## $^{72}$Ge(n,$\gamma$) E=thermal      1972Gr34,1972We10,1991Is01

### History

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

1972Gr34: thermal neutrons were produced from the IRT-M reactor at the I.V.Kurchatov Atomic Energy Institute. Target was isotopically enriched $^{72}$Ge (90.1%). $\gamma$ rays were detected with Ge(Li) detectors. Measured E$\gamma$, I$\gamma$. Deduced levels.

1972We10: thermal neutrons were produced from the FRM reactor at Technical University of Munich. Target was natural Ge. $\gamma$ rays were detected with two Ge(Li) detectors. Measured E$\gamma$, I$\gamma$, $\gamma\gamma$-coin. Deduced levels. Comparisons with available data.

1991Is01: thermal neutrons were produced from the McMaster University Nuclear Reactor. Targets were pure or mixed Ge powder. $\gamma$ rays were detected with Ge and NaI(Tl) detectors. Measured E$\gamma$, I$\gamma$. Deduced levels, S(n)=6782.94 5.

1972Ha74: thermal neutrons were produced from the 1-MW reactor R1 in Stockholm. Target was enriched Ge oxide (90.88% in $^{72}$Ge). $\gamma$ rays were detected with Ge(Li) and NaI detectors. Measured E$\gamma$, I$\gamma$, $\gamma\gamma$-coin. Deduced levels.

Other: 1971Jo15.

Level scheme is from 1972Gr34, unless otherwise noted. Due to little evidence to support the placements for some of the primary transitions from the 6783 capture state and no support from other reactions, levels without observed $\gamma$ decay proposed based on those placements, as well as those primary transitions, are considered questionable. $\gamma\gamma$ coincidence data are from 1972We10.

### $^{73}$Ge Levels

| E(level)[†] | J$^{\pi}$[#] | Comments |
|---|---|---|
| 0.0 | 9/2$^+$ | |
| 2.90?[‡] 5 | | |
| 13.28 5 | 5/2$^+$ | |
| 66.75 7 | 1/2$^-$ | |
| 68.82 5 | 7/2$^+$ | |
| 319.7?[‡] 9 | | |
| 353.58 21 | (5/2)$^-$ | |
| 364.02 10 | 3/2$^-$ | |
| 392.50 11 | 3/2$^-$ | |
| 499.01 21 | 7/2$^+$ | |
| 501.54? 24 | 5/2$^+$ | E(level): this level is not reported in any of the measurements in this study. It is placed here by the evaluators based on the facts that there could a doublet around E=500 keV as explained in Adopted Levels and that an unassigned 432.7$\gamma$ is observed by 1972We10 in coincidence with the 430.2$\gamma$ that could be also placed from the 932 level and thus matches a level at a different energy other than that of the 499 level on the basis of energy sums. |
| 523.6?[‡] 2 | | |
| 554.77 15 | 1/2$^+$ | |
| 597.62 23 | 5/2$^-$ | |
| 763.3?[‡] 2 | | |
| 915.51 25 | 5/2$^+$ | |
| 931.74 13 | (1/2$^+$) | |
| 951.9?[‡] 2 | | |
| 1042.54 11 | 3/2$^-$ | |
| 1131.91 13 | 1/2$^-$ | |
| 1264.44 11 | 3/2$^-$ | |
| 1339.9 5 | (5/2)$^+$ | E(level): from 1972We10 only, not reported in 1972Gr34 and 1972Ha74. |
| 1386.9 15 | (3/2$^-$) | |
| 1544.5? 15 | | |
| 1892.1? 5 | | |
| 2132.1 15 | 1/2$^-$,3/2$^-$ | |
| 2188.8 15 | 1/2$^-$,3/2$^-$ | |
| 2210.5? 15 | | |
| 2290.8? 15 | | |
| 2401.6? 15 | | |
| 2419.3? 15 | | |

### $^{72}$Ge(n,$\gamma$) E=thermal    1972Gr34,1972We10,1991Is01 (continued)

#### $^{73}$Ge Levels (continued)

| E(level)[†] | J$^{\pi}$[#] | Comments |
|---|---|---|
| 2483.5 *15* | 1/2$^-$,3/2$^-$ | |
| 2564.9 *15* | 1/2$^-$,3/2$^-$ | |
| 2706.2? *15* | | |
| 2720.5? *15* | | |
| 2774.8? *15* | | |
| 2884.5? *15* | | |
| 2930.5? *15* | | |
| (6782.96 *11*) | 1/2$^+$ | J$^{\pi}$: s-wave capture in 0$^+$. |

[†] From a least-squares fit to $\gamma$-ray energies.

[‡] Reported in 1972We10 only. These levels are not seen in other (n,$\gamma$) measurements or other reactions and thus are considered questionable.

[#] From Adopted Levels, unless otherwise noted.

#### $\gamma$($^{73}$Ge)

| E$_{\gamma}$[†] | I$_{\gamma}$[†@] | E$_i$(level) | J$_i^{\pi}$ | E$_f$ | J$_f^{\pi}$ | Mult. | Comments |
|---|---|---|---|---|---|---|---|
| 2.87[a] *5* | | 2.90? | | 0.0 | 9/2$^+$ | | |
| 10.32[a] *5* | | 13.28 | 5/2$^+$ | 2.90? | | | |
| 13.26 *5* | | 13.28 | 5/2$^+$ | 0.0 | 9/2$^+$ | | |
| 53.47 *5* | 2.45 | 66.75 | 1/2$^-$ | 13.28 | 5/2$^+$ | | |
| 55.42 *10* | | 68.82 | 7/2$^+$ | 13.28 | 5/2$^+$ | | I$_{\gamma}$: negligible from Fig. 3 of 1972We10. |
| 68.84 *5* | 3.80 | 68.82 | 7/2$^+$ | 0.0 | 9/2$^+$ | M1+E2 | E$_{\gamma}$: others: 68.746 *18* measured by 1971Jo15 via (n,$\gamma$) has been used in the averaging with other values measured by 1971Jo15 in Coulomb excitation; 68.9 *15* (1972Gr34). I$_{\gamma}$: other: 7.95 (1972Gr34). Mult.: from $\alpha$(exp)=0.81 *22* (1972We10) and RUL, with $\delta$=0.52 *13* deduced from $\alpha$(exp) using the BrIccMixing code. Note that with the adopted T$_{1/2}$=1.78 ns *11*, the deduced $\delta$ would give an unreasonably large B(E2)(W.u.)=1330, greatly exceeding RUL. |
| 191.0[a] *3* | | 554.77 | 1/2$^+$ | 364.02 | 3/2$^-$ | | |
| 203.9[a] *2* | 0.95 *15* | 523.6? | | 319.7? | | | |
| 233.6 *2* | 0.72 *15* | 597.62 | 5/2$^-$ | 364.02 | 3/2$^-$ | | |
| 253.01[a] *6* | 12.1 *25* | 319.7? | | 66.75 | 1/2$^-$ | | |
| 284.7 *2* | 2.67 *13* | 353.58 | (5/2)$^-$ | 68.82 | 7/2$^+$ | | E$_{\gamma}$,I$_{\gamma}$: from 1972We10, not placed in 1972We10. E$_{\gamma}$: placement from 1972Ha74; value from 1972We10 but not placed. Others: 284.9 *15* (1972Gr34), 283.7 *15* (1972Ha74). It is placed from 650.2 level by 1972Gr34. I$_{\gamma}$: others: 2.02 (1972Gr34), 1.54 (1972Ha74). |
| 297.24 *8* | 7.4 *3* | 364.02 | 3/2$^-$ | 66.75 | 1/2$^-$ | | E$_{\gamma}$: others: 297.3 *15* (1972Gr34), 296.6 *15* (1972Ha74). I$_{\gamma}$: other: 6.03 (1972Gr34), 6.14 (1972Ha74). |
| $^x$316.9 *2* | 0.90 *15* | | | | | | E$_{\gamma}$: placed from a 319.7 level by 1972We10, but energy doesn't match. |
| 326.0 *2* | 14.3 *5* | 392.50 | 3/2$^-$ | 66.75 | 1/2$^-$ | | E$_{\gamma}$: others: 325.6 *15* (1972Gr34), 325.1 *15* (1972Ha74). I$_{\gamma}$: other: 9.16 (1972Gr34), this value has been used by evaluators to re-normalize relative intensities in 1972Ha74. |
| 430.2[&] *2* | 2.4[&] *2* | 499.01 | 7/2$^+$ | 68.82 | 7/2$^+$ | | E$_{\gamma}$: placement from 1972Gr34 and 1972Ha74; value is from 1972We10 but not assigned to any nuclei. Others: E=431.4 *15* (1972Gr34), 430.9 *10* (1972Ha74). |

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$^{72}$**Ge(n,$\gamma$) E=thermal**     **1972Gr34,1972We10,1991Is01 (continued)**

$\underline{\gamma(^{73}\text{Ge}) \text{ (continued)}}$

| E$_\gamma$[†] | I$_\gamma$[†@] | E$_i$(level) | J$^\pi_i$ | E$_f$ | J$^\pi_f$ | Comments |
|---|---|---|---|---|---|---|
| | | | | | | Additional information 1. |
| | | | | | | I$_\gamma$: deduced by the evaluators from the ratio of relative intensities I(430.2$\gamma$)/I(297.24$\gamma$)=1.19 *8*/3.70 *11* and the absolute I(297.24$\gamma$)=7.44 *25* given in 1972We10. Others: 4.30 (1972Gr34), 3.90 (1972Ha74). |
| 430.2[&] *2* | 2.4[&] *2* | 931.74 | (1/2$^+$) | 501.54? | 5/2$^+$ | E$_\gamma$: placement suggested by 1972Ha74; value from 1972We10. I$_\gamma$: see comment for 430.2$\gamma$ placed from 499 level. |
| 432.7[a] *2* | 1.60 *14* | 501.54? | 5/2$^+$ | 68.82 | 7/2$^+$ | E$_\gamma$: tentatively placed by the evaluators on the basis of energy sums. E$_\gamma$ value is from 1972We10 only but not assigned to any nuclei and this $\gamma$ is seen in coincidence with 430.2$\gamma$ which could also be placed from the 932 level other than from the 499 level. |
| [x]474.0[‡] *15* | 2.65[‡] | | | | | |
| 485.3[‡] *15* | <2.9[‡] | 499.01 | 7/2$^+$ | 13.28 | 5/2$^+$ | I$_\gamma$: 2.9 is probably overestimated in 1972Gr34 considering it is not observed in 1972We10 and 1972Ha74. |
| 488.0[&a] *2* | 0.9[&] *3* | 501.54? | 5/2$^+$ | 13.28 | 5/2$^+$ | E$_\gamma$: tentatively placed by the evaluators on the basis of energy sums. E$_\gamma$ value is from 1972We10 only and it is also placed by 1972We10 from 555 level. |
| 488.0[&] *2* | 0.9[&] *3* | 554.77 | 1/2$^+$ | 66.75 | 1/2$^-$ | |
| [x]528.4[‡] *15* | 1.17[‡] | | | | | |
| 531.1[#a] *10* | 0.96[#] | 597.62 | 5/2$^-$ | 66.75 | 1/2$^-$ | E$_\gamma$: placement suggested by 1972Ha74, but possibly contaminated with 531$\gamma$ from $^{74}$Ge; see 1972Ha74 and 1972We10 (531.2 *2* is observed and assigned to $^{74}$Ge by 1972We10). 1972Ha74 also suggest a placement from 1131 level. |
| 541.8[a] *2* | 1.50 *7* | 554.77 | 1/2$^+$ | 13.28 | 5/2$^+$ | E$_\gamma$: others: 541.8 *15* (1972Gr34); 541.5 *10* placed from 1042 by 1972Ha74. I$_\gamma$: others: 1.80 (1972Gr34), 1.18 (1972Ha74). |
| 560.3[‡] *10* | 1.49[‡] | 915.51 | 5/2$^+$ | 353.58 | (5/2)$^-$ | E$_\gamma$: possibly contaminated with 562$\gamma$ from $^{71}$Ge; see 1972Gr34 and 1972We10. Others: 560.3 *15* (1972Gr34), 561.5 *10* (1972Ha74). I$_\gamma$: others: 1.49 (1972Gr34), 1.03 (1972Ha74). |
| 632.2[a] *2* | 1.20 *20* | 951.9? | | 319.7? | | |
| 650.1 *4* | 1.0 *9* | 1042.54 | 3/2$^-$ | 392.50 | 3/2$^-$ | E$_\gamma$: others: 650.2 *15* (1972Gr34, placed from a 650.2 level), 649.7 *10* (1972Ha74). I$_\gamma$: others: 1.90 (1972Gr34), 1.01 (1972Ha74). |
| 679.3 *2* | 0.60 *10* | 1042.54 | 3/2$^-$ | 364.02 | 3/2$^-$ | E$_\gamma$: other: 678.3 *10* (1972Ha74). I$_\gamma$: other: 0.98 (1972Ha74). |
| [x]707.5[#] *10* | 0.59[#] | | | | | E$_\gamma$: placed from a 1260 level by 1972Ha74. |
| 739.4 *6* | 1.81 *25* | 1131.91 | 1/2$^-$ | 392.50 | 3/2$^-$ | E$_\gamma$: others: 740.0 *15* (1972Gr34), 739.4 *10* (1972Ha74). I$_\gamma$: others: 3.60 (1972Gr34), 2.61 (1972Ha74). |
| [x]757.5[#] *10* | 2.07[#] | | | | | |
| 763.3[a] *2* | 1.75 *13* | 763.3? | | 0.0 | 9/2$^+$ | |
| 769.9 *6* | 0.26 *4* | 1131.91 | 1/2$^-$ | 364.02 | 3/2$^-$ | E$_\gamma$: others: 763.5 *10* (1972Ha74), 765.4 *15* (1972Gr34, placed from 1265 level). I$_\gamma$: others: 0.93 (1972Ha74); 3.81 from 1972Gr34 differs significantly. |
| 784.7[a] *3* | 0.96 *15* | 1339.9 | (5/2)$^+$ | 554.77 | 1/2$^+$ | |
| [x]913.7[#] *10* | 0.54[#] | | | | | |
| [x]961.6[#] *10* | 1.06[#] | | | | | |
| 975.6[#a] *10* | 0.70[#] | 1042.54 | 3/2$^-$ | 66.75 | 1/2$^-$ | |
| 975.9 *4* | 1.1 *3* | 1339.9 | (5/2)$^+$ | 364.02 | 3/2$^-$ | E$_\gamma$: others: 975.6 *10* (1972Ha74, placed from 1042 level), 978.4 *15* (1972Gr34, unplaced). I$_\gamma$: others: 2.00 (1972Gr34), 0.7 (1972Ha74). |

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### $^{72}$Ge(n,$\gamma$) E=thermal    1972Gr34,1972We10,1991Is01 (continued)

$\gamma(^{73}$Ge) (continued)

| $E_\gamma$[†] | $I_\gamma$[†@] | $E_i$(level) | $J_i^\pi$ | $E_f$ | $J_f^\pi$ | Comments |
|---|---|---|---|---|---|---|
| 1250.1[‡] 15 | 6.90[‡] | 1264.44 | 3/2$^-$ | 13.28 | 5/2$^+$ | |
| [x]3140.8[‡] 15 | 0.78[‡] | | | | | |
| [x]3334.5[‡] 15 | 0.52[‡] | | | | | |
| [x]3520.3[‡] 15 | 0.24[‡] | | | | | |
| [x]3651.6[‡] 15 | 0.28[‡] | | | | | |
| [x]3704.4[‡] 15 | 0.32[‡] | | | | | |
| [x]3789.9[‡] 15 | 0.44[‡] | | | | | |
| 3852.4[‡a] 15 | 0.33[‡] | (6782.96) | 1/2$^+$ | 2930.5? | | |
| 3898.4[‡a] 15 | 0.85[‡] | (6782.96) | 1/2$^+$ | 2884.5? | | $E_\gamma$,$I_\gamma$: other: 3896.3 20, $I_\gamma$=0.60 (1972Ha74). |
| 4008.0[‡a] 15 | 0.52[‡] | (6782.96) | 1/2$^+$ | 2774.8? | | $E_\gamma$,$I_\gamma$: other: 4007.2 20, $I_\gamma$=0.44 (1972Ha74). |
| 4062.3[‡a] 15 | 0.86[‡] | (6782.96) | 1/2$^+$ | 2720.5? | | $E_\gamma$,$I_\gamma$: other: 4063.1 20, $I_\gamma$=1.05 (1972Ha74). |
| 4076.6[‡a] 15 | 0.90[‡] | (6782.96) | 1/2$^+$ | 2706.2? | | $E_\gamma$,$I_\gamma$: other: 4077.4 20, $I_\gamma$=0.85 (1972Ha74). |
| 4217.9[‡] 15 | 0.83[‡] | (6782.96) | 1/2$^+$ | 2564.9 | 1/2$^-$,3/2$^-$ | $E_\gamma$,$I_\gamma$: other: 4216.7 20, $I_\gamma$=0.64 (1972Ha74). |
| 4299.3[‡] 15 | 0.29[‡] | (6782.96) | 1/2$^+$ | 2483.5 | 1/2$^-$,3/2$^-$ | |
| 4363.5[‡a] 15 | 0.45[‡] | (6782.96) | 1/2$^+$ | 2419.3? | | $E_\gamma$,$I_\gamma$: other: 4362.7 20, $I_\gamma$=0.41 (1972Ha74). |
| 4381.2[‡a] 15 | 0.33[‡] | (6782.96) | 1/2$^+$ | 2401.6? | | |
| 4492.0[‡a] 15 | 0.35[‡] | (6782.96) | 1/2$^+$ | 2290.8? | | $E_\gamma$,$I_\gamma$: other: 4495.3 20, $I_\gamma$=0.28 (1972Ha74). |
| 4572.3[‡a] 15 | 0.26[‡] | (6782.96) | 1/2$^+$ | 2210.5? | | |
| 4594.0[‡] 15 | 0.40[‡] | (6782.96) | 1/2$^+$ | 2188.8 | 1/2$^-$,3/2$^-$ | $E_\gamma$,$I_\gamma$: other: 4593.1 20, $I_\gamma$=0.39 (1972Ha74). |
| 4650.7[‡] 15 | 0.39[‡] | (6782.96) | 1/2$^+$ | 2132.1 | 1/2$^-$,3/2$^-$ | $E_\gamma$,$I_\gamma$: other: 4651.9 20, $I_\gamma$=0.26 (1972Ha74). |
| 4890.7[a] 4 | 0.62 18 | (6782.96) | 1/2$^+$ | 1892.1? | | $E_\gamma$,$I_\gamma$: other: 4890.9 15, $I_\gamma$=0.25 (1972Gr34). |
| 5238.3[‡a] 15 | 0.32[‡] | (6782.96) | 1/2$^+$ | 1544.5? | | |
| 5395.9[‡] 15 | 0.21[‡] | (6782.96) | 1/2$^+$ | 1386.9 | (3/2$^-$) | |
| 5518.30 4 | 9.4 9 | (6782.96) | 1/2$^+$ | 1264.44 | 3/2$^-$ | $E_\gamma$: others: 5518.1 11 (1972Gr34), 5521.1 20 (1972Ha74). $I_\gamma$: others: 4.86 (1972Gr34), 3.23 (1972Ha74). |
| 5650.86 8 | 4.1 4 | (6782.96) | 1/2$^+$ | 1131.91 | 1/2$^-$ | $E_\gamma$: others: 5650.8 11 (1972Gr34), 5650.7 20 (1972Ha74). $I_\gamma$: others: 2.14 (1972Gr34), 1.34 (1972Ha74). |
| 5740.21 4 | 4.8 4 | (6782.96) | 1/2$^+$ | 1042.54 | 3/2$^-$ | $E_\gamma$: others: 5740.8 11 (1972Gr34), 5738.9 20 (1972Ha74). $I_\gamma$: others: 2.35 (1972Gr34),1.59 (1972Ha74). |
| 5850.97 8 | 2.21 23 | (6782.96) | 1/2$^+$ | 931.74 | (1/2$^+$) | $E_\gamma$: others: 5850.9 11 (1972Gr34), 5851.2 20 (1972Ha74). $I_\gamma$: others: 1.15 (1972Gr34), 0.70 (1972Ha74). |
| 5867.12 23 | 0.75 24 | (6782.96) | 1/2$^+$ | 915.51 | 5/2$^+$ | $E_\gamma$: others: 5867.2 15 (1972Gr34), 5868.3 20 (1972Ha74). $I_\gamma$: others: 0.44 (1972Gr34), 0.18 (1972Ha74). |
| 6227.89 16 | 1.54 20 | (6782.96) | 1/2$^+$ | 554.77 | 1/2$^+$ | $E_\gamma$: others: 6227.7 15 (1972Gr34), 6228.1 20 (1972Ha74). $I_\gamma$: others: 0.73 (1972Gr34), 0.50 (1972Ha74). |
| 6390.17 4 | 10.5 9 | (6782.96) | 1/2$^+$ | 392.50 | 3/2$^-$ | $E_\gamma$: others: 6390.6 11 (1972Gr34), 6389.0 20 (1972Ha74). $I_\gamma$: others: 5.23 (1972Gr34), 2.39 (1972Ha74). |
| 6418.60 4 | 4.8 4 | (6782.96) | 1/2$^+$ | 364.02 | 3/2$^-$ | $E_\gamma$: others: 6419.0 11 (1972Gr34), 6417.4 20 (1972Ha74). $I_\gamma$: others: 2.93 (1972Gr34), 1.64 (1972Ha74). |
| 6716.9 15 | 1.43 14 | (6782.96) | 1/2$^+$ | 66.75 | 1/2$^-$ | $E_\gamma$: others: 6716.9 20 (1972Gr34), 6713.6 20 (1972Ha74). $I_\gamma$: others: 0.58 (1972Gr34), 0.73 (1972Ha74). |

[†] From 1991Is01 for the primary transitions from the 6783 capture state and from 1972We10 for other transitions, unless otherwise noted. Values of $I_\gamma$ are photon intensity per 100 neutron captures in $^{72}$Ge. For $I_\gamma$ from 1991Is01, a 9% error due to the uncertainty in $\sigma_\gamma$ of $^{72}$Ge has been added by the evaluators. Values are from the indicated source only if no other data are given under comments.

[‡] From 1972Gr34 where the value of the absolute $\gamma$ intensity of 1.49 per 100 neutron captures for the 7262.3$\gamma$ in $^{74}$Ge from

$^{72}$**Ge(n,$\gamma$) E=thermal     1972Gr34,1972We10,1991Is01 (continued)**

$\gamma(^{73}$Ge) (continued)

1969Ma31 was used for normalization.

[#] From renormalization of relative intensities in 1972Ha74 to I$\gamma$(325.6$\gamma$)=9.16 per 100 neutron captures given by 1972Gr34. The original values in 1972Ha74 are given relative to the sum=100 of observed transitions from the capture state.

[@] Intensity per 100 neutron captures.

[&] Multiply placed with undivided intensity.

[a] Placement of transition in the level scheme is uncertain.
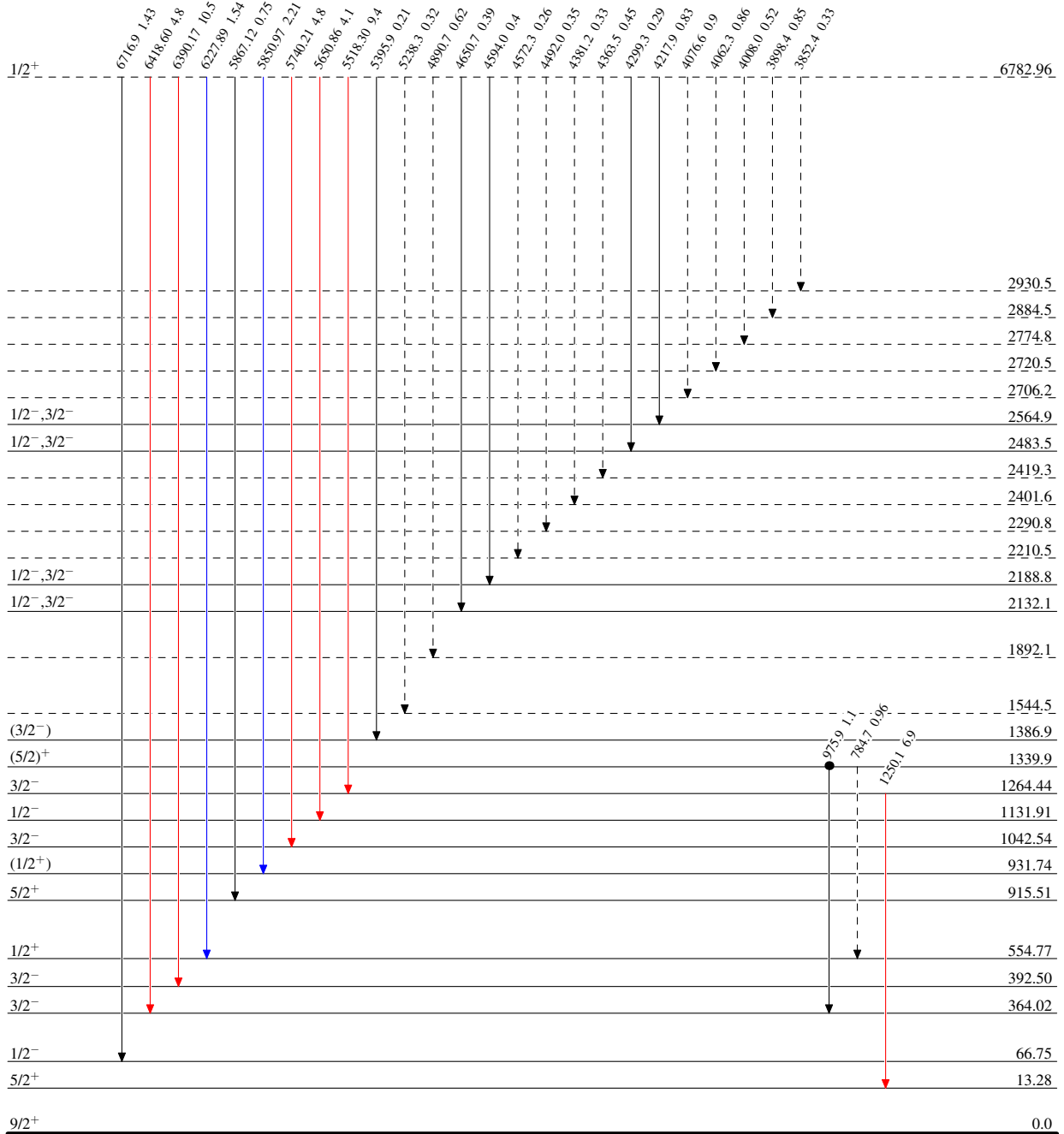
[x] $\gamma$ ray not placed in level scheme.

**$^{72}$Ge(n,$\gamma$) E=thermal     1972Gr34,1972We10,1991Is01**

<u>Level Scheme</u>

Intensities: Per 100 N-captures.

Legend

$I_\gamma <$ 2%$\times I_\gamma^{max}$
$I_\gamma <$ 10%$\times I_\gamma^{max}$
$I_\gamma >$ 10%$\times I_\gamma^{max}$
$\gamma$ Decay (Uncertain)
● Coincidence



$^{73}_{32}$Ge$_{41}$

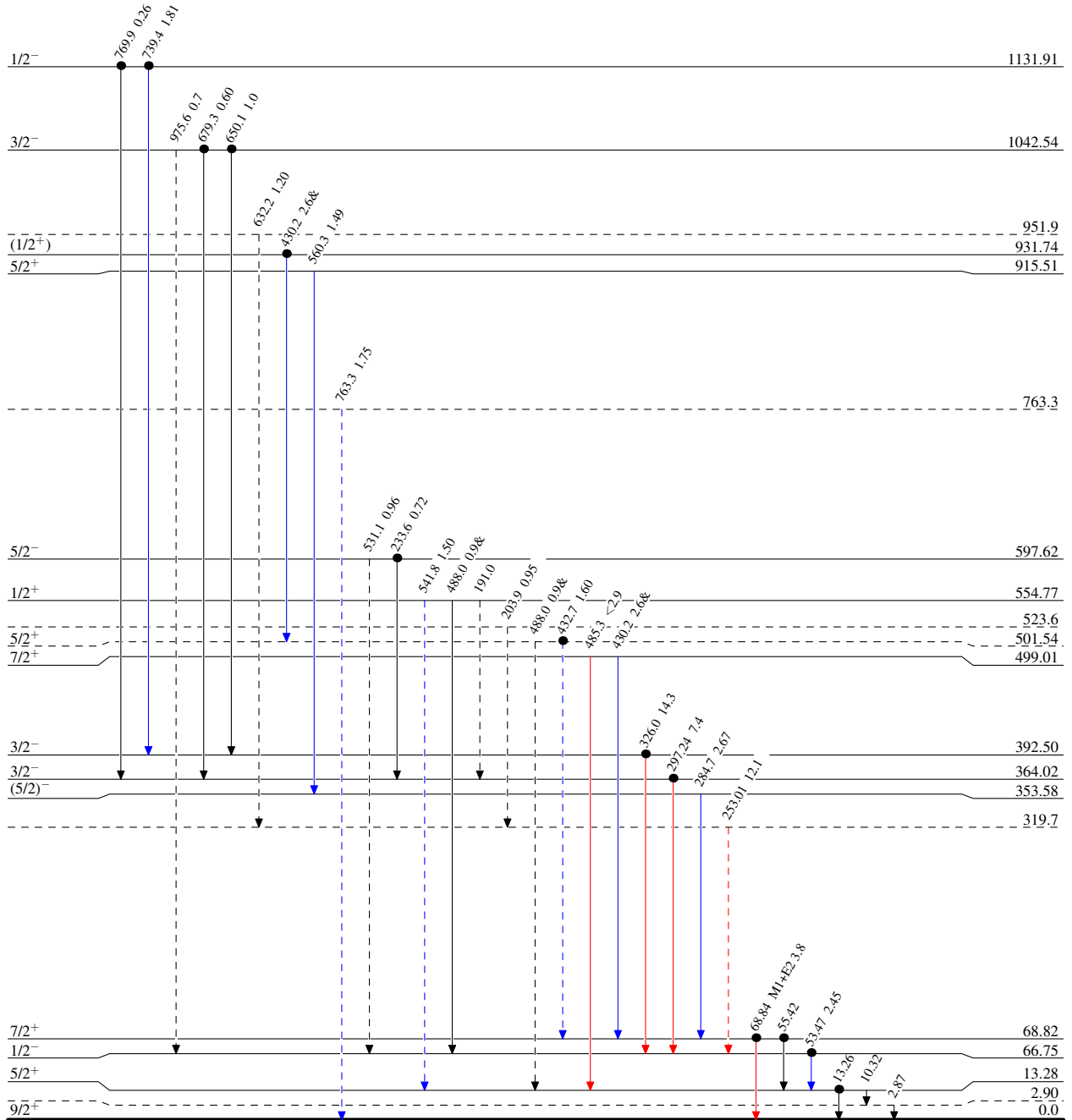**$^{72}$Ge(n,$\gamma$) E=thermal　　1972Gr34,1972We10,1991Is01**

Level Scheme (continued)

Intensities: Per 100 N-captures.
& Multiply placed: undivided intensity given

Legend

| | |
|---|---|
| → | $I_\gamma <\ \ 2\% \times I_\gamma^{max}$ |
| → | $I_\gamma < 10\% \times I_\gamma^{max}$ |
| → | $I_\gamma > 10\% \times I_\gamma^{max}$ |
| ⇢ | $\gamma$ Decay (Uncertain) |
| ● | Coincidence |

$^{73}_{32}$Ge$_{41}$