] From a least-squares fit to γ-ray energies, assuming ΔE_γ=1 keV where not available.

[‡] The two levels are only proposed by 1994Ca04 based on the placement of a single transition from each level. The same transitions are placed differently in other studies (1991Ca30,2002Br42), which are adopted in Adopted Levels, Gammas.

From RDM in 1973Hu08.

@ From Adopted Levels. Assignments are supported by γ angular anisotropy from 1994Ca04 and γ(θ) from 1973Hu08 in this dataset.

& Seq.(C): Sequence based on g.s.

^a Band(A): Band based on 1010, 4⁻ state.

^b Band(B): Band based on 520, 1⁻ state.

γ(^{48}V)

γ anisotropy given under comments are from 1994Ca04; A₂ and A₄ values are from 1973Hu08. Expected anisotropy are ≈0.8 for J to J-1 (stretched dipole), ≈1.4 for J to J (dipole), and ≈1.5 for J to J-2 (stretched quadrupole), with the last two indistinguishable in practice (1991Ca23,1994Ca04).

E _γ [†]	I _γ [†]	E _i (level)	J _i ^π	E _f	J _f ^π	Mult. [#]	Comments
99.0 10	4 1	519.6	1 ⁻	420.9	1 ⁺		I _γ : other: 0.4 (1994Ca04). A ₂ =+0.01 8, A ₄ =+0.04 10.
112.2 5	5 1	420.9	1 ⁺	308.8	2 ⁺		I _γ : other: 1.8 (1994Ca04). A ₂ =-0.06 4, A ₄ =+0.07 5.
186	0.5	613.9	4 ⁺	428.3	5 ⁺	D	I _γ : other: 55 (1994Ca04).
199.6 5	44 1	627.6	6 ⁺	428.3	5 ⁺		Mult.: γ(θ) shows strong stretched dipole pattern (1973Hu08). A ₂ =-0.40 2, A ₄ =+0.02 2. Anisotropy=0.82 2.
210.8 5	8 1	519.6	1 ⁻	308.8	2 ⁺		I _γ : other: 1.1 (1994Ca04). A ₂ =-0.03 6, A ₄ =+0.09 8.
226.4 5	14 1	745.9	2 ⁻	519.6	1 ⁻	D	I _γ : other: 5.5 (1994Ca04). Mult.: γ(θ) consistent with stretched dipole (1973Hu08). A ₂ =-0.11 4, A ₄ =+0.03 5. Anisotropy=0.89 7.
308.9 5	40 4	308.8	2 ⁺	0.0	4 ⁺		I _γ : other: 0.4 (1994Ca04). A ₂ =-0.09 2, A ₄ =+0.03 3.
310	3.6	1055.6	3 ⁻	745.9	2 ⁻	D	E _γ : from 1973Hu08 and 1994Ca04.
395	36	2626.8	9 ⁺	2231.8	8 ⁺		E _γ : 1973Hu08 assigned this γ to a 1651 state. Anisotropy=0.89 3.
414	3.6	4394.6	(9 ⁻)	3978.6	(8 ⁻)	D	Anisotropy=0.9 1.
428.2 5	63 3	428.3	5 ⁺	0.0	4 ⁺	D	I _γ : other: 55 (1994Ca04). A ₂ =-0.40 2, A ₄ =+0.03 3. Anisotropy=0.89 2.
441	0.4	1055.6	3 ⁻	613.9	4 ⁺		
458	0.7	1557.7	4 ⁻	1099.8	4 ⁻		
486	1.8	1099.8	4 ⁻	613.9	4 ⁺		
502	3.6	1557.7	4 ⁻	1055.6	3 ⁻		E _γ : from 1973Hu08 and 1994Ca04.
505	3.6	2062.7	5 ⁽⁻⁾	1557.7	4 ⁻		

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$^{10}\text{B}(^{40}\text{Ca},2\text{p}\gamma), ^{40}\text{Ca}(^{10}\text{B},2\text{p}\gamma)$ **1994Ca04,1973Hu08** (continued) $\gamma(^{48}\text{V})$ (continued)

E_γ [†]	I_γ [†]	$E_i(\text{level})$	J_i^π	E_f	J_f^π	Mult. [#]	Comments
537 ^a	<0.4	1055.6	3 ⁻	519.6	1 ⁻		
586	16	1685.7	5 ⁽⁻⁾	1099.8	4 ⁻	D	Anisotropy=0.71 4.
613	3.6	613.9	4 ⁺	0.0	4 ⁺		
627.7 ^{& 5}	100 ^{& 10}	627.6	6 ⁺	0.0	4 ⁺		I_γ : other: 100 from 1994Ca04, and the original value=55 is normalized to 100 for the sum of all decays to the ground state. $A_2=0.00$ 2, $A_4=-0.01$ 2.
627.7 ^{& 5}	23 ^{& 3}	1254.8	7 ⁺	627.6	6 ⁺		I_γ : other: 73 (1994Ca04), from coincidence spectra.
712	11	2397.6	6 ⁻	1685.7	5 ⁽⁻⁾	D	Anisotropy=0.72 6.
775.8 5	14 2	775.8	3,5	0.0	4 ⁺		
776	9	3173.6	(7 ⁻)	2397.6	6 ⁻	D	Anisotropy=0.71 8.
803	11	3978.6	(8 ⁻)	3173.6	(7 ⁻)	D	Anisotropy=1.06 9.
812	3.6	1557.7	4 ⁻	745.9	2 ⁻		
825	1.8	1254.8	7 ⁺	428.3	5 ⁺		
977	27	2231.8	8 ⁺	1254.8	7 ⁺	D	Anisotropy=0.69 4.
1007	1.8	2062.7	5 ⁽⁻⁾	1055.6	3 ⁻		
1100.0 10	53 5	1099.8	4 ⁻	0.0	4 ⁺	(Q) [@]	I_γ : other: 24 (1994Ca04). Anisotropy=1.3 1.
1223	1.1	4394.6	(9 ⁻)	3173.6	(7 ⁻)		
1349 ^{‡a}	1.3	3978.6	(8 ⁻)	2626.8	9 ⁺		
1372	73	2626.8	9 ⁺	1254.8	7 ⁺	(Q) [@]	Anisotropy=1.30 6.
1449	1.8	2062.7	5 ⁽⁻⁾	613.9	4 ⁺		
1588 ^a	5.5	3978.6	(8 ⁻)	2397.6	6 ⁻	(Q) [@]	E_γ : this energy is inconsistent with level-energy difference=1581 and values in other studies. It is more likely in error. Anisotropy=1.7 4.
1604	36	2231.8	8 ⁺	627.6	6 ⁺	(Q) [@]	
1681	73	4307.8	(11 ⁺)	2626.8	9 ⁺	(Q) [@]	Anisotropy=1.52 8.
1744 ^{‡a}	3.6	3978.6	(8 ⁻)	2231.8	8 ⁺		
1770	11	2397.6	6 ⁻	627.6	6 ⁺	D	Mult.: γ anisotropy suggests dipole, $\Delta J=0$. Anisotropy=1.2 2.
1937	36	6244.9	(13 ⁺)	4307.8	(11 ⁺)	(Q) [@]	Anisotropy=1.4 1.
1969	1.8	2397.6	6 ⁻	428.3	5 ⁺		
2045 ^a	13	8289.9?	(15,13)	6244.9	(13 ⁺)	(Q) [@]	placed from the 4675 level by 1991Ca30 in $^{27}\text{Al}(^{27}\text{Al},3\text{n}3\text{p}\gamma)$ and 2002Br42 in $^{24}\text{Mg}(^{28}\text{Si},\text{n}3\text{p}\gamma)$, which is adopted by the evaluator. Anisotropy=1.4 1.
2344 ^a	5.5	8589.0?	(14)	6244.9	(13 ⁺)	D	placed from the 4969 level by 1991Ca30 in $^{27}\text{Al}(^{27}\text{Al},3\text{n}3\text{p}\gamma)$ and 2002Br42 in $^{24}\text{Mg}(^{28}\text{Si},\text{n}3\text{p}\gamma)$, which is adopted by the evaluator. Anisotropy=0.8 2.
2546	3.6	3173.6	(7 ⁻)	627.6	6 ⁺		

[†] Values with uncertainties are from 1973Hu08 and those without uncertainties are from 1994Ca04, unless otherwise noted. Intensity values from 1994Ca04 have been re-normalized to $I_\gamma(627.7\gamma)=100$ (from the 627 level) by the evaluator from the original values which are normalized to 100 for decays to the ground state.

[‡] 1994Ca04 report 1349 γ and 1744 γ to deexcite the 1976 level, however, these two transitions are not seen in any spectra for ^{48}V in 1994Ca04 but clearly seen and labeled (1349 as 1347) in coincidence spectra for ^{48}Cr , and they are not seen in any other studies for ^{48}V . It is most likely that these two transitions belong to ^{48}Cr .

[#] Stretched ($\Delta J=1$) dipole from angular anisotropy where available (1994Ca04), unless otherwise noted.

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${}^{10}\text{B}({}^{40}\text{Ca},2\text{p}\gamma), {}^{40}\text{Ca}({}^{10}\text{B},2\text{p}\gamma)$ [1994Ca04,1973Hu08](#) (continued)

$\gamma({}^{48}\text{V})$ (continued)

[@] Anisotropy in [1994Ca04](#) is consistent with dipole ($\Delta J=0$) or stretched quadrupole ($\Delta J=2$); $\Delta J=(2)$ from level scheme.

[&] Multiply placed with intensity suitably divided.

^a Placement of transition in the level scheme is uncertain.

$^{10}\text{B}(^{40}\text{Ca},2\text{p}\gamma), ^{40}\text{Ca}(^{10}\text{B},2\text{p}\gamma)$ 1994Ca04,1973Hu08

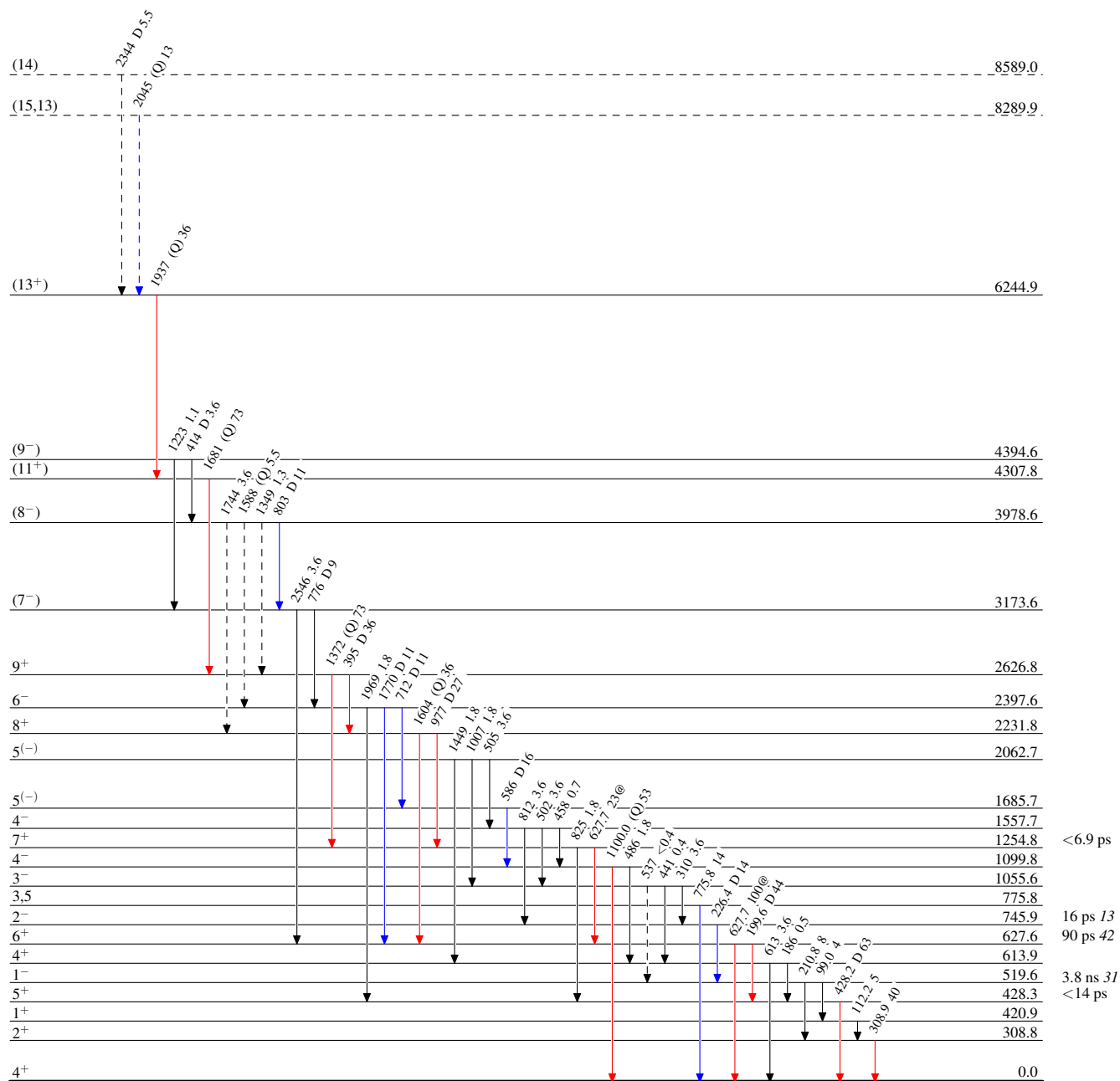
Level Scheme

Intensities: Relative I_γ

@ Multiply placed: intensity suitably divided

Legend

- $\longrightarrow$ $I_\gamma < 2\% \times I_\gamma^{\max}$
 $\longrightarrow$ $I_\gamma < 10\% \times I_\gamma^{\max}$
 $\longrightarrow$ $I_\gamma > 10\% \times I_\gamma^{\max}$
 $-\cdots-\cdots$ γ Decay (Uncertain)



${}^{10}\text{B}({}^{40}\text{Ca}, 2p\gamma), {}^{40}\text{Ca}({}^{10}\text{B}, 2p\gamma)$ 1994Ca04,1973Hu08