Energy Levels of Light Nuclei
$A = 5$

D.R. Tilley [a,b], C.M. Cheves [a,c], J.L. Godwin [a,c], G.M. Hale [d], H.M. Hofmann [e], J.H. Kelley [a,b], C.G. Sheu [a,c] and H.R. Weller [a,c]

[a] *Triangle Universities Nuclear Laboratory, Durham, NC 27708-0308*
[b] *Department of Physics, North Carolina State University, Raleigh, NC 27695-8202*
[c] *Department of Physics, Duke University, Durham, NC 27708-0305*
[d] *Los Alamos National Laboratory, Los Alamos, NM 87545*
[e] *Universität Erlangen-Nürnberg, Erlangen, Germany*

Abstract: An evaluation of $A = 5$–7 was published in *Nuclear Physics A*708 (2002), p. 3. This version of $A = 5$ differs from the published version in that we have corrected some errors discovered after the article went to press. The introduction and introductory tables have been omitted from this manuscript. Reference key numbers are in the NNDC/TUNL format.

(References closed August 23, 2001)

This work is supported by the US Department of Energy, Office of High Energy and Nuclear Physics, under: Contract No. DEFG02-97-ER41042 (North Carolina State University); Contract No. DEFG02-97-ER41033 (Duke University).

Table of Contents for $A = 5$

Below is a list of links for items found within the PDF document. The introductory Table 3 *is available on this website via the link.*

$\mathbf{A = 5}$

$A = 5$ resonance parameters:

The resonance parameters tabulated here are based on comprehensive multichannel R-matrix analyses of reactions in the ^{5}He and ^{5}Li systems (Hale, Dodder and Witte, private communication [1]). These analyses include data from all possible reactions for the two-body channels d + t (or d + ^{3}He in the case of ^{5}Li) and N + ^{4}He at cm energies corresponding to $E_x < 23$ MeV. In addition, N + ^{4}He* channels are included to approximate the effects of three-body breakup processes. The fits obtained to the measurements for the two-body reactions are generally quite good. In the ^{5}He analysis, for example, the χ^2 per degree of freedom for the fit is 1.6, and it includes more than 2600 data points. Similar results were obtained for the ^{5}Li analysis, which includes even more data.

The level information has been obtained from the $A = 5$ R-matrix parameters using two different prescriptions, given in separate tables. The recommended prescription, called the "extended" R-matrix method (1987HA20, 1997CS01), comes from the complex poles and residues of the S matrix. This prescription has been found to give resonance parameters that are free, both formally and practically, of all dependence on the "geometric" parameters of R-matrix theory, such as boundary conditions and channel radii. The parameters are listed in Table 5.1 for ^{5}He and in Table 5.3 for ^{5}Li. Positions and widths for the lowest two $A = 5$ states have already been given in (1997CS01), and for the second excited state of ^{5}He ($\frac{3}{2}^+$) in (1987HA20), using this prescription.

For comparison, we also list in Tables 5.2 and 5.4 the more standard R-matrix resonance parameters that were used in the $A = 4$ level compilation (1992TI02), as defined in the Appendix there. This multi-level generalization of the single-level resonance prescription given by Lane and Thomas (1958LA73) is based on the real poles and residues of the "resonant" reactance matrix (K_R), which, because it is not truly an asymptotic quantity as is the S matrix, retains dependence on the channel radii, and on the specification of the "non-resonant" phase shift. Our prescription is based on the usual assumption that the non-resonant phase shifts are the "hard-sphere" phases associated with the complete reflection of ingoing waves at the nuclear surface.

The single-level prescription of Lane and Thomas was used recently by Barker (1997BA72) to obtain an interpretation of the behavior of the cross sections near the $J^\pi = 3/2^+$ resonance in $A = 5$ equivalent to that of the complex S-matrix pole and shadow pole description of (1987HA20).

A comparison of the tables for a given system shows that the resonance parameters from the two prescriptions can be quite different, however. The widths for the resonant reactance-matrix pole prescription tend to be much larger than those of the S-matrix pole prescription, and they do not usually correspond with the experimental values. For that reason, reaction numbers were not given in the Tables (5.2 and 5.4) listing the K_R-based parameters, as defined in (1992TI02).

In some cases, resonances seen using the recommended method are not present in the usual prescription, even though the input R-matrix parameters are identically the same. These differences, which are most evident for light systems having broad resonances, stem from the fact that the resonant K-matrix prescription is based on the *apparent* positions of the S-matrix poles as seen from

[1] For a discussion of the methods used and earlier results, see G.M. Hale and D.C. Dodder, Proc. Int. Conf. on Nuclear Cross Sections for Technology, Knoxville, TN 1979, Eds. J.L. Fowler, C.H. Johnson and C.D. Bowman (NBS Special Publication 594) p.650.

the real axis of the physical sheet. For broad resonances, as is known from the complex-eigenvalue expansion of the level matrix (1958LA73), the apparent pole positions can change rapidly (or even disappear entirely) as the vantage point is varied, causing significant differences with the actual positions (and residues) of the poles in the complex energy plane.

GENERAL: References to articles on general properties of $A = 5$ nuclei published since the previous review (1988AJ01) are grouped into categories and listed, along with brief descriptions of each item, in the General Tables for $A = 5$ located on our website at (*www.tunl.duke.edu/nucldata/General_Tables/05.shtml*).

^{5}n

(Not illustrated)

^{5}n has not been observed. It is suggested that it is unbound by 10 MeV: see (1984AJ01). See also (1984DE52).

^{5}H

(Not illustrated)

The previous review (1988AJ01) noted that the ^{9}Be(^{11}B, ^{15}O) reaction at $E(^{11}\text{B}) = 52$–76 MeV showed no evidence for the formation of ^{5}H (1986BE35, 1987BO40). For the earlier work see (1984AJ01). See also (1987KO47, 1988SEZJ). In several experiments on π^- absorption at rest there is some evidence for the formation of a very broad (8 ± 3 MeV) resonance in the ^{5}H system with $E_\text{r} = 7.4 \pm 0.7$ MeV in the ^{9}Be(π^-, X) reaction [see (1987GO25) and the more recent work of (1991GO19, 1992AM1H)]. Measurements reported in (1990AM04, 1992AM1H) provide evidence for a state at $E_\text{r} = 11.8 \pm 0.7$ MeV, $\Gamma = 5.6 \pm 0.9$ MeV from ^{6}Li(π^-, p) and a state at $E_\text{r} = 9.1 \pm 0.7$ MeV, $\Gamma = 7.4 \pm 0.6$ MeV from ^{7}Li(π^-, d). In an experiment on ^{6}Li(π^-, p) at $E_\pi = 125$ MeV (1980SE1A) a broad ^{5}H state with $E_\text{r} = 11.1 \pm 1.5$, $\Gamma \approx 14$ MeV was observed. Evidence for a dineutron-containing breakup channel was reported in (1991SE06). Work on an experiment on ^{7}Li(^{6}Li, ^{8}B)^{5}H described in (1995ALZU) reported evidence for an unstable ^{5}H nucleus at 5.2 ± 0.4 MeV above the $^3\text{H} + 2\text{n}$ dissociation threshold. See also (1995AU04). A recent study of the ^{1}H(^{6}He, 2p)^{5}H reaction (1997KO07) reported a ^{5}H resonance with decay energy into $^3\text{H} + 2\text{n}$ of $1.1 \pm 0.4 \pm 0.3$ MeV (0.3 MeV is the systematic error).

^{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 $E_\text{x} = 2.44$, 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 $E_\text{x} = 2.85$, 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] (1985PO10). A three-body calculation (2000SH23) predicts states in the $^3\text{H} + \text{n} + \text{n}$ continuum with $J^\pi = \frac{1}{2}^+$, $E_\text{x} = 2.5$–3.0 MeV, $\Gamma = 3$–4 MeV; $J^\pi = \frac{3}{2}^+$, $E_\text{x} = 6.4$–6.9 MeV, $\Gamma = 8$ MeV; $J^\pi = \frac{5}{2}^+$, $E_\text{x} = 4.6$–5.0 MeV, $\Gamma = 5$ MeV. A calculation (2001DE02) with the generator-coordinate method using $^3\text{H} + \text{n} + \text{n}$ three-cluster state predicts a ^{5}H ground state energy

$E \approx 3$ MeV above the $^3H + n + n$ threshold with $\Gamma_n \approx$ 1–4 MeV and a lifetime longer than the ^4H lifetime. See also (1982SM09, 1983ANZQ, 1986BE44, 1987PE1C).

^{5}He

(Figs. 1 and 3)

GENERAL: References to articles on general properties of ^{5}He published since the previous review (1988AJ01) are grouped into categories and listed, along with brief descriptions of each item, in the General Tables for ^{5}He located on our website at (*www.tunl.duke.edu/nucldata/General_Tables/5he.shtml*).

1. ^{1}H(^{6}He, np)^{5}He $\qquad Q_m = -1.771$

The quasi-free neutron knockout reaction was studied with ^{6}He beams produced by 115 MeV ^{15}N primary beams (1997KOZV, 1997KO07). ^{5}He was observed in the separation energy spectra. The $^5\text{He} \rightarrow {}^4\text{He} + \text{n}$ decay energy is reported to be consistent with the "known mass of ^{5}He" and is given as 0.97 MeV.

2. ^{3}H(d, γ)^{5}He $\qquad Q_m = 16.792$

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 $(5.6 \pm 0.6) \times 10^{-5}$ (1986MO05), in very good agreement with the earlier value of $(5.4 \pm 1.3) \times 10^{-5}$ for $E_d = 45$ to 146 keV (1984CE08). Assuming Γ_n of ^{5}He*(16.7) is 37 ± 5 keV (see reaction 8), then $\Gamma_{\gamma_0} = 2.1 \pm 0.4$ eV. (1986MO05) also report branching ratios up to $E_d = 0.72$ MeV and summarize the earlier work to 5 MeV. More recently, a measurement (1993KA01) at $E_d = 100$ keV of the ^{3}H(d, γ)^{5}He/^{3}H(d, α)n ratio gave $(1.2 \pm 0.3) \times 10^{-4}$ which is larger than the results of (1986MO05) and (1984CE08) but includes contribution from decay to both the ground and first excited states.

Differential cross sections, vector- and tensor-analyzing powers were measured at $E_d = 400$ keV for ^{3}H(d, γ)^{5}He (1989RI04) and at $E_d = 0.1$, 0.45 and 8.6 MeV for ^{3}H(d, γ) and ^{3}He(d, γ) by (1994BA02). These results were compared with coupled channels resonating group model (CCRGM) calculations. See also the shell model description of the $\frac{3}{2}^+$ resonance presented in (1993KU02).

The ^{3}H(d, γ)^{5}He and ^{3}He(d, γ)^{5}Li reactions were used in a measurement (1991BA02) of the ground state widths of ^{5}He and ^{5}Li. The results were $\Gamma_n = 1.36 \pm 0.19$ MeV in ^{5}He and $\Gamma_p = 2.44 \pm 0.21$ MeV for ^{5}Li. These values lead to reduced widths for ^{5}He and ^{5}Li which are equal (within error). This is consistent with charge symmetry expectations. The ground-state widths

Table 5.1: Energy levels of ^{5}He, extended R-matrix prescription [a]

E_x (MeV)	$J^\pi; T$	Γ_{cm} [b] (MeV)	Γ_n (MeV)	Γ_d (MeV)	Γ_{n*} [c] (MeV)	Decay	Reactions (used in analysis)
g.s. [d]	$\frac{3}{2}^-; \frac{1}{2}$	0.648	0.578	8.80 [e]	66.0 [e]	n, α	5, 8, 13, 23, 24, 25
1.27	$\frac{1}{2}^-; \frac{1}{2}$	5.57	3.18	38.0 [e]	1.27 [e]	n, α	5, 8, 21, 24, 25
16.84	$\frac{3}{2}^+; \frac{1}{2}$	0.0745	0.040	0.025 [f]		γ, n, d, t, α	2, 3, 7, 8, 10, 13, 14, 23, 24, 25
19.14	$\frac{5}{2}^+; \frac{1}{2}$	3.56	0.003	1.62 [g]		n, d, t, α	4, 10, 14, 23
19.26	$\frac{3}{2}^+; \frac{1}{2}$	3.96	0.014	1.83 [g]		n, d, t, α	4, 10, 14, 23
19.31	$\frac{7}{2}^+; \frac{1}{2}$	3.02	0.045	1.89 [g]		n, d, t, α	4, 10, 14
19.96	$\frac{3}{2}^-; \frac{1}{2}$	1.92	0.003	0.325 [h]	0.862	n, p, d, t, α	3, 17, 24, 25
21.25	$\frac{3}{2}^+; \frac{1}{2}$	4.61	0.098	2.38 [i]		n, d, t, α	21
21.39	$\frac{5}{2}^+; \frac{1}{2}$	3.95	0.091	2.12 [l]		n, d, t, α	21
21.64	$\frac{1}{2}^+; \frac{1}{2}$	4.03	0.050	0.878 [j]	0.726	n, p, d, t, α	21
23.97	$\frac{7}{2}^+; \frac{1}{2}$	5.44	0.053	2.85 [g]		n, d, t, α	
24.06	$\frac{5}{2}^-; \frac{1}{2}$	5.23	0.013	2.18 [k]		n, d, t, α	
(35.7 ± 0.4) [l]		≈ 2 [l]					21, 25

[a] This prescription, based on the complex poles and residues of the S-matrix, is the recommended one (see Introduction). The channel radii are: $a_n = 3.0$ fm, $a_d = 5.1$ fm. The uncertainties in the widths and positions of the first three levels are less than 1%. Above 19 MeV excitation energy, they increase rapidly, varying from about 5% up to as much as 50% for the broad higher levels. Except where noted, all parameters in the table are newly adopted in this evaluation.

[b] The fact that the sum of the partial widths is unequal to the total width in the extended R-matrix prescription is characteristic of non-Breit-Wigner resonances as was discussed in the appendix of (1992TI02).

[c] The n* designation indicates $n + \alpha$* where the first excited state of the α particle was included as a way to approximate the effects of three-body breakup on the two-body channels.

[d] Situated 798 keV above the $n + \alpha$ threshold. This value is in excellent agreement with early measurements reported by (1963SM03; 790 ± 30 keV) and by (1960YO06; 800 ± 100 keV).

[e] These large partial widths in closed channels have no meaning as decay widths, but rather as asymptotic normalization constants.

[f] Entirely $^4S(d)$.

[g] Primarily $^4D(d)$.

[h] Primarily $^2P(d)$.

[i] Primarily $^2D(d)$.

[j] Primarily $^2S(d)$.

[k] Primarily $^4P(d)$.

[l] Retained from the previous evaluation (1988AJ01).

Table 5.2: Energy levels of ^{5}He, R-matrix prescription [a]

E_x (MeV)	$J^{\pi}; T$	Γ_{cm} (MeV)	Γ_n (MeV)	Γ_d (MeV)	Γ_{n^*} (MeV)
g.s. [b]	$\frac{3}{2}^-; \frac{1}{2}$	0.963	0.963	0	0
6.17	$\frac{1}{2}^-; \frac{1}{2}$	20.61	20.61	0	0
16.66	$\frac{3}{2}^+; \frac{1}{2}$	0.889	0.691	0.198 [c]	
19.97	$\frac{3}{2}^-; \frac{1}{2}$	3.49	0.127	2.85 [d]	0.508
20.32	$\frac{1}{2}^+; \frac{1}{2}$	6.64	0.273	5.08 [e]	1.29
20.48	$\frac{7}{2}^+; \frac{1}{2}$	4.43	0.066	4.37 [f]	
21.67	$\frac{3}{2}^+; \frac{1}{2}$	6.87	0.156	6.72 [f]	
21.77	$\frac{5}{2}^+; \frac{1}{2}$	6.58	0.247	6.33 [f]	
23.52	$\frac{5}{2}^+; \frac{1}{2}$	25.21	0.028	25.18 [f]	
24.10	$\frac{1}{2}^-; \frac{1}{2}$	57.3	0.177	44.8 [d]	12.3
24.58	$\frac{5}{2}^-; \frac{1}{2}$	5.56	0.020	5.54 [g]	

[a] See the Introduction for a discussion of the two prescriptions. The prescription used here is defined in (1992TI02). The channel radii are: $a_n = 3.0$ fm, $a_d = 5.1$ fm.

[b] Situated 985 keV above the $n + \alpha$ threshold.

[c] Entirely $^{4}S(d)$.

[d] Primarily $^{2}P(d)$.

[e] Primarily $^{2}S(d)$.

[f] Primarily $^{4}D(d)$.

[g] Primarily $^{4}P(d)$.

given by the conventional R-matrix prescription in Tables 5.2 and 5.4 are 0.963 MeV and 2.11 MeV for ^{5}He and ^{5}Li, respectively.

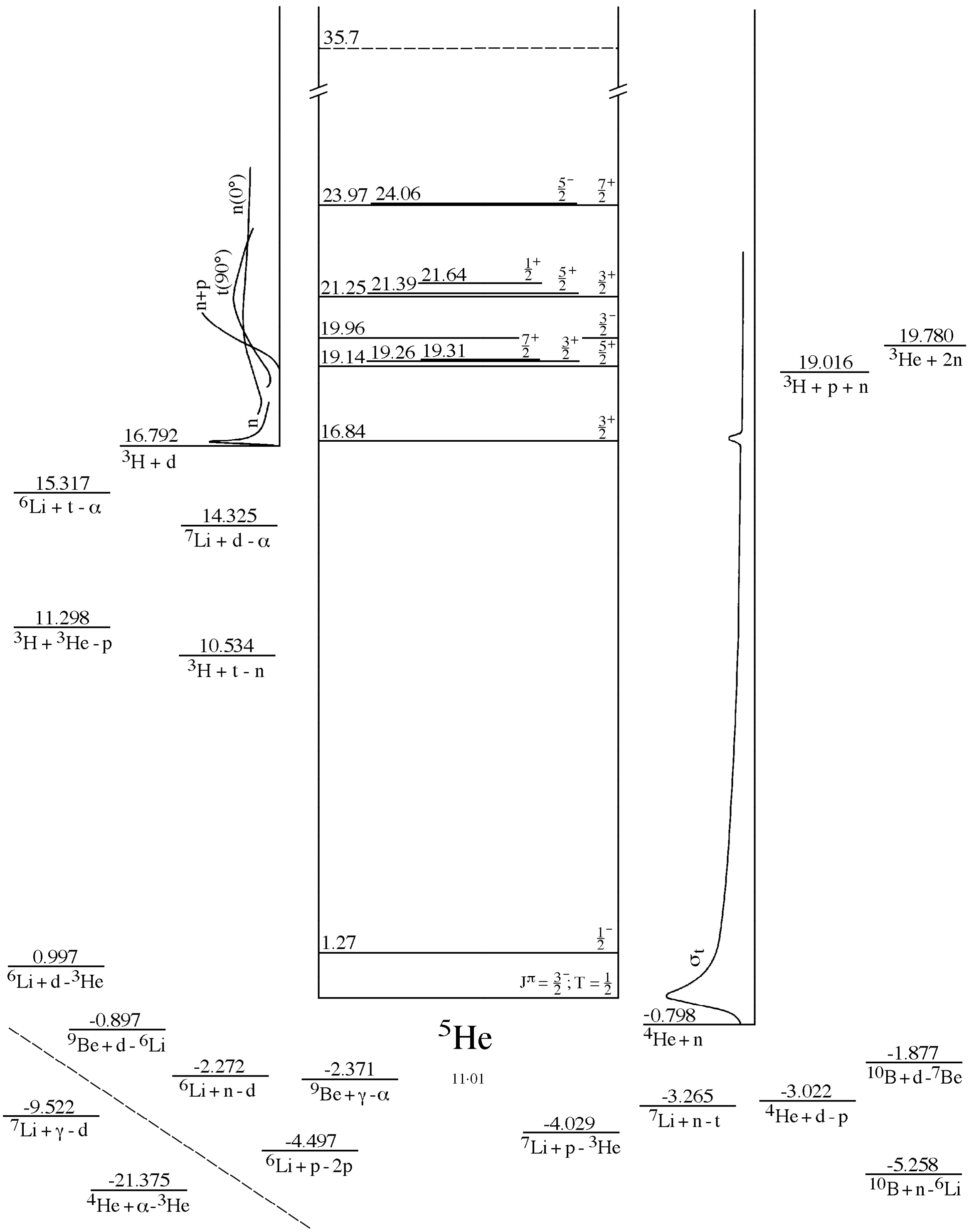
The data of (1991BA02) were used by (1996EF03) in a single-level R-matrix analysis to obtain values of the ground-state energies and widths of ^{5}He and ^{5}Li, close to those given by the extended R-matrix prescription in Tables 5.1 and 5.3.

3. (a) ^{3}H(d, n)^{4}He	$Q_m = 17.58928$	$E_b = 16.79151$
(b) ^{3}H(d, 2n)^{3}He	$Q_m = -2.98834$	
(c) ^{3}H(d, pn)^{3}H	$Q_m = -2.22457$	

The cross section for reaction (a) has been measured in the range $E_t = 12.5$ to 117 keV (1984JA08) [$0.525(\pm 4.8\%)$ mb to $3.739(\pm 1.4\%)$ b] and in the range $E_d = 79.913$ to 115.901 keV (± 0.015 keV) (1987BR10) [3.849 to 4.734 b ($\pm 1.6\%$)]. See also (1985FI1G; $E_d = 13.8$ to 114.3 keV). A strong resonance, σ (peak) $= 4.88$ b, appears at $E_d = 105$ keV: see Table 5.2 in (1979AJ01) and (1987BR10). For a discussion of R-matrix analysis and evidence for a "shadow" pole, see (1987BR10, 1987HA20). See also (1987HA44, 1987MO1K). The related work of (1991BO23) uses a resonance coupled channels model to interpret the ^{5}He $(\frac{3}{2}^+)$ resonance as a coupled channel pole associated predominantly with the d-t system. A later study by (1993CS02) uses a realistic dynamical microscopic reaction approach and reaches the same conclusion. A more recent analysis of cross section data for $E_d = 8$–116 keV is described in (1995LA33). Resonance parameters for the ^{5}He $\frac{3}{2}^+$ second excited state were determined.

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. (See however the discussion below.) 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 (1974AJ01, 1979AJ01, 1984AJ01)] as well as at 1.0, 1.5 and 2.0 MeV (1987LI07). Neutron yields from reaction (a) above have been measured at $E_d = 140$–300 keV (1989SH17). Measurements to determine the intensity of intermediate energy neutrons are described in (1989GA21). An absolute measurement of the polarization of 50 MeV neutrons at $\theta_{lab} = 29.7°$ was reported in (1991SA18).

Figure 1: Energy levels of ^{5}He, extended R-matrix prescription (see Table 5.1). In these diagrams, energy values are plotted vertically in MeV, based on the ground state as zero. For the $A = 5$ diagrams all levels are represented by discrete horizontal lines. Values of total angular momentum J, parity, and isobaric spin T which appear to be reasonably well established are indicated on the levels; less certain assignments are enclosed in parentheses. For reactions in which ^{5}He is the compound nucleus, some typical thin-target excitation functions are shown schematically, with the yield plotted horizontally and the bombarding energy vertically. Bombarding energies are indicated in laboratory coordinates and plotted to scale in cm coordinates. Excited states of the residual nuclei involved in these reactions have generally not been shown. For reactions in which the present nucleus occurs as a residual product, excitation functions have not been shown. Q values and threshold energies are based on atomic masses from (1995AU04) except for the ground state energies of the $A = 5$ nuclei for which the values from Tables 5.1 and 5.3 are used. Further information on the levels illustrated, including a listing of the reactions in which each has been observed, is contained in Table 5.1.


35.7
23.97 24.06
5/2−
7/2+
21.25 21.39 21.64
1/2+
5/2+
3/2+
19.96
3/2−
19.14 19.26 19.31
7/2+
3/2+
5/2+
16.84
3/2+
1.27
1/2−
Jπ = 3/2−; T = 1/2
n(0°)
t(90°)
n+p
n
16.792
3H + d
15.317
6Li + t - α
14.325
7Li + d - α
11.298
3H + 3He - p
10.534
3H + t - n
0.997
6Li + d - 3He
-0.897
9Be + d - 6Li
-2.272
6Li + n - d
-2.371
9Be + γ - α
-9.522
7Li + γ - d
-4.497
6Li + p - 2p
-21.375
4He + α - 3He
5He
11·01
-4.029
7Li + p - 3He
σt
-0.798
4He + n
-3.265
7Li + n - t
-3.022
4He + d - p
19.016
3H + p + n
19.780
3He + 2n
-1.877
10B + d - 7Be
-5.258
10B + n - 6Li

A study of reaction (a) with polarized deuterons at $E_{\rm d} = 0.2$ to 1.0 MeV indicates intervention of the s-wave, $J^\pi = \frac{1}{2}^+$ channel, as well as possible p-waves above $E_{\rm d} = 0.3$ MeV. The polarization increases monotonically from 0.03 at $E_{\rm d} = 3$ MeV to ≈ 0.5 at $E_{\rm d} = 6.5$ MeV and then with a lower slope to 0.69 at $E_{\rm d} = 13$ 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 cm energies shows excellent agreement between the polarization values in the two reactions up to $E_{\rm d} = 6$ MeV, but then the proton polarization becomes $\approx 15\%$ higher, converging back to the neutron values at $E_{\rm d} \approx 12$–13 MeV. This may be due to experimental factors. Vector polarization transfer coefficients, $K_{\rm y}^{\rm y'}(0°)$ have been measured for $E_{\rm d} = 5$ to 11 MeV (1985HOZU, 1986HO1E). For earlier polarization work see (1984AJ01).

An R-matrix formalism was used in a phase shift analysis of d + ^{3}H below 1 MeV to obtain the contribution of ^{2}S$_{1/2}$- and P-wave channels near the ^{5}He $(\frac{3}{2}^+)$ resonance. See also the recent work (1997BA72) in which properties of the $\frac{3}{2}^+$ levels of ^{5}He and ^{5}Li are discussed in terms of conventional R-matrix parameters. The multichannel resonating group model has been used in a study (1990BL08) of partial wave contributions in this energy region.

Improved formulae for fusion cross sections and thermal reactivities utilizing new data and R-matrix techniques are presented in (1992BO47). See also (1989AB21, 1989SC1F, 1989SC19, 1989SC25, 1989SC41).

The ^{3}H(d, n) reactivity in fusion reactors and screening-effect corrections needed for low energy data are discussed in (1989LA29).

(1987BR10) have derived astrophysical S-factors in the range $E_{\rm d} = 8.3$ to 115.9 keV [$S(0) = 11.71 \pm 0.08$ MeV · b], as well as reactivities. See (1984AJ01) for the earlier work, and (1985CA41, 1987VA36). Angular distributions of α particles were measured for $E_{\rm d} < 200$ keV (1997BE59) and evidence for a D-wave contribution to the cross section in the vacinity of the $\frac{3}{2}^+$ s-wave resonance in ^{5}He was reported. Thermonuclear reaction rates for this reaction calculated from evaluated data are presented in the compilation (1999AN35).

Reaction (b) has been studied for $E_{\rm d} = 10.9$ to 83 MeV. A study of reaction (c) leads to the suggestion of a resonance at $E_{\rm cm} = 2.9 \pm 0.3$ MeV [$E_{\rm x} = 19.7$ MeV], $\Gamma_{\rm cm} = 1.9 \pm 0.2$ MeV, consistent with $J^\pi = \frac{3}{2}^-$ [see Table 5.1]: see (1974AJ01, 1979AJ01). See also the references cited in (1988AJ01). For applications and developments in muon-catalyzed fusion see the references cited in (1988AJ01) and the General Table for ^{5}He located on our website at (*www.tunl.duke.edu/nucldata/General_Tables/5he.shtml*).

4. ^{3}H(d, d)^{3}H $\qquad E_{\rm b} = 16.792$

The elastic scattering has been studied for $E_{\rm d} = 2.6$ to 11.0 MeV: see (1984AJ01). For earlier measurements at other energies see (1966LA04). The excitation curves show an interference at $E_{\rm x} \approx 19$ MeV and a broad ($\Gamma > 1$ MeV) resonance corresponding to $E_{\rm x} = 20.0 \pm 0.5$ 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 $E_x \approx 19.7$ 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). Elastic scattering data is also utilized in the S-matrix studies of the ^{5}He $(\frac{3}{2}^+)$ resonance at $E_x = 16.84$ MeV (1988BE1U, 1991BO23, 1993CS02). (See reaction 3.) See also the effective-range expansion and Coulomb renormalization for d + t and related systems (1991KA31, 1996PO26). For earlier references see (1979AJ01, 1988AJ01). For d-t correlations see (1987PO03). See also "Complex reactions" in the General section of (1988AJ01) and (1981PL1A, 1983HAYX, 1986BO01). See also (1997BA72) in which properties of the $\frac{3}{2}^+$ levels of ^{5}He and ^{5}Li are discussed in terms of conventional R-matrix parameters.

5. ^{3}H(t, n)^{5}He $\quad Q_m = 10.534$

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$_{g.s.}$; (iii) sequential decay via a broad excited state of ^{5}He. The width of ^{5}He$_{g.s.}$ 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 (1979AJ01). See also ^{6}He and (1986BA73).

6. ^{3}H(α, dα)n $\quad Q_m = -6.257$

A kinematically complete experiment at $E_\alpha = 67.2$ MeV has been reported by (2000GO35). They report observation of ^{5}He excited states at $E_x = 18.9$, 19.9 and 20.7 MeV with widths of 0.3, 0.25 and 0.25 MeV, respectively.

7. ^{3}He(t, p)^{5}He $\quad Q_m = 11.298$

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 (1979AJ01). See also ^{6}Li.

8. ^{4}He(n, n)^{4}He $\quad E_b = -0.798$

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 (1984AJ01)] and at $E_n = 1.5$ to 40 MeV (1983HA20).

The total cross section has a peak of 7.6 b at $E_n = 1.15 \pm 0.05$ MeV, $E_{cm} = 0.92 \pm 0.04$ MeV, with a width of about 1.2 MeV: see (1979AJ01). 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 $\Gamma_n = 37 \pm 5$ keV (1983HA20). Attempts to detect additional resonances in the total cross section have been unsuccessful: see (1979AJ01). For curves and tables of neutron cross sections see (1988MCZT, 1990NAZH, 1990SH1C).

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. (1966HO07) 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 (1979AJ01)). See also (1997BA72) in which properties of the $\frac{3}{2}^+$ levels of ^{5}He and ^{5}Li are discussed in terms of conventional R-matrix parameters.

An R-function analysis of the $^4\mathrm{He} + \mathrm{n}$ 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 $^4\mathrm{He} + \mathrm{n}$ data alone (rather than also including the $^4\mathrm{He}+\mathrm{p}$ data). At $a = 3.3$ fm the values obtained for the $P_{1/2}$ and $P_{3/2}$ resonances are, respectively, $E_{cm} = 1.97$ and 0.77 MeV, $\Gamma_{cm} = 5.22$ and 0.64 MeV: see (1984AJ01). Angular distributions of A_y have been studied by (1984KL05, 1984KR23, 1986KL04) for $E_n = 15$ 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 (1985BA68) 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 (1984VA06). 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. (1985BA68) suggest that the phase-shift analysis should be redone with values of a larger than those previously used ($a \approx 3$ fm). See also references cited in (1988AJ01). In more recent work S-matrix studies of the low energy $\frac{3}{2}^-$ and $\frac{1}{2}^-$ states are described in (1997CS01, 1998CS02). See also the calculations of (1999AO01, 1999FI10).

Nucleon-α potentials have been derived from phase shifts by (1991CO05) and constructed from experimental data by the Marchenko inversion method as discussed in (1993HO09). The scattering amplitude in the vicinity of the ^{5}He $(\frac{3}{2}^+)$ resonance is expressed in terms of the scattering length and the d-t effective range by (1994MU07). A study of the two-pole structure of the $\frac{3}{2}^+$ resonance is discussed in (1993CS02). See also the discussion of Pauli blocking in this reaction (1990AM07) and an application of an algebraic cluster approach to n-α scattering (1989US02).

9. ^{4}He(p, π^+)^{5}He $\qquad Q_m = -141.150$

As reported in (1988AJ01), differential cross sections were measured at $E_p = 201$ MeV (1985LE19) and at $E_p = 800$ MeV (1984HO01; also A_y). See also (1987SO1C) and (1985GE06).

More recently differential cross sections and analyzing powers were measured at incident proton energies between 240 and 507 MeV, spanning the region of the Δ_{1232} resonance (1994FU06).

These results were compared with the prediction of a microscopic (p, π^+) model and with a phenomenological model. See (1994FA10).

10. (a) ^{4}He(d, p)^{5}He $\quad Q_m = -3.022$

(b) ^{4}He(d, pn)^{4}He $\quad Q_m = -2.2246$

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 ± 0.1 [$\Gamma = 80 \pm 30$ keV]) and suggests some fine structure near $E_x = 19$ MeV [see also reactions 15 and 23]: see (1979AJ01). Differential cross sections and VAP have been measured for the ground state group at $E_d = 5.4$, 6.0, and 6.8 MeV (1985LU08) and at 6 to 11 MeV (1985OS02). Measurements of differential cross sections, analyzing powers, and polarization transfer coefficients at $E_d = 56$ MeV were reported in (1990YOZZ). 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 (1985WI15). See also ^{6}Li (1988PUZZ; $E_d = 2.1$ GeV) and other references cited in (1988AJ01).

Cross sections and transverse tensor analyzing powers for reaction (b) at $E_d = 7$ MeV were measured with kinematic conditions chosen to correspond to singlet deuteron production (1988GA14).

Theoretical studies relevant to reaction (b) include: a study of effects of the proton Coulomb field on α, n resonance peaks (1988KA38); comparisons of measured cross sections and polarization observables at $E_d = 12$, 17 MeV with a three-body model (1988SU12); a study of the influence of three-particle Coulomb dynamics on the cross section (1991AS02); a study of the effects of the internal structure of the α particle on the reaction (1990KU27); and a multiconfiguration resonating group study of the six-nucleon system (1991FU01, 1995FU16).

11. ^{4}He(^{4}He, ^{3}He)^{5}He $\quad Q_m = -21.375$

Differential cross sections for this reaction to ^{5}He$_{g.s.}$ were measured at $E(^4\text{He}) = 118$ MeV, and compared with DWBA predictions (1994WA06). Measurements of angular distributions at $E_\alpha = 158$ and 200 MeV were reported by (1996ST25).

12. ^{4}He(^{7}Li, ^{6}Li)^{5}He $\quad Q_m = -8.048$

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 was reported by (1988WO10). Properties of the two lowest states of ^{5}He and ^{5}Li, from R-matrix parameters ($a = 5.5$ fm) are displayed in Table 5.2 of (1988AJ01). As noted there, 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 (1988WO10). See also the analysis in (1988BA75).

13. (a) ^{6}Li(γ, p)^{5}He $\quad Q_m = -4.497$
(b) ^{6}Li(e, ep)^{5}He $\quad Q_m = -4.497$
(c) ^{6}Li(π^+, π^+p)^{5}He $\quad Q_m = -4.497$
(d) ^{6}Li(π^-, π^-p)^{5}He $\quad Q_m = -4.497$

At $E_\gamma = 60$ MeV, the proton spectrum shows two prominent peaks. In early work cited in (1979AJ01) these peaks are attributed to ^{5}He*($0 + 4.0$, 20 ± 2): see (1979AJ01). 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 (1988CA11). A review of photodisintegration data for energies up to $E_\gamma = 50$ MeV was presented in (1990VA16). More recently, measurements were made at $E_\gamma = 60$ MeV (1994RY01), at $E_\gamma = 61$, 77 MeV (1994NI04), and at $E_\gamma = 59$–75 MeV (1995DI01). In reaction (b) the missing energy spectrum shows strong peaks due to ^{5}He*(0, 16.7) and possibly some strength in the region $E_x = 5$–15 MeV (1986LAZH). See also ^{6}Li, and see the recent triple cross section measurements of (1999HO02). Reviews of (e, e′p) data are presented in (1990DE16, 1991VA05). See also (1989LA13, 1990DE06, 1990LA06). A microscopic cluster model used to interpret these experiments is discussed in (1990LO14). For reaction (c) at $E_{\pi^+} = 130$ and 150 MeV, ^{5}He*(0, 16.7) are populated (1987HU02). Measurements at $E_{\pi^+} = 500$ MeV were made by (1998PA31) to search for Δ components. Reaction (d) was studied at GeV energies by (2000AB25) to deduce Fermi momentum distributions.

14. ^{6}Li(n, d)^{5}He $\quad Q_m = -2.272$

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 (1979AJ01, 1984AJ01). Measured cross sections and analysis for $E_n = 14.1$ MeV are presented in (1989SHZS). See also (1986BOZG). A Multiconfiguration Resonating-Group Method calculation applied to this reaction is discussed in (1995FU16).

15. ^{6}Li(p, 2p)^{5}He $\quad Q_m = -4.497$

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. Measurements were reported at $E_p = 47$ and 70 MeV (1983VD03), 70 MeV (1983GO06), 392 MeV (1996KAZZ, 1997HA15, 1998NO04), and 1 GeV (1985BE30, 1985DO16, 2000MI17). See also (1984AJ01). Experimental and theoretical studies for $E_{\rm p} = 30$–150 MeV were reviewed in (1987VD1A). See also (1987VD01). The influence of noncoplanarity on information obtained from these reactions was studied by (1990GO34).

16. ^{6}Li(d, ^{3}He)^{5}He $\quad Q_{\rm m} = 0.997$

^{5}He$_{\rm g.s.}$ has been observed at $E_{\rm d} = 14.5$ MeV: see (1979AJ01).

17. ^{6}Li(α, αp)^{5}He $\quad Q_{\rm m} = -4.497$

At $E_{\alpha} = 140$ MeV ^{5}He*(0, 20.0) are populated: see (1984AJ01).

18. ^{6}Li(^{6}Li, ^{7}Be)^{5}He $\quad Q_{\rm m} = 1.109$

Angular distributions have been obtained at $E(^{6}{\rm Li}) = 156$ MeV to ^{5}He$_{\rm g.s.}$. Unresolved states at $E_{\rm x} = 16$–20 MeV are also populated (1987MI34).

19. ^{6}Li(^{12}C, ^{13}N)^{5}He $\quad Q_{\rm m} = -2.553$

See reaction 12 and (1988WO10).

20. ^{7}Li(γ, d)^{5}He $\quad Q_{\rm m} = -9.522$

Cross sections and excitation functions were calculated by (1988DU04). Also see ^{7}Li.

21. (a) ^{7}Li(π^{+}, 2p)^{5}He $\quad Q_{\rm m} = 128.606$
(b) ^{7}Li(π^{-}, 2n)^{5}He $\quad Q_{\rm m} = 127.041$

Reaction (a) at $E_{\pi^{+}} = 59.4$ MeV involves ^{5}He*(0, 4.) and a broad peak centered at $E_{\rm x} \approx 21$ MeV with $\Gamma \approx 4$ MeV. It is not clear whether ^{5}He*(16.7) is populated (1986RI01). See also (1979AJ01, 1984AJ01).

DWIA calculations of cross sections and analyzing powers for population of ^{5}He($\frac{3}{2}^{-}$, g.s.) are described in (1992KH04).

22. ^{7}Li(n, t)^{5}He $\quad Q_{\rm m} = -3.265$

The angular distribution of t_0 has been measured at $E_{\rm n} = 14.4$ MeV: see (1979AJ01) and ^{8}Li in (1988AJ01). See also (1986BOZG, 1989SHZS).

23. (a) ^{7}Li(p, ^{3}He)^{5}He $\quad Q_{\rm m} = -4.029$
(b) ^{7}Li(p, pd)^{5}He $\quad Q_{\rm m} = -9.522$

At $E_{\rm p} = 43.7$ 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 $^{4}D_{3/2}$ or $^{4}D_{5/2}$ [compare ^{3}H(d, d)]. Particle-particle coincidence data have been obtained at $E_{\rm p} = 43.7$ 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 (1979AJ01). Measurements of angular distributions at $E_{\rm p} = 29.1$–44.6 MeV are reported in (1989BA88). In reaction (b) ^{5}He*($0 + 4$, 16.7, 25) appear to be involved at $E_{\rm p} = 670$ MeV (1981ER10) while at 200 MeV some structure at $E_{\rm x} \approx 20$ MeV is reported in addition to the ground state (1986WA11).

24. (a) ^{7}Li(d, α)^{5}He $\quad Q_{\rm m} = 14.325$
(b) ^{7}Li(d, n)^{4}He^{4}He $\quad Q_{\rm m} = 15.1223$

At $E_{\rm d} = 24$ MeV, the α-particle spectrum from reaction (a) shows structures corresponding to the ground and 16.7 MeV states and to states at $E_{\rm x} \approx 20.2$ and 23.8 MeV with $\Gamma \approx 2$ MeV and ≈ 1 MeV, respectively. Measurements of the α-particle energy spectra at $E_{\rm d} = 13.6$ MeV were reported in (1993PAZP). An analysis of cross section data measured at $E_{\rm d} = 0$–12 MeV is reported in (1997HAZX). Astrophysical S factors were measured at $E_{\rm cm} = 57$–141 keV by (1997YA08). Measurements of the reaction rate at low energies for ^{7}Li implanted in Pd foil were reported by (2000BAZO). Reaction (b) proceeds mainly via excited states of ^{8}Be and ^{5}He$_{\rm g.s.}$ and possibly as well ^{5}He*(4.): see (1979AJ01). Measurements at $E_{\rm d} = 4.35$ MeV have been reported by (2000MIZU). See also (1987WA21) and ^{8}Be in (1988AJ01).

Measurements of $\sigma(\theta)$ at $E_{\rm d} = 6.8$ MeV were reported in (1989AR04). Parameters of the resonance for the ^{5}He state at $E_{\rm x} = 16.76$ MeV were extracted. Analysis (1991AR10, 1993FA12) of coincidence measurements at $E_{\rm d} = 1.4$, 2.1 and 2.5 MeV gave $E_{\rm x} = 4.1 \pm 0.2$ MeV, $\Gamma = 2.9 \pm 0.4$ MeV for the ^{5}He $p_{1/2}$ first excited state.

25. (a) ^{7}Li(^{3}He, pα)^{5}He $\qquad Q_{\rm m} = 8.831$

(b) ^{7}Li(^{3}He, ^{3}He d)^{5}He $\qquad Q_{\rm m} = -9.522$

A kinematically complete experiment is reported at $E(^3{\rm He}) = 120$ 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 (1985FR01).

26. ^{8}Li(p, α)^{5}He $\qquad Q_{\rm m} = 14.516$

Differential cross sections were measured at $E_{\rm cm} = 1.5$ MeV with a ^{8}Li beam, and the data were used to calculate thermonuclear reaction rates for ^{8}Li destruction (1992BEZZ, 1992BE46).

27. (a) ^{9}Be(p, pα)^{5}He $\qquad Q_{\rm m} = -2.371$

(b) ^{9}Be(p, d^{3}He)^{5}He $\qquad Q_{\rm m} = -20.724$

Both reactions have been studied at $E_{\rm p} = 26.0$ to 101.5 MeV [see (1984AJ01)]. Reaction (a) was studied at $E_{\rm p} = 150.5$ MeV (1985WA13) and at $E_{\rm p} = 200$ MeV (1989NA10), who analyzed the data in terms of DWIA. Absolute spectroscopic factors were derived. See also (1985VD03). More recently, cross sections and polarization observables were measured at $E_{\rm p} = 296$ MeV by (1996YOZZ, 1997YOZQ, 1998YO09). Alpha spectroscopic factors were deduced.

28. ^{9}Be(d, ^{6}Li)^{5}He $\qquad Q_{\rm m} = -0.897$

The angular distribution to $^5{\rm He}_{\rm g.s.}$ has been measured at $E_{\rm d} = 13.6$ MeV (1984SH1F). See also (1989VAZJ).

29. (a) ^{9}Be(^{3}He, ^{7}Be)^{5}He $\qquad Q_{\rm m} = -0.785$

(b) ^{9}Be(^{3}He, α)^{4}He^{4}He $\qquad Q_{\rm m} = 19.0041$

See (1984AJ01) and (1990MAYW). A coupled-channel model analysis of data at $E_{^3{\rm He}} = 60$ MeV is described in (1996RU13). For reaction (b) see ^{8}Be in (1988AJ01) and (1987WA25).

30. ^{9}Be(α, 2α)^{5}He $\qquad Q_{\rm m} = -2.371$

Measurements at $E_\alpha = 197$ MeV of energy-sharing distributions were reported by (1994CO16). Spectroscopic factors were extracted. See (1984AJ01) for earlier work. Cross section measurements at $E_\alpha = 580$ MeV with DWIA calculations are described in (1999NA05).

31. ^{9}Be(^{7}Li, ^{7}Liα)^{5}He $\qquad Q_{\rm m} = -2.371$

This reaction was studied at $E_{^7{\rm Li}} = 52$ MeV (1998SO05, 1998SO26), and decay from ^{9}Be excited state into the $\alpha + {}^{5}$He channel was observed.

32. ^{9}Be(^{18}O, ^{22}Ne)^{5}He $\qquad Q_{\rm m} = 7.296$

Cross sections were measured and the mass excess was extracted by (1990BEYY).

33. ^{10}B(n, ^{5}He)^{6}Li $\qquad Q_{\rm m} = -5.258$

See ^{6}Li.

34. ^{10}B(d, ^{7}Be)^{5}He $\qquad Q_{\rm m} = -1.877$

An angular distribution has been measured at $E_{\rm d} = 13.6$ MeV involving ^{5}He$_{\rm g.s.}$ and ^{7}Be*(0.43) (1983DO10).

35. (a) ^{11}B(^{7}Li, ^{13}C)^{5}He $\qquad Q_{\rm m} = 9.157$
(b) ^{11}B(^{9}Be, ^{15}N)^{5}He $\qquad Q_{\rm m} = 8.620$

At $E(^{11}{\rm B}) = 88$ MeV a broad structure is observed at $E_{\rm x} = 5.2 \pm 0.3$ MeV, $\Gamma = 2.0 \pm 0.5$ MeV (1988BE34). For reaction (b) see (1990BEYX).

36. ^{12}C(^{6}He, ^{5}He n)^{12}C $\qquad Q_{\rm m} = -1.771$

Peripheral fragmentation of 240 MeV/A ^{6}He was studied by (1997CH24, 1997CH1P). It was found that one-neutron stripping to ^{5}He is the dominant mechanism.

^{5}Li
(Figs. 2 and 3)

GENERAL: References to articles on general properties of ^{5}Li published since the previous review (1988AJ01) are grouped into categories and listed, along with brief descriptions of each item, in the General Tables for ^{5}Li located on our website at (*www.tunl.duke.edu/nucldata/General_Tables/5li.shtml*).

1. ^{1}H(α, γ)^{5}Li $\rightarrow$ ^{1}H + α $\qquad Q_{\rm m} = -1.69$

Gamma rays were measured over a large dynamic range for $E_{\alpha} = 200$ MeV (2000HO18). Both inclusive and exclusive (coincidence with either α particle, proton or both) measurements were performed. A pronounced contribution from capture into the unbound ground and first excited states of ^{5}Li was observed. For the measured parameters of the ^{5}Li resonances, see Table 5.5.

2. ^{2}H(^{3}He, ^{3}He)^{2}H $\qquad E_{\rm b} = 16.66$

Angular distributions and analyzing powers for polarized ^{3}He on ^{2}H at $E_{^3{\rm He}} = 22.5$, 24, 27, 30, 33 MeV were measured and analyzed by (2000OK01). Based on the phase shifts, they report the following resonances identified with ^{5}Li with excitation energies between 15 and 30 MeV: "(i) the well-established (1988AJ01) ^{4}S$_{3/2}$ state at 16.7 MeV; (ii) a broad ^{2}S$_{1/2}$ state around 19 MeV; (iii) quartet D states around 20 MeV, [$\frac{5}{2}^{+}$ and $\frac{3}{2}^{+}$ assigned before (1988AJ01)]; (iv) two doublet P states ($\frac{3}{2}^{-}$, $\frac{1}{2}^{-}$) around 25 MeV; and (v) at least one negative parity state around 29 MeV."

The results are compared with shell model calculations. See also reaction 5 below.

3. ^{3}He(d, γ)^{5}Li $\qquad Q_{\rm m} = 16.66$

The previous review (1988AJ01) describes the earlier work as follows: "The ratio $\Gamma_{\gamma}/\Gamma_{{\rm p}\alpha}$ has been determined for $E(^{3}{\rm He}) = 63$ to 150 keV [$E_{\rm cm} = 25$ to 60 keV] by (1985CE13) 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 $E_{\rm x} = 3.0 \pm 1.0$ MeV for the excited state. $\Gamma_{\gamma_0}/\Gamma_{{\rm p}\alpha}$ is roughly constant for $E_{\rm cm} = 25$ to 60 keV at $(4.5 \pm 1.2) \times 10^{-5}$ and $\Gamma_{\gamma_1}/\Gamma_{{\rm p}\alpha} = (8 \pm 3) \times 10^{-5}$ at $E(^{3}{\rm He}) = 150$ keV (1985CE13)". For applications see (1985CE13, 1985CE16, 1988CE04, 1992LI32).

"Excitation curves and angular distributions have been measured for $E_{\rm d} = 0.2$ to 5 MeV and $E(^{3}{\rm He}) = 2$ to 26 MeV. A broad maximum in the cross section is observed at $E_{\rm d} = 0.45 \pm 0.04$

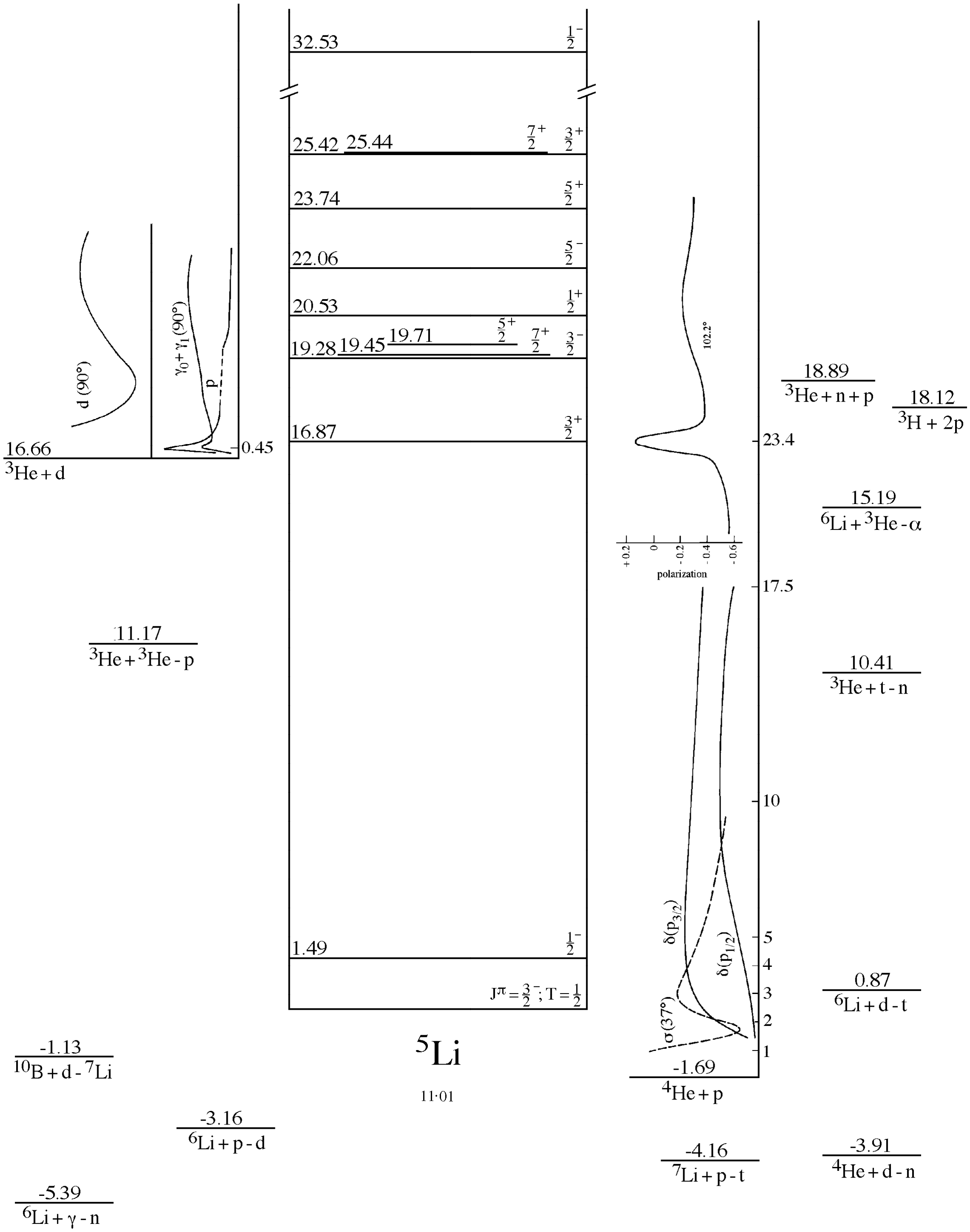


Figure 2: Energy levels of ^{5}Li, extended R-matrix prescription (see Table 5.3). For notation see Fig. 1.

Table 5.3: Energy levels of ^{5}Li, extended R-matrix prescription [a]

E_x (MeV)	$J^\pi; T$	Γ_{cm} [b] (MeV)	Γ_p (MeV)	Γ_d (MeV)	Γ_{p^*} [c] (MeV)	Decay	Reactions (used in analysis)
g.s. [d]	$\frac{3}{2}^-; \frac{1}{2}$	1.23	1.06	43.1 [e]	0.009 [e]	p, α	3, 6, 9, 13, 18, 20, 23
1.49	$\frac{1}{2}^-; \frac{1}{2}$	6.60	3.78	16.4 [e]		p, α	3, 9, 13, 18, 20
16.87	$\frac{3}{2}^+; \frac{1}{2}$	0.267	0.055	0.134 [f]		γ, p, d, ^{3}He, α	3, 4, 5, 18, 20
19.28	$\frac{3}{2}^-; \frac{1}{2}$	0.959	0.001	0.040 [g]	0.741	n, p, d, ^{3}He, α	4, 5, 9
19.45	$\frac{7}{2}^+; \frac{1}{2}$	3.28	0.040	1.82 [h]		p, d, ^{3}He, α	5
19.71	$\frac{5}{2}^+; \frac{1}{2}$	4.31	0.011	2.03 [h]		p, d, ^{3}He, α	3, 5
20.53	$\frac{1}{2}^+; \frac{1}{2}$	5.00	0.026	1.53 [i]	0.196	n, p, d, ^{3}He, α	6
22.06	$\frac{5}{2}^-; \frac{1}{2}$	15.5	0.928	2.33 [j]		p, d, ^{3}He, α	23, 24
23.74	$\frac{5}{2}^+; \frac{1}{2}$	5.43	0.234	2.49 [k]		p, d, ^{3}He, α	
25.42	$\frac{3}{2}^+; \frac{1}{2}$	0.534	0.023	0.467 [l]		p, d, ^{3}He, α	
25.44	$\frac{7}{2}^+; \frac{1}{2}$	2.63	0.043	1.94 [h]		p, d, ^{3}He, α	23
32.53	$\frac{1}{2}^-; \frac{1}{2}$	35.7	8.75	0.013 [m]		p, d, ^{3}He, α	23, 24

[a] This prescription, based on the complex poles and residues of the S-matrix, is the recommended one (see Introduction). The channel radii are $a_p = 2.9$ fm, $a_d = 4.8$ fm. The uncertainties in the widths and positions of the first three levels are less than 1%. Above 19 MeV excitation energy, they increase rapidly, varying from about 5% up to as much as 50% for the broader levels. All parameters in this table are newly adopted in this evaluation.

[b] The fact that the sum of the partial widths is unequal to the total width in the extended R-matrix prescription is characteristic of non-Breit-Wigner resonances as was discussed in the appendix of (1992TI02).

[c] The p* designation indicates p + α* where the first excited state of the α particle was included as a way to approximate the effects of three-body breakup on the two-body channels.

[d] Situated 1.69 MeV above the p + α threshold.

[e] These partial widths in closed channels have no meaning as decay widths, but rather as asymptotic normalization constants.

[f] Primarily $^4S(d)$.

[g] Primarily $^2P(d)$.

[h] Primarily $^4D(d)$.

[i] Primarily $^2S(d)$.

[j] Primarily $^2F(d)$.

[k] Primarily $^2D(d)$.

[l] Mixture of $^4S(d)$ and $^4D(d)$.

[m] Mixture of $^4P(d)$ and $^2P(d)$.

MeV [^{5}Li*(16.7)]. $\sigma_{\gamma_0} = 21 \pm 4\ \mu$b, $\Gamma_{\gamma_0} = 5 \pm 1$ 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 (but see below), and $E_x = 7.5 \pm 1.0$ MeV, $\Gamma = 6.6 \pm 1.2$ MeV for the $\frac{1}{2}^-$ state: see (1979AJ01, 1988AJ01). 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 (1979AJ01)". In more recent measurements at $E_d = 8.6$ MeV a ground state width $\Gamma_p = 2.44 \pm 0.21$ MeV was extracted from the γ_0 spectrum (1991BA02). An analysis of these data with single level R-matrix fits (1996EF03) gave values for the energies and widths of the ground states of ^{5}Li and ^{5}He. Cross section and analyzing power measurements in the $\frac{3}{2}^+$ fusion resonance region ($E_d = 0.45$ MeV) and $E_d = 8.6$ MeV were reported by (1991WEZZ, 1992BA04, 1994BA02, 1998WE07), and comparisons with the results of coupled-channels resonating group model calculations were discussed. See also the shell model description of the $\frac{3}{2}^+$ resonance discussed in (1993KU02). Potential model descriptions of this reaction are discussed in (1990NE14, 1992LI32, 1992NE03, 1995DU13). Analyzing power formulae derived in a model-independent way are presented in (1996TA09).

Measurements of high-energy (> 20 MeV) gamma ray production in the reaction are described in (1992PI04).

4. (a) ^{3}He(d, p)^{4}He	$Q_m = 18.35304$	$E_b = 16.66292$
(b) ^{3}He(d, np)^{3}He	$Q_m = -2.22457$	
(c) ^{3}He(d, 2p)^{3}H	$Q_m = -1.46081$	
(d) ^{3}He(d, 2d)^{1}H	$Q_m = -5.49349$	
(e) ^{3}He(d, tp)^{1}H	$Q_m = -1.46081$	

Excitation functions and angular distributions have been measured for $E_{cm} = 6.95$ to 171.3 keV, and values of $S(E)$ have been deduced: $S(0) = 6.3 \pm 0.6$ MeV · b (1987KR18). See also (1984AJ01, 1988AJ01). S-factors have been obtained down to $E_{cm} = 5.88$ keV. The effect on S of electron screening at low energies has been studied by (1988EN03, 1988SCZG, 1988SC1F). See also the calculations of (1989BE08, 1990BR12).

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 (1979AJ01). The recent work of (1997BA72) discusses a description of the $\frac{3}{2}^+$ levels of ^{5}Li and ^{5}He in terms of conventional R-matrix parameters. Excitation functions for ground-state protons have also been reported for $E(^3\mathrm{He}) = 0.39$ to 2.15 MeV and 18.7 to 44.1 MeV and for $E_d = 2.8$ to 17.8 MeV [see (1979AJ01)]. Angular distributions have been measured for $E_d = 0.25$ to 27 MeV and $E(^3\mathrm{He}) = 18.7$ to 44.1 MeV [see Table 5.6 in (1974AJ01) and (1979AJ01)]. Resonance-like behavior has been suggested at $E_x = 16.6$, 17.5, 20.0, 20.9 and 22.4 MeV: see (1979AJ01).

Table 5.4: Energy levels of ^{5}Li, conventional R-matrix prescription [a]

E_x (MeV)	$J^\pi; T$	Γ_{cm} (MeV)	Γ_p (MeV)	Γ_d (MeV)	Γ_{p^*} (MeV)
g.s. [b]	$\frac{3}{2}^-; \frac{1}{2}$	2.11	2.11	0	0
6.18	$\frac{1}{2}^-; \frac{1}{2}$	19.8	19.8	0	0
16.63	$\frac{3}{2}^+; \frac{1}{2}$	2.09	0.570	1.52 [c]	
19.17	$\frac{3}{2}^-; \frac{1}{2}$	1.50	0.0006	0.136 [d]	1.36
20.30	$\frac{1}{2}^+; \frac{1}{2}$	4.64	0.208	3.72 [e]	0.709
21.09	$\frac{7}{2}^+; \frac{1}{2}$	7.47	0.115	7.36 [f]	
22.60	$\frac{5}{2}^+; \frac{1}{2}$	12.5	0.010	12.5 [f]	
24.27	$\frac{5}{2}^+; \frac{1}{2}$	8.15	1.11	7.04 [g]	
26.86	$\frac{3}{2}^+; \frac{1}{2}$	24.2	0.009	24.2 [f]	

[a] See the Introduction for a discussion of the two prescriptions. The channel radii are $a_p = 2.9$ fm, $a_d = 4.8$ fm.

[b] Situated 2.08 MeV above the $p + \alpha$ threshold.

[c] Entirely $^4S(d)$.

[d] Primarily $^2P(d)$.

[e] Primarily $^2S(d)$.

[f] Primarily $^4D(d)$.

[g] Primarily $^2D(d)$.

In early work, tensor analyzing power measurements were reported for $E_d = 0.48$ to 6.64 MeV (1980DR01). [See, however, (1980GR14) for a discussion of the (1980DR01) results and for a summary of $T_{20}(0°)$ for $E_d = 0$ to 40 MeV.] Measurements of angular distributions and analyzing powers at $E(^3\text{He}) = 27$ 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 $E_d = 1.0$ to 13.0 MeV (1986BI1C, 1986BIZP) and 18, 20 and 22 MeV (1986SA1L). See also (1986RO1J) and Tables 5.6 in (1979AJ01) and 5.4 in (1979AJ01). In recent work of (1999GE19), angular distributions and complete sets of analyzing powers were measured at five energies between $E_d = 60$ and 641 keV. The data were included in an R-matrix analysis of the ^{5}Li system (see Table 5.6). Multichannel resonating group model calculations for this reaction are presented in (1988GU07, 1990BL02, 1990BL08). A model-independent description of the d + ^{3}He system near the low energy $\frac{3}{2}^+$ resonance using the effective range expansion is described in (1996PO26).

Differential cross sections for reaction (b) were measured at $E_d = 23.08$ MeV (1988BR27, 1990BR14). Triple differential cross sections and vector analyzing powers were measured at $E_d =$ 17 MeV (1989AYZZ, 1990AYZW) and at $E(^3\text{He}) = 32.25$ MeV (1988DA18, 1991DA06).

The d-^{3}He fusion process in reactors is discussed in (1988DA26, 1988MI29, 1988MO36). Applications of the reaction in studying deuterium diffusion behavior in materials is discussed in

Table 5.5: Parameters of ^{5}Li resonances deduced from α + p gamma spectra

J^π	Quantity	Experimental result [a]	Conventional [b] R-matrix	Extended [b] R-matrix
$\frac{3}{2}^-$	σ (μb)	8.0 ± 0.7	–	–
	E_x (MeV) [c]	2.9 ± 0.2	2.08	1.69
	Γ (MeV)	1 ± 0.2	2.11	1.23
$\frac{1}{2}^-$	σ (μb)	4.5 ± 0.4	–	–
	E_x (MeV) [c]	9.3 ± 0.4	8.26	3.18
	Γ (MeV)	10 ± 1	19.8	6.60

[a] From Table I of (2000HO18). These results were obtained by fitting the photon spectrum to a background plus two Gaussian peaks representing the two resonances.

[b] See Tables 5.3 and 5.4.

[c] These energies are relative to the α + p threshold.

Table 5.6: A scheme of ^{5}Li levels below E_x = 17 MeV obtained from an R-matrix analysis [a] of ^{3}He(d, d)^{3}He, ^{3}He(d, p)^{4}He, and ^{4}He(p, p)^{4}He data and comparison with the present evaluation [b]

(1999GE19) scheme [a]			Present evaluation [b]		
E_x (MeV)	J^π	Γ_{cm} (MeV)	E_x (MeV)	J^π	Γ_{cm} (MeV)
g.s.	$\frac{3}{2}^-$	1.25	g.s.	$\frac{3}{2}^-$	1.23
1.28	$\frac{1}{2}^-$	6.29	1.49	$\frac{1}{2}^-$	6.60
16.86	$\frac{3}{2}^+$	0.25	16.87	$\frac{3}{2}^+$	0.27
16.88 [c]	$\frac{1}{2}^+$	2.26	20.53	$\frac{1}{2}^+$	5.00
17.65 [c, d]	$\frac{3}{2}^-$	2.57	19.28	$\frac{3}{2}^-$	0.96
			19.45	$\frac{7}{2}^+$	3.28

[a] See Tables II and III of (1999GE19).

[b] See Table 5.3.

[c] Weak resonance.

[d] Above the range of the analysis.

(1989PA26, 1990QIZZ). See also (1990LE30, 1990WI1L).

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., $E_x = 18.9 \pm 0.2$ MeV]: see (1979AJ01). Other studies of the breakup have been reported at $E_d = 23.08$ MeV (1986BR1J; reaction (c)) and 60 MeV (1985OK03; reaction (d)). For the earlier work see (1984AJ01). See also other references cited in (1988AJ01). For a descriptive list of theoretical work on this reaction see the General Table for ^{5}Li located on our website at (*www.tunl.duke.edu/nucldata/General_Tables/5li.shtml*).

5. ^{3}He(d, d)^{3}He $\qquad E_b = 16.66292$

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 ($\Gamma > 1$ MeV) corresponding to $E_x = 20.0 \pm 0.5$ MeV. From the behavior of the angular distributions an assignment of $^2\mathrm{D}_{3/2}$ or ($^2\mathrm{D}$, $^4\mathrm{D}_{5/2}$ is favored, if only one state is involved: see (1979AJ01). 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 (1984AJ01). See also (1987KR18).

Angular distributions and analyzing powers have been measured at many energies to $E = 44$ MeV: see (1979AJ01, 1984AJ01) for the earlier work, (1982COZO, 1983COZR; $E_d = 10$ MeV) and (1987YAZJ; $E_d = 29.5$ MeV on polarized ^{3}He). For d-^{3}He correlations see (1987PO03). See also "Complex reactions" in the ^{5}Li General section of (1988AJ01). The R-matrix formalism was used by (1990TR08) to calculate the $S(\frac{1}{2}^+)$-wave cross section for d + ^{3}He, using p + ^{4}He cross section data and d + ^{3}He analyzing power data from the $^5\mathrm{Li}(\frac{3}{2}^+)$ region. See also the work of (1997BA72). A generalized potential model description of ^{3}He + d scattering is discussed in (1991NE01). For earlier theoretical work see references cited in (1988AJ01).

6. ^{3}He(t, n)^{5}Li $\qquad Q_m = 10.41$

At $E(^3\mathrm{He}) = 14$ to 26 MeV ^{5}Li*(0, 20.5 ± 0.8) are populated: see (1979AJ01). See also ^{6}Li.

7. ^{3}He(^{3}He, p)^{5}Li $\qquad Q_m = 11.17$

The spectrum of protons at $E(^3\mathrm{He}) = 3$ to 18 MeV shows a pronounced peak corresponding to $^5\mathrm{Li}_{g.s.}$ superposed on a continuum: see (1979AJ01). The angular distribution of p_0 has been measured at $E(^3\mathrm{He}) = 26$ MeV (1983KI10; polarized target). See also ^{6}Be and (1986OS1D).

8. ^{3}He(α, d)^{5}Li $\qquad Q_m = -7.18$

The contribution of unbound ^{6}Li nuclear states to deuteron spectra from this reaction was calculated by (1993GO16).

9. ^{4}He(p, p)^{4}He $\qquad E_b = -1.69012$

Differential cross sections and polarization measurements have been carried out at many energies: see (1966LA04, 1974AJ01, 1979AJ01, 1984AJ01) for the earlier work. More recent measurements were reported (1988AJ01) at $E_p = 65$ MeV (1986FU05; A_y), 100 MeV (1983NAZV, 1985GUZX; $\sigma(\theta)$, A_y) and 495 MeV (1988STZZ) and at $E_p = 695$, 793, 890, 991 MeV (1985VE13; $\sigma(\theta)$) and 1 GeV (1985AL09; $\sigma(\theta)$). Cross sections and A_y at $E_p = 98.7$ and 149.3 MeV for the continuum were reported by (1985WE06). In experimental work reported since the previous review (1988AJ01), differential cross sections were measured for $E_p = 695$, 793, 890, 991 MeV by (1989GR20) with phase shift analysis and at 607 MeV/c by (1991BA1V). Differential cross sections and analyzing powers at 71.9 MeV were measured (1989BU01) and combined with existing data for $E_p = 30$–65 MeV for a phase shift analysis. Measurements of analyzing power at $E_p = 180$ MeV were reported by (1990WEZY). Cross sections for the p + ^{4}He interaction at GeV energies have been measured at 2.7 GeV/c (1993AB07), at 8.6 and 13.6 GeV/c (1989BR30, 1993GL09), and at $\sqrt{s} = 31.5$ GeV (1989AK05). For earlier work at very high energies, see references cited in (1988AJ01). The previous review (1988AJ01) summarizes the analyses reported prior to 1988 as follows:

"Phase shifts below $E_p = 18$ MeV have been determined by (1977DO01) 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 ^{5}Li$_{g.s.}$ 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 (1977DO01). (1986TH1C; prelim.) have measured A_y for $1.1 \leq E_p \leq 2.15$ MeV: $A_y = 1$ for $E_p = 1.89$ MeV, $\theta_{cm} = 87.0°$."

"A phase-shift analysis for $E_p = 21.8$ to 55 MeV is presented by (1978HO17) [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 (1979AJ01)]. 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 $E_{\rm p} = 20$ to 55 MeV (1978HO17). For a contour diagram of the analyzing power for $E_{\rm p} = 130$ to 1800 MeV see (1980MO09). For a measurement of the spin rotation parameter, R, at $E_{\rm p} = 500$ MeV see (1983MO01). See also (1986SA1J; prelim.; $E_{\rm p} = 65$ MeV)."

Theory and analyses reported since the previous review (1988AJ01) include: the S-matrix studies of resonances in the $A = 5$ system of (1998CS02); the S-matrix and R-matrix determination of the $\frac{3}{2}^-$ and $\frac{5}{2}^-$ states of ^{5}Li of (1997CS01); and the study of the $\frac{3}{2}^+$ levels of ^{5}Li on ^{5}He based on conventional R-matrix parameters (1997BA72). See also the study of the cluster potential model (1997DU15), and the calculation of interaction potentials by inversion of scattering phase shifts (1996AL01). See also (1996CO20).

Other theoretical work reported since the previous review (1988AJ01) includes calculations for p-α potentials derived from phase shifts for $E_{\rm p} \leq 23$ MeV (1991CO05) and at $E_{\rm p} = 64.9$ MeV (1989CO11). Multichannel resonating group calculations are presented in (1989KA39, 1990BL02). The resonating group method was applied in the region $E_{\rm p} = 50$–120 MeV by (1993KA47). See also the dynamic microscopic model calculation reported by (1993CS02). Glauber theory calculations of cross sections at intermediate energies were reported by (1993MA47). Other theoretical work related to ^{4}He + p scattering is included in the descriptive list in the General Table for ^{5}Li located on our website at (*www.tunl.duke.edu/nucldata/ General_Tables/5li.shtml*).

In earlier work PNC effects were studied via the elastic scattering of 46 MeV longitudinally polarized protons on ^{4}He: 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 (1985LA01, 1986LA29): 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 (1984AJ01) and (1986ADZT, 1986HA1Q, 1988NA18). For $\alpha + {\rm p}$ correlations see (1987PO03).

In application-related work, a method for precise absolute calibration of polarization effects is applied to p-α scattering at $E_{\rm p} = 25.68$ MeV by (1989CL04). Measurements of recoil cross sections for α particles on protons in connection with depth profiling were reported at $E(^3{\rm He}) = 0.9$–3.4 MeV (1989SZ04) and at $E(^3{\rm He}) = 1.3$–2.1 MeV (1988WA22).

10. (a) ^{4}He(p, d)^{3}He	$Q_{\rm m} = -18.35304$	$E_{\rm b} = -1.69012$
(b) ^{4}He(p, pn)^{3}He	$Q_{\rm m} = -20.57762$	
(c) ^{4}He(p, 2p)^{3}H	$Q_{\rm m} = -19.81385$	
(d) ^{4}He(p, pd)^{2}H	$Q_{\rm m} = -23.84653$	

As reported in (1988AJ01) angular distributions of deuterons and of ^{3}He ions (reaction (a)) have been measured for $E_{\rm p} = 27.9$ to 770 MeV and at $E_\alpha = 3.98$ GeV/c [see (1979AJ01, 1984AJ01)]. Angular distributions and analyzing powers were measured at $E_{\rm p} = 100$ MeV (1983NAZV), 200 and 400 MeV (1986AL01). Excitation functions are reported at several energies in the range $E_{\rm p} = 38.5$ to 44.6 MeV and 200 to 500 MeV. Continuum yields and analyzing powers have been studied at $E_p = 98.7$ and 149.3 MeV by (1985WE06). For polarization measurements to 500 MeV see above and (1979AJ01, 1984AJ01, 1988BAZH). More recently, analyzing powers and differential cross sections were measured at $E_p = 32$, 40, 50 and 52.5 MeV by (1991SA17).

For reactions (b), (c) and (d) see (1974AJ01, 1979AJ01, 1984AJ01). The breakup of ^{4}He via reaction (c) has been studied by (1986FU05): large values of A_y in the FSI region were reported. In more recent work on reactions (b), (c) and (d), quasi-free knockout of charged particles for ^{4}He was studied at $E_p = 100$ MeV by (1990WH01). For astrophysics-related theoretical work see (1989GU28, 1990BI06). For breakup processes at high energies, including pion production, see (1988AJ01).

11. ^{4}He($\bar{p}$, $\bar{p}$)^{4}He

In early work, antiproton interactions with ^{4}He were studied by (1984BA60, 1985BA76, 1987BA12, 1987BA47, 1987BA69). See also (1983FA16, 1984BA74, 1984FA14, 1986DO20, 1987NA23). More recently, the production rate of ^{1}H, ^{2}H, ^{3}H in $\bar{p}$-^{4}He annihilation was studied between 0–600 MeV/c by (1988BA62), the annihilation cross section near 45 MeV/c was measured (1989BA59), and the cross section for production of Λ hyperons and K^0_s mesons at 600 MeV/c was measured by (1989BA94).

Calculations for the knockout and annihilation reactions were presented by (1989NA16), and a study of the change of the branching ratio of channels for $\bar{p}$-^{4}He annihilation in the nuclear medium is discussed in (1989NA16).

12. (a) ^{4}He(d, n)^{5}Li $\qquad Q_m = -3.91$
(b) ^{4}He(d, np)^{4}He $\qquad Q_m = -2.22457$

For reaction (a) see reaction 10 in ^{5}He, (1985WI15) and (1987KAZL; $E_d = 15$ MeV; n_0). Early work on reaction (b) reported in (1988AJ01) includes measurements at $E_d = 12$ to 17 MeV and at $E_\alpha = 18.0$ to 140 MeV: see (1979AJ01, 1984AJ01), ^{6}Li and (1985DO03, 1987KUZI).

More recently, measurements of cross sections and analyzing powers at $E_d = 7$ MeV were reported by (1988GA14). Comparison of data at $E_d = 12$ and 17 MeV with predictions of the three-body model are made by (1988SU12). The effects of the internal structure of the α particle in a three-body description of the d + α reaction are explored by (1990KU27). Multi-configuration resonating group calculations are discussed in (1991FU01, 1992FU10).

13. (a) ^{4}He(^{3}He, d)^{5}Li $\qquad Q_m = -7.18$
(b) ^{4}He(^{3}He, pd)^{4}He $\qquad Q_m = -5.49349$

At $E_\alpha = 26.3$ MeV, $^5\mathrm{Li}_{\mathrm{g.s.}}$ is reported to have a width of 1.9 ± 0.25 MeV while the first excited state is suggested to lie at $E_\mathrm{x} = 2.82 \pm 0.35$ MeV, $\Gamma = 1.64 \pm 0.25$ MeV [reaction (b)]: see (1982NE09, 1986YA01). See also (1985NEZW).

14. ^{4}He(α, t)^{5}Li $\quad Q_\mathrm{m} = -21.50$

Measurements were made at $E_\alpha = 120$, 160 and 200 MeV (1998ST07). Differential cross sections were extracted from measured triton energy spectra. Line shapes of the ^{5}Li ground state resonance was well reproduced by DWBA calculations.

15. ^{4}He(^{7}Li, ^{6}He)^{5}Li $\quad Q_\mathrm{m} = -11.67$

See reaction 12 in ^{5}He and (1988WO10).

16. ^{6}Li(γ, n)^{5}Li $\quad Q_\mathrm{m} = -5.39$

Available experimental data at energies up to $E_\gamma = 50$ MeV are reviewed and analyzed (1990VA16) to explore cluster effects and final-state interactions.

17. ^{6}Li(π^+, p)^{5}Li $\quad Q_\mathrm{m} = 134.96$

In early work, differential cross sections have been measured at $T_\pi = 75$ and 150 MeV for p_0: see (1984AJ01). More recently cross section measurements at $E_\pi = 50$, 100, 150 and 200 MeV were reported by (1992RA01). DWIA calculations presented in (1992KH04) provide predictions of cross sections at $T_\pi = 115$, 165 and 255 MeV.

18. (a) ^{6}Li(p, d)^{5}Li $\quad Q_\mathrm{m} = -3.16$
(b) ^{6}Li(p, pd)^{4}He $\quad Q_\mathrm{m} = -1.4743$
(c) ^{6}Li(p, pn)^{5}Li $\quad Q_\mathrm{m} = -5.39$

Angular distributions have been measured at $E_\mathrm{p} = 18.6$ to 185 MeV. At the highest energy, the spectra are characterized by a broad asymmetric peak corresponding to $^5\mathrm{Li}_{\mathrm{g.s.}}$, a narrow peak [^{5}Li* (16.7)] and a broad peak at $E_\mathrm{x} \approx 20$ 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 (1984AJ01).

Reaction (b) has been studied at $E_{\rm p} = 9$ to 50 MeV: the p-α FSI corresponding to ^{5}Li$_{\rm g.s.}$ is observed [see (1979AJ01)]. See also (1983CA13, 1986NI1B). 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 (1985BE30, 1985DO16). See also (1985PA03; $E_{\rm p} = 70$ MeV).

19. (a) ^{6}Li(d, t)^{5}Li $Q_{\rm m} = 0.87$
(b) ^{6}Li(d, pt)^{4}He $Q_{\rm m} = 2.5583$

In early work, angular distributions of the t_0 group were measured at $E_{\rm d} = 15$ and 20 MeV: see (1979AJ01). More recently the production cross section for triton was measured by radiochemical methods (1997ABZY). Calculations of differential cross sections for $E_{\rm d} < 30$ MeV are described in (1997HAZK, 1997HAZY). Reaction (b) has been studied at $E_{\rm d} = 0.12$ to 10.5 MeV: see (1984AJ01). See also ^{8}Be in (1988AJ01).

20. (a) ^{6}Li(^{3}He, α)^{5}Li $Q_{\rm m} = 15.19$
(b) ^{6}Li(^{3}He, pα)^{4}He $Q_{\rm m} = 16.8787$

In early work reviewed in (1988AJ01) at $E(^3\text{He}) = 25.5$ MeV, ^{5}Li*(0, 16.7) and two broad peaks at $E_{\rm x} \approx 19.8$ and 22.7 MeV [$\Gamma_{\rm cm} = 2$ and 1 MeV] are populated: see (1979AJ01). 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 (1984AJ01). More recently, in experiments at $E(^3\text{He}) = 8$, 11, 13 and 14 MeV (1989ARZI, 1990AR17), the ^{5}Li state at $E_{\rm x} = 16.7$ MeV was observed and the width measured to be $\Gamma = 150 \pm 40$ keV.

In reaction (b) an analysis (1989AR20) of data at $E(^3\text{He}) = 2.5$ MeV gave $\Gamma = 1.55 \pm 0.2$ MeV for ^{5}Li$_{\rm g.s.}$. Measurements at $E(^3\text{He}) = 1.6$, 3.5, 7.0 and 9.0 (1992AR20) found the ^{5}Li$_{\rm g.s.}$ width consistent with (1988AJ01) and independent of ^{3}He incident energy. Work reported for $E(^3\text{He}) = 1.6$ MeV (1991AR25) and $E(^3\text{He}) = 7$ and 9 MeV (1993AR12) determined that the ground state width is independent of detector angle. In early work reviewed in (1988AJ01) the parameters of the first excited state are deduced to be $E_{\rm x} = 5.0 \pm 0.7$ MeV, $\Gamma_{\rm cm} = 5.7 \pm 0.7$ MeV (1984AR17; $E(^3\text{He}) = 1.7$ and 2.3 MeV), $E_{\rm x} = 5.8 \pm 0.5$ MeV, $\Gamma_{\rm cm} = 5.2 \pm 0.5$ MeV (1987FA1I; $E(^3\text{He}) = 1.65$ MeV). More recently an experiment at $E(^3\text{He}) = 2.0$ and 2.2 MeV (1992DA1K) found values in line with those measured at $E(^3\text{He}) = 1.65$ and 1.7 MeV. Measurements at $E(^3\text{He}) = 11$, 13 and 14 MeV reported by (1989AR08) determined parameters for $E_{\rm x} \approx 18$ MeV and found a level at $E_{\rm x} = 17.9 \pm 0.4$ MeV, $\Gamma = 3.5 \pm 0.8$ MeV. Angular distributions of protons from the decay of ^{5}Li$_{\rm g.s.}$ are reported by (1988BU04; $E(^3\text{He}) = 1.5$ MeV). See also references cited in (1988AJ01).

A recent theoretical study (1996FA05) of the properties of resonance scattering in two fragment systems calculates parameters for the $E_{\rm x} = 16.66$ MeV states formed in reaction (b).

21. ^{6}Li(^{6}Li, ^{7}Li)^{5}Li $\quad Q_m = 1.86$

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 (1987MI34).

22. ^{6}Li(^{13}C, ^{14}C)^{5}Li $\quad Q_m = 2.79$

See reaction 12 in ^{5}He and (1988WO10).

23. (a) ^{7}Li(p, t)^{5}Li $\quad Q_m = -4.16$
(b) ^{7}Li(p, nd)^{5}Li $\quad Q_m = -10.41$

At $E_p = 43.7$ MeV, a triton group is observed to $^5\text{Li}_{\text{g.s.}}$ ($\Gamma = 1.55 \pm 0.15$ 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 23 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 (1979AJ01). Measurements of angular distributions and differential cross sections at $E_p = 29.1$ and 35 MeV are reported in (1989BA88). See also (1988BAZH). For reaction (b) at $E_p = 670$ MeV see (1984AJ01). See also (1985NEZW).

24. ^{7}Li(^{3}He, dt)^{5}Li $\quad Q_m = -9.65$

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 (1985FR01).

25. ^{7}Li(^{6}Li, ^{8}Li)^{5}Li $\quad Q_m = -3.36$

See (1984KO25).

26. ^{9}Be(α, ^{8}Li)^{5}Li $\quad Q_m = -18.58$

Table 5.7: Mirror states in $A = 5$ nuclei [a]

^{5}He		^{5}Li		
E_x (MeV)	J^π	E_x (MeV)	J^π	ΔE_x (MeV) [b]
0	$\frac{3}{2}^-$	0	$\frac{3}{2}^-$	—
1.27	$\frac{1}{2}^-$	1.49	$\frac{1}{2}^-$	$+0.22$
16.84	$\frac{3}{2}^+$	16.87	$\frac{3}{2}^+$	$+0.03$
19.14	$\frac{5}{2}^+$	19.71	$\frac{5}{2}^+$	$+0.57$
19.26	$\frac{3}{2}^+$	25.42	$\frac{3}{2}^+$	$+6.16$
19.31	$\frac{7}{2}^+$	19.45	$\frac{7}{2}^+$	$+0.14$
19.96	$\frac{3}{2}^-$	19.28	$\frac{3}{2}^-$	-0.68

[a] As taken from Tables 5.1 and 5.3.

[b] Defined as $E_x(^5\text{Li}) - E_x(^5\text{He})$.

At $E_\alpha = 90$ MeV differential cross sections have been measured for the transitions to $^5\text{Li}_{\text{g.s.}} + {}^8\text{Li}_{\text{g.s.}}$: see (1984AJ01).

27. ^{10}B(d, ^{7}Li)^{5}Li $\qquad Q_m = -1.13$

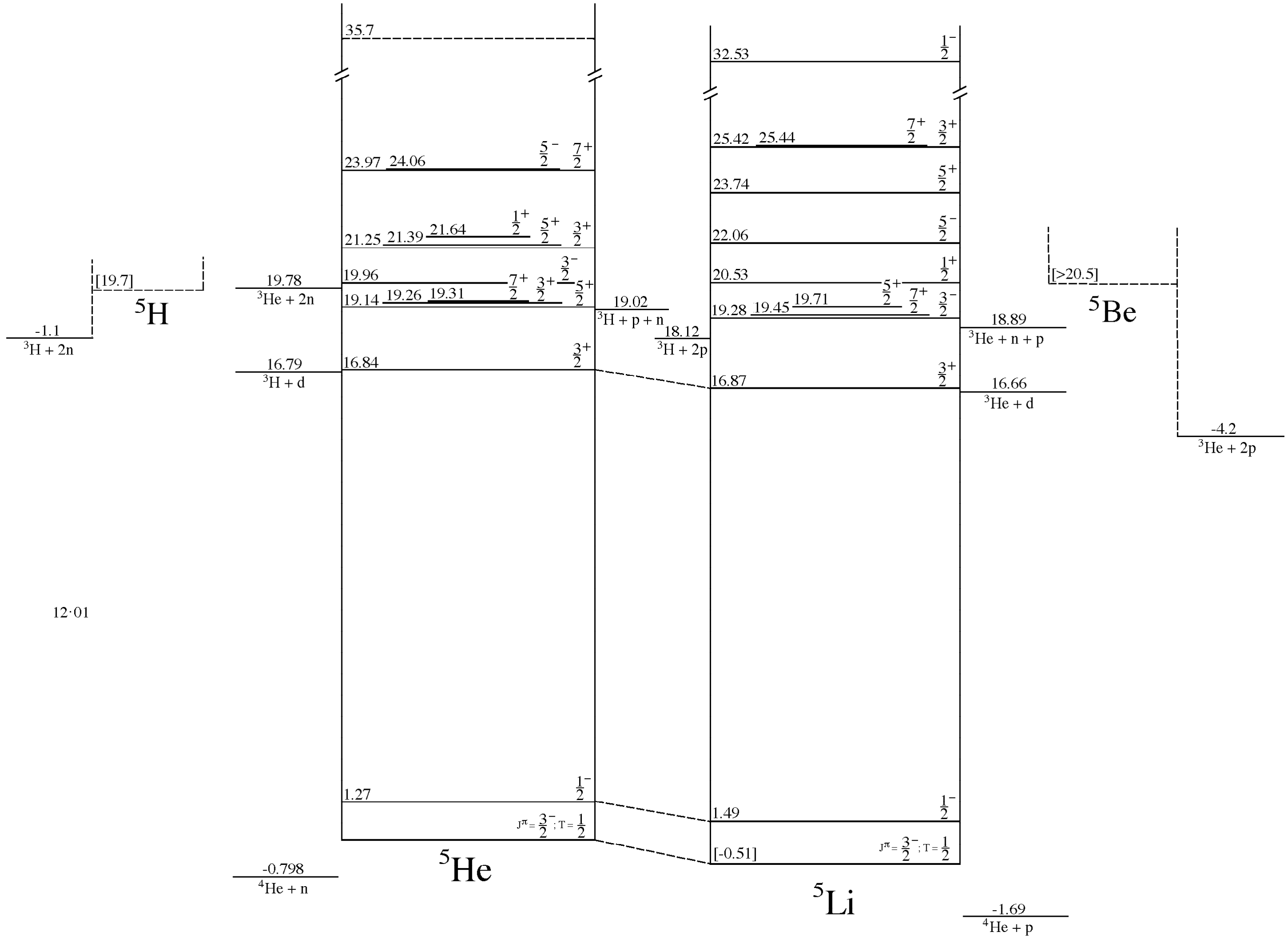
An angular distribution is reported at $E_d = 13.6$ MeV (1983DO10). See also (1984SHZJ).

28. ^{10}B(^{3}He, 2α)^{5}Li $\qquad Q_m = 10.73$

At $E(^3\text{He}) = 2.3$ and 5.0 MeV the reaction is reported to proceed via ^{9}B*(4.9) to $^5\text{Li}_{\text{g.s.}}$ (1986AR14). See also (1988AR05) and ^{9}B in (1988AJ01).

^{5}Be
(Fig. 3)

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 $^5\text{Be}_{\text{g.s.}}$ 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 (1979AJ01).



12·01

Figure 3: Isobar diagram, $A = 5$. The diagrams for individual isobars have been shifted vertically to eliminate the neutron-proton mass difference and the Coulomb energy, taken as $E_C = 0.60Z(Z-1)/A^{1/3}$. Energies in square brackets represent the (approximate) nuclear energy, $E_N = M(Z, A) - ZM(\mathrm{H}) - NM(\mathrm{n}) - E_C$, minus the corresponding quantity for ^{5}He: here M represents the atomic mass excess in MeV. Levels which are presumed to be isospin multiplets are connected by dashed lines.

References

(Closed 23 August 2001)

References are arranged and designated by the year of publication followed by the first two letters of the first-mentioned author's name and then by two additional characters. Most of the references appear in the National Nuclear Data Center files (Nuclear Science References Database) and have NNDC key numbers. Otherwise, TUNL key numbers were assigned with the last two characters of the form 1A, 1B, etc. In response to many requests for more informative citations, we have, when possible, included up to ten authors per paper and added the authors' initials.

1958LA73 A.M. Lane and R.G. Thomas, Rev. Mod. Phys. 30 (1958) 257

1960YO06 L.G. Youn, G.M. Osetinskii, N. Sodnom, A.M. Govorov, I.V. Sizov and V.I. Salatskii, Zh. Eksp. Teor. Fiz. 39 (1960) 225; JETP (Sov. Phys.) 12 (1961) 163

1963SM03 D.B. Smith, N. Jarmie and A.M. Lockett, Phys. Rev. 129 (1963) 785

1966HO07 B. Hoop, Jr. and H.H. Barschall, Nucl. Phys. 83 (1966) 65

1966LA04 T. Lauritsen and F. Ajzenberg-Selove, Nucl. Phys. 78 (1966) 1

1974AJ01 F. Ajzenberg-Selove and T. Lauritsen, Nucl. Phys. A227 (1974) 1

1977DO01 D.C. Dodder, G.M. Hale, N. Jarmie, J.H. Jett, P.W. Keaton, Jr., R.A. Nisley and K. Witte, Phys. Rev. C15 (1977) 518

1978HO17 A. Houdayer, N.E. Davison, S.A. Elbakr, A.M. Sourkes, W.T.H. van Oers and A.D. Bacher, Phys. Rev. C18 (1978) 1985

1979AJ01 F. Ajzenberg-Selove, Nucl. Phys. A320 (1979) 1

1980DR01 L.J. Dries, H.W. Clark, R. Detoma, Jr., J.L. Regner and T.R. Donoghue, Phys. Rev. C21 (1980) 475

1980GR14 W. Gruebler, P.A. Schmelzbach and V. Konig, Phys. Rev. C22 (1980) 2243

1980MO09 G.A. Moss, L.G. Greeniaus, J.M. Cameron, D.A. Hutcheon, R.L. Liljestrand, C.A. Miller, G. Roy, B.K.S. Koene, W.T.H. van Oers, A.W. Stetz et al., Phys. Rev. C21 (1980) 1932

1980SE1A K.K. Seth, in Berkeley (1980) 659

1981ER10 J. Ero, Z. Fodor, P. Koncz, Z. Seres, M. Csatlos, B.A. Khomenko, N.N. Khovanskij, Z.V. Krumstein, Yu.P. Merekov and V.I. Petrukhin, Nucl. Phys. A372 (1981) 317

1981PL1A G.R. Plattner, Nukleonika 26 (1981) 1005

1982COZO P.C. Colby and W. Haeberli, Bull. Amer. Phys. Soc. 27 (1982) 700, AE7

1982NE09 O.F. Nemets, A.M. Yasnogorodsky, V.V. Ostashko, O.M. Povoroznik and V.N. Unn, Pisma Zh. Eksp. Teor. Fiz. 35 (1982) 537; JETP Lett. 35 (1982) 666

1982SM09 P.F. Smith, J.R.J. Bennett, G.J. Homer, J.D. Lewin, H.E. Walford and W.A. Smith, Nucl. Phys. B206 (1982) 333

1983ANZQ Y. Ando, M. Uno and M. Yamada, JAERI-M-83-025 (1983)

1983CA13 G. Calvi, M. Lattuada, F. Riggi, C. Spitaleri, D. Vinciguerra and D. Miljanic, Lett. Nuovo Cim. 37 (1983) 279

1983COZR P.C. Colby and W. Haeberli, Bull. Amer. Phys. Soc. 28 (1983) 987, DB3

1983DO10 V.N. Dobrikov, O.F. Nemets, A.S. Gass and A.A. Shvedov, Izv. Akad. Nauk. SSSR, Ser. Fiz. 47 (1983) 943; Bull. Acad. Sci. USSR Phys. Ser. 47 (1983) 114

1983FA16 I.V. Falomkin, F. Nichitiu and G. Piragino, Lett. Nuovo Cim. 38 (1983) 211

1983GO06 O.K. Gorpinich, E.P. Kadkin, S.N. Kondratev, Yu.N. Lobach, M.V. Pasechnik, L.S. Saltykov and V.V. Tokarevsky, Izv. Akad. Nauk. SSSR Ser. Fiz. 47 (1983) 185; Bull. Acad. Sci. USSR Phys. Ser. 47 (1983) 179

1983HA20 B. Haesner, W. Heeringa, H.O. Klages, H. Dobiasch, G. Schmalz, P. Schwarz, J. Wilczynski, B. Zeitnitz and F. Kappeler, Phys. Rev. C28 (1983) 995

1983HAYX G.M. Hale, D.C. Dodder and J.C. DeVeaux, in Antwerp (1983) 326; Phys. Abs. 37643 (1984)

1983KI10 U. Kirchner, R. Beckmann, U. Holm and H.-G. Korber, Nucl. Phys. A405 (1983) 159

1983MO01 G.A. Moss, C.A. Davis, J.M. Greben, L.G. Greeniaus, G. Roy, J. Uegaki, R. Abegg, D.A. Hutcheon, C.A. Miller and W.T.H. Van Oers, Nucl. Phys. A392 (1983) 361

1983NAZV A. Nadasen, P.G. Roos, G. Ciangaru, D. Mack, L. Rees, A.A. Cowley, K. Kwiatkowski, P. Schwandt and R.E. Warner, Bull. Amer. Phys. Soc. 28 (1983) 987

1983VD03 A.I. Vdovin, E.P. Kadkin, I.I. Loshchakov, M.V. Pasechnik and L.S. Saltykov, Izv. Akad. Nauk. SSSR, Ser. Fiz. 47 (1983) 2219

1984AJ01 F. Ajzenberg-Selove, Nucl. Phys. A413 (1984) 1

1984AR17 N. Arena, S. Cavallaro, A.S. Figuera, P. D'Agostino, G. Fazio, G. Giardina and F. Mezzanares, Lett. Nuovo Cim. 41 (1984) 59

1984BA60 F. Balestra, Yu.A. Batusov, G. Bendiscioli, M.P. Bussa, L. Busso, I.V. Falomkin, L. Ferrero, V. Filippini, G. Fumagalli, G. Gervino et al., Phys. Lett. B149 (1984) 69

1984BA74 Yu.A. Batusov and the Dubna-Frascati-Padpva-Pavia-Torino Collaboration, Lett. Nuovo Cim. 41 (1984) 223

1984CE08 F.E. Cecil and F.J. Wilkinson III, Phys. Rev. Lett. 53 (1984) 767

1984DE52 F.W.N. de Boer, R. van Dantzig, M. Daum, J. Jansen, P.J.S. Watson, L. Felawka, C. Grab, A. van der Schaaf, T. Kozlowski, J. Martino and A.I. Smirnov, Phys. Rev. Lett. 53 (1984) 423

1984FA14 I.V. Falomkin, G.B. Pontecorvo, M.G. Sapozhnikov, M.Yu. Khlopov, F. Balestra and G. Piragino, Nuovo Cim. A79 (1984) 193

1984HO01 B. Hoistad, M. Gazzaly, B. Aas, G. Igo, A. Rahbar, C. Whitten, G.S. Adams and R. Whitney, Phys. Rev. C29 (1984) 553

1984JA08 N. Jarmie, R.E. Brown and R.A. Hardekopf, Phys. Rev. C29 (1984) 2031; Erratum Phys. Rev. C33 (1986) 385

1984KL05 H.O. Klages, H. Dobiasch, P. Doll, H. Krupp, M. Oexner, P. Plischke, B. Zeitnitz, F.P. Brady and J.C. Hiebert, Nucl. Instrum. Meth. Phys. Res. A219 (1984) 269

1984KO25 I. Koenig, D. Fick, S. Kossionides, P. Egelhof, K.-H. Mobius and E. Steffens, Z. Phys. A318 (1984) 135

1984KR23 H. Krupp, J.C. Hiebert, H.O. Klages, P. Doll, J. Hansmeyer, P. Plischke, J. Wilczynski and H. Zankel, Phys. Rev. C30 (1984) 1810

1984SH1F Shvedov, Dobrikov and Nemets, in Jurmala (1984) 333

1984SHZJ A.A. Shvedov, V.N. Dobrikov and O.F. Nemets, in Alma-Ata (1984) 332

1984VA06 A.G.M. van Hees and P.W.M. Glaudemans, Z. Phys. A315 (1984) 223

1985AL09 G.D. Alkhazov, S.L. Belostotsky, Yu.V. Dotsenko, O.A. Domchenkov, N.P. Kuropatkin and V.N. Nikulin, Yad. Fiz. 41 (1985) 561; Sov. J. Nucl. Phys. 41 (1985) 357

1985BA68 F.C. Barker and C.L. Woods, Aust. J. Phys. 38 (1985) 563

1985BA76 F. Balestra, S. Bossolasco, M.P. Bussa, L. Ferrero, D. Panzieri, G. Piragino, F. Tosello, C. Guaraldo, A. Maggiora, Yu.A. Batusov et al., Phys. Lett. B165 (1985) 265

1985BE30 S.L. Belostotsky, S.S. Volkov, A.A. Vorobyev, Yu.V. Dotsenko, L.G. Kudin, N.P. Kuropatkin, O.V. Miklukho, V.N. Nikulin and O.E. Prokofyev, Yad. Fiz. 41 (1985) 1425; Sov. J. Nucl. Phys. 41 (1985) 903

1985CA41 G.R. Caughlan, W. A. Fowler, M.J. Harris and B.A. Zimmerman, At. Data Nucl. Data Tables 32 (1985) 197

1985CE13 F.E. Cecil, D.M. Cole, R. Philbin, N. Jarmie and R.E. Brown, Phys. Rev. C32 (1985) 690

1985CE16 F.E. Cecil, D.M. Cole, F.J. Wilkinson III and S.S. Medley, Nucl. Instrum. Meth. Phys. Res. B10-11 (1985) 411

1985DO03 P. Doleschall, Gy. Bencze, M. Bruno, F. Cannata and M. D'Agostino, Phys. Lett. B152 (1985) 1

1985DO16 Yu.V. Dotsenko and V.E. Starodubsky, Yad. Fiz. 42 (1985) 107; Sov. J. Nucl. Phys. 42 (1985) 66.

1985FI1G First Research Group, First Research Div., Phys. Energ. Fortis Phys. Nucl. 9 (1985) 723

1985FR01 R. Franke, K. Kochskamper, B. Steinheuer, K. Wingender, W. Von Witsch and H. Machner, Nucl. Phys. A433 (1985) 351

1985GE06 J.-F. Germond and C. Wilkin, J. Phys. G11 (1985) 1131

1985GUZX G. Gunderson, S. Villanueva, A. Judd, A. Nadasen, P.G. Roos, D. Mack, F. Khazaie, J. Templon, K. Kwiatkowski, P. Schwandt et al., Bull. Amer. Phys. Soc. 30 (1985) 1268

1985HOZU D. Holslin, J. Sromicki and W. Haeberli, Bull. Amer. Phys. Soc. 30 (1985) 1267

1985LA01 J. Lang, Th. Maier, R. Muller, F. Nessi-Tedaldi, Th. Roser, M. Simonius, J. Sromicki and W. Haeberli, Phys. Rev. Lett. 54 (1985) 170; Erratum Phys. Rev. Lett. 54 (1985) 2729

1985LE19 Y. Le Bornec, L. Bimbot, M.P. Combes-Comets, J.C. Jourdain, F. Reide, A. Willis and N. Willis, J. Phys. G11 (1985) 1125

1985LU08 R.C. Luhn, S. Sen, N.O. Gaiser, S.E. Darden and Y. Koike, Phys. Rev. C32 (1985) 11

1985NEZW O.F. Nemets, V.V. Ostashko and A.M. Yasnogorodsky, in Leningrad 85 (1985) 320

1985OK03 A. Okihana, Nucl. Phys. A443 (1985) 435

1985OS02 H. Oswald, M. Buballa, J. Helten, M. Karus, B. Laumann, R. Melzer, P. Niessen, G. Rauprich, J. Schulte-Uebbing, H. Paetz gen. Schieck and Y. Koike, Nucl. Phys. A435 (1985) 77

1985PA03 M.V. Pasechnik, L.S. Saltykov, E.P. Kadkin, I.I. Loshchakov and A.I. Vdovin, Izv. Akad. Nauk. SSSR Ser. Fiz. 49 (1985) 53; Bull. Acad. Sci. USSR Phys. Ser. 49 (1985) 55

1985PO10 N.A.F.M. Poppelier, L.D. Wood and P.W.M. Glaudemans, Phys. Lett. B157 (1985) 120.

1985VD03 A.I. Vdovin, A.V. Golovin and I.I. Loshchakov, Yad. Fiz. 42 (1985) 134; Sov. J. Nucl. Phys. 42 (1985) 84

1985VE13 G.N. Velichko, A.A. Vorobyov, A.V. Dobrovolsky, G.A. Korolev, S.I. Manayenkov, J. Saudinos and A.V. Khanzadeev, Yad. Fiz. 42 (1985) 1325; Sov. J. Nucl. Phys. 42 (1985) 837

1985WA13 C.W. Wang, P.G. Roos, N.S. Chant, G. Ciangaru, F. Khazaie, D.J. Mack, A. Nadasen, S.J. Mills, R.E. Warner, E. Norbeck et al., Phys. Rev. C31 (1985) 1662

1985WE06 W.-M. Wendler and M. Micklinghoff, Nucl. Phys. A439 (1985) 13

1985WI15 K. Wick, U. Berghaus, H. Bruckmann, P. Lara, W. Schutte, B. Anders and Y. Koike, Nucl. Phys. A444 (1985) 49

1986ADZT E.G. Adelberger, in AIP Conf. Proc. 150 (1986) 1177

1986AL01 P.W.F. Alons, J.J. Kraushaar, J.R. Shepard, J.M. Cameron, D.A. Hutcheon, R.P. Liljestrand, W.J. McDonald, C.A. Miller, W.C. Olsen, J.R. Tinsley et al., Phys. Rev. C33 (1986) 406

1986AR14 N. Arena, Seb. Cavallaro, G. Fazio, G. Giardina, A. Italiano and F. Mezzanares, Phys. Rev. Lett. 57 (1986) 1839

1986BA73 A.G. Baryshnikov, L.D. Blokhintsev, R. Kapote and D.A. Savin, Izv. Akad. Nauk SSSR Ser. Fiz. 50 (1986) 1962; Bull. Acad. Sci. USSR Phys. Ser. 50 (1986) 90

1986BE35 A.V. Belozyorov, C. Borcea, Z. Dlouhy, A.M. Kalinin, R. Kalpakchieva, Nguyen Hoai Chau, Yu.Ts. Oganessian and Yu.E. Penionzhkevich, Nucl. Phys. A460 (1986) 352

1986BE44 A.V. Belozerov, K. Borcha, Z. Dlouty, A.M. Kalinin, Nguen Khoai Tyau and Yu.E. Penionzhkevich, Izv. Akad. Nauk SSSR Ser. Fiz. 50 (1986) 1936; Bull. Acad. Sci USSR Phys. Ser. 50 (1986) 64

1986BI1C M. Bittcher, V. Konig, P.A. Schmelzbach, C. Forstner, W. Gruebler, B. Vuaridel, D. Singy and J. Ulbricht, J. Phys. Soc. Jpn. Suppl. 55 (1986) 906

1986BIZP M. Bittcher, V. Konig, P.A. Schmelzbach, Ch. Forstner, W. Gruebler, B. Vuaridel, D. Singy and J. Ulbricht, in Harrogate (1986) 333; C146

1986BO01 D.H. Boal and J.C. Shillcock, Phys. Rev. C33 (1986) 549

1986BOZG I.M. Bondarenko and E.E. Petrov, INDC(CCP)-265/L (1986)

1986BR1J M. Bruno, F. Cannata, M. D'Agostino, M.L. Fiandri, M. Frisoni and M. Lombardi, Few-Body Syst. 1 (1986) 63

1986DO20 C.B. Dover, Czech. J. Phys. B36 (1986) 329

1986FU05 K. Fukunaga, S. Kakigi, T. Ohsawa, A. Okihana, T. Sekioka, H. Nakamura-Yokota and S. Tanaka, Nucl. Phys. A456 (1986) 48

1986HA1Q Haxton, in Harrogate (1986) 415

1986HO1E D. Holslin, J. Sromicki and W. Haeberli, J. Phys. Soc. Jpn. Suppl. 55 (1986) 904

1986KL04 H.O. Klages, F.P. Brady, P. Doll, R. Garrett, J. Hansmeyer, W. Heeringa, J.C. Hiebert, K. Hofmann, P. Jany, H. Krupp et al., Radiat. Eff. 94 (1986) 195

1986LA29 J. Lang, Th. Maier, R. Muller, F. Nessi-Tedaldi, Th. Roser, M. Simonius, J. Sromicki and W. Haeberli, Phys. Rev. C34 (1986) 1545

1986LAZH J.B.J.M. Lanen, A.M. van den Berg, J.F.J. van den Brand, J.A. Hendriks, J.W.A. den Herder, E. Jans, P.H.M. Keizer, G.J. Kramer, L. Lapikas, E.N.M. Quint et al., in Harrogate (1986) 361, C174

1986MO05 G.L. Morgan, P.W. Lisowski, S.A. Wender, R.E. Brown, N. Jarmie, J.F. Wilkerson and D.M. Drake, Phys. Rev. C33 (1986) 1224

1986NI1B P. Niessen, M. Buballa, D. Gola, H.J. Hahn, B. Laumann, K.R. Nyga, H. Oswald, B. Polke, G. Rauprich, J. Schulte-Uebbing et al., J. Phys. Soc. Jpn. Suppl. 55 (1986) 794

1986OS1D A. Osman, J. Phys. Soc. Jpn. Suppl. 55 (1986) 744

1986RI01 R. Rieder, P.D. Barnes, B. Bassalleck, R.A. Eisenstein, G. Franklin, R. Grace, C. Maher, P. Pile, J. Szymanski, W.R. Wharton et al., Phys. Rev. C33 (1986) 614

1986RO1J R. Roy, J. Pouliot, P. Bricault, C. Rioux, R.J. Slobodrian, H.E. Conzett and R.M. Larimer, J. Phys. Soc. Jpn. Suppl. 55 (1986) 1142

1986SA1J H. Sakaguchi, M. Yosoi, M. Nakamura, T. Noro, H. Sakamoto, T. Ichihara, M. Ierei, Y. Takeuchi, H. Togawa, T. Tsutsumi et al., J. Phys. Soc. Jpn. Suppl. 55 (1986) 61

1986SA1L T. Sakai, K. Hashimoto, M. Takei, M. Kurokawa, A. Manabe, K. Aoki, Y. Aoki, Y. Tagishi and K. Yagi, J. Phys. Soc. Jpn. Suppl. 55 (1986) 652

1986TH1C S. Tharraketta, W. Arnold, H. Baumgart, J. Gunzl, A. Hofmann, E. Huttel, N. Kniest and G. Clausnitzer, J. Phys. Soc. Jpn. Suppl. 55 (1986) 880

1986WA11 R.E. Warner, B.A. Vaughan, D.L. Friesel, P. Schwandt, J.-Q. Yang, G. Caskey, A. Galonsky, B. Remington and A. Nadasen, Nucl. Phys. A453 (1986) 605

1986YA01 A.M. Yasnogorodsky, Yad. Fiz. 43 (1986) 281; Sov. J. Nucl. Phys. 43 (1986) 178

1987BA12 F. Balestra, M.P. Bussa, L. Busso, L. Fava, L. Ferrero, D. Panzieri, G. Piragino, F. Tosello, G. Bendiscioli, A. Rotondi et al., Nucl. Phys. A465 (1987) 714

1987BA47 F. Balestra, R. Barbieri, Yu.A. Batusov, G. Bendiscioli, S. Bossolasco, M.P. Bussa, L. Busso, I.V. Falomkin, L. Ferrero, C. Guaraldo et al., Phys. Lett. B194 (1987) 343

1987BA69 F. Balestra, S. Bossolasco, M.P. Bussa, L. Busso, L. Fava, L. Ferrero, D. Panzieri, G. Piragino, F. Tosello, G. Bendiscioli et al., Nucl. Phys. A474 (1987) 651

1987BO40 C. Borcea, A.V. Belozyorov, Z. Dlouhy, A.M. Kalinin, N.H. Chau and Yu.E. Penionzhkevich, Rev. Roum. Phys. 32 (1987) 497

1987BR10 R.E. Brown, N. Jarmie and G.M. Hale, Phys. Rev. C35 (1987) 1999; Erratum Phys. Rev. C36 (1987) 1220

1987FA1I G. Fazio, S. Femino, G. Giardina, A. Italiano, F. Mezzanares and R. Palamara, Hadronic J. 10 (1987) 21

1987GO25 M.G. Gornov, Yu.B. Gurov, V.P. Koptev, P.V. Morokhov, K.O. Oganesyan, B.P. Osipenko, V.A. Pechkurov, V.I. Savelev, F.M. Sergeev, A.A. Khomutov et al., Pisma Zh. Eksp. Teor. Fiz. 45 (1987) 205; JETP Lett. (USSR) 45 (1987) 252

1987HA20 G.M. Hale, R.E. Brown and N. Jarmie, Phys. Rev. Lett. 59 (1987) 763

1987HA44 G.M. Hale, R.E. Brown and N. Jarmie, Phys. Rev. Lett. 59 (1987) 2819

1987HU02 J.R. Hurd, J.S. Boswell, R.C. Minehart, L.B. Rees, Y. Tzeng, H.J. Ziock and K.O.H. Ziock, Nucl. Phys. A462 (1987) 605

1987KAZL F. Kadirov, M.A. Kayumov, Sh. Kayumov, A.M. Mukhamedzhanov, U.I. Faizullaev, K. Khamidova and R. Yarmukhamedov, in Yurmala (1987) 343

1987KO47 A.A. Korsheninnikov, E.Yu. Nikolsky and A.A. Ogloblin, Pisma Zh. Eksp. Teor. Fiz. 46 (1987) 306; JETP Lett. (USSR) 46 (1987) 384

1987KR18 A. Krauss, H.W. Becker, H.P. Trautvetter, C. Rolfs and K. Brand, Nucl. Phys. A465 (1987) 150

1987KUZI V.I. Kukulin, in Yurmala (1987) 151

1987LI07 J. Li, H. Lu, H. Ma, W. Zhao, Y. Cui, P. Fan and D. Wang, Nucl. Instrum. Meth. Phys. Res. A255 (1987) 115

1987MI34 S. Micek, H. Rebel, H.J. Gils, H. Klewe-Nebenius, S. Zagromski and D.K. Srivastava, Z. Phys. A328 (1987) 467

1987MO1K D. Morgan, M.R. Pennington, G.M. Hale, R.E. Brown and N.Jarmie, Phys. Rev. Lett. 59 (1987) 2818

1987NA23 V.I. Nazaruk, Yad. Fiz. 46 (1987) 80; Sov. J. Nucl. Phys. 46 (1987) 51

1987PE1C Penionshkevich, in Dubna (1987) 364

1987PO03 J. Pochodzalla, C.K. Gelbke, W.G. Lynch, M. Maier, D. Ardouin, H. Delagrange, H. Doubre, C. Gregoire, A. Kyanowski, W. Mittig et al., Phys. Rev. C35 (1987) 1695

1987SO1C Soundranayagam, Seth and Parker, in Panic (1987) 292

1987VA36 V.S. Vasilevsky, I.F. Gutich and I.P. Okhrimenko, Yad. Fiz. 46 (1987) 757; Sov. J. Nucl. Phys. 46 (1987) 427

1987VD01 A.I. Vdovin and I.N. Loshchakov, Yad. Fiz. 45 (1987) 67; Sov. J. Nucl. Phys. 45 (1987) 42

1987VD1A A.I. Vdovin, A.V. Golovin and I.I. Loschakov, Sov. J. Part. Nucl. 18 (1987) 573

1987WA21 R.E. Warner, B.A. Vaughan, J.A. Ditusa, J.W. Rovine, R.S. Wakeland, C.P. Browne, S.E. Darden, S. Sen, A. Nadasen, A. Basak et al., Nucl. Phys. A470 (1987) 339

1987WA25 R.E. Warner, F.G. Johnson, C.P. Browne, A. Rollefson, A. Galonsky and A. Nadasen, Nucl. Phys. A472 (1987) 522

1987YAZJ A.M. Yasnogorodsky, V.V. Ostashko, V.N. Urin and A.N. Nenakhov, in Yurmala (1987) 321

1988AJ01 F. Ajzenberg-Selove, Nucl. Phys. A490 (1988) 1

1988AR05 N. Arena, Seb. Cavallaro, G. Fazio, G. Giardina, A. Italiano and F. Mezzanares, Europhys. Lett. 5 (1988) 517

1988BA62 F. Balestra, S. Bossolasco, M.P. Bussa, L. Busso, L. Fava, L. Ferrero, D. Panzieri, G. Piragino, F. Tosello, R. Barbieri et al., Nuovo Cim. A100 (1988) 323

1988BA75 F.C. Barker, Aust. J. Phys. 41 (1988) 743

1988BAZH I.Ya. Barit, S.V. Zuev, V.A. Simonov and A.M. Yasnogorodsky, in Baku (1988) 277

1988BE1U P. Bem, V. Presperin, M. Trginova, B.P. Adyasevich and V.G. Antonenko, Muon Catal. Fus. 3 (1988) 389

1988BE34 A.V. Belozerov, K. Borcha, Z. Dlougy, A.M. Kalinin, Nguyen Hoai Thiau and Yu.E. Penionzhkevich, Izv. Akad. Nauk SSSR Ser. Fiz. 52 (1988) 100; Bull. Acad. Sci. USSR Phys. Ser. 52 (1988) 94

1988BR27 M. Bruno, F. Cannata, M. D'Agostino, M.L. Fiandri, M. Frisoni and M. Lombard, J. Phys. (London) G14 (1988) L235

1988BU04 S. Burzynski, J. Turkiewicz, K. Rusek, I.M. Turkiewicz and P. Zupranski, Nucl. Phys. A480 (1988) 51

1988CA11 P.J. Carlos, Ph. Bourgeois, J. Fagot, J.L. Fallou, P. Garganne, J.M. Laget, A. Lepretre, A. de Miniac, A. Veyssiere, J. Jury et al., Phys. Lett. B203 (1988) 33

1988CE04 F.E. Cecil and S.S. Medley, Nucl. Instrum. Meth. Phys. Res. A271 (1988) 628

1988DA18 S.E. Darden, O. Karban, C. Blyth, J.B.A. England, J.M. Nelson and S. Roman, Nucl. Phys. A486 (1988) 285

1988DA26 A.E. Dabiri, Nucl. Instrum. Meth. Phys. Res. A271 (1988) 71

1988DU04 E.I. Dubovoy and G.I. Chitanava, Yad. Fiz. 47 (1988) 75; Sov. J. Nucl. Phys. 47 (1988) 48.

1988EN03 S. Engstler, A. Krauss, K. Neldner, C. Rolfs, U. Schroder and K. Langanke, Phys. Lett. B202 (1988) 179

1988GA14 N.O. Gaiser, S.E. Darden, R.C. Luhn, H. Paetz gen. Schieck and S. Sen, Phys. Rev. C38 (1988) 1119

1988GU07 I.F. Gutich and I.P. Okhrimenko, Yad. Fiz. 47 (1988) 1238; Sov. J. Nucl. Phys. 47 (1988) 788

1988KA38 V.I. Karmanov, V.V. Komarov, A.M. Popova, N.A. Sotnikova and V.L. Shablov, Izv. Akad. Nauk SSSR Ser. Fiz. 52 (1988) 936; Bull. Acad. Sci. USSR Phys. Ser. 52 (1988) 99

1988MCZT V. McLane, C.L. Dunford and P.F. Rose, Neutron Cross Sections, Vol. 2 (Academic Press, New York, 1988)

1988MI29 G.H. Miley, Nucl. Instrum. Meth. Phys. Res. A271 (1988) 197

1988MO36 H. Momota, M. Okamato, Y. Nomura, M. Ohnishi, H.L. Berk and T. Tajima, Nucl. Instrum. Meth. Phys. Res. A271 (1988) 7

1988NA18 V.A. Nazarenko, J. Phys. (London) G14 (1988) S381

1988PUZZ V. Punjabi, C.F. Perdrisat, C. Lyndon, P. Ulmer, J. Yonnet, R. Beurtey, M. Boivin, A. Boudard, F. Plouin, J.P. Didelez et al., Bull. Amer. Phys. Soc. 33 (1988) 962, DI7

1988SC1F U. Schroder, S. Engstler, A. Krauss, K. Neldner, C. Rolfs, E. Somorjai and K. Langanke, Nucl. Instrum. Meth. Phys. Res. B40-41 (1988) 466

1988SCZG U. Schroder, Bull. Amer. Phys. Soc. 33 (1988) 1712

1988SEZJ K.K. Seth, AIP Conf. Proc. 164 (1988) 324

1988STZZ S.M. Sterbenz, D. Dehnhard, M.K. Jones, C.E. Parman, Y.F. Yen, K.W. Jones and S.K. Nanda, Bull. Amer. Phys. Soc. 33 (1988) 961

1988SU12 I. Supek, I. Slaus, Y. Koike, P.A. Treado and J.M. Lambert, Few-Body Syst. 4 (1988) 39

1988WA22 Wang Hong and Zhou Guo Qing, Nucl. Instrum. Meth. Phys. Res. B34 (1988) 145

1988WO10 C.L. Woods, F.C. Barker, W.N. Catford, L.K. Fifield and N.A. Orr, Aust. J. Phys. 41 (1988) 525

1989AB21 S.N. Abramovich, B.Ya. Guzhovsky, S.A. Dunaeva and A.G. Zvenigorodsk, Izv. Akad. Nauk SSSR Ser. Fiz. 53 (1989) 2116; Bull. Acad. Sci. USSR Phys. Ser. 53 (1989) 54

1989AK05 T. Akesson and the Axial Field Spectrometer Collaboration, Phys. Lett. B231 (1989) 359

1989AR04 N. Arena, Seb. Cavallaro, G. Fazio, G. Giardina, A. Italiano, M. Herman, M. Bruno, F. Cannata, M. D'Agostino and M. Lombardi, Phys. Rev. C40 (1989) 55

1989AR08 N. Arena, Seb. Cavallaro, A. D'Arrigo, G. Fazio, G. Giardina, A. Italiano, M. Herman and M. Lombardi, Phys. Rev. C40 (1989) 1126

1989AR20 N. Arena, Seb. Cavallaro, P. D'Agostino, G. Fazio, G. Giardina, A. Italiano, F. Mezzanares, M. Herman and M. Lombardi, Nuovo Cim. A102 (1989) 1327

1989ARZI N. Arena, S. Cavallaro, A. D'Arrigo, G. Fazio, G. Giardina, A. Italiano, R. Palamara and A. Taccone, in Sao Paulo (1989) 379

1989AYZZ Z. Ayer, S.E. Darden, S. Sen and R.E. Warner, Bull. Amer. Phys. Soc. 34 (1989) 1140

1989BA59 F. Balestra, R. Barbieri, Yu.A. Batusov, G. Bendiscioli, S. Bossolasco, F.O. Breivik, M.P. Bussa, L. Busso, C. Guaraldo, I.V. Falomkin et al., Phys. Lett. B230 (1989) 36

1989BA88 I.Ya. Barit, S.V. Zuev, V.V. Ostashko, V.N. Urin and A.M. Yasnogorodsky, Izv. Akad. Nauk SSSR Ser. Fiz. 53 (1989) 2455; Bull. Acad. Sci. USSR Phys. Ser. 53 (1989) 179

1989BA94 Yu.A. Batusov and the Dubna-Turin-Frascati-Brescia-Bergen-Oslo Collaboration PS179, Yad. Fiz. 50 (1989) 1524; Sov. J. Nucl. Phys. 50 (1989) 945

1989BE08 Gy. Bencze, Nucl. Phys. A492 (1989) 459

1989BR30 H. Braun, A. Dirner, J.P. Gerber, V.V. Glagolev, J. Hlavacova, P. Juillot, A.K. Kacharava, K.U. Khairetdinov, R.M. Lebedev, G. Martinska et al., Czech. J. Phys. B39 (1989) 1267

1989BU01 S. Burzynski, J. Campbell, M. Hammans, R. Henneck, W. Lorenzon, M.A. Pickar and I. Sick, Phys. Rev. C39 (1989) 56

1989CL04 M. Clajus, P. Egun, W. Gruebler, P. Hautle, A. Weber, P.A. Schmelzbach, W. Kretschmer, M. Haller, C.J. Prenzel, A. Rauscher et al., Nucl. Instrum. Meth. Phys. Res. A281 (1989) 17

1989CO11 S.G. Cooper and R.S. Mackintosh, Phys. Rev. C40 (1989) 502

1989GA21 C.A. Gagliardi and A.C. Betker, Nucl. Instrum. Meth. Phys. Res. A284 (1989) 356

1989GR20 O.G. Grebenyuk, A.V. Khanzadeev, G.A. Korolev, S.I. Manayenkov, J. Saudinos, G.N. Velichko and A.A. Vorobyov, Nucl. Phys. A500 (1989) 367

1989GU28 N. Guessoum and R.J. Gould, Astrophys. J. 345 (1989) 356.

1989KA39 H. Kanada, T. Kaneko and Y.C. Tang, Nucl. Phys. A504 (1989) 529

1989LA13 J.B.J.M. Lanen, A.M. van den Berg, H.P. Blok, J.F.J. van den Brand, C.T. Christou, R. Ent, A.G.M. van Hees, E. Jans, G.J. Kramer, L. Lapikas et al., Phys. Rev. Lett. 62 (1989) 2925

1989LA29 K. Langanke and C. Rolfs, Mod. Phys. Lett. A4 (1989) 2101

1989NA10 A. Nadasen, P.G. Roos, N.S. Chant, C.C. Chang, G. Ciangaru, H.F. Breuer, J. Wesick and E. Norbeck, Phys. Rev. C40 (1989) 1130

1989NA16 V.I. Nazaruk, Phys. Lett. B229 (1989) 348

1989PA26 R.S. Payne, A.S. Clough, P. Murphy and P.J. Mills, Nucl. Instrum. Meth. Phys. Res. B42 (1989) 130

1989RI04 J.C. Riley, H.R. Weller and D.R. Tilley, Phys. Rev. C40 (1989) 1517

1989SC19 A. Scalia, Nuovo Cim. A101 (1989) 795

1989SC1F A. Scalia, Sao Paulo (1989) 462

1989SC25 A. Scalia, Nuovo Cim. A102 (1989) 953

1989SC41 A. Scalia, Nuovo Cim. A102A (1989) 1101

1989SH17 S. Shirato, S. Shibuya, Y. Ando, T. Kokubu and K. Hata, Nucl. Instrum. Meth. Phys. Res. A278 (1989) 477

1989SHZS S. Shirato, S. Shibuya, K. Hata, Y. Ando and K. Shibata, JAERI-M 89-107 (Jpn. Atomic Energy Res.) (1989)

1989SZ04 E. Szilagyi, F. Paszti, A. Manuaba, C. Hajdu and E. Kotai, Nucl. Instrum. Meth. Phys. Res. B43 (1989) 502

1989US02 M.N. Ustinin and V.D. Efros, Yad. Fiz. 49 (1989) 1297; Sov. J. Nucl. Phys. 49 (1989) 807

1989VAZJ Yu.O. Vasilev, Yu.N. Pavlenko and V.M. Pugach, in Tashkent (1989) 335

1990AM04 A.I. Amelin, M.G. Gornov, Yu.B. Gurov, A.I. Ilin, V.P. Koptev, P.V. Morokhov, K.O. Oganesyan, V.A. Pechkurov, V.I. Savelev, F.M. Sergeev et al., Pisma Zh. Eksp. Teor. Fiz. 51 (1990) 607; JETP Lett. (USSR) 51 (1990) 688

1990AM07 R.D. Amado, F. Cannata and J.P. Dedonder, Phys. Rev. C41 (1990) 1289

1990AR17 N. Arena, Seb. Cavallaro, A. D'Arrigo, G. Fazio, G. Giardina, A. Italiano and A. Taccone, J. Phys. G16 (1990) 1511

1990AYZW Z. Ayer, S.E. Darden, S. Sen and R.E. Warner, Bull. Amer. Phys. Soc. 35 (1990) 1659

1990BEYX A.V. Belozerov, I. Vintsour, R.G. Kalpakchieva, I.V. Kuznetsov, Yu.E. Penionzhkevich, Sh. Piskorzh and N.K. Skobelev, in Leningrad 90 (1990) 364

1990BEYY A.V. Belozerov, I. Vintsour, R.G. Kalpakchieva, I.V. Kuznetsov, Yu.E. Penionahkevich and Sh. Piskorzh, in Leningrad (1990) 359

1990BI06 L. Bildsten, I. Wasserman and E.E. Salpeter, Nucl. Phys. A516 (1990) 77

1990BL02 G. Bluge and K. Langanke, Phys. Rev. C41 (1990) 1191

1990BL08 G. Bluge, K. Langanke, M. Plagge, K.R. Nyga and H. Paetz gen. Schieck, Phys. Lett. B238 (1990) 137

1990BR12 L. Bracci, G.Fiorentini, V.S. Melezhik, G. Mezzorani and P. Quarati, Nucl. Phys. A513 (1990) 316

1990BR14 M. Bruno, F. Cannata, M. D'Agostino and M.L. Fiandri, Phys. Rev. C42 (1990) 448

1990DE06 P.K.A. De Witt Huberts, Nucl. Phys. A507 (1990) 189c.

1990DE16 P.K.A. de Witt Huberts, J. Phys. (London) G16 (1990) 507

1990GO34 I.G. Golikov, A.V. Golovin, K.A. Gridnev and I.I. Loshchakov, Yad. Fiz. 52 (1990) 718; Sov. J. Nucl. Phys. 52 (1990) 460

1990KU27 Yu.A. Kuperin, Yu.B. Melnikov and A.K. Motovilov, Yad. Fiz. 52 (1990) 433; Sov. J. Nucl. Phys. 52 (1990) 276

1990LA06 J.B.J.M. Lanen, H.P. Blok, E. Jans, L. Lapikas, G. van der Steenhoven and P.K.A. de Witt Huberts, Phys. Rev. Lett. 64 (1990) 2250

1990LE30 S.R. Lee, D.S. Walsh and B.L. Doyle, Nucl. Instrum. Meth. Phys. Res. B45 (1990) 285

1990LO14 R.G. Lovas, A.T. Kruppa and J.B.J.M. Lanen, Nucl. Phys. A516 (1990) 325

1990MAYW Yu.G. Mashkarov, E.I. Koshchy, N.T. Burtebaev, A.D. Duisebaev, G.N. Ivanov, V.I. Kanashevich, V.A. Khaimin and V.V. Adodin, in Leningrad 90 (1990) 317

1990NAZH T. Nakagawa, T. Asami and T. Yoshida, JAERI-M 90-099 (Jpn. Atomic Energy Res.) (1990)

1990NE14 V.G. Neudachin, V.N. Pomerantsev and A.A. Sakharuk, Yad. Fiz. 52 (1990) 738; Sov. J . Nucl. 52 (1990) 473

1990QIZZ Q. Qiu, Bull. Amer. Phys. Soc. 35 (1990) 1700

1990SH1C K. Shibata, Report JEARI-M-90-024 (Jpn. At. Energy Res.) (1990)

1990TR08 M. Trginova, P. Bem and V. Presperin, Izv. Akad. Nauk SSSR, Ser. Fiz. 54 (1990) 982; Bull. Acad. Sci. USSR, Phys. Ser. 52 (1990) 165

1990VA16 V.V. Varlamov, B.S. Ishkhanov and A.P. Chernyaev, Izv. Akad. Nauk SSSR, Ser. Fiz. 54 (1990) 561; Bull. Acad. Sci. USSR, Phys. Ser. 54 (1990) 181

1990WEZY S.P. Wells, S.W. Wissink, A.D. Bacher, P. Li, J. Lisantti, C. Olmer, A.K. Opper, R. Sawafta, P. Schwandt, J. Sowinski and E.J. Stephenson, Bull. Amer. Phys. Soc. 35 (1990) 1037

1990WH01 D.M. Whittal, A.A. Cowley, J.V. Pilcher, S.V. Fortsch, F.D. Smit and J.J. Lawrie, Phys. Rev. C42 (1990) 309

1990WI1L Wielunski and Moller, Nucl. Instrum. Meth. Phys. Res. B50 (1990) 23

1990YOZZ M. Yosoi, H. Sakaguchi, M. Nakamura, H. Togawa, S. Hirata, T. Nakano, O. Kamigaito, Y. Nakai, H. Kaneko, F. Hiei et al., RCNP (Osaka), Ann. Rept. 1989 (1990) 49

1991AR10 N. Arena, S. Cavallaro, A. D'Arrigo, G. Fazio, G. Giardina, A. Italiano, F. Mezzanares, R. Palamara and A. Taccone, J. Phys. Soc. Jpn. 60 (1991) 100

1991AR25 N. Arena, Seb. Cavallaro, A. D'Arrigo, G. Fazio, G. Giardina, A. Italiano, A. Taccone, V.D. Chesnokova, V.S. Olkhovsky and A.K. Zaichenko, Nuovo Cim. A104 (1991) 1809

1991AS02 A.R. Ashurov, D.A. Zubarev, A.M. Mukhamedzhanov and R. Yarmukhamedov, Yad. Fiz. 53 (1991) 151; Sov. J. Nucl. Phys. 53 (1991) 97

1991BA02 M.J. Balbes, G. Feldman, L.H. Kramer, H.R. Weller and D.R. Tilley, Phys. Rev. C43 (1991) 343

1991BA1V F. Balestra, Yu.A. Batusov, G. Bendiscioli, S. Bossolasco, F.O. Breivik, S.A. Bunyatov, M.P. Bussa, L. Busso, C. Guaraldo, I.V. Falomkin et al., in Stockholm 90 (1991) 245

1991BO23 L.N. Bogdanova, G.M. Hale and V.E. Markushin, Phys. Rev. C44 (1991) 1289

1991CO05 S.G. Cooper and R.S. Mackintosh, Phys. Rev. C43 (1991) 1001

1991DA06 S.E. Darden, O. Karban, C. Blyth, J.B.A. England, J.M. Nelson and S. Roman, Nucl. Phys. A526 (1991) 45

1991FU01 Y. Fujiwara and Y.C. Tang, Phys. Rev. C43 (1991) 96

1991GO19 M.G. Gornov, Yu.B. Gurov, P.V. Morokhov, V.A. Pechkurov, V.I. Savelyev, F.M. Sergeev, B.A. Chernyshev, R.R. Shafigullin, A.V. Shishkov, V.P. Koptev et al., Nucl. Phys. A531 (1991) 613

1991KA31 B.M. Karnakov, V.D. Mur, S.G. Pozdnyakov and V.S. Popov, Pisma Zh. Eksp. Teor. Fiz. 54 (1991) 131; JETP Lett. (USSR) 54 (1991) 127

1991NE01 V.G. Neudatchin, V.I. Kukulin, V.N. Pomerantsev and A.A. Sakharuk, Phys. Lett. B255 (1991) 482

1991SA17 A.L. Sagle, B.E. Bonner, F.P. Brady, N.S.P. King and J.L. Romero, Nucl. Phys. A530 (1991) 370

1991SA18 A.L. Sagle, B.E. Bonner, F.P. Brady, N.S.P. King, M.W. McNaughton, J.L. Romero and J.L. Ullmann, Nucl. Phys. A530 (1991) 387

1991SE06 K.K. Seth and B. Parker, Phys. Rev. Lett. 66 (1991) 2448

1991VA05 G. van der Steenhoven, Nucl. Phys. A527 (1991) 17c.

1991WEZZ H.R. Weller, G. Feldman, M.J. Balbes, L.H. Kramer, J.Z. Williams and D.R. Tilley, AIP Conf. Proc. 238 (1991) 587

1992AM1H A.I. Amelin, B.A. Chernyshev, M.G. Gornov, Yu.B. Gurov, P.V. Morokhov, V.A. Pechkurov, V.I. Savel'ev, R.R. Shafigullin, A.V. Shishkov and V.P. Koptev, in Penyscola (1992) 516

1992AR20 N. Arena, Seb. Cavallaro, A. D'Arrigo, G. Fazio, G. Giardina, A. Italiano and A. Taccone, J. Phys. G18 (1992) 2003

1992BA04 M.J. Balbes, G. Feldman, H.R. Weller and D.R. Tilley, Phys. Rev. C45 (1992) R487

1992BE46 F.D. Becchetti, J.A. Brown, W.Z. Liu, J.W. Janecke, D.A. Roberts, J.J. Kolata, R.J. Smith, K. Lamkin, A. Morsad, R.E. Warner et al., Nucl. Phys. A550 (1992) 507

1992BEZZ F.D. Becchetti, J.A. Brown, W.Z. Liu, J.W. Janecke, D.A. Roberts, J.J. Kolata, R.J. Smith, K. Lamkin, A. Morsad, R.E. Warner et al., Bull. Amer. Phys. Soc. 37 (1992) 868

1992BO47 H.-S. Bosch and G.M. Hale, Nucl. Fusion 32 (1992) 611

1992DA1K A. D'Arrigo, G. Fazio, G. Giardina, A. Italiano, M. Lombardi, V.S. Olkhovsky, A. Taccone, V.D. Tchesnokova and A.K. Zaichenko, Hadronic J. 15 (1992) 303

1992FU10 Y. Fujiwara and Y.C. Tang, Few-Body Syst. 12 (1992) 21

1992KH04 M.G. Khayat, N.S. Chant, P.G. Roos and T.-S.H. Lee, Phys. Rev. C46 (1992) 2415

1992LI32 J.R. Lierzer, K.W. Wenzel, R.D. Petrasso, D.H. Lo, J.W. Coleman, C.K. Li, E. Hsieh and T. Bernat, Rev. Sci. Instrum. 63 (1992) 4847

1992NE03 V.G. Neudatchin, V.I. Kukulin, V.N. Pomerantsev and A.A. Sakharuk, Phys. Rev. C45 (1992) 1512

1992PI04 J.A. Pinston, V. Bellini, W. Cassing, S. Drissi, J. Guillot, J. Julien, H. Nifenecker, F. Schussler and M.L. Sperduto, Nucl. Phys. A536 (1992) 321

1992RA01 R.D. Ransome, C.L. Morris, V.R. Cupps, R.W. Fergerson, J.A. McGill, D.L. Watson, J.D. Zumbro, B.G. Ritchie, J.R. Comfort, J.R. Tinsley et al., Phys. Rev. C45 (1992) R509

1992TI02 D.R. Tilley, H.R. Weller and G.M. Hale, Nucl. Phys. A541 (1992) 1

1993AB07 S.K. Abdullin, A.V. Blinov, I.A. Vanyushin, V.E. Grechko, V.A. Ergakov, S.M. Zombkovskii, I.L. Kiselevich, Y.V. Korolev and Y.M. Selektor, Phys. At. Nucl. 56 (1993) 536; Yad. Fiz. 56 (1993) 204

1993AR12 N. Arena, S. Cavallaro, A. D'Arrigo, G. Fazio, G. Giardina, A. Italiano, A. Taccone, D.Q. Hung and V.S. Olkhovsky, Nuovo Cim. A106 (1993) 1007

1993CS02 A. Csoto, R.G. Lovas and A.T. Kruppa, Phys. Rev. Lett. 70 (1993) 1389

1993FA12 G. Fazio, G. Giardina and R. Palamara, J. Phys. Soc. Jpn. 62 (1993) 1804

1993GL09 V.V. Glagolev, R.M. Lebedev, G.D. Pestova, S.S. Shimansky, M. Kravcikova, M. Seman, L. Sandor, A. Dirner, J. Hlavacova, G. Martinska et al., Z. Phys. C60 (1993) 421

1993GO16 O.K. Gorpinich, Yu.N. Pavlenko, O.M. Povoroznik and B.G. Struzhko, Izv. Akad. Nauk Ser. Fiz. 57 (1993) 121; Bull. Russ Acad Sci. 57 (1993) 112

1993HO09 L.L. Howell, S.A. Sofianos, H. Fiedeldey and G. Pantis, Nucl. Phys. A556 (1993) 29

1993KA01 J.E. Kammeraad, J. Hall, K.E. Sale, C.A. Barnes, S.E. Kellogg and T.R. Wang, Phys. Rev. C47 (1993) 29

1993KA47 H. Kanada, T. Kaneko and S. Nagata, Prog. Theor. Phys. 89 (1993) 1103

1993KU02 D. Kurath, Phys. Rev. C47 (1993) 1306

1993MA47 S.I. Manayenkov, Phys. At. Nucl. 56 (1993) 1525

1993PAZP Yu.N. Pavlenko, V.M. Pugach, A.G. Prokopets, V.N. Dobrikov, V.S. Zaritsky, V.A. Kiva, A.A. Klipenshtein and I.N. Kolomiets, in Dubna 93 (1993) 245

1994BA02 M.J. Balbes, J.C. Riley, G. Feldman, H.R. Weller and D.R. Tilley, Phys. Rev. C49 (1994) 912

1994CO16 A.A. Cowley, G.F. Steyn, S.V. Fortsch, J.J. Lawrie, J.V. Pilcher, F.D. Smit and D.M. Whittal, Phys. Rev. C50 (1994) 2449

1994FA10 W.R. Falk, Phys. Rev. C50 (1994) 1574

1994FU06 K.M. Furutani, W.R. Falk, H. Guan, J.R. Campbell, F.A. Duncan, P.L. Walden, S. Yen, G.M. Huber, R.D. Bent, G.J. Lolos, E. Korkmaz, A. Trudel and A. Celler, Phys. Rev. C50 (1994) 1561

1994MU07 V.D. Mur, B.M. Karnakov, S.G. Pozdnyakov and V.S. Popov, Phys. At. Nucl. 57 (1994) 769; Yad. Fiz. 57:5 (1994) 820

1994NI04 D. Nilsson, J.-O. Adler, B.-E. Andersson, K.I. Blomqvist, L. Isaksson, A. Sandell, B. Schroder, K. Ziakas, L. Van Hoorebeke, D. Rykbosch and R. Van de Vyver, Phys. Scr. 49 (1994) 397

1994RY01 D. Ryckbosch, L. Van Hoorebeke, R. Van de Vyver, C. Van den Abeele, J. Dias, J.-O. Adler, K.I. Blomqvist, D. Nilsson, B. Schroder and K. Ziakas, Nucl. Phys. A568 (1994) 52

1994WA06 R.E. Warner, J.M. Getter, R.A. Swartz, A. Okihana, T. Konishi, R. Yoshimura, P.D. Kunz, M. Fujiwara, K. Fukunaga, S. Kasagi and N. Koori, Phys. Rev. C49 (1994) 1534

1995ALZU D.V. Aleksandrov, E.Yu. Nikolsky, B.G. Novatsky and D.N. Stepanov, in Arles (1995) 329

1995AU04 G. Audi and A.H. Wapstra, Nucl. Phys. A595 (1995) 409

1995DI01 J.F. Dias, D. Ryckbosch, R. Vandevyver, C. Vandenabeele, G. Demeyer, L. Vanhoorebeke, J.O. Adler, K.I. Blomqvist, D. Nilsson, H. Ruijter et al., Nucl. Phys. A587 (1995) 434

1995DU13 S.B. Dubovichenko, Phys. At. Nucl. 58 (1995) 1174; Yad. Fiz. 58 (1995) 1253

1995FU16 Y. Fujiwara and Y.C. Tang, Prog. Theor. Phys. (Kyoto) 93 (1995) 711

1995LA33 L.M. Lazarev, Bull. Russ. Acad. Sci. Phys. 59 (1995) 866; Izv. Ross. Akad. Nauk Ser. Fiz. 59 (1995) 171

1996AL01 N. Alexander, K. Amos, B. Apagyi and D.R. Lun, Phys. Rev. C53 (1996) 88

1996CO20 S.G. Cooper, R.S. Mackintosh, Phys. Rev. C54 (1996) 3133

1996EF03 V.D. Efros and H. Oberhummer, Phys. Rev. C54 (1996) 1485

1996FA05 G. Fazio, G. Giardina, F.I. Karmanov and V.L. Shablov, Int. J. Mod. Phys. E5 (1996) 175

1996KAZZ M. Kawabata, H. Akimune, H. Akiyoshi, Y. Arimoto, T. Baba, I. Daito, K. Hatanaka, F. Ihara, H. Kohri, Y. Maeda et al., RCNP Osaka Ann. Rept. 1995 (1996) 35

1996PO26 V.S. Popov, B.M. Karnakov and V.D. Mur, Hyperfine Interactions 102 (1996) 401

1996RU13 A.T. Rudchik, E.I. Koshchy, A. Budzanowski, R. Siudak, A. Szczurek, I. Skwirczynska, Yu.G. Mashkarov, L. Glowacka, J. Turkiewicz, I.I. Zalyubovsky et al., Nucl. Phys. A609 (1996) 147

1996ST25 G.F. Steyn, S.V. Fortsch, J.J. Lawrie, F.D. Smit, R.T. Newman, A.A. Cowley and R. Lindsay, Phys. Rev. C54 (1996) 2485

1996TA09 M. Tanifuji and H. Kameyama, Nucl. Phys. A602 (1996) 1

1996YOZZ T. Yoshimura, A. Okihana, R.E. Warner, N.S. Chant, P.G. Roos, C. Samanta, S. Kakigi, N. Koori, M. Fujiwara, N. Matsuoka et al., RCNP Osaka Ann. Rept. 1995 (1996) 38

1997ABZY S.N. Abramovich, L.N. Generalov, and A.G. Zvenigorodsky, in Trieste (1997) 632

1997BA72 F.C. Barker, Phys. Rev. C56 (1997) 2646

1997BE59 P. Bem, V. Kroha, J. Mares, E. Simeckova, M. Trinova and P. Vercimak, Few-Body Syst. 22 (1997) 77

1997CH1P L.V. Chulkov, T. Aumann, D. Aleksandrov, L. Axelsson, T. Baumann, M.J.G. Borge, R. Collatz, J. Cub, W. Dostal, B. Eberlein et al., in Darmstadt (1997) 4

1997CH24 L.V. Chulkov et al., Phys. Rev. Lett. 79 (1997) 201

1997CS01 A. Csoto and G.M. Hale, Phys. Rev. C55 (1997) 536

1997DU15 S.B. Dubovichenko and A.V. Dzhazairov-Kakhramanov, Fiz. Elem. Chastits At. Yadra 28 (1997) 1529; Phys. Part. Nucl. 28 (1997) 615

1997HA15 K. Hatanaka, M. Kawabata, N. Matsuoka, Y. Mizuno, S. Morinobu, M. Nakamura, T. Noro, A. Okihana, K. Sagara, K. Takahisa et al., Phys. Rev. Lett. 78 (1997) 1014

1997HAZK Y. Han, Q. Shen, and J. Zhang, in Trieste (1997) 958

1997HAZX Y. Han, Q. Shen, J. Zhang, Z. Zhang and X. Sun, INDC(CPR)-042/L (1997) 45

1997HAZY Y. Han, Q. Shen, J. Zhang, Z. Zhang and X. Sun, INDC(CPR)-042/L (1997) 27

1997KO07 T. Kobayashi, K. Yoshida, A. Ozawa, I. Tanihata, A. Korsheninnikov, E. Nikolsky and T. Nakamura, Nuc. Phys. A616 (1997) 223c.

1997KOZV T. Kobayashi, A. Ozawa, K. Yoshida, A. Korsheninnikov, I. Tanihata, E.Y. Nikolsky and T. Nakamura, RIKEN-96 (1997) 53

1997YA08 J. Yan, F.E. Cecil, J.A. McNeil and M.A. Hofstee, Nucl. Phys. A621 (1997) 127c.

1997YOZQ T. Yoshimura, A. Okihana, R.E. Warner, N.S. Chant, P.G. Roos, C. Samanta, S. Kakigi, N. Koori, N. Fujiwara, N. Matsuoka et al., RCNP (Osaka) Ann. Rept. 1996 (1997) 43

1998CS02 A. Csoto and G.M. Hale, Nucl. Phys. A631 (1998) 783c.

1998NO04 T. Noro, T. Baba, K. Hatanaka, M. Ito, M. Kawabata, N. Matsuoka, Y. Mizuno, S. Morinobu, M. Nakamura, A. Okihana et al., Nucl. Phys. A629 (1998) 324c.

1998PA31 E.A. Pasyuk, C.L. Morris, J.L. Ullman, J.D. Zumbro, L.W. Kwok, J.L. Matthews and Y. Tan, Acta Phys. Pol. B29 (1998) 2335

1998SO05 N. Soic, D. Cali, S. Cherubini, E. Costanzo, M. Lattuada, D. Miljanic, S. Romano, C. Spitaleri and M. Zadro, Europhys. Lett. 41 (1998) 489

1998SO26 N. Soic, D. Cali, S. Cherubini, E. Costanzo, M. Lattuada, M. Milin, D. Miljanic, S. Romano, C. Spitaleri and M. Zadro, Eur. Phys. J. A3 (1998) 303

1998ST07 G.F. Steyn, S.V. Fortsch, A.A. Cowley, S. Karataglidis, R. Lindsay, J.J. Lawrie, F.D. Smit and R.T. Newman, Phys. Rev. C57 (1998) 1817

1998WE07 H.R. Weller, M.J. Balbes, Nucl. Instrum. Meth. Phys. Res. A402 (1998) 428

1998YO09 T. Yoshimura, A. Okihana, R.E. Warner, N.S. Chant, P.G. Roos, C. Samanta, S. Kakigi, N. Koori, M. Fujiwara, N. Matsuoka et al., Nucl. Phys. A641 (1998) 3

1999AN35 C. Angulo, M. Arnould, M. Rayet, P. Descouvemont, D. Baye, C. Leclercq-Willain, A. Coc, S. Barhoumi, P. Auger, C. Rolfs et al., Nucl. Phys. A656 (1999) 3

1999AO01 S. Aoyama, Phys. Rev. C59 (1999) 531

1999FI10 G.F. Filippov, A.D. Bazavov and K. Kato, Phys. At. Nucl. 62 (1999) 1642; Yad. Fiz. 62 (1999) 1763

1999GE19 W.H. Geist, C.R. Brune, H.J. Karwowski, E.J. Ludwig, K.D. Veal and G.M. Hale, Phys. Rev. C60 (1999) 054003

1999HO02 T. Hotta, T. Tamae, T. Miura, H. Miyase, I. Nakagawa, T. Suda, M. Sugawara, T. Tadokoro, A. Takahashi, E. Tanaka and H. Tsubota, Nucl. Phys. A645 (1999) 492

1999NA05 A. Nadasen, J. Brusoe, J. Farhat, K.A.G. Rao, D. Sisan, J. Williams, P.G. Roos, F. Adimi, T. Gu, M. Khayat et al., Phys. Rev. C59 (1999) 760

2000AB25 B.M. Abramov, Yu.A. Borodin, S.A. Bulychiev, I.A. Dukhovskoy, A.P. Krutenkova, V.V. Kulikov, M.A. Matsyuk, I.A. Radkevich, E.N. Turdakina and A.I. Khanov, Pisma Zh. Eksp. Teor. Fiz. 71 (2000) 524; JETP Lett. 71 (2000) 359

2000BAZO T. Baba, T. Noda, M. Shimokawa, J. Taguchi, H. Yuki and J. Kasagi, Res. Rep. Lab. Nucl. Sci., Tohoku Univ. 33 (2000) 19

2000GO35 O.K. Gorpinich, O.M. Povoroznik, A.P. Pshedzyal and B.G. Struzhko, Bull. Russ. Acad. Sci. Phys. 64 (2000) 82; Izv. Ross. Akad. Nauk. Ser. Fiz. 64 (2000) 100

2000HO18 M. Hoefman, L. Aphecetche, J.C.S. Bacelar, H. Delagrange, P. Descouvemont, J. Diaz, D. d'Enterria, M.-J. van Goethem, R. Holzmann, H. Huisman et al., Phys. Rev. Lett. 85 (2000) 1404

2000MI17 O.V. Miklukho, N.P. Aleshin, S.L. Belostotsky, O.G. Grebenyuk, O.Ya. Fedorov, A. A. Izotov, A.Yu. Kisselev, Yu.G. Naryshkin,V.V. Nelyubin et al., Yad. Fiz. 63 (2000) 894; Phys. At. Nucl. 63 (2000) 824

2000MIZU D. Miljanic, S. Blagus, M. Bogovac, M. Milin, D. Rendic, N. Soic, M. Zadro, M. Aliotta, D. Cali, E. Costanzo et al., in Croatia (2000) 241

2000OK01 N.T. Okumusoglu and C.O. Blyth, Nucl. Phys. A671 (2000) 33

2000SH23 N.B. Shulgina, B.V. Danilin, L.V. Grigorenko, M.V. Zhukov and J.M. Bang, Phys. Rev. C62 (2000) 014312

2001DE02 P. Descouvemont and A. Kharbach, Phys. Rev. C63 (2001) 027001