^{65}Cu(^{36}S,p2nγ) 1998Kh01,2000Kh02

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Jun Chen, Balraj Singh	NDS 164, 1 (2020)	15-Feb-2020

1998Kh01 (also 1993Re09,1997Kh03): E=142 MeV ^{36}S beam was produced from the 88-inch cyclotron at LBNL. Target was made of two stacked self-supporting ^{65}Cu foils (~0.5 mg/cm^2 each). γ rays were detected with the Gammasphere of 36 large CSGe detectors. Measured Eγ, Iγ, $\gamma\gamma$-coin, $\gamma\gamma\gamma$-coin, (particle)γ-coin, $\gamma\gamma$(DCO). Deduced levels, J, π, band structures, γ-ray multipolarities. Comparisons with shell-model calculations.

2000Kh02: E=142 MeV ^{36}S beam was produced from the Argonne Tandem Superconducting Linear Accelerator System (ATLAS). Target was a stretched, self-supporting, 1 mg/cm^2 thick ^{65}Cu foil. γ rays were detected with the Argonne-Notre Dame BGO γ-ray facility consisting of 12 Compton-suppressed Ge detectors. Measured Eγ, Iγ, recoil-distance. Deduced lifetimes, transition strengths. Comparisons with shell-model calculations. Same authors as 1998Kh01.

The level scheme (high-spin and high-energy region) proposed by 1998Kh01 differs significantly from that proposed by 2000Ti07 in ^{70}Zn(^{36}S,α4nγ) using EUROGAM-2 spectrometer with more counting statistics. Only in the low-energy region, the two level schemes are in agreement. About 30 γ rays out of a total of about 60 γ rays and a large number of levels were not confirmed by 2000Ti07. The ordering of the some of the main cascades is also different in the two studies. The level scheme in 2000Ti07 is adopted by evaluators (see comments in Adopted Levels).

The 1475-1482-877-826-726-1070-1032-821-848 cascade built over the first 8$^+$ state at 3128 is established (by 2000Ti07) as 878-1474-1481-826-1032-1070-849-822-725 cascade. Some of the transitions in band #2 of 1998Kh01 were seen by 2000Ti07 but their placement as proposed by 1998Kh01 could not be confirmed by 2000Ti07. See comments also in ^{70}Zn(^{36}S,α4nγ) (2000Ti07).

^{98}Ru Levels

E(level)[†]	J$^\pi$[a]	T$_{1/2}$[b]	Comments
0.0[c]	0$^+$		
652.9[c] *4*	2$^+$	5.5 ps *8*	
1399.1[c] *6*	4$^+$	7.6 ps *16*	
2224.4[c] *7*	6$^+$	4.3 ps *5*	
3128.7[c] *8*	8$^+$	13.9 ps *21*	
3193.5[d] *8*	(7$^-$)		J$^\pi$: 8$^+$ in Adopted Levels.
3977.1[c] *9*	(10$^+$)	4.6 ps *4*	E(level): 5521, 13$^-$ level in the Adopted Levels.
4004.2[d] *8*	(9$^-$)	14.3 ps *21*	J$^\pi$: 10$^+$ in the Adopted Levels.
4798.4[‡c] *10*	(12$^+$)	6.4 ps *5*	E(level): 4673, 11$^-$ level in the Adopted Levels.
4804.5[‡&d] *10*	(11$^-$)	2.8 ps *3*	E(level),T$_{1/2}$: 800γ is unplaced in 2000Ti07.
5799.6[&d] *10*	(13$^-$)	≤1.6 ps	E(level),T$_{1/2}$: 995γ is unplaced in 2000Ti07.
5830.6[c] *11*	(14$^+$)	1.46 ps *14*	E(level): 7623, 17$^-$ level in the Adopted Levels.
6900.7[c] *12*	(16$^+$)	3.1 ps *8*	E(level): 6591, 15$^-$ level in the Adopted Levels.
7030.0[&d] *11*	(15$^-$)		
7626.4[c] *12*	(18$^+$)	≤6.0 ps	E(level): 3851, 9$^-$ level in the Adopted Levels.
8317.3[&d] *12*	(17$^-$)		
8452.5[‡c] *13*	(20$^+$)		E(level): 8450, 19$^-$ level in the Adopted Levels.
9329.2[c] *14*	(22$^+$)		E(level): 12282, (25$^-$) level in the Adopted Levels.
9721.0[&d] *12*	(19$^-$)		
10716.5[&d] *13*	(20$^-$)		
10810.8[c] *14*	(24$^+$)		E(level): 9930, (21$^-$) level in the Adopted Levels.
11088.0 *15*	(26$^+$)		E(level): 6869, 16$^+$ level in the Adopted Levels.
11210.2 *15*	(25$^+$)		E(level): 11405, (23$^-$) level in the Adopted Levels.
11628.6[d] *15*	(21$^-$)		E(level): 4914, 12$^+$ level in the Adopted Levels.
12099.0 *15*	(26$^+$)		E(level): 15499, with no J^π in the Adopted Levels.
12285.8[#c] *15*	(26$^+$)		E(level): 11006, (22$^-$) level in the Adopted Levels.

Continued on next page (footnotes at end of table)

^{65}Cu(^{36}S,p2nγ) 1998Kh01,2000Kh02 (continued)

^{98}Ru Levels (continued)

E(level)†	Jπa	Comments
12533.6d 15	(22−)	E(level): 5819, 14+ level in the Adopted Levels.
12781& 2	(26+)	
12940.5d 15	(23−)	5626 level in the Adopted Levels.
13295& 2	(27+)	
13310.1c 15	(28+)	15500, with no J^π in the Adopted Levels.
13566.9& 15	(27+)	
13751.1& 15	(28+)	
13810.2& 15	(29+)	
13957.7&d 15	(24−)	
14341& 2	(28+)	
14411& 2	(28+)	
14519& 2	(24−)	
14947.5d 15	(25−)	4989, (12+) in the Adopted Levels.
15009.8& 15	(28+)	
15048c 2	(30+)	17238, with no J^π in the Adopted Levels.
15076& 2	(29+)	
15173& 2	(30+)	
15180.9& 15	(25−)	
15236& 2	(28+)	
15375& 2	(30+)	
15466.1& 15	(29+)	
15470& 2	(30+)	
15637& 2	(30+)	
15997.6d 15	(27−)	6870, 16+ in the Adopted Levels.
16054.7& 15	(27−)	
16720& 2	(26−)	
17240c 2	(32+)	14476, with no J^π in the Adopted Levels.
17598& 2	(32+)	
18282& 2	(29−)	
19029&c 2	(34+)	
21244?@&c 3	(36+)	
23425c 3	(38+)	17592, with no J^π in the Adopted Levels.

† From a least-squares fit to γ-ray energies. Level energies are systematically higher as compared to those in Adopted Levels due to more precise Eγ values adopted from other datasets for transitions from low-lying levels.
‡ Large intensity imbalance at this level, incoming γ-intensity is 30% to 100% larger than outgoing intensity.
# Non-yrast (26+) level (1998Kh01).
@ The ordering of 2181-2215 is not established (1998Kh01). Reverse ordering leads to E(level)=21210.
& Level is not listed in the Adopted Levels, as it is not confirmed in a later higher statistics work of 2000Ti07.
a From 1998Kh01, based on γγ(DCO) data and band associations. The assignments should be considered as tentative where the γ-ray intensities are very low and no γγ(DCO) data are available.
b From recoil-distance Doppler-shift method (RDDS) in 2000Kh02.
c Band(A): g.s. band.
d Band(B): Band based on (7−).

^{65}Cu(^{36}S,p2nγ) 1998Kh01,2000Kh02 (continued)

$\gamma(^{98}Ru)$

Directional correlation ratios DCO=Iγ(backward)/Iγ(90°) (1998Kh01).

E_γ [†]	I_γ [&]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[a]	Comments
277.2 *4*	≤1	11088.0	(26$^+$)	10810.8	(24$^+$)		
399.4 *4*	10.0 *10*	11210.2	(25$^+$)	10810.8	(24$^+$)	(D)	DCO=1.6 *2* 1075.6-399.4 cascade is reversed in 2000Ti07.
406.9 *4*	1.5 *3*	12940.5	(23$^-$)	12533.6	(22$^-$)		
456.3[‡] *4*	≤1	15466.1	(29$^+$)	15009.8	(28$^+$)		
500.1[‡] *4*	≤1	13810.2	(29$^+$)	13310.1	(28$^+$)		
652.9 *4*	100 *10*	652.9	2$^+$	0.0	0$^+$	E2	DCO=1.9 *2*
725.7[@] *4*	22.0 *22*	7626.4	(18$^+$)	6900.7	(16$^+$)	(E2)	DCO=2.0 *3*
746.2 *4*	81 *8*	1399.1	4$^+$	652.9	2$^+$	E2	DCO=1.8 *2*
800.3[#] *4*	5.5 *9*	4804.5	(11$^-$)	4004.2	(9$^-$)	(E2)	DCO=1.9 *3*
810.9 *4*	2.5 *10*	4004.2	(9$^-$)	3193.5	(7$^-$)	(E2)	
821.3[@] *4*	23.0 *23*	4798.4	(12$^+$)	3977.1	(10$^+$)	(E2)	DCO=2.1 *2*
825.3 *4*	57 *6*	2224.4	6$^+$	1399.1	4$^+$	E2	DCO=2.0 *2*
826.1[@] *4*	19.0 *19*	8452.5	(20$^+$)	7626.4	(18$^+$)	(Q)	DCO=1.9 *2*
848.4[@] *4*	31 *3*	3977.1	(10$^+$)	3128.7	8$^+$	(E2)	DCO=2.1 *2*
875.2 *4*	1.0 *4*	4004.2	(9$^-$)	3128.7	8$^+$	(D)[b]	
876.7[@] *4*	28 *3*	9329.2	(22$^+$)	8452.5	(20$^+$)	(Q)	DCO=2.0 *2*
888.8 *4*	≤1	12099.0	(26$^+$)	11210.2	(25$^+$)		
904.1 *4*	26 *3*	3128.7	8$^+$	2224.4	6$^+$	E2	DCO=1.9 *2*
905.0 *4*	1.5 *4*	12533.6	(22$^-$)	11628.6	(21$^-$)		
912.1 *4*	3.0 *8*	11628.6	(21$^-$)	10716.5	(20$^-$)	(D)	DCO=1.5 *3*
969.4 *4*	7.1 *7*	3193.5	(7$^-$)	2224.4	6$^+$	(D)[b]	DCO=1.3 *3*
989.8 *4*	1.0 *6*	14947.5	(25$^-$)	13957.7	(24$^-$)		
995.1[‡] *4*	14.0 *14*	5799.6	(13$^-$)	4804.5	(11$^-$)	(E2)	DCO=2.0 *2*
995.4[#] *4*	4.1 *9*	10716.5	(20$^-$)	9721.0	(19$^-$)		
1017.2[‡] *4*	1.2 *5*	13957.7	(24$^-$)	12940.5	(23$^-$)		
1024.3 *4*	3.6 *8*	13310.1	(28$^+$)	12285.8	(26$^+$)	(Q)	DCO=2.1 *3*
1032.2[@] *4*	30 *3*	5830.6	(14$^+$)	4798.4	(12$^+$)	(E2)	DCO=1.9 *2*
1050.1 *4*	1.0 *2*	15997.6	(27$^-$)	14947.5	(25$^-$)		
1070.1[@] *4*	34 *3*	6900.7	(16$^+$)	5830.6	(14$^+$)	(E2)	DCO=2.0 *3*
1075.6 *4*	9.5 *9*	12285.8	(26$^+$)	11210.2	(25$^+$)	(D)	DCO=1.6 *2* 1075.6-399.4 cascade is reversed in 2000Ti07.
1107.2[‡] *4*	1.0 *4*	16054.7	(27$^-$)	14947.5	(25$^-$)		
1223.2[‡] *4*	≤1	15180.9	(25$^-$)	13957.7	(24$^-$)		
1230.4[#] *4*	10.0 *10*	7030.0	(15$^-$)	5799.6	(13$^-$)	(Q)	DCO=1.9 *3*
1281.1[‡] *4*	1.0 *4*	13566.9	(27$^+$)	12285.8	(26$^+$)		
1287.3[#] *4*	12.5 *13*	8317.3	(17$^-$)	7030.0	(15$^-$)	(Q)	DCO=2.2 *3*
1403.7[#] *4*	5.7 *8*	9721.0	(19$^-$)	8317.3	(17$^-$)	(Q)	DCO=2.1 *3*
1442.9[‡] *4*	1.0 *3*	15009.8	(28$^+$)	13566.9	(27$^+$)		
1465.3[‡] *4*	≤1	13751.1	(28$^+$)	12285.8	(26$^+$)		
1475.0[@] *4*	15.0 *15*	12285.8	(26$^+$)	10810.8	(24$^+$)	(Q)	DCO=2.1 *2*
1481.6[@] *4*	21.0 *21*	10810.8	(24$^+$)	9329.2	(22$^+$)	(Q)	DCO=1.9 *2*
1509[‡] *1*	≤1	15076	(29$^+$)	13566.9	(27$^+$)		
1738 *1*	5.2 *8*	15048	(30$^+$)	13310.1	(28$^+$)	(Q)	DCO=2.1 *3*
1773[‡] *1*	≤1	16720	(26$^-$)	14947.5	(25$^-$)		

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^{65}Cu(^{36}S,p2nγ) 1998Kh01,2000Kh02 (continued)

γ(^{98}Ru) (continued)

E_γ †	I_γ &	E_i(level)	J_i^π	E_f	J_f^π	E_γ †	I_γ &	E_i(level)	J_i^π	E_f	J_f^π
1789‡ *1*	1.3 *6*	19029	(34$^+$)	17240	(32$^+$)	2085‡ *1*	1.3 *5*	13295	(27$^+$)	11210.2	(25$^+$)
1827‡ *1*	1.0 *5*	15637	(30$^+$)	13810.2	(29$^+$)	2125‡ *1*	1.0 *5*	14411	(28$^+$)	12285.8	(26$^+$)
1863‡ *1*	1.0 *5*	15173	(30$^+$)	13310.1	(28$^+$)	2160‡ *1*	≤1	15470	(30$^+$)	13310.1	(28$^+$)
1941‡ *1*	≤1	15236	(28$^+$)	13295	(27$^+$)	2181 *1*	1.0 *5*	23425	(38$^+$)	21244?	(36$^+$)
1970‡ *1*	1.3 *5*	12781	(26$^+$)	10810.8	(24$^+$)	2192 *1*	1.0 *5*	17240	(32$^+$)	15048	(30$^+$)
1985‡ *1*	1.1 *5*	14519	(24$^-$)	12533.6	(22$^-$)	2215‡ *1*	1.0 *5*	21244?	(36$^+$)	19029	(34$^+$)
2055‡ *1*	1.0 *5*	14341	(28$^+$)	12285.8	(26$^+$)	2223‡ *1*	1.0 *5*	17598	(32$^+$)	15375	(30$^+$)
2065‡ *1*	1.2 *5*	15375	(30$^+$)	13310.1	(28$^+$)	2227‡ *1*	≤1	18282	(29$^-$)	16054.7	(27$^-$)

† Uncertainties are assigned by evaluators according to the statement in 1998Kh01 that $\Delta E\gamma \approx 0.4$ keV for $E\gamma<1500$ and ≈1 keV for $E\gamma>1500$.

‡ This γ is not confirmed by 2000Ti07 in ^{70}Zn(^{36}S,α4nγ), and is not given in the Adopted dataset.

800-995-1230-1287-1404 cascade seen by 2000Ti07 in coincidence with γ rays in two known bands, but exact placement as proposed by 1998Kh01 could not be confirmed by 2000Ti07.

@ The 1475-1482-877-826-726-1070-1032-821-848 cascade built over the first 8$^+$ state at 3128 in 1998Kh01 is revised by 2000Ti07 as 878-1474-1481-826-1032-1070-849-822-725, resulting in changes in energies of several levels listed here.

& 1998Kh01 give uncertainties explicitly only for several Iγ values with large uncertainties (>10%) and state that uncertainties are <10% for others. According to that, uncertainty of 10% is assigned by evaluators when not given explicitly in 1998Kh01.

a From 1998Kh01 based on DCO ratios, interpreted as Q with $\Delta J=2$ or D with $\Delta J=1$. RUL further limits Q to E2 for levels of known lifetime.

b Inconsistent with $\Delta J=2$, E2 in Adopted Gammas based on $\gamma(\theta)$ and ce data in (α,4nγ) (1981Du06), and $\gamma\gamma$(DCO) and γ(lin pol) data (^{36}S,α4nγ) (2000Ti07).

$^{65}Cu(^{36}S,p2n\gamma)$ **1998Kh01,2000Kh02**

Level Scheme

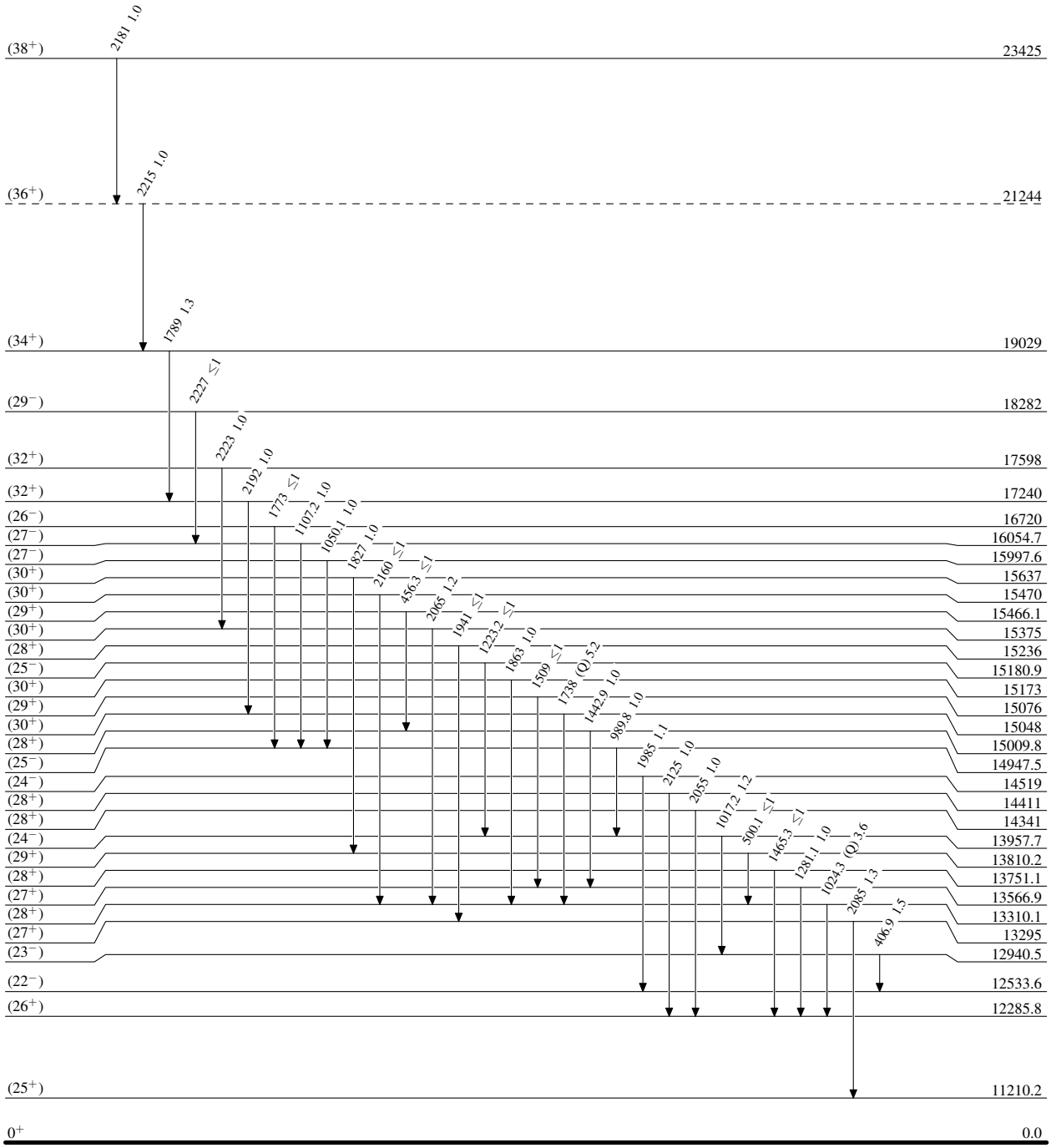
Intensities: Relative I_γ

Legend

$I_\gamma < 2\% \times I_\gamma^{max}$

$I_\gamma < 10\% \times I_\gamma^{max}$

$I_\gamma > 10\% \times I_\gamma^{max}$



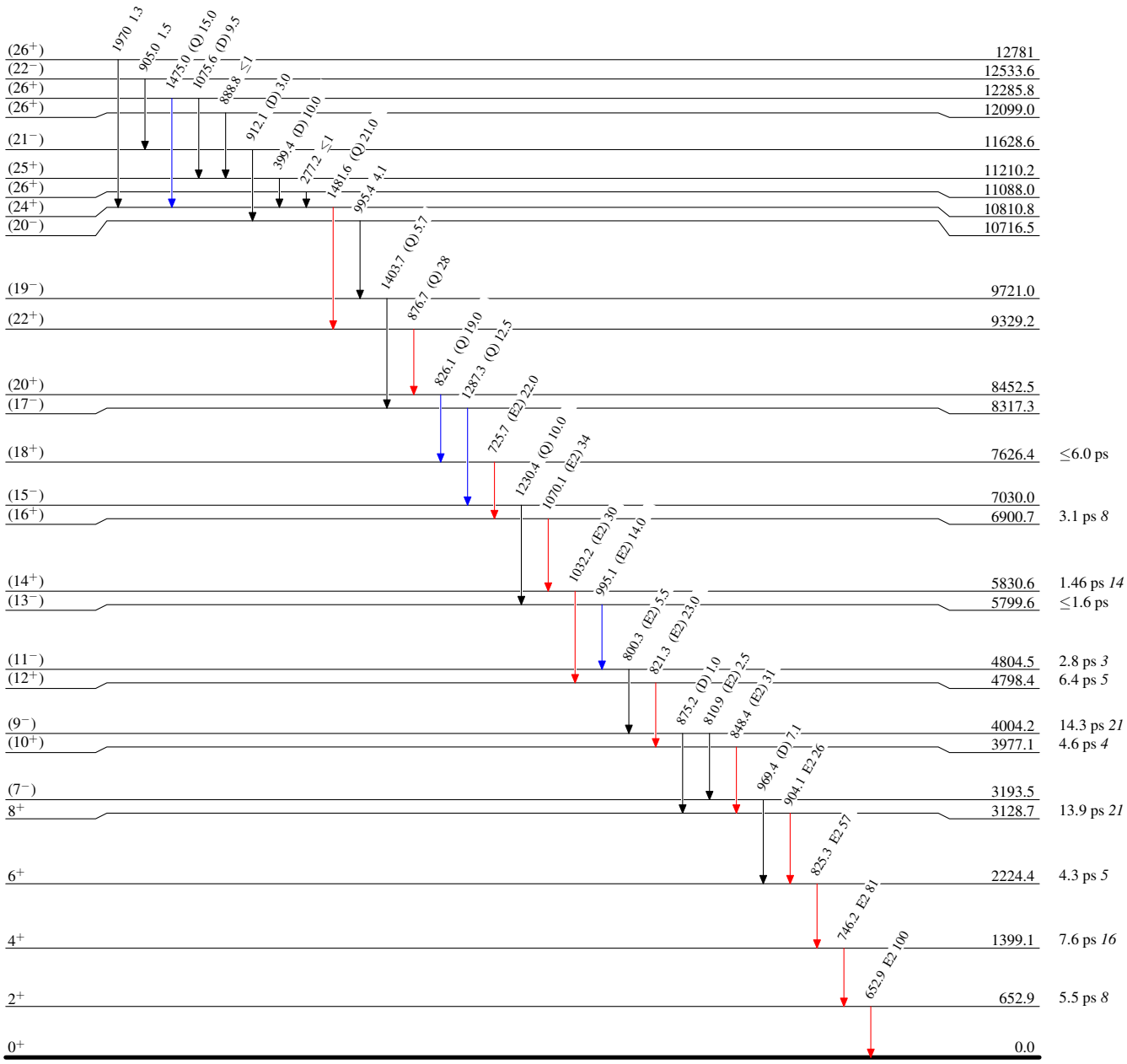
$^{98}_{44}Ru_{54}$

^{65}Cu(^{36}S,p2nγ) 1998Kh01,2000Kh02

Level Scheme (continued)

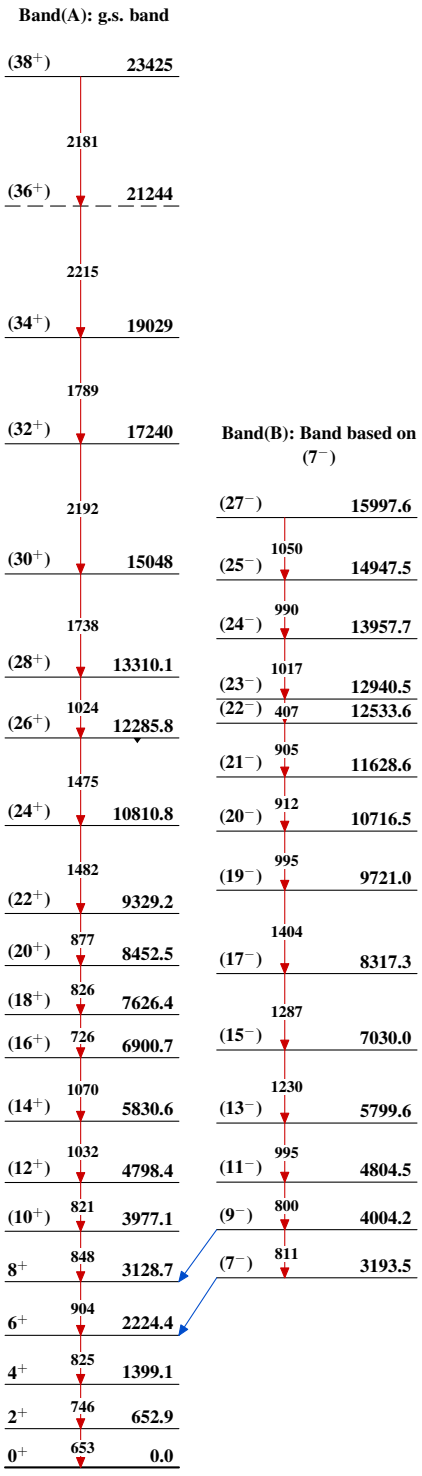
Intensities: Relative I_γ

Legend
$I_\gamma < 2\% \times I_\gamma^{max}$
$I_\gamma < 10\% \times I_\gamma^{max}$
$I_\gamma > 10\% \times I_\gamma^{max}$



$^{98}_{44}Ru_{54}$

$^{65}Cu(^{36}S,p2n\gamma)$ 1998Kh01,2000Kh02



$^{98}_{44}Ru_{54}$