

<sup>40</sup>Ca(<sup>6</sup>Li,d) [1996Ya01](#),[1993Gu10](#),[1977Fu03](#)

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Jun Chen and Balraj Singh	NDS 190,1 (2023)	20-Jun-2023

Target <sup>40</sup>Ca J<sup>π</sup>=0<sup>+</sup>.

Also includes (pol <sup>6</sup>Li,d) in [1999Ve11](#).

[1996Ya01](#), [1998Ya21](#): E=37 MeV <sup>6</sup>Li<sup>2+</sup> beam of 100 enA produced from the AVF cyclotron at the Institute for Nuclear Study (INS) of the University of Tokyo. A 150 μg/cm<sup>2</sup> 99.8% enriched <sup>40</sup>Ca target on a gold backing. Deuterons analyzed with a QDD magnetic spectrograph (FWHM=70 keV) and detected by a ΔE-E telescope counter. Measured σ(E<sub>d</sub>,θ). Deduced levels, J<sup>π</sup>, L, spectroscopic factors from DWBA analysis. Previous data at E=50 MeV in [1990Ya09](#) and [1990Ya03](#) by the same authors are re-analyzed in [1996Ya01](#). Quoted data are mostly from [1996Ya01](#) while [1998Ya21](#) is a detailed review article about α-cluster features of <sup>44</sup>Ti structure.

[1993Gu10](#): E=60.1 MeV <sup>6</sup>Li<sup>2+</sup> beam of 20 enA produced from the VICKSI accelerator at the Hahn-Meitner Institute in Berlin. A 300 μg/cm<sup>2</sup> self-supporting <sup>40</sup>Ca target (99% enriched). Deuterons analyzed with a Q3D magnetic spectrometer (FWHM=100 keV) and identified by a focal plane detector. Measured σ(E<sub>d</sub>,θ). Deduced levels, J<sup>π</sup>, L, spectroscopic factors S<sub>α</sub> from DWBA analysis. [1993Gu10](#) (also [1992Ki18](#)) reanalyzed and deduced S<sub>α</sub> from previous data at E=28 MeV (from [1977Fu03](#)) and E=50 MeV (from [1990Ya09](#)).

[1977Fu03](#), [1975Fu02](#), [1974St03](#), [1972St21](#): E=28, 32 MeV <sup>6</sup>Li beam produced from the Rochester Van de Graaff accelerator. An enriched <sup>40</sup>Ca target. Deuterons analyzed with a magnetic spectrometer (FWHM=50-125 keV) and detected by a focal plane detector. Measured σ(E<sub>d</sub>,θ). Deduced levels, J<sup>π</sup>, L from DWBA analysis. See also [1980An16](#) and [1975An13](#) for g.s. strengths. Data reported in [1974St03](#) (also in [1977Fu03](#)) are for E=32 MeV; [1977Fu03](#) also report data for E=28 MeV.

Others:

[1999Ve11](#): E=34 MeV polarized <sup>6</sup>Li<sup>2+</sup> beam produced from the Super FN Tandem accelerator at Florida State University. Target of 0.9 mg/cm<sup>2</sup> of natural Ca sandwiched between 0.3 mg/cm<sup>2</sup> layers of Au. Two pairs of Si ΔE-E detector telescopes for detecting deuterons. Measured σ(E<sub>d</sub>,θ), analyzing powers iT<sub>11</sub>(θ). Deduced levels, J<sup>π</sup> for the g.s. and first 2<sup>+</sup> level.

[1995Ar15](#): E=22 MeV. Measured dα coin.

[1986Pi01](#), [1982Ne02](#): E=156 MeV <sup>6</sup>Li beam produced from the Karlsruhe Isochronous cyclotron. A 14 mg/cm<sup>2</sup> <sup>40</sup>Ca target. A ΔE-E telescope of silicon detectors. Measured (fragment)γ coin, σ(E<sub>d</sub>,θ).

[1982Ta20](#): E=76 MeV. Measured σ(E<sub>d</sub>,θ).

[1973De07](#): re-analysis of data in [1972St21](#). Deduced spectroscopic factors from DWBA analysis.

[1969Go17](#): E=25.8 MeV. Measured σ(E<sub>d</sub>,θ).

[1998Mi33](#): detailed review of α-cluster structure features for <sup>44</sup>Ti, as deduced from <sup>40</sup>Ca(α,α) and (<sup>6</sup>Li,d) reactions.

<sup>44</sup>Ti Levels

E(level) <sup>†</sup>	L <sup>‡</sup>	S <sub>α</sub> <sup>#</sup>	Comments
0 <sup>c</sup>	0	0.24	S <sub>α</sub> : other: 0.25 at E=37 MeV ( <a href="#">1996Ya01</a> ). Relative S <sub>α</sub> =1.0 ( <a href="#">1974St03</a> , <a href="#">1977Fu03</a> ).
1080 <sup>c</sup> 20	2	0.12	E(level): other: 1080 ( <a href="#">1996Ya01</a> , <a href="#">1993Gu10</a> ). S <sub>α</sub> : other: 0.13 at E=37 MeV ( <a href="#">1996Ya01</a> ). Relative S <sub>α</sub> =0.33 ( <a href="#">1974St03</a> ), 0.46 ( <a href="#">1977Fu03</a> ).
1900 20	0	0.043	E(level): other: 1900 ( <a href="#">1996Ya01</a> , <a href="#">1993Gu10</a> ). S <sub>α</sub> : other: 0.030 at E=37 MeV ( <a href="#">1996Ya01</a> ). Relative S <sub>α</sub> =0.25 ( <a href="#">1974St03</a> ), 0.27 ( <a href="#">1977Fu03</a> ).
2440 <sup>c</sup> 20	4	0.10	E(level): other: 2450 ( <a href="#">1996Ya01</a> , <a href="#">1993Gu10</a> ). S <sub>α</sub> : other: 0.08 at E=37 MeV ( <a href="#">1996Ya01</a> ). Relative S <sub>α</sub> =0.16 ( <a href="#">1974St03</a> ), 0.29 ( <a href="#">1977Fu03</a> ).
2520 20	2	0.08	E(level): other: 2530 ( <a href="#">1996Ya01</a> , <a href="#">1993Gu10</a> ). S <sub>α</sub> : other: 0.12 at E=37 MeV ( <a href="#">1996Ya01</a> ). Relative S <sub>α</sub> =0.25 ( <a href="#">1974St03</a> ), 0.26 ( <a href="#">1977Fu03</a> ).
2890 <sup>@</sup>	2 <sup>@</sup>	0.007	L: also from <a href="#">1977Fu03</a> . Relative S <sub>α</sub> =0.046 ( <a href="#">1977Fu03</a> ).
3180 <sup>@</sup>	3 <sup>@</sup>	0.004	L: other: 2 ( <a href="#">1977Fu03</a> ).

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$^{40}\text{Ca}(^6\text{Li,d})$  **1996Ya01,1993Gu10,1977Fu03 (continued)**

$^{44}\text{Ti}$  Levels (continued)

E(level) <sup>†</sup>	L <sup>‡</sup>	S <sub>α</sub> <sup>#</sup>	Comments
3350 20	4	0.083	Relative S <sub>α</sub> =0.032 (1977Fu03). E(level): other: 3370 (1996Ya01), 3390 (1993Gu10). S <sub>α</sub> : other: 0.085 at E=37 MeV (1996Ya01).
3630 20	2		Relative S <sub>α</sub> =0.12 (1974St03), 0.24 (1977Fu03). E(level),L: from 1977Fu03 only.
3740 20	1	0.014	Relative S <sub>α</sub> =0.024 (1977Fu03). E(level): other: 3760 (1996Ya01). S <sub>α</sub> : other: 0.015 at E=37 MeV (1996Ya01).
3920 20	3	0.020	Relative S <sub>α</sub> =0.17 (1977Fu03). E(level): others: 3960 (1990Ya09), 3940 (1993Gu10). Not seen in 1996Ya01. L: from 1990Ya09 and 1977Fu03.
4000 <sup>c</sup> 20	6	0.11	Relative S <sub>α</sub> =0.052 (1977Fu03). E(level): other: 4020 (1996Ya01, 1993Gu10). S <sub>α</sub> : other: 0.13 at E=37 MeV (1996Ya01).
4060 <sup>&amp;</sup>	3 <sup>&amp;</sup>		Relative S <sub>α</sub> =0.11 (1974St03), 0.35 (1977Fu03).
4100 30	2	0.033	E(level): others: 4100 (1996Ya01), 4090 30 (1977Fu03). S <sub>α</sub> : other: 0.030 at E=37 MeV (1996Ya01).
4840 30	0	0.11	Relative S <sub>α</sub> =0.2 (1974St03), 0.15 (1977Fu03). E(level): others: 4850 (1996Ya01), 4830 30 (1977Fu03), 4840 (1993Gu10). S <sub>α</sub> : other: 0.13 at E=37 MeV (1996Ya01).
5080 30	3		Relative S <sub>α</sub> =0.67 (1977Fu03). It is noted in 1977Fu03 the value of 1.35 in their previous work (1974St03) is probably erroneous. E(level): other: 5060 (1993Gu10). L: from 1993Gu10. Others: 2 (1977Fu03); 1993Gu10 also give (1,3) from reanalysis of data in 1977Fu03.
5230 30	5		Relative S <sub>α</sub> =0.072 (1977Fu03) for L=2. E(level): others: 5230 (1993Gu10), 5210 30 (1977Fu03). L: from 1993Gu10. Other: 4 (1977Fu03); 1993Gu10 also give 5 from reanalysis of data in 1977Fu03.
5330 30	5	0.023	Relative S <sub>α</sub> =0.046 (1977Fu03). E(level): others: 5310 (1996Ya01), 5330 (1993Gu10). L: others: 3 (1993Gu10), 4 (1977Fu03).
5410	3	0.044	S <sub>α</sub> : other: 0.020 at E=37 MeV (1996Ya01). Relative S <sub>α</sub> =0.09 (1974St03) and 0.083 if J=4. E(level): from 1996Ya01. L: other: 4 (1992Ki18).
6030 30	2	0.15	S <sub>α</sub> : other: 0.040 at E=37 MeV (1996Ya01). E(level): others: 6030 (1996Ya01, 1993Gu10). L: from 1990Ya09.
6220 <sup>d</sup> 30	1	0.14	S <sub>α</sub> : other: 0.12 at E=37 MeV (1996Ya01). E(level): other: 6220 (1996Ya01, 1993Gu10). L: from 1990Ya09. Others: (1) (1993Gu10), 2 (1977Fu03).
6470 <sup>c</sup> 30	8	0.20	S <sub>α</sub> : other: 0.13 at E=37 MeV (1996Ya01). E(level): others: 6470 (1996Ya01, 1993Gu10), 6440 30 (1977Fu03). L: from 1990Ya09.
6610 <sup>&amp;</sup>	2 <sup>&amp;</sup>		S <sub>α</sub> : other: 0.21 at E=37 MeV (1996Ya01). Relative S <sub>α</sub> =0.083 (1977Fu03).
6800 <sup>@</sup>	2 <sup>@</sup>	0.11	
6960 <sup>&amp;</sup>	(4) <sup>&amp;</sup>		
7340 <sup>@d</sup>	3 <sup>@</sup>	0.11	E(level): other: 7340 (1993Gu10).
7560 30	3	0.093	E(level): other: 7560 (1990Ya09, 1993Gu10). L: from 1993Gu10. Other: (3) (1990Ya09).

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<sup>40</sup>Ca(<sup>6</sup>Li,d) 1996Ya01,1993Gu10,1977Fu03 (continued)

<sup>44</sup>Ti Levels (continued)

E(level) <sup>†</sup>	L <sup>‡</sup>	S <sub>α</sub> <sup>#</sup>	Comments
7670 <sup>b</sup> 30	6 <sup>b</sup>	0.17	E(level): other: 7670 (1996Ya01, 1993Gu10). L: other: 10 (1993Gu10, 1992Ki18) considered unlikely. S <sub>α</sub> : other: 0.26 at E=37 MeV (1996Ya01).
8040 <sup>b</sup> 30	3 <sup>b</sup>	0.14	E(level): other: 8040 (1996Ya01, 1993Gu10). L: others: 12 (1993Gu10,1992Ki18), 8 (1990Ya09), ≥6 (1974St03), considered unlikely. S <sub>α</sub> : other: 0.13 at E=37 MeV (1996Ya01). Relative S <sub>α</sub> =0.16 if J=6 (1974St03).
8170	1	0.10	E(level): from 1996Ya01. Other: 8180 (1993Gu10). S <sub>α</sub> : other: 0.12 at E=37 MeV (1996Ya01).
8380 30	2+3 <sup>a</sup>	0.12	E(level): other: 8380 (1996Ya01, 1993Gu10). L: others: 2 (1990Ya09), 3 (1993Gu10). S <sub>α</sub> : other: 0.11 at E=37 MeV (1996Ya01).
8450	2+3 <sup>a</sup>	0.08	E(level): from 1996Ya01. L: others: 4 (1992Ki18), 3 (1990Ya09). S <sub>α</sub> : other: 0.05 at E=37 MeV (1996Ya01).
8540 30	2+3	0.08	E(level): others: 8540 (1996Ya01, 1993Gu10). L: others: 6 (1990Ya09,1992Ki18), 3 (1993Gu10), (0) (1974St03). 1990Ya03 state that their data do not give a good fit to any L value but L=0 is definitely not supported. S <sub>α</sub> : other: 0.08 at E=37 MeV (1996Ya01).
8750 <sup>&amp;</sup>	(6) <sup>&amp;</sup>		
8960	2	0.20	E(level): others: 8950 (1993Gu10), 8960 30 (1974St03, questionable). L: other: 4 (1993Gu10,1992Ki18). S <sub>α</sub> : other: 0.20 at E=37 MeV (1996Ya01).
9000 <sup>@</sup>	4 <sup>@</sup>	0.10	E(level): other: 9030 30 (1974St03, questionable).
9190 <sup>@</sup>	6 <sup>@</sup>	0.092	L: other: 8 (1993Gu10).
9320 <sup>&amp;</sup>	(0) <sup>&amp;</sup>		Additional information 1.
9430 <sup>d</sup>	5	0.12	E(level): from 1996Ya01. S <sub>α</sub> : other: 0.16 at E=37 MeV (1996Ya01).
9580	5	0.11	E(level): from 1996Ya01. L: other: 8 (1990Ya09). S <sub>α</sub> : other: 0.14 at E=37 MeV (1996Ya01).
10860	0	1.16	E(level): from 1996Ya01. Other: 10700 30 (1974St03, questionable). S <sub>α</sub> : other: 1.06 at E=37 MeV (1996Ya01).
11000? 30			

<sup>†</sup> From 1974St03, unless otherwise noted. Uncertainty is not given in 1974St03 and assigned by the evaluators based on a statement in 1977Fu03 for similar measurements with the same setup, that the accuracy in E(level) is 20 keV for levels below 4 MeV and becomes worse at higher energies. The evaluators have assigned 30 keV for E>4 MeV levels. 1998Ya21 state that a level at 11.7 MeV, 1<sup>-</sup>, known from other reactions, is scarcely seen in (<sup>6</sup>Li,d). Two possible groups at 14700 (5<sup>-</sup>) and 16100 (6<sup>+</sup>) are reported by 1995Ar15.

<sup>‡</sup> From 1996Ya01, unless otherwise stated. Values are also available in 1977Fu03 and 1993Gu10, and are in general agreement with those in 1996Ya01, with exceptions given under comments.

<sup>#</sup> α spectroscopic factor from 1996Ya01, based on reanalysis of their earlier data at E(beam)=50 MeV in 1990Ya09, unless otherwise stated. 1996Ya01 also report values from their new data at E(beam)=37 MeV, which are less complete and given under comments. Relative S<sub>α</sub> values from 1974St03 (E=32 MeV) and 1977Fu03 (E=28 MeV) are also given under comments. See 1993Gu10 for values at E=60.1 MeV and 1992Ki18 for values at E=28 and 50 MeV with a different normalization, with the latter from reanalysis of previous data at E=28 MeV (from 1977Fu03) and E=50 MeV (from 1990Ya09). The normalization factors are different in various studies which makes it difficult to provide a comparison between different measurements.

<sup>@</sup> From 1990Ya09; not seen in 1996Ya01.

<sup>&</sup> From 1993Gu10 only.

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${}^{40}\text{Ca}({}^6\text{Li,d})$  [1996Ya01](#),[1993Gu10](#),[1977Fu03](#) (continued)

${}^{44}\text{Ti}$  Levels (continued)

<sup>a</sup> For 8380+8450 doublet ([1996Ya01](#)).

<sup>b</sup> High L-transfer (10 or 12) as proposed in previous studies ([1993Gu10](#),[1992Ki18](#)) is unlikely as discussed by [1996Ya01](#), implying that this level does not correspond to a high-spin level seen near the same energy in (HI,xn $\gamma$ ) reactions.

<sup>c</sup> Band(A):  $K^\pi=0^+$  band ([1998Ya21](#)).

<sup>d</sup> Band(B):  $K^\pi=(0^-)$  band (?) ([1998Ya21](#)).

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 ${}^{40}\text{Ca}({}^6\text{Li,d})$  1996Ya01,1993Gu10,1977Fu03Band(B):  $K^\pi=(0^-)$  band  
(?) (1998Ya21)

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9430

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7340Band(A):  $K^\pi=0^+$  band  
(1998Ya21)

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6470

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6220

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4000

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2440

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1080

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0 ${}^{44}_{22}\text{Ti}_{22}$