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Energy Levels of Light Nuclei
$A = 5$

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Abstract: An evaluation of A = 5–10 was published in *Nuclear Physics A*490 (1995), p. 1. This version of A = 5 differs from the published version in that we have corrected some errors discovered after the article went to press. Figures and introductory tables have been omitted from this manuscript. Also, reference key numbers have been changed to the NNDC/TUNL format — see introduction to references for more information.

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^{5}n

^{5}n has not been observed. It is suggested that it is unbound by 10 MeV: see (84AJ01). See also (84DE1D).

^{5}H

The ^{9}Be(^{11}B, ^{15}O) reaction at $E(^{11}\mathrm{B}) = 52$–76 MeV shows no evidence for the formation of ^{5}H (86BE35, 87BO40). For the earlier work see (84AJ01). See also (87KO47, 88SE1C). There is some evidence for the formation of a very broad (8 ± 3 MeV) state of ^{5}H at $E_\mathrm{x} = 7.4 \pm 0.7$ MeV in the ^{9}Be(π^-, pt) reaction (87GO25). ^{5}H is calculated to have $J^\pi = \frac{1}{2}^+$, to be unstable with respect to two neutron emission and to have excited states at $E_\mathrm{x} = 2.44$, 4.29 and 7.39 MeV with $J^\pi = \frac{5}{2}^+$, $\frac{3}{2}^+$, and $\frac{3}{2}^+$ [$(0+1)\hbar\omega$ model space], and at $E_\mathrm{x} = 2.85$, 3.46 and 6.02 MeV with $J^\pi = \frac{3}{2}^+$, $\frac{5}{2}^+$ and $\frac{3}{2}^+$ [$(0+2)\hbar\omega$ model space] (85PO10). See also (82SM1B, 86BE44, 87PE1C) and (83ANZQ; theor.).

^{5}He

GENERAL: See also (84AJ01).

Model discussions: (83JA09, 84VA06, 84ZW1A, 85FI1E, 85GE06, 85KW02, 86KR12, 88WO04).

Special states: (82PO12, 83VO02, 84BE1B, 84FI1G, 84GL1C, 84VA06, 84VA1C, 84ZW1A, 85BA68, 85FI1E, 87SV1A, 88BA75, 88KW1A, 88US1B).

Electromagnetic transitions: (85FI1E).

Astrophysical questions: (84SU1A, 85BO1E).

Complex reactions involving ^{5}He: (85BO1J, 85DE17, 85PO11, 86CS1A, 86PO06, 87BL1K, 87BO40, 87KI16, 87PE1C).

Reactions involving pions: (84DE1D, 85BE1C, 85GE06, 86CE04).

Hypernuclei: (82KA1D, 83BA1D, 83BE1G, 83MO1C, 83SH1E, 83SH38, 84AS1D, 84BO1A, 84BO1H, 84CH1G, 84HU1B, 84KO1F, 84MI1E, 84SH07, 84SH1J, 84ZH1B, 85AH1A, 85BA1F, 85GI1E, 85IK1A, 85KO1G, 85KU1A, 85MO1F, 85OS1C, 85TA1E, 85YA05, 85YA1B, 86AN1R, 86BA1H, 86BA1W, 86BO1E, 86CH1I, 86DA1B, 86DO1B, 86LI1L, 86MA1C, 86SH1I, 86SH1K, 86SH1V, 86SZ1A, 86WA1J, 86YA1F, 87BO1L, 87BO1O, 87KA1Q, 87MI1A, 87PO1H, 87SH1H, 87YA1C, 87YA1M, 88BA1G, 88BO1E, 88LA1B, 88LI1C, 88NO1A, 88PO1H, 88TA1B).

Other topics: (83BE55, 84BE1B, 84PO11, 85AN28, 85GI1E, 86BL1D, 87SV1A, 88K-W1A, 88US1B).

Table 5.1
Energy levels of ^{5}He [a])

E_x (MeV) [b])	$J^\pi; T$	$\Gamma_{c.m.}$ (MeV)	Decay	Reactions
g.s.	$\frac{3}{2}^-; \frac{1}{2}$	0.60 ± 0.02 [a])	n, α	1, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29
4 ± 1	$\frac{1}{2}^-; \frac{1}{2}$	4 ± 1	n, α	4, 6, 9, 10, 16, 20, 21, 29
16.75 ± 0.05	$\frac{3}{2}^+; \frac{1}{2}$	0.076 ± 0.012	γ, n, d, t, α	1, 2, 5, 6, 8, 10, 11, 12, 20, 21, 22
19.8 ± 0.4 [c])	$(\frac{3}{2}, \frac{5}{2})^+; \frac{1}{2}$	2.5 ± 0.5	n, d, t, α	2, 3, 5, 8, 10, 12, 14, 18, 20, 21, 22
24–25 [c])		broad		20, 21
(35.7 ± 0.4)		≈ 2		18, 22

[a]) See table 5.2 in (66LA04) and table 5.2 here. A study by G.M. Hale, D. Dodder and K. Witte on the S-matrix pole parameters for ^{5}He is underway. I thank Dr. Hale for his comments concerning questions regarding R- and S-matrix calculations.
[b]) Positive-parity states are predicted to lie at $E_x \sim 5$ MeV ($\frac{1}{2}^+$) and 12 MeV ($\frac{3}{2}^+$, $\frac{5}{2}^+$): see (88WO10).
[c]) See (74AJ01), pp. 7–8.

Ground state of ^{5}*He*: (83ANZQ, 84FR13, 85AN28, 85FI1E, 85TA1F, 85WA1D, 87SV1A, 88WA08, 88WO04).

1. ^{3}H(d, γ)^{5}He $\qquad Q_m = 16.70$

At low energies the reaction is dominated by a resonance at $E_d = 107$ keV; the mirror reaction shows resonance at $E_d = 430$ keV. The branching ratio $\Gamma_{\gamma_0}/\Gamma_n$ integrated over the resonance from 0 to 275 keV is $(5.6 \pm 0.6) \times 10^{-5}$ (86MO05), in very good agreement with the earlier value of $(5.4 \pm 1.3) \times 10^{-5}$ for $E_d = 45$ to 146 keV (84CE08). Assuming Γ_n of ^{5}He*(16.7) is 37 ± 5 keV (see reaction 6), then $\Gamma_{\gamma_0} = 2.1 \pm 0.4$ eV. (86MO05) also report branching ratios up to $E_d = 0.72$ MeV and summarize the earlier work to 5 MeV. For measurements of TAP and VAP at $E_{\vec{d}} = 0.4$ and 8.6 MeV, see (87RI1D; prelim.). See also (85RI1A), (79AJ01) and (84NE1B, 86LA1F, 88KI1C; applications).

2. (a) ^{3}H(d, n)^{4}He $\qquad Q_m = 17.5894 \qquad E_b = 16.70$
(b) ^{3}H(d, 2n)^{3}He $\qquad Q_m = -2.9883$
(c) ^{3}H(d, pn)^{3}H $\qquad Q_m = -2.2259$

The cross section has been measured in the range $E_t = 12.5$ to 117 keV (84JA08) [0.525(±4.8%) mb to 3.739(±1.4%) b] and in the range $E_d = 79.913$ to 115.901 keV

(± 0.015 keV) (87BR10) [3.849 to 4.734 b (± 1.6%)]. See also (85FI1G; E_d = 13.8 to 114.3 keV). A strong resonance, σ (peak) = 4.88 b, appears at E_d = 105 keV: see table 5.2 in (79AJ01) and (87BR10). For a discussion of R-matrix analysis and evidence for a "shadow" pole, see (87BR10, 87HA20). See also (87HA1W, 87MO1K). From E_d = 10 to 500 keV, the cross section is well fitted with the assumption of s-wave formation of a $J^\pi = \frac{3}{2}^+$ state. Measurements of cross sections and angular distributions for reaction (a) have been reported to E_d = 21 MeV and E_t = 20.0 MeV [see (74AJ01, 79AJ01, 84AJ01)] as well as at 1.0, 1.5 and 2.0 MeV (87LI07).

A study of reaction (a) with polarized deuterons at E_d = 0.2 to 1.0 MeV indicates intervention of the s-wave, $J^\pi = \frac{1}{2}^+$ channel, as well as possible p-waves above E_d = 0.3 MeV. The polarization increases monotonically from 0.03 at E_d = 3 MeV to ≈ 0.5 at E_d = 6.5 MeV and then with a lower slope to 0.69 at E_d = 13 MeV. The change in the slope may be caused by excited states of ^{5}He near 20 MeV. Comparison with the ^{3}He(d, p)^{4}He mirror reaction at corresponding c.m. energies shows excellent agreement between the polarization values in the two reactions up to E_d = 6 MeV, but then the proton polarization becomes ≈ 15% higher, converging back to the neutron values at E_d ≈ 12–13 MeV. This may be due to experimental factors. Vector polarization transfer coefficients, $K_\mathrm{y}^{\mathrm{y}'}$ (0°) have been measured for $E_{\vec{\mathrm{d}}}$ = 5 to 11 MeV (85HO1C, 86HO1E; prelim.). For other polarization work see (84AJ01).

(87BR10) have derived astrophysical S-factors in the range E_d = 79.9 to 115.9 keV [$S(0) = 11.71 \pm 0.08$ MeV · b; multilevel fit], as well as reactivities. See (84JA08) for the earlier work, and (85CA41, 87VA36).

Reaction (b) has been studied for E_d = 10.9 to 83 MeV. A study of reaction (c) leads to the suggestion of a resonance at $E_\mathrm{c.m.} = 2.9 \pm 0.3$ MeV [E_x = 19.6 MeV], $\Gamma_\mathrm{c.m.}$ = 1.9±0.2 MeV, consistent with $J^\pi = \frac{3}{2}^-$ [see, however, table 5.1]: see (74AJ01, 79AJ01). See also (83BA1C, 84SL1A, 87GO1O), (86BR1K, 86RA1F) and (84SH1A, 85FI1C, 86CO1J, 86IL1A, 86KO21, 86VA1E; theor.). For applications see (83GO1C, 83HU1A, 84BA1D, 84HU04, 84MA71, 84VL1A, 86AL1H, 86CA1E, 86EN1A, 86GR1H, 86HA1N, 86HA1V, 86KE1H, 86KN1A, 86KU1G, 86LE1F, 86LO1B, 86OK1B, 86PA1G, 86PE1H, 86SA1M, 86TA1K, 86WI1B, 87BA2I, 87BO1Q, 87KA1O, 87LE1G, 87SO1A, 87WU1C, 87ZW1A, 88KU1E).

For recent developments in muon-catalyzed fusion see (86JO1B, 87BA2P, 87BR1G) and (83JO1B, 83TA1C, 84AN1A, 84BA1V, 84BR1G, 84CA1B, 87AC1A, 87BA2L, 87BE1Y, 87BR1T, 87CA1O, 87NA1K, 87PE1D), (83PO1E, 84AJ01, 84AN1C, 84CH1F, 84HA1J, 84KR1B, 84MO1G, 84OT1A, 86BR1H, 86JO1C, 86KA1K, 87BR1W, 87JO1A, 87PO1M) and (83SG1A, 84BU1E, 84BY1B, 84FI1F, 84ME1B, 85BA1G, 85CO1C, 85FR1D, 85GO1E, 85GU1G, 85HI1A, 85KA1C, 85KA1N, 85ME1C, 85ME1D, 85RA1B, 85VA1B, 86BL15, 86BO1F, 86CO1K, 86DA1D, 86HU1C, 86JO1C, 86KH1B, 86ME1D, 86TA1J, 86TA1L, 87AK1B, 87BE1W, 87CO1N, 87CO1P, 87CO1W, 87CO1Y, 87KA1Z, 87KO1R, 87ME1E, 87RA1L, 87TA1I, 87WY1A, 88JA1C, 88RO1G; theor.).

3. ^{3}H(d, d)^{3}H $\qquad E_\mathrm{b} = 16.70$

The elastic scattering has been studied for E_d = 2.6 to 11.0 MeV: see (84AJ01). The excitation curves show an interference at $E_x \approx 19$ MeV and a broad ($\Gamma > 1$ MeV) resonance corresponding to $E_x = 20.0 \pm 0.5$ MeV, similar to that seen in ^{3}He(d, d) [see ^{5}Li]. Together with data from ^{3}H(d, n)^{4}He, this work favors an assignment $D_{3/2}$ or $D_{5/2}$ with a mixture of doublet and quartet components (channel spin $\frac{1}{2}$ and $\frac{3}{2}$) if only one state is involved [any appreciable doublet component would, however, be in conflict with results from ^{7}Li(p, ^{3}He)^{5}He]. Measurements of differential cross section and analyzing power using polarized deuterons with $E_d = 3.2$ to 12.3 MeV show resonance-like behavior in the vector analyzing power near $E_d = 5$ MeV. The anomaly appears in the odd Legendre coefficients and is interpreted in terms of a $(\frac{1}{2}, \frac{3}{2})^-$ excited state of ^{5}He with $E_x \approx 19.6$ MeV. Broad structure in the differential cross section near 6 MeV, principally in the even Legendre coefficients, corresponds to an even parity state ^{5}He*(20.0). For other polarization measurements (and for references) see (79AJ01). For d-t correlations see (87PO03). See also "Complex reactions" in the ^{5}He GENERAL section and (81PL1A, 83HA1K, 86BO01; theor.).

4. ^{3}H(t, n)^{5}He $\qquad Q_m = 10.44$

At $E_t = 0.5$ MeV, the reaction appears to proceed via three channels: (i) direct breakup into ^{4}He + 2n, the three-body breakup shape being modified by the n-n interaction; (ii) sequential decay via ^{5}He(0); (iii) sequential decay via a broad excited state of ^{5}He. The width of ^{5}He(0) is estimated to be 0.74 ± 0.18 MeV. Some evidence is also shown for ^{5}He* at $E_x \approx 2$ MeV, $\Gamma \approx 2.4$ MeV: see (79AJ01). See also ^{6}He and (86BA73; theor.).

5. ^{3}He(t, p)^{5}He $\qquad Q_m = 11.20$

Some evidence is reported at $E_t = 22.25$ MeV for a broad state of ^{5}He at $E_x \approx 20$ MeV, in addition to a sharp peak corresponding to ^{5}He*(16.7): see (79AJ01). See also ^{6}Li.

6. ^{4}He(n, n)^{4}He $\qquad E_b = -0.89$

The coherent scattering length (thermal, bound) is 3.07 ± 0.02 fm, $\bar{\sigma}_s = 0.76 \pm 0.01$ b. Total cross sections have been measured for $E_n = 4 \times 10^{-4}$ eV to 150.9 MeV and at 10 GeV/c [see (84AJ01)] and at $E_n = 1.5$ to 40 MeV (83HA20).

The total cross section has a peak of 7.6 b at $E_n = 1.15 \pm 0.05$ MeV, $E_{c.m.} = 0.92 \pm 0.04$ MeV, with a width of about 1.2 MeV: see (66LA04). A second resonance is observed at $E_n = 22.133 \pm 0.010$ MeV [$\sigma_{peak} = 0.9$ b] with a total width of 76 ± 12 keV and $\Gamma_n = 37 \pm 15$ keV (83HA20). Attempts to detect additional resonances in the total cross section have been unsuccessful: see (66LA04).

The $P_{3/2}$ phase shift shows strong resonance behavior near 1 MeV, while the $P_{1/2}$ phase shift changes more slowly, indicating a broad $P_{1/2}$ level at several MeV excitation.

(66HO07) have constructed a set of phase shifts for $E_n = 0$ to 31 MeV, $l = 0, 1, 2, 3$, using largely p-α phase shifts. At the $\frac{3}{2}^+$ state the best fit to all data is given by $E_{res} = 17.669$ MeV $\pm$ 10 keV, $\gamma_d^2 = 2.0$ MeV $\pm$ 25%, $\gamma_n^2 = 50$ keV$\pm$20% (see table 5.2 in 79AJ01).

An R-function analysis of the ^{4}He + n data below 21 MeV (including absolute neutron analyzing power measurement and accurate cross section measurements) has led to a set of phase shifts and analyzing powers which are based on the ^{4}He + n data alone (rather than also including the ^{4}He + p data). At $r = 3.3$ fm the values obtained for the $P_{1/2}$ and $P_{3/2}$ resonances are, respectively, $E_{c.m.} = 1.97$ and 0.77 MeV, $\Gamma_{c.m.} = 5.22$ and 0.64 MeV: see (84AJ01). Angular distributions of A_y have been studied by (84KL05, 84KR23, 86KL1C) for $E_{\vec{n}} = 15$ to 50 MeV: see also for phase-shift analysis and comparison with ^{4}He(p, p).

The excitation energies and the spectroscopic factors for ^{5}He states are obtained by (85BA68) from 2-level R-matrix fits to the phase shifts, as functions of the channel radius. For $a \approx 5.1$ fm a very broad state with $J^\pi = \frac{1}{2}^+$ is found to lie at $E_x \approx 7$ MeV in both ^{5}He and ^{5}Li, in agreement with the shell-model calculation by (84VA06). Broad $\frac{3}{2}^+$ and $\frac{5}{2}^+$ states then lie at ≈ 14 MeV and the $\frac{1}{2}^-$ state is at about 2.6 MeV. (85BA68) suggest that the phase-shift analysis should be redone with values of a larger than those previously used ($a \approx 3$ fm). See also (84AJ01, 84SI1A, 85AL1D, 85SI1B, 85WI1B, 86BA1Y), (86BU1D, 86DO1H; applications) and (81PL1A, 82AZ02, 83DM01, 83KU06, 84BL21, 84FI1G, 84SC1A, 84SH1A, 85HA04, 85HO1B, 85KI11, 85MI1F, 85NE1B, 85SO06, 85SO08, 85SP05, 85TI07, 85TI08, 86CA1K, 86KO1J, 86OK06, 86WI04, 87CA13, 87DU1B, 87HA1W, 87KR16, 87MO1K, 87PO1G, 87QI01, 87SH09, 87SO04, 87US1A, 87VA36; theor.). For the breakup reaction see (87MI1N, theor.).

7. ^{4}He(p, π^+)^{5}He $\qquad Q_m = -141.24$

Differential cross sections have recently been reported at $E_p = 201$ MeV (85LE19) and at $E_{\vec{p}} = 800$ MeV (84HO01; also A_y). See also (87SO1C) and (85GE06; theor.).

8. (a) ^{4}He(d, p)^{5}He $\qquad Q_m = -3.12$
   (b) ^{4}He(d, pn)^{4}He $\qquad Q_m = -2.22459$

A typical proton spectrum (reaction (a)) consists of a peak corresponding to the formation of the ground state of ^{5}He, plus a continuum of protons ascribed to reaction (b). A study of the latter reaction shows evidence for sequential decay via ^{5}He*(0, 16.7 $\pm$ 0.1 [$\Gamma = 80 \pm 30$ keV]) and suggests some fine structure near $E_x = 19$ MeV [see also reactions 12 and 20]: see (79AJ01). Differential cross sections and VAP have been measured for the ground state group at $E_{\vec{d}} = 5.4$, 6.0, and 6.8 MeV (85LU08; also TAP) and at 6 to 11 MeV (85OS02). At $E_\alpha = 28.3$ MeV tensor polarization measurements involving the ground state transitions to ^{5}He (and ^{5}Li) deviate from theoretical predictions which assume charge symmetry (85WI15). See also ^{6}Li (88PUZZ; $E_{\vec{d}} = 2.1$ GeV) and (85DO03, 85NE1B, 86KO1J, 87FU10, 87KA1M, 87KU1F; theor.).

Table 5.2
R-matrix values of the peak energy and FWHM of the $\frac{3}{2}^-$ and $\frac{1}{2}^-$ states of ^{5}He and ^{5}Li [a]

	E_{max} ($\frac{3}{2}^-$)		Γ ($\frac{3}{2}^-$)		E_x ($\frac{1}{2}^-$)		Γ ($\frac{1}{2}^-$)	
	^{5}He	^{5}Li	^{5}He	^{5}Li	^{5}He	^{5}Li	^{5}He	^{5}Li
[b]	0.838 ± 0.018	1.76 ± 0.06	0.645 ± 0.046	1.18 ± 0.13	1.94 ± 0.46	1.87 ± 0.56	3.6 ± 1.2	4.1 ± 2.5
[c]	0.869 ± 0.003	1.86 ± 0.01	0.723 ± 0.019	1.44 ± 0.08	2.58 ± 0.40	2.68 ± 0.50	5.3 ± 2.3	6.1 ± 2.8

[a] (88WO10): a = 5.5 fm. Energies are in MeV. See also footnote [a] to table 5.1.
[b] Stripping reactions: ^{4}He(^{7}Li, ^{6}Li)^{5}He and ^{4}He(^{7}Li, ^{6}He)^{5}Li.
[c] Pickup reactions: ^{6}Li(^{12}C, ^{13}N)^{5}He and ^{6}Li(^{13}C, ^{14}C)^{5}Li.

9. ^{4}He(^{7}Li, ^{6}Li)^{5}He $\quad Q_m = -8.14$

(88WO10) report a study of this reaction and of the ^{4}He(^{7}Li, ^{6}He)^{5}Li reaction at $E(^7\text{Li}) = 50$ MeV, and of the ^{6}Li(^{12}C, ^{13}N)^{5}He and ^{6}Li(^{13}C, ^{14}C)^{5}Li reactions at $E(\text{C}) =$ 90 MeV. Properties of the two lowest states of $A = 5$, from R-matrix parameters ($a =$ 5.5 fm), are displayed in table 5.2. Positive-parity states are then predicted to lie at $E_x \approx 5$ MeV ($\frac{1}{2}^+$) and 12 MeV ($\frac{3}{2}^+$, $\frac{5}{2}^+$) in ^{5}He–^{5}Li (88WO10).

10. (a) ^{6}Li(γ, p)^{5}He $\quad Q_m = -4.59$
(b) ^{6}Li(e, ep)^{5}He $\quad Q_m = -4.59$
(c) ^{6}Li(π^+, π^+p)^{5}He $\quad Q_m = -4.59$

At $E_\gamma = 60$ MeV, the proton spectrum shows two prominent peaks attributed to ^{5}He*(0 + 4.0, 20 ± 2): see (79AJ01). The (γ, p_{0+1}) cross section has been reported for $E_\gamma = 34.5$ to 98.8 MeV. A broad secondary structure is also observed (88CA11). In reaction (b) the missing energy spectrum show strong peaks due to ^{5}He*(0, 16.7) and possibly some strength in the region $E_x = 5$–15 MeV (86LA1K; prelim.). See also ^{6}Li. At $E_{\pi^+} = 130$ and 150 MeV, ^{5}He*(0, 16.7) are populated (87HU02).

11. ^{6}Li(n, d)^{5}He $\quad Q_m = -2.37$

Angular distributions of d_0 have been studied at $E_n = 6.6$ to 56.3 MeV. At $E_n =$ 56.3 MeV angular distributions have also been obtained to ^{5}He*(16.7) and, possibly, to two higher states: see (79AJ01, 84AJ01). See also (86BO1J).

12. ^{6}Li(p, 2p)^{5}He $\quad Q_m = -4.59$

At E_p = 100 MeV the population of ^{5}He*(0, 16.7) and possibly of a broad structure at $E_x \approx$ 19 MeV is observed: momentum distributions for ^{5}He*(0, 16.7) and angular correlation measurements are also reported. Recent work is reported at E_p = 47 and 70 MeV (83VD03), 70 MeV (83GO06) and 1 GeV (85BE1J, 85DO1B). See also (84AJ01).

13. ^{6}Li(d, ^{3}He)^{5}He $\quad Q_m = 0.90$

^{5}He$_{g.s.}$ has been observed at E_d = 14.5 MeV: see (79AJ01).

14. ^{6}Li(α, αp)^{5}He $\quad Q_m = -4.59$

At E_α = 140 MeV ^{5}He*(0, 20.0) are populated: see (84AJ01).

15. ^{6}Li(^{6}Li, ^{7}Be)^{5}He $\quad Q_m = 1.01$

Angular distributions have been obtained at $E(^6\mathrm{Li})'$ = 156 MeV to ^{5}He$_{g.s.}$. Unresolved states at E_x = 16–20 MeV are also populated (87MI34).

16. ^{6}Li(^{12}C, ^{13}N)^{5}He $\quad Q_m = -2.65$

See reaction 9 (88WO10).

17. ^{7}Li(γ, d)^{5}He $\quad Q_m = -9.62$

See ^{7}Li.

18. (a) ^{7}Li(π^+, 2p)^{5}He $\quad Q_m = 128.51$
(b) ^{7}Li(π^-, 2n)^{5}He $\quad Q_m = 126.94$

Reaction (a) at E_{π^+} = 59.4 MeV involves ^{5}He*(0, 4.) and a broad peak centered at $E_x \approx$ 21 MeV with $\Gamma \approx$ 4 MeV. It is not clear whether ^{5}He*(16.7) is populated (86RI01). See also (79AJ01, 84AJ01).

19. ^{7}Li(n, t)^{5}He $\quad Q_m = -3.36$

The angular distribution of t_0 has been measured at $E_n = 14.4$ MeV: see (79AJ01) and ^{8}Li. See also (86BO1J).

20. (a) ^{7}Li(p, ^{3}He)^{5}He $\qquad Q_m = -4.13$
    (b) ^{7}Li(p, pd)^{5}He $\qquad Q_m = -9.62$

At $E_p = 43.7$ MeV, angular distributions of the ^{3}He groups to the ground state of ^{5}He ($\Gamma = 0.80 \pm 0.04$ MeV; $L = 0 + 2$) and to levels at 16.7 MeV ($L = 1$) and 19.9 ± 0.4 MeV ($\Gamma = 2.7$ MeV) have been studied. Since no transitions are observed in the ^{7}Li(p, t)^{5}Li reaction to the analog 20 MeV state in ^{5}Li [see ^{5}Li], the transition is presumably S-forbidden and the states in ^{5}He–^{5}Li near 20 MeV are $^4D_{3/2}$ or $^4D_{5/2}$ [compare ^{3}H(d, d)]. Particle-particle coincidence data have been obtained at $E_p = 43.7$ MeV. They suggest the existence of ^{5}He*(20.0) with $\Gamma = 3.0 \pm 0.6$ MeV and of a broad state at ≈ 25 MeV. No $T = \frac{3}{2}$ states decaying via $T = 1$ states in ^{4}He were observed: see (79AJ01). In reaction (b) ^{5}He*$(0 + 4$, 16.7, 25) appear to be involved at $E_p = 670$ MeV (81ER10) while at 200 MeV some structure at $E_x \approx 20$ MeV is reported in addition to the ground state (86WA11).

21. (a) ^{7}Li(d, α)^{5}He $\qquad Q_m = 14.23$
    (b) ^{7}Li(d, n)2 ^{4}He $\qquad Q_m = 15.1216$

At $E_d = 24$ MeV, the α-particle spectrum from reaction (a) shows structures corresponding to the ground and 16.7 MeV states and to states at $E_x \approx 20.2$ and 23.8 MeV with $\Gamma \approx 2$ MeV and ≈ 1 MeV, respectively. Reaction (b) proceeds mainly via excited states of ^{8}Be and ^{5}He$_{g.s.}$ and possibly as well ^{5}He*(4.): see (79AJ01). See also (87WA21) and ^{8}Be.

22. (a) ^{7}Li(^{3}He, pα)^{5}He $\qquad Q_m = 8.73$
    (b) ^{7}Li(^{3}He, ^{3}He d)^{5}He $\qquad Q_m = -9.62$

A kinematically complete experiment is reported at $E(^3\text{He}) = 120$ MeV. The cross section for reaction (b) is an order of magnitude greater than that for reaction (a). The missing mass spectrum for the composite of both reactions suggests the population of several states of ^{5}He, in addition to ^{5}He*(0, 16.7, 20.0), including a state at 35.7 ± 0.4 MeV with a width of ≈ 2 MeV (85FR01).

23. (a) ^{9}Be(p, pα)^{5}He $\qquad Q_m = -2.47$
    (b) ^{9}Be(p, d^{3}He)^{5}He $\qquad Q_m = -20.82$

Both reactions have been studied at $E_p = 26.0$ to 101.5 MeV [see (84AJ01)] and at $E_p = 150.5$ MeV (85WA13) [reaction (a)]. See also (85VD03; theor.).

24. ^{9}Be(d, ^{6}Li)^{5}He $\quad Q_m = -9.92$

The angular distribution to $^{5}He_{g.s.}$ has been measured at $E_d = 13.6$ MeV (84SH1F; prelim.).

25. (a) ^{9}Be(^{3}He, ^{7}Be)^{5}He $\quad Q_m = -0.88$
(b) ^{9}Be(^{3}He, α)2 ^{4}He $\quad Q_m = 19.0043$

See (84AJ01). For reaction (b) see ^{8}Be and (87WA25).

26. ^{9}Be(α, 2α)^{5}He $\quad Q_m = -2.47$

See (84AJ01).

27. ^{10}B(n, ^{5}He)^{6}Li $\quad Q_m = -5.35$

See ^{6}Li.

28. ^{10}B(d, ^{7}Be)^{5}He $\quad Q_m = -1.97$

An angular distribution has been measured at $E_d = 13.6$ MeV involving $^{5}He_{g.s.}$ and ^{7}Be*(0.43) (83DO10).

29. ^{11}B(^{7}Li, ^{13}C)^{5}He $\quad Q_m = 9.06$

At $E(^{11}B) = 88$ MeV a broad structure is observed at $E_x = 5.2 \pm 0.3$ MeV, $\Gamma = 2.0 \pm 0.5$ MeV (87BEYI). See also (88BEYJ).

Table 5.3
Energy levels of ^{5}Li

E_x (MeV) [a]	$J^\pi; T$	$\Gamma_{c.m.}$ (MeV)	Decay	Reactions
g.s.	$\frac{3}{2}^-; \frac{1}{2}$	≈ 1.5	p, α	1, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23
5–10	$\frac{1}{2}^-; \frac{1}{2}$	5 ± 2	p, α	1, 6, 10, 11, 13, 14, 15, 17, 18
16.66 ± 0.07	$\frac{3}{2}^+; \frac{1}{2}$	≈ 0.3	γ, p, d, ^{3}He, α	1, 2, 3, 6, 13, 15, 18
(18 ± 1) [a]	$(\frac{1}{2}^+); \frac{1}{2}$	broad	γ, p, d, ^{3}He, α	1, 2, 13
(20.0 ± 0.5) [b]	$(\frac{3}{2}, \frac{5}{2})^+; \frac{1}{2}$	≈ 5	γ, p, d, ^{3}He, α	1, 2, 3, 4, 6, 13, 15
(34)		≈ 4		18, 19

[a]) See also table 5.2. Positive-parity states are predicted to lie at $E_x \approx 5$ MeV ($\frac{1}{2}^+$) and 12 MeV ($\frac{3}{2}^+$, $\frac{5}{2}^+$): see (88WO10).
[b]) For possible additional states see reactions 2 and 18.

^{5}Li

GENERAL: See also (84AJ01).

Model discussions: (84ZW1A, 85BA68, 85FI1E, 85KW02).

Special states: (82PO12, 83FE07, 84BE1B, 84FI1G, 84GL1C, 84VA1C, 84ZW1A, 85BA68, 85FI1E, 85PO18, 85PO19, 85WI1A, 87SV1A, 88BA1H, 88KW1A).

Electromagnetic transitions: (85FI1E, 87KR16).

Astrophysical questions: (84BA1K, 84SU1A, 85BO1E, 86HU1D).

Complex reactions involving ^{5}Li: (85PO18, 85PO19, 85WI1A, 86BA2D, 86CH10, 86CS1A, 86MA1V, 86XU1B, 87BL1K, 87CH33, 87CH32, 87DE1O, 87DU07, 87FO08, 87GA20, 87GE1B, 87HA1M, 87KI16, 87LY04, 87PE1B, 88CEZZ, 88SA09).

Reactions involving pions: (81MC09, 83SP06, 85BA1H, 85BE1C).

Hypernuclei: (82KA1D).

Other topics: (83BE55, 84BE1B, 85AN28, 87DU09, 87SV1A, 88KW1A).

Ground state of ^{5}Li: (83ANZQ, 85AN28, 85FI1E, 85TA1F, 85WA1D, 85WI1A, 87KR16, 87SV1A, 88WA08).

1. ^{3}He(d, γ)^{5}Li $\qquad Q_m = 16.39$

The ratio $\Gamma_{\gamma}/\Gamma_{p\alpha}$ has been determined for $E(^3He) = 63$ to 150 keV [$E_{c.m.} = 25$ to 60 keV] by (85CE13) by measuring simultaneously the γ-rays and the charged particles. Because of the large widths of the final states, γ_0 and γ_1 could not be resolved but the results are consistent with $E_x = 3.0 \pm 1.0$ MeV for the excited state. $\Gamma_{\gamma_0}/\Gamma_{p\alpha}$ is roughly constant for $E_{c.m.} = 25$ to 60 keV at $(4.5 \pm 1.2) \times 10^{-5}$ and $\Gamma_{\gamma_1}/\Gamma_{p\alpha} = (8 \pm 3) \times 10^{-5}$ at $E(^3He) = 150$ keV (85CE13). For applications see (85CE13, 85CE16).

Excitation curves and angular distributions have been measured for $E_d = 0.2$ to 5 MeV and $E(^3He) = 2$ to 26 MeV. A broad maximum in the cross section is observed at $E_d = 0.45 \pm 0.04$ MeV [^{5}Li*(16.66)]. $\sigma_{\gamma_0} = 21 \pm 4$ μb, $\Gamma_{\gamma_0} = 5 \pm 1$ eV. The radiation at resonance is isotropic, consistent with s-wave capture. Study of γ_0 and γ_1 yields $\Gamma = 2.6 \pm 0.4$ MeV for the ground-state width, and $E_x = 7.5 \pm 1.0$ MeV, $\Gamma = 6.6 \pm 1.2$ MeV for the $\frac{1}{2}^-$ state: see (74AJ01). An excess in the cross section at higher bombarding energies is interpreted as being due to a state at $E_x \approx 18$ MeV: even parity is deduced from the relative intensity of γ_0 and γ_1. A broad peak is also observed at $E_x \approx 20.7$ MeV in the γ_0 cross section. The cross section for γ_1 is ≈ 0. The observations are consistent with $J^\pi = \frac{5}{2}^+$: angular distributions appear to require at least one other state with significant strength near 19 MeV: see (74AJ01). For cross section and analyzing power measurements for $E_{\vec{d}} = 4$ to 9 MeV see (85RI1A; prelim.).

2. (a) ^{3}He(d, p)^{4}He	$Q_m = 18.35319$	$E_b = 16.39$
(b) ^{3}He(d, np)^{3}He	$Q_m = -2.22458$	
(c) ^{3}He(d, 2p)^{3}H	$Q_m = -1.46083$	
(d) ^{3}He(d, 2d)^{1}H	$Q_m = -5.49353$	

Excitation functions and angular distributions have recently been measured for $E_{c.m.} = 6.95$ to 171.3 keV, and $S(E)$ have been deduced: $S(0) = 6.3 \pm 0.6$ MeV $\cdot$ b (87KR18). See also (84AJ01). Recently, S-factors have been obtained down to $E_{c.m.} = 5.88$ keV. The effect on S of electron screening at low energies has been studied by (88EN03).

A pronounced resonance occurs at $E_d = 430$ keV, $\Gamma \approx 450$ keV. The peak cross section is 695 ± 14 mb: see table 5.2 in (79AJ01). Excitation functions for ground-state protons have also been reported for $E(^3He) = 0.39$ to 2.15 MeV and 18.7 to 44.1 MeV and for $E_d = 2.8$ to 17.8 MeV [see (74AJ01)]. Angular distributions have been measured for $E_d = 0.25$ to 27 MeV and $E(^3He) = 18.7$ to 44.1 MeV [see table 5.6 in (74AJ01) and (79AJ01)]. Resonance-like behavior has been suggested at $E_x = 16.6$, 17.5, 20.0, 20.9 and 22.4 MeV: see (79AJ01).

Tensor analyzing power measurements are reported for $E_{\vec{d}} = 0.48$ to 6.64 MeV (80DR01). [See, however, (80GR14) for a discussion of the (80DR01) results and for a summary of $T_{20}(0^\circ)$ for $E_{\vec{d}} = 0$ to 40 MeV.] Measurements of angular distributions and analyzing powers at $E(^3He) = 27$ and 33 MeV have suggested the presence of a broad resonance(s) at $E_x \approx 28$ MeV. Vector and tensor analyzing powers have been studied at $E_{\vec{d}} = 1.0$ to 13.0 MeV (86BI1C, 86BI1F; prelim.) and 18, 20 and 22 MeV (86SA1L; prelim.). See also (86RO1J) and tables 5.6 in (74AJ01) and 5.4 in (79AJ01).

It is suggested that at low energies [E_d = 2.2 to 6 MeV] reaction (c) goes primarily via a $J^\pi = \frac{3}{2}^-$, $T = \frac{1}{2}$ state of ^{5}Li located 0.8 ± 0.2 MeV above threshold [i.e., E_x = 18.9 ± 0.2 MeV]: see (79AJ01). Recent studies of the breakup have been reported at E_d = 23.08 MeV (86BR1J; reaction (c)) and 60 MeV (85OK03; reaction (d)). For the earlier work see (84AJ01).

See also (83MA1E, 84ALZU, 84GA1C, 84HA1J, 84MU1C, 84VL1A, 84WI1C, 85GU1F, 85KU1B, 86BI1E, 86JA1E, 86KA1L, 86LO1B, 86PO1F, 86WI1B, 86WI1E, 87JO1A, 87KA1O, 87TE1D, 88GU1G, 88KU1E; applications), (84YA1A, 85CA41, 86DE1K, 87DO1H, 87RO1D; astrophysics), (86VA1D, 87GR08) and (84DU1A, 84KR1B, 86AB1C, 86BL15, 86IL1A, 87AS05; theor.).

3. ^{3}He(d, d)^{3}He E_b = 16.39

In the range E_d = 380 to 570 keV, the scattering cross section is consistent with s-wave formation of the $J^\pi = \frac{3}{2}^+$ state at 16.66 MeV. The excitation curves for E_d = 1.96 to 10.99 MeV show a broad resonance (Γ > 1 MeV) corresponding to E_x = 20.0 ± 0.5 MeV. From the behavior of the angular distributions an assignment of $^2\mathrm{D}_{3/2}$ or (^{2}D, $^4\mathrm{D}_{5/2}$ is favored, if only one state is involved: see (79AJ01). A phase-shift analysis of the angular distribution and VAP data below 5 MeV suggests several MeV broad states [$^2\mathrm{P}_{3/2}$, $^4\mathrm{D}_{7/2}$, $^4\mathrm{D}_{5/2}$, $^4\mathrm{D}_{3/2}$ and, possibly, $^4\mathrm{D}_{1/2}$]: see (84AJ01). See also (87KR18).

Angular distributions and analyzing powers have been measured at many energies to E = 44 MeV: see (79AJ01, 84AJ01) for the earlier work, (82CO1B, 83CO1C; $E_{\vec{\mathrm{d}}}$ = 10 MeV; TAP; prelim.) and (87YA1H; E_d = 29.5 MeV on polarized ^{3}He; prelim.). For d-^{3}He correlations see (87PO03). See also "Complex reactions" in the ^{5}Li GENERAL section. See also (87GR08) and (81PL1A, 83ZE06, 83ZE1B, 85SH08, 86BO01, 86KA28, 86YA1E, 87ZE1D; theor.).

4. ^{3}He(t, n)^{5}Li Q_m = 10.13

At $E(^3\mathrm{He})$ = 14 to 26 MeV ^{5}Li*(0, 20.5 ± 0.8) are populated: see (79AJ01). See also ^{6}Li.

5. ^{3}He(^{3}He, p)^{5}Li Q_m = 10.89

The spectrum of protons at $E(^3\mathrm{He})$ = 3 to 18 MeV shows a pronounced peak corresponding to $^5\mathrm{Li}_\mathrm{g.s.}$ superposed on a continuum: see (74AJ01). The angular distribution of p_0 has been measured at $E(^3\mathrm{He})$ = 26 MeV (83KI10; polarized target). See also ^{6}Be and (86OS1D; theor.).

6. ^{4}He(p, p)^{4}He E_b = −1.97

Differential cross sections and polarization measurements have been carried out at many energies: see (66LA04, 74AJ01, 79AJ01, 84AJ01) for the earlier work. Recent measurements are reported at $E_{\vec{p}} = 65$ MeV (86FU05; A_y), 100 MeV (83NA1B, 85GU1H; $\sigma(\theta)$, A_y; prelim.) and 495 MeV (88STZZ; prelim.) and at $E_p = 695$, 793, 890, 991 MeV (85VE13; $\sigma(\theta)$) and 1 GeV (85AL1E; $\sigma(\theta)$). Cross sections and A_y at $E_{\vec{p}} = 98.7$ and 149.3 MeV for the continuum are reported by (85WE12).

Phase shifts below $E_p = 18$ MeV have been determined by (77DO01) based on all the available cross-section and polarization measurements, using an R-matrix analysis program. The $P_{3/2}$ phase shift shows a pronounced resonance corresponding to $^5Li_{g.s.}$ while the $P_{1/2}$ shift changes slowly over a range of several MeV, suggesting that the first excited state is very broad and located 5–10 MeV above the ground state. The reduced widths of the P-wave resonance states are nearly the same. The $D_{5/2}$, $D_{3/2}$, $F_{7/2}$ and $F_{5/2}$ phase shifts become greater than 1° at $E_p \approx 11$, 13, 14 and 16 MeV, respectively (77DO01). (86TH1C; prelim.) have measured A_y for $1.1 \leq E_{\vec{p}} \leq 2.15$ MeV: $A_y = 1$ for $E_p = 1.89$ MeV, $\theta_{c.m.} = 87.0°$.

A phase-shift analysis for $E_p = 21.8$ to 55 MeV is presented by (78HO17) [see also analyzing-power contour diagram for $E_p = 20$ to 65 MeV]. A striking anomaly is seen in the analyzing power at $E_p = 23$ MeV and the $^2D_{3/2}$ phase shift clearly shows the $\frac{3}{2}^+$ state at $E_x = 16.7$ MeV [see also (79AJ01)]. The other phase shifts $^2S_{1/2}$, $^2P_{3/2}$, $^2P_{1/2}$, $^2D_{5/2}$, $^2F_{7/2}$, $^2F_{5/2}$, $^2G_{9/2}$ and $^2G_{7/2}$ are smooth functions of energy. Both the $^2P_{3/2}$ and $^2P_{1/2}$ inelastic parameters show a somewhat anomalous behavior at $E_p \approx 30$ MeV; the absorption first increases then decreases to stay rather constant at $E_p > 40$ MeV. These results are consistent with broad and overlapping states with $J^\pi = \frac{1}{2}^-$ and $\frac{3}{2}^-$ at $E_x \approx 22$ MeV. There is very little splitting of the real parts of the F-wave phase shifts up to 40 MeV. There is some indication (from the $^2G_{7/2}$ phase shifts) of a $\frac{7}{2}^+$ level around $E_p = 29$ MeV [$E_x \approx 21$ MeV]. The G-waves are necessary to fit the detailed shape of the angular distributions for $E_p = 20$ to 55 MeV (78HO17). For a contour diagram of the analyzing power for $E_p = 130$ to 1800 MeV see (80MO09). For a measurement of the spin rotation parameter, R, at $E_{\vec{p}} = 500$ MeV see (83MO01). See also (86SA1J; prelim.; $E_{\vec{p}} = 65$ Mev).

PNC effects have been studied via the elastic scattering of 46 MeV longitudinally polarized protons on ^4He: the longitudinal power $A_z = -(3.3 \pm 0.9) \times 10^{-7}$. This was obtained by measuring σ^+ and σ^- for the positive and negative helicity of the incident protons (85LA01, 86LA29): the conclusion reached by the authors from this, and all other experiments, is that there does not exist any evidence for a non-zero value of f_π, the weak isovector coupling constant. See also (84AJ01), (86AD1A) and (86HA1Q, 88NA1C; theor.).

Work at very high energies ($\gg 1$ GeV) is reported by (82AB1B, 84GL04, 84SA1C, 85AB1A, 85BA1H, 85GL1B, 86BE1S, 87OT1D): see also reaction 7 and (84AJ01). See also (87MU1B). For $\alpha + p$ correlations see (87PO03) and p. 16.

See also (86GO1D), (82NA1B, 83FA1A, 84FA1B, 84FR1C, 84HA1L, 84HO1H, 84SI1A, 85AD1A, 85AL1D, 85FA1A, 85MI10, 86BA1N, 86ST1D), (84SP1A; applications), (84KR1B; muon fusion) and (81PL1A, 83AL1C, 83BI1C, 83GR20, 83PA1B, 83SA38, 83ZA1A, 83ZE06, 83ZE1B, 84AH03, 84BL21, 84CA1C, 84DE1G, 84FI1G, 84KW01, 84LA1B, 84PR1A, 84SC1A,

85BA68, 85BL1C, 85DA1A, 85FL1A, 85HA04, 85HE1D, 85HO1B, 85JA1F, 85KI11, 85KO05, 85KO1A, 85MI1F, 85NE1B, 85RO16, 85SO06, 85SO08, 85TE02, 86AU05, 86BA2L, 86BL02, 86BO01, 86FR12, 86GU1E, 86KA1G, 86KA1H, 86KA35, 86KO1J, 86OK06, 86OR03, 86SA05, 86SA30, 86WA21, 87DU1B, 87FO1C, 87FR1D, 87FU10, 87KR16, 87LI1K, 87LI1L, 87PO1G, 87PR08, 87QI01, 87WA11, 88FR06, 88HE1C; theor.).

7. (a) ^{4}He(p, d)^{3}He $Q_m = -18.35320$ $E_b = -1.97$
   (b) ^{4}He(p, pn)^{3}He $Q_m = -20.57778$
   (c) ^{4}He(p, 2p)^{3}H $Q_m = -19.81403$
   (d) ^{4}He(p, pd)^{2}H $Q_m = -23.84674$

Angular distributions of deuterons and of ^{3}He ions (reaction (a)) have been measured for E_p = 27.9 to 770 MeV and at E_α = 3.98 GeV/c [see (79AJ01, 84AJ01)] as well as at $E_{\vec{p}}$ = 100 MeV (83NA1B; prelim.; also A_y), 200 and 400 MeV (86AL01; also A_y). Excitation functions are reported at several energies in the range E_p = 38.5 to 44.6 MeV and 200 to 500 MeV. Continuum yields and A_y have been studied at $E_{\vec{p}}$ = 98.7 and 149.3 MeV by (85WE12). For polarization measurements to 500 MeV see above and (79AJ01, 84AJ01). See also (88BAZH).

For reactions (b), (c) and (d) see (74AJ01, 79AJ01, 84AJ01). The breakup of ^{4}He via reaction (c) has recently been studied by (86FU05): large values of A_y in the FSI region are reported. For breakup processes at high energies, including pion production, see (83AN13, 83MO14, 84WA1K, 85BA1H, 85GL1B, 86BA2E, 86BA2M). See also (83AN18, 87MU1F, 87TE1C, 88PA1E), (83CH1B, 87MU1B), (83ZH04, 84KO1E, 84LI1B, 86GO1J, 87LY1C, 87MI1N; theor.).

8. ^{4}He($\bar{p}$, $\bar{p}$)^{4}He

Antiproton interactions with ^{4}He have been studied by (84BA60, 85BA76, 87BA12, 87BA47, 87BA69). See also (84BA1K, 84FA1A; astrophysics) and (83FA16, 86DO1G, 87NA23; theor.).

9. (a) ^{4}He(d, n)^{5}Li $Q_m = -4.19$
   (b) ^{4}He(d, np)^{4}He $Q_m = -2.22459$

For reaction (a) see reaction 8 in ^{5}He (85WI15) and (87KAZL; E_d = 15 MeV; n_0; prelim.). Reaction (b) has been studied at E_d = 12 to 17 MeV and at E_α = 18.0 to 140 MeV: see (79AJ01, 84AJ01), ^{6}Li and (85DO03, 87KU1F; theor.).

10. (a) ^{4}He(^{3}He, d)^{5}Li $\quad Q_m = -7.46$
(b) ^{4}He(^{3}He, pd)^{4}He $\quad Q_m = -5.49354$

At $E_\alpha = 26.3$ MeV, ^{5}Li$_{g.s.}$ is reported to have a width of 1.9 ± 0.25 MeV while the first excited state is suggested to lie at $E_x = 2.82 \pm 0.35$ MeV, $\Gamma = 1.64 \pm 0.25$ MeV [reaction (b)]: see (82NE09, 86YA01). See also (85NE1B).

11. ^{4}He(^{7}Li, ^{6}He)^{5}Li $\quad Q_m = -11.94$

See reaction 9 in ^{5}He (88WO10).

12. ^{6}Li(π^+, p)^{5}Li $\quad Q_m = 134.69$

Differential cross sections have been measured at $E_\pi = 75$ and 150 MeV for p_0: see (84AJ01).

13. (a) ^{6}Li(p, d)^{5}Li $\quad Q_m = -3.44$
(b) ^{6}Li(p, pd)^{4}He $\quad Q_m = -1.4750$
(c) ^{6}Li(p, pn)^{5}Li $\quad Q_m = -5.66$

Angular distributions have been measured at $E_p = 18.6$ to 185 MeV. At the highest energy, the spectra are characterized by a broad asymmetric peak corresponding to ^{5}Li$_{g.s.}$, a narrow peak [^{5}Li* (16.7)] and a broad peak at $E_x \approx 20$ MeV. DWBA analysis leads to $C^2S = 0.64$ and 0.57 for ^{5}Li*(0, 16.7). The first excited state of ^{5}Li is also reported to be populated: see (84AJ01).

Reaction (b) has been studied at $E_p = 9$ to 50 MeV: the p-α FSI corresponding to ^{5}Li$_{g.s.}$ is observed [see (79AJ01)]. See also (83CA13, 86NI1B). At 1 GeV (reaction (c)) the separation energy between 4–5 MeV broad $1p_{3/2}$ and $1s_{1/2}$ peaks is reported to be 17.7 ± 0.5 MeV (85BE1J, 85DO1B). See also (85PA03; $E_p = 70$ MeV).

14. (a) ^{6}Li(d, t)^{5}Li $\quad Q_m = 0.59$
(b) ^{6}Li(d, pt)^{4}He $\quad Q_m = 2.5577$

Angular distributions of the t_0 group have been measured at $E_d = 15$ and 20 MeV: see (74AJ01). Reaction (b) has been studied at $E_d = 0.12$ to 10.5 MeV: see (84AJ01). See also ^{8}Be.

15. (a) ^{6}Li(^{3}He, α)^{5}Li $\qquad Q_m = 14.91$
(b) ^{6}Li(^{3}He, pα)^{4}He $\qquad Q_m = 16.8782$

At $E(^3\text{He}) = 25.5$ MeV, ^{5}Li*(0, 16.7) and two broad peaks at $E_x \approx 19.8$ and 22.7 MeV [$\Gamma_{\text{c.m.}} = 2$ and 1 MeV] are populated: see (79AJ01). At $E(^3\text{He}) = 33.3$ MeV angular distributions and analyzing powers have been studied for ^{5}Li*(0, 16.7) [$\Gamma \approx 1.6$ and ≈ 0.4 MeV]: see (84AJ01). In reaction (b) the parameters of the first excited state are deduced to be $E_x = 5.0 \pm 0.7$ MeV, $\Gamma_{\text{c.m.}} = 5.7 \pm 0.7$ MeV (84AR17; $E(^3\text{He}) = 1.7$ and 2.3 MeV), $E_x = 5.8 \pm 0.5$ MeV, $\Gamma_{\text{c.m.}} = 5.2 \pm 0.5$ MeV (87FA1I; $E(^3\text{He}) = 1.65$ MeV). Angular distributions of protons from the decay of $^5\text{Li}_{\text{g.s.}}$ are reported by (88BU04; $E(^3\text{He}) = 1.5$ to 3.5 MeV). See also (85BA1U, 87ZA07), (84AJ01) and ^{8}Be.

16. ^{6}Li(^{6}Li, ^{7}Li)^{5}Li $\qquad Q_m = 1.58$

Angular distributions have been measured at $E(^6\text{Li}) = 156$ MeV to $^5\text{Li}_{\text{g.s.}}$. Unresolved states at $E_x = 16$–20 MeV are also populated (87MI34).

17. ^{6}Li(^{13}C, ^{14}C)^{5}Li $\qquad Q_m = 2.51$

See reaction 9 in ^{5}He (88WO10).

18. (a) ^{7}Li(p, t)^{5}Li $\qquad Q_m = -4.43$
(b) ^{7}Li(p, nd)^{5}Li $\qquad Q_m = -10.69$

At $E_p = 43.7$ MeV, a triton group is observed to ^{5}Li(0) ($\Gamma = 1.55 \pm 0.15$ MeV): the angular distribution is consistent with a substantial mixing of $L = 0$ and 2 transfer. There is some evidence also for a very broad excited state between $E_x = 2$ and 5 MeV. ^{5}Li*(16.7, 20.0) were not observed. The formation of ^{5}Li*(16.7)($^4\text{S}_{3/2}$) would be S-forbidden: the absence of ^{5}Li*(20.0) would indicate that this state(s) is also of quartet character [see reaction 20 in ^{5}He]. Weak, broad states at $E_x = 22.0 \pm 0.5$ MeV and 25.0 ± 0.5 MeV and possibly 34 MeV are reported in a coincidence experiment in which three- and four-particle breakup was analyzed: see (79AJ01). See also (88BAZH). For reaction (b) at $E_p = 670$ MeV see (84AJ01). See also (85NE1B; theor.).

19. ^{7}Li(^{3}He, dt)^{5}Li $\qquad Q_m = -9.93$

A kinematically complete experiment is reported at $E(^3\text{He}) = 120$ MeV. The missing mass spectrum shows the ground-state peak and a 4 MeV wide bump at $E_x \approx 34$ MeV, and some slight indication of a small bump at 22.0 ± 0.5 MeV (85FR01).

20. ^{7}Li(^{6}Li, ^{8}Li)^{5}Li $\qquad Q_m = -3.63$

See (84KO25).

21. ^{9}Be(α, ^{8}Li)^{5}Li $\qquad Q_m = -18.85$

At $E_\alpha = 90$ MeV differential cross sections have been measured for the transitions to ^{5}Li$_{g.s.}$ + ^{8}Li$_{g.s.}$: see (84AJ01).

22. ^{10}B(d, ^{7}Li)^{5}Li $\qquad Q_m = -1.40$

An angular distribution is reported at $E_d = 13.6$ MeV (83DO10). See also (84SH1E; theor.).

23. ^{10}B(^{3}He, 2α)^{5}Li $\qquad Q_m = 10.45$

At $E(^{3}\text{He}) = 2.3$ and 5.0 MeV the reaction is reported to proceed via ^{9}B*(4.9) to ^{5}Li$_{g.s.}$ (86AR14). See also (88AR05) and ^{9}B.

^{5}Be

The absence of any group structure in the neutron spectrum in the reaction ^{3}He(^{3}He, n)^{5}Be at $E(^{3}\text{He}) = 18.0$ to 26.0 MeV indicates that ^{5}Be(0) is at least 4.2 MeV unstable with respect to $^{3}\text{He} + 2\text{p}$ [$(M - A) > 33.7$ MeV]. With Coulomb corrections adjusted to match the 16.7 MeV states of ^{5}He–^{5}Li, this observation places the first $T = \frac{3}{2}$ level in these nuclei above $E_x = 21.4$ MeV: see (79AJ01).

References

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