^{40}Ca(^{36}Ar,2pnγ),(^{40}Ca,α2pnγ) 2002Ke03

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Balraj Singh and Jun Chen	NDS 158, 1 (2019)	16-May-2019

2002Ke03: E(^{36}Ar)=145 MeV, E(^{40}Ca)=160 MeV. Measured Eγ, Iγ, γγ-coin, (particle)γγ-coin, γγ(θ)(DCO) using Gammasphere array for γ rays, Microball CsI detector array for charged particles and an array of 30 liquid scintillation counters for neutrons at ATLAS-ANL facility. Deduced high-spin levels, J^π, bands.

2008Jo07: E(^{40}Ca)=165 MeV beam provided by ATLAS accelerator at Argonne. Measured Eγ, γγ-coin, level lifetimes by DSAM method using Gammasphere array of 99 HPGe detectors with Compton-suppression. Detected charged particles using MICROBALL array. From measured lifetimes, transition quadrupole moments (Q_t) were deduced. Discussed triaxial shapes. Comparison with predictions of cranked Nilsson-Strutinsky and cranked relativistic mean-field theory calculations. See also 2003KeZZ conference report from the same group.

1993Fr03 (also Ph.D. thesis by S. Freund, University of Cologne, 1998): ^{40}Ca(^{36}Ar,2pnγ) E=130-145 MeV. Measured Eγ, γγ, nγγ-coin, γγ(θ)(DCO) using OSIRIS array of 12 BGO-shielded Ge detectors in combination with neutron multiplicity filter in one experiment and BGO-γ multiplicity filter in the other. Negative parity bands up to 25/2$^-$ and positive parity bands up to 21/2$^+$ were identified. All the 18 excited states agree with those from 2002Ke03, but the spins for the negative-parity bands are lower by one unit in 1993Fr03, due to g.s. spin of 5/2 (in 1993Fr03) rather than 3/2, as proposed by 1999Mi17 and 2002Ke03.

Others:

1993Mo14: ^{40}Ca(^{36}Ar,2pnγ) E=95 MeV. Measured Eγ, Iγ, γγ, nγγ coin using HERA array for γ rays and a neutron detector. Out of 28 γ rays and four cascades assigned to ^{73}Kr, only eight γ rays in one cascade have been verified by 2002Ke03. The other γ rays and cascades probably belong to ^{73}Se and ^{76}Br.

1990Sa04: ^{40}Ca(^{35}Cl,pnγ) E=95 MeV. Measured Eγ, Iγ, γγ using an array of 20 Ge detectors. Out of 22 γ rays assigned to ^{73}Kr, only five γ rays may correspond to those in 2002Ke03. None of the two cascades proposed is verified by 2002Ke03. These seem to belong to ^{73}Se and ^{76}Br, as pointed out by 1993Fr03.

^{73}Kr Levels

Q_t=transition quadrupole moment, deduced by 2008Jo07 from their lifetime measurements. Values of lifetimes are not available, although, F(τ) values are listed in authors′ table I, and in comments here.

E(level)[†]	J^π[‡]	$T_{1/2}$	Comments
0.0[#]	3/2$^-$		
143.97[@] *10*	5/2$^-$		
367.83[&] *10*	5/2$^+$		
392.88[#] *13*	7/2$^-$		
433.66[&] *12*	9/2$^+$	107 ns *10*	$T_{1/2}$: from Adopted Levels. Other: 97-416 ns (1993Fr03).
511.7[a] *6*	(7/2$^+$)		
660.07[@] *13*	9/2$^-$		
852.7?			E(level): from 1993Fr03 only, not included in the Adopted Levels, Gammas dataset.
1003.88[#] *16*	11/2$^-$		
1066.0[a] *4*	11/2$^+$		
1177.77[&] *23*	13/2$^+$		
1372.18[@] *16*	13/2$^-$		
1830.6[#] *3*	15/2$^-$		
1892.1[a] *4*	15/2$^+$		
2069.8[&] *3*	17/2$^+$		
2285.18[@] *19*	17/2$^-$		
2864.6[#] *4*	(19/2$^-$)		F(τ)=0.891 *7* for 1034γ (2008Jo07). Q_t=2.99 *8* (2008Jo07).
2937.5[a] *5*	19/2$^+$		

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^{40}Ca(^{36}Ar,2pnγ),(^{40}Ca,α2pnγ) 2002Ke03 (continued)

^{73}Kr Levels (continued)

E(level)[†]	J$^{\pi}$[‡]	Comments
3155.2[&] *4*	21/2$^+$	
3382.29[@] *22*	21/2$^-$	F(τ)=0.891 *1* for 1097γ (2008Jo07). Q_t=3.26 *8* (2008Jo07).
4087.7[#] *4*	(23/2$^-$)	F(τ)=0.894 *7* for 1223γ (2008Jo07). Q_t=2.95 *8* (2008Jo07).
4139.3[a] *8*	(23/2$^+$)	
4401.3[&] *4*	25/2$^+$	F(τ)=0.891 *2* for 1246γ (2008Jo07). Q_t=2.44 *8* (2008Jo07).
4645.4[@] *3*	25/2$^-$	F(τ)=0.896 *2* for 1263γ (2008Jo07). Q_t=3.21 *8* (2008Jo07).
5407.6[#] *5*	(27/2$^-$)	F(τ)=0.901 *7* for 1320γ (2008Jo07). Q_t=2.90 *8* (2008Jo07).
5493.4[a] *22*	(27/2$^+$)	E(level): this level is not included in Adopted Levels, Gammas dataset, as the tentative 1354γ is not confirmed in ^{40}Ca(^{40}Ca,α2pnγ) (2010St05).
5504.6 *6*		
5615.2[&] *5*	29/2$^+$	F(τ)=0.891 *2* for 1214γ (2008Jo07). Q_t=2.39 *8* (2008Jo07).
6027.4[@] *5*	(29/2$^-$)	F(τ)=0.901 *2* for 1382γ (2008Jo07). Q_t=3.16 *8* (2008Jo07).
6567.6[#] *6*	(31/2$^-$)	F(τ)=0.903 *4* for 1160γ (2008Jo07). Q_t=2.85 *8* (2008Jo07).
6700[a] *4*	(31/2$^+$)	
6812.2[&] *6*	(33/2$^+$)	F(τ)=0.893 *2* for 1197γ (2008Jo07). Q_t=2.34 *8* (2008Jo07).
7002.1 *9*		
7330.4[@] *6*	(33/2$^-$)	F(τ)=0.911 *3* for 1303γ (2008Jo07). Q_t=3.10 *8* (2008Jo07).
7890.7[#] *6*	(35/2$^-$)	F(τ)=0.909 *7* for 1323γ (2008Jo07). Q_t=2.78 *8* (2008Jo07).
8109.2[&] *7*	(37/2$^+$)	F(τ)=0.904 *3* for 1297γ (2008Jo07). Q_t=2.27 *8* (2008Jo07).
8741.4[@] *9*	(37/2$^-$)	F(τ)=0.926 *4* for 1411γ (2008Jo07). Q_t=3.03 *8* (2008Jo07).
9400.7[#] *7*	(39/2$^-$)	F(τ)=0.931 *4* for 1510γ (2008Jo07). Q_t=2.70 *8* (2008Jo07).
9534.2[&] *8*	(41/2$^+$)	F(τ)=0.918 *3* for 1425γ (2008Jo07). Q_t=2.19 *8* (2008Jo07).
10356.6[@] *10*	(41/2$^-$)	F(τ)=0.937 *4* for 1615γ (2008Jo07). Q_t=2.95 *8* (2008Jo07).
11105.6[#] *8*	(43/2$^-$)	F(τ)=0.957 *4* for 1705γ (2008Jo07). Q_t=2.50 *8* (2008Jo07).
11253.3[&] *10*	(45/2$^+$)	F(τ)=0.947 *3* for 1719γ (2008Jo07). Q_t=1.99 *8* (2008Jo07).
12099.7[@] *11*	(45/2$^-$)	F(τ)=0.946 *5* for 1743γ (2008Jo07). Q_t=2.85 *8* (2008Jo07).
12987.6[#] *10*	(47/2$^-$)	
13388.3[&] *15*	(49/2$^+$)	
13967.8[@] *13*	(49/2$^-$)	F(τ)=0.958 *6* for 1868γ (2008Jo07). Q_t=2.60 *8* (2008Jo07).
15031.5[#] *12*	(51/2$^-$)	

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^{40}Ca(^{36}Ar,2pnγ),(^{40}Ca,α2pnγ) 2002Ke03 (continued)

^{73}Kr Levels (continued)

E(level)[†]	J$^{\pi}$[‡]	E(level)[†]	J$^{\pi}$[‡]	E(level)[†]	J$^{\pi}$[‡]	E(level)[†]	J$^{\pi}$[‡]
16013[&] *6*	(53/2$^+$)	17334.6[#] *16*	(55/2$^-$)	19185[&] *10*	(57/2$^+$)	21930[@] *10*	(61/2$^-$)
16146.8[@] *15*	(53/2$^-$)	18768.9[@] *25*	(57/2$^-$)	20029.6[#] *19*	(59/2$^-$)	23237[#] *5*	(63/2$^-$)

[†] From least-squares fit to Eγ data.

[‡] As proposed by 2002Ke03, based on multipolarity and ΔJ assignments from their $\gamma\gamma(\theta)$(DCO) data, and band assignments.

[#] Band(a): Band based on 3/2$^-$,α=−1/2. At high spins, configuration=$\pi[((pf)^5 g^3_{9/2})]\otimes\nu[(pf)^6 g^3_{9/2}]$.

[@] Band(A): Band based on 5/2$^-$,α=+1/2. At high spins, configuration=$\pi[((pf)^5 g^3_{9/2})]\otimes\nu[(pf)^6 g^3_{9/2}]$.

[&] Band(B): Band based on 5/2$^+$,α=+1/2. At high spins, configuration=$\pi[((pf)^6 g^2_{9/2})]\otimes\nu[(pf)^6 g^3_{9/2}]$. This band is nearly prolate with ν5/2[422] as the dominant component; $\beta_2\approx$0.37 at low frequencies and $\beta_2\approx$0.30 after the $\pi g^2_{9/2}$ alignment, triaxial parameter γ=2-3° (2002Ke03).

[a] Band(b): Band based on (7/2$^+$),α=−1/2. At high spins, configuration=$\pi[((pf)^6 g^2_{9/2})]\otimes\nu[(pf)^6 g^3_{9/2}]$. See also comment for α=+1/2 signature partner. 2002Ke03 state that this band may be based on a different configuration.

γ(^{73}Kr)

With gates on stretched quadrupole transitions, average DCO values were ≈1.1 for stretched quadrupoles and ≈0.8 for stretched dipoles (2002Ke03).

E$_\gamma$[†]	I$_\gamma$[†]	E$_i$(level)	J$^{\pi}_i$	E$_f$	J$^{\pi}_f$	Mult.[#]	δ[@]	Comments
40.8[‡]		433.66	9/2$^+$	392.88	7/2$^-$			
65.8[‡]		433.66	9/2$^+$	367.83	5/2$^+$			
143.6		511.7	(7/2$^+$)	367.83	5/2$^+$			E$_\gamma$: from 1993Fr03, listed as 144 in figure 1 of 2002Ke03.
144.0 *1*	100 *5*	143.97	5/2$^-$	0.0	3/2$^-$	D		DCO=0.77 *11* Mult.: from DCO, expected to be M1 or M1(+E2) from ΔJ^{π}. I$_\gamma$: 100 *4*.
224 *1*		367.83	5/2$^+$	143.97	5/2$^-$			I$_\gamma$: 7 *2*.
249.0 *2*	23 *12*	392.88	7/2$^-$	143.97	5/2$^-$	(M1+E2)	+0.30 *9*	DCO=0.76 *6* δ: other: 0.76 *8* from E2/M1 γ-intensity ratio (2002Ke03). I$_\gamma$: 24 *6*. Iγ(249)/Iγ(393)=13.7 *12*/28.8 *12* (1993Mo14).
267.1 *3*	17 *5*	660.07	9/2$^-$	392.88	7/2$^-$	(M1+E2)	+0.77 *12*	DCO=0.63 *5* δ: other: 0.62 *11* from E2/M1 γ-intensity ratio (2002Ke03). I$_\gamma$: 6 *3*. Iγ(267)/Iγ(516)=13.3 *11*/32 *3* (1993Mo14).
343.6 *8*		1003.88	11/2$^-$	660.07	9/2$^-$	(M1+E2)	+1.05 *29*	δ: other: 1.06 *26* from E2/M1 γ-intensity ratio (2002Ke03). I$_\gamma$: 5 *2*.
367.8[‡]		367.83	5/2$^+$	0.0	3/2$^-$			Iγ(368)/Iγ(224)=27.0 *22*/47 *3* (1993Mo14).
368.4 *6*		1372.18	13/2$^-$	1003.88	11/2$^-$	(M1+E2)	+0.64 *23*	δ: other: 0.45 *15* from E2/M1 γ-intensity ratio (2002Ke03). I$_\gamma$: 4 *2*.
393 *1*	43 *6*	392.88	7/2$^-$	0.0	3/2$^-$	Q		DCO=0.97 *10* I$_\gamma$: 59 *2*.
419[&]		852.7?		433.66	9/2$^+$			E$_\gamma$: from 1993Fr03 only, not included in the Adopted Levels, Gammas dataset.

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^{40}Ca(^{36}Ar,2pnγ),(^{40}Ca,α2pnγ) 2002Ke03 (continued)

γ(^{73}Kr) (continued)

E_γ †	I_γ †	E_i(level)	J_i^π	E_f	J_f^π	Mult.#	δ@	Comments
516.1 *1*	68 *12*	660.07	$9/2^-$	143.97	$5/2^-$	Q		DCO=0.91 *7* I_γ: 68 *2*.
554.3 *5*		1066.0	$11/2^+$	511.7	$(7/2^+)$			I_γ: 7 *4*.
611.0 *1*	68 *11*	1003.88	$11/2^-$	392.88	$7/2^-$	Q		DCO=1.26 *18* I_γ: 58 *6*.
632.3 *4*		1066.0	$11/2^+$	433.66	$9/2^+$			I_γ: 16 3.
712.1 *1*	67 *10*	1372.18	$13/2^-$	660.07	$9/2^-$	Q		DCO=1.17 *10* I_γ: 71 *14*.
714.3 *4*		1892.1	$15/2^+$	1177.77	$13/2^+$	(M1+E2)	−0.42 *21*	δ: other: 0.65 *20* from E2/M1 γ-intensity ratio (2002Ke03). I_γ: 12 *5*.
744.1 *2*	63 *7*	1177.77	$13/2^+$	433.66	$9/2^+$	Q		DCO=1.00 *20* I_γ: 99 *4*.
826.2 *5*		1892.1	$15/2^+$	1066.0	$11/2^+$			I_γ: <20.
826.7 *2*	66 *8*	1830.6	$15/2^-$	1003.88	$11/2^-$	Q		DCO=1.4 *3* I_γ: 61 *4*.
867.8 *4*		2937.5	$19/2^+$	2069.8	$17/2^+$	(M1+E2)	−0.29 *25*	δ: other: 0.42 *12* from E2/M1 γ-intensity ratio (2002Ke03). I_γ: 14 *5*.
892.0 *2*	54 *7*	2069.8	$17/2^+$	1177.77	$13/2^+$	Q		DCO=0.94 *5* I_γ: 95 *4*.
913.0 *1*	63 *10*	2285.18	$17/2^-$	1372.18	$13/2^-$	Q		DCO=0.94 *9* I_γ: 64 *4*.
984 *1*		4139.3	$(23/2^+)$	3155.2	$21/2^+$			I_γ: <5.
1034.0 *2*	63 *9*	2864.6	$(19/2^-)$	1830.6	$15/2^-$			I_γ: 63 *6*.
1045.3 *6*		2937.5	$19/2^+$	1892.1	$15/2^+$			I_γ: <20.
1085.4 *2*	49 *6*	3155.2	$21/2^+$	2069.8	$17/2^+$	Q		DCO=1.7 *2* I_γ: 75 *4*.
1097.1 *1*	56 *8*	3382.29	$21/2^-$	2285.18	$17/2^-$	(Q)		DCO=0.90 *13* I_γ: 61 *2*.
1160.0 *3*	36 *6*	6567.6	$(31/2^-)$	5407.6	$(27/2^-)$			I_γ: 14 *2*.
1197.0 *2*	30 *6*	6812.2	$(33/2^+)$	5615.2	$29/2^+$			I_γ: 33 *4*.
1202 *1*		4139.3	$(23/2^+)$	2937.5	$19/2^+$			I_γ: <10.
1207& *3*		6700	$(31/2^+)$	5493.4	$(27/2^+)$			I_γ: <5. This γ is placed from a 5342, $(27/2^+)$ level in Adopted dataset as in ^{40}Ca(^{40}Ca,α2pnγ) (2010St05).
1213.9 *3*	40 *5*	5615.2	$29/2^+$	4401.3	$25/2^+$	Q		DCO=1.6 *4* I_γ: 37 *4*.
1223.1 *2*	55 *7*	4087.7	$(23/2^-)$	2864.6	$(19/2^-)$	Q		DCO=1.7 *3* I_γ: 42 *4*.
1246.1 *2*	35 *6*	4401.3	$25/2^+$	3155.2	$21/2^+$	(Q)		DCO=0.90 *20* I_γ: 48 *4*.
1263.1 *2*	52 *8*	4645.4	$25/2^-$	3382.29	$21/2^-$	Q		DCO=1.22 *15* I_γ: 34 *4*.
1297.0 *3*	28 *4*	8109.2	$(37/2^+)$	6812.2	$(33/2^+)$	Q		DCO=2.1 *5* I_γ: 19 *4*.
1303.0 *3*	29 *6*	7330.4	$(33/2^-)$	6027.4	$(29/2^-)$	Q		DCO=1.4 *3* I_γ: 9 *2*.
1319.9 *2*	29 *6*	5407.6	$(27/2^-)$	4087.7	$(23/2^-)$			I_γ: 18 *6*.
1323.1 *2*	42 *7*	7890.7	$(35/2^-)$	6567.6	$(31/2^-)$	Q		DCO=1.04 *13* I_γ: 11 *6*.
1354& *2*		5493.4	$(27/2^+)$	4139.3	$(23/2^+)$			I_γ: <5.
1382.0 *4*	40 *8*	6027.4	$(29/2^-)$	4645.4	$25/2^-$			I_γ: 17 *4*.
1411.0 *6*	18 *5*	8741.4	$(37/2^-)$	7330.4	$(33/2^-)$	Q		DCO=1.03 *16* I_γ: 10 *2*.

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^{40}Ca(^{36}Ar,2pnγ),(^{40}Ca,α2pnγ) 2002Ke03 (continued)

γ(^{73}Kr) (continued)

E_γ †	I_γ †	E_i(level)	J^π_i	E_f	J^π_f	Mult.#	Comments
1416.9 *4*	17 *4*	5504.6		4087.7	(23/2⁻)		I_γ: 12 *2*.
1425.0 *5*	27 *4*	9534.2	(41/2⁺)	8109.2	(37/2⁺)	Q	DCO=1.5 *3* I_γ: 11 *2*.
1497.5 *7*	11 *3*	7002.1		5504.6			
1510.0 *3*	24 *5*	9400.7	(39/2⁻)	7890.7	(35/2⁻)	Q	DCO=1.4 *3*
1615.1 *4*	14 *5*	10356.6	(41/2⁻)	8741.4	(37/2⁻)		
1704.8 *5*	18 *3*	11105.6	(43/2⁻)	9400.7	(39/2⁻)		
1719.0 *6*	11 *3*	11253.3	(45/2⁺)	9534.2	(41/2⁺)		
1743.1 *5*	11 *2*	12099.7	(45/2⁻)	10356.6	(41/2⁻)		
1868.1 *7*	10 *3*	13967.8	(49/2⁻)	12099.7	(45/2⁻)		
1882.0 *6*	14 *3*	12987.6	(47/2⁻)	11105.6	(43/2⁻)		
2043.9 *6*	11 *2*	15031.5	(51/2⁻)	12987.6	(47/2⁻)		
2135 *1*	6 *2*	13388.3	(49/2⁺)	11253.3	(45/2⁺)		
2179.0 *7*	7 *3*	16146.8	(53/2⁻)	13967.8	(49/2⁻)		
2303 *1*	5 *2*	17334.6	(55/2⁻)	15031.5	(51/2⁻)		
2622 *2*	3 *2*	18768.9	(57/2⁻)	16146.8	(53/2⁻)		
2625 *5*	4 *1*	16013	(53/2⁺)	13388.3	(49/2⁺)		
2695 *1*	5 *1*	20029.6	(59/2⁻)	17334.6	(55/2⁻)		
3161 *9*	1 *1*	21930	(61/2⁻)	18768.9	(57/2⁻)		
3172 *8*	1 *1*	19185	(57/2⁺)	16013	(53/2⁺)		
3207 *4*	1 *1*	23237	(63/2⁻)	20029.6	(59/2⁻)		

† From (^{36}Ar,2pnγ) reaction (2002Ke03), unless otherwise noted. Corresponding Iγ values from ^{40}Ca(^{40}Ca,α2pnγ) (2002Ke03) are given under comments.

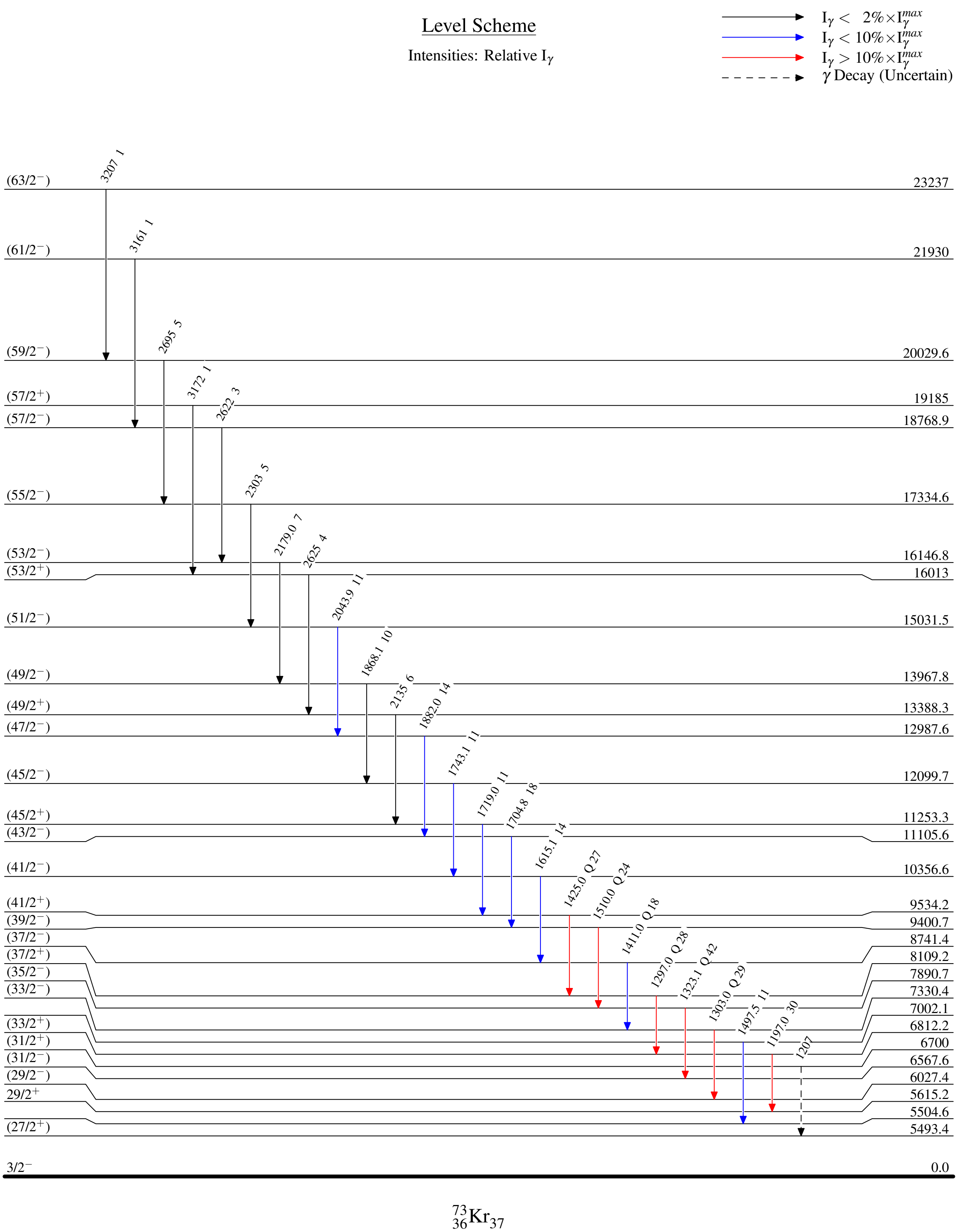
‡ From 2000Ch07, uncertainty of 0.1 keV assumed by the evaluator.

Assigned by evaluators based on DCO data in 2002Ke03. Mult=Q indicates ΔJ=2 stretched quadrupole (most likely E2) transition.

@ From angular distribution data (2002Ke03), as displayed in authors′ Fig. 5. Authors also deduced δ(E2/M1) from E2/M1 γ-intensity ratios, as given in their Table II, and in comments here.

& Placement of transition in the level scheme is uncertain.

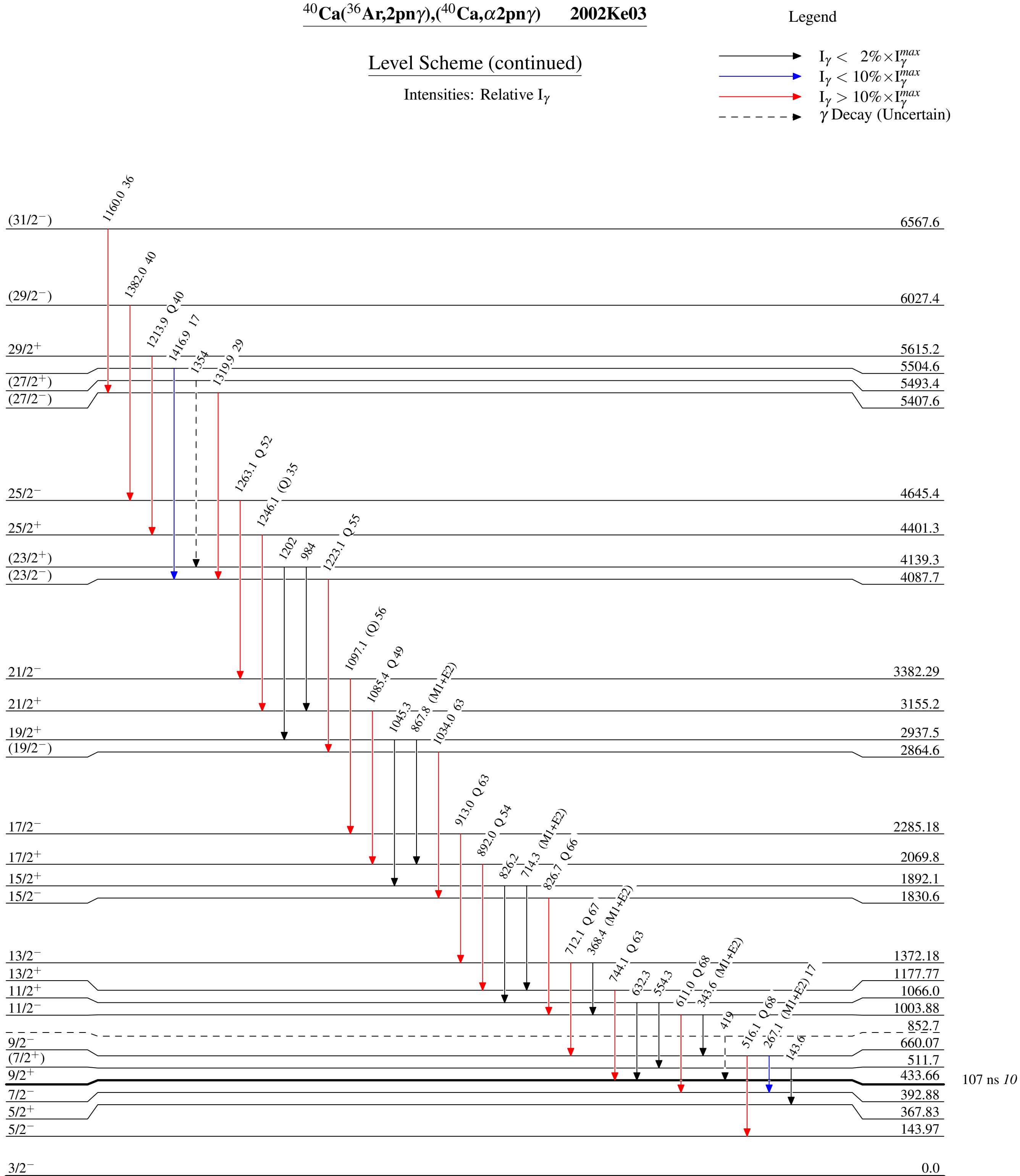
$^{40}Ca(^{36}Ar,2pn\gamma),(^{40}Ca,\alpha 2pn\gamma)$ 2002Ke03



^{40}Ca(^{36}Ar,2pnγ),(^{40}Ca,α2pnγ) 2002Ke03

Level Scheme (continued)

Intensities: Relative I_γ

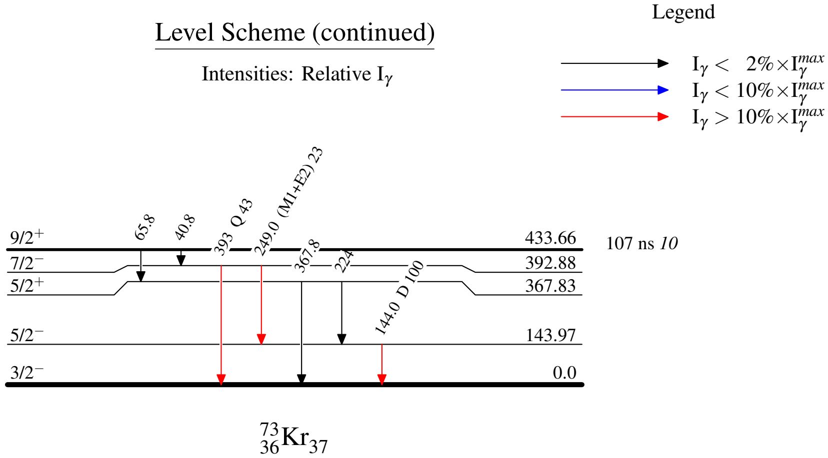


$^{73}_{36}Kr_{37}$

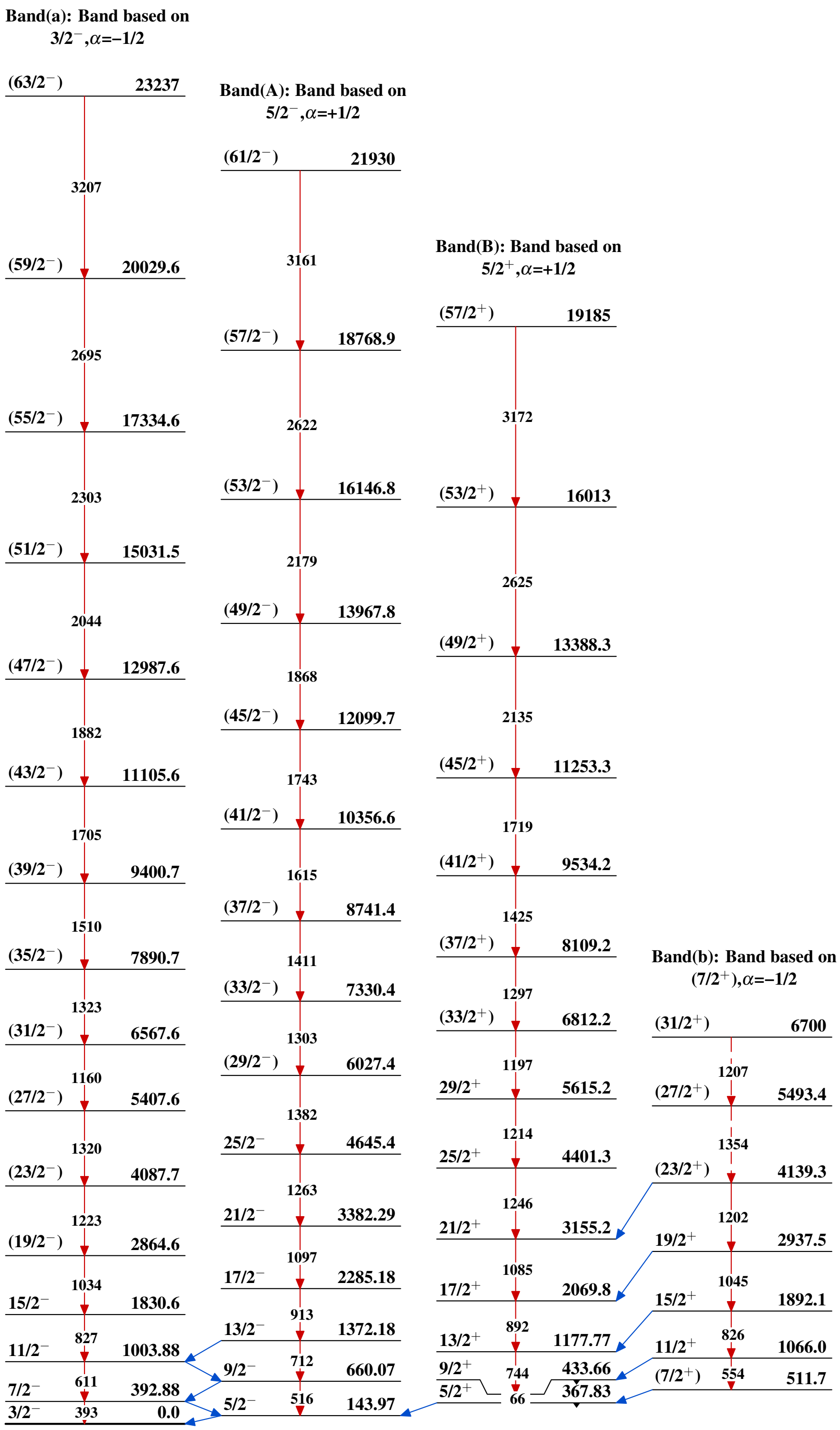
$^{40}Ca(^{36}Ar,2pn\gamma),(^{40}Ca,\alpha 2pn\gamma)$ 2002Ke03

Level Scheme (continued)

Intensities: Relative I_γ



$^{40}Ca(^{36}Ar,2pn\gamma),(^{40}Ca,\alpha 2pn\gamma)$ 2002Ke03



$^{73}_{36}Kr_{37}$