

Energy Levels of Light Nuclei $A = 8$

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Abstract: An evaluation of $A = 8-10$ was published in *Nuclear Physics A745* (2004), p. 155. This version of $A = 8$ 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 March 31, 2004)

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A = 8

GENERAL: References to articles on general properties of $A = 8$ 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 $A = 8$ located on our website at (www.tunl.duke.edu/nuclldata/General_Tables/08.shtml).

${}^8\text{n}$

(Not illustrated)

The nucleus ${}^8\text{n}$ has not been observed. Reaction products from the interaction of 700 MeV and 400 GeV protons with uranium showed no evidence of an ${}^8\text{n}$ resonance: see (1979AJ01). See also (1988AJ01).

${}^8\text{He}$

(Figs. 1 and 5)

GENERAL: References to articles on general properties of ${}^8\text{He}$ published since the previous review (1988AJ01) are grouped into categories and listed, along with brief descriptions of each item, in the General Tables for ${}^8\text{He}$ located on our website at (www.tunl.duke.edu/nuclldata/General_Tables/8he.shtml).

Mass of ${}^8\text{He}$: The atomic mass excess of ${}^8\text{He}$ adopted by us and by (2003AU03) is 31598 ± 7 keV. ${}^8\text{He}$ is then stable with respect to decay into ${}^6\text{He} + 2\text{n}$ by 2.140 MeV. See (1979AJ01, 1984AJ01, 1988AJ01).

The interaction nuclear radius of ${}^8\text{He}$ is 2.48 ± 0.03 fm (1985TA13, 1985TA18) [see also for derived nuclear matter, charge and neutron matter r.m.s. radii. See also reaction 12].

1. ${}^8\text{He}(\beta^-){}^8\text{Li}$ $Q_m = 10.651$

The half-life of ${}^8\text{He}$ is 119.0 ± 1.5 msec. The decay takes place (84 ± 1)% to ${}^8\text{Li}^*(0.98)$ [$\log ft = 4.20$] and (16 ± 1)% via the neutron unstable states ${}^8\text{Li}^*(3.21, 5.4)$. A small decay branch (≈ 0.9 %) populates ${}^8\text{Li}^*(9.67)$. (32 ± 3)% of the emitted neutrons then populate ${}^7\text{Li}^*(0.48)$. The decay to ${}^8\text{Li}^*(3.21, 5.4)$ suggests $\pi = +$ for ${}^8\text{Li}^*(3.21)$ and 0^+ or 1^+ for ${}^8\text{Li}^*(5.4)$ (1981BJ03). Branching ratios for intermediate states are given in (1988BA67): see also reaction 11 in ${}^8\text{Li}$ and Fig. 2. For discussion of ${}^8\text{He}$ β -decay (1988BA67, 1991BO31, 1993BO24, 1996BA66, 1996GR16, 1997SH19). See also (1990ZH01, 1993CH06, 1994HA39).

Table 8.1: Energy Levels of ${}^8\text{He}$ ^a

E_x (MeV) ^b	$J^\pi; T$	$\tau_{1/2}$ or Γ	Decay	Reactions
g.s.	$0^+; 2$	119.0 ± 1.5 msec	β^-	1, 2, 5, 6, 7, 8, 9, 10, 12
2.7–3.6 ^{c,f}	2^+	0.6 ± 0.2 MeV		2, 6, 7, 8, 9, 10, 12
4.36 ± 0.2 ^{d,f}	(1^-)	1.3 ± 0.5 MeV ^{d,e}		5, 7, 9, 10, 12
(6.03 ± 0.10) ^f		0.15 ± 0.15 MeV		9
7.16 ± 0.04 ^f	(3^-)	0.1 ± 0.1 MeV		6, 9

^a Excited states are calculated at $E_x = 5.83, 7.92$ and 8.18 MeV, with $J^\pi = 2^+, 1^-$ and 2^- [($0+1$) $\hbar\omega$ model space]. In the ($0+2$) $\hbar\omega$ model space the excited states are at 5.69, 9.51 and 11.59 MeV, with $J^\pi = 2^+, 1^+$ and 0^+ (1985PO10).

^b A level has been reported at 1.3 MeV in reactions 7 and 10. However, this result has not been supported by other measurements.

^c This 2^+ level is reported near 2.7 MeV in reactions 6, 7, 10, and 12, and near 3.6 MeV in reactions 2, 8 and 9.

^d Uncertainty enlarged for weighted average. This may represent a group of states based on observations of a broad resonance observed at 4.4 MeV (reactions 5 and 12), a narrow resonance at 4 MeV (reactions 7 and 10), and a narrow resonance at 4.54 MeV (reaction 9).

^e Measured widths range from 500 ± 300 keV to 1.8 ± 0.2 MeV.

^f From data reviewed in this evaluation.

2. ${}^1\text{H}({}^8\text{He}, {}^8\text{He}){}^1\text{H}$

$$E_b = 13.933$$

Invariant mass spectroscopy was used to determine the ${}^8\text{He}$ excitation spectra in a complete kinematics measurement of the ${}^1\text{H}({}^8\text{He}, {}^8\text{He} + \text{p})$ reaction at 72 MeV/A (1993KO34, 1995KO27). The ground state and an excited state at 3.55 ± 0.15 MeV were observed. The 3.55 MeV state has $J^\pi = 2^+$, $\Gamma = 0.50 \pm 0.35$ MeV and $\Gamma(\alpha + 4n)/\Gamma({}^6\text{He} + 2n) \leq 5\%$ (1995KO27); possible evidence for a resonance at 5–6 MeV is seen.

The ${}^1\text{H}({}^8\text{He}, {}^8\text{He} + \text{p})$ scattering distribution at $E({}^8\text{He}) = 674$ MeV/A was analyzed using a Glauber scattering model and yields an ${}^8\text{He}$ matter radius $R_{\text{r.m.s.}} = 2.45 \pm 0.07$ fm (1997AL09). Elastic and inelastic scattering distributions from ${}^1\text{H}({}^8\text{He}, {}^8\text{He} + \text{p})$ at 72 MeV/A were evaluated in an eikonal approximation and indicate a matter radius $R_{\text{r.m.s.}} = 2.52$ fm and a deformation parameter $\beta_2 = 0.3$ for the first 2^+ excited state (1995CH19). A folding model analysis of the ${}^8\text{He}$ first excited $J^\pi = 2^+$ state, using $E_x = 3.57$ MeV, indicates $L = 2$ and a deformation parameter $\beta = 0.28$ (2002GU02).

Evaluation of the four-momentum transfer distribution yields $R_{\text{rms}} = 2.45 \pm 0.07$ fm at $E({}^8\text{He}) = 800$ MeV/A (2002EG02) and $R_{\text{rms}} = 2.53 \pm 0.08$ fm at $E({}^8\text{He}) \approx 700$ MeV/A (2002AL26). See also (2003LA22; $E({}^8\text{He}) = 15.6$ MeV/A), (2002WO08; $E({}^8\text{He}) = 26$ MeV/A), (1995KO10; $E({}^8\text{He}) = 33$ MeV/A), (1997KO06; $E({}^8\text{He}) = 66$ MeV/A), (1997KO12; $E({}^8\text{He}) = 73.5$ MeV/A),

(1995NE04; $E(^8\text{He}) = 674 \text{ MeV}/A$), (2002EG02; $E(^8\text{He}) \approx 700 \text{ MeV}/A$), and (1995BE26, 1995CR03, 1995GO32, 1998AN25, 2000GU19, 2000KA04, 2000WE03, 2001AV02, 2001SA79, 2003BA65; theor.).

3. $^4\text{He}(^8\text{He}, ^8\text{He})^4\text{He}$ $E_b = 8.946$

The Generator-Coordinate Method was used to calculate $^8\text{He}(\alpha, \alpha)$ scattering in an investigation of excited states in ^{12}Be (2000BB06). A search for 4-neutron cluster contributions to the reaction was performed at $E(^8\text{He}) = 26 \text{ MeV}/A$, no evidence was observed (2003WO13).

4. $^8\text{He}(p, t)^6\text{He}$ $Q_m = 6.342$

The 2-neutron transfer reaction $^1\text{H}(^8\text{He}, t)$ was measured at $E(^8\text{He}) = 61.3 \text{ MeV}/A$. The results indicate a significant contribution of $^6\text{He}^*(1.8)$ in the ^8He ground state (2003KO11); spectroscopic factors yield $S(^6\text{He}_{\text{g.s.}})/S(^6\text{He}^*(1.8)) = 1$.

5. (a) $^9\text{Be}(\pi^-, p)^8\text{He}$ $Q_m = 112.031$

(b) $^{11}\text{B}(\pi^-, p + d)^8\text{He}$ $Q_m = 96.215$

Using $E_{\pi^-} = 125 \text{ MeV}$, the ^8He ground state was observed in the $^9\text{Be}(\pi^-, p)$ missing mass spectra; the measured $^6\text{He} + 2n$ phase space appears to favor a di-neutron final state (1991SE06). The ground state and the 4.4 MeV state were observed in (1998GO30) following the capture of stopped π^- -mesons in $^9\text{Be}(\pi^-, p)$, $E_x = 4.4 \pm 0.2 \text{ MeV}$, $\Gamma = 1.8 \pm 0.2 \text{ MeV}$ and in $^{11}\text{B}(\pi^-, p + d)$ $E_x = 4.4 \pm 0.4 \text{ MeV}$, $\Gamma = 1.2 \pm 0.2 \text{ MeV}$.

6. $^9\text{Be}(^7\text{Li}, ^8\text{B})^8\text{He}$ $Q_m = -28.264$

At $E(^7\text{Li}) = 83 \text{ MeV}$, $\theta = 10^\circ$, the population of $^8\text{He}_{\text{g.s.}}$, an excited state at $2.8 \pm 0.4 \text{ MeV}$ (presumably $J^\pi = 2^+$) and a structure near $E_x \approx 7 \text{ MeV}$ are reported by (1985AL29).

7. $^9\text{Be}(^9\text{Be}, ^{10}\text{C})^8\text{He}$ $Q_m = -24.602$

At $E(^9\text{Be}) \approx 11 \text{ MeV}/A$, the ground state and three excited states are populated at $E_x = 1.3 \pm 0.3 \text{ MeV}$, $E_x = 2.7 \pm 0.3 \text{ MeV}$, $\Gamma = 0.5 \pm 0.3 \text{ MeV}$ and $E_x = 4.0 \pm 0.3 \text{ MeV}$, $\Gamma = 0.5 \pm 0.3 \text{ MeV}$ (1988BE34).

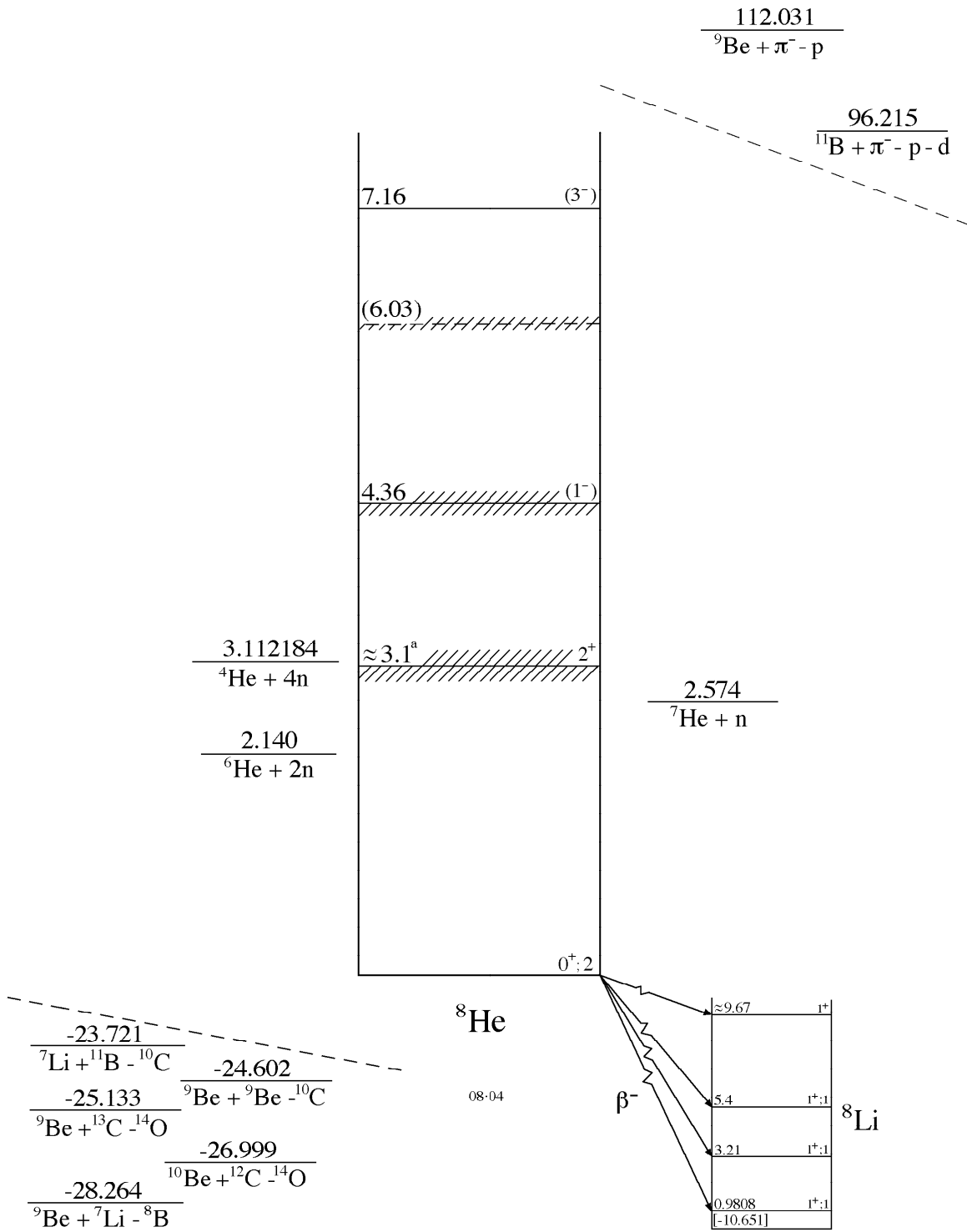


Figure 1: Energy levels of ${}^8\text{He}$. For notation see Fig. 2.

^a See comment ^c in Table 8.1.

8. ${}^9\text{Be}({}^{13}\text{C}, {}^{14}\text{O}){}^8\text{He}$ $Q_m = -25.133$

At $E({}^{13}\text{C}) = 380$ MeV, the ground state of ${}^8\text{He}$ was observed (1988BO20). A measurement at $E({}^{13}\text{C}) = 337$ MeV observed the ground state and the first 2^+ excited state at 3.59 MeV, $\Gamma \approx 800$ keV (1995VO05).

9. ${}^{10}\text{Be}({}^{12}\text{C}, {}^{14}\text{O}){}^8\text{He}$ $Q_m = -26.999$

At $E({}^{12}\text{C}) = 357$ MeV, population of the ground state and 3.6 MeV state are reported. Excited states are also observed at $E_x = 4.54 \pm 0.15$ MeV [$\Gamma = 0.70 \pm 0.25$ MeV], 6.03 ± 0.10 MeV [$\Gamma = 0.15 \pm 0.15$ MeV] and 7.16 ± 0.04 MeV [$\Gamma = 0.10 \pm 0.10$ MeV] (1995ST29, 1999BO26). The narrow width of the 7.16 MeV state leads to a preliminary $J^\pi = (3^-)$ assignment (1999BO26).

10. ${}^{11}\text{B}({}^7\text{Li}, {}^{10}\text{C}){}^8\text{He}$ $Q_m = -23.721$

At $E({}^{11}\text{B}) = 87$ MeV the ground state of ${}^8\text{He}$ is populated and excited states are reported at $E_x = 1.3, 2.6$ and 4.0 MeV (± 0.3 MeV). The width of the latter is 0.5 ± 0.3 MeV (1987BE2B). In (1988BE34) the ground state and a state at 2.7 ± 0.3 MeV with $\Gamma = 1.0 \pm 0.5$ MeV are reported. See also (1988BEYJ).

11. ${}^{\text{nat}}\text{C}(\mu, {}^8\text{He})\text{X}$

A measurement to determine muon induced background rates in large-volume scintillation solar neutrino detectors found $\sigma = 2.12 \pm 1.46$ μb for ${}^{\text{nat}}\text{C}(\mu, {}^8\text{He}$ or ${}^9\text{Li})$ at $E_\mu = 100$ GeV (2000HA33).

12. (a) ${}^{12}\text{C}({}^8\text{He}, {}^6\text{He} + 2n)$
 (b) $\text{Al}({}^8\text{He}, {}^6\text{He} + 2n)$
 (c) $\text{Sn}({}^8\text{He}, {}^6\text{He} + 2n)$
 (d) $\text{Pb}({}^8\text{He}, {}^6\text{He} + 2n)$
 (e) $\text{C}({}^8\text{He}, \text{X})$
 (f) $\text{Si}({}^8\text{He}, \text{X})$

At $E(^8\text{He}) = 227 \text{ MeV}/A$ structures are seen in reaction (a) corresponding to sequential decay through the $J^\pi = \frac{3}{2}^- \text{ } ^7\text{He}_{\text{g.s.}}$ ($E_{\text{res}} = 0.44 \text{ MeV}$, $\Gamma = 0.16 \text{ MeV}$), and a suggested $J^\pi = \frac{1}{2}^-$ resonance at $E_{\text{res}} = 1.2 \pm 0.2 \text{ MeV}$ with $\Gamma = 1.0 \pm 0.2 \text{ MeV}$ (2001MA05). A reconstruction of the $^6\text{He} + 2n$ reaction kinematics indicated that $^8\text{He}^*(2.9 \pm 0.2 \text{ MeV}, \Gamma = 0.3 \pm 0.3 \text{ MeV} (2^+)$ and $4.15 \pm 0.20 \text{ MeV}, \Gamma = 1.6 \pm 0.2 \text{ MeV} (1^-)$) participate in the breakup. Cross sections for the one- and two-neutron knockout reactions (i.e., where one or none of the removed neutrons is observed) were determined as $\sigma_{1n} = 129 \pm 15 \text{ mb}$ and $\sigma_{2n} = 29 \pm 23 \text{ mb}$. Contributions for various cluster configurations in ^8He were estimated to be 45% $^6\text{He}^* + 2n (p_{3/2}, p_{1/2})$, 33% $^6\text{He} + 2n (p_{3/2})$ and 22% $^6\text{He} + 2n (p_{1/2})$. See (1996NI02) for earlier work at $E(^8\text{He}) = 240 \text{ MeV}$ by this group, where $E_x = 3.72 \pm 0.24 \text{ MeV}$ and $\Gamma = 0.53 \pm 0.43 \text{ MeV}$, were reported for the first excited state, and where the total 2-neutron removal cross section was determined as $\sigma_{2n} = 0.27 \pm 0.03 \text{ b}$.

Complete reaction kinematics were measured for reactions (b, c, d) in ($^8\text{He}, ^6\text{He} + 2n$) on Al, Sn and Pb targets at $E(^8\text{He}) = 24 \text{ MeV}/A$ (2000IW05). Observation of a peak in the $^6\text{He} + n$ relative energy spectra indicates a substantial participation (40–60%) of sequential decay via $^7\text{He} + n$. A peak in the missing mass spectra corresponds to the first excited state of ^8He , which is assumed to dominate in nuclear breakup since it cannot be excited by E1 Coulomb processes. By integrating the remaining excitation strength up to 3 MeV (assumed to be E1 Coulomb) $B(E1) = 0.091 \pm 0.026 \text{ e}^2 \cdot \text{fm}^2$ was determined.

Measurements of ^8He breakup on C and Pb are presented in (2002ME09); the results indicate that the ^8He Coulomb dissociation cross section is 3 times smaller than the Coulomb dissociation cross section for ^6He . The measurements of (2002ME09) also support $J^\pi = 1^-$ for $^8\text{He}^*(4.15)$. The two-neutron- and four-neutron-removal cross sections were measured for reaction (e) at 800 MeV/A (1992TA18), and for reaction (f) at $E(^8\text{He}) = 20\text{--}60 \text{ MeV}/A$ (1996WA27). The large neutron removal cross sections indicate a ^8He matter radius of $2.49 \pm 0.04 \text{ fm}$ (1992TA18). Analysis indicates that ^8He is well represented as four neutrons that are bound to a ^4He core. See also (1994ZH14, 1995SU13, 2001CA50; theor.), and a review of nuclear radii deduced from interaction cross sections in (2001OZ04).

13. $^{14}\text{C}(^8\text{He}, ^8\text{He})^{14}\text{C}$

A double folding model was used to predict the influence of the ^8He neutron skin on $^{14}\text{C}(^8\text{He}, ^8\text{He})$ elastic-scattering angular-dependent cross sections at 20, 30, 40, and 60 MeV (1988KN02).

⁸Li
(Figs. 2 and 5)

GENERAL: References to articles on general properties of ⁸Li published since the previous review (1988AJ01) are grouped into categories and listed, along with brief descriptions of each item, in the General Tables for ⁸Li located on our website at (www.tunl.duke.edu/nuclldata/General_Tables/8li.shtml).

Ground State Properties:

$$\begin{aligned}\mu &= +1.653560 \pm 0.000018 \mu_N: \text{ see (1989RA17),} \\ Q &= +32.7 \pm 0.6 \text{ mb: see (1993MI34).}\end{aligned}$$

The interaction nuclear radius of ⁸Li is 2.36 ± 0.02 fm (1985TA18) [see (1985TA18) also for derived nuclear matter, charge and neutron matter r.m.s. radii].

⁸Li atomic transitions: Atomic excitations in the lithium isotopes were analyzed in (2000YA05) where a theoretical framework was developed that correlates the atomic decay energies in neutral Li ions with the nuclear sizes.

1. ⁸Li(β^-)⁸Be $Q_m = 16.0052$

The β^- decay is mainly to the broad 2^+ first-excited state of ⁸Be, which then breaks up into 2α [see reaction 24 in ⁸Be]. The weighted average of the ⁸Li half-life is 839.9 ± 0.9 ms based on measured values of 838 ± 6 ms (1971WI05), 836 ± 3 ms (1979MI1E) and 840.3 ± 0.9 ms (1990SA16). The $\log ft \geq 5.6$, using $\tau_{1/2} = 839.9$ ms, $Q = 16.0052$ MeV and branching ratio $\leq 100\%$; other values in the literature that account for the decay to the broad $\Gamma \approx 1.5$ MeV ⁸Be*(3.0) state are $\log ft = 5.37$ (1986WA01) and $\log ft = 5.72$ (1989BA31).

The quadrupole moment of ⁸Li was deduced by measuring the asymmetry in β -NMR spectra. We adopt $Q(^8\text{Li}) = +32.7 \pm 0.6$ mb, which results from a new method, modified β -NMR (NNQR), that is 100 times more sensitive than previous methods (1993MI34). This value is larger than 28.7 ± 0.7 mb (1988AR17) and the previous adopted value 24 ± 2 mb (1988AJ01). The sign of the ⁸Li quadrupole moment was measured and is positive (1994JA05).

The tilted foil technique was used to polarize atomic ⁸Li, and the hyperfine interaction led to a nuclear polarization of $1.2 \pm 0.3\%$ which was deduced from the measured β -decay asymmetry (1987NO04). The polarization quantum beat in the hyperfine interaction was measured by varying the foil separation distances (1993MO33, 1996NO11). See also (1987AR22) for discussion of hyperfine structure splitting in lithium isotopes.

The pure Gamow-Teller ($\Delta T = 1$) β -decay of ⁸Li to the ⁸Be*(3.0) level has been measured in a search for time-reversal violation (1990SR03, 1992AL01, 1996SR02, 2003HU06); the present constraint for the time violating parameter is $R = (0.9 \pm 2.2) \times 10^{-3}$. See also (1992DE07, 1995YI01, 1998KA51). Searches for second-class currents in ⁸Li β -decay have yielded negative

Table 8.2: Energy levels of ${}^8\text{Li}$ ^a

E_x (MeV \pm keV)	$J^\pi; T$	τ or Γ_{cm} (keV)	Decay	Reactions
g.s.	$2^+; 1$	$\tau_{1/2} = 839.9 \pm 0.9$ msec ^c	β^-	1, 3, 4, 8, 9, 10, 14, 15, 16, 17, 18, 21, 22
0.9808 ± 0.1	$1^+; 1$	$\tau_m = 12 \pm 4$ fsec ^c	γ	3, 8, 9, 11, 14, 15, 16, 21, 22, 28
2.255 ± 3	$3^+; 1$	$\Gamma = 33 \pm 6$ keV ^c	γ, n	3, 4, 5, 8, 14, 15, 16, 31
3.21	$1^+; 1$	≈ 1000	n	6, 11
5.4 ^d	$1^+; 1$	≈ 650	n	6, 11
6.1 ± 100	(3); 1	≈ 1000	n	5
6.53 ± 20	$4^+; 1$	35 ± 15	n	3, 5, 8, 15, 16
7.1 ± 100		≈ 400	n	5
(9)		≈ 6000		14
≈ 9.67 ^{b,c}	1^+	≈ 1000 ^c	t	11
10.8222 ± 5.5	$0^+; 2$	< 12		19

^a For additional states see reactions 5 and 16.

^b From multi-level multi-channel R -matrix fit to ${}^8\text{He}$ decay spectra.

^c From information given in this evaluation.

^d A level at $E_x = 5.4$ MeV with uncertain $J^\pi = (2^+)$ was observed in ${}^7\text{Li}(n, n')$ (1972PR03).

 Table 8.3: Electromagnetic transitions in ${}^8\text{Li}$

$E_{x_i} \rightarrow E_{x_f}$ (MeV)	$J_i^\pi \rightarrow J_f^\pi$	Γ_γ (eV)	Mult.	Γ_γ/Γ_w
$0.9808 \rightarrow 0$	$1^+ \rightarrow 2^+$	$(5.5 \pm 1.8) \times 10^{-2}$	M1	2.8 ± 0.9
$2.255 \rightarrow 0$	$3^+ \rightarrow 2^+$	$(7.0 \pm 3.0) \times 10^{-2}$	M1	0.29 ± 0.13

results: see (1988HA21, 1989TE04, 2003SM02). For an analysis of the anti-neutrino energy distribution shape in ${}^8\text{Li}$ β -decay, see (1987LY05, 2002BH03). For a comment on the usefulness of β -decay asymmetries to reveal information on spin dynamics in nuclear reactions involving polarized projectiles see (2001DZ02). A suggestion to use ${}^8\text{Li}$ β -decay for calibration of the SNO detector is described in (1998JO09, 2002TA22). β -NMR is used to measure the ${}^8\text{Li}$ quadrupole-coupling constants in Mg and Zn (1993OH11). For condensed matter applications of ${}^8\text{Li}$ β -decay see (1993BU29, 1993NO08, 1994HO23, 1996EB01). See also (1993CH06, 1993MO28, 2003SU04).

2. ${}^1\text{H}({}^8\text{Li}, {}^8\text{Li}){}^1\text{H}$

Small angle scattering in the ${}^1\text{H}({}^8\text{Li}, {}^8\text{Li})$ reaction was measured at $E({}^8\text{Li}) = 698 \text{ MeV}/A$ (2002EG02, 2003EG03).

3. ${}^6\text{Li}(t, p){}^8\text{Li}$ $Q_m = 0.80079$

Angular distributions have been obtained at $E_t = 23 \text{ MeV}$ for the proton groups to ${}^8\text{Li}^*(0, 0.98, 2.26, 6.54 \pm 0.03)$; Γ_{cm} for ${}^8\text{Li}^*(2.26, 6.54)$ are 35 ± 10 and $35 \pm 15 \text{ keV}$, respectively. J for the latter is ≥ 4 : see (1979AJ01). A multi-cluster model is used to calculate excitation function and γ -ray flux from ${}^6\text{Li}(t, p_1){}^8\text{Li}^*(0.981)$, which is proposed as a diagnostic tool for fusion reactions (2000VO22, 2001VO02).

4. ${}^7\text{Li}(n, \gamma){}^8\text{Li}$ $Q_m = 2.03229$

Figure 2: Energy levels of ${}^8\text{Li}$. In these diagrams, energy values are plotted vertically in MeV, based on the ground state as zero. For the $A = 8$ diagrams all levels are represented by discrete horizontal lines. Values of total angular momentum J^π , 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 ${}^8\text{Li}$ 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 the lab reference frame, while the excitation function is scaled into the cm reference frame so that resonances are aligned with levels. 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 (2003AU03). Further information on the levels illustrated, including a listing of the reactions in which each has been observed, is contained in Table 8.2.

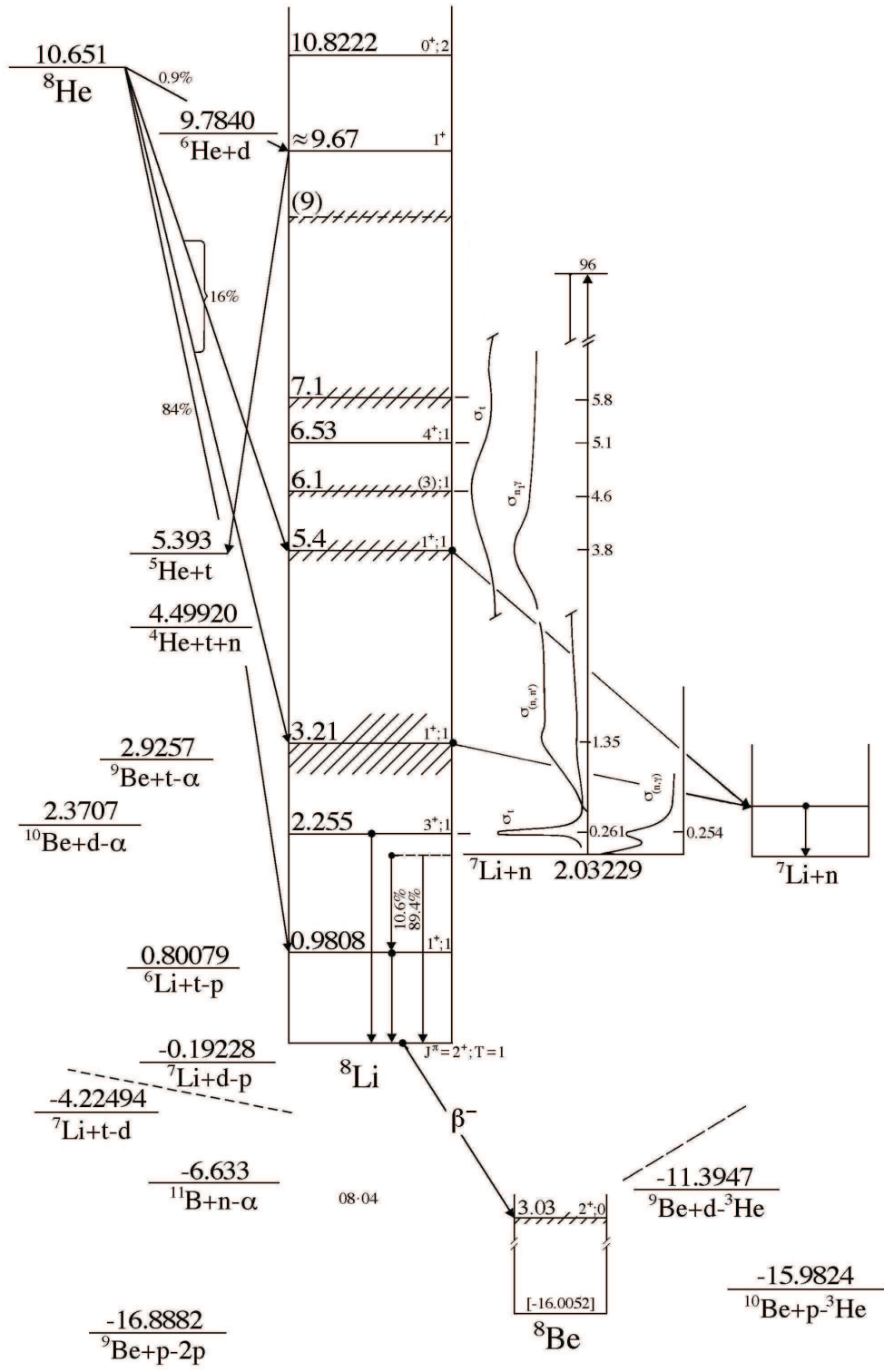


Table 8.4: Measured γ -rays from thermal neutron capture on ${}^7\text{Li}$ ^a

E_γ (keV) ^b	σ_γ (mb)	I_γ ($\gamma/100n$)
980.6 ± 0.2	4.82 ± 0.50	10.6 ± 1.0
1052.0 ± 0.2	4.80 ± 0.50	10.6 ± 1.0
2032.5 ± 0.3	40.56 ± 1.00	89.4 ± 1.0

^a See Table I in (1991LY01).

^b E_γ not corrected for recoil.

At $E_n = 1.5\text{--}1340$ eV agreement was found with the expected $1/v$ (velocity) energy dependence, and a thermal cross section of $40 \pm 2(\text{stat.}) \pm 4(\text{syst.})$ mb was measured (1996BL10). (1998HE35) measured $\sigma_{\text{ave.}} = 101.9$ mb for an energy bin for $E_n = 1.7\text{--}20$ meV, and $\sigma_{\text{ave.}} = 36.6$ μb for $E_n = 5\text{--}150$ keV. A reanalysis of the ion chamber efficiencies used by (1989WI16) led to a revised cross section $\sigma(E_n = 25 \text{ keV}) = 57 \pm 9$ $\mu\text{-barns}$ and $\Gamma_\gamma = 0.18$ eV (1998HE35). Measurements by (1991LY01), who analyzed $\sigma(E)$ from E_{thermal} to 3.0 MeV, determined $\sigma_{\text{thermal}} = 45.4 \pm 3.0$ mb and the γ -ray branching ratios at $E_n = \text{thermal}$ (see Table 8.4). At $E_n = 30$ keV, (1991NA16, 1991NA19) measured $\sigma_{\gamma_0} = 35.4 \pm 6.0$ $\mu\text{-barns}$ and $\sigma_{\gamma_1} < 9.1$ $\mu\text{-barns}$. The excitation function shows the resonance corresponding to ${}^8\text{Li}^*(2.26)$: $E_{\text{res}} = 254 \pm 3$ keV, $\Gamma_n = 31 \pm 7$ keV, $\Gamma_\gamma = 0.07 \pm 0.03$ eV: see Table 8.5 and (1974AJ01). Theoretical models are discussed in (1988DE38, 1993KR18, 1994DE03, 1996SH02, 1997BA04, 1999BE25, 2000BE21, 2000CS01, 2001KO54). The decay of ${}^8\text{Li}^*(2.26) \rightarrow {}^7\text{Li}_{\text{g.s.}} + n$ in the interaction of 35 MeV/A ${}^{14}\text{N}$ ions on Ag is reported by (1987BL13).

5. ${}^7\text{Li}(n, n){}^7\text{Li}$

$$E_b = 2.03229$$

The thermal cross section is 0.97 ± 0.04 b [see (1981MUZQ)], $\sigma_{\text{free}} = 1.07 \pm 0.03$ b (1983KO17). The real coherent scattering length is -2.22 ± 0.01 fm. The complex scattering lengths are $b_+ = -4.15 \pm 0.06$ fm and $b_- = 1.00 \pm 0.08$ fm (1983KO17); see also (1979GL12). See (1984AJ01) for earlier references.

Total and elastic cross sections have been reported for $E_n = 5$ eV to 49.6 MeV: see (1979AJ01, 1984AJ01, 1988AJ01). Cross sections have also been reported for n_0 , n_{0+1} and n_2 at $E_n = 6.82$, 8.90 and 9.80 MeV. (1987SC08; n_2 at the two higher energies).

A pronounced resonance is observed at $E_n = 254$ keV with $J^\pi = 3^+$, formed by p-waves: see Table 8.5. A good account of the polarization is given by the assumption of levels at $E_n = 0.25$ and 3.4 MeV, with $J^\pi = 3^+$ and 2^- , together with a broad $J^\pi = 3^-$ level at higher energy. Broad peaks are reported at $E_n = 4.6$ and 5.8 MeV (± 0.1 MeV) [${}^8\text{Li}^*(6.1, 7.1)$] with $\Gamma \approx 1.0$ and 0.4 MeV, respectively, and there is indication of a narrow peak at $E_n = 5.1$ MeV [${}^8\text{Li}^*(6.5)$] with

Table 8.5: Resonance parameters for ${}^8\text{Li}^*(2.26)$ ^a

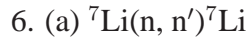
E_{res} (keV)	254 ± 3
E_x (MeV) ^b	2.261
Γ (keV)	35 ± 5
$\Gamma_n(E_r)$ (keV)	31 ± 7 ^c
Γ_γ (eV) ^b	0.07 ± 0.03
γ_n^2 (keV)	594
θ^2	0.091
radius (fm)	3.30
σ_{max}	12.0
J^π	3^+
l_n	1

^a Energies in lab system except for those labeled ^b. For references see (1974AJ01, 1979AJ01).

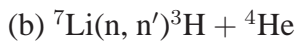
^b Energies in cm system.

^c $\Gamma_n \approx \Gamma$ since Γ_γ is small.

$\Gamma \ll 80$ keV and of a weak, broad peak at $E_n = 3.7$ MeV: see (1974AJ01, 1984AJ01, 1988AJ01). A multi-level, multi-channel R -matrix calculation is reported by (1987KN04). This analysis leads to predictions for the cross section for elastic scattering, for (n, n') to ${}^7\text{Li}^*(0.48, 4.68, 6.68)$ and for triton production. A number of additional (broad) states of ${}^8\text{Li}$, unobserved directly in this and in other reactions, derive from this analysis (1987KN04). See (1989FU03) for a resonating group study of ${}^8\text{Li}^*(6.53)$ [$J^\pi = 4^+$; $T = 1$]; see also (2002GR25). See also references cited in (1988AJ01).



$$E_b = 2.03229$$



$$Q_m = -2.44832$$

The excitation function for 0.48 MeV γ -rays shows an abrupt rise from threshold (indicating s-wave formation and emission) and a broad maximum ($\Gamma \approx 1$ MeV) at $E_n = 1.35$ MeV. A good fit is obtained with either $J^\pi = 1^-$ or 1^+ (2^+ not excluded), $\Gamma_{\text{lab}} = 1.14$ MeV. A prominent peak is observed at $E_n = 3.8$ MeV ($\Gamma_{\text{lab}} = 0.75$ MeV) and there is some indication of a broad resonance ($\Gamma_{\text{lab}} = 1.30$ MeV) at $E_n = 5.0$ MeV. At higher energies there is evidence for structure at $E_n = 6.8$ and 8 MeV followed by a decrease in the cross section to 20 MeV: see (1979AJ01, 1984AJ01).

The total cross section for $(n_0 + n_1)$ and n_2 have been reported at $E_n = 8.9$ MeV (1984FE1A). For R -matrix analyses see (1987KN04) in reaction 5 and (1984AJ01).

The cross section for reaction (b) rises from threshold to ≈ 360 mb at $E_n \approx 6$ MeV and then decreases slowly to ≈ 250 mb at $E_n \approx 16$ MeV: see (1985SW01, 1987QA01). Cross sections for tritium production have been reported from threshold to $E_n = 16$ MeV (1983LI1C), 4.57 to 14.1 MeV (1985SW01), 7.9 to 10.5 MeV (1987QA01), 14.74 MeV (1984SMZX) and at 14.94 MeV (1985GO18: 302 ± 18 mb). At $E_n = 14.95$ MeV the total α production cross section [which includes the $(n, 2n d)$ process] is 336 ± 16 mb (1986KN06). Spectra at 14.6 MeV may indicate the involvement of states of ${}^4\text{H}$ (1986MI11). See also references cited in (1988AJ01).

$$7. {}^7\text{Li}(n, 2n){}^6\text{Li} \quad Q_m = -7.25030 \quad E_b = 2.03229$$

See (1985CH37, 1986CH24). See also (1988AJ01).

$$8. {}^7\text{Li}(p, \pi^+){}^8\text{Li} \quad Q_m = -138.32024$$

Angular distributions and analyzing powers for the transitions to ${}^8\text{Li}^*(0, 0.98, 2.26)$ have been studied at $E_p = 200.4$ MeV. [The (p, π^-) reaction to the analog states in ${}^8\text{B}$ is discussed: see reaction 4 in ${}^8\text{B}$.] The (p, π^+) cross sections are an order of magnitude greater than the (p, π^-) cross sections and show a much stronger angular dependence (1987CA06). Angular distributions of cross section and A_y have also been measured at $E_p = 250, 354$ and 489 MeV to the first three states of ${}^8\text{Li}$. Those to ${}^8\text{Li}^*(0, 2.26)$ have differential cross sections which exhibit a maximum near the invariant mass of the $\Delta(1232)$ and A_y which are similar to each other and to those of the $\bar{p}p \rightarrow d\pi^+$ reaction. ${}^8\text{Li}^*(6.53)$ is populated (1987HU12, 1988HU11).

$$9. {}^7\text{Li}(d, p){}^8\text{Li} \quad Q_m = -0.19228$$

Measurements in the vicinity of the $E_{\text{cm}} = 0.61$ MeV ${}^9\text{Be}^*(17.3)$ resonance found $\sigma[{}^7\text{Li}(d, p)] = 143.6 \pm 8.9$ mb (1996ST18), $\sigma[{}^7\text{Li}(d, {}^8\text{Li})p: {}^8\text{Li} \xrightarrow{\beta^-} {}^8\text{Be} \rightarrow 2\alpha] = 151 \pm 20$ mb (1996ST18), and $\sigma[{}^7\text{Li}(d, p)] = 155 \pm 8$ mb (1998WE05). An extensive review in (1998AD12) presented the results found in Table 8.6. However, (1998WE05) suggest that systematic errors may persist in the (1998AD12) evaluation.

Angular distributions of the p_0 and p_1 groups [$l_n = 1$] at $E_d = 12$ MeV have been analyzed using DWBA: $S_{\text{expt.}} = 0.87$ and 0.48 respectively for ${}^8\text{Li}^*(0, 0.98)$. Angular distributions have also been measured at several energies in the range of $E_d = 0.49$ to 3.44 MeV (p_0) and 0.95 to 2.94 MeV (p_1). The lifetime of ${}^8\text{Li}^*(0.98)$, determined from ${}^2\text{H}({}^7\text{Li}, p){}^8\text{Li}$ via the Doppler-shift attenuation method, is 10.1 ± 4.5 fsec: see (1979AJ01). See also references cited in (1988AJ01).

Table 8.6: The ${}^7\text{Li}(d, p){}^8\text{Li}$ peak cross section at the 0.6 MeV resonance ^a

σ (mb)	Ref.
138 ± 20	(1975MC02)
144 ± 15 ^{a,b}	(1996ST18)
146 ± 13	(1982EL03)
146 ± 19 ^{a,b}	(1982FI03)
148 ± 12	(1982FI03)
147 ± 11	Recommended value ^a

^a (1998AD12).

^b Re-evaluated.

The ${}^7\text{Li}(d, p){}^8\text{Li} \xrightarrow{\beta^-} {}^8\text{Be} \rightarrow 2\alpha$ reaction was studied in the range of 0.4–1.8 MeV to investigate a mechanism where the ${}^8\text{Li}$ reaction products are backscattered out of the target which introduces up to a 20% systematic error in measurements of the reaction yield (1998ST20). They determined that ${}^8\text{Li}$ reaction products are increasingly backscattered out of the target with: (i) increasing the Z of the backing material, (ii) decreasing the thickness of the deposited Li/Be target, and (iii) decreasing the incident projectile energy.

10. (a) ${}^7\text{Li}({}^6\text{Li}, {}^5\text{Li}){}^8\text{Li}$ $Q_m = -3.632$
 (b) ${}^7\text{Li}({}^7\text{Li}, {}^6\text{Li}){}^8\text{Li}$ $Q_m = -5.21801$

See (1984KO25).

11. ${}^8\text{He}(\beta^-){}^8\text{Li}$ $Q_m = 10.651$

See reaction 1 in ${}^8\text{He}$.

The triton spectrum observed in ${}^8\text{He}$ β -decay was analyzed in a single-level R -matrix model that indicated the triton emission branching ratio is $(8.0 \pm 0.5) \times 10^{-3}$ (1991BO31, 1993BO24). The R -matrix fit indicates a level at ${}^8\text{Li}^*(9.3 \pm 1.0 \text{ MeV}, J^\pi = 1^+)$ with a reduced width $\gamma_{\text{reduced}} = 0.978 \pm 0.012 \text{ MeV}^{1/2}$ that decays primarily by triton emission; this corresponds to $B(\text{GT}) = 5.18$ and $\log ft = 2.87$ [$B(\text{GT}) = 8.29$, using the definition given in the introduction]. A subsequent analysis of the (1993BO24) data used a multi-level, multi-channel R -matrix model that included low-lying 1^+ states in ${}^8\text{Li}$ that participate in ${}^8\text{He}$ β -decay (see Table 8.7) and suggests $E_x =$

Table 8.7: R -matrix parameters for ${}^8\text{He}$ decay to 1^+ levels in ${}^8\text{Li}$ ^a

Decay to ${}^8\text{Li}^*$ (MeV)	$\log ft$
0.98	4.20
3.08	4.52
5.15	4.53
9.67	2.91

^a From (1988BA67, 1996BA66).

9.67 MeV, $B(\text{GT}) = 4.75$ and $\log ft = 2.91$ (1996BA66) [$B(\text{GT}) = 7.56$, using the definition given in the introduction]. Branching ratios for ${}^8\text{Li}$ states are given in (1988BA67). See also Fig. 2.

$$12. {}^9\text{Be}(\gamma, \text{p}){}^8\text{Li} \quad Q_{\text{m}} = -16.8882$$

The ${}^9\text{Be}(\gamma, \text{p}_0)$ reaction was measured in the range from $E_{\gamma} = 22\text{--}25.5$ MeV and was evaluated in a simple cluster model (1999SH05). The analysis indicated that mainly E1 and E2 multipolarities contribute to the breakup cross section. The photodisintegration of ${}^9\text{Be}$ was measured at $E_{\gamma} = 180\text{--}240$ MeV, and the $(\gamma + \text{nucleon})$ reaction dynamics were studied by measuring ${}^9\text{Be}(\gamma, \text{p})$ at $E_{\gamma} = 187\text{--}427$ MeV in the $\Delta(1232)$ resonance region (1988TE04).

$$13. {}^9\text{Be}(\gamma, \text{p}\pi^0){}^8\text{Li} \quad Q_{\text{m}} = -151.8648$$

The total cross section for ${}^9\text{Be}(\gamma, \text{p}\pi^0)$ was measured with bremsstrahlung γ -rays in the range of $E_{\gamma} = 200\text{--}850$ MeV (1987AN14).

$$14. \text{(a) } {}^9\text{Be}(\text{e}, \text{ep}){}^8\text{Li} \quad Q_{\text{m}} = -16.8882$$

$$\text{(b) } {}^9\text{Be}(\text{p}, 2\text{p}){}^8\text{Li} \quad Q_{\text{m}} = -16.8882$$

For reaction (a) see (1984AJ01) and (1985KI1A). The summed proton spectrum (reaction (b)) at $E_{\text{p}} = 156$ MeV shows peaks corresponding to ${}^8\text{Li}_{\text{g.s.}}$ and ${}^8\text{Li}^*(0.98 + 2.26)$ [unresolved]. In addition, s-states [$J^{\pi} = 1^-, 2^-$] are suggested at $E_{\text{x}} = 9$ and 16 MeV, with $\Gamma_{\text{cm}} \approx 6$ and 8 MeV; the latter may actually be due to continuum protons: see (1974AJ01). At $E_{\text{p}} = 1$ GeV the separation

Table 8.8: Spectroscopic factors of the ${}^9\text{Be}(t, \alpha)$ reaction ^a

E_x (MeV)	J^π	l	$C^2S_{\text{rel.}}$	$C^2S_{\text{abs.}}$
0	2^+	1	0.843	1.059
0.981	1^+	1	0.506	0.636
2.255	3^+	1	0.552	0.693
2.4–2.8		1	0.099	

^a See (1988LI27).

energy between 5 and 8 MeV broad $1p_{3/2}$ and $1s_{1/2}$ groups is reported to be 10.7 ± 0.5 MeV (1985BE30, 1985DO16). See also (1987GAZM).

For reaction (b) angular distributions were measured at 70 MeV. The data were evaluated using the distorted wave T -matrix approximation (DWTA) where it was determined that the $1s$ and $1p$ shells dominate in the nucleus-nucleon single-particle-knockout reaction mechanism (2000SH01).

$$15. \quad {}^9\text{Be}(d, {}^3\text{He}){}^8\text{Li} \quad Q_m = -11.3947$$

Angular distributions have been reported for the ${}^3\text{He}$ ions to ${}^8\text{Li}^*(0, 0.98, 2.26, 6.53)$ at $E_d = 28$ MeV [C^2S (abs.) = 1.63, 0.61, 0.48, 0.092] and 52 MeV. The distributions to ${}^8\text{Li}^*(6.53)[\Gamma < 100 \text{ keV}]$ are featureless: see (1979AJ01).

$$16. \quad {}^9\text{Be}(t, \alpha){}^8\text{Li} \quad Q_m = 2.9257$$

At $E_t = 12.98$ MeV, angular distributions of the α -particles to ${}^8\text{Li}^*(0, 0.98, 2.26, 6.53 \pm 0.02)$ [$\Gamma_{\text{cm}} < 40 \text{ keV}$] have been measured: see (1974AJ01). Angular dependent differential cross sections for ${}^9\text{Be}(t, \alpha)$ at $E_t = 15$ MeV were compared with DWBA and coupled-channel Born approximation calculations to extract the relative and absolute C^2S factors for ${}^8\text{Li}+p$: see Table 8.8 (1988LI27). At $E_t = 17$ MeV, $\sigma(\theta)$ and A_y measurements, analyzed by CCBA, lead to $J^\pi = 4^+$ for ${}^8\text{Li}^*(6.53)$: see (1984AJ01). For ${}^8\text{Li}^*(0.98)$, $\tau_m = 14 \pm 5$ fsec, $E_x = 980.80 \pm 0.10 \text{ keV}$: see (1974AJ01).

$$17. \quad {}^9\text{Be}({}^7\text{Li}, {}^8\text{Be}){}^8\text{Li} \quad Q_m = 0.3669$$

At $E({}^7\text{Li}) = 52$ MeV, numerous ${}^{12}\text{B}$ states are observed with E_x between 10–18 MeV; ${}^8\text{Li}^*(0, 0.98, 2.25)$ participate (2003SO22). See also (1984KO25).

18. ${}^9\text{Be}({}^{11}\text{B}, {}^{12}\text{C}){}^8\text{Li}$ $Q_m = -0.931$

See (1986BE1Q).

19. ${}^{10}\text{Be}(p, {}^3\text{He}){}^8\text{Li}$ $Q_m = -15.9824$

At $E_p = 45$ MeV, ${}^3\text{He}$ ions are observed to a state at $E_x = 10.8222 \pm 0.0055$ MeV ($\Gamma_{\text{cm}} < 12$ keV): the angular distributions for the transition to this state, and to its analog (${}^8\text{Be}^*(27.49)$), measured in the analog reaction [${}^{10}\text{Be}(p, t){}^8\text{Be}$] are very similar. They are both consistent with $L = 0$ using a DWBA (LZR) analysis: see (1979AJ01).

20. ${}^{11}\text{B}(\pi^+, 3p){}^8\text{Li}$ $Q_m = 105.424$

The ${}^{11}\text{B}(\pi^+, 3p)$ reaction was studied at 50, 100, 140 and 180 MeV using a large solid angle detector to measure the missing energy spectra (1992RA11).

21. ${}^{11}\text{B}(n, \alpha){}^8\text{Li}$ $Q_m = -6.633$

The excitation function for ${}^{11}\text{B}(n, \alpha){}^8\text{Li}$ was measured at $E_n = 7.6$ – 12.6 MeV to determine, via detailed balance, the astrophysical rate for the ${}^8\text{Li}(\alpha, n)$ reaction in the vicinity of the ${}^{12}\text{B}^*(10.58)$ level (1990PA22).

Angular distributions of the α_0 and α_1 groups have been measured at $E_n = 14.1$ and 14.4 MeV: see (1974AJ01, 1984AJ01, 1988AJ01). Energy dependent ${}^8\text{Li}(\alpha, \alpha)$ elastic scattering phase shifts, which are important for calculating the ${}^{11}\text{B}(n, \alpha){}^8\text{Li}$ reaction rate, were calculated in the range of $E_{\text{cm}} < 4$ MeV (1996DE02).

22. ${}^{11}\text{B}({}^7\text{Li}, {}^{10}\text{B}){}^8\text{Li}$ $Q_m = -9.422$

At $E({}^7\text{Li}) = 34$ MeV angular distributions have been studied involving ${}^8\text{Li}^*(0, 0.98)$ and ${}^{10}\text{B}_{\text{g.s.}}$ (1987CO16).

23. (a) ${}^{12}\text{C}(\pi^-, 2d){}^8\text{Li}$ $Q_m = 92.35190$
 (b) ${}^{12}\text{C}(\pi^-, \alpha){}^8\text{Li}$ $Q_m = 116.19842$

Differential and total cross sections for $^{12}\text{C}(\pi^-, 2d)$ were measured at 165 MeV (1990PA03). See (1987GA11) for a theoretical treatment of the reaction mechanism.

24. $^{12}\text{C}(\pi^+, 4p)^8\text{Li}$ $Q_m = 89.46746$

The π^+ absorption reaction mechanism was studied by measuring protons produced in $^{12}\text{C} + \pi^+$ reactions at 30–135 MeV (2000GI07).

25. (a) $^{12}\text{C}(p, X)$
 (b) $^{13}\text{C}(p, X)$

Nuclear effects in the spallation reaction mechanism (i.e., even-odd and odd-odd nucleon pairing) were studied via $^{12,13}\text{C}(p, ^{6,7,8,9}\text{Li})$ reactions at 1 GeV (1992BE65).

26. $^{13}\text{C}(d, ^7\text{Be})^8\text{Li}$ $Q_m = -20.45614$

See (1984NE1A).

27. $^{13}\text{C}(^7\text{Li}, ^8\text{Li})^{12}\text{C}$ $Q_m = -2.91402$

Angular distributions were measured at $E(^7\text{Li}) = 9 \text{ MeV}/A$, and a DWBA analysis was used to determine the ratio of $p_{1/2}/p_{3/2}$ contributions, and the Asymptotic Normalization Constant (ANC) for $^7\text{Li} + n \rightarrow ^8\text{Li}$ (2003TR04). Then, using charge symmetry, the $^7\text{Be} + p \rightarrow ^8\text{B}$ ANC was deduced, which corresponds to $S_{17}(0) = 17.6 \pm 1.7 \text{ eV} \cdot \text{b}$.

28. (a) $\text{C}(^8\text{Li}, ^8\text{Li}')\text{C}$
 (b) $\text{Ni}(^8\text{Li}, ^8\text{Li}')\text{Ni}$
 (c) $\text{Au}(^8\text{Li}, ^8\text{Li}')\text{Au}$
 (d) $\text{Pb}(^8\text{Li}, ^8\text{Li}')\text{Pb}$

Elastic and inelastic scattering of ^8Li on $^{\text{nat}}\text{C}$ were measured at $E(^8\text{Li}) = 13.8\text{--}14 \text{ MeV}$ (1991SM02). Optical model parameters were deduced for the 2^+ ground state and the first 1^+ excited state at $\approx 1 \text{ MeV}$ and $B(E2) \uparrow = 30 \pm 15 \text{ e}^2 \cdot \text{fm}^4$ was deduced. In addition $^{\text{nat}}\text{Au}(^8\text{Li}, ^8\text{Li})$ was measured for comparison with Rutherford scattering.

The ${}^8\text{Li}$ first 1^+ excited state at 1.0 ± 0.1 MeV was observed in Coulomb excitation on ${}^{\text{nat}}\text{Ni}$ at $E({}^8\text{Li}) = 14.6$ MeV (1991BR14) and $B(E2) \uparrow = 55 \pm 15 e^2 \cdot \text{fm}^4$ was determined for this excitation. See (2003BE38) for elastic and inelastic scattering on Pb at $E({}^8\text{Li}) = 20\text{--}36$ MeV.

29. ${}^{\text{nat}}\text{C}(\mu, {}^8\text{Li})\text{X}$

A measurement to determine muon induced background rates in large-volume scintillation solar neutrino detectors found $\sigma = 2.93 \pm 0.80 \mu\text{b}$ and $4.02 \pm 1.46 \mu\text{b}$ for ${}^{\text{nat}}\text{C}(\mu, {}^8\text{Li})$ at $E_\mu = 100$ and 190 GeV, respectively (2000HA33).

30. (a) $\text{C}({}^8\text{Li}, \text{X})$

(b) $\text{Si}({}^8\text{Li}, \text{X})$

(c) $\text{Pb}({}^8\text{Li}, \text{X})$

Total cross sections and charge-changing cross sections for the lithium isotopes on C and Pb were measured at 80 MeV/A (1992BL10); it was deduced that post-abrasion evaporation plays a minor role in these reactions. For reaction (b) the energy-dependent total reaction cross sections at 20–60 MeV/A were measured (1996WA27) and compared with microscopic and shell model predictions. A review of nuclear radii deduced from interaction cross sections is given in (2001OZ04).

31. (a) ${}^{\text{nat}}\text{Ag}({}^{14}\text{N}, {}^8\text{Li})$

(b) ${}^{\text{nat}}\text{Ag}({}^{14}\text{N}, \text{n} + {}^7\text{Li})$

(c) ${}^{165}\text{Ho}({}^{14}\text{N}, \text{X})$

Population of the ${}^8\text{Li}$ ground state and 2.255 MeV neutron unbound state was reported in reactions (a) and (b) at 35 MeV/A. The reaction nuclear temperature was estimated (1987BL13). In a similar study of 35 MeV/A ${}^{14}\text{N}$ on ${}^{165}\text{Ho}$, (1987KI05) deduced that the ${}^8\text{Li}^*(2.255)$ state has $\Gamma = 33$ keV from the ${}^7\text{Li} + \text{n}$ relative energy spectrum.

⁸Be
(Figs. 3 and 5)

GENERAL: References to articles on general properties of ⁸Be published since the previous review (1988AJ01) are grouped into categories and listed, along with brief descriptions of each item, in the General Tables for ⁸Be located on our website at (www.tunl.duke.edu/nucldata/General_Tables/8be.shtml).

1. ⁸Be → ⁴He⁴He $Q_m = 0.0918$

Γ_{cm} for ⁸Be_{g.s.} = 5.57 ± 0.25 eV: see reaction 4. See also reaction 29 and references cited in (1974AJ01, 1988AJ01).

2. ⁴He(α, γ)⁸Be $Q_m = -0.0918$

The yield of γ_1 has been measured for $E_\alpha = 32$ to 36 MeV. The yield of γ_0 for $E_\alpha = 33$ to 38 MeV is twenty times lower than for γ_1 , consistent with E2 decay: see (1979AJ01). Angular distributions were measured in the ⁴He(α, γ) reaction in the region around the 16 MeV isospin mixed doublet as a study of CVC in $A = 8$ nuclei and second class currents (1994DE30, 1995DE18). No evidence for CVC violation was observed. Mixing ratios were reported as $\epsilon = [\Gamma_{\text{M1}}^{T=0}/\Gamma_{\text{M1}}^{T=1}]^{1/2} = +0.04 \pm 0.02$, $\delta_0 = [\Gamma_{\text{E2}}^{T=0}/\Gamma_{\text{M1}}^{T=1}]^{1/2} = +0.21 \pm 0.04$, $\delta_1 = [\Gamma_{\text{E2}}^{T=1}/\Gamma_{\text{M1}}^{T=1}]^{1/2} = +0.01 \pm 0.03$ and $\Gamma_{\text{M1}}^{T=1} = 2.80 \pm 0.18$ eV (1995DE18), and they note that earlier values (1978BO30) were troubled by a transformation error. The E_x of ⁸Be*(3.0) is determined in this reaction to be 3.18 ± 0.05 MeV (1979AJ01) [see also Table 8.11].

The E2 bremsstrahlung cross section to ⁸Be_{g.s.} has been calculated as a function of E_x over the 3 MeV state: the total Γ_γ for this transition is 8.3 meV, corresponding to 75 W.u. (1986LA05). A calculation of the Γ_γ from the decay of the 4⁺ 11.4 MeV state to the 2⁺ state yields 0.46 eV (19 W.u.). The maximum cross section for the intrastate γ -ray transition within the 2⁺ resonance is calculated to be ≤ 2.5 nb at $E_x \approx 3.3$ MeV (1986LA19). See also (2001CS04) for discussion of the impact of variation in the NN force on the nucleosynthesis rates of ⁸Be and ¹²C.

3. (a) ⁴He(α, n)⁷Be $Q_m = -18.99152$ $E_b = -0.09184$
 (b) ⁴He(α, p)⁷Li $Q_m = -17.34695$
 (c) ⁴He(α, d)⁶Li $Q_m = -22.372683$

The cross sections for formation of ⁷Li*(0, 0.48) [$E_\alpha = 39$ to 49.5 MeV] and ⁷Be*(0, 0.43)

Table 8.9: Energy levels of ${}^8\text{Be}$

E_x (MeV \pm keV)	$J^\pi; T$	Γ_{cm} (keV)	Decay	Reactions
g.s.	$0^+; 0$	$5.57 \pm 0.25 \text{ eV}^i$	α	1, 2, 4, 5, 10, 11, 12, 13, 14, 19, 20, 21, 22, 23, 25, 28, 29, 30, 31, 33, 36, 39, 40, 41, 42, 43, 44, 45, 46, 47, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62
3.03 ± 10^i	$2^+; 0$	1513 ± 15^i	α	2, 4, 5, 10, 11, 12, 13, 14, 19, 20, 21, 22, 24, 27, 28, 29, 30, 31, 33, 36, 40, 41, 42, 43, 44, 50, 51, 53, 54, 61
11.35 ± 150^i	$4^+; 0$	$\approx 3500^b$	α	4, 12, 13, 19, 21, 29, 30, 31, 41, 51, 53, 54
16.626 ± 3	$2^+; 0 + 1$	108.1 ± 0.5	γ, α	2, 4, 10, 11, 13, 14, 19, 20, 21, 27, 29, 30, 31, 40, 41, 44, 51, 53
16.922 ± 3	$2^+; 0 + 1$	74.0 ± 0.4	γ, α	2, 4, 10, 11, 13, 14, 19, 20, 21, 29, 30, 31, 40, 41, 44, 51, 53
17.640 ± 1.0^f	$1^+; 1$	10.7 ± 0.5	γ, p	5, 11, 14, 16, 19, 20, 29, 30, 31, 41, 53
18.150 ± 4	$1^+; 0$	138 ± 6	γ, p	11, 14, 16, 19, 20, 29, 30, 41, 44
18.91	$2^-; 0(+1)$	122^e	γ, n, p	11, 14, 15, 16, 19, 23
19.07 ± 30	$3^+; (1)$	270 ± 20	γ, p	11, 14, 16, 19, 29, 30
19.235 ± 10^i	$3^+; (0)$	227 ± 16^i	n, p	15, 16, 19, 29, 30, 31, 41, 64
19.40	1^-	$\approx 645^i$	n, p	11, 15, 16, 29
19.86 ± 50^g	$4^+; 0$	700 ± 100	p, α	4, 11, 18, 21, 22, 30, 31, 41
20.1^h	$2^+; 0$	880 ± 20^i	n, p, α	4, 15, 16, 18, 19, 22, 41
20.2	$0^+; 0$	720 ± 20^i	α	4, 19, 41
20.9	4^-	1600 ± 200	p	16
21.5	$3(+)$	1000	γ, n, p	14, 15, 41
22.0^c	$1^-; 1$	≈ 4000	γ, p	14

Table 8.9: Energy levels of ${}^8\text{Be}$ (continued)

E_x (MeV \pm keV)	$J^\pi; T$	Γ_{cm} (keV)	Decay	Reactions
22.05 \pm 100		270 \pm 70		29, 31
22.2	2 ⁺ ; 0	\approx 800	n, p, d, α	4, 9, 13, 15, 16, 18, 41
22.63 \pm 100		100 \pm 50		31
22.98 \pm 100		230 \pm 50		31
24.0 ^c	(1, 2) ⁻ ; 1	\approx 7000	γ , p, α	14, 18, 41
25.2	2 ⁺ ; 0		p, d, α	4, 9, 18, 41
25.5	4 ⁺ ; 0	broad	d, α	9
27.4941 \pm 1.8 ^d	0 ⁺ ; 2	5.5 \pm 2.0	γ , n, p, d, t, ${}^3\text{He}$, α	5, 7, 9, 35
(28.6)		broad	γ , p	14
(32) ⁱ		1 MeV ⁱ		41
(\approx 41) ⁱ				9
(\approx 43) ⁱ				9
(\approx 50) ⁱ				9

^a See also Table 8.10 and reaction 4.

^b See, however, reaction 29.

^c Giant resonance: see reaction 14.

^d For the parameters of this state please see Table 8.5 in (1984AJ01).

^e From R -matrix fit: see reaction 23.

^f $\Gamma_{\gamma_0}/\Gamma_{(\gamma_0+\gamma_1)} = 0.72 \pm 0.07$ (1995ZA03).

^g $\Gamma_\alpha/\Gamma_p = 2.3 \pm 0.5$ (1992PU06).

^h $\Gamma_\alpha/\Gamma_p = 4.5 \pm 0.6$ (1992PU06).

ⁱ From data reviewed in this evaluation.

^j Intruder state at ≈ 9 MeV, deduced from R -matrix analysis of β -delayed 2α breakup spectra (2000BA89). The placement of this level is dependent on the channel radius used in the R -matrix fit (1986WA01, 2000BA89). However, (1986WA01) finds no need to introduce intruder states below $E_x = 26$ MeV.

[39.4 to 47.4 MeV] both show structures at $E_\alpha \approx 40.0$ and ≈ 44.5 MeV: they are due predominantly to the 2⁺ states ${}^8\text{Be}^*(20.1, 22.2)$: see (1979AJ01). The excitation functions for p₀, p₂, d₀, d₁ for $E_\alpha = 54.96$ to 55.54 MeV have been measured in order to study the decay of the first $T = 2$ state in ${}^8\text{Be}$: see Table 8.5 in (1984AJ01). Cross sections for p₀₊₁ are also reported at $E_\alpha = 37.5$ to 140.0 MeV: see (1979AJ01, 1984AJ01). The cross sections for reaction (c) has been measured at three energies in the range $E_\alpha = 46.7$ to 49.5 MeV: see (1979AJ01) and below.

The production of ${}^6\text{Li}$, ${}^7\text{Li}$ and ${}^7\text{Be}$ [and ${}^6\text{He}$] has been studied at $E_\alpha = 61.5$ to 158.2 MeV by (1982GL01), at 198.4 MeV by (1985WO11), and at $E_\alpha = 160, 280$ and 320 MeV by (2001ME13). The production of ${}^7\text{Li}$ (via reactions (a) and (b)) and of ${}^6\text{Li}$ is discussed. At energies beyond $E_\alpha \approx$

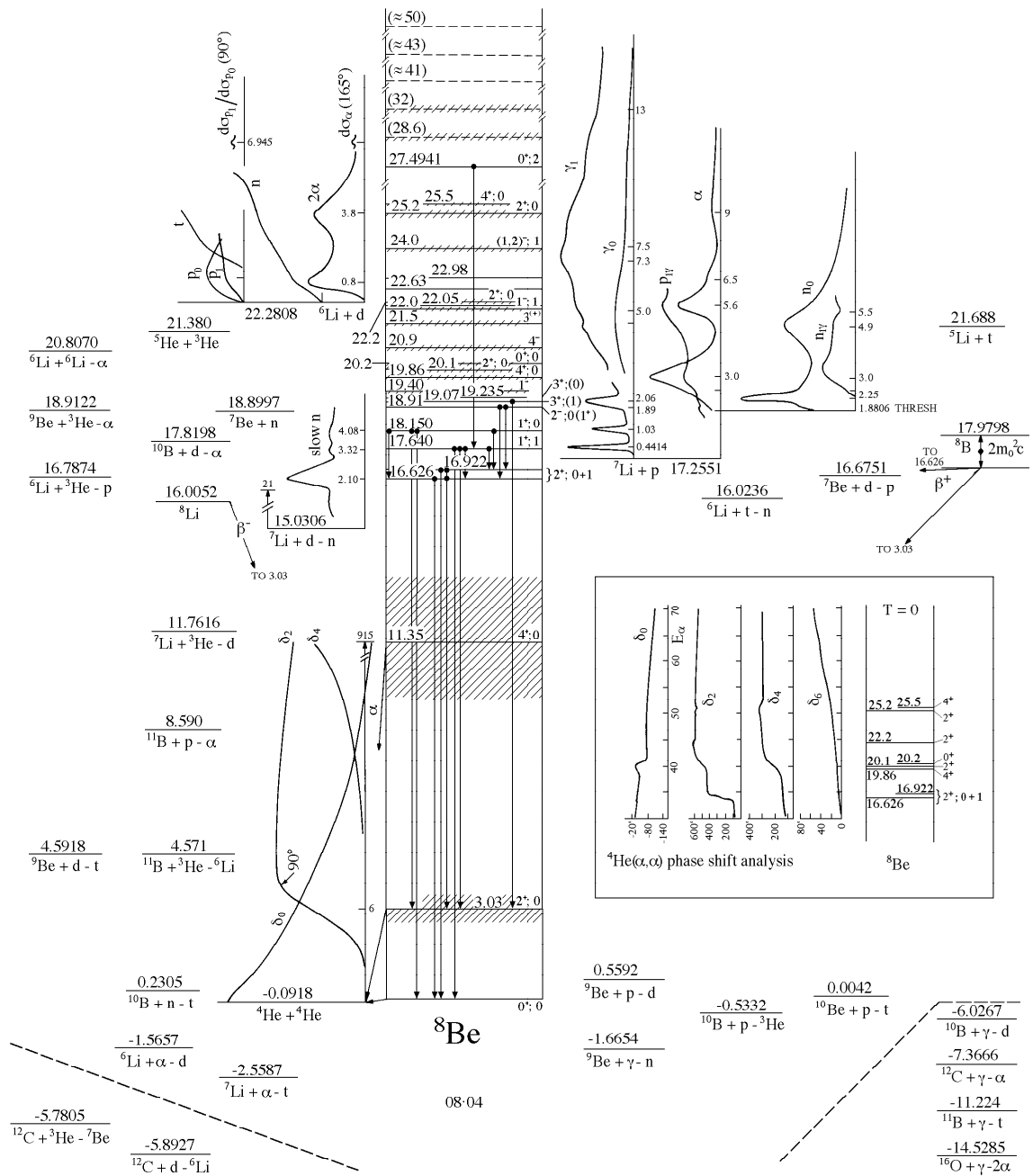


Figure 3: Energy levels of ${}^8\text{Be}$. For notation see Fig. 2.

Table 8.10: Electromagnetic transition strengths in ${}^8\text{Be}$

$E_i \rightarrow E_f$ (MeV)	$J_i^\pi; T_i \rightarrow J_f^\pi; T_f$	Γ_γ (eV)	Mult.	Γ_γ/Γ_w
16.626 \rightarrow 0 ^a	$2^+; 0+1 \rightarrow 0^+; 0$	$(7.0 \pm 2.5) \times 10^{-2}$	E2	$(7.1 \pm 2.5) \times 10^{-2}$
16.92 \rightarrow 0 ^a	$2^+; 0+1 \rightarrow 0^+; 0$	$(8.4 \pm 1.4) \times 10^{-2}$	E2	$(7.8 \pm 1.3) \times 10^{-2}$
(16.626 + 16.92) \rightarrow 3.03 ^b	$2^+; 1 \rightarrow 2^+; 0$	2.80 ± 0.18	M1	$(5.3 \pm 0.3) \times 10^{-2}$
17.64 \rightarrow 0 ^c	$1^+; 1 \rightarrow 0^+; 0$	15.0 ± 1.8	M1	0.13 ± 0.02
\rightarrow 3.03 ^{c,d}	$\rightarrow 2^+; 0$	6.7 ± 1.3	M1	0.10 ± 0.02
		0.12 ± 0.05	E2	0.23 ± 0.10
\rightarrow 16.626 ^{e,f}	$\rightarrow 2^+; 0+1$	$(3.2 \pm 0.3) \times 10^{-2}$	M1	1.5 ± 0.2
\rightarrow 16.92 ^e	$\rightarrow 2^+; 0+1$	$(1.3 \pm 0.3) \times 10^{-3}$	M1	0.17 ± 0.04
18.15 \rightarrow 0 ^g	$1^+; 0 \rightarrow 0^+; 0$	1.9 ± 0.4	M1	$(1.5 \pm 0.3) \times 10^{-2}$
\rightarrow 3.03 ^g	$\rightarrow 2^+; 0$	4.3 ± 1.2	M1	$(5.9 \pm 1.7) \times 10^{-2}$
\rightarrow 16.626 ^e	$\rightarrow 2^+; 0+1$	$(7.7 \pm 1.9) \times 10^{-2}$	M1	1.0 ± 0.3
\rightarrow 16.92 ^e	$\rightarrow 2^+; 0+1$	$(6.2 \pm 0.7) \times 10^{-2}$	M1	1.6 ± 0.2
18.91 \rightarrow 16.626 ^h	$2^-; 0 \rightarrow 2^+; 0+1$	0.17 ± 0.07	E1	$(5.3 \pm 2.0) \times 10^{-2}$
\rightarrow 16.92 ^h	$\rightarrow 2^+; 0+1$	$(9.9 \pm 4.3) \times 10^{-2}$	E1	$(4.6 \pm 2.0) \times 10^{-2}$
19.07 \rightarrow 3.03 ⁱ	$3^+; (1) \rightarrow 2^+; 0$	10.5	M1	0.122
27.49 \rightarrow 17.64 ^j	$0^+; 2 \rightarrow 1^+; 1$	21.9 ± 3.9	M1	1.10 ± 0.20

^a From (1995DE18).

^b From (1995DE18). The $T = 1$ centroid of the isospin-mixed 16.626 MeV and 16.92 MeV levels is at 16.80 MeV. For mixing ratios, see reaction 2 or (1995DE18).

^c $\sigma_{\gamma_0+\gamma_1} = 5.9 \pm 0.5$ mb and $\sigma_{\gamma_0}/\sigma_{\gamma_0+\gamma_1} = 0.69 \pm 0.05$ from (1995ZA03). Using $\Gamma_{\text{cm}} = 10.7 \pm 0.5$ keV from Table 8.10 gives $\Gamma_{\gamma_0+\gamma_1} = 21.8 \pm 2.1$ eV.

^d From (1961ME10), the mixing ratio is 0.133 ± 0.027 .

^e From (1969SW01).

^f From (1969SW02), the mixing ratio is -0.014 ± 0.013 .

^g From (1995ZA03).

^h From the cross sections and $\Gamma_{\text{cm}} = 131 \pm 44$ keV of (1969SW01).

ⁱ From (1976FI05).

^j From (1979FR04).

Table 8.11: Some ${}^8\text{Be}$ states with $3.0 < E_x < 23.0$ MeV ^a

E_x (MeV \pm keV)	Γ_{cm} (keV)	Reaction
3.18 \pm 50		${}^4\text{He}(\alpha, \gamma)$
2.83 \pm 200	1750 \pm 300	${}^6\text{Li}({}^3\text{He}, \text{p}), {}^{10}\text{B}(\text{d}, \alpha)$
	1200 \pm 300	${}^6\text{Li}(\alpha, \text{d})$
3.1 \pm 100	1750 \pm 100	${}^7\text{Li}(\text{d}, \text{n})$
3.10 \pm 90	1740 \pm 80	${}^7\text{Li}(\text{d}, \text{n})$
2.90 \pm 60	1530 \pm 40	${}^7\text{Be}(\text{d}, \text{p})$
	1500 \pm 100	${}^9\text{Be}(\text{p}, \text{d})$
3.038 \pm 25	1500 \pm 20	${}^9\text{Be}(\text{p}, \text{d})$
3.03 \pm 10	1430 \pm 60	${}^9\text{Be}(\text{d}, \text{t})$
2.90 \pm 40	1350 \pm 150	${}^9\text{Be}({}^3\text{He}, \alpha)$
	1480 \pm 70	${}^{11}\text{B}(\text{p}, \alpha)$
3.03 \pm 0.01	1513 \pm 15	“mean” value ^d
11.5 \pm 300	4000 \pm 400	${}^4\text{He}(\alpha, \alpha)$
11.3 \pm 400		${}^6\text{Li}(\alpha, \text{d})$
11.3 \pm 200	2800 \pm 300	${}^7\text{Li}(\text{d}, \text{n})$
	5200 \pm 100	${}^9\text{Be}(\text{p}, \text{d})$
11.35 \pm 150	\approx 3500 keV	“mean” value
16.627 \pm 5	113 \pm 3	${}^7\text{Li}({}^3\text{He}, \text{d})$
	90 \pm 5	${}^{10}\text{B}(\text{d}, \alpha)$
16.623 \pm 3	107.7 \pm 0.5	${}^4\text{He}(\alpha, \alpha)$ ^b
16.630 \pm 3	108.5 \pm 0.5	${}^4\text{He}(\alpha, \alpha)$ ^c
16.626 \pm 3	108.1 \pm 0.5	“mean” value
16.901 \pm 5	77 \pm 3	${}^7\text{Li}({}^3\text{He}, \text{d})$
	70 \pm 5	${}^{10}\text{B}(\text{d}, \alpha)$
16.925 \pm 3	74.4 \pm 0.4	${}^4\text{He}(\alpha, \alpha)$ ^b
16.918 \pm 3	73.6 \pm 0.4	${}^4\text{He}(\alpha, \alpha)$ ^c
16.922 \pm 3	74.0 \pm 0.4	“mean” value
17.640 \pm 1.0	10.7 \pm 0.5	${}^7\text{Li}(\text{p}, \gamma)$
18.155 \pm 5	147	${}^7\text{Li}(\text{p}, \text{p}'\gamma)$
18.150 \pm 5	138 \pm 6	${}^{10}\text{B}(\text{d}, \alpha)$
18.144 \pm 5		${}^9\text{Be}(\text{d}, \text{t})$
18.150 \pm 4	138 \pm 6	“mean” value

Table 8.11: Energy levels of ^8Be (continued)

E_x (MeV \pm keV)	Γ_{cm} (keV)	Reaction
19.06 \pm 20	270 \pm 20	$^7\text{Li}(p, \gamma)$
19.071 \pm 10	270 \pm 30	$^9\text{Be}(d, t)$
19.07 \pm 30	270 \pm 20	“mean” value
19.21	208 \pm 30	$^9\text{Be}(p, d)$
19.22 \pm 30	265 \pm 30	$^9\text{Be}(^3\text{He}, \alpha)$
19.234 \pm 12	210 \pm 35	$^{\text{nat}}\text{Ag}(^{14}\text{N}, ^8\text{Be})$
19.26 \pm 30	220 \pm 30	$^9\text{Be}(d, t)$
19.235 \pm 10	227 \pm 10	“mean” value
19.86 \pm 50	700 \pm 100	$^9\text{Be}(d, t)$
22.05 \pm 100	270 \pm 70	$^9\text{Be}(^3\text{He}, \alpha)$
22.63 \pm 100	100 \pm 50	$^9\text{Be}(^3\text{He}, \alpha)$
22.98 \pm 100	230 \pm 50	$^9\text{Be}(^3\text{He}, \alpha)$

^a See Table 8.5 in (1979AJ01) for references. See also Tables 8.11 and 8.12 here.

^b From R -matrix analysis.

^c Complex eigenvalue theory.

^d These parameters represent the weighted average of values given in Table 8.4 of (1974AJ01): the value $E_x = 3.18 \pm 0.05$ MeV from $^4\text{He}(\alpha, \gamma)$, the values $E_x = 3.038 \pm 0.025$ MeV, $\Gamma = 1500 \pm 20$ keV from $^9\text{Be}(p, d)$ that were adopted in (1984AJ01); and $E_x = 3.03 \pm 0.01$ MeV, $\Gamma = 1430 \pm 60$ keV from $^9\text{Be}(d, t)$. The average of the most recent values from $^9\text{Be}(p, d)$ and $^9\text{Be}(d, t)$ yields $E_x = 3.03 \pm 0.01$ MeV and $\Gamma = 1490 \pm 20$ keV. See also (2002BH03).

250 MeV the $\alpha + \alpha$ reaction does not contribute to the natural abundance of lithium, reinforcing theories which produce ^6Li in cosmic-ray processes and the “missing” ^7Li in the Big Bang: thus the universe is open (1982GL01, 1985WO11). The measurements of (2001ME13) have observed smaller cross sections for ^6Li production than previous extrapolations, and reduce uncertainty in extrapolation to higher energies.

The inclusive cross section for production of ^3He has been measured at $E_\alpha = 218$ MeV (1984AL03). For a fragmentation study at 125 GeV see (1985BE1E). See also references cited in (1988AJ01).

4. $^4\text{He}(\alpha, \alpha)^4\text{He}$

$$E_b = -0.091839$$

The $^8\text{Be}_{\text{g.s.}}$ parameters are determined from α - α scattering across the resonance region. Evaluation of the parameters requires an analysis of the influence of various possible charge states in the low-energy $^4\text{He}(\alpha, \alpha)$ scattering process (1992WU09). A measurement that detected α - α coincidences at

$\theta(\alpha_1, \alpha_2) = (45^\circ, 45^\circ)$ and $(30^\circ, 60^\circ)$ was performed using a gas jet target, which permitted an energy resolution of 26 eV; the resulting parameters for ${}^8\text{Be}_{\text{g.s.}}$ are $E_b = -92.04 \pm 0.05$ keV and $\Gamma = 5.57 \pm 0.25$ eV (1992WA09). Previous values that had been obtained in a configuration that yielded 95 eV energy resolution were $E_b = -92.12 \pm 0.05$ keV and $\Gamma = 6.8 \pm 1.7$ eV (1968BE02). For $E_\alpha = 30$ to 70 MeV the $l = 0$ phase shift shows resonant behavior at $E_\alpha = 40.7$ MeV, corresponding to a 0^+ state at $E_x = 20.2$ MeV, $\Gamma < 1$ MeV, $\Gamma_\alpha/\Gamma < 0.5$. No evidence for other 0^+ states is seen above $E_\alpha = 43$ MeV.

The d-wave phase shift becomes appreciable for $E_\alpha > 2.5$ MeV and passes through a resonance at $E_\alpha = 6$ MeV ($E_x = 3.18$ MeV, $\Gamma = 1.5$ MeV, $J^\pi = 2^+$): see Table 8.11. Five 2^+ levels are observed from $l = 2$ phase shifts measured from $E_\alpha = 30$ to 70 MeV: ${}^8\text{Be}^*(16.6, 16.9)$ with $\Gamma_\alpha = \Gamma$ [see Table 8.11], and states with $E_x = 20.1, 22.2$ and 25.2 MeV. The latter has a small Γ_α . The $l = 2$ α - α phase shifts have been analyzed by (1986WA01) up to $E_\alpha = 34$ MeV: intruder states below $E_x = 26$ MeV need not be introduced. However, see discussion in reactions 24 and 27, and see (1988BA75, 1989BA31, 2000BA89) which introduces an intruder state at ≈ 9 MeV.

The $l = 4$ phase shift rises from $E_\alpha \approx 11$ MeV and indicates a broad 4^+ level at $E_x = 11.5 \pm 0.3$ MeV [$\Gamma = 4.0 \pm 0.4$ MeV]. A rapid rise of δ_4 at $E_\alpha = 40$ MeV corresponds to a 4^+ state at 19.9 MeV with $\Gamma_\alpha/\Gamma \approx 0.96$; $\Gamma < 1$ MeV and therefore $\Gamma_\alpha < 1$ MeV, which is $< 5\%$ of the Wigner limit. A broad 4^+ state is also observed near $E_\alpha = 51.3$ MeV ($E_x = 25.5$ MeV). Over the range $E_\alpha = 30$ to 70 MeV a gradual increase in δ_6 is observed. Some indications of a 6^+ state at $E_x \approx 28$ MeV and of an 8^+ state at ≈ 57 MeV have been reported; $\Gamma_{\text{cm}} \approx 20$ and ≈ 73 MeV, respectively. A resonance is not observed at the first $T = 2$ state, ${}^8\text{Be}^*(27.49)$. See (1979AJ01) for references.

The elastic scattering has also been studied at $E_\alpha = 56.3$ to 95.5 MeV (1987NE1C), 158.2, 650 and 850 MeV, and at 4.32 and 5.07 GeV/c [see (1979AJ01, 1984AJ01)], as well as at 198.4 MeV (1985WO11). For α - α correlations involving ${}^8\text{Be}^*(0, 3.0)$ see (1987CH33, 1987PO03). Resonances in α - α scattering and the role of α clustering in ${}^8\text{Be}$ have been investigated in theoretical studies of ${}^4\text{He}(\alpha, \alpha)$ (1987PR01, 1987VI05, 1987WA07, 1995LI07, 1996KU08, 1996VO15, 2000MO07, 2002BH03). For inclusive cross sections see (1984AJ01) and (1984AL03; 218 MeV). For studies at very high energies see reaction 3 and references cited in (1988AJ01).

5. ${}^6\text{Li}(d, \gamma){}^8\text{Be}$

$$Q_m = 22.2809$$

The yield of γ -rays to ${}^8\text{Be}^*(17.64)$ [1^+ ; $T = 1$] has been measured for $E_d = 6.85$ to 7.10 MeV. A resonance is observed at $E_d = 6965$ keV [$E_x = 27495.8 \pm 2.4$ keV, $\Gamma_{\text{cm}} = 5.5 \pm 2.0$ keV]; $\Gamma_\gamma = 23 \pm 4$ eV [1.14 ± 0.20 W.u.] for this M1 transition from the first 0^+ ; $T = 2$ state in ${}^8\text{Be}$, in good agreement with the intermediate coupling model: see Table 8.5 in (1984AJ01)[†]. Angular distributions of cross sections and polarization observables [$A_y^{(\theta)}$, $A_{yy}^{(\theta)}$, $T_{20}^{(\theta)}$] were measured at $E_d = 9$ MeV (1991WI19) and $E_d = 2$ and 9 MeV (1994WI08). In addition, (1994WI08) measured the excitation function from $E_d = 7$ –14 MeV; capture to the ${}^8\text{Be}$ ground state and 3.0 MeV state were observed. A transition matrix element analysis for ${}^6\text{Li}(\vec{d}, \gamma_0)$ at 9 MeV indicates a 13–21% E1 contribution in addition to the expected dominant E2 strength. This suggests $\approx 1.5\%$ D -state admixture in the ${}^8\text{Be}$ ground state. See also (1979AJ01).

[†] However, please note that there is an error in Table 8.5 from (1984AJ01). For the 27.5 MeV level, the parameter given as Γ_{γ_0} should be listed as $\Gamma_\gamma(27.5 \text{ to } 17.6)$.

6. ${}^6\text{Li}(d, n){}^7\text{Be}$

$$Q_m = 3.38117$$

$$E_b = 22.28085$$

Yield curves and cross sections have been measured for $E_d = 48$ keV to 17 MeV: see (1979AJ01, 1984AJ01). At $E_{cm} = 96.6$ keV $\sigma = 3.17$ mb $\pm 3\%$ (stat.) $\pm 7.5\%$ (syst.) (2001HO23). Polarization measurements are reported at $E_d = 0.27$ to 3.7 MeV. Angular distributions were measured for ${}^6\text{Li}(d, n)$ at $E_d = 0.7$ –2.3 and 5.6–12.1 MeV and excitation functions for neutrons corresponding to ${}^7\text{Be}^*(0, 0.43, 4.57, 7.21)$ are reported (1996BO27). Comparisons of the populations of ${}^7\text{Be}^*(0, 0.43)$ and of ${}^7\text{Li}^*(0, 0.48)$ have been made at energies up to $E_d = 7.2$ MeV. The (d, n)/(d, p) ratios are closely equal for analog states, as expected from charge symmetry: see (1979AJ01). However, the n_1/p_1 yield ratio decreases from 1.05 at $E_d = 160$ keV to 0.94 at 60 keV: it is suggested that this is due to charge polarization of the deuteron (1985CE12). See reaction 7 for additional comments about the (d, p)/(d, n) ratio. See also ${}^7\text{Be}$ in (2002TI10) and (1988AJ01).

7. ${}^6\text{Li}(d, p){}^7\text{Li}$

$$Q_m = 5.02573$$

$$E_b = 22.28085$$

Excitation functions have been measured for $E_d = 30$ keV to 5.4 MeV: see (1979AJ01, 1984AJ01). The thick target yield of 0.48 MeV γ -rays is reported from ≈ 50 to 170 keV (1985CE12). An anomaly is observed in the p_1/p_0 intensity ratio at $E_d = 6.945$ MeV [see (1979AJ01)], corresponding to the first 0^+ ; $T = 2$ state, $\Gamma = 10 \pm 3$ keV, $\Gamma_{p_0} \ll \Gamma_{p_1}$, $\Gamma_{p_0} < \Gamma_d$. The (d, p_0)/(d, n_0) ratio is measured in the astrophysical range from 65 keV $< E_d < 200$ keV (1993CZ01, 1997CZ04). In this region the subthreshold isospin mixed 2^+ level at ${}^8\text{Be}^*(22.2; \Gamma \approx 800$ keV) could influence the (d, p_0)/(d, n_0) ratio, which is important in inhomogeneous Big Bang nucleosynthesis models. The observed ratio is $\Gamma_{n_0}/\Gamma_{p_0} = 0.95 \pm 0.03$ which is consistent with the presently accepted isospin mixing parameter $\epsilon = 0.20$. The ${}^6\text{Li}(d, p)$ and ${}^6\text{Li}(d, \alpha)$ reactions were measured at $E_d = 20$ –135 keV (1993CE02), and a nearly constant $\sigma(d, p_0 + p_1)/\sigma(d, \alpha)$ ratio of 0.55 was observed indicating that there is no anomalous behavior in the low energy ${}^6\text{Li}(d, p)$ cross section. Polarization measurements have been reported at $E_d = 0.6$ to 10.9 MeV: see (1979AJ01). See also ${}^7\text{Li}$ in (2002TI10) and (1984KU15; theor.).

8. (a) ${}^6\text{Li}(d, d){}^6\text{Li}$

$$E_b = 22.280845$$

(b) ${}^6\text{Li}(d, t){}^5\text{Li}$

$$Q_m = 0.593$$

The yield of elastically scattered deuterons has been measured for $E_d = 2$ to 7.14 MeV. No resonances are observed: see (1974AJ01). See also (1983HA1D, 1985LI1C; theor.). The cross section for tritium production rises rapidly to 190 mb at 1 MeV, then more slowly to 290 mb near 4 MeV: see (1974AJ01). For VAP and TAP measurements at $E_d = 191$ and 395 MeV see (1986GA18).

9. (a) ${}^6\text{Li}(d, \alpha){}^4\text{He}$

$$Q_m = 22.372683$$

$$E_b = 22.280845$$

(b) ${}^6\text{Li}(d, \alpha p){}^3\text{H}$

$$Q_m = 2.558823$$

Cross sections and angular distributions (reaction (a)) have been measured at $E_d = 10$ keV to 31 MeV: see (1979AJ01, 1984AJ01), (1992EN01, 1992EN04) for $E_d = 10$ –1450 keV, and (1997CZ01) for $E_d = 50$ –180 keV. A DWBA analysis by (1997CZ01) of data up to 1 MeV evaluated the impact of the subthreshold resonance ${}^8\text{Be}^*(22.2)$ on the measured cross sections. In the DWBA analysis, data was limited to energies above $E_d = 60$ keV in order to minimize the effect of screening; the analysis indicated an energy $E_{\text{res}} = (-50 \pm 20)$ keV for the subthreshold resonance. The ${}^6\text{Li}({}^6\text{Li}, 2\alpha){}^4\text{He}$ reaction was measured at $E({}^6\text{Li}) = 6$ MeV and was evaluated in the “Trojan Horse” method to extract the ${}^6\text{Li}(d, \alpha)$ reaction cross sections and S -factors in the astrophysically relevant range from $E_{\text{cm}} = 13$ to 750 keV (2001SP04); a detailed analysis of these data, that accounted for the electron screening process, deduced $S(0) = 16.9 \pm 0.5$ MeV · b (2001MU30). See also (1992EN01, 1992EN04) for detailed discussion of electron screening in direct measurements of ${}^6\text{Li}(d, \alpha)$ and ${}^2\text{H}({}^6\text{Li}, \alpha)$ in the energy range of $E_{\text{cm}} < 1500$ keV. See also (2002BA77). Polarization measurements are reported in the range 0.4 to 11 MeV: see (1979AJ01, 1984AJ01) and see below. See also reaction 7 for comments about the astrophysical (d, p)/(d, α) ratio. See (1984AJ01) for a critical analysis of thermonuclear reaction rate parameters.

Pronounced variations are observed in the cross sections and in the analyzing powers. Maxima are seen at $E_d = 0.8$ MeV, $\Gamma_{\text{lab}} \approx 0.8$ MeV and $E_d = 3.75$ MeV, $\Gamma_{\text{lab}} \approx 1.4$ MeV. The 4 MeV peak is also observed in the tensor component coefficients with $L = 0, 4$ and 8 and in the vector component coefficients: two overlapping resonances are suggested. At higher energies all coefficients show a fairly smooth behavior which suggests that only broad resonances can exist. The results are in agreement with those from reaction 4, that is with two 2^+ states at $E_x = 22.2$ and 25.2 MeV and a 4^+ state at 25.5 MeV. A strong resonance is seen in the α^* channel [to ${}^4\text{He}(20.1)$, $J^\pi = 0^+$] presumably due to ${}^8\text{Be}^*(25.2, 25.5)$. In addition the ratio of the α^*/α differential cross sections at 30° shows a broad peak centered at $E_x \approx 26.5$ MeV (which may be due to interference effects) and suggests a resonance-like anomaly at $E_x \approx 28$ MeV. $A_{yy} = 1$ points are reported at $E_d = 5.55 \pm 0.12$ ($\theta_{\text{cm}} = 29.7 \pm 1.0^\circ$) and 8.80 ± 0.25 MeV ($\theta_{\text{cm}} = 90.0 \pm 1.0^\circ$) [corresponding to $E_x = 26.44$ and 28.87 MeV]. For references see (1974AJ01, 1979AJ01).

At $E_d = 6.945$ MeV, the α_0 yield shows an anomaly corresponding to ${}^8\text{Be}^*(27.49)$, the 0^+ ; $T = 2$ analog of ${}^8\text{He}_{\text{g.s.}}$. This $T = 2$ state has recently been studied using both polarized deuterons and ${}^6\text{Li}$ ions. The ratio of the partial widths for decay into ${}^6\text{Li}+d$ states with channel spin 2 and 0, $\Gamma_2/\Gamma_0 = 0.322 \pm 0.091$ (1986SO07).

A measurement of angular distributions and the excitation function for ${}^6\text{Li}(d, \alpha)$ for $E_d = 18.2$ –44.5 MeV (1994AR24) found evidence for possible states at ≈ 41 MeV, ≈ 43 MeV and ≈ 50 MeV.

A kinematically complete study of reaction (b) has been reported at $E_d = 1.2$ to 8.0 MeV: the transition matrix element squared plotted as a function of $E_{\alpha\alpha^*}$ (the relative energy in the channel ${}^4\text{He}_{\text{g.s.}} + {}^4\text{He}^*(20.1)$ [0^+]) shows a broad maximum at $E_x \approx 25$ MeV. Analysis of these results, and of a study of ${}^7\text{Li}(p, \alpha)\alpha^*$ [see reaction 18] which shows a peak of different shape at $E_x \approx 24$ MeV, indicate the formation and decay of overlapping states of high spatial symmetry, if the observed structures are interpreted in terms of ${}^8\text{Be}$ resonances: see (1984AJ01). For other work see (1984AJ01). See also ${}^6\text{Li}$ in (2002TI10) and references cited in (1988AJ01).

10. ${}^6\text{Li}(t, n){}^8\text{Be}$ $Q_m = 16.0236$

At $E_t = 2$ to 4.5 MeV ${}^8\text{Be}^*(0, 3.0, 16.6, 16.9)$ are populated (1984LIZY). See also (1966LA04, 1974AJ01).

11. (a) ${}^6\text{Li}({}^3\text{He}, \text{p}){}^8\text{Be}$ $Q_{\text{m}} = 16.7874$
 (b) ${}^6\text{Li}({}^3\text{He}, \text{p}){}^4\text{He}{}^4\text{He}$ $Q_{\text{m}} = 16.879206$

Angular distributions have been studied in the range $E({}^3\text{He}) = 0.46$ to 17 MeV and at $E({}^6\vec{\text{Li}}) = 21$ MeV. ${}^8\text{Be}^*(0, 3.0, 16.63, 16.92, 17.64, 18.15, 19.0, 19.4, 19.9)$ are populated in this reaction: see (1974AJ01, 1979AJ01, 1984AJ01). Angular distributions of cross sections and $A_y(\theta)$ were measured for ${}^6\text{Li}({}^3\vec{\text{He}}, \text{p}_0$ and $\text{p}_1)$ at $E_{{}^3\vec{\text{He}}} = 4.6$ MeV (1995BA24). A DWBA analysis indicates that a direct reaction mechanism dominated for both states, in contradiction with previous results that suggested a dominant compound nucleus contribution. See also (2003VO02, 2003VO08) for an evaluation of the reaction rates below $E({}^3\text{He}) = 1$ MeV. For reaction (b) see (1974AJ01) and (1987ZA07). See also ${}^9\text{B}$.

12. (a) ${}^6\text{Li}(\alpha, \text{d}){}^8\text{Be}$ $Q_{\text{m}} = -1.5657$
 (b) ${}^6\text{Li}(\alpha, 2\alpha){}^2\text{H}$ $Q_{\text{m}} = -1.473844$

Deuteron groups have been observed to ${}^8\text{Be}^*(0, 3.0, 11.3 \pm 0.4)$. Angular distributions have been measured at $E_\alpha = 15.8$ to 48 MeV: see (1974AJ01, 1979AJ01). A study of reaction (b) shows that the peak due to ${}^8\text{Be}^*(3.0)$ is best fitted by using $\Gamma = 1.2 \pm 0.3$ MeV. At $E_\alpha = 42$ MeV the α - α FSI is dominated by ${}^8\text{Be}^*(0, 3.0)$. See also Table 8.11 and (1983BE51; theor.).

13. (a) ${}^6\text{Li}({}^6\text{Li}, \alpha){}^8\text{Be}$ $Q_{\text{m}} = 20.8070$
 (b) ${}^6\text{Li}({}^6\text{Li}, \alpha){}^4\text{He}{}^4\text{He}$ $Q_{\text{m}} = 20.898839$
 (c) ${}^6\text{Li}({}^6\text{Li}, 2\text{d}){}^4\text{He}{}^4\text{He}$ $Q_{\text{m}} = -2.947688$

At $E_{\text{max}}({}^6\text{Li}) = 13$ MeV reaction (a) proceeds via ${}^8\text{Be}^*(0, 3.0, 16.6, 16.9, 22.5)$. The involvement of a state at $E_x = 19.9$ MeV ($\Gamma = 1.3$ MeV) is suggested. Good agreement with the shapes of the peaks corresponding to ${}^8\text{Be}^*(16.6, 16.9)$ is obtained by using a simple two-level formula with interference, corrected for the effect of final-state Coulomb interaction, assuming $\Gamma(16.6) = 90$ keV and $\Gamma(16.9) = 70$ keV: see also Table 8.11. The ratio of the intensities of the groups corresponding to ${}^8\text{Be}^*(16.6, 16.9)$ remains constant for $E({}^6\text{Li}) = 4.3$ to 5.5 MeV: $I(16.6)/I(16.9) = 1.22 \pm 0.08$. Partial angular distributions for the α_0 group have been measured at fourteen energies for $E({}^6\text{Li}) = 4$ to 24 MeV. See (1979AJ01) for the references. The reaction mechanism for ${}^6\text{Li}({}^6\text{Li}, \text{X})$ was studied by measuring charged particle angular distributions for $E({}^6\text{Li}) = 2$ –16 MeV (1990LE05). Analysis in a statistical model indicated that the ${}^6\text{Li}({}^6\text{Li}, \alpha)$ reaction proceeds dominantly via direct, cluster transfer rather than an intermediate compound nucleus.

At $E({}^6\text{Li}) = 36$ to 46 MeV sequential decay (reaction (b)) via ${}^8\text{Be}$ states at $E_x = 3.0, 11.4, 16.9$ and 19.65 MeV is reported: see (1984AJ01). (1987LA25) report the possible involvement of the 2^+ state ${}^8\text{Be}^*(22.2)$. At $E({}^6\text{Li}) = 6$ MeV the ‘‘Trojan Horse’’ method was used to evaluate ${}^6\text{Li}({}^6\text{Li}, 2\alpha)$ data to extract the ${}^6\text{Li}(\text{d}, \alpha)$ reaction cross sections and S -factors (2001SP04, 2001MU30): see reaction 9.

For reaction (c) see (1983WA09) and ${}^{12}\text{C}$ in (1985AJ01). See also (1983MI10) and (1982LA19, 1985NO1A; theor.).

14. (a) ${}^7\text{Li}(p, e^+e^-){}^8\text{Be}$ $Q_m = 16.2331$
 (b) ${}^7\text{Li}(p, \gamma){}^8\text{Be}$ $Q_m = 17.2551$

For reaction (a) electron/positron pair decay from ${}^8\text{Be}^*(17.6, 18.15)$ $J^\pi = 1^+$ levels was measured in a search for M1 de-excitation via pair production that would indicate the involvement of a short-lived isoscalar axion 4–15 MeV/ c^2 in mass. While an anomaly is seen in the pair production, the overall results are not consistent with the involvement of a neutral boson (1996DE51, 1997DE46, 2001DE11). Limits of $< 10^{-3}$ (1990DE02) and 4.1×10^{-4} (2001DE11) were obtained for the axion to γ -ray ratio.

For reaction (b) cross sections and angular distributions have been reported from $E_p = 30$ keV to 18 MeV. Gamma rays are observed to the ground (γ_0) and to the broad, 2^+ , excited state at 3.0 MeV (γ_1) and to ${}^8\text{Be}^*(16.6, 16.9)$ (γ_3, γ_4). An R -matrix fit to the γ -ray spectrum obtained at $E_p = 7.5$ and 8 MeV yielded $E_x = 2.91$ MeV and $\Gamma = 1.23$ MeV for the ${}^8\text{Be}$ first excited state (1990RI06). See also (1994DE09) for comments on model dependences for deduced widths. Resonances for both γ_0 and γ_1 occur at $E_p = 0.44$ and 1.03 MeV, and for γ_1 alone at $E_p = 2, 4.9, 6.0, 7.3$, and possibly at 3.1 and 11.1 MeV. The excitation function was measured for γ_0 and γ_1 across the resonance at $E_p = 441$ keV; the peak cross section was $\sigma_{\gamma_0+\gamma_1} = 5.0 \pm 0.7$ mb (yielding an average of 5.9 ± 0.5 mb when weighted with previous measurements). The branching ratio was $\sigma(\gamma_0)/\sigma(\gamma_0 + \gamma_1) = 0.72 \pm 0.07$ (1995ZA03). Broad resonances are reported at $E_p \approx 5$ MeV (γ_0), $\Gamma \approx 4$ –5 MeV, and at $E_p \approx 7.3$ MeV (γ_1), $\Gamma \approx 8$ MeV: see Table 8.12. The $E_p \approx 5$ MeV resonance ($E_x \approx 22$ MeV) represents the giant dipole resonance based on ${}^8\text{Be}_{g.s.}$ while the γ_1 resonance, ≈ 2.2 MeV higher, is based on ${}^8\text{Be}^*(3.0)$. The γ_0 and γ_1 giant resonance peaks each contain about 10% of the dipole sum strength. The main trend between $E_p = 8$ and 17.5 MeV is a decreasing cross section.

At the $E_p = 0.44$ MeV resonance ($E_x = 17.64$ MeV) the radiation is nearly isotropic and has been interpreted as arising from p-wave formation, $J^\pi = 1^+$, with channel spin ratio $\sigma(J_c = 2)/\sigma(J_c = 1) = 3.2 \pm 0.5$. Radiative widths for the γ_0 and γ_1 decay are displayed in Table 8.10. A careful study of the α -breakup of ${}^8\text{Be}^*(16.63, 16.92)$ [both $J^\pi = 2^+$] for $E_p = 0.44$ to 2.45 MeV shows that the non-resonant part of the cross section for production of ${}^8\text{Be}^*(16.63)$ is accounted for by an extranuclear direct-capture process. The γ -ray transitions to ${}^8\text{Be}^*(16.63, 16.92)$ are observed at $E_p = 0.44, 1.03$ and 1.89 MeV [${}^8\text{Be}^*(17.64, 18.15, 18.9)$]. The results are consistent with the hypothesis of nearly maximal isospin mixing for ${}^8\text{Be}^*(16.63, 16.92)$: decay to these states is not observed from the 3^+ states at $E_x = 19$ MeV, but rather from the 2^- state at $E_x = 18.9$ MeV. Squared $T = 1$ components calculated for ${}^8\text{Be}^*(16.6, 16.9)$ are 40 and 60%, and for ${}^8\text{Be}^*(17.6, 18.2)$ they are 95 and 5%, respectively. At $E_p = 25$ MeV, the capture cross section to the 16 MeV 2^+ doublet was measured ($\sigma_{\theta(\gamma)=90^\circ} < 0.04$ $\mu\text{b/sr}$) via a triple coincidence $\gamma + 2\alpha$ method (1991BR11). The cross section for ($\gamma_3 + \gamma_4$) has also been measured for $E_p = 11.5$ to 30 MeV ($\theta = 90^\circ$) by detecting the γ -rays and for $E_p = 4$ to 13 MeV (at five energies) by detecting the two α -particles from the decay of ${}^8\text{Be}^*(16.6, 16.9)$: a broad bump is observed at $E_p = 8 \pm 2$ MeV (1981MA33). The angle and energy integrated yield only exhausts 8.6% of the classical dipole sum for $E_p = 4$ to 30 MeV, suggesting that this structure does not represent the GDR built on ${}^8\text{Be}^*(16.6, 16.9)$. A weak, very broad [$\Gamma \geq 20$ MeV] peak may also be present at $E_x = 20$ –30 MeV. A direct capture calculation adequately describes the observed cross section (1981MA33). For the earlier references see (1979AJ01). See also references cited in (1988AJ01).

Low energy ${}^7\text{Li}(p, \gamma)$ angular distributions and cross sections, mainly for γ_0 and γ_1 capture, were measured at $E_p = 40$ –180 keV (1992CE02), $E_p = 80$ keV (1994CH23, 1996GO01, 1997GO13), $E_p = 100$ –1500 keV (1995ZA03), $E_p = 80, 402$ and 450 keV (1996HA06), and $E_p = 40$ –100 keV (2000SP01). The

Table 8.12: ${}^8\text{Be}$ levels from ${}^7\text{Li}(p, \gamma){}^8\text{Be}$ ^a

E_{res} (keV)	Γ_{lab} (keV)	${}^8\text{Be}^*$ (MeV)	l_p	J^π	Res. ^b
441.4 ± 0.5 ^c	12.2 ± 0.5	17.640	1	1^+	$\gamma_0, \gamma_1, \gamma_3, \gamma_4$
1030 ± 5	168	18.155	1	1^+	$\gamma_0, \gamma_1, \gamma_3, \gamma_4$
1890	150 ± 50	18.91		(2^-)	γ_3, γ_4
2060 ± 20	310 ± 20	19.06		$J = 1, 2, 3,$ $\pi = (-)$ ^d	γ_1
(3100)		(20.0)			γ_1
4900		21.5			γ_1
5000	≈ 4500	21.6	0	$1^-; T = 1$	γ_0
6000		22.5			γ_1
7500	≈ 8000	23.8	(0)	$(1^-, 2^-); T = 1$	γ_1
(11100)		(27.0)			γ_1
13000	broad	28.6			

^a See Tables 8.6 in (1974AJ01, 1979AJ01) for the references.

^b $\gamma_0, \gamma_1, \gamma_3, \gamma_4$ represent transitions to ${}^8\text{Be}^*(0, 3.0, 16.6, 16.9)$, respectively.

^c See (1959AJ76). See also (1983FI13, 1984JE1B).

^d See, however, reaction 16.

angular dependent cross-section and analyzing power data indicate significant near-threshold contributions from p-wave capture. Estimates of the p-wave strength have been deduced from Transition Matrix Element (TME) fits to the polarization data (1994CH23, 1996GO01, 1997GO13), R -matrix fits to the data (1995BB21, 1996BB26, 2000BA89), and other direct-plus-resonances capture calculations (1992CE02, 1994RO16, 1995WE11, 1996CS05, 1997BA04, 1997GO13, 2000SP01, 2001SA30). The estimates range from $< 10\%$ up to $\approx 95\%$. It was suggested that the origin of p-wave strength was the result of interference in the extended tails of the two 1^+ resonances at $E_p = 441$ keV and 1030 keV, while a more recent measurement (2000SP01) that observed a negative slope in the astrophysical S -factor, as the energy approaches zero, indicates that the sub-threshold ${}^8\text{Be}$ state at $E_x = 16.92$ MeV is involved in the capture. There appears to be some agreement on the issue that there is a need for new model calculations for low-energy capture that include the subthreshold state and the two resonances at $E_p = 441$ and 1030 keV. Polarized proton capture to the ${}^8\text{Be}^*(16.6)$ state was measured at $E_p = 80$ keV (1996GO01). See (1995ZA03, 2000NE09) for thermonuclear reaction rates and (1994CH70) for applications. Thick target proton induced γ -ray yields, useful for elemental analysis, were measured at $E_p = 2.2\text{--}3.8$ MeV (1988BO37) and $E_p = 7\text{--}9$ MeV (1987RA23).

$$15. {}^7\text{Li}(p, n){}^7\text{Be}$$

$$Q_m = -1.64456$$

$$E_b = 17.25512$$

Measurements of cross sections have been reported for $E_p = 1.9$ to 199.1 MeV [see (1974AJ01, 1979AJ01, 1984AJ01)] and in the range 60.1 to 480.0 MeV (1984DA22; activation σ). Polarization measurements have been reported at $E_p = 2.05$ to 5.5 MeV, 30 and 50 MeV [see (1974AJ01)] and at $E_p = 52.8$ MeV (1988HE08) [$K_z^{z'} = 0.07 \pm 0.02$]. See also below.

The yield of ground state neutrons (n_0) rises steeply from threshold and shows pronounced resonances at $E_p = 2.25$ and 4.9 MeV. The yield of n_1 also rises steeply from threshold and exhibits a broad maximum near $E_p = 3.2$ MeV and a broad dip at $E_p \approx 5.5$ MeV, also observed in the p_1 yield. Multi-channel scattering length approximation analysis of the 2^- partial wave near the n_0 threshold indicates that the 2^- state at $E_x = 18.9$ MeV has a width $\Gamma = 50 \pm 20$ keV. See, however, reaction 23 here. The ratio of the cross section for ${}^7\text{Li}(p, \gamma){}^8\text{Be}^*(18.9) \rightarrow {}^8\text{Be}^*(16.6 + 16.9) + \gamma$ to the thermal neutron capture cross section ${}^7\text{Be}(n, \gamma){}^8\text{Be}^*(18.9) \rightarrow {}^8\text{Be}^*(16.6 + 16.9) + \gamma$, provides a rough estimate of the isospin impurity of ${}^8\text{Be}^*(18.9)$: $\sigma_{p,\gamma}/\sigma_{n,\gamma} \approx 1.5 \times 10^{-5}$. The $T = 1$ isospin impurity is $\leq 10\%$ in intensity. See also reaction 23 here and (1979AJ01, 1984AJ01).

The structure at $E_p = 2.25$ MeV is ascribed to a $J^\pi = 3^+, T = (1), l = 1$ resonance with $\Gamma_n \approx \Gamma_p$ and $\gamma_n^2/\gamma_p^2 = 3$ to 10: see (1966LA04). At higher energies the broad peak in the n_0 yield at $E_p = 4.9$ MeV can be fitted by $J^\pi = 3^{(+)}$ with $\Gamma = 1.1$ MeV, $\gamma_n^2 \approx \gamma_p^2$. The behavior of the n_1 cross section can be fitted by assuming a 1^- state at $E_x = 19.5$ MeV and a $J = 0, 1, 2$, positive-parity state at 19.9 MeV [presumably the 20.1–20.2 MeV states reported in reaction 4]. In addition the broad dip at $E_p \approx 5.5$ MeV may be accounted for by the interference of two 2^+ states. See Table 8.8 in (1979AJ01). The 0° differential cross section increases rapidly to ≈ 35 mb/sr at 30 MeV and then remains constant to 100 MeV: see references cited in (1988AJ01). The total reaction cross section [${}^7\text{Be}^*(0, 0.43)$] decreases inversely with E_p in the range 60.1 to 480.0 MeV (1984DA22) [note: the values of σ_t supersede those reported earlier in (1979AJ01)]. The transverse polarization transfer, $D_{NN}(0^\circ)$, for the ground-state transition has been measured at $E_p = 160$ MeV (1984TA07). See also (1986MC09; $E_p = 800$ MeV) and references cited in (1988AJ01).

16. (a) ${}^7\text{Li}(p, p){}^7\text{Li}$

$E_b = 17.25512$

(b) ${}^7\text{Li}(p, p'){}^7\text{Li}^*$

Absolute differential cross sections for elastic scattering have been reported for $E_p = 0.4$ to 12 MeV and at 14.5, 20.0 and 31.5 MeV. The yields of inelastically scattered protons (to ${}^7\text{Li}^*(0.48)$) and of 0.48 MeV γ -rays have been measured for $E_p = 0.8$ to 12 MeV: see (1974AJ01). Polarization measurements have been reported at a number of energies in the range $E_p = 0.67$ MeV to 2.1 GeV/c [see (1974AJ01, 1979AJ01, 1984AJ01)], at $E_p = 1.89$ to 2.59 MeV (1986SA1P; p_0) and at 65 MeV (1987TO06; continuum). See also (1983GLZZ).

Anomalies in the elastic scattering appear at $E_p = 0.44, 1.03, 1.88, 2.1, 2.5, 4.2$ and 5.6 MeV. Resonances at $E_p = 1.03, 3$ and 5.5 MeV and an anomaly at $E_p = 1.88$ MeV appear in the inelastic channel. A phase-shift analysis and a review of the cross-section data show that the 0.44 and 1.03 MeV resonances are due to 1^+ states which are a mixture of ${}^5\text{P}_1$ and ${}^3\text{P}_1$ with a mixing parameter of $+25^\circ$; that the 2^- state at the neutron threshold ($E_p = 1.88$ MeV) has a width of about 50 keV [see also reaction 14]; and that the $E_p = 2.05$ MeV resonance corresponds to a 3^+ state. The anomalous behavior of the ${}^5\text{P}_3$ phase around $E_p = 2.2$ MeV appears to result from the coupling of the two 3^+ states [resonances at $E_p = 2.05$ and 2.25 MeV]. The ${}^3\text{S}_1$ phase begins to turn positive after 2.2 MeV suggesting a 1^- state at $E_p = 2.5$ MeV: see Table 8.13. The polarization data show structures at $E_p = 1.9$ and 2.3 MeV. A phase-shift analysis of the

Table 8.13: ${}^8\text{Be}$ levels from ${}^7\text{Li}(p, p_0){}^7\text{Li}$ and ${}^7\text{Li}(p, p_1){}^7\text{Li}^*$ ^a

E_p (MeV)	Γ_{lab} (keV)	${}^8\text{Be}^*$ (MeV)	J^π	$\Gamma_{p'}$ (keV)
0.441	12.2 ^b	17.640 ^c	1 ⁺	
1.030 ± 0.005	168	18.155	1 ⁺	≈ 6
1.895 ^{d,i}	55 ± 20	18.912 ⁱ	2 ⁻	
2.058 ⁱ	≈ 294 ⁱ	19.055 ⁱ	3 ⁺	small
2.245 ⁱ	≈ 203 ⁱ	19.218 ⁱ	3 ⁺	small
2.451 ⁱ	≈ 640 ^{e,i}	19.399 ⁱ	1 ⁻	> 0
f				
4.2 ± 0.2	1800 ± 200 ^g	20.9	4 ⁻	(> 0)
5.6	broad	22.2	^h	> 0

^a See references in Table 8.9 in (1979AJ01) and (1988GU10).

^b $\theta_p^2 = 0.064$.

^c See also (1981BA36; theor.).

^d (p, n) threshold: see reaction 15.

^e See also Table 8.8 in (1979AJ01), γ_{n1}^2 and $\gamma_{p1}^2 \approx 1\%$ of Wigner limit.

^f A 2⁺ state at $E_x \approx 20$ MeV appears to be necessary to account for the cross sections: see Table 8.9 and reaction 4.

^g Reduced width is 70% of the Wigner limit.

^h May be due to two 2⁺ states. See also reaction 15.

ⁱ (1988GU10).

(p, p) data finds no indication of a possible 1⁻ state with $17.4 < E_x < 18.5$ MeV [see, however, reaction 15 in (1979AJ01)].

An attempt has been made to observe the $T = 2$ state [${}^8\text{Be}^*(27.47)$] in the p_0 , p_1 and p_2 yields. None of these shows the effect of the $T = 2$ state. Table 8.5 in (1984AJ01) displays the upper limit for Γ_{p_0}/Γ .

The proton total reaction cross section has been reported for $E_p = 25.1$ to 48.1 MeV by (1985CA36). (1987CH33, 1987PO03) have studied p- ${}^7\text{Li}$ correlations involving ${}^8\text{Be}^*(17.64, 18.15, 18.9 + 19.1 + 19.2)$. Elastic proton scattering on ${}^7\text{Li}$ was measured near the (p, n) threshold, $E_{\text{cm}} = 1.2$ –2.4 MeV (1988GU10). Parameters for observed near-threshold resonances are in Table 8.13. See also (1994DE09) for comments on model dependences for deduced widths. See also ${}^7\text{Li}$ in (2002TI10) and references cited in (1988AJ01).

17. ${}^7\text{Li}(p, d){}^6\text{Li}$

$$Q_m = -5.02573$$

$$E_b = 17.25512$$

Angular distributions were measured for ${}^7\text{Li}(p, d)$ at $E_p = 18.6$ MeV (1987GO27); neutron spectroscopic factors were deduced, via DWBA analysis, for deuterons corresponding to the ${}^6\text{Li}$ ground state and

first excited state. The excitation function for d_0 measured for $E_p = 11.64$ to 11.76 MeV does not show any effect from the $T = 2$ state [${}^8\text{Be}^*(27.47)$]: see (1979AJ01). See also (1984BA1T).

18. ${}^7\text{Li}(p, \alpha){}^4\text{He}$

$$Q_m = 17.34695$$

$$E_b = 17.25512$$

The cross section increases from $(4.3 \pm 0.9) \times 10^{-5}$ mb at $E_p = 28.1$ keV to 6.33 mb at 998 keV. Astrophysical S -factors have been calculated over that range: $S(0) = 52 \pm 8$ keV \cdot b (1986RO13), $S(0) = 0.59$ keV \cdot b (1992EN01, 1992EN04). An analysis of the ${}^2\text{H}({}^7\text{Li}, \alpha)$ reaction (see reaction 19) in the Trojan Horse Method (THM), which assumes that the deuteron acts as a participant proton plus an spectator neutron and is not sensitive to electron screening effects, indicates $S(0) = 55 \pm 3$ keV \cdot b (2001LA35, 2003PI13, 2003SP02). Earlier work on the THM by the same group published the value $S(0) = 36 \pm 7$ keV \cdot b (1997CA36, 1999SP09, 2000AL04). For comments on the S factor see (1990RA28, 1991SC12, 1991SC25, 1991SC32, 1992SC22, 1992SO25, 1993RA14, 1993SC06, 1994KA02, 1995IC02, 1995YA02, 1997KI02, 2000BA89). See additional comments on electron screening in (1992EN01, 1992EN04, 1997BA95, 1997BO12, 2002BA77, 2002HA51, 2003PI13). See comments on nucleosynthesis rates and primordial abundances in (1991RI03, 1998FI02, 2000BU10). For the earlier work see (1984AJ01).

Excitation functions and angular distributions have been measured at $E_p = 10$ keV–62.5 MeV: see (1979AJ01, 1984AJ01), $E_p = 20$ –250 keV (1989HA14), and $E_{\text{cm}} = 10$ –1450 keV (1992EN01, 1992EN04). Polarization measurements have been carried out for $E_p = 0.8$ to 22 MeV: see (1974AJ01), $E_p = 9$ –22 MeV (1992TA21). In the range $E_p = 23$ keV to 62.5 MeV: see (1979AJ01, 1984AJ01). Polarization measurements have been carried out for $E_p = 0.8$ to 10.6 MeV [see (1974AJ01)]: in the range $E_p = 3$ to 10 MeV the asymmetry has one broad peak in the angular distribution at all energies except near 5 MeV; the peak value is 0.98 ± 0.04 at 6 MeV and is essentially 1.0 for $E_p = 8.5$ to 10 MeV. Above 10 MeV the asymmetry begins to decrease slowly.

Broad resonances are reported to occur at $E_p = 3.0$ MeV [$\Gamma \approx 1$ MeV] and at ≈ 5.7 MeV [$\Gamma \approx 1$ MeV]. Structures are also reported at $E_p = 6.8$ MeV and at $E_p = 9.0$ MeV: see (1979AJ01). The 9.0 MeV resonance is also reflected in the behavior of the A_2 coefficient. The experimental data on yields and on polarizations appear to require including two 0^+ states [at $E_x \approx 19.7$ and 21.8 MeV] with very small α -particle widths, and four 2^+ states [at $E_x \approx 15.9, 20.1, 22.2$ and 25 MeV]. See, however, reaction 4. A 4^+ state near 20 MeV was also introduced in the calculation but its contribution was negligible. The observed discrepancies are said to be probably due to the assumption of pure $T = 0$ for these states. At $E_p = 11.64$ to 11.76 MeV the excitation function does not show any effect due to the $T = 2$ state at $E_x = 27.47$ MeV. See (1979AJ01) for references.

A study of the ${}^7\text{Li}(p, \alpha){}^4\text{He}^*$ reaction to ${}^4\text{He}^*(20.1) [0^+]$ at $E_p = 4.5$ to 12.0 MeV shows a broad maximum at $E_x \approx 24$ MeV: see reaction 9 and (1984AJ01). See also references cited in (1988AJ01).

19. (a) ${}^7\text{Li}(d, n){}^8\text{Be}$

$$Q_m = 15.0306$$

(b) ${}^7\text{Li}(d, n){}^4\text{He}{}^4\text{He}$

$$Q_m = 15.12239$$

The population of ${}^8\text{Be}^*(0, 3.0, 16.6, 16.9, 17.6, 18.2, 18.9, 19.1, 19.2)$ has been reported in reaction (a). For the parameters of ${}^8\text{Be}^*(3.0)$ see Table 8.4 in (1974AJ01). Angular distributions were measured for

${}^7\text{Li}(d, n)$ at $E_d = 0.7\text{--}2.3$ and $5.6\text{--}12.1$ MeV and excitation functions were reported for neutrons corresponding to ${}^8\text{Be}^*(0 + 3.0, 16.6 + 16.9, 17.6, 18.15)$ (1996BO27). The ${}^8\text{Be}^*(11.4)$ level is not observed. Angular distributions of n_0 and n_1 have been reported at $E_d = 0.7$ to 3.0 MeV and at $E_d = 15.25$ MeV [see (1974AJ01, 1979AJ01)], at 0.19 MeV (1983DA32, 1987DA25) and at 0.40 and 0.46 MeV (1984GA07; n_0 only). The angular distributions of the neutrons to ${}^8\text{Be}^*(16.6, 17.6, 18.2)$ are fit by $l_p = 1$: see (1974AJ01). At $E_{\text{cm}} = 50, 83$ and 199 keV, the measured cross sections are $\sigma = 0.125, 2.11$ and 4.01 mb, respectively ($\pm \approx 5\%$ (stat.), $\pm 7.5\%$ (syst.)) (2001HO23).

Reaction (b) at $E_d = 2.85$ to 14.97 MeV proceeds almost entirely through the excitation and sequential decay of ${}^8\text{Be}^*(16.6, 16.9)$ (1987WA21). See also (1988AJ01). At $E_d = 19.7$ MeV, ${}^8\text{Be}^*(11.4)$ was observed at $E_x = 11.3 \pm 0.2$ MeV with $\Gamma = 3.7 \pm 0.2$ MeV (1995AR25). At $E_d = 7$ MeV, population of the two $T = 0$ levels at $20.1, 2^+$ and $20.2, 0^+$ is reported with widths $\Gamma_{20.1} = 0.85 \pm 0.25$ MeV and $\Gamma_{20.2} = 0.75 \pm 0.25$ MeV (1991AR18), and $\Gamma_{20.1} = 0.90 \pm 0.20$ MeV and $\Gamma_{20.2} = 0.70 \pm 0.20$ MeV (1992DA22). A complete kinematics measurement of $d^3\sigma/(d\Omega_\theta d\Psi dE_{12})$ at $E_d = 3\text{--}6$ MeV reported population of the 2^+ doublet at 16.6 MeV and 16.9 MeV; intense forward neutrons were observed corresponding to the 16.6 MeV state indicating the ${}^7\text{Li} + p$ configuration of that state (1999GO15). See (2001LA35, 2003PI13, 2003SP02), and reaction 18 for measurements at $E_p = 19\text{--}21$ MeV that are evaluated in the ‘‘Trojan Horse’’ method to obtain information on the astrophysical ${}^7\text{Li}(p, \alpha)$ rate. See also (2000HA50) for fusion applications. See also ${}^9\text{Be}$.

$$\begin{aligned} 20. \text{ (a) } & {}^7\text{Li}({}^3\text{He}, d){}^8\text{Be} & Q_m &= 11.7616 \\ & \text{(b) } & {}^7\text{Li}({}^3\text{He}, \alpha d){}^4\text{He} & Q_m &= 11.85348 \end{aligned}$$

Deuteron groups are observed to ${}^8\text{Be}^*(0, 3.0, 16.6, 16.9, 17.6, 18.2)$. For the $J^\pi = 2^+$ isospin mixed states see Table 8.11. Angular distributions have been measured for $E({}^3\text{He}) = 390\text{--}1130$ keV (2003FR22), for $E({}^3\text{He}) = 0.9$ to 24.3 MeV and at $E({}^3\text{He}) = 33.3$ MeV: see (1974AJ01, 1979AJ01, 1984AJ01). Reaction (b) has been studied at $E({}^3\text{He}) = 5.0$ MeV (1985DA29) and at $9, 11$ and 12 MeV (1986ZA09). ${}^8\text{Be}^*(0, 3.0)$ are reported to be involved (1985DA29). Implications of this reaction for destroying ${}^7\text{Li}$ and ${}^7\text{Be}$ in astrophysical environments is discussed in (2003FR22). See also ${}^{10}\text{B}$.

$$\begin{aligned} 21. \text{ (a) } & {}^7\text{Li}(\alpha, t){}^8\text{Be} & Q_m &= -2.5588 \\ & \text{(b) } & {}^7\text{Li}(\alpha, \alpha t){}^4\text{He} & Q_m &= -2.46691 \end{aligned}$$

Angular distributions have been measured to $E_\alpha = 50$ MeV: see (1974AJ01, 1979AJ01, 1988AJ01). The ground state of ${}^8\text{Be}$ decays isotropically in the cm system: $J^\pi = 0^+$. Sequential decay (reaction (b)) is reported at $E_\alpha = 50$ MeV via ${}^8\text{Be}^*(0, 3.0, 11.4, 16.6, 16.9, 19.9)$: see (1974AJ01). See also (1992KO26).

$$\begin{aligned} 22. \text{ (a) } & {}^7\text{Li}({}^7\text{Li}, {}^6\text{He}){}^8\text{Be} & Q_m &= 7.2789 \\ & \text{(b) } & {}^7\text{Li}({}^7\text{Li}, \alpha + {}^6\text{He}){}^4\text{He} & Q_m &= 7.3707 \end{aligned}$$

Table 8.14: R -matrix parameters for ${}^8\text{Be}$ levels observed in ${}^7\text{Be}(n, p)$ (2003AD05)

E_x (MeV)	E_{res} (MeV)	Γ_n (MeV)	Γ_p (MeV)
18.90	0.0027	0.225	1.409
19.23	0.33	0.077	0.088
21.56	2.66	0.490	0.610

${}^8\text{Be}^*(0, 3.0)$ have been populated. For reaction (a) see (1987BO1M; $E({}^7\text{Li}) = 22$ MeV), and for reaction (b) see (1996SO17; $E({}^7\text{Li}) = 8$ MeV).

23. (a) ${}^7\text{Be}(n, p){}^7\text{Li}$	$Q_m = 1.64456$	$E_b = 18.89968$
(b) ${}^7\text{Be}(n, \alpha){}^4\text{He}$	$Q_m = 18.99152$	
(c) ${}^7\text{Be}(n, \gamma\alpha){}^4\text{He}$	$Q_m = 18.99152$	

The total (n, p) cross section has been measured from 25×10^{-3} eV to 13.5 MeV. For thermal neutrons the cross sections to ${}^7\text{Li}^*(0, 0.48)$ are 38400 ± 800 and 420 ± 120 b, respectively. A departure from a $1/v$ shape in σ_t is observed for $E_n > 100$ eV. The astrophysical reaction rate is $\approx \frac{1}{3}$ lower than that previously used, which could lead to an increase in the calculated rate of production of ${}^7\text{Li}$ in the Big Bang by as much as 20% (1988AJ01): see also (1998FI02). Results from a R -matrix analysis of reaction (a) over the range from $E_{\text{cm}} = 10^{-8}$ –9.0 MeV (2003AD05) are summarized in Table 8.14. In their analysis, ${}^8\text{Be}^*(19.07)$ and ${}^8\text{Be}^*(19.24)$ are treated as a single resonance. A different R -matrix analysis (1988KO03) found a $T = 1$ impurity of $\approx 24\%$ and $\Gamma = 122$ keV for the 2^- ${}^8\text{Be}^*(18.9)$ state. The approach of (1988KO03) defines the resonance energy and width as a pole of the S -matrix on the so-called Riemann sheet, which yields total widths that are smaller than the sum of the partial widths (2003AD05). At thermal energies the (n, α) cross section is ≤ 0.1 mb and the $(n, \gamma\alpha)$ cross section is 155 mb: see (1974AJ01). See also references cited in (1988AJ01).

24. ${}^8\text{Li}(\beta^-){}^8\text{Be}$	$Q_m = 16.0052$
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${}^8\text{Li}$ decays mainly to the broad 3.0 MeV, 2^+ level of ${}^8\text{Be}$, which decays into two α -particles. Both the β -spectrum and the resulting α -spectrum have been extensively studied: see (1955AJ61, 1966LA04). See also ${}^8\text{B}(\beta^+)$. Studies of the distribution of recoil momenta and neutrino recoil correlations indicate that the decay is overwhelmingly GT, axial vector [see reaction 1 in ${}^8\text{Li}$] and that the ground state of ${}^8\text{Li}$ has $J^\pi = 2^+$: see (1980MC07). Detailed calculations are necessary to obtain the $\log ft$ values for decay to ${}^8\text{Be}^*(3.0)$; values in the literature are: $\log ft = 5.37$ (1986WA01), $\log ft = 5.72$ (1989BA31).

The data of (1971WI05) for ${}^8\text{Li}$ and ${}^8\text{B}$ β -decay have been analyzed extensively (1986WA01, 1989BA31, 2002BH03). In (1986WA01) a many-level one-channel approximation R -matrix analysis of the β -delayed

α particle spectra in the decay of both ${}^8\text{Li}$ and ${}^8\text{B}$ [as well as of the $L = 2$ α - α phase shifts] found that there was no need to introduce “intruder” states below $E_x \approx 26$ MeV of ${}^8\text{Be}$ in order to explain the data [see, e.g. (1969BA43, 1974AJ01, 1976BA67, 1979AJ01)]. Warburton extracted the GT matrix elements, for the decay to ${}^8\text{Be}^*(3.0)$ and the doublet near 16 MeV, and pointed out the difficulties in extracting meaningful E_x , Γ and $\log ft$ values from β^\pm decay to the broad ${}^8\text{Be}^*(3.0)$ state. On the other hand, the R -matrix analysis of Barker (1989BA31) requires a broad 2^+ intruder state at ≈ 9 MeV. See (1998FA05, 2000BA89, 2001CA50) for further comments on intruder states in ${}^8\text{Be}$.

Beta- α angular correlations have been measured for the decays of ${}^8\text{Li}$ and ${}^8\text{B}$ for the entire final-state distribution: see Table 8.10 in (1979AJ01). (1980MC07) have measured $\beta - \alpha$ correlations as a function of E_x in the decay of ${}^8\text{Li}$ and ${}^8\text{B}$; by detecting the β and both α particles involved in the ${}^8\text{Be}$ decay, the $\beta - \nu - \alpha$ correlations were determined. They find that the decay is GT for $2 < E_x < 8$ MeV. The absence of Fermi decay strength is expected because the isovector contributions from the tails of ${}^8\text{Be}^*(16.6, 16.9)$ interfere destructively in this energy region: see (1980MC07). The measurement of the β -decay asymmetry as a function of E_β is reported by (1985BIZZ, 1986BI1D). (1986NAZZ) have measured the β -spectrum and compared it with the spectrum predicted from the α -breakup data. See also references cited in (1988AJ01).

$$25. {}^8\text{Li}(p, n){}^8\text{Be} \quad Q_m = 15.2228$$

Angular distributions of ${}^8\text{Be}$ from ${}^1\text{H}({}^8\text{Li}, {}^8\text{Be})$ were measured at $E_{\text{cm}} = 1.5$ MeV (1993CA04). The ${}^8\text{Be}_{\text{g.s.}}$ was reconstructed by detecting the coincident α particles and the data were transformed to represent the inverse kinematics ${}^8\text{Li}(p, n)$ reaction. The observed cross section, $\sigma_{\text{tot}} = 21 \pm 2(\text{stat.}) \pm 4.2(\text{norm.})$ mb, was 2 times smaller than estimates based on a Hauser-Feshbach calculation and indicates that ${}^8\text{Li}(p, n)$ does not contribute significantly to ${}^8\text{Li}$ burning in nucleosynthesis. See also (2003IS12).

$$26. {}^8\text{Be}(\gamma, p){}^7\text{Li} \quad Q_m = -17.2551$$

A dynamic semi-microscopic model study of ${}^8\text{Be}(\gamma, p)$ considered dipole-dipole and quadrupole-quadrupole forces on the properties of Giant Dipole Resonances built on the ground state and first excited state of ${}^8\text{Be}$ (1995GO21). See also reaction 14 here.

$$27. {}^8\text{B}(\beta^+){}^8\text{Be} \quad Q_m = 17.9798$$

The decay [see reaction 1 in ${}^8\text{B}$] proceeds mainly to ${}^8\text{Be}^*(3.0)$. Detailed study of the high-energy portion of the α -spectrum reveals a maximum near $E_\alpha = 8.3$ MeV, corresponding to transitions to ${}^8\text{Be}^*(16.63)$, for which parameters $E_x = 16.67$ MeV, $\Gamma = 150$ to 190 keV or $E_x = 16.62$ MeV, $\Gamma = 95$ keV are derived: see (1974AJ01). Analyses (1986WA01, 1989BA31) of the β^\pm delayed α -spectra following ${}^8\text{B}$ and ${}^8\text{Li}$ decay are described in reaction 24. The analysis of (1989BA31) requires a 2^+ intruder state in ${}^8\text{Be}$ at $E_x \approx 9$ MeV, while the analysis of (1986WA01) excludes intruder states below $E_x = 26$ MeV. See also (1988WA1E) and (1988BA75, 1998FA05, 2000BA89, 2001CA50).

The determination of $\log ft$ values requires detailed calculations; values in the literature are: for decay to ${}^8\text{Be}^*(3.0)$ $\log ft = 5.6$ (1974AJ01), $\log ft = 5.77$ (1989BA31); for decay to ${}^8\text{Be}^*(16.63)$ $\log ft = 3.3$ (1969BA43, 1979AJ01).

The β^+ spectrum has been measured by (1987NA08) and by (2000OR04): see reaction 1 in ${}^8\text{B}$. See (1988AJ01) for additional references and discussion. See also (2000GR03, 2000GR07) for theoretical discussion of the cluster structure of 16.6 and 16.9 MeV resonances and their role in ${}^8\text{B}$ β -decay. See also (1994DE30).

28. (a) ${}^9\text{Be}(\gamma, n){}^4\text{He}{}^4\text{He}$	$Q_m = -1.5736$
(b) ${}^9\text{Be}(\gamma, n){}^8\text{Be}$	$Q_m = -1.6654$
(c) ${}^9\text{Be}(n, 2n){}^8\text{Be}$	$Q_m = -1.6654$
(d) ${}^9\text{Be}(t, n + t){}^8\text{Be}$	$Q_m = -1.6654$
(e) ${}^9\text{Be}(\alpha, \alpha n){}^8\text{Be}$	$Q_m = -1.6654$

Neutron groups to ${}^8\text{Be}^*(0, 3.0)$ have been studied for $E_\gamma = 18$ to 26 MeV: see (1974AJ01, 1979AJ01). For reactions (a) and (b) bremsstrahlung γ rays from 4–8 MeV electrons were used to measure the $\theta_{\text{lab}} = 90^\circ$ photo-neutron emission excitation function (1989VA18). ${}^9\text{Be}$ levels at $E_x = 1.735 \pm 0.003$, 2.43 and 3.077 ± 0.09 MeV were excited using a technique that uses electrons in a storage ring to Compton backscatter laser photons to produce high-quality nearly mono-energetic γ -rays (2001UT01, 2001UT03, 2002SU19, 2003UT02); $B(E1)$ and $B(M1)$ values are deduced in (2001UT01, 2002IT07, 2002SU19). A measurement from neutron threshold to $E_\gamma \approx 20$ MeV indicated that ${}^8\text{Be}$ excited states are strongly populated following neutron emission (1992GO27).

The $\alpha(\alpha n, \gamma)$ reaction competes with the 3α reaction to bridge the $A = 5$ and $A = 8$ mass gaps. γ -rays with $E_\gamma = 1.5$ to 6 MeV were used to study the $\alpha(\alpha n, \gamma)$ reaction rate in inverse kinematics (2001UT03), and the resulting cross sections favor the compilation by NACRE (1999AN35) rather than the evaluation by (1988CA28). A theoretical study of photodisintegration in the threshold region around the ${}^9\text{Be}^*(1.684)$ $J^\pi = \frac{1}{2}^+$ resonance is presented in (2001ME11). A multicluster-model study of ${}^9\text{Be}$ photodisintegration (1998EF05) and an R -matrix analysis of the situation (2000BA21) address discrepancies in the low-energy cross section measurements. See also (1994KA25; theor.) for ${}^9\text{Be}$ Coulomb dissociation. Neutrons from ${}^9\text{Be}(\gamma, n)$ were used to estimate the number of hard X-rays (with $E_\gamma > 1.67$ MeV) that are produced in the plasma that results from impinging a 5×10^8 W/cm² laser on a Ta foil (2001SC12). See (1974AJ01, 1979AJ01) and ${}^9\text{Be}$.

Reaction (c) appears to proceed largely via excited states of ${}^9\text{Be}$ with subsequent decay mainly to ${}^8\text{Be}^*(3.0)$: see (1966LA04, 1974AJ01), and ${}^9\text{Be}$ and ${}^{10}\text{Be}$ here. Neutrons from ${}^9\text{Be}(n, 2n)$ for $E_n < 10.3$ MeV were analyzed to determine the neutron-neutron scattering length $a_{nn} = -16.5 \pm 1.0$ fm (1990BO43). Measurements of ${}^9\text{Be}(n, 2n)$ for $E_n < 12$ MeV were made to assess the possibility of using ${}^9\text{Be}$ as a neutron multiplier in fusion reactors (1994ME08). See also (1988BE04) for a theoretical evaluation in the range from 5.9–14.1 MeV.

For reactions (d) and (e) see (1974AJ01) and ${}^9\text{Be}$. For reaction (e) see (1979AJ01).

29. (a) ${}^9\text{Be}(p, d){}^8\text{Be}$	$Q_m = 0.5592$
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$$\begin{aligned} \text{(b) } {}^9\text{Be}(p, p+n){}^8\text{Be} & \quad Q_m = -1.6654 \\ \text{(c) } {}^9\text{Be}(p, d){}^4\text{He}{}^4\text{He} & \quad Q_m = 0.6510 \end{aligned}$$

For reaction (a) angular distributions of deuteron groups have been reported at $E_p = 0.11$ to 185 MeV [see (1974AJ01, 1979AJ01, 1984AJ01)] and at 18.6 MeV (1986GO23, 1987GO27; d_0 and d_1) and 50 and 72 MeV (1984ZA07; to ${}^8\text{Be}^*(0, 3.0, 16.9, 19.2)$). Angular distributions of cross sections and analyzing powers were measured for deuterons from ${}^9\text{Be}(\vec{p}, d)$ at $E_{\vec{p}} = 60$ MeV. Analyzing powers for deuterons corresponding to ${}^8\text{Be}^*(3.04, 11.4, 16.92, 19.24)$ were presented while peaks corresponding to ${}^8\text{Be}$ states at (0, 11.04, 17.64, 18.25, 19.4, 22.05) were observed; evidence for very broad states at higher energies was also reported (1987KA25). The angular distributions to ${}^8\text{Be}^*(0, 3.0, 16.9, 17.6, 18.2, 19.1)$ are consistent with $l_n = 1$: see (1974AJ01). Neutron spectroscopic factors for $n + {}^8\text{Be}_{g.s.}$ and $n + {}^8\text{Be}^*(3.04)$ were extracted from a DWBA analysis of ${}^9\text{Be}(p, d)$ at $E_p = 18.6$ MeV (1987GO27), and spectroscopic factors for $n + {}^8\text{Be}^*(0, 3.04, 16.626, 16.922, 17.640, 18.15, 19.07)$ were extracted from ${}^9\text{Be}(p, d)$ at 33.6 MeV (1991AB04): see ${}^9\text{B}$. For other spectroscopic factor measurements see (1979AJ01, 1984ZA07).

An anomalous group is reported in the deuteron spectra between the d_0 and the d_1 groups. At $E_p = 26.2$ MeV, $E_x = 0.6 \pm 0.1$ MeV (constant with θ). Analyses of the spectral shape and transfer cross sections are consistent with this “ghost” feature being part of the Breit-Wigner tail of the $J^\pi = 0^+ {}^8\text{Be}_{g.s.}$: it contains $< 10\%$ of the ground-state transfer strength. An analysis of reported Γ_{cm} widths for ${}^8\text{Be}^*(3.0)$ in this reaction shows that there is no E_p dependence. The average Γ_{cm} at $E_p = 14.3$ and 26.2 MeV is 1.47 ± 0.04 MeV. $\Gamma_{cm} = 5.5 \pm 1.3$ eV for ${}^8\text{Be}_{g.s.}$ and 5.2 ± 0.1 MeV for ${}^8\text{Be}^*(11.4)$. Spectroscopic factors for ${}^8\text{Be}_{g.s.}$ (including the “ghost” anomaly) and ${}^8\text{Be}^*(3.0)$ are 1.23 and 0.22 respectively at $E_p = 14.3$ MeV, and 1.53 and 1.02 respectively at $E_p = 26.2$ MeV. The width of ${}^8\text{Be}^*(3.0)$ is not appreciably ($< 10\%$) reaction dependent but the nearness of the decay threshold indicates that care must be taken in comparing decay widths from reaction and from scattering data: $E_{res} = 3130 \pm 25$ keV (resonance energy in the $\alpha + \alpha$ cm system) [$E_x = 3038 \pm 25$ keV] and $\Gamma_{cm} = 1.50 \pm 0.02$ MeV for ${}^8\text{Be}^*(3.0)$: the corresponding observed and formal reaction widths and channel radii are $\gamma_{res}^2 = 580 \pm 50$ keV, $\gamma_\lambda^2 = 680 \pm 100$ keV and $r_c = 4.8$ fm. A study of the continuum part of the inclusive deuteron spectra is reported at $E_{\vec{p}} = 60$ MeV (1987KA25). See (1979AJ01, 1984AJ01) for the earlier work.

The effects of electron screening were studied at around $E_p = 16$ –390 keV. A direct-plus resonance model fit to the data result in the values of $E_{res} = 336 \pm 3$ keV and $\Gamma_{lab} = 205 \pm 6$ keV for ${}^{10}\text{B}^*(6.87)$ and $\Gamma_\alpha = 68 \pm 2$ keV and $\Gamma_d = 90 \pm 4$ keV (1997ZA06). See also (2002BA77). At $E_p = 77$ –321 keV, angular distributions and analyzing powers of deuterons were measured; an R -matrix evaluation of the data indicated that a direct-reaction model can adequately account for the observations (1998BR10) indicating that the sub-threshold state in ${}^{10}\text{B}$ at $E_x = 6.57$ MeV does not contribute. An R -matrix analysis of ${}^{10}\text{B}$ levels populated for $E_p < 700$ keV is reported in (2001BA47).

Reaction (b) has been studied at $E_p = 45$ and 47 MeV: the reaction primarily populates ${}^8\text{Be}^*(0, 3.0)$. At $E_p = 70$ MeV data were evaluated using a DWTA (T -matrix) approach to decompose the $1s$ and $1p$ shell contributions in the quasielastic knockout of neutrons (2000SH01). See (1979AJ01), and ${}^9\text{Be}$, ${}^9\text{B}$ here. For work at $E_p = 1$ GeV see (1985BE30, 1985DO16). For reaction (c) [FSI through ${}^8\text{Be}^*(0, 3.0)$] see (1974AJ01, 1984AJ01). See also (1992KO26; theor.) and ${}^{10}\text{B}$.

$$\begin{aligned} 30. \text{(a) } {}^9\text{Be}(d, t){}^8\text{Be} & \quad Q_m = 4.5919 \\ \text{(b) } {}^9\text{Be}(d, t){}^4\text{He}{}^4\text{He} & \quad Q_m = 4.6834 \end{aligned}$$

At astrophysically-relevant energies, $E_{\text{cm}} = 57\text{--}139$ keV, ${}^9\text{Be}(d, t_0)$ angular distributions and total cross sections were measured and are compared with DWBA calculations (1997YA02). At $E_d = 8\text{--}50$ MeV, angular distributions of t_0 and t_1 are evaluated in a DWBA analysis and vertex constants, $|G|^2$, and neutron spectroscopic factors are deduced (1995GU22). Angular distributions of t_0 were measured at $E_d = 7$ MeV and were evaluated in a DWBA analysis that indicated transfer mechanisms dominated at forward angles while compound nucleus mechanisms were most important at backward angles (1989SZ02). Levels of ${}^{11}\text{B}$ were observed in measurements of the excitation function and angular distribution for tritons from ${}^9\text{Be}(d, t_0)$ at $E_d = 0.9\text{--}11.2$ MeV (1994AB25) and $E_d = 3\text{--}11$ MeV (1995AB41, 2000GE16). A review of the ${}^9\text{Be}(d, t_0)$ excitation function for $E_d = 237$ keV to 11 MeV is given in (2000GE16). Angular distributions have been measured at $E_d = 0.3$ to 28 MeV [see (1979AJ01)], at $E_d = 18$ MeV (1988GO02; t_0, t_1) and at $E_{\bar{d}} = 2.0$ to 2.8 MeV (1984AN16; t_0). At $E_d = 28$ MeV angular distributions of triton groups to ${}^8\text{Be}^*(16.6, 16.9, 17.6, 18.2, 19.1, 19.2, 19.8)$ have been analyzed using DWUCK: absolute C^2S are 0.074, 1.56, 0.22, 0.17, 0.41, 0.48, 0.40, respectively. See also Table 8.11. An isospin amplitude impurity of 0.21 ± 0.03 is found for ${}^8\text{Be}^*(17.6, 18.2)$: see (1979AJ01).

At $E_d = 7$ MeV a complete kinematics measurement of ${}^9\text{Be}(d, t + {}^8\text{Be})$ observed states participating in the sequential decay of ${}^8\text{Be}$ (1991SZ06). The relative energy spectrum was reconstructed and yielded peaks corresponding to the ground state, $E_x \approx 0.6$ MeV and 3.00 ± 0.01 MeV; the observed width for the 3 MeV state was $\Gamma = 1.23 \pm 0.02$ MeV. Analysis in a single-level R -matrix formalism, best fit with $r_c = 4.5 \pm 0.1$ fm, indicates that the “ghost anomaly” structure at ≈ 0.6 MeV is the result of deformation in the high-energy tail of the ${}^8\text{Be}$ ground state. While the cross section corresponding to the first excited state peaks at 3.00 MeV, the R -matrix fit indicates that the resonance energy is 3.12 ± 0.01 MeV ($E_x = 3.03 \pm 0.01$ MeV) with $\Gamma_{\text{res}} = 1.43 \pm 0.06$ MeV (1991SZ06).

A kinematically complete study of reaction (b) at $E_d = 26.3$ MeV indicates the involvement of ${}^8\text{Be}^*(0, 3.0, 11.4, 16.9, 19.9 + 20.1)$: see (1974AJ01).

$$\begin{aligned} 31. \text{ (a) } {}^9\text{Be}({}^3\text{He}, \alpha){}^8\text{Be} & \quad Q_m = 18.9122 \\ \text{ (b) } {}^9\text{Be}({}^3\text{He}, \alpha){}^4\text{He}{}^4\text{He} & \quad Q_m = 19.0041 \end{aligned}$$

Angular distributions have been measured in the range $E({}^3\text{He}) = 3.0$ to 26.7 MeV and at $E({}^3\vec{\text{He}}) = 33.3$ MeV (to ${}^8\text{Be}^*(16.9, 17.6, 19.2)$) [$S = 1.74, 0.72, 1.17$, assuming mixed isospin for ${}^8\text{Be}^*(16.9)$]. The possibility of a broad state at $E_x \approx 25$ MeV is also suggested: see (1979AJ01). See also (1987VA11).

Reaction (b) has been studied at $E({}^3\text{He}) = 1.0$ to 10 MeV [see (1979AJ01, 1984AJ01)], at $E({}^3\text{He}) = 3$ to 12 MeV (1986LA26) and at 11.9 to 24.0 MeV (1987WA25). The reaction is reported to proceed via ${}^8\text{Be}^*(0, 3.0, 11.4, 16.6, 16.9, 19.9, 22.5)$: see (1979AJ01) and (1986LA26, 1987WA25). For a discussion of the width of ${}^8\text{Be}^*(11.4)$ see (1987WA25). Angular distributions for ${}^9\text{Be}({}^3\text{He}, \alpha)$ were evaluated to determine the contributions from neutron pickup vs. heavy particle stripping; ${}^9\text{Be}$ spectroscopic factors for S_n and S_α were calculated (1997ZH40). See also (1992KO26; theor.). See also ${}^9\text{Be}$ here, ${}^{12}\text{C}$ in (1980AJ01), and (1988AJ01).

$$32. {}^9\text{Be}(\alpha, \alpha'n){}^8\text{Be} \quad Q_m = -1.6654$$

A summary of the (α , α' n) cross sections used in the SOURCES code is given in (2003SH22). The SOURCES code (2002WI1K) is used, for example, to calculate neutron energies and doses from ^9Be -actinide radioactive sources.

33. (a) $^9\text{Be}(^6\text{Li}, ^7\text{Li})^8\text{Be}$ $Q_m = 5.5849$
 (b) $^9\text{Be}(^7\text{Li}, ^8\text{Li})^8\text{Be}$ $Q_m = 0.3669$
 (c) $^9\text{Be}(^9\text{Be}, ^{10}\text{Be})^8\text{Be}$ $Q_m = 5.1468$

Angular distributions have been studied at $E(^6\text{Li}) = 32$ MeV involving $^8\text{Be}^*(0, 3.0)$ and $^7\text{Li}^*(0, 0.48)$ (1985CO09). For reaction (b) see (1984KO25). For reaction (c) measurements at $E(^9\text{Be}) = 48$ MeV were evaluated with a CCBA model; $^8\text{Be}^*(3.04, 11.3)$ played an important role in the reaction (2003AS04). Also see ^{10}Be and (1985JA09). For the earlier work see (1979AJ01).

34. $^9\text{Be}(^{12}\text{C}, ^{13}\text{C})^8\text{Be}$ $Q_m = 3.2809$

Optical model parameters for $^8\text{Be} + ^{13}\text{C}$ were deduced from $^9\text{Be}(^{12}\text{C}, ^{13}\text{C})^8\text{Be}$ for $E(^{12}\text{C}) = 65$ MeV. For $^9\text{Be} + ^{12}\text{C}$ and $^8\text{Be} + ^{13}\text{C}$, energy-dependent optical model parameters are given for $E_{\text{cm}} = 5\text{--}50$ MeV (1999RU10).

35. $^{10}\text{Be}(p, t)^8\text{Be}$ $Q_m = 0.0042$

The angular distribution for the transition to the first $T = 2$ state $^8\text{Be}^*(27.49)$ is very similar to the measured $^{10}\text{Be}(p, ^3\text{He})$ angular distribution that is measured for population of the analog state, $^8\text{Li}^*(10.82)$. They are both consistent with $L = 0$ using a DWBA (LZR) analysis: see (1979AJ01, 1984AJ01) and Table 8.5 in (1984AJ01).

36. (a) $^{10}\text{B}(\pi^+, 2p)^8\text{Be}$ $Q_m = 132.1013$
 (b) $^{11}\text{B}(\pi^+, 2p n)^8\text{Be}$ $Q_m = 120.6472$

Total proton emission cross sections following π^+ absorption on ^{10}B and ^{11}B were measured at $E_{\pi^+} = 0, 100, 140$ and 180 MeV, corresponding cross sections were $\sigma[^{10}\text{B}(\pi^+, 2p)] = 8, 18, 17, 17$ mb and $\sigma[^{11}\text{B}(\pi^+, 2pn)] = 0.18, 0.80, 2.0, 3.4$ mb, respectively (1992RA11).

37. $^{10}\text{B}(K^+, K^+ + d)^8\text{Be}$ $Q_m = -6.0267$

Angular distributions were measured for $^{10}\text{B}(K^+, K^+d)$ at $E_{K^+} = 130\text{--}268$ MeV. A DWIA analysis indicated that direct knock-out and 2-step mechanisms are important (1991BE42).

$$38. \ ^{10}\text{B}(\gamma, p + n)^8\text{Be} \quad Q_m = -8.2513$$

Bremsstrahlung photons were used to measure the $^{10}\text{B}(\gamma, pn)$ reaction at $E_\gamma = 66\text{--}103$ MeV in a study of two-body photon absorption and final state interactions (1988SU14).

$$39. \ ^{10}\text{B}(n, t)^8\text{Be} \quad Q_m = 0.2305$$

The breakup of ^{10}B by 14.4 MeV neutrons involves, among others, $^8\text{Be}_{g.s.}$ (1984TU02). The cross section of $^{10}\text{B}(n, t)2\alpha$, for thermal neutrons is reported as $\sigma_{\text{thermal}} = 7 \pm 2$ mb (1987KA32). See also (1979AJ01) and ^{11}B in (1990AJ01).

$$40. \ ^{10}\text{B}(p, ^3\text{He})^8\text{Be} \quad Q_m = -0.5332$$

Angular distributions of the ^3He ions to $^8\text{Be}^*(0, 3.0, 16.6, 16.9)$ have been studied at $E_p = 39.4$ MeV [see (1974AJ01)] and at $E_p = 51.9$ MeV (1983YA05; see for a discussion of isospin mixing of the 16.8 MeV states).

$$41. \text{ (a) } ^{10}\text{B}(d, \alpha)^8\text{Be} \quad Q_m = 17.8198$$

$$\text{ (b) } ^{10}\text{B}(d, \alpha)^4\text{He}^4\text{He} \quad Q_m = 17.9117$$

Angular distributions have been reported at $E_d = 0.5$ to 7.5 MeV: see (1974AJ01, 1979AJ01). At $E_d = 67\text{--}141$ keV, angular distributions of α_0 and α_1 were measured and the $^{10}\text{B}(d, \alpha_0)$ and $^{10}\text{B}(d, \alpha_1)$ astrophysical S -factors were deduced (1997YA02). The angular-dependent cross sections for α_0, α_1 and 3α processes were measured for $E_d = 120\text{--}340$ keV and in each case the S -factor was observed to increase with decreasing energy (2001HO22). Yield ratios for $^{10}\text{B}(d, p)/^{10}\text{B}(d, \alpha)$ were measured at $E_d = 58\text{--}142$ keV (1993CE02). At $E_d = 7.5$ MeV the population of $^8\text{Be}^*(16.63, 16.92)$ is closely the same, consistent with their mixed isospin character while $^8\text{Be}^*(17.64)$ is relatively weak consistent with its nearly pure $T = 1$ character. $^8\text{Be}^*(16.63, 16.92, 17.64, 18.15)$ have been studied for $E_d = 4.0$ to 12.0 MeV. Interference between the 2^+ states $^8\text{Be}^*(16.63, 16.92)$ varies as a function of energy. The cross-section ratios for formation of $^8\text{Be}^*(17.64, 18.15)$ vary in a way consistent with a change in the population of the $T = 1$ part of the wave function over the energy range: at the higher energies, there is very little isospin violation. At higher E_x the 3^+ state at $E_x = 19.2$ MeV is observed, the neighboring 3^+ state at $E_x = 19.07$ MeV is not seen. $\Gamma_{16.6} = 90 \pm 5$ keV, $\Gamma_{16.9} = 70 \pm 5$ keV, $\Delta Q = 290 \pm 7$ keV: see Table 8.11 and (1979AJ01). Relative widths of ^8Be levels at 19.86 and 20.1 MeV, $\Gamma_\alpha/\Gamma_p = 2.3 \pm 0.5$ and $\Gamma_\alpha/\Gamma_p = 4.5 \pm 0.6$ respectively, were determined by a complete kinematics measurement of $^{10}\text{B}(d, 2\alpha)$ and $^{10}\text{B}(d, ^7\text{Li} + p)$ at $E_d = 13.6$ MeV

(1992PU06). At $E_d = 48$ MeV evidence was observed for an ${}^8\text{Be}$ state at $E_x = 32$ MeV with $\Gamma = 1$ MeV (1993PA31); levels were also seen at ${}^8\text{Be}^*(0, 3.0, 11.4, 16.6[\text{u}], 16.9[\text{u}], 17.6, \approx 19, \approx 20, 21.5, 22.2, 24, 25.2)$.

At $E_d = 4.2$ to 6.6 MeV measurements were carried out by detecting α coincidences in a kinematical star configuration (1992BO1H). ${}^{12}\text{C}$ was excited into the excitation energy region near 30 MeV, which was then followed by 3α decay. The analysis, which indicated sequential decay through the ${}^8\text{Be}^*(11.4)$ state, was intended to stimulate activity in 3-body interactions by invoking an alternative approach.

Reaction (b) [$E_d < 5$ MeV] takes place mainly by a sequential process involving ${}^8\text{Be}^*(0, 2.9, 11.4, 16.6, 16.9)$: see (1979AJ01). See also (1983DA11) [The work quoted in (1984AJ01) has not been published.] At $E_d = 13.6$ MeV in addition to ${}^8\text{Be}^*(16.6, 16.9)$, states with $E_x \approx 19.9\text{--}20.2$ MeV with $\Gamma \approx 0.7\text{--}1.1$ MeV are involved (1988KA1K). See also (1992KO26).

$$42. \quad {}^{10}\text{B}(\alpha, {}^6\text{Li}){}^8\text{Be} \quad Q_m = -4.5529$$

Angular distributions for the ${}^8\text{Be}^*(0, 3.0)$ are reported in a measurement of ${}^{10}\text{B}(\alpha, {}^6\text{Li})$ at $E_\alpha = 27.2$ MeV (1995FA21); it was deduced that direct processes are dominant in the reactions. See reaction 40 in (1984AJ01) and ${}^6\text{Li}$ in (2002TI10).

$$\begin{aligned} 43. \quad (a) \quad & {}^{11}\text{B}(\text{p}, \alpha){}^8\text{Be} & Q_m &= 8.590 \\ & (b) \quad {}^{11}\text{B}(\text{p}, \alpha){}^4\text{He}{}^4\text{He} & Q_m &= 8.682 \\ & (c) \quad {}^{11}\text{B}(\text{p}, 2\alpha){}^4\text{He} & Q_m &= 8.682 \end{aligned}$$

Angular distributions have been measured at $E_p = 0.04$ to 45 MeV [see (1974AJ01, 1979AJ01, 1984AJ01)]. The α_0 and α_1 excitation functions and astrophysical reaction rates have been determined by measuring angular dependent differential cross sections and total cross sections at $E_{\text{cm}} = 0.12\text{--}1.10$ MeV (1987BE17), at $E_p = 4.5$ to 7.5 MeV (1983BO19), at $E_p = 40\text{--}180$ keV (1992CE02), at $E_{\text{cm}} = 17\text{--}134$ keV (1993AN06), at $1.7\text{--}2.7$ MeV (1998MA54), and at $E_p = 0.4\text{--}1.6$ MeV (2002LI29). A DWBA evaluation of data at $398, 498$ and 780 keV indicated that direct mechanisms dominated over exchange processes at astrophysical energies (1995YA07). A calculation of the expected influence of electron screening, due to using atomic nuclei, indicates that the astrophysical $S(0)$ -factor deduced from lab measurements may be 2.5 times greater than the rate when bare ions participate in the reaction (1993AN06). See also (2002BA77, 2002HA51). The effects of higher order processes including vacuum polarization, relativity, bremsstrahlung, atomic screening and atomic polarization are reviewed in (1997BA95). See also (1996RA14) for DWBA analysis of data from $10\text{--}1000$ keV.

Angular distributions of α_0 and α_1 particles were measured around the ${}^{12}\text{C}^*(16.1)$ resonance at $E_p = 163$ keV; $E_{\text{cm}} = 148.3 \pm 0.1$ keV and $\Gamma = 5.3 \pm 0.2$ keV were deduced (1987BE17). The ${}^{12}\text{C}^*(16.57)$ resonance was evaluated in (p, α) data and resonance parameters of $E_{\text{res}} = 596 \pm 30$ keV and $\Gamma = 383 \pm 40$ keV were deduced (1993AN06).

Reaction (b) has been studied for $E_p = 0.15$ to 20 MeV: see (1974AJ01, 1984AJ01). The reaction proceeds predominantly by sequential two-body decay via ${}^8\text{Be}^*(0, 3.0)$. See also ${}^{12}\text{C}$ in (1990AJ01), and (1992KO26).

Reaction (c) was measured at $E_p = 2\text{--}5.5$ MeV by (1995BO35). A re-construction of the 2α relative energy spectrum was analyzed to evaluate parameters for ${}^8\text{Be}^*(3.0)$.

44. ${}^{11}\text{B}({}^3\text{He}, {}^6\text{Li}){}^8\text{Be}$ $Q_m = 4.571$

At $E({}^3\text{He}) = 71.8$ MeV angular distributions of the ${}^6\text{Li}$ ions to ${}^8\text{Be}^*(0, 3.0, 16.6, 16.9, 17.6, 18.2)$ are reported (1986JA14). For the earlier work at 25.6 MeV see (1979AJ01). See also (1986JA02).

45. ${}^{11}\text{B}(\alpha, {}^7\text{Li}){}^8\text{Be}$ $Q_m = -8.757$

The work reported in (1984AJ01) has not been published. See also ${}^7\text{Li}$ in (2002TI10) and references cited in (1988AJ01).

46. ${}^{11}\text{B}({}^9\text{Be}, {}^{12}\text{B}){}^8\text{Be}$ $Q_m = 1.705$

See (1984DA17) and ${}^{12}\text{B}$ in (1990AJ01).

47. ${}^{12}\text{C}(\gamma, p + t){}^8\text{Be}$ $Q_m = -27.1804$

The ${}^8\text{Be}$ ground state and excited 0^+ and 2^+ states are reported to participate in the ${}^{12}\text{C}$ photodisintegration reaction ${}^{12}\text{C}(\gamma, pt)$ at energies up to $E_\gamma = 150$ MeV; see (1989VO04, 1990DO03).

48. ${}^{12}\text{C}(e, e'\alpha){}^8\text{Be}$ $Q_m = -7.3666$

A DWIA calculation of ${}^{12}\text{C}(e, e'\alpha)$ at 500–650 MeV qualitatively evaluated the restructuring of excited clusters following knockout reactions (1999SA27).

49. ${}^{12}\text{C}(\pi^+, 3p + n){}^8\text{Be}$ $Q_m = 104.6903$

The energy and mass dependence of pion (π^+) absorption leading to multiple protons in the final state was measured at $E_{\pi^+} = 30\text{--}135$ MeV (2000GI07).

50. (a) $^{12}\text{C}(n, n\alpha)^8\text{Be}$ $Q_m = -7.3666$
 (b) $^{12}\text{C}(p, p\alpha)^8\text{Be}$ $Q_m = -7.3666$
 (c) $^{12}\text{C}(p, d + ^3\text{He})^8\text{Be}$ $Q_m = -25.7196$

The first two of these reactions involve $^8\text{Be}^*(0, 3.0)$: see (1974AJ01, 1979AJ01, 1984AJ01) and (1985AJ01). For reaction (a), see (1986AN22). For reaction (b) α -spectroscopic factors in ^{12}C for $\alpha + ^8\text{Be}^*(0, 3.0)$ are deduced in (1995NE11, 1997SA04, 1998YO09). The α -cluster knockout reaction mechanism is evaluated in (1987ZH10, 1994NE05, 1995GA39, 1995NE11, 1995TC01, 1997SA04, 1998YO09, 1999HA27). For reaction (c) see (1983LI18; theor.).

51. (a) $^{12}\text{C}(d, ^6\text{Li})^8\text{Be}$ $Q_m = -5.8927$
 (b) $^{12}\text{C}(d, d\alpha)^8\text{Be}$ $Q_m = -7.3666$

Measurements of angular distributions and polarization observables [$iT_{11}(\theta)$, $T_{20}(\theta)$, $T_{21}(\theta)$ and $T_{22}(\theta)$] are reported for $^{12}\text{C}(\vec{d}, ^6\text{Li})^8\text{Be}_{\text{g.s.}}$ at 18 and 22 MeV (1987TA07). DWBA analysis is used to evaluate α -spectroscopic factors from $^{12}\text{C}(d, ^6\text{Li})$ at $E_d = 41$ MeV (1988RA20) and at $E_d = 15$ – 55 MeV (1988RA27). Angular distributions have been studied at $E_d = 12.7$ to 54.3 MeV [see (1974AJ01, 1979AJ01, 1984AJ01)] and at $E_d = 18$ and 22 MeV (1986YA12; to $^8\text{Be}_{\text{g.s.}}$) and 51.7 MeV (1986YA12; to $^8\text{Be}^*(0, 3.0, 11.4)$) as well as at $E_d = 50$ MeV (1987GO1S), 54.2 MeV (1984UM04; FRDWBA) [$S_\alpha = 0.48, 0.51$ and 0.82 for $^8\text{Be}^*(0, 3.0, 11.4)$] and 78.0 MeV (1986JA14; to $^8\text{Be}^*(0, 3.0, 16.6, 16.9)$). See also (1985GO1G; $E_d = 50$ MeV). For reaction (b) see (1984AJ01). See also (1984NE1A) and references cited in (1988AJ01).

52. (a) $^{12}\text{C}(t, ^7\text{Li})^8\text{Be}$ $Q_m = -4.8997$
 (b) $^{13}\text{C}(t, ^8\text{Li})^8\text{Be}$ $Q_m = -7.8137$

Angular distributions from $^{12}\text{C}(t, ^7\text{Li})$ and $^{13}\text{C}(t, ^8\text{Li})$ were evaluated in a DWBA analysis to deduce spectroscopic factors in ^{12}C for $\alpha + ^8\text{Be}_{\text{g.s.}}$ (1989SI02). See also ^7Li in (2002TH10).

53. $^{12}\text{C}(^3\text{He}, ^7\text{Be})^8\text{Be}$ $Q_m = -5.7805$

Angular distributions have been obtained at $E(^3\text{He}) = 25.5$ to 70 MeV [see (1979AJ01, 1984AJ01)] and at $E(^3\vec{\text{He}}) = 33.4$ MeV (1986CL1B; $^8\text{Be}_{\text{g.s.}}$; also A_y). $^8\text{Be}^*(0, 3.0, 11.4, 16.6, 16.9, 17.6)$ have been populated.

54. (a) $^{12}\text{C}(\alpha, 2\alpha)^8\text{Be}$ $Q_m = -7.3666$
 (b) $^{12}\text{C}(\alpha, ^8\text{Be})^8\text{Be}$ $Q_m = -7.4584$

These reactions have been studied at E_α to 104 MeV [see (1979AJ01, 1984AJ01) and ^{12}C in (1985AJ01)] and at 31.2 MeV (1986XI1A; reaction (a)): $^8\text{Be}^*(0, 3.0, 11.4)$ are populated. See also references cited in (1988AJ01). Alpha spectroscopic factors $^8\text{Be}^*(0, 3.0)$ were measured by $(\alpha, 2\alpha)$ knockout at 200 MeV (1999ST06) and 580 MeV (1999NA05). α -particle angular correlations were measured from the $^{12}\text{C}^* \rightarrow \alpha + ^8\text{Be}$ decay to determine the polarization characteristics of the $^{12}\text{C}^*(9.64; 3^-)$ state, which was excited by $^{12}\text{C}(\alpha, \alpha')^{12}\text{C}^*(9.64) \rightarrow \alpha + ^8\text{Be}$ (1989KO55).

$$\begin{aligned} 55. \text{ (a) } & ^{12}\text{C}(^9\text{Be}, ^{13}\text{C})^8\text{Be} & Q_m = 3.2809 \\ & \text{ (b) } & ^{12}\text{C}(^{11}\text{B}, ^{15}\text{N})^8\text{Be} & Q_m = 3.6248 \end{aligned}$$

Angular distributions involving $^8\text{Be}_{\text{g.s.}} + ^{13}\text{C}_{\text{g.s.}}$ (reaction (a)) have been reported at $E(^9\text{Be}) = 20$ to 22.9 MeV and $E(^{12}\text{C}) = 10.5$ to 13.5 MeV: see (1984AJ01). For both reactions see also (1983DEZW).

$$\begin{aligned} 56. \text{ (a) } & ^{12}\text{C}(^{12}\text{C}, ^{16}\text{O})^8\text{Be} & Q_m = -0.2047 \\ & \text{ (b) } & ^{12}\text{C}(^{16}\text{O}, ^{20}\text{Ne})^8\text{Be} & Q_m = -2.6367 \\ & \text{ (c) } & ^{12}\text{C}(^{20}\text{Ne}, ^{24}\text{Mg})^8\text{Be} & Q_m = 1.9500 \\ & \text{ (d) } & ^{12}\text{C}(^{20}\text{Ne}, \alpha + ^{20}\text{Ne})^8\text{Be} & Q_m = -7.3666 \\ & \text{ (e) } & ^{12}\text{C}(^{24}\text{Mg}, ^{16}\text{O} + ^{12}\text{C})^8\text{Be} & Q_m = -14.1382 \end{aligned}$$

For reaction (a) $^{12}\text{C}(^{12}\text{C}, ^{16}\text{O})$ was measured in a study of ^{24}Mg excited states near 33 MeV at $E(^{12}\text{C}) = 27$ –36 MeV (1995AL25, 1996AL03, 1997SZ01). See also ^{16}O in (1993TI07) and references cited in (1988AJ01). For reaction (b) see reaction 18 in ^{20}Ne in (1987AJ02), (1985MU14) and (1988AL07; location of a 10^+ state in ^{20}Ne at $E_x \approx 27.5$ MeV). Evidence for 11 states in ^{24}Mg with excitation energy between 22 and 30 MeV is seen in reaction (c) at $E(^{20}\text{Ne}) = 110$ and 160 MeV (2001FR03). For reaction (d) see (1987SI06). States in ^{28}Si at $E_x = 28.0$ MeV [$J^\pi = 13^-$], 29.8 MeV [(11)], 33.4 MeV [$8^+(10^+)$] and 34.5 MeV [(12, 14) $^+$] are observed in reaction (e) at $E(^{24}\text{Mg}) = 170$ MeV (2001SH08).

$$57. \ ^{13}\text{C}(d, ^7\text{Li})^8\text{Be} \quad Q_m = -3.5888$$

See ^7Li in (2002TI10).

$$58. \ ^{13}\text{C}(\alpha, ^9\text{Be})^8\text{Be} \quad Q_m = -10.7393$$

See (1984SH1D, 1988SH1F; $E_\alpha = 27.2$ MeV) and ^9Be in (1979AJ01).

$$59. \ ^{13}\text{C}(^9\text{Be}, ^{14}\text{C})^8\text{Be} \quad Q_m = 6.5110$$

See ^{14}C in (1986AJ01).

60. $^{14}\text{N}(n, ^7\text{Li})^8\text{Be}$ $Q_m = -8.9148$

See ^7Li in (2002TI10).

61. $^{16}\text{O}(\gamma, 4\alpha)$ $Q_m = -14.4367$

The $^{16}\text{O}(\gamma, 4\alpha)$ reaction was studied with bremsstrahlung γ rays up to $E_\gamma = 300$ MeV (1995GO10). Evidence in the energy reconstruction spectra indicates that participation of the $^8\text{Be}^*(0, 3.0)$ states increases with increasing γ -ray energy.

62. $^{16}\text{O}(p, p + 2\alpha)^8\text{Be}$ $Q_m = -14.5285$

See (1986VD04; $E_p = 50$ MeV).

63. $^{16}\text{O}(^{16}\text{O}, ^{24}\text{Mg})^8\text{Be}$ $Q_m = -0.4821$

See (1987CZ02).

64. $^{\text{nat}}\text{Ag}(^{14}\text{N}, ^8\text{Be})X$

Sequential-decay neutron spectroscopy of $^7\text{Be} + n$ products from $^{\text{nat}}\text{Ag} + ^{14}\text{N}$ at 35 MeV/A indicates the participation of $^8\text{Be}^*(19.24)$ with 19.234 ± 0.012 MeV and $\Gamma = 210 \pm 35$ keV (1989HE24).

⁸B

(Figs. 4 and 5)

GENERAL: References to articles on general properties of ⁸B published since the previous review (1988AJ01) are grouped into categories and listed, along with brief descriptions of each item, in the General Tables for ⁸B located on our website at (www.tunl.duke.edu/nucldata/General_Tables/8b.shtml).

$$\mu = 1.0355 \pm 0.0003 \mu_N: \text{ see (1996FIZY).}$$

$$Q = 68.3 \pm 2.1 \text{ mb (1992MI18, 1993MI35).}$$

1. ⁸B(β^+)⁸Be $Q_m = 17.9798$

The β^+ decay leads mainly to ⁸Be*(3.0). The half-life is 770 ± 3 msec; $\log ft = 5.6$ (1974AJ01). There is also a branch to ⁸Be*(16.63), and evidence for population of an ⁸Be intruder state at $E_x \approx 9$ MeV. See reactions 24 and 27 in ⁸Be. See also references cited in (1988AJ01).

A new β -NMR technique (NNQR) was used to measure the quadrupole moment of ⁸B, $|Q(^8\text{B}, 2^+)| = 68.3 \pm 2.1$ mb (1992MI18, 1993MI35). The large quadrupole moment was reported as the first evidence of a proton halo in ⁸B.

The tilted foil technique was used to polarize atomic ⁸B nuclei. The polarization was transferred to the nucleus via the hyperfine interaction and the resulting β -decay asymmetry indicated that the polarization was saturated at $3.71 \pm 0.28\%$ (1993MO34).

The β -decay of ⁸B provides the high-energy neutrinos that are measured by large volume neutrino detectors that are attempting to resolve the “solar neutrino problem”. The neutrino energy spectrum from ⁸B β -decay, which is essential to interpret the data from these detectors, has been measured and evaluated in (1987NA08, 1996BA28, 1999DE33, 2000OR04, 2003RE26, 2003WI16). The ⁸B neutrino absorption cross sections ($\pm 3\sigma$) for Cl and Ga are $\sigma_{\text{Cl}} = 1.14 \pm 0.11 \times 10^{-42}$ cm² and $\sigma_{\text{Ga}} = 2.46_{-1.1}^{+2.1} \times 10^{-42}$ cm² (1996BA28). However, the results of (2000OR04) suggest a harder neutrino spectrum than that used by (1996BA28).

For comments about the weak neutral current interaction in ⁸B β -decay see (1989TE04, 1992DE07, 2003SM02). For theoretical discussion of ⁸Be levels that are involved in the decay see (1989BA31, 1993CH06, 2000GR07, 2002BH03) and reaction 27 in ⁸Be.

2. ⁶Li(d, π^-)⁸B $Q_m = -135.2692$

At $E_d = 300$ and 600 MeV ⁸B*(0, 0.77, 2.32) are populated: see (1984AJ01).

3. ⁶Li(³He, n)⁸B $Q_m = -1.9748$

Table 8.15: Energy levels of ${}^8\text{B}$ ^a

E_x (MeV \pm keV)	$J^\pi; T$	$\tau_{1/2}$ or Γ_{cm} (keV)	Decay	Reactions
g.s.	$2^+; 1$	$\tau_{1/2} = 770 \pm 3$ msec	β^+	1, 2, 3, 4, 5, 6, 8, 9, 10, 12
0.7695 ± 2.5 ^{b,c}	$1^+; 1$ ^{c,d}	$\Gamma = 35.6 \pm 0.6$ ^{b,c}	γ, p	2, 3, 4, 6, 7, 9, 10, 12
2.32 ± 20 ^c	$3^+; 1$	350 ± 30 ^c		4, 6, 7, 9, 10, 12
3.5 ± 500 ^c	2^-	8 ± 4 MeV ^c		6, 7
10.619 ± 9	$0^+; 2$	< 60		12

^a See reactions 6 and 7 for evidence of additional states.

^b Average of values from reactions 3, 6 and 7.

^c From data reviewed in this evaluation.

^d See (2004TA17).

Table 8.16: Electromagnetic transition strengths in ${}^8\text{B}$

$E_i \rightarrow E_f$ (MeV)	$J_i^\pi; T_i \rightarrow J_f^\pi; T_f$	Γ_γ (eV)	Mult.	Γ_γ/Γ_w
$0.7695 \rightarrow 0$	$(1^+; 1) \rightarrow 2^+; 1$	$(2.52 \pm 0.11) \times 10^{-2}$ ^a	M1	2.63 ± 0.12
$2.32 \rightarrow 0$	$3^+; 1 \rightarrow 2^+; 1$	0.10 ± 0.05 ^b	M1	0.38 ± 0.19

^a Γ_γ is an average of 24.8 ± 2.9 meV (2003BA51) and 25.3 ± 1.2 meV (2003JU04).

^b From a reanalysis of the data in (2003JU04) [K.A. Snover, private communication].

Angular distributions for the n_0 group have been reported at $E(^3\text{He}) = 4.8$ to 5.7 MeV: $L = 0$. Two measurements for the E_x of $^8\text{B}^*(0.77)$ are 767 ± 12 and 783 ± 10 keV [$\Gamma = 40 \pm 10$ keV]: see (1974AJ01) and ^9B .

$$4. \ ^7\text{Li}(p, \pi^-)^8\text{B} \quad Q_m = -140.2949$$

Angular distributions and analyzing powers have been measured for the transitions to $^8\text{B}^*(0, 0.77, 2.32)$ at $E_p = 199.2$ MeV (1987CA06) and at 280, 345 and 489 MeV (1988HU11): the A_y to $^8\text{B}^*(2.32)$ is characteristic of that to a stretched high-spin, two-particle one-hole final state [J^π of $^8\text{B}^*(2.32)$ is 3^+] (1987CA06).

$$5. \ ^7\text{Li}(^7\text{Li}, ^6\text{H})^8\text{B} \quad Q_m = -34.966$$

See ^6H .

$$6. \ ^7\text{Be}(p, \gamma)^8\text{B} \quad Q_m = 0.1375$$

Absolute cross sections have been measured for $E_p = 112$ keV to 10.0 MeV. See also (1984AJ01) and references cited in (1988AJ01). Resonances are observed at $E_p = 720$ and 2497 keV: see Table 8.17. An R -matrix evaluation of (p, γ) and (p, p') [reaction 7] data supports the existence of a 2^- level at $E_x = 3\text{--}4$ MeV (2000BA46), and a 1^+ resonance is predicted at $E_x \approx 1.4$ MeV (2000CS01). See however (2001RO32) and reaction 9.

Direct measurements of $^7\text{Be}(p, \gamma)$ at low energies are typically carried out by measuring β -delayed alpha particles from decay of the residual ^8B nucleus. However, systematic errors associated with ^8B backscattering losses from the target prior to counting have become a concern, based on new measurements and Monte Carlo calculations (see (1998ST20) and reaction 9 in ^8Li).

A review of astrophysical reaction rates (1998AD12) favored the measurements of (1982FI03) and deduced a value of $S(0) = 19_{-2}^{+4}$ eV \cdot b, however, several measurements [see Table 8.18] have been reported since this review. See other overviews of direct and indirect measurements in (2001MO32, 2001MU20, 2002MO11, 2003DA30, 2003MO23, 2003MO28): for cluster model calculations see (1988DE38, 1988KO29, 1993DE30, 1993RO04, 1994DE03, 1995CS01, 1997CS07, 1998CS03, 1998MO13, 2000CS03); for direct-plus-resonances and R -matrix calculations see (1987KI01, 1988BA29, 1993KR18, 1995BA36); and for shell model calculations see (1996BR04, 1998BE44). See also (1992SC22, 1993TR06, 1994SC14, 2003CH79, 2003PA33).

The role of electron screening and other effects, for example, ^7Be deformation, are discussed in (1994KA02, 1997CS07, 1997NU01, 1998BE1Q, 2000LI13). The correlation of the capture rate with properties such as the ^8B quadrupole-moment and the ^8B valence proton spatial distribution is discussed in (1993RI04, 1996BR04, 1998CS03, 2000CS03, 2000JE10, 2001CS03).

The nature of the shape of the S -factor as the proton capture energy approaches zero is discussed in (1998JE04, 1998JE10, 1998JE11, 2000BA09, 2000BB09, 2000JE10, 2002MU16). The authors of

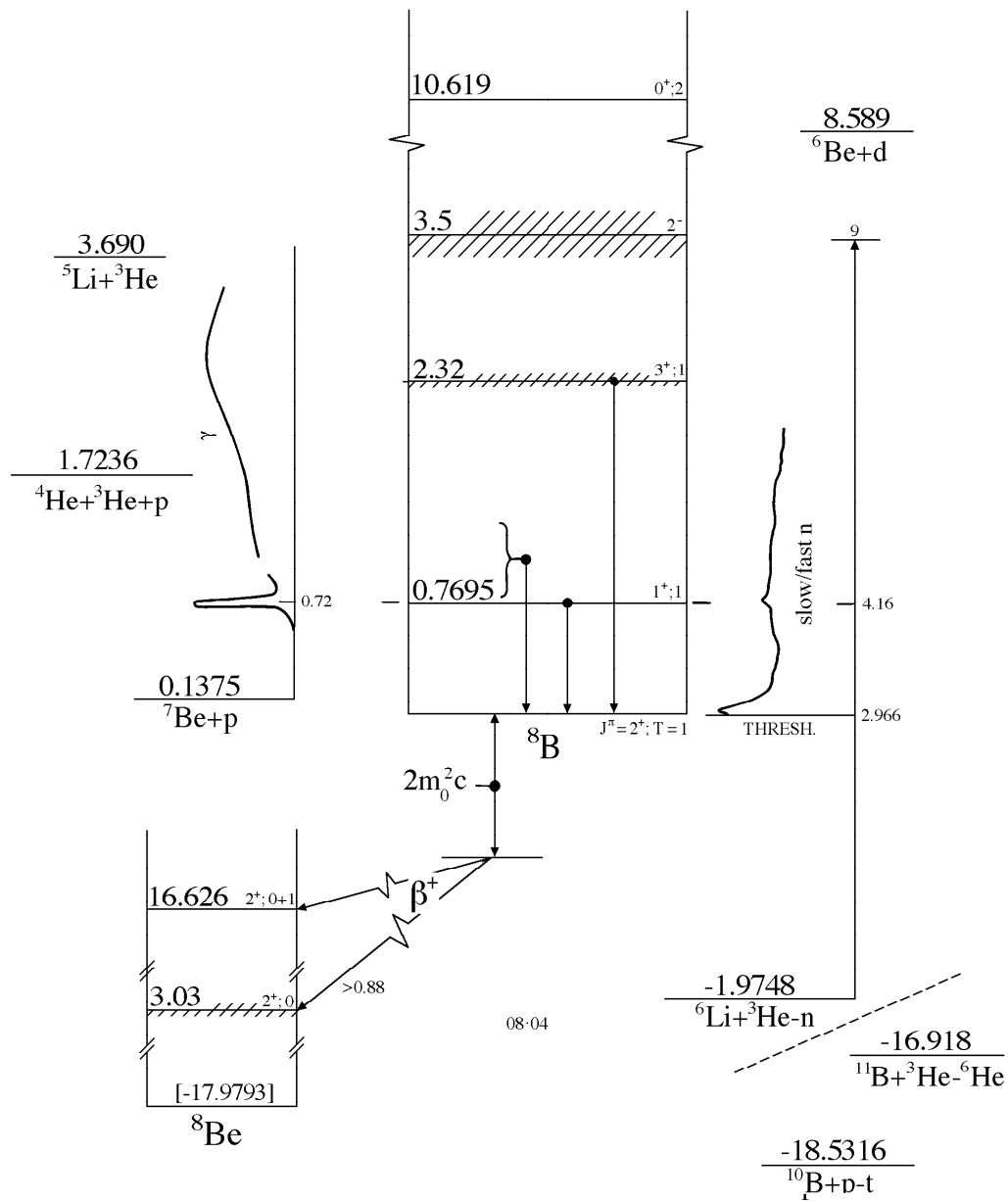


Figure 4: Energy levels of ${}^8\text{B}$. For notation see Fig. 2.

Table 8.17: Resonances observed in ${}^7\text{Be}(p, \gamma){}^8\text{B}$

E_{cm} (keV)	Γ_{p} (keV)	σ (nb)	Γ_{γ} (meV)	Reference
632 ± 10	37 ± 5	1180 ± 120	24.7 ± 4.2	(1983FI13)
633	35 ± 3	1250 ± 100	24.8 ± 2.9	(2003BA51)
630 ± 3	35.7 ± 0.6		25.3 ± 1.2	(2003JU04)
630 ± 3	35.7 ± 0.6	1221 ± 77	25.2 ± 1.1	“mean” value ^a
2183	350		100 ± 50 ^b	(2003JU04)

^a Excludes $\sigma_{\text{R}} = 2200 \pm 220$ nb, $\Gamma_{\gamma} = 50 \pm 25$ meV from (1966PA16), which had been cited in (1988AJ01).

^b Private communication from K.A. Snover; revised from $\Gamma_{\gamma} = 150 \pm 30$ meV (2003JU04).

(1998JE10, 2000VE01) suggest that $S(20 \text{ keV})$ is more relevant than $S(0)$ since the Gamow energy is $\approx 20 \text{ keV}$, and they suggest that the extrapolation of the reaction rate to 20 keV has less uncertainty than the extrapolation to zero energy proton capture.

The time reversed reaction ${}^8\text{B} + \gamma \rightarrow {}^7\text{Be} + \text{p}$ has been measured by exciting ${}^8\text{B}$ nuclei in the Coulomb field of high- Z target nuclei and detecting the ${}^7\text{Be}$ and proton products (1994MO33, 1998KI19, 1999IW03, 2001DA03, 2001DA11, 2002DA15, 2002DA26, 2003HA30, 2003SC14). The ${}^7\text{Be}(p, \gamma){}^8\text{B}$ cross sections are related to the photodisintegration cross sections by the Detailed Balance Theorem. Resulting values of $S(0)$ are $18.9 \pm 1.8 \text{ eV} \cdot \text{b}$ (1998KI19; RIKEN), $18.6 \pm 1.2(\text{expt.}) \pm 1.0(\text{theor.}) \text{ eV} \cdot \text{b}$ (1999IW03, 2003HA30, 2003SC14; GSI), and $17.8_{-1.2}^{+1.4} \text{ eV} \cdot \text{b}$ (2001DA03, 2001DA11, 2002DA15, 2002DA26; MSU). The field of virtual photons that induce breakup can excite the ${}^8\text{B}$ mainly via E1 and E2 multiplicities; however, the proton capture reaction is dominated by E1 strength. Since the numbers of E1 and E2 virtual photons created in the Coulomb field of the target are calculable, depending on projectile energy and impact parameter, the ratio of $\sigma(\text{E2})/\sigma(\text{E1})$ in the Coulomb dissociation experiments was deduced from asymmetries in, for example, the measured angular distributions. Values for the ratio, which depends on the relative $\text{p} + {}^7\text{Be}$ energy and theory that is used to determine the E2 strength, range from $(0.5 \text{ to } 5) \times 10^{-4}$ at $E_{\text{cm}} = 0.6 \text{ MeV}$ (1997KI01, 1999IW03, 2001DA03, 2001DA11, 2002DA15, 2003SC14). See also (1996KE16, 1996VO09). Calculated estimates of the $\sigma(\text{E2})/\sigma(\text{E1})$ ratio in Coulomb dissociation are given in (1994LA08, 1995GA25, 1995LA17, 1996BE83, 1996ES02, 1996SH08, 1997TY01, 1999BB07, 1999DE23, 2002BE76, 2003FO07). Interference between nuclear and Coulomb mechanisms is discussed in (1997TY01, 1998DA15, 1998NU01, 2003MA88). See also (1993TI01, 1994TY03, 1996RE16, 1997CS02).

Calculations showing the relationship between the low-energy astrophysical S -factor for ${}^7\text{Be}(p, \gamma)$ and the asymptotic normalization coefficient (ANC) for (${}^7\text{Be}, {}^8\text{B}$) reactions are presented in (1990MU13, 1994XU08, 1995MU10, 1997TI03, 1998GR07, 2000JE10, 2003TI13). See also reactions 8 and 11.

7. ${}^7\text{Be}(p, p){}^7\text{Be}$

$$E_{\text{b}} = 0.1375$$

The ${}^7\text{Be}(p, p)$ scattering was measured at $E_{\text{cm}} = 0.3\text{--}0.75$ MeV using a ${}^7\text{Be}$ beam (2003AN29). The data were analyzed in an R -matrix analysis and indicate $E_{\text{res}} = 634 \pm 5$ keV and $\Gamma_{\text{res}} = 31 \pm 4$ keV for the 1^+ first excited state. Scattering length of $a_{01} = 25 \pm 9$ fm (channel spin $I = 1$) and $a_{02} = -7 \pm 3$ fm (channel spin $I = 2$) were also deduced from the data.

At $E({}^7\text{Be}) = 32$ MeV (1998GO16), two resonances were prominent in the inverse kinematics scattering excitation function, $E_x = 2.32 \pm 0.02$ MeV, $\Gamma = 350 \pm 30$ keV, $J^\pi = 3^+$ and $E_x = 2.83 \pm 0.15$ MeV, $\Gamma = 780 \pm 200$ keV, $J^\pi = 1^+$, though poor statistics in the measurement prevent a firm acceptance of the 2.83 MeV level. In addition there was evidence for a broad 2^- or 1^- level at ≈ 3 MeV. At $E({}^7\text{Be}) = 25.5$ MeV the $E_x = 2.32$ MeV $J^\pi = 3^+$ level was observed with an additional level at $E_x = 3.5 \pm 0.5$ MeV, $\Gamma = 8 \pm 4$ MeV (2001RO32). An R -matrix analysis of the interference between the 2.32 and 3.5 MeV levels indicates $J^\pi = 2^-$ for the higher state. In the later work, the 1^+ state at $E_x = 2.8$ MeV, suggested by (1998GO16), was not necessary to obtain a good fit to the data. In addition there was no evidence for a level at $E_x = 1.4$ MeV that had been suggested by (2000CS01): see reaction 6.

$$8. {}^7\text{Be}(d, n){}^8\text{B} \quad Q_{\text{m}} = -2.0871$$

The total ${}^2\text{H}({}^7\text{Be}, n)$ cross section was measured at $E({}^7\text{Be}) = 26$ MeV ($\sigma_{\text{tot}} = 58 \pm 8$ mb) and was evaluated to determine the ${}^8\text{B} \rightarrow {}^7\text{Be} + p$ asymptotic normalization coefficient (ANC) $C_{\text{p}3/2}^2 = 0.711 \pm 0.092$ fm $^{-1}$. This can be related to the ${}^7\text{Be}(p, \gamma)$ astrophysical capture rate and indicates $S_{17}(0) = 27.4 \pm 4.4$ eV \cdot b (1996LI12, 1997LI05). Re-analysis of the data using better optical model parameters indicates a smaller ANC and a reduced value of $S_{17}(0) = 23.5 \pm 3.7$ eV \cdot b (1998GA02, 1999FE04). To remove the dependence on the optical model parameters, (2003OG02) performed a Continuum-Discretized coupled channels calculation using the spectroscopic factors $S = 0.849$ (1987KI01), from this they deduce $S_{17}(0) = 20.96$ eV \cdot b.

$$9. {}^9\text{Be}({}^7\text{Li}, {}^8\text{He}){}^8\text{B} \quad Q_{\text{m}} = -28.264$$

Angular dependent differential cross sections were measured for ${}^9\text{Be}({}^7\text{Li}, {}^8\text{He}){}^8\text{B}$ from 0° to $\approx 12^\circ$ at $E({}^7\text{Li}) = 350$ MeV. States in ${}^8\text{B}$ were observed at 0, 0.770 and 2.32 MeV (2001CA37).

$$10. {}^{10}\text{B}(p, t){}^8\text{B} \quad Q_{\text{m}} = -18.5316$$

At $E_{\text{p}} = 49.5$ MeV [see (1974AJ01)] and 51.9 MeV (1983YA05) angular distributions have been measured for the tritons to ${}^8\text{B}^*(0, 2.32)$: $L = 2$ and $L = 0 + 2$ leading to $J^\pi = 2^+$ and 3^+ , respectively. Measurements of E_x for ${}^8\text{B}^*(2.32)$ yield 2.29 ± 0.05 MeV and 2.34 ± 0.04 MeV [$\Gamma_{\text{lab}} = 0.39 \pm 0.04$ MeV]. ${}^8\text{B}^*(0.77)$ is also observed: see (1974AJ01).

$$11. \text{(a) } {}^{10}\text{B}({}^7\text{Be}, {}^8\text{B}){}^9\text{Be} \quad Q_{\text{m}} = -6.4484$$

$$\text{(b) } {}^{14}\text{N}({}^7\text{Be}, {}^8\text{B}){}^{13}\text{N} \quad Q_{\text{m}} = -9.6335$$

Table 8.18: Summary of recent direct measurements of ${}^7\text{Be}(p, \gamma){}^8\text{B}$ ^a

Energy	$S(0)$ factor (eV · b)	Refs.
$E_{\text{cm}} = 117\text{--}1230$ keV	21.7 ± 2.5	(1983FI13)
$E_p = 0.35\text{--}1.4$ MeV	18.5 ± 1.0 ^b	(1997SC46, 1998HA05)
$E_{\text{cm}} = 1.09$ and 1.29 MeV	20.3 ^c	(1999HA51)
$E_p = 0.32\text{--}2.61$ MeV	18.4 ± 0.6	(2001ST27)
$E_p = 111.7, 134.7$ and 185.8 keV	18.8 ± 1.7 ^d	(2001HA26, 2001HA36)
$E_{\text{cm}} = 116\text{--}2460$ keV	$22.1 \pm 0.6(\text{expt.}) \pm 0.6(\text{theory})$ ^e	(2003JU04)
$E_{\text{cm}} = 992$ keV ^f	16 ± 4	(2000GL04)
	15.3 ± 4.5	(2001TE03)
$E_{\text{cm}} = 302\text{--}1078$ keV	21.2 ± 0.7 ^g	(2003BA04, 2003BA51, 2003BA84)

^a See (1983FI13, 1998AD12) for discussion of prior measurements.

^b Depending on the extrapolation theory, values of $S(0)$ ranging from 16.6 to 20.0 eV · b were deduced; $S(0) = 18.5 \pm 1.0$ eV · b was recommended.

^c Measured $S(1.09 \text{ MeV}) = 22.7 \pm 1.2$ eV · b and $S(1.29) = 23.8 \pm 1.5$ eV · b using a ${}^7\text{Be}$ target that was implanted on a Cu backing [to minimize backscattering losses]; these values are extrapolated to $S(0) = 20.3$ eV · b.

^d Weighted mean including data from (1998HA05), data below 0.43 MeV yield $S(0) = 19.2 \pm 1.2$ eV · b.

^e Based on $E_{\text{cm}} = 116\text{--}362$ keV. This value is revised from $S = 22.3 \pm 0.6(\text{expt.}) \pm 0.6(\text{theory})$ which was given in (2001JU01, 2002JU01).

^f Measurement with ${}^7\text{Be}$ particles on a windowless hydrogen target: $\sigma(992 \text{ keV}) = 0.41 \pm 0.11$ p-barns.

^g Cu substrate with implanted ${}^7\text{Be}$. The low-energy part of the data extrapolate to $S(0) = 20.8 \pm 1.3$ eV · b.

In reaction (a) the asymptotic normalization coefficient (ANC), $C_{3/2}^2$, for ${}^8\text{B} \rightarrow {}^7\text{Be} + p$ was determined by measuring differential cross sections for ${}^{10}\text{B}({}^7\text{Be}, {}^8\text{B})$ from 0° to $\approx 35^\circ$ at $E({}^7\text{Be}) = 84$ MeV. The value of $C_{p_{3/2}}^2 = 0.398 \pm 0.062 \text{ fm}^{-1}$ was deduced which, together with $C_{1/2}^2/C_{3/2}^2 = 0.157$, corresponds to $S_{17}(0) = 17.8 \pm 2.8$ eV · b (1999AZ02). For reaction (b) $C_{p_{3/2}}^2 = 0.371 \pm 0.043 \text{ fm}^{-1}$ was measured in ${}^{14}\text{N}({}^7\text{Be}, {}^8\text{B})$ at $E({}^7\text{Be}) = 85$ MeV, and $S_{17}(0) = 16.6 \pm 1.9$ eV · b was deduced (1999AZ04).

A re-evaluation of the data from (a) and (b) using improved model parameters leads to revised values and a weighted average of $C_{p_{3/2}}^2 = 0.388 \pm 0.039 \text{ fm}^{-1}$ which corresponds to $S(0) = 17.3 \pm 1.8$ eV · b (2001AZ01, 2001GA19, 2002GA11). In addition, the $C_{p_{3/2}}^2$ gives $R_{\text{r.m.s.}} = 4.20 \pm 0.22$ fm for the valence proton (2001CA21). See also ${}^{13}\text{C}({}^7\text{Li}, {}^8\text{Li}){}^{12}\text{C}$ [reaction 27 in ${}^8\text{Li}$] for a determination of the ANC from charge symmetry.

12. ${}^{11}\text{B}({}^3\text{He}, {}^6\text{He}){}^8\text{B}$

$$Q_m = -16.9175$$

At $E(^3\text{He}) = 72$ MeV the first $T = 2$ state is observed at $E_x = 10.619 \pm 0.009$ MeV, $\Gamma < 60$ keV: $d\sigma/d\Omega$ (lab) = 190 nb/sr at $\theta_{\text{lab}} = 9^\circ$. No other states are observed within 2.4 MeV of this state. $^8\text{B}^*(0, 0.77, 2.32)$ have also been populated: see (1979AJ01).

13. $^{12}\text{C}(\pi^+, \text{dd})^8\text{B}$ $Q_m = 90.3772$

The pion absorption mechanism, which has a characteristic of high energy transfer and small momentum transfer, was studied at $E(\pi^+) = 100$ and 165 MeV (2002HU06). The role of 2-step processes, such as pion scattering prior to absorption and nucleon pickup after absorption, is discussed, and simple models for neutron-pickup final state interactions are presented and shown to reasonably represent the data.

14. $^{12}\text{C}(^8\text{B}, ^8\text{B})^{12}\text{C}$

Angular distributions from quasielastic scattering of ^8B on ^{12}C were measured at 40 MeV/A (1995PE09). Analysis of the data appears consistent with a proton halo (1995FA17, 1996KN05, 1997PE03).

15. $^{14}\text{C}(^8\text{B}, ^8\text{B})^{14}\text{C}$

Elastic scattering of ^8B on ^{14}C was calculated in a folding potential model. Results suggest that scattering of exotic nuclei from non- $N = Z$ nuclei could reveal new information about the nuclear potentials, particularly in cases where rainbow effects are observed (1998KN02).

16. $^{\text{nat}}\text{C}(\mu, ^8\text{B})\text{X}$

A measurement to determine muon induced background rates in large-volume scintillation solar neutrino detectors found $\sigma = 4.16 \pm 0.81$ μb and 7.13 ± 1.46 μb for $^{\text{nat}}\text{C}(\mu, ^8\text{B})$ at $E_\mu = 100$ and 190 GeV, respectively (2000HA33).

17. $^{58}\text{Ni}(^8\text{B}, ^7\text{Be})^{59}\text{Cu}$ $Q_m = 3.2810$

Angular distributions of ^7Be following the breakup of ^8B on a ^{58}Ni target were measured at $E(^8\text{B}) = 25\text{--}75$ MeV to evaluate the importance of Coulomb-nuclear interference effects (2000GU05).

18. ^9Be to $^{208}\text{Pb}(^8\text{B}, \text{X})$

Table 8.19: Inclusive measurements of ${}^8\text{B}$ breakup

${}^8\text{B}$ energy (MeV/A)	Target	Refs.
10–40	${}^{\text{nat}}\text{Si}$	(1996NE06, 1997SK03)
20–60	${}^{\text{nat}}\text{Si}$	(1995WA19)
40	${}^{12}\text{C}$	(1995PE09, 1996SK04)
40, 60	${}^9\text{Be}$, ${}^{12}\text{C}$, ${}^{27}\text{Al}$	(1999FU08)
41	${}^9\text{Be}$, ${}^{197}\text{Au}$	(1996KE16)
44, 81	${}^{208}\text{Pb}$	(1998DA14)
76	${}^{12}\text{C}$	(2003EN05)
142, 285	${}^{\text{nat}}\text{C}$, ${}^{27}\text{Al}$, ${}^{\text{nat}}\text{Sn}$, ${}^{208}\text{Pb}$	(1997BL08)
790	${}^9\text{Be}$, ${}^{12}\text{C}$, ${}^{27}\text{Al}$	(1988TA10, 1996OB01)
936	${}^{\text{nat}}\text{C}$, ${}^{\text{nat}}\text{Pb}$	(2002CO04, 2002CO06, 2003ME16)
1440	${}^{12}\text{C}$	(1999SM04)
1440	${}^{12}\text{C}$, ${}^{208}\text{Pb}$	(2001CO06)
1470	${}^{12}\text{C}$, ${}^{27}\text{Al}$, ${}^{208}\text{Pb}$	(1995SC10)

Inclusive measurements of ${}^8\text{B}$ breakup have been reported: see Table 8.19.

The measured total reaction cross sections for nuclear processes are related to the ${}^8\text{B}$ r.m.s. radius and valence proton r.m.s. radius in simple Glauber-type models. The cross sections range from $\sigma_{\text{tot}} \approx 800$ mb and $\sigma(\text{proton removal}) \approx 95$ mb at $E({}^8\text{B}) = 1471$ MeV/A on a ${}^{12}\text{C}$ target to $\sigma_{\text{tot}} \approx 1.95$ b at $E({}^8\text{B}) \approx 15$ MeV/A on Si (1995WA19, 1996NE06). These cross sections correspond to ${}^8\text{B}$ r.m.s. radii around 2.43 ± 0.01 fm (1996OB01); the valence proton r.m.s. radius deduced from the proton removal cross-section measurements is model dependent and values in the range of 3.97 ± 0.12 fm (1996NE06) to 6.83 fm (1995SC10) are deduced. See also (1997KN07, 1998SH09, 1999KN04). A review of nuclear sizes deduced from interaction cross sections is in (2001OZ04).

Measurements of the parallel momentum distribution of ${}^7\text{Be}$ fragments following the breakup of ${}^8\text{B}$ projectiles are reported in (1995SC10, 1996KE16, 1996NE06, 1997SC03, 1998DA14, 1999SM04, 2000CO31) and are interpreted in Serber-type models as reflecting detailed information about the ${}^8\text{B}$ valence proton wave function. At $E({}^8\text{B}) = 1.47$ GeV/A the momentum distribution widths from breakup on C, Al and Pb are $\Gamma_{\text{FWHM}} \approx 81 \pm 6$ MeV/c (1995SC10). This width is much narrower than that expected from the breakup of nuclei with “normal” densities and was interpreted as an indication of a proton halo in ${}^8\text{B}$. However, at energies near 40 MeV/A the momentum distribution of ${}^7\text{Be}$ fragments from ${}^8\text{B}$ breakup range from $\Gamma = 62 \pm 3$ MeV/c on an Au target (mainly Coulomb breakup processes) (1996KE16) to $\Gamma = 95 \pm 7$ MeV/c on a Si target (mainly nuclear breakup processes) (1996NE06); this is an indication that at this energy, simple Serber-type models are not adequate to explain the observed momentum distributions since the breakup mechanisms play a role in determining the observed distributions.

By evaluating fragment momentum distributions in more complex models, it was suggested that the asymmetric ${}^7\text{Be}$ fragment momentum distribution from ${}^8\text{B}$ breakup on Au at 41 MeV/A reflects the in-

Table 8.20: Isospin triplet states ($T = 1$) in $A = 8$ nuclei ^a

⁸ Li		⁸ Be			⁸ B		
E_x (MeV)	J^π	E_x (MeV)	J^π	ΔE_x (MeV) ^b	E_x (MeV)	J^π	ΔE_x (MeV) ^c
0	2 ⁺	16.626 + 16.922 ^d	2 ⁺		0	2 ⁺	
0.9808	1 ⁺	17.640 ^e	1 ⁺	-0.143	0.7695	1 ⁺	-0.211
2.255	3 ⁺	19.07 ^f	3 ⁺	0.013	2.32	3 ⁺	0.065

^a As taken from Tables 8.2, 8.9 and 8.15. The analogs of the broad 1⁺ levels near 3.2 and 5.4 MeV and the narrow 4⁺ level at 6.53 MeV in ⁸Li (see Table 8.2) are unknown in ⁸Be and ⁸B.

^b Defined as $E_x(^8\text{Be}) - E_x(^8\text{Li}) - 16.802$.

^c Defined as $E_x(^8\text{B}) - E_x(^8\text{Li})$.

^d The $T = 1$ centroid of the 16.626 and 16.922 MeV levels is 16.802 MeV in ⁸Be, assuming an isospin-mixed doublet with $T = 0$ intensities proportional to the observed α widths in Table 8.9.

^e Predominantly $T = 1$. A small amount of isospin mixing improves the γ -ray branching ratios for the decay of the 17.64 and 18.15 MeV levels, and also the channel spin ratio for the formation of the 17.64 MeV level in the ⁷Li(p, γ) reaction.

^f Predominantly $T = 1$. Isospin mixing at the few % level is needed to reproduce the widths of the 19.07 and 19.24 MeV levels.

interference of E1 and E2 contributions in Coulomb Dissociation and gives information about the relative E2/E1 strength (1996ES02, 1996KE16). A high-resolution measurement of the asymmetric distribution from breakup on Pb at $E(^8\text{B}) = 44$ and 81 MeV/A deduced that $\sigma(\text{E2})/\sigma(\text{E1}) \approx 6.7 \times 10^{-4} \begin{smallmatrix} +2.8 \\ -1.9 \end{smallmatrix}$ at $E_{\text{rel.}}(\text{p} + ^7\text{Be}) = 0.6$ MeV (1998DA14). A more precise value of $\sigma(\text{E2})/\sigma(\text{E1}) \approx 4.9 \times 10^{-4} \begin{smallmatrix} +1.5 \\ -1.3 \end{smallmatrix}$ at $E_{\text{rel.}} = 0.6$ MeV was deduced by including measurements at $E(^8\text{B}) = 83$ MeV/A (2002DA15).

Breakup cross sections and ⁷Be core-like fragment momentum distributions are analyzed in a modified Glauber model to obtain asymptotic normalization coefficients (ANC) for the ⁸B \rightarrow ⁷Be + p reaction (2004TR06). In this analysis of breakup data, the value $S_{17}(0) = 18.7 \pm 1.9$ eV · b is deduced.

At $E(^8\text{B}) = 936$ MeV/A, the ratio of (⁷Be*(0.429) + γ)/⁷Be production was measured on C and Pb targets (2002CO04, 2003CO06, 2003ME16). The measurements indicate a $13.3 \pm 2.2\%$ component of ⁷Be*(0.429) in the ground state of ⁸B (2003ME16). Spectroscopic factors for ⁷Be*(0, 0.43) were deduced from measurements of ¹²C(⁸B, ⁷Be) at $E(^8\text{B}) = 76$ MeV/A; $C^2S = 1.036$ and 0.220, respectively (2003EN05).

${}^8\text{C}$
(Fig. 5)

Mass of ${}^8\text{C}$: The atomic mass excess of ${}^8\text{C}$ is 35094 ± 23 keV (2003AU03); $\Gamma_{\text{cm}} = 230 \pm 50$ keV [$J^\pi = 0^+$; $T = 2$]: see (1979AJ01). ${}^8\text{C}$ is stable with respect to ${}^7\text{B} + \text{p}$ ($Q = -0.07$ MeV) and unstable with respect to ${}^6\text{Be} + 2\text{p}$ ($Q = 2.14$), ${}^5\text{Li} + 3\text{p}$ ($Q = 1.55$) and ${}^4\text{He} + 4\text{p}$ ($Q = 3.51$). At $E({}^3\text{He}) = 76$ MeV the differential cross section for formation of ${}^8\text{C}_{\text{g.s.}}$ in the ${}^{14}\text{N}({}^3\text{He}, {}^9\text{Li})$ reaction is ≈ 5 nb/sr at $\theta_{\text{lab}} = 10^\circ$. The ${}^{12}\text{C}(\alpha, {}^8\text{He}){}^8\text{C}$ reaction has been studied at $E_\alpha = 156$ MeV: $d\sigma/d\Omega \approx 20$ nb/sr at $\theta_{\text{lab}} = 20^\circ$: see (1979AJ01). See also (1985AN28) and (1987BL18, 1987SA15, 1988CO15, 1996GR21, 1996KA14, 1996SU24, 1997BA54, 1997PO12, 1998WI10, 1999HA61, 2000WI09, 2001CO21, 2003BA99).

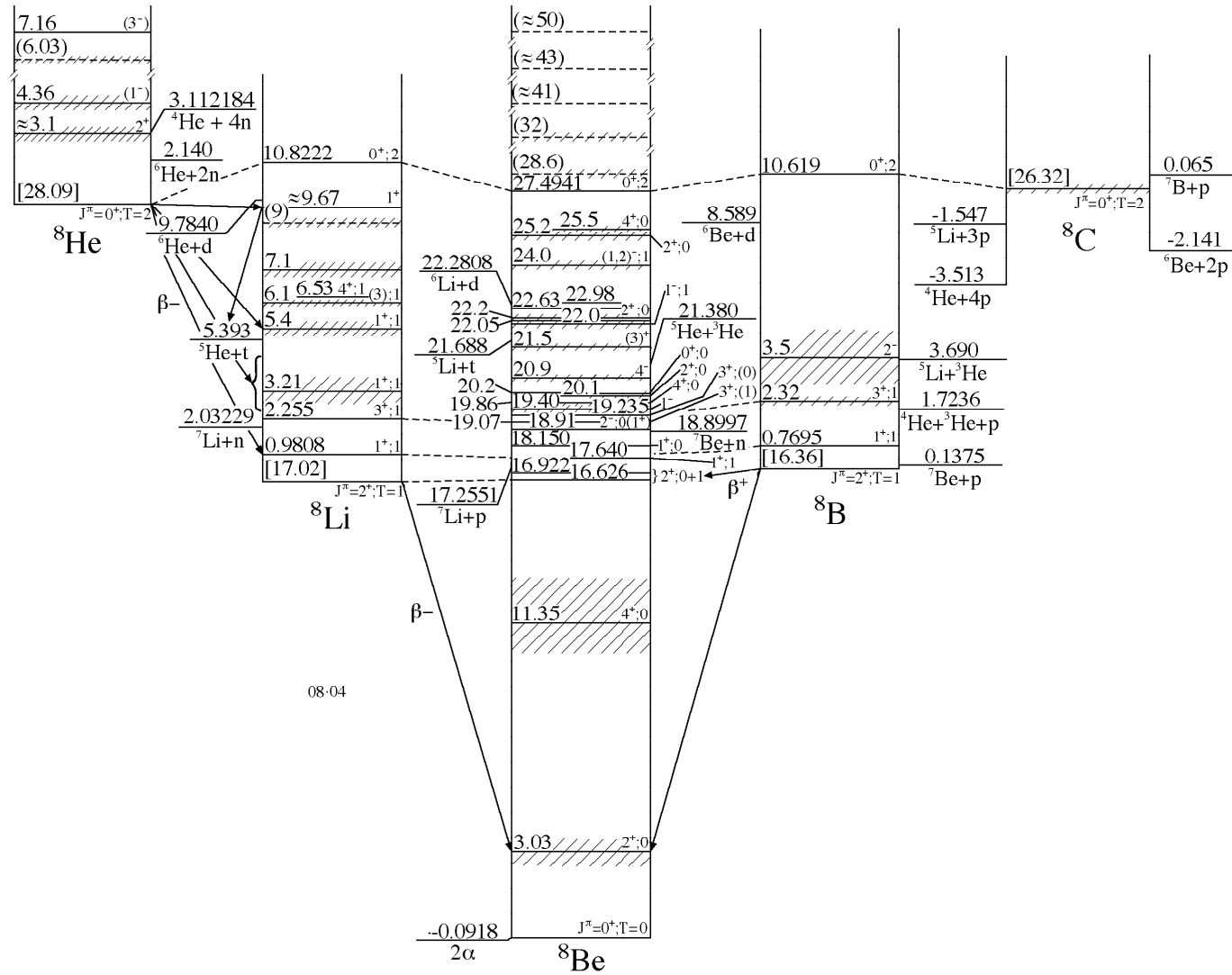


Figure 5: Isobar diagram, $A = 8$. The diagrams for individual isobars have been shifted vertically to eliminate the neutron-proton mass difference and the Coulomb energy, taken as $E_C = 0.60Z(Z - 1)/A^{1/3}$. Energies in square brackets represent the (approximate) nuclear energy, $E_N = M(Z, A) - ZM(\text{H}) - NM(\text{n}) - E_C$, minus the corresponding quantity for ${}^8\text{Be}$: here M represents the atomic mass excess in MeV. Levels which are presumed to be isospin multiplets are connected by dashed lines.

References

(Closed 31 March 2004)

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.

- 1955AJ61 F. Ajzenberg and T. Lauritsen, *Rev. Mod. Phys.* 27 (1955) 77
- 1959AJ76 F. Ajzenberg and T. Lauritsen, *Nucl. Phys.* 11 (1959) 1
- 1961ME10 V. Meyer, H. Muller, H.H. Staub and R. Zurmuhle, *Nucl. Phys.* 27 (1961) 284
- 1966LA04 T. Lauritsen and F. Ajzenberg-Selove, *Nucl. Phys.* 78 (1966) 1
- 1966PA16 P.D. Parker, *Phys. Rev.* 150 (1966) 851
- 1968BE02 J. Benn, E.B. Dally, H.H. Muller, R.E. Pixley, H.H. Staub and H. Winkler, *Nucl. Phys.* A106 (1968) 296
- 1969BA43 F.C. Barker, *Aust. J. Phys.* 22 (1969) 293
- 1969SW01 W.E. Sweeney, Jr. and J.B. Marion, *Phys. Rev.* 182 (1969) 1007
- 1969SW02 W.E. Sweeney, Jr., *Phys. Rev.* 182 (1969) 1022
- 1971WI05 D.H. Wilkinson and D.E. Alburger, *Phys. Rev. Lett.* 26 (1971) 1127
- 1972PR03 G. Presser and R. Bass, *Nucl. Phys.* A182 (1972) 321
- 1974AJ01 F. Ajzenberg-Selove and T. Lauritsen, *Nucl. Phys.* A227 (1974) 1
- 1975MC02 C.R. McClenahan and R.E. Segel, *Phys. Rev.* C11 (1975) 370
- 1976BA67 F.C. Barker, G.M. Crawley, P.S. Miller and W.F. Steele, *Aust. J. Phys.* 29 (1976) 245
- 1976FI05 G.A. Fisher, P. Paul, F. Reiss and S.S. Hanna, *Phys. Rev.* C14 (1976) 28
- 1978BO30 T.J. Bowles and G.T. Garvey, *Phys. Rev.* C18 (1978) 1447; Erratum *Phys. Rev.* C26 (1982) 2336
- 1979AJ01 F. Ajzenberg-Selove, *Nucl. Phys.* A320 (1979) 1
- 1979FR04 S.J. Freedman, C.A. Gagliardi, M.A. Oothoudt, A.V. Nero, R.G.H. Robertson, F.J. Zutavern, E.G. Adelberger and A.B. McDonald, *Phys. Rev.* C19 (1979) 1907
- 1979GL12 H. Glattli, G.L. Bacchella, M. Fourmond, A. Malinovski, P. Meriel, M. Pinot, P. Roubeau and A. Abragam, *J. Phys. (Paris)* 40 (1979) 629
- 1979MI1E Mingay, S. *Afr. J. Phys.* 2 (1979) 107
- 1980AJ01 F. Ajzenberg-Selove and C.L. Busch, *Nucl. Phys.* A336 (1980) 1

- 1980MC07 R.D. McKeown, G.T. Garvey and C.A. Gagliardi, Phys. Rev. C22 (1980) 738; Erratum Phys. Rev. C26 (1982) 2336
- 1981BA36 F.C. Barker and N. Ferdous, J. Phys. (London) G7 (1981) 1239
- 1981BJ03 T. Bjornstad, H.A. Gustafsson, B. Jonson, P.O. Larsson, V. Lindfors, S. Mattsson, G. Nyman, A.M. Poskanzer, H.L. Ravn and D. Schardt, Nucl. Phys. A366 (1981) 461
- 1981MA33 S. Manglos, N.R. Roberson, H.R. Weller and D.R. Tilley, Phys. Rev. C24 (1981) 2378
- 1981MUZQ S.F. Mughabghab, M. Divadeenam and N.E. Holden, Neutron Cross Sections Part A, Z=1-60 (Academic Press, New York, 1981)
- 1982EL03 A.J. Elwyn, R.E. Holland, C.N. Davids and W. Ray, Jr., Phys. Rev. C25 (1982) 2168
- 1982FI03 B.W. Filippone, A.J. Elwyn, W. Ray, Jr. and D.D. Koetke, Phys. Rev. C25 (1982) 2174
- 1982GL01 B.G. Glagola, V.E. Viola, Jr., H. Breuer, N.S. Chant, A. Nadasen, P.G. Roos, S.M. Austin and G.J. Mathews, Phys. Rev. C25 (1982) 34
- 1982LA19 M. Lattuada, F. Riggi, C. Spitaleri, D. Vinciguerra and C.M. Sutura, Phys. Rev. C26 (1982) 1330
- 1983BE51 T.L. Belyaeva, N.S. Zelenskaya and I.B. Teplov, Yad. Fiz. 38 (1983) 901; Sov. J. Nucl. Phys. 38 (1983) 540
- 1983BO19 F. Borchers, H. De Jong, J. Krug and E. Kuhlmann, Nucl. Phys. A405 (1983) 141
- 1983DA11 V. D'Amico, G. Fazio, G. Giardina and F. Mezzanares, Can. J. Phys. 61 (1983) 923
- 1983DA32 N.X. Dai, Y. Chen, H.J. Lu, B.J. Qi, F. Zhuang and H.C. Sun, Chin. J. Nucl. Phys. 5 (1983) 19
- 1983DEZW L.C. Dennis, A.D. Frawley and J.F. Mateja, Bull. Amer. Phys. Soc. 28 (1983) 669, BF1
- 1983FI13 B.W. Filippone, A.J. Elwyn, C.N. Davids and D.D. Koetke, Phys. Rev. C28 (1983) 2222
- 1983GLZZ C.W. Glover, C.C. Foster, P. Schwandt, J.R. Comfort, J. Rapaport, T.N. Taddeucci, D. Wong, J. Seubert and G. Wagner, Bull. Amer. Phys. Soc. 28 (1983) 996, EC3
- 1983HA1D W.S. Han and H.J. Lu, in Florence (1983) 314
- 1983KO17 L. Koester, K. Knopf and W. Waschkowski, Z. Phys. A312 (1983) 81
- 1983LI18 X.H. Liu and X.J. Chen, Chin. J. Nucl. Phys. 5 (1983) 249
- 1983LI1C H. Liskien, R. Wolfle and S.M. Qaim, in Belgium, 1982 (1983) 349
- 1983MI10 D. Miljanic, E. Kossionides, G. Vourvopoulos and P. Assimakopoulos, Z. Phys. A312 (1983) 267
- 1983WA09 R.E. Warner, K. Blum, D. Friesel, P. Schwandt, P.P. Singh and A. Galonsky, Nucl. Phys. A401 (1983) 521

- 1983YA05 M. Yasue, H. Yokomizo, T. Hasegawa, F. Soga, M.H. Tanaka, K. Koyama and K. Iwatani, Nucl. Phys. A408 (1983) 205
- 1984AJ01 F. Ajzenberg-Selove, Nucl. Phys. A413 (1984) 1
- 1984AL03 J.P. Alard, J. Arnold, M.M. Avome Nze, J.P. Costilhes, L. Fraysse, W. Raja and J.C. Tamain, Lett. Nuovo Cim. 39 (1984) 139
- 1984AN16 Yu.P. Antufyev, A.S. Deineko, I.I. Zalyubovsky, V.D. Sarana, V.E. Storizhko, A.I. Tutubalin, C. Hategan and N.A. Schliakhov, Yad. Fiz. 40 (1984) 53; Sov. J. Nucl. Phys. 40 (1984) 35
- 1984BA1T Bayukov et al., in Panic (1984) I16
- 1984DA17 B. Dasmahapatra, B. Cujec and F. Lahlou, Nucl. Phys. A427 (1984) 186
- 1984DA22 J. D'Auria, M. Dombisky, L. Moritz, T. Ruth, G. Sheffer, T.E. Ward, C.C. Foster, J.W. Watson, B.D. Anderson and J. Rapaport, Phys. Rev. C30 (1984) 1999
- 1984FE1A Ferch et al., INDC (CCP)-221/L (1984) 18
- 1984GA07 R.B. Galloway and A.M. Ghazarian, Phys. Rev. C29 (1984) 2349
- 1984JE1B S.C. Jeong, J.C. Kim, C.W. Nahm, B.N. Sung and S.W. Cho, New Phys. (Korea) 24 (1984) 404
- 1984KO25 I. Koenig, D. Fick, S. Kossionides, P. Egelhof, K.-H. Mobius and E. Steffens, Z. Phys. A318 (1984) 135
- 1984KU15 V.I. Kukulín, M. Kamal, V.T. Voronchev and V.M. Krasnopolsky, J. Phys. (London) G10 (1984) L213
- 1984LIZY P.W. Lisowski, R.E. Brown, J.C. Gursky, S.D. Howe, N. Jarmie and G.L. Morgan, Bull. Amer. Phys. Soc. 29 (1984) 748, JH13
- 1984NE1A Nemets, Rudchik and Chuvilski, in Alma Ata (1984) 334
- 1984SH1D Shvedov, Dobrikov and Nemets, in Alma Ata (1984) 331
- 1984SMZX D.L. Smith, J.W. Meadows, M.M. Bretscher and S.A. Cox, Bull. Amer. Phys. Soc. 29 (1984) 1036, BD4
- 1984TA07 T.N. Taddeucci, T.A. Carey, C. Gaarde, J. Larsen, C.D. Goodman, D.J. Horen, T. Masterson, J. Rapaport, T.P. Welch and E. Sugarbaker, Phys. Rev. Lett. 52 (1984) 1960
- 1984TU02 M. Turk and B. Antolkovic, Nucl. Phys. A431 (1984) 381
- 1984UM04 K. Umeda, T. Yamaya, T. Suehiro, K. Takimoto, R. Wada, E. Takada, S. Shimoura, A. Sakaguchi, S. Murakami, M. Fukada et al., Nucl. Phys. A429 (1984) 88
- 1984ZA07 N.I. Zaika, A.V. Mokhnach, A.T. Rudchik, V.S. Semenov, V.A. Shityuk and P.L. Shmarin, Yad. Fiz. 39 (1984) 1081; Sov. J. Nucl. Phys. 39 (1984) 682
- 1985AJ01 F. Ajzenberg-Selove, Nucl. Phys. A433 (1985) 1; Erratum Nucl. Phys. A449 (1986) 155.

- 1985AL29 D.V. Aleksandrov, Yu.A. Glukhov, B.G. Novatsky, E.Yu. Nikolsky, A.A. Ogloblin and D.N. Stepanov, *Izv. Akad. Nauk. SSSR, Ser. Fiz.* 49 (1985) 2115; *Bull. Acad. Sci. USSR, Phys. Ser.* 49 (1985) 30
- 1985AN28 M.S. Antony, J. Britz, J.B. Bueb and A. Pape, *At. Data Nucl. Data Tables* 33 (1985) 447
- 1985BE1E W. Bell, K. Braune, G. Claesson, D. Drijard, M. A. Faessler, H. G. Fischer, H. Frehse, R. W. Frey, S. Garpman, W. Geist et al; CERN-Heidelberg-Lund Collaboration, *Nucl. Phys.* B254 (1985) 475
- 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
- 1985BIZZ R.A. Bigelow, P.A. Quin, S.J. Freedman and J. Napolitano, *Bull. Amer. Phys. Soc.* 30 (1985) 701, AE8
- 1985CA36 R.F. Carlson, A.J. Cox, T.N. Nasr, M.S. De Jong, D.L. Ginther, D.K. Hasell, A.M. Sourkes, W.T.H. Van Oers and D.J. Margaziotis, *Nucl. Phys.* A445 (1985) 57.
- 1985CE12 F.E. Cecil, R.J. Peterson and P.D. Kunz, *Nucl. Phys.* A441 (1985) 477
- 1985CH37 S. Chiba, M. Baba, H. Nakashima, M. Ono, N. Yabuta, S. Yukinori and N. Hirakawa, *J. Nucl. Sci. Tech. (Tokyo)* 22 (1985) 771
- 1985CO09 J. Cook and K.W. Kemper, *Phys. Rev.* C31 (1985) 1745
- 1985DA29 V. D'Amico, G. Fazio, S. Femino, G. Giardina, A. Italiano and F. Mezzanares, *Can. J. Phys.* 63 (1985) 1438
- 1985DO16 Yu.V. Dotsenko and V.E. Starodubsky, *Yad. Fiz.* 42 (1985) 107; *Sov. J. Nucl. Phys.* 42 (1985) 66.
- 1985GO18 E. Goldberg, R.L. Barber, P.E. Barry, N.A. Bonner, J.E. Fontanilla, C.M. Griffith, R.C. Haight, D.R. Nethaway and G.B. Hudson, *Nucl. Sci. Eng.* 91 (1985) 173
- 1985GO1G Gorionov et al., in *Leningrad* (1985) 310
- 1985JA09 L. Jarczyk, B. Kamys, A. Magiera, A. Strzalkowski, A. Szczurek, K. Bodek, M. Hugi, J. Lang, R. Muller and E. Ungricht, *J. Phys. (London)* G11 (1985) 843
- 1985KI1A Kitching, McDonald, Maris and Vasconcellos, *Adv. Nucl. Phys.* 15 (1985) 43
- 1985LI1C Y.-G. Ling, X. Zhao and F.-A. Zeng, *Phys. Energ. Fortis Phys. Nucl.* 9 (1985) 236; *Phys. Abs.* 83976 (1985)
- 1985MU14 T. Murakami, E. Ungricht, Y.-W. Lui, Y.Mihara, E. Takada and R.E. Tribble, *Phys. Rev.* C32 (1985) 1558
- 1985NO1A Norbeck and Lin, *Bull. Amer. Phys. Soc.* 30 (1985) 1248
- 1985PO10 N.A.F.M. Poppelier, L.D. Wood and P.W.M. Glaudemans, *Phys. Lett.* B157 (1985) 120.

- 1985SW01 M.T. Swinhoe and C.A. Uttley, Nucl. Sci. Eng. 89 (1985) 261
- 1985TA13 I. Tanihata, H. Hamagaki, O. Hashimoto, S. Nagamiya, Y. Shida, N. Yoshikawa, O. Yamakawa, K. Sugimoto, T. Kobayashi, D.E. Greiner et al., Phys. Lett. B160 (1985) 380
- 1985TA18 I. Tanihata, H. Hamagaki, O. Hashimoto, Y. Shida, N. Yoshikawa, K. Sugimoto, O. Yamakawa, T. Kobayashi and N. Takahashi, Phys. Rev. Lett. 55 (1985) 2676
- 1985WO11 L.W. Woo, K. Kwiatkowski, S.H. Zhou and V.E. Viola, Phys. Rev. C32 (1985) 706
- 1986AJ01 F. Ajzenberg-Selove, Nucl. Phys. A449 (1986) 1
- 1986AN22 B. Antolkovic, M. Turk and K. Kadija, Radiat. Eff. 92 (1986) 183
- 1986BE1Q Belozarov et al., in P7-86-322, Dubna (1986) 53
- 1986BI1D R.A. Bigelow, S.J. Freedman, J. Napolitano and P.A. Quin, J. Phys. Soc. Jpn. Suppl. 55 (1986) 1030
- 1986CH24 S. Chiba, M. Baba, H. Nakashima, M. Ono, N. Yabuta, S. Yukinori and N. Hirakawa, Radiat. Eff. 92 (1986) 227
- 1986CL1B N.M. Clarke, P.J. Simmons, K.I. Pearce, S. Roman, A. Farooq and G. Rai, J. Phys. Soc. Jpn. Suppl. 55 (1986) 756
- 1986GA18 M. Garcon, B. Bonin, G. Bruge, J.C. Duchazeaubeneix, M. Rouger, J. Saudinos, B.H. Silverman, D.M. Sheppard, J. Arvieux, G. Gaillard et al., Nucl. Phys. A458 (1986) 287
- 1986GO23 S.A. Goncharov, Yu.I. Denisov, A.M. Mukhamedzhanov, E.A. Romanovsky, G.E. Valiev, I.R. Gulamov, T. Iskhakov, G. Ni, N.K. Timofeyuk, R. Yarmukhamedov et al., Yad. Fiz. 44 (1986) 303; Sov. J. Nucl. Phys. 44 (1986) 191
- 1986JA02 L. Jarczyk, B. Kamys, Z. Rudy, A. Strzalkowski, B. Styczen, G.P.A. Berg, A. Magiera, J. Meissburger, W. Oelert, P. Von Rossen et al., Nucl. Phys. A448 (1986) 1
- 1986JA14 L. Jarczyk, B. Kamys, Z. Rudy, A. Strzalkowski, B. Styczen, G.P.A. Berg, A. Magiera, J. Meissburger, W. Oelert, P. von Rossen et al., Nucl. Phys. A459 (1986) 52
- 1986KN06 D.W. Kneff, B.M. Oliver, E. Goldberg and R.C. Haight, Nucl. Sci. Eng. 94 (1986) 136
- 1986LA05 K. Langanke and C. Rolfs, Phys. Rev. C33 (1986) 790
- 1986LA19 K. Langanke and C. Rolfs, Z. Phys. A324 (1986) 307
- 1986LA26 M. Lattuada, F. Riggi, C. Spitaleri, D. Vinciguerra, D. Miljanic, M. Zadro and J.Z. Yao, Nucl. Phys. A458 (1986) 493
- 1986MC09 M.W. McNaughton, H. Spinka and H. Shimizu, Nucl. Instrum. Meth. Phys. Res. A243 (1986) 137

- 1986MI11 D. Miljanic, S. Blagus and M. Zadro, Phys. Rev. C33 (1986) 2204
- 1986NAZZ J. Napolitano, J. Camp and S.J. Freedom, Bull. Amer. Phys. Soc. 31 (1986) 780, BF9
- 1986RO13 C. Rolfs and R.W. Kavanagh, Nucl. Phys. A455 (1986) 179
- 1986SA1P K.E. Sale, T.R. Donoghue, A. Abduljalil, J. Cummings, C. Rolfs, P. Schmalbrock, R.G. Seyler, T. Clegg, E.J. Ludwig, R. Fauber et al., J. Phys. Soc. Jpn. Suppl. 55 (1986) 992.
- 1986SO07 J.P. Soderstrum and L.D. Knutson, Phys. Rev. C34 (1986) 401
- 1986VD04 A.I. Vdovin, I.G. Golikov, A.V. Golovin, M.N. Zhukov and I.I. Loshchakov, Izv. Akad. Nauk SSSR, Ser. Fiz. 50 (1986) 936; Bull. Acad. Sci. USSR, Phys. Ser. 50 (1986) 103
- 1986WA01 E.K. Warburton, Phys. Rev. C33 (1986) 303
- 1986XI1A X.-L. Xie, X.-J. Kong, C.-W. Sun and S.-M Wang, Chin. Phys. 6 (1986) 52
- 1986YA12 T. Yamaya, J.I. Hirota, K. Takimoto, S. Shimoura, A. Sakaguchi, S. Kubono, M. Sugitani, S. Kato, T. Suehiro and M. Fukada, Phys. Rev. C34 (1986) 2369
- 1986ZA09 M. Zadro, S. Blagus, D. Miljanic, M. Lattuada, F. Riggi and C. Spitaleri, Z. Phys. A325 (1986) 119
- 1987AJ02 F. Ajzenberg-Selove, Nucl. Phys. A475 (1987) 1
- 1987AN14 A.K. Ananikyan, E.A. Arakelyan, G.L. Bayatyan, G.S. Vartanyan, A.R. Voskanyan, K.T. Darbinyan, N.K. Grigoryan, S.G. Knyazyan, A.T. Margaryan, G.G. Marikyan et al., Yad. Fiz. 46 (1987) 401; Sov. J. Nucl. Phys. 46 (1987) 208
- 1987AR22 E. Arnold, J. Bonn, R. Gegenwarth, W. Neu, R. Neugart, E.-W. Otten, G. Ulm, K. Wendt and ISOLDE Collaboration, Phys. Lett. B197 (1987) 311
- 1987BE17 H.W. Becker, C. Rolfs and H.P. Trautvetter, Z. Phys. A327 (1987) 341
- 1987BE2B A.S. Belousov, Ya. A. Vazdik, E.I. Malinovskii, S.V. Rusakov, P.A. Smirnov, Yu.V. Solovev, A.P. Usik, A.R. Terkulov and A.M. Fomenko, Kratkie Soobshcheniya po Fizike 9 (1987) 28; Sov. Phys. - Lebedev Inst. Rep. No. 9 (1987) 35
- 1987BL13 C. Bloch, W. Bensenon, A.I. Galonsky, E. Kashy, J. Heltsley, L. Heilbronn, M.Lowe, B. Remington, D.J. Morrissey and J. Kasagi, Phys. Rev. C36 (1987) 203
- 1987BL18 R. Blumel and K. Dietrich, Nucl. Phys. A471 (1987) 453
- 1987BO1M Bochkarev et al., in Yurmala (1987) 384
- 1987CA06 Z.-J. Cao, T.E. Ward, R.D. Bent, J.D. Brown, E. Korkmaz, H. Nann and T.G. Throwe, Phys. Rev. C35 (1987) 825
- 1987CH33 Z. Chen, C.K. Gelbke, W.G. Gong, Y.D. Kim, W.G. Lynch, M.R. Maier, J. Pochodzalla, M.B. Tsang, F. Saint-Laurent, D. Ardouin et al., Phys. Rev. C36 (1987) 2297
- 1987CO16 J. Cook, M.N. Stephens and K.W. Kemper, Nucl. Phys. A466 (1987) 168

- 1987CZ02 J. Czakanski, W. Zipper, W. Dunnweber, W. Hering, D. Konnerth, W. Trombik, K.G. Bernhardt, H. Bohn, K.A. Eberhard and R. Vandenbosch, Phys. Lett. 199 (1987) 166
- 1987DA25 N.X. Dai, B.J. Qi, Y.J. Mao, F. Zhuang, J.Z. Yao and X.Z. Wang, Chin. J. Nucl. Phys. 9 (1987) 103
- 1987GA11 E. Gadioli and E. Gadioli Erba, Phys. Rev. C36 (1987) 741
- 1987GAZM S.A. Gaidaenko, E.P. Kadkin, M.V. Pasechnik, L.S. Saltykov and A.D. Fursa, in Yurmala (1987) 299
- 1987GO1S Goryunov et al., in Yurmala (1987) 474
- 1987GO27 S.A. Goncharov, A.M. Mukhamedzhanov, E.A. Romanovsky, G.E. Valiev, I.R. Gulamov, T. Iskhakov, G. Nie, N.K. Tomopheyuk, R. Yarmukhamedov, V. Kroha et al., Czech. J. Phys. B37 (1987) 168
- 1987HU12 G.M. Huber, G.J. Lolos, Z. Papandreou, K.H. Hicks, P.L. Walden, S. Yen, E.G. Auld, F.A. Duncan, R.D. Bent and W.R. Falk, Phys. Rev. C36 (1987) 2683
- 1987KA25 K. Kadija, G. Paic, D. Vranic, A. Berdoz, F. Foroughi, Ch. Nussbaum, H.H. Muller, P. Schober and St. Steiner, Nucl. Phys. A469 (1987) 183
- 1987KA32 R.W. Kavanagh and R.G. Marcley, Phys. Rev. C36 (1987) 1194
- 1987KI01 K.H. Kim, M.H. Park and B.T. Kim, Phys. Rev. C35 (1987) 363
- 1987KI05 A. Kiss, F. Deak, Z. Seres, G. Caskey, A. Galonsky, L. Heilbronn, B.A. Remington and J. Kasagi, Phys. Lett. B184 (1987) 149
- 1987KN04 H.D. Knox, D.A. Resler and R.O. Lane, Nucl. Phys. A466 (1987) 245
- 1987LA25 M. Lattuada, F. Riggi, D. Vinciguerra, C. Spitaleri and D. Miljanic, Z. Phys. A328 (1987) 497
- 1987LY05 Yu.S. Lyutostansky and V.N. Tikhonov, Yad. Fiz. 46 (1987) 66; Sov. J. Nucl. Phys. 46 (1987) 42
- 1987NA08 J. Napolitano, S.J. Freedman and J. Camp, Phys. Rev. C36 (1987) 298
- 1987NE1C Nemets et al., in Yurmala (1987) 323
- 1987NO04 Y. Nojiri, K. Takeyama, K. Matsuta and T. Minamisono, Hyperfine Interactions 35 (1987) 1015
- 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
- 1987PR01 D. Provoost, F. Grummer and K. Goeke, Ann. Phys. (New York) 174 (1987) 202
- 1987QA01 S.M. Qaim and R. Wolfle, Nucl. Sci. Eng. 96 (1987) 52
- 1987RA23 J. Raisanen, T. Witting and J. Keinonen, Nucl. Instrum. Meth. Phys. Res. B28 (1987) 199
- 1987SA15 H. Sagawa and H. Toki, J. Phys. (London) G13 (1987) 453

- 1987SC08 D. Schmidt, D. Seeliger, G.N. Lovchikova and A.M. Trufanov, Nucl. Sci. Eng. 96 (1987) 159
- 1987SI06 K. Siwek-Wilczynska, J. Wilczynski, C.R. Albiston, Y. Chan, E. Chavez, S.B. Gazes, H.R. Schmidt and R.G. Stokstad, Phys. Rev. C35 (1987) 1316
- 1987TA07 Y. Tagishi, Y. Aoki, M. Kurokawa, T. Murayama, T. Sakai, M. Takei, M. Tomizawa and K. Yagi, Phys. Rev. C35 (1987) 1153
- 1987TO06 M. Tosaki, M. Fujiwara, K. Hosono, T. Noro, H. Ito, T. Yamazaki and H. Ikegami, Nucl. Phys. A463 (1987) 429c.
- 1987VA11 Valiev et al., in Yurmala (1987) 346
- 1987VI05 G.A. Viano, Phys. Rev. C36 (1987) 933
- 1987WA07 H. Walliser and S. Nakaichi-Maeda, Nucl. Phys. A464 (1987) 366
- 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
- 1987ZA07 M. Zadro, D. Miljanic, M. Lattuada, F. Riggi and C. Spitaleri, Nucl. Phys. A474 (1987) 373
- 1987ZH10 M.A. Zhusupov and Yu.N. Uzikov, Fiz. Elem. Chastits At. Yadra 18 (1987) 323; Sov. J. Part. Nucl 18 (1987) 136
- 1988AJ01 F. Ajzenberg-Selove, Nucl. Phys. A490 (1988) 1
- 1988AL07 S.C. Allcock, W.D.M. Rae, P.R. Keeling, A.E. Smith, B.R. Fulton and D.W. Banes, Phys. Lett. B201 (1988) 201
- 1988AR17 E. Arnold, J. Bonn, W. Neu, R. Neugart, E.W. Otten and the ISOLDE Collaboration, Z. Phys. A331 (1988) 295
- 1988BA29 F.C. Barker, Phys. Rev. C37 (1988) 2920
- 1988BA67 F.C. Barker and E.K. Warburton, Nucl. Phys. A487 (1988) 269
- 1988BA75 F.C. Barker, Aust. J. Phys. 41 (1988) 743
- 1988BE04 T.D. Beynon and B.S. Sim, Ann. Nucl. Energy 15 (1988) 27
- 1988BE34 A.V. Belozerov, K. Borch, 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
- 1988BEYJ A.V. Belozerov, K. Borch, I. Vintsour, Z. Dlougy, N.K. Tyau and Yu.Eh. Penionzhkevich, in Baku (1988) 380.
- 1988BO20 H.G. Bohlen, B. Gebauer, D. Kolbert, W. von Oertzen, E. Stiliaris, M. Wilpert and T. Wilpert, Z. Phys. A330 (1988) 227

- 1988BO37 C. Boni, E. Cereda, G.M. Braga Marcazzan and V. De Tomasi, Nucl. Instrum. Meth. Phys. Res. B35 (1988) 80
- 1988CA28 G.R. Caughlan and W.A. Fowler, At. Data Nucl. Data Tables 40 (1988) 283
- 1988CO15 E. Comay, I. Kelson and A. Zidon, Phys. Lett. B210 (1988) 31
- 1988DE38 P. Descouvemont and D. Baye, Nucl. Phys. A487 (1988) 420
- 1988GO02 S.A. Goncharov, A.M. Mukhamedzhanov, E.A. Romanovsky, G.E. Valiev, I.R. Gulamov, Yu.I. Denisov, T. Iskhakov, A. Karakhodzhaev, G.K. Nie, R. Yarmukhamedov et al., Czech. J. Phys. B38 (1988) 12
- 1988GU10 B.Ya. Guzhovsky, L.M. Lazarev and A.V. Ershov, Izv. Akad. Nauk SSSR Ser. Fiz. 52 (1988) 61; Bull. Acad. Sci. USSR Phys. Ser. 52 (1988) 56
- 1988HA21 J.R. Hall, D.L. Clark, S.J. Freedman and S.S. Hanna, Nucl. Phys. A483 (1988) 1
- 1988HE08 R. Henneck, C. Gysin, P. Haffter, M. Hammans, W. Lorenzon, M.A. Pickar, I. Sick and S. Burzynski, Phys. Rev. C37 (1988) 2224
- 1988HU11 G.M. Huber, G.J. Lolos, K.M. Furutani, W.R. Falk, R.D. Bent, K.H. Hicks, P.L. Walden and S. Yen, Phys. Rev. C38 (1988) 1304
- 1988KA1K Karmanov et al., in Baku (1988) 326
- 1988KN02 J. Knoll and R. Shyam, Nucl. Phys. A483 (1988) 711
- 1988KO03 P.E. Koehler, C.D. Bowman, F.J. Steinkruger, D.C. Moody, G.M. Hale, J.W. Starner, S.A. Wender, R.C. Haight, P.W. Lisowski and W.L. Talbert, Phys. Rev. C37 (1988) 917
- 1988KO29 E. Kolbe, K. Langanke and H.J. Assenbaum, Phys. Lett. B214 (1988) 169
- 1988LI27 G.-B. Liu and H.T. Fortune, Phys. Rev. C38 (1988) 1985
- 1988RA20 Md.A. Rahman, S.N. Rahman, H.M. Sen Gupta, H.-J. Trost, P. Lezoch and U. Strobusch, Nuovo Cim. A99 (1988) 317
- 1988RA27 Md.A. Rahman, Nuovo Cim. A100 (1988) 419
- 1988SH1F Shvedov, Nemets and Rudchik, in Baku (1988) 352
- 1988SU14 T. Suda, O. Konno, I. Nomura, T. Suzuki, T. Terasawa, Y. Torizuka, J. Yokokawa, K. Maeda, J. Eden, G. O'Keefe et al., J. Phys. Soc. Jpn. 57 (1988) 5
- 1988TA10 I. Tanihata, T. Kobayashi, O. Yamakawa, S. Shimoura, K. Ekuni, K. Sugimoto, N. Takahashi, T. Shimoda and H. Sato, Phys. Lett. B206 (1988) 592.
- 1988TE04 H. Tezuka, J. Phys. Soc. Jpn. 57 (1988) 3766
- 1988WA1E E.K. Warburton, in Brighton (1988) 81
- 1989BA31 F.C. Barker, Aust. J. Phys. 42 (1989) 25
- 1989FU03 Y. Fujiwara and Y.C. Tang, Phys. Rev. Lett. B222 (1989) 311
- 1989HA14 J.F. Harmon, Nucl. Instrum. Meth. Phys. Res. B40-41 (1989) 507

- 1989HE24 L. Heilbronn, A. Galonsky, X. Yang, F. Deak, A. Kiss and Z. Seres, Phys. Rev. C40 (1989) 2576; Erratum Phys. Rev. C43 (1991) 2898
- 1989KO55 Yu.E. Kozyr and M.V. Sokolov, Izv. Akad. Nauk SSSR Ser. Fiz. 53 (1989) 2246; Bull. Acad. Sci. USSR Phys. Ser. 53, No.11 (1989) 194
- 1989RA17 P. Raghavan, At. Data Nucl. Data Tables 42 (1989) 189.
- 1989SI02 P.J. Simmonds, N.M. Clarke, K.I. Pearce, R.J. Griffiths, B. Stanley, S. Roman, A. Farooq, G. Rai, M.C. Mannion and C.A. Ogilvie, J. Phys. (London) G15 (1989) 353
- 1989SZ02 A. Szczurek, K. Bodek, J. Krug, W. Lubcke, H. Ruhl, M. Steinke, M. Stephan, D. Kamke, W. Hajdas, L. Jarczyk et al., Z. Phys. A333 (1989) 271
- 1989TE04 H. Terazawa, J. Phys. Soc. Jpn. 58 (1989) 767
- 1989VA18 T.N. Vasina, V.M. Golovkov and M.R. Yakovlev, At. Energ. 66 (1989) 56; Sov. At. Energy 66 (1989) 75
- 1989VO04 V.I. Voloshchuk, I.V. Dogyust, V.V. Kirichenko and A.F. Khodyachikh, Yad. Fiz. 49 (1989) 916; Sov. J. Nucl. Phys. 49 (1989) 569
- 1989WI16 M. Wiescher, R. Steininger and F. Kappeler, Astrophys. J. 344 (1989) 464
- 1990AJ01 F. Ajzenberg-Selove, Nucl. Phys. A506 (1990) 1.
- 1990BO43 K. Bodek, J. Krug, W. Lubcke, S. Obermanns, H. Ruhl, M. Steinke, M. Stephan and D. Kamke, Few-Body Syst. 8 (1990) 23
- 1990DE02 F.W.N. de Boer, J. Lehmann and J. Steyaert, J. Phys. (London) G16 (1990) L1
- 1990DO03 I.V. Dogyust, V.A. Zolenko and V.V. Kirichenko, Yad. Fiz. 51 (1990) 913; Sov. J. Nucl. Phys. 51 (1990) 583
- 1990LE05 Y. Leifels, G. Domogala, R.P. Eule and H. Freiesleben, Z. Phys. A335 (1990) 183
- 1990MU13 A.M. Mukhamedzhanov and N.K. Timofeyuk, Pisma Zh. Eksp. Teor. Fiz. 51 (1990) 247; JETP Lett. 51 (1990) 282
- 1990PA03 Z. Papandreou, G.J. Lolos, G.M. Huber, J.C. Cormier, S.I.H. Naqvi, D.F. Ottewell, P.L. Walden and G. Jones, Phys. Rev. C41 (1990) R1339
- 1990PA22 T. Paradellis, S. Kossionides, G. Doukellis, X. Aslanoglou, P. Assimakopoulos, A. Pakou, C. Rolfs and K. Langanke, Z. Phys. A337 (1990) 211
- 1990RA28 G. Raimann, B. Bach, K. Grun, H. Herndl, H. Oberhummer, S. Engstler, C. Rolfs, H. Abele, R. Neu and G. Staudt, Phys. Lett. B249 (1990) 191
- 1990RI06 L. Ricken, K. Bodek and A. Szczurek, Nucl. Phys. A515 (1990) 226
- 1990SA16 K.E. Sale, T.-F. Wang, R.N. Boyd, G.J. Mathews, D.W. Heikkinen, M.L. Roberts, M.S. Islam and P.B. Corn, Phys. Rev. C41 (1990) 2418
- 1990SR03 J. Sromicki, M. Allet, A. Converse, W. Hajdas, J. Lang, H. Luscher, R. Muller, O. Naviliat-Cuncic, W. Haeberli, M.A. Miller et al., J. Phys. (Paris) Colloq.C6 (1990) 527

- 1990ZH01 D.-C. Zheng, L. Zamick and N. Auerbach, *Ann. Phys.* 197 (1990) 343
- 1991AB04 S. Abdel-Kariem, *Czech. J. Phys.* B41 (1991) 545
- 1991AR18 N. Arena, S. Cavallaro, A. D'Arrigo, G. Fazio, G. Giardina, A. Italiano and A. Taccone, *J. Phys. Soc. Jpn.* 60 (1991) 2175
- 1991BE42 Ya.A. Berdnikov, *Yad. Fiz.* 54 (1991) 1197; *Sov. J. Nucl. Phys.* 54 (1991) 726
- 1991BO31 M.J.G. Borge, P.G. Hansen, L. Johannsen, B. Jonson, T. Nilsson, G. Nyman, A. Richter, K. Riisager, O. Tengblad, K. Wilhelmsen et al., *Z. Phys.* A340 (1991) 255
- 1991BR11 D. Branford, A. Sada, T. Davinson, N.J. Davis, E.W. Macdonald, J. Rahighi, P. Sellin, C.H. Shepherd-Themistocleous and A.C. Shotton, *Phys. Rev.* C43 (1991) 2866
- 1991BR14 J.A. Brown, F.D. Becchetti, J.W. Janecke, K. Ashktorab, D.A. Roberts, J.J. Kolata, R.J. Smith, K. Lamkin and R.E. Warner, *Phys. Rev. Lett.* 66 (1991) 2452
- 1991LY01 J.E. Lynn, E.T. Jurney and S. Raman, *Phys. Rev.* C44 (1991) 764
- 1991NA16 Y. Nagai, M. Igashira, N. Mukai, T. Ohsaki, F. Uesawa, K. Takeda, T. Ando, H. Kitazawa, S. Kubono and T. Fukuda, *Astrophys. J.* 381 (1991) 444
- 1991NA19 Y. Nagai, K. Takeda, S. Motoyama, T. Ohsaki, M. Igashira, N. Mukai, F. Uesawa, T. Ando, H. Kitazawa and T. Fukuda, *Nucl. Instrum. Meth. Phys. Res.* B56-57 (1991) 492
- 1991RI03 S.P. Riley and J.M. Irvine, *J. Phys. (London)* G17 (1991) 35
- 1991SC12 A. Scalia, *Nuovo Cim.* A104 (1991) 563
- 1991SC25 A. Scalia, *Nuovo Cim.* A104 (1991) 713
- 1991SC32 A. Scalia, *Nuovo Cim.* A104 (1991) 1441
- 1991SE06 K.K. Seth and B. Parker, *Phys. Rev. Lett.* 66 (1991) 2448
- 1991SM02 R.J. Smith, J.J. Kolata, K. Lamkin, A. Morsad, F.D. Becchetti, J.A. Brown, W.Z. Liu, J.W. Janecke, D.A. Roberts and R.E. Warner, *Phys. Rev.* C43 (1991) 2346
- 1991SZ06 A. Szczurek, K. Bodek, L. Jarczyk, B. Kamys, J. Krug, W. Lubcke, H. Ruhl, M. Steinke, M. Stephan, D. Kamke et al., *Nucl. Phys.* A531 (1991) 77
- 1991WI19 J.Z. Williams, G. Feldman, H.R. Weller and D.R. Tilley, *Phys. Lett.* 273B (1991) 216
- 1992AL01 M. Allet, W. Hajdas, J. Lang, H. Lüscher, R. Müller, O. Naviliat-Cuncic, J. Sromicki, A. Converse, W. Haeberli, M.A. Miller et al., *Phys. Rev. Lett.* 68 (1992) 572
- 1992BE65 B.N. Belyaev, V.D. Domkin and V.S. Mukhin, *Sov. J. Part. Nucl.* 23 (1992) 439; *Fiz. Elem. Chastits At. Yad.* 23 (1992) 993
- 1992BL10 B. Blank, J.-J. Gaimard, H. Geissel, K.-H. Schmidt, H. Stelzer, K. Summerer, D. Bazin, R. Del Moral, J.P. Dufour, A. Fleury et al., *Z. Phys.* A343 (1992) 375
- 1992BO1H M. Bogovac, G. Calvi, M. Lattuada, D. Miljanic, D. Rendic, F. Riggi, C. Spitaleri and M. Zadro, *Few-Body Syst.* 12 (1992) 191

- 1992CE02 F.E. Cecil, D. Ferg, H. Liu, J.C. Scorby, J.A. McNeil and P.D. Kunz, Nucl. Phys. A539 (1992) 75
- 1992DA22 P. D'Agostino, A. D'Arrigo, G. Fazio, G. Giardina, A. Italiano, A. Taccone and R. Palamara, Fizika (Zagreb) B1 (1992) 139
- 1992DE07 L. De Braeckeleer, Phys. Rev. C45 (1992) 1935
- 1992EN01 S. Engstler, G. Raimann, C. Angulo, U. Greife, C. Rolfs, U. Schroder, E. Somorjai, B. Kirch and K. Langanke, Phys. Lett. B279 (1992) 20
- 1992EN04 S. Engstler, G. Raimann, C. Angulo, U. Greife, C. Rolfs, U. Schroder, E. Somorjai, B. Kirch and K. Langanke, Z. Phys. A342 (1992) 471
- 1992GO27 A.M. Goryachev, G.N. Zalesny and I.V. Pozdnev, Bull. Russ. Acad. Sci. Phys. 56 (1992) 762
- 1992KO26 V.V. Komarov, A.M. Popova, F.I. Karmanov, V.L. Shablov, O.F. Nemets, Yu.N. Pavlenko and V.M. Pugach, Fiz. Elem. Chastits At. Yadra 23 (1992) 1035; Sov. J. Part. Nucl. 23 (1992) 459
- 1992MI18 T. Minamisono, T. Ohtsubo, I. Minami, S. Fukuda, A. Kitagawa, M. Fukuda, K. Matsuta, Y. Nojiri, S. Takeda, H. Sagawa et al., Phys. Rev. Lett. 69 (1992) 2058
- 1992PU06 V.M. Pugach, Yu.N. Pavlenko, A.G. Prokopets, Yu.O. Vasiliev, V.A. Kiva and V.I. Medvedev, Bull. Russ. Acad. Sci. 56 (1992) 1768; Izv. Ross. Akad. Nauk. Ser. Fiz. 56 (1992) 129
- 1992RA11 R.D. Ransome, C.L. Morris, M.K. Jones, B.G. Ritchie, D.L. Watson, J.A. McGill, K. Pujara, D.B. Clayton, I. Brown, P. Campbell and C.F. Moore, Phys. Rev. C46 (1992) 273
- 1992SC22 A. Scalia and P. Figuera, Phys. Rev. C46 (1992) 2610
- 1992SO25 E. Somorjai, Fiz. Elem. Chastits At. Yad. 23 (1992) 974; Sov. J. Part. Nucl. 23 (1992) 430
- 1992TA18 I. Tanihata, D. Hirata, T. Kobayashi, S. Shimoura, K. Sugimoto and H. Toki, Phys. Lett. B289 (1992) 261
- 1992TA21 Y. Tagishi, A. Tomizawa, M. Tomizawa and K. Yagi, Nucl. Instrum. Meth. Phys. Res. A322 (1992) 304
- 1992WA09 R.E. Warner, A. Okihana, M. Fujiwara, N. Matsuoka, S. Kakigi, S. Hayashi, K. Fukunaga, J. Kasagi and M. Tosaki, Phys. Rev. C45 (1992) 2328
- 1992WU09 S. Wustenbecker, H.W. Becker, H. Ebbing, W.H. Schulte, M. Berheide, M. Buschmann, C. Rolfs, G.E. Mitchell and J.S. Schweitzer, Z. Phys. A344 (1992) 205
- 1993AN06 C. Angulo, S. Engstler, G. Raimann, C. Rolfs, W.H. Schulte and E. Somorjai, Z. Phys. A345 (1993) 231
- 1993BO24 M.J.G. Borge, L. Johannsen, B. Jonson, T. Nilsson, G. Nyman, K. Riisager, O. Tengblad and K.W. Rolander, Nucl. Phys. A560 (1993) 664

- 1993BU29 M.I. Bulgakov, A.D. Gul'ko, F.S. Dzheparov, S.V. Stepanov and S.S. Trostin, *Pisma Zh. Eksp. Teor. Fiz.* 58 (1993) 614; *JETP Lett.* (1993) 592
- 1993CA04 D.D. Caussyn, N.R. Fletcher, K.W. Kemper, E.E. Towers, J.J. Kolata, K. Lamkin, R.J. Smith, F.D. Becchetti, J.A. Brown, J.W. Janecke et al., *Phys. Rev. C* 47 (1993) 387
- 1993CE02 F.E. Cecil, H. Liu, J.S. Yan and G.M. Hale, *Phys. Rev. C* 47 (1993) 1178
- 1993CH06 W.T. Chou, E.K. Warburton and B.A. Brown, *Phys. Rev. C* 47 (1993) 163
- 1993CZ01 K. Czerski, H. Bucka, P. Heide and T. Makubire, *Phys. Lett. B* 307 (1993) 20
- 1993DE30 P. Descouvemont, *J. Phys. (London)* G19 Suppl. (1993) S141
- 1993KO34 A.A. Korshennikov, K. Yoshida, D.V. Aleksandrov, N. Aoi, Y. Doki, N. Inabe, M. Fujimaki, T. Kobayashi, H. Kumagai, C.-B. Moon et al., *Phys. Lett. B* 316 (1993) 38
- 1993KR18 H. Krauss, K. Grun, T. Rauscher and H. Oberhummer, *Ann. Physik* 2 (1993) 258
- 1993MI34 T. Minamisono, T. Ohtsubo, Y. Nakayama, S. Fukuda, T. Izumikawa, M. Tanigaki, M. Matsui, S. Takeda, N. Nakamura, M. Fukuda et al., *Hyperfine Interactions* 78 (1993) 159
- 1993MI35 T. Minamisono, T. Ohtsubo, I. Minami, A. Kitagawa, S. Fukuda, Y. Nakayama, M. Fukuda, K. Matsuta, Y. Nojiri, S. Takeda, H. Sagawa and H. Kitagawa, *Hyperfine Interactions* 78 (1993) 165
- 1993MO28 C.P. Montoya, S. Schadmand, R. Varma, P.H. Zhang, R. Butsch, I. Diószegi, D.J. Hofman and P. Paul, *Nucl. Instrum. Meth. Phys. Res. A* 334 (1993) 437
- 1993MO33 S. Momota, Y. Nojiri, M.-B. Tanaka, T. Yanagisawa, M. Fukuda, K. Matsuta and T. Minamisono, *Hyperfine Interactions* 80 (1993) 1275
- 1993MO34 S. Momota, Y. Nojiri, M.-B. Tanaka, T. Yanagisawa, M.-Y. Tanaka, M. Fukuda, K. Matsuta and T. Minamisono, *Hyperfine Interactions* 80 (1993) 1281
- 1993NO08 Y. Nojiri, S. Momota, T. Yanagisawa, M.-B. Tanaka, M. Fukuda, K. Matsuta and T. Minamisono, *Hyperfine Interactions* 80 (1993) 567
- 1993OH11 T. Ohtsubo, Y. Nakayama, I. Minami, M. Tanigaki, S. Fukuda, A. Kitagawa, M. Fukuda, K. Matsuta, Y. Nojiri, H. Akai et al., *Hyperfine Interactions* 80 (1993) 1051
- 1993PA31 Yu.N. Pavlenko, B.M. Pugach, V.A. Kiva, V.I. Medvedev, Yu.O. Vasilev, V.N. Dobrikov and I.N. Kolomiets, *Bull. Russ. Acad. Sci. Phys.* 57 (1993) 1788; *Izv. Akad. Nauk Ser. Fiz.* 57:10 (1993) 140
- 1993RA14 G. Raimann, *Z. Phys.* A347 (1993) 73
- 1993RI04 K. Riisager and A.S. Jensen, *Phys. Lett. B* 301 (1993) 6
- 1993RO04 G. Royer and F. Haddad, *Phys. Rev. C* 47 (1993) 1302
- 1993SC06 A. Scalia, *Phys. Rev. C* 47 (1993) 1247
- 1993TI01 N.K. Timofeyuk, D. Baye and P. Descouvemont, *Nucl. Phys. A* 551 (1993) 1

- 1993TI07 D.R. Tilley, H.R. Weller and C.M. Cheves, Nucl. Phys. A564 (1993) 1
- 1993TR06 H.P. Trautvetter, J. Phys. (London) G19 (1993) S95
- 1994AB25 S.N. Abramovich, L.N. Generalov, B.Ya. Guzhovsky, L.N. Kryazhinskaya, E.G. Orlikova and V.N. Popov, Bull. Russ. Acad. Sci. Phys. 58 (1994) 75; Izv. Ross. Akad. Nauk Ser. Fiz. 58 (1994) 87
- 1994AR24 N. Arena, I.Ya. Barit, Seb. Cavallaro, A. d'Arrigo, G. Fazio, G. Giardina, V.V. Ostashko, M. Sacchi, V.N. Urin and S.V. Zuyev, J. Phys. (London) G20 (1994) 1973
- 1994CH23 R.M. Chasteler, H.R. Weller, D.R. Tilley and R.M. Prior, Phys. Rev. Lett. 72 (1994) 3949
- 1994CH70 R.M. Chasteler and H.R. Weller, Nucl. Instrum. Meth. Phys. Res. A344 (1994) 429
- 1994DE03 P. Descouvemont and D. Baye, Nucl. Phys. A567 (1994) 341
- 1994DE09 P. Descouvemont and D. Baye, Nucl. Phys. A573 (1994) 28
- 1994DE30 L. De Braekeleer, Nucl. Phys. A577 (1994) 383c
- 1994HA39 I. Hamamoto, Nucl. Phys. A577 (1994) 19
- 1994HO23 H. Hofsass, U. Wahl, M. Restle, C. Ronning, E. Recknagel and S.G. Jahn, Nucl. Instrum. Meth. Phys. Res. B85 (1994) 468
- 1994JA05 H.J. Jansch, M. Detje, H.D. Ebinger, W. Preyss, H. Reich, R. Veith, W. Widdra, D. Fick, M. Rockelein and H.-G. Volk, Nucl. Phys. A568 (1994) 544
- 1994KA02 M. Kamionkowski and J.N. Bahcall, Phys. Rev. C49 (1994) 545
- 1994KA25 D.M. Kalassa and G. Baur, J. Phys. (London) G20 (1994) 1023
- 1994LA08 K. Langanke and T.D. Shoppa, Phys. Rev. C49 (1994) R1771; Erratum Phys. Rev. C51 (1995) 2844
- 1994ME08 J.W. Meadows, D.L. Smith, L.R. Greenwood, D.W. Kneff and B.M. Oliver, Ann. Nucl. Energy 21 (1994) 155
- 1994MO33 T. Motobayashi, N. Iwasa, Y. Ando, M. Kurokawa, H. Murakami, J. Ruan, S. Shimoura, S. Shirato, N. Inabe, M. Ishihara et al., Phys. Rev. Lett. 73 (1994) 2680
- 1994NE05 V.G. Neudatchin, A.A. Sakharuk, W.W. Kurowsky and Yu.M. Tchuvil'sky, Phys. Rev. C50 (1994) 148
- 1994RO16 C. Rolfs and R.W. Kavanagh, Z. Phys. A350 (1994) 93
- 1994SC14 A. Scalia, Phys. Rev. C49 (1994) 2847
- 1994TY03 S. Typel and G. Baur, Phys. Rev. C50 (1994) 2104
- 1994WI08 J.Z. Williams, G. Feldman, H.R. Weller and D.R. Tilley, Nucl. Phys. A577 (1994) 653
- 1994XU08 H.M. Xu, C.A. Gagliardi, R.E. Tribble, A.M. Mukhamedzhanov and N.K. Timofeyuk, Phys. Rev. Lett. 73 (1994) 2027

- 1994ZH14 M.V. Zhukov, A.A. Korshennikov and M.H. Smedberg, *Phys. Rev. C* 50 (1994) R1
- 1995AB41 S.N. Abramovich, Yu.I. Vinogradov, L.N. Generalov, B.Ya. Guzhovsky, B.P. Sabanin and V.V. Chulkov, *Izv. Ross. Akad. Nauk Ser. Fiz.* 59 (1995) 88; *Bull. Russ. Acad. Sci. Phys.* 59 (1995) 1880.
- 1995AL25 P. Alexa and J. Kvasil, *Z. Phys.* A353 (1995) 255
- 1995AR25 N. Arena, S. Cavallaro, P. Dagostino, G. Fazio, G. Giardina, O.Y. Goryunov, V.V. Ostashko, R. Palamara and A.A. Shvedov, *J. Phys. (London)* G21 (1995) 1403
- 1995BA24 D. Baddou, C. Rioux, R.J. Slobodrian and J.M. Nelson, *Can. J. Phys.* 73 (1995) 74
- 1995BA36 F.C. Barker, *Nucl. Phys.* A588 (1995) 693
- 1995BB21 F.C. Barker, *Aust. J. Phys.* 48 (1995) 813
- 1995BE26 C.A. Bertulani and H. Sagawa, *Nucl. Phys.* A588 (1995) 667
- 1995BO35 M. Bogovac, S. Fazinic, M. Jaksic, M. Lattuada, D. Miljanic, N. Soic, C. Spitaleri and M. Zadro, *Fizika (Zagreb)* B4 (1995) 229
- 1995CH19 L.V. Chulkov, C.A. Bertulani and A.A. Korshennikov, *Nucl. Phys.* A587 (1995) 291
- 1995CR03 R. Crespo, J.A. Tostevin and R.C. Johnson, *Phys. Rev. C* 51 (1995) 3283
- 1995CS01 A. Csoto, K. Langanke, S.E. Koonin and T.D. Shoppa, *Phys. Rev. C* 52 (1995) 1130
- 1995DE18 L. De Braekeleer, E.G. Adelberger, J.H. Gundlach, M. Kaplan, D. Markoff, A.M. Nathan, W. Schieff, K.A. Snover, D.W. Storm, K.B. Swartz et al., *Phys. Rev. C* 51 (1995) 2778; *Erratum Phys. Rev. C* 52 (1995) 3509
- 1995FA17 S.A. Fayans, O.M. Knyazkov, I.N. Kuchtina, Y.E. Penionzhkevich and N.K. Skobelev, *Phys. Lett.* B357 (1995) 509
- 1995FA21 G. Fazio, G. Giardina, O.Yu. Goryunov, A.A. Shvedov and R. Palamara, *J. Phys. Soc. Jpn.* 64 (1995) 1141
- 1995GA25 M.S. Gai and C.A. Bertulani, *Phys. Rev. C* 52 (1995) 1706
- 1995GA39 L.I. Galanina and N.S. Zelenskaya, *Yad. Fiz.* 58 (1995) 1518; *Phys. At. Nucl.* 58 (1995) 1435
- 1995GO10 R.A. Golubev and V.V. Kirichenko, *Nucl. Phys.* A587 (1995) 241
- 1995GO21 E.N. Golovach, B.S. Ishkhanov and V.N. Orlin, *Yad. Fiz.* 58 (1995) 404; *Phys. At. Nucl.* 58 (1995) 354
- 1995GO32 S.A. Goncharov and A.A. Korshennikov, *Europhys. Lett.* 30 (1995) 13
- 1995GU22 I.R. Gulamov, A.M. Mukhamedzhanov and G.K. Nie, *Phys. At. Nucl.* 58 (1995) 1689; *Yad. Fiz.* 58 (1995) 1789
- 1995IC02 S. Ichimaru and H. Kitamura, *J. Phys. Soc. Jpn.* 64 (1995) 2270

- 1995KO10 A.A. Korshennikov, E.Y. Nikolskii, T. Kobayashi, D.V. Aleksandrov, M. Fujimaki, H. Kumagai, A.A. Ogloblin, B. Ozawa, I. Tanihata, Y. Watanabe et al., Phys. Lett. B343 (1995) 53.
- 1995KO27 A.A. Korshennikov, D.V. Aleksandrov, N. Aoi, Y. Doki, N. Inabe, M. Fujimaki, T. Kobayashi, H. Kumagai, C.B. Moon, E.Y. Nikolskii et al., Nucl. Phys. A588 (1995) 23c
- 1995LA17 K. Langanke and T.D. Shoppa, Phys. Rev. C52 (1995) 1709
- 1995LI07 Q.K.K. Liu and S.G. Cooper, Phys. Rev. C51 (1995) 2268.
- 1995MU10 A.M. Mukhamedzhanov, R.E. Tribble and N.K. Timofeyuk, Phys. Rev. C51 (1995) 3472
- 1995NE04 S. Neumaier, G.D. Alkhozov, M.N. Andronenko, T. Beha, K.H. Behr, A. Brunle, K. Burkhard, A.V. Dobrovolsky, P. Egelhof, C. Fischer et al., Nucl. Phys. A583 (1995) 799c
- 1995NE11 V.G. Neudatchin, A.A. Sakharuk, W.W. Kurowsky and Y.M. Tchuvilsky, Phys. At. Nucl. 58 (1995) 1155; Yad. Fiz. 58 (1995) 1234
- 1995PE09 I. Pecina, R. Anne, D. Bazin, C. Borcea, V. Borrel, F. Carstoiu, J.M. Corre, Z. Dlouhy, A. Fomitchev, D. Guillemaudmueller et al., Phys. Rev. C52 (1995) 191
- 1995SC10 W. Schwab, H. Geissel, H. Lenske, K.H. Behr, A. Brunle, K. Burkard, H. Irmich, T. Kobayashi, G. Kraus, A. Magel et al., Z. Phys. A350 (1995) 283
- 1995ST29 E.A. Stokovsky and F.A. Gareev, Yad. Fiz. 58 (1995) 1404; Phys. At. Nucl. 58 (1995) 1320
- 1995SU13 Y. Suzuki, K. Arai, Y. Ohbayasi and K. Varga, Nucl. Phys. A588 (1995) 15c.
- 1995TC01 Yu.M. Tchuvilsky, W.W. Kurowsky, A.A. Sakharuk and V.G. Neudatchin, Phys. Rev. C51 (1995) 784
- 1995VO05 W. von Oertzen, H.G. Bohlen, B. Gebauer, M. von Lucke-Petsch, A.N. Ostrowski, Ch. Seyfert, Th. Stolla, M. Wilpert, Th. Wilpert, D.V. Alexandrov et al., Nucl. Phys. A588 (1995) 129c.
- 1995WA19 R.E. Warner, J.H. Kelley, P. Zecher, F.D. Becchetti, J.A. Brown, C.L. Carpenter, A. Galonsky, J. Kruse, A. Muthukrishnan, A. Nadasen et al., Phys. Rev. C52 (1995) R1166
- 1995WE11 H.R. Weller and R.M. Chasteler, Z. Phys. A352 (1995) 353
- 1995YA02 Y. Yamashita, Nucl. Phys. A582 (1995) 270
- 1995YA07 Y. Yamashita and Y. Kudo, Nucl. Phys. A589 (1995) 460
- 1995YI01 S. Ying and E.M. Henley, Nucl. Phys. A585 (1995) 463
- 1995ZA03 D. Zahnow, C. Angulo, C. Rolfs, S. Schmidt, W.H. Schulte and E. Somorjai, Z. Phys. A351 (1995) 229

- 1996AL03 M. Aliotta, S. Cherubini, E. Costanzo, M. Lattuada, S. Romano, C. Spitaleri, A. Tumino, D. Vinciguerra and M. Zadro, *Z. Phys.* A354 (1996) 119
- 1996BA28 J.N. Bahcall, E. Lisi, D.E. Alburger, L. De Braeckelee, S.J. Freedman and J. Napolitano, *Phys. Rev.* C54 (1996) 411
- 1996BA66 F.C. Barker, *Nucl. Phys.* A609 (1996) 38
- 1996BB26 F.C. Barker, *Aust. J. Phys.* 49 (1996) 1081
- 1996BE83 C.A. Bertulani, *Z. Phys.* A356 (1996) 293
- 1996BL10 J.C. Blackmon, A.E. Champagne, J.K. Dickens, J.A. Harvey, M.A. Hofstee, S. Kopecky, D.C. Larson, D.C. Powell, S. Raman and M.S. Smith, *Phys. Rev.* C54 (1996) 383
- 1996BO27 O.V. Bochkarev, V.A. Vukolov, E.A. Koltipin, E.A. Kuzmin, Yu.D. Molchanov, L.V. Chulkov and G.B. Yankov, *Yad. Fiz.* 59 (1996) 1749; *Phys. At. Nucl.* 59 (1996) 1690
- 1996BR04 B.A. Brown, A. Csoto and R. Sherr, *Nucl. Phys.* A597 (1996) 66
- 1996CS05 A. Csoto and S. Karataglidis, *Nucl. Phys.* A607 (1996) 62; Erratum *Nucl. Phys.* A609 (1996) 601
- 1996DE02 P. Descouvemont, *Nucl. Phys.* A596 (1996) 285
- 1996DE51 F.W.N. de Boer, O. Frohlich, K.E. Stiebing, K. Bethge, H. Bokemeyer, A. Balanda, A. Buda, R. van Dantzig, Th.W. Elze, H. Folger et al., *Phys. Lett.* 388B (1996) 235
- 1996EB01 H.D. Ebinger, H.J. Jansch, C. Polenz, B. Polivka, W. Preyss, V. Saier, R. Veith and D. Fick, *Phys. Rev. Lett.* 76 (1996) 656
- 1996ES02 H. Esbensen and G.F. Bertsch, *Nucl. Phys.* A600 (1996) 37
- 1996FIZY R.B. Firestone, *Table of Isotopes*, 8th Ed., Eds. V.S. Shirley, C.M. Baglin, S.Y.F. Chu and J. Zipkin, Vol. 1 (John Wiley and Sons, Inc. Publ., New York, 1996)
- 1996GO01 M.A. Godwin, R.M. Chasteler, C.M. Laymon, R.M. Prior, D.R. Tilley and H.R. Weller, *Phys. Rev.* C53 (1996) R1
- 1996GR16 L.V. Grigorenko, N.B. Shulgina and M.V. Zhukov, *Nucl. Phys.* A607 (1996) 277; Erratum *Nucl. Phys.* A614 (1997) 567
- 1996GR21 F. Grummer, B.Q. Chen, Z.Y. Ma and S. Krewald, *Phys. Lett.* B387 (1996) 673
- 1996HA06 K.I. Hahn, C.R. Brune, R.W. Kavanagh, *Phys. Rev.* C53 (1996) 1273
- 1996KA14 Y. Kanada-Enyo and H. Horiuchi, *Phys. Rev.* C54 (1996) R468
- 1996KE16 J.H. Kelley, S.M. Austin, A. Azhari, D. Bazin, J.A. Brown, H. Esbensen, M. Fauerbach, M. Hellstrom, S.E. Hirzebruch, R.A. Kryger et al., *Phys. Rev. Lett.* 77 (1996) 5020
- 1996KN05 O.M. Knyazkov, I.N. Kukhtina, Yu.E. Penionzhkevich, N.K. Skobelev and S.A. Fayans, *Yad. Fiz.* 59 (1996) 1188; *Phys. At. Nucl.* 59 (1996) 1138

- 1996KU08 A.V. Kulik, *Yad. Fiz.* 59 (1996) 217; *Phys. At. Nucl.* 59 (1996) 199
- 1996LI12 W. Liu, X. Bai, S. Zhou, Z. Ma, Z. Li, Y. Wang, A. Li, Z. Ma, B. Chen, X. Tang et al., *Phys. Rev. Lett.* 77 (1996) 611
- 1996NE06 F. Negoita, C. Borcea, F. Carstoiu, M. Lewitowicz, M.G. Saint-Laurent, R. Anne, D. Bazin, J.M. Corre, P. Roussel-Chomaz, V. Borrel et al., *Phys. Rev.* C54 (1996) 1787
- 1996NI02 T. Nilsson, F. Humbert, W. Schwab, H. Simon, M.H. Smedberg, M. Zinser, T. Blaich, M.J.G. Borge, L.V. Chulkov, T.W. Elze et al., *Nucl. Phys.* A598 (1996) 418
- 1996NO11 Y. Nojiri, *Hyperfine Interactions* 100 (1996) 23
- 1996OB01 M.M. Obuti, T. Kobayashi, D. Hirata, Y. Ogawa, A. Ozawa, K. Sugimoto, I. Tanihata, D. Olson, W. Christie and H. Wieman, *Nucl. Phys.* A609 (1996) 74
- 1996RA14 T. Rauscher and G. Raimann, *Phys. Rev.* C53 (1996) 2496
- 1996RE16 H. Rebel, *Acta Phys. Pol.* B27 (1996) 231
- 1996SH02 N.B. Shul'gina, B.V. Danilin, V.D. Efros, J.M. Bang, J.S. Vaagen and M.V. Zhukov, *Nucl. Phys.* A597 (1996) 197
- 1996SH08 R. Shyam, I.J. Thompson and A.K. Duttmazumder, *Phys. Lett.* B371 (1996) 1
- 1996SK04 N.K. Skobelev, S.M. Lukyanov, Yu.E. Penionzhkevich, O.B. Tarasov, A.S. Fomichev, R. Anne, D. Bazin, J.-M. Corre, M. Lewitowicz, P. Roussel-Chomaz et al., *Bull. Russ. Acad. Sci. Phys.* 60 (1996) 123; *Izv. Ross. Akad. Nauk. Ser. Fiz.* 60 (1996) 154
- 1996SO17 N. Soic, S. Blagus, M. Bogovac, S. Fazinic, M. Lattuada, M. Milin, D. Miljanic, D. Rendic, C. Spitaleri, T. Tadic and M. Zadro, *Europhys. Lett.* 34 (1996) 7
- 1996SR02 J. Sromicki, M. Allet, K. Bodek, W. Hajdas, J. Lang, R. Muller, S. Navert, O.N. Naviliat-Cuncic, J. Zejma and W. Haeberli, *Phys. Rev.* C53 (1996) 932
- 1996ST18 F. Strieder, L. Gialanella, U. Greife, C. Rolfs, S. Schmidt, W.H. Schulte, H.P. Trautvetter, D. Zahnnow, F. Terrasi, L. Campajola et al., *Z. Phys.* A355 (1996) 209
- 1996SU24 Y. Sugahara, K. Sumiyoshi, H. Toki, A. Ozawa and I. Tanihata, *Prog. Theor. Phys.* 96 (1996) 1165
- 1996VO09 J. von Schwarzenberg, J.J. Kolata, D. Peterson, P. Santi, M. Belbot and J.D. Hinnefeld, *Phys. Rev.* C53 (1996) R2598
- 1996VO15 P. von Brentano, *Phys. Rept.* 264 (1996) 57
- 1996WA27 R.E. Warner, R.A. Patty, P.M. Voyles, A. Nadasen, F.D. Becchetti, J.A. Brown, H. Esbensen, A. Galonsky, J.J. Kolata, J. Kruse et al., *Phys. Rev.* C54 (1996) 1700
- 1997AL09 G.D. Alkhazov, M.N. Andronenko, A.V. Dobrovolsky, P. Egelhof, G.E. Gavrilov, H. Geissel, H. Irnich, A.V. Khanzadeev, G.A. Korolev, A.A. Lobodenko et al., *Phys. Rev. Lett.* 78 (1997) 2313
- 1997BA04 F.C. Barker, *Phys. Rev.* C55 (1997) 535
- 1997BA54 X. Bai and J. Hu, *Phys. Rev.* C56 (1997) 1410

- 1997BA95 A.B. Balantekin, C.A. Bertulani and M.S. Hussein, Nucl. Phys. A627 (1997) 324
- 1997BL08 B. Blank, C. Marchand, M.S. Pravikoff, T. Baumann, F. Boue, H. Geissel, M. Hellstrom, N. Iwasa, W. Schwab, K. Summerer et al., Nucl. Phys. A624 (1997) 242
- 1997BO12 Y. Boudouma, A.C. Chami and H. Beaumevielle, Nucl. Phys. A617 (1997) 57
- 1997CA36 G. Calvi, S. Cherubini, M. Lattuada, S. Romano, C. Spitaleri, M. Aliotta, G. Rizzari, M. Sciuto, R.A. Zappala, V.N. Kondratyev et al., Nuc. Phys. A621 (1997) 139c
- 1997CS02 A. Csoto, Phys. Lett. B394 (1997) 247
- 1997CS07 A. Csoto, Acta Phys. Hung. 6 (1997) 103
- 1997CZ01 K. Czerski, A. Huke, H. Bucka, P. Heide, G. Ruprecht and B. Unrau, Phys. Rev. C55 (1997) 1517
- 1997CZ04 K. Czerski, G. Ruprecht, H. Bucka and P. Heide, Nuc. Phys. A621 (1997) 119c.
- 1997DE46 F.W.N. de Boer, R. van Dantzig, J. van Klinken, K. Bethge, H. Bokemeyer, A. Buda, K.A. Muller and K.E. Stiebing, J. Phys. (London) G23 (1997) L85
- 1997GO13 M.A. Godwin, C.M. Laymon, R.M. Prior, D.R. Tilley and H.R. Weller, Phys. Rev. C56 (1997) 1605
- 1997KI01 T. Kikuchi, T. Motobayashi, N. Iwasa, Y. Ando, M. Kurokawa, S. Moriya, H. Murakami, T. Nishio, J. Ruan, S. Shirato et al., Phys. Lett. B391 (1997) 261
- 1997KI02 Y.E. Kim, Y.J. Kim, A.L. Zubarev and J.-H. Yoon, Phys. Rev. C55 (1997) 801
- 1997KN07 O.M. Knyazkov, I.N. Kukhtina and S.A. Fayans, Fiz. Elem. Chastits At. Yadra 28 (1997) 1061; Phys. Part. Nucl. 28 (1997) 418
- 1997KO06 A.A. Korshennikov, E. A. Kuzmin, E. Yu. Nikolsky, C.A. Bertulani, O.V. Bochkarev, S. Fukuda, T. Kobayashi, S. Momota, B.G. Novatsky, A.A. Ogloblin et al., Nucl. Phys. A616 (1997) 189c
- 1997KO12 A.A. Korshennikov, E. Yu. Nikolskii, C.A. Bertulnai, S. Fukuda, T. Kobayashi, E.A. Kuzmin, S. Momota, B.G. Novatskii, A.A. Ogloblin, A. Ozawa et al., Nucl. Phys. A617 (1997) 45
- 1997LI05 W. Liu, X. Bai, S. Zhou, Z. Ma, Z. Li, Y. Wang, A. Li, Z. Ma, B. Chen, X. Tang et al., Nucl. Phys. A616 (1997) 131c
- 1997NU01 F.M. Nunes, R. Crespo and I.J. Thompson, Nucl. Phys. A615 (1997) 69; Erratum Nucl. Phys. A627 (1997) 747
- 1997PE03 Yu. E. Penionzhkevich, Nucl. Phys. A616 (1997) 247c
- 1997PO12 I.V. Poplavsky and M.N. Popushoi, Bull. Russ. Acad. Sci. Phys. 61 (1997) 160; Izv. Akad. Nauk Ser. Fiz. 61 (1997) 197
- 1997SA04 A.A. Sakharuk and V. Zelevinsky, Phys. Rev. C55 (1997) 302
- 1997SC03 R.-W. Schulze and P.U. Sauer, Phys. Rev. C55 (1997) 1051

- 1997SC46 J.N. Scheurer, F. Hammache, G. Bogaert, C. Angulo, L. Brillard, A. Coc, J.F. Chemin, G. Claverie, M. Hussonis, M. Jacotin et al., *Acta Phys. Hung.* 6 (1997) 107
- 1997SH19 N.B. Shul'gina, L.V. Grigorenko, M.V. Zhulov and J.M. Bang, *Nucl. Phys.* A619 (1997) 143
- 1997SK03 N.K. Skobelev, S.M. Lukyanov, Yu.E. Penionzhkevich, O.B. Tarasov, A.S. Fomichev, F. Negoita, C. Borcea, F. Carstoiu, M. Lewitowicz, M.-G. Saint-Laurent et al., *Bull. Russ. Acad. Sci. Phys.* 61 (1997) 1762; *Izv. Ross. Akad. Nauk Ser. Fiz.* 61 (1997) 2239
- 1997SZ01 S. Szilner, Z. Basrak, R.M. Freeman, F. Haas, A. Morsad and C. Beck, *Phys. Rev.* C55 (1997) 1312
- 1997TI03 N.K. Timofeyuk, D. Baye and P. Descouvemont, *Nucl. Phys.* A620 (1997) 29
- 1997TY01 S. Typel, H.H. Wolter and G. Baur, *Nucl. Phys.* A613 (1997) 147
- 1997YA02 J.S. Yan, F.E. Cecil, J.A. McNeil, M.A. Hofstee and P.D. Kunz, *Phys. Rev.* C55 (1997) 1890
- 1997ZA06 D. Zahnow, C. Rolfs, S. Schmidt and H.P. Trautvetter, *Z. Phys.* A359 (1997) 211
- 1997ZH40 M.A. Zhusupov, A.K. Morzabaev and S.K. Sahiev, *Izv. Akad. Nauk Ser. Fiz.* 61 (1997) 2484; *Bull. Russ. Acad. Sci. Phys.* 61 (1997) 1959
- 1998AD12 E.G. Adelberger, S.M. Austin, J.B. Bahcall, A.B. Balantekin, G. Bogaert, L.S. Brown, L. Buchmann, F.E. Cecil, A.E. Champagne, L. de Braeckelee et al., *Rev. Mod. Phys.* 70 (1998) 1265
- 1998AN25 A.A. Andrianov, K.A. Gridnev, T.V. Tarutina and M.A. Yugal'din, *Izv. Ross. Akad. Nauk Ser. Fiz.* 62 (1998) 89; *Bull. Russ. Acad. Sci. Phys.* 62 (1998) 75.
- 1998BE1Q V.B. Belyaev, D.E. Monakhov, D.V. Naumov and F.M. Penkov, *Phys. Lett.* A247 (1998) 241
- 1998BE44 K. Bennaceur, F. Nowacki, J. Okolowicz and M. Ploszajczak, *J. Phys. (London)* G24 (1998) 1631
- 1998BR10 C.R. Brune, W.H. Geist, H.J. Karwowski, E.J. Ludwig and K.D. Veal, *Phys. Rev.* C57 (1998) 3437
- 1998CS03 A. Csoto and K. Langanke, *Nucl. Phys.* A636 (1998) 240
- 1998DA14 B. Davids, D.W. Anthony, Sam M. Austin, D. Bazin, B. Blank, J.A. Caggiano, M. Chartier, H. Esbensen, P. Hui, C.F. Powell et al., *Phys. Rev. Lett.* 81 (1998) 2209
- 1998DA15 C.H. Dasso, S.M. Lenzi and A. Vitturi, *Nucl. Phys.* A639 (1998) 635
- 1998EF05 V.D. Efros, H. Oberhummer, A. Pushkin and I.J. Thompson, *Eur. Phys. J.* A1 (1998) 447
- 1998FA05 M.S. Fayache, E. Moya de Guerra, P. Sarriguren, Y.Y. Sharon and L. Zamick, *Phys. Rev.* C57 (1998) 2351; *Comment Phys. Rev.* C59 (1999) 2956; *Erratum Phys. Rev.* C61 (2000) 059901

- 1998FI02 G. Fiorentini, E. Lisi, S. Sarkar and F.L. Villante, Phys. Rev. D58 (1998) 063506
- 1998GA02 C.A. Gagliardi, A.M. Mukhamedzhanov, R.E. Tribble and H.M. Xu, Phys. Rev. Lett. 80 (1998) 421
- 1998GO16 V.Z. Goldberg, G.V. Rogachev, M.S. Golovkov, V.I. Dukhanov, I.N. Serikov and V.A. Timofeev, Pisma Zh. Eksp. Teor. Fiz. 67 (1998) 959; JETP Lett. 67 (1998) 1013
- 1998GO30 M.G. Gornov, Yu.B. Gurov, S.V. Lapushkin, P.V. Morokhov, V.A. Pechkurov, K. Seth, T. Pedlar, J. Wise and D. Zhao, Bull. Russ. Acad. Sci. Phys. 62 (1998) 1781
- 1998GR07 L.V. Grigorenko, B.V. Danilin, V.D. Efros, N.B. Shul'gina and M.V. Zhukov, Phys. Rev. C57 (1998) R2099
- 1998HA05 F. Hammache, G. Bogaert, P. Aguer, C. Angulo, S. Barhoumi, L. Brillard, J.F. Chemin, G. Claverie, A. Coc, M. Hussonnois et al., Phys. Rev. Lett. 80 (1998) 928
- 1998HE35 M. Heil, F. Kappeler, M. Wiescher and A. Mengoni, Astrophys. J. 507 (1998) 997
- 1998JE04 B.K. Jennings, S. Karataglidis and T.D. Shoppa, Phys. Rev. C58 (1998) 579
- 1998JE10 B.K. Jennings and S. Karataglidis, Phys. Rev. C58 (1998) 3002
- 1998JE11 B.K. Jennings, S. Karataglidis and T.D. Shoppa, Phys. Rev. C58 (1998) 3711
- 1998JO09 G. Jonkmans, I.S. Towner and B. Sur, Phys. Rev. C58 (1998) 1278
- 1998KA51 F.F. Karpeshin, M.A. Listengarten and L.I. Mileshina, Bull. Russ. Acad. Sci. Phys. 62 (1998) 20
- 1998KI19 T. Kikuchi, T. Motobayashi, N. Iwasa, Y. Ando, M. Kurokawa, S. Moriya, H. Murakami, T. Nishio, J. Ruan, S. Shirato et al., Eur. Phys. J. A3 (1998) 213
- 1998KN02 O.M. Knyazkov, I.N. Kuchtina and S.A. Fayans, Phys. At. Nucl. 61 (1998) 533
- 1998MA54 M. Mayer, A. Annen, W. Jacob and S. Grigull, Nucl. Instrum. Meth. Phys. Res. B143 (1998) 244
- 1998MO13 D.E. Monakhov, V.B. Belyaev, S.A. Sofianos, S.A. Rakityansky and W. Sandhas, Nucl. Phys. A635 (1998) 257
- 1998NU01 F.M. Nunes and I.J. Thompson, Phys. Phys. C57 (1998) R2818
- 1998SH09 R. Shyam and H. Lenske, Phys. Rev. C57 (1998) 2427
- 1998ST20 F. Strieder, F. Schumann, L. Gialanella, U. Greife, D. Rogalla, C. Rolfs, H.P. Trautvetter, Zs. Fulop, G. Gyurky, E. Somorjai et al., Eur. Phys. J. A3 (1998) 1
- 1998WE05 L. Weissman, C. Broude, G. Goldring, R. Hadar, M. Hass, F. Schwamm and M. Shaanan, Nucl. Phys. A630 (1998) 678
- 1998WI10 R.B. Wiringa, Nucl. Phys. A631 (1998) 70c.
- 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
- 1999AZ02 A. Azhari, V. Burjan, F. Carstoiu, H. Dejbakhsh, C.A. Gagliardi, V. Kroha, A.M. Mukhamedzhanov, L. Trache and R.E. Tribble, Phys. Rev. Lett. 82 (1999) 3960
- 1999AZ04 A. Azhari, V. Burjan, F. Carstoiu, C.A. Gagliardi, V. Kroha, A.M. Mukhamedzhanov, X. Tang, L. Trache and R.E. Tribble, Phys. Rev. C60 (1999) 055803
- 1999BB07 F.C. Barker, Nucl. Phys. A660 (1999) 249
- 1999BE25 K. Bennaceur, F. Nowacki, J. Okolowicz and M. Ploszajczak, Nucl. Phys. A651 (1999) 289
- 1999BO26 H.G. Bohlen, A. Blazevic, B. Gebauer, W. von Oertzen, S. Thummerer, R. Kalpakchieva, S.M. Grimes and T.N. Massey, Prog. Part. Nucl. Phys. 42 (1999) 17
- 1999DE23 P. Descouvemont and D. Baye, Phys. Rev. C60 (1999) 015803
- 1999DE33 V.M. de Aquino and M. Canaves, Jr., Phys. Rev. D60 (1999) 073001
- 1999FE04 J.C. Fernandes, R. Crespo, F.M. Nunes and I.J. Thompson, Phys. Rev. C59 (1999) 2865
- 1999FU08 M. Fukuda, M. Mihara, T. Fukao, S. Fukuda, M. Ishihara, S. Ito, T. Kobayashi, K. Matsuta, T. Minamisono, S. Momota et al., Nucl. Phys. A656 (1999) 209
- 1999GO15 N. Godinovic, S. Blagus, M. Bogovac, M. Latuada, M. Milin, D. Miljanic, D. Rendic, N. Soic, C. Spitaleri and M. Zadro, Phys. Rev. C60 (1999) 037601
- 1999HA27 M. Harada, Y. Watanabe, A. Yamamoto, S. Yoshioka, K. Sato, T. Nakashima, H. Ijiri, H. Yoshida, Y. Uozumi, N. Koori et al., J. Nucl. Sci. Tech. (Tokyo) 36 (1999) 313
- 1999HA51 M. Hass, C. Broude, V. Fedoseev, G. Goldring, G. Huber, J. Lettry, V. Mishin, H.J. Ravn, V. Sebastian, L. Weissman and the ISOLDE Collaboration, Phys. Lett. B462 (1999) 237
- 1999HA61 I. Hamamoto and H. Sagawa, Phys. Rev. C60 (1999) 064314
- 1999IW03 N. Iwasa, F. Boue, G. Surowka, K. Summerer, T. Baumann, B. Blank, S. Czajkowski, A. Forster, M. Gai, H. Geissel et al., Phys. Rev. Lett. 83 (1999) 2910
- 1999KN04 O.M. Knyazkov, I.N. Kukhtina and S.A. Fayans, Fiz. Elem. Chastits At. Yad. 30 (1999) 870, Phys. Part. Nucl. 30 (1999) 369
- 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
- 1999RU10 A.T. Rudchik, O.A. Momotyuk, A. Budzanowski, A. Szczurek, V.K. Chernievsky, A.V. Mokhnach, V.A. Ziman, E.I. Koshchy, S. Kliczewski, R. Siudak et al., Nucl. Phys. A660 (1999) 267
- 1999SA27 A. Sakharuk, V. Zelevinsky and V.G. Neudatchin, Phys. Rev. C60 (1999) 014605
- 1999SH05 K. Shoda and T. Tanaka, Phys. Rev. C59 (1999) 239

- 1999SM04 M.H. Smedberg, T. Baumann, T. Aumann, L. Axelsson, U. Bergmann, M.J.G. Borge, D. Cortina-Gil, L.M. Fraile, H. Geissel, L. Grigorenko et al., Phys. Lett. B452 (1999) 1
- 1999SP09 C. Spitaleri, M. Aliotta, S. Cherubini, M. Lattuada, Dj. Miljanic, S. Romano, N. Soic, M. Zadro and R.A. Zappala, Phys. Rev. C60 (1999) 055802
- 1999ST06 G.F. Steyn, S.V. Fortsch, A.A. Cowley, J.J. Lawrie, G.J. Arendse, G.C. Hillhouse, J.V. Pilcher, F.D. Smit and R. Neveling, Phys. Rev. C59 (1999) 2097
- 2000AL04 D. Aleksandrov, T. Aumann, L. Axelsson, T. Baumann, M.J.G. Borge, L.V. Chulkov, J. Cub, W. Dostal, B. Eberlein, Th.W. Elze et al., Nucl. Phys. A669 (2000) 51
- 2000BA09 D. Baye and E. Brainis, Phys. Rev. C61 (2000) 025801
- 2000BA21 F.C. Barker, Aust. J. Phys. 53 (2000) 247
- 2000BA46 F.C. Barker and A.M. Mukhamedzhanov, Nucl. Phys. A673 (2000) 526
- 2000BA89 F.C. Barker, Phys. Rev. C62 (2000) 044607
- 2000BB06 D. Baye, P. Descouvemont and R. Kamouni, Few-Body Syst. 29 (2000) 131
- 2000BB09 D. Baye, Phys. Rev. C62 (2000) 065803
- 2000BE21 K. Bennaceur, F. Nowacki, J. Okolowicz and M. Ploszajczak, Acta Phys. Pol. B31 (2000) 311
- 2000BU10 K. Buckley, T. Fugleberg and A. Zhitnitsky, Phys. Rev. Lett. 84 (2000) 4814
- 2000CO31 D. Cortina-Gil, F. Attallah, T. Aumann, L. Axelsson, T. Baumann, J. Benlliure, M.J.G. Borge, K. Boretzky, L. Chulkov, U.D. Pramanik et al., Acta Phys. Hung. N. S. 12 (2000) 275
- 2000CS01 A. Csoto, Phys. Rev. C61 (2000) 024311
- 2000CS03 A. Csoto, Phys. Rev. C61 (2000) 037601
- 2000GE16 L.N. Generalov, S.N. Abramovich and A.G. Zvenigorodsky, Bull. Russ. Acad. Sci. Phys. 64 (2000) 352; Izv. Ross. Akad. Nauk Ser. Fiz. 64 (2000) 440
- 2000GI07 R.A. Giannelli, B.G. Ritchie, J.M. Applegate, E. Beck, J. Beck, A.O. Vanderpool, C.L. Morris, M. Rawool-Sullivan, M.K. Jones, R.D. Ransome et al., Phys. Rev. C61 (2000) 054615
- 2000GL04 V.V. Glagolev, K.G. Gulamov, V.D. Lipin, S.L. Lutpullaev, K. Olimov, A.A. Yuldashev and B.S. Yuldashev, Yad. Fiz. 63 (2000) 575; Phys. At. Nucl. 63 (2000) 520
- 2000GR03 L.V. Grigorenko, N.B. Shul'gina and M.V. Zhukov, Nucl. Phys. A665 (2000) 105
- 2000GR07 L.V. Grigorenko, N.B. Shulgina and B.V. Danilin, Nucl. Phys. A671 (2000) 136
- 2000GU05 V. Guimaraes, J.J. Kolata, D. Peterson, P. Santi, R.H. White-Stevens, S.M. Vincent, F.D. Becchetti, M.Y. Lee, T.W. O'Donnell, D.A. Roberts et al., Phys. Rev. Lett. 84 (2000) 1862

- 2000GU19 D. Gupta, C. Samanta and R. Kanungo, Nucl. Phys. A674 (2000) 77
- 2000HA33 T. Hagner, R. von Hentig, B. Heisinger, L. Oberauer, S. Schonert, F. von Feilitzsch and E. Nolte, Astropart. Phys. 14 (2000) 33
- 2000HA50 M. Hashmi and G. Staudenmaier, Phys. Scr. 62 (2000) 268
- 2000IW05 Y. Iwata, K. Ieki, A. Galonsky, J. J. Kruse, J. Wang, R. H. White-Stevens, E. Tryggestad, P. D. Zecher, F. Deak, A. Horvath et al., Phys. Rev. C62 (2000) 064311
- 2000JE10 B.K. Jennings, Phys. Rev. C62 (2000) 027602
- 2000KA04 S. Karataglidis, P.J. Dortmans, K. Amos and C. Bennhold, Phys. Rev. C61 (2000) 024319
- 2000LI13 T.E. Liolios, Phys. Rev. C61 (2000) 055802
- 2000MO07 P. Mohr, Phys. Rev. C61 (2000) 045802
- 2000NE09 S.O. Nelson, E.A. Wulf, J.H. Kelley and H.R. Welle, Nucl. Phys. A679 (2000) 199
- 2000OR04 C.E. Ortiz, A. Garcia, R.A. Waltz, M. Bhattacharya and A.K. Komives, Phys. Rev. Lett. 85 (2000) 2909
- 2000SH01 V.B. Shostak, G.P. Palkin, N.I. Voloshin, V.P. Likhachev, M.N. Martins and J.D.T. Arruda-Neto, Phys. Rev. C61 (2000) 024601
- 2000SP01 M. Spraker, R.M. Prior, M.A. Godwin, B.J. Rice, E.A. Wulf, J.H. Kelley, D.R. Tilley and H.R. Weller, Phys. Rev. C61 (2000) 015802
- 2000VE01 S. Vecchi for the OBELIX Collaboration, Nucl. Phys. A663-664 (2000) 613c
- 2000VO22 V.T. Voronchev and V.I. Kukulín, J. Phys. (London) G26 (2000) L123
- 2000WE03 S.P. Weppner, O. Garcia and Ch. Elster, Phys. Rev. C61 (2000) 044601
- 2000WI09 R.B. Wiringa, S.C. Pieper, J. Carlso and V.R. Pandharipande, Phys. Rev. C62 (2000) 014001
- 2000YA05 Z.-C. Yan and G.W.F. Drake, Phys. Rev. A61 (2000) 022504
- 2001AV02 S.P. Avdeyev, V.A. Karnaukhov, L.A. Petrov, V.K. Rodionov, V.D. Toneev, H. Oeschler, O.V. Bochkarev, L.V. Chulkov, E.A. Kuzmin, A. Budzanowski et al., Phys. Lett. B503B (2001) 256
- 2001AZ01 A. Azhari, V. Burjan, F. Carstoiu, C.A. Gagliardi, V. Kroha, A.M. Mukhamedzhanov, F.M. Nunes, X. Tang, L. Trache and R.E. Tribble, Phys. Rev. C63 (2001) 055803
- 2001BA47 F.C. Barker and Y. Kondo, Nucl. Phys. A688 (2001) 959
- 2001CA21 F. Carstoiu, L. Trache, C.A. Gagliardi, R.E. Tribble and A.M. Mukhamedzhanov, Phys. Rev. C63 (2001) 054310
- 2001CA37 J.A. Caggiano, D. Bazin, W. Benenson, B. Davids, R. Ibbotson, H. Scheit, B.M. Sherrill, M. Steiner, J. Yurkon, A.F. Zeller et al., Phys. Rev. C64 (2001) 025802
- 2001CA50 E. Caurier, P. Navratil, W.E. Ormand and J.P. Vary, Phys. Rev. C64 (2001) 051301

- 2001CO06 D. Cortina-Gil, T. Baumann, H. Geissel, H. Lenske, K. Summerer, L. Axelsson, U. Bergmann, M.J.G. Borge, L.M. Fraile, M. Hellstrom et al., *Eur. Phys. J. A*10 (2001) 49
- 2001CO21 L. Corraggio, A. Covello, A. Gargano, N. Itaco and T.T.S. Kuo, *J. Phys. (London) G*27 (2001) 2351
- 2001CS03 A. Csoto and K. Langanke, *Nucl. Phys. A*688 (2001) 511c
- 2001CS04 A. Csoto, H. Oberhummer and H. Schlattl, *Nucl. Phys. A*688 (2001) 560c
- 2001DA03 B. Davids, D.W. Anthony, T. Aumann, S.M. Austin, T. Baumann, D. Bazin, R.R.C. Clement, C.N. Davids, H. Esbensen, P.A. Lofy et al., *Phys. Rev. Lett.* 86 (2001) 2750
- 2001DA11 B. Davids, S.M. Austin, D. Bazin, H. Esbensen, B.M. Sherrill, I.J. Thompson and J.A. Tostevin, *Phys. Rev. C*63 (2001) 065806
- 2001DE11 F.W.N. de Boer, K. Bethge, H. Bokemeyer, R. van Dantzig, J. van Klinken, V. Mironov, K.A. Muller and K.E. Stiebing, *J. Phys. (London) G*27 (2001) L29
- 2001DZ02 F. Dzheparov, A. Gulko, P. Heitjans, D. Lvov, A. Schirmer, V. Shestopal, S. Stepanov and S. Trostin, *Physica B*297 (2001) 288
- 2001FR03 M. Freer, J.T. Murgatroyd, S.M. Singer, N. Curtis, D.J. Henderson, D.J. Hofman and A.H. Wuosmaa, *Phys. Rev. C*63 (2001) 034317
- 2001GA19 C.A. Gagliardi, A. Azhari, P. Bem, V. Burjan, F. Carstoiu, J. Cejpek, H.L. Clark, V. Kroha, Y.-W. Lui, A.M. Mukhamedzhanov et al., *Nucl. Phys. A*682 (2001) 369c
- 2001HA26 F. Hammache, G. Bogaert, P. Aguer, C. Angulo, S. Barhoumi, L. Brillard, J.F. Chemin, G. Claverie, A. Coc, M. Hussonnois et al., *Phys. Rev. Lett.* 86 (2001) 3985
- 2001HA36 F. Hammache, G. Bogaert, P. Aguer, C. Angulo, S. Barhoumi, L. Brillard, J.F. Chemin, G. Claverie, A. Coc, M. Hussonnois et al., *Nucl. Phys. A*688 (2001) 273c
- 2001HO22 M. Hoefft, K. Czerski, P. Heide and M. Lang, *Nucl. Phys. A*688 (2001) 524c
- 2001HO23 M.A. Hofstee, A.K. Pallone, F.E. Cecil, J.A. McNeil and C.S. Galovich, *Nucl. Phys. A*688 (2001) 527c.
- 2001JU01 B. Julia-Diaz, F. Fernandez, P. Gonzalez and A. Valcarce, *Phys. Rev. C*63 (2001) 024006
- 2001KO54 A.Yu. Konobeyev, Yu.A. Korovin, P.E. Pereslavitsev, U. Fischer and U. von Mollendorff, *Nucl. Sci. Eng.* 139 (2001) 1
- 2001LA35 M. Lattuada, R.G. Pizzone, S. Typel, P. Figuera, D. Miljanic, A. Musumarra, M.G. Pellegriti, C. Rolfs, C. Spitaleri and H.H. Wolter, *Astrophys. J.* 562 (2001) 1076
- 2001MA05 K. Markenroth, M. Meister, B. Eberlein, D. Aleksandrov, T. Aumann, L. Axelsson, T. Baumann, M.J.G. Borge, L.V. Chulkov, W. Dostal et al., *Nucl. Phys. A*679 (2001) 462
- 2001ME11 A. Mengoni, *Nucl. Phys. A*687 (2001) 92c

- 2001ME13 D.J. Mercer, S.M. Austin, J.A. Brown, S.A. Danczyk, S.E. Hirzebruch, J.H. Kelley, T. Suomijarvi, D.A. Roberts and T.P. Walker, Phys. Rev. C63 (2001) 065805
- 2001MO32 T. Motobayashi, Nucl. Phys. A693 (2001) 258
- 2001MU20 A.M. Mukhamedzhanov, C.A. Gagliardi and R.E. Tribble, Nucl. Phys. A688 (2001) 277c
- 2001MU30 A. Musumarra, R.G. Pizzone, S. Blagus, M. Bogovac, P. Figuera, M. Lattuada, M. Milin, D. Miljanic, M.G. Pellegriti, D. Rendic et al., Phys. Rev. C64 (2001) 068801
- 2001OZ04 A. Ozawa, T. Suzuki and I. Tanihata, Nucl. Phys. A693 (2001) 32
- 2001RO32 G.V. Rogachev, J.J. Kolata, F.D. Becchetti, P.A. DeYoung, M. Hencheck, K. Helland, J.D. Hinnefeld, B. Hughey, P.L. Jolivet, L.M. Kiessel et al., Phys. Rev. C64 (2001) 061601
- 2001SA30 J.M. Sampaio, A.M. Eiro and I.J. Thompson, Nucl. Phys. A688 (2001) 518c
- 2001SA79 C. Samanta, Pramana J. Phys. 57 (2001) 519
- 2001SC12 H. Schwoerer, P. Gibbon, S. Dusterer, R. Behrens, C. Ziener, C. Reich and R. Sauerbrey, Phys. Rev. Lett. 86 (2001) 2317
- 2001SH08 M. Shawcross, N. Curtis, W.N. Catford, N.M. Clarke, B.R. Fulton, S.J. Hall, J.T. Murgatroyd, S.P.G. Chappell, R.L. Cowin, G. Dillon et al., Phys. Rev. C63 (2001) 034311
- 2001SP04 C. Spitaleri, S. Typel, R.G. Pizzone, M. Aliotta, S. Blagus, M. Bogovac, S. Cherubini, P. Figuera, M. Lattuada, M. Milin et al., Phys. Rev. C63 (2001) 055801
- 2001ST27 F. Strieder, L. Gialanella, G. Gyurky, F. Schumann, R. Bonetti, C. Broggin, L. Campajola, P. Corvisiero, H. Costantini, A. D'Onofrio et al., Nucl. Phys. A696 (2001) 219
- 2001TE03 F. Terrasi, L. Gialanella, G. Imbriani, F. Strieder, L. Campajola, A. D'Onofrio, U. Greife, G. Gyurky, C. Lubritto, A. Ordine et al., Nucl. Phys. A688 (2001) 539c
- 2001UT01 H. Utsunomiya, Y. Yonezawa, H. Akimune, T. Yamagata, M. Ohta, M. Fujishiro, H. Toyokawa and H. Ohgaki, Phys. Rev. C63 (2001) 018801
- 2001UT03 H. Utsunomiya, Y. Yonezawa, H. Akimune, T. Yamagata, M. Ohta, H. Toyokawa, H. Ohgaki and K. Sumiyoshi, Nucl. Phys. A688 (2001) 340c
- 2001VO02 V.T. Voronchev, V.I. Kukulkin and Y. Nakao, Phys. Rev. E63 (2001) 026413
- 2002AL26 G.D. Alkhozov, A.V. Dobrovolsky, P. Egelhof, H. Geissel, H. Irnich, A.V. Khanzadeev, G.A. Korolev, A.A. Lobodenko, G. Munzenberg, M. Mutterer et al., Nucl. Phys. A712 (2002) 269.
- 2002BA77 F.C. Barker, Nucl. Phys. A707 (2002) 277
- 2002BE76 C.A. Bertulani, Phys. Lett. B547 (2002) 205
- 2002BH03 M. Bhattacharya and E.G. Adelberger, Phys. Rev. C65 (2002) 055502

- 2002CO04 D. Cortina-Gil, K. Markenroth, F. Attallah, T. Baumann, J. Benlliure, M.J.G. Borge, L.V. Chulkov, U.D. Pramanik, J. Fernandez-Vazquez, C. Forssen et al., Phys. Lett. B529 (2002) 36
- 2002CO06 M. Colonna, Ph. Chomaz and S. Ayik, Phys. Rev. Lett. 88 (2002) 122701
- 2002DA15 B. Davids, D.W. Anthony, T. Aumann, S.M. Austin, T. Baumann, D. Bazin, R.R.C. Clement, P.A. Lofy, T. Nakamura, B.M. Sherrill et al., Nucl. Phys. A701 (2002) 14c
- 2002DA26 B. Davids, S.M. Austin, D. Bazin, H. Esbensen, B.M. Sherrill, I.J. Thompson and J.A. Tostevin, Eur. Phys. J. A15 (2002) 65
- 2002EG02 P. Egelhof, G.D. Alkhozov, M.N. Andronenko, A. Bauchet, A.V. Dobrovolsky, S. Fritz, G.E. Gavrilov, H. Geissel, C. Gross, A.V. Khanzadeev et al., Eur. Phys. J. A15 (2002) 27.
- 2002GA11 C.A. Gagliardi, A. Azhari, V. Burjan, F. Carstoiu, V. Kroha, A.M. Mukhamedzhanov, A. Sattarov, X. Tang, L. Trache and R.E. Tribble, Eur. Phys. J. A13 (2002) 227
- 2002GR25 L.V. Grigorenko, R.C. Johnson, I.G. Mukha, I.J. Thompson and M.V. Zhukov, Eur. Phys. J. A15 (2002) 125
- 2002GU02 D. Gupta and C. Samanta, J. Phys. (London) G28 (2002) 85.
- 2002HA51 K. Hagino and A.B. Balantekin, Phys. Rev. C66 (2002) 055801
- 2002HU06 G.M. Huber, G.J. Lolos, Z. Papandreou, J. Hovdebo, S.I.H. Naqvi, D.F. Ottewell, P.L. Walden, G. Jones and X. Aslanoglou, Nucl. Phys. A705 (2002) 367
- 2002IT07 N. Itagaki and K. Hagino, Phys. Rev. C66 (2002) 057301
- 2002JU01 A.R. Junghans, E.C. Mohrmann, K.A. Snover, T.D. Steiger, E.G. Adelberger, J.M. Casandjian, H.E. Swanson, L. Buchmann, S.H. Park and A. Zyuzin, Phys. Rev. Lett. 88 (2002) 041101
- 2002LI29 J. Liu, X. Lu, X. Wang and W.-K. Chu, Nucl. Instrum. Meth. Phys. Res. B190 (2002) 107
- 2002ME09 M. Meister, K. Markenroth, D. Aleksandrov, T. Aumann, T. Baumann, M.J.G. Borge, L.V. Chulkov, D. Cortina-Gil, B. Eberlein, Th.W. Elze et al., Nucl. Phys. A700 (2002) 3
- 2002MO11 T. Motobayashi, Eur. Phys. J. A13 (2002) 207
- 2002MU16 A.M. Mukhamedzhanov and F.M. Nunes, Nucl. Phys. A708 (2002) 437
- 2002SU19 K. Sumiyoshi, H. Utsunomiya, S. Goko and T. Kajino, Nucl. Phys. A709 (2002) 467
- 2002TA22 N.J. Tagg, A.S. Hamer, B. Sur, E.D. Earle, R.L. Helmer, G. Jonkmans, B.A. Moffat and J.J. Simpson, Nucl. Instrum. Meth. Phys. Res. A489 (2002) 178
- 2002TI10 D.R. Tilley, C.M. Cheves, J.L. Godwin, G.M. Hale, H.M. Hofmann, J.H. Kelley, C.G. Sheu and H.R. Weller, Nucl. Phys. A708 (2002) 3.
- 2002WI1K W.B. Wilson et al., Los Alamos Rept. LA-UR-02-1839 (2002)

- 2002WO08 R. Wolski, A.S. Fomichev, A.M. Rodin, S.I. Sidorchuk, S.V. Stepantsov, G.M. Ter-Akopian, Yu.Ts. Oganessian, W. Mittig, P. Roussel-Chomaz, N. Alamanos et al., Nucl. Phys. A701 (2002) 29c
- 2003AD05 A. Adahchour and P. Descouvemont, J. Phys. (London) G29 (2003) 395
- 2003AN29 C. Angulo, P. Descouvemont, M. Cogneau, M. Couder, M. Gaelens, P. Leleux, M. Loiselet, G. Ryckewaert, G. Tabacaru, F. Vanderbist et al., Nucl. Phys. A719 (2003) 300c
- 2003AS04 N.I. Ashwood, N.M. Clarke, M. Freer, B.R. Fulton, R.J. Woolliscroft, W.N. Catford, V.A. Ziman, R.P. Ward, C.J. Bickerton, C.E. Harrison et al., Phys. Rev. C68 (2003) 017603
- 2003AU03 G. Audi, A.H. Wapstra and C. Thibault, Nucl. Phys. A729 (2003) 337
- 2003BA04 L.T. Baby, C. Bordeanu, G. Goldring, M. Hass, L. Weissman, V.N. Fedoseyev, U. Koster, Y. Nir-El, G. Haquin, H.W. Gaggeler et al., and the ISOLDE Collaboration, Phys. Rev. Lett. 90 (2003) 022501
- 2003BA51 L.T. Baby, C. Bordeanu, G. Goldring, M. Hass, L. Weissman, V.N. Fedoseyev, U. Koster, Y. Nir-el, G. Haquin, H.W. Gaggeler et al., and the ISOLDE Collaboration, Phys. Rev. C67 (2003) 065805
- 2003BA65 E. Baldini-Neto, B.V. Carlson, R.A. Rego and M.S. Hussein, Nucl. Phys. A724 (2003) 345
- 2003BA84 L.T. Baby, C. Bordeanu, G. Goldring, M. Hass, L. Weissman, V.N. Fedoseyev, U. Koster, Y. Nir-El, G. Haquin, H.W. Gaggeler et al., and the ISOLDE Collaboration, Nucl. Phys. A718 (2003) 487c
- 2003BA99 F.C. Barker, Phys. Rev. C68 (2003) 054602
- 2003BE38 F.D. Becchetti, M.Y. Lee, T.W. O'Donnell, D.A. Roberts, J.J. Kolata, L.O. Lamm, G. Rogachev, V. Guimaraes, P.A. DeYoung and S. Vincent, Nucl. Instrum. Meth. Phys. Res. A505 (2003) 377
- 2003CH79 S.S. Chandel, S.K. Dhiman and R. Shyam, Phys. Rev. C68 (2003) 054320
- 2003CO06 D. Cortina-Gil, J. Fernandez-Vazquez, F. Attallah, T. Baumann, J. Benlliure, M.J.G. Borge, L. Chulkov, C. Forssen, L.M. Fraile, H. Geissel et al., Nucl. Phys. A720 (2003) 3
- 2003DA30 B. Davids and S. Typel, Phys. Rev. C68 (2003) 045802
- 2003EG03 P. Egelhof, Nucl. Phys. A722 (2003) 254c
- 2003EN05 J. Enders, T. Baumann, B.A. Brown, N.H. Frank, P.G. Hansen, P.R. Heckman, B.M. Sherrill, A. Stolz, M. Thoennessen, J.A. Tostevin et al., Phys. Rev. C67 (2003) 064301
- 2003FO07 C. Forssen, N.B. Shul'gina and M.V. Zhukov, Phys. Rev. C67 (2003) 045801
- 2003FR22 R.H. France III, L.T. Baby, C. Bordeanu, Th. Delbar, J.A. Dooley, M. Gai, M. Hass, J.E. McDonald, A. Ninane and C.M. Przybycien, Nucl. Phys. A718 (2003) 398c

- 2003HA30 F. Hammache, F. Schumann, S. Typel and K. Summerer, and the S223 Collaboration, Nucl. Phys. A718 (2003) 109c
- 2003HU06 R. Huber, J. Lang, S. Navert, J. Sromicki, K. Bodek, St. Kistryn, J. Zejma, O. Naviliat-Cuncic, E. Stephan and W. Haerberli, Phys. Rev. 90 (2003) 202301
- 2003IS12 H. Ishiyama, T. Hashimoto, T. Kawamura, T. Ishikawa, H. Miyatake, M.H. Tanaka, Y. Fuchi, N. Yoshikawa, S.C. Jeong, Y. Watanabe et al., Nucl. Phys. A718 (2003) 481c
- 2003JU04 A.R. Junghans, E.C. Mohrmann, K.A. Snover, T.D. Steiger, E.G. Adelberger, J.M. Casandjian, H.E. Swanson, L. Buchmann, S.H. Park, A. Zyuzin et al., Phys. Rev. C68 (2003) 065803
- 2003KO11 A.A. Korshennikov, E.Yu. Nikolskii, E.A. Kuzmin, A. Ozawa, K. Morimoto, F. Tokanai, R. Kanungo, I. Tanihata, N.K. Timofeyuk, M.S. Golovkov et al., Phys. Rev. Lett. 90 (2003) 082501
- 2003LA22 V. Lapoux, N. Alamanos, F. Auger, A. Drouart, A. Gillibert, C. Jouanne, G. Lobo, L. Nalpas, A. Obertelli, E. Pollacco et al., Nucl. Phys. A722 (2003) 49c
- 2003MA88 R.N. Majumdar, J. Phys. Soc. Jpn. 72 (2003) 3087
- 2003ME16 M. Meister, D. Cortina-Gil, J. Fernandez-Vazquez, K. Markenroth, F. Attallah, T. Baumann, J. Benlliure, M.J.G. Borge, L.V. Chulkov, U. Datta Pramanik et al., Nucl. Phys. A718 (2003) 431c
- 2003MO23 T. Motobayashi, Nucl. Phys. A718 (2003) 101c
- 2003MO28 T. Motobayashi, Nucl. Phys. A719 (2003) 65c
- 2003OG02 K. Ogata, M. Yahiro, Y. Iseri and M. Kamimura, Phys. Rev. C67 (2003) 011602; Erratum Phys. Rev. C67 (2003) 019902
- 2003PA33 S.H. Park, A.R. Junghans, E.C. Mohrmann, K.A. Snover, T.D. Steiger, E.G. Adelberger, J.M. Casandjian, H.E. Swanson, L. Buchmann, A. Zyuzin and A. Laird, Nucl. Phys. A718 (2003) 113c
- 2003PI13 R.G. Pizzone, C. Spitaleri, M. Lattuada, A. Musumarra, M.G. Pellegriti, S. Romano, A. Tumino, S. Cherubini, P. Figuera, D. Miljanic et al., Nucl. Phys. A718 (2003) 496c
- 2003RE26 K.E. Rehm, W. Winter, C.L. Jiang, I. Ahmad, S.J. Freedman, J. Greene, A. Heinz, D. Henderson, R.V.F. Janssens, E.F. Moore et al., Nucl. Phys. A718 (2003) 443c
- 2003SC14 F. Schumann, F. Hammache, S. Typel, F. Uhlig, K. Summerer, L. Bottcher, D. Cortina, A. Forster, M. Gai, H. Geissel et al., Phys. Rev. Lett. 90 (2003) 232501
- 2003SH22 E.F. Shores, G.E. Mueller and G.A. Schlapper, Appl. Radiat. Isot. 59 (2003) 151
- 2003SM02 N.A. Smirnova and C. Volpe, Nucl. Phys. A714 (2003) 441
- 2003SO22 N. Soic, S. Cherubini, M. Lattuada, D. Miljanic, S. Romano, C. Spitaleri and M. Zadro, Europhys. Lett. 63 (2003) 524.

- 2003SP02 C. Spitaleri, S. Cherubini, A. Del Zoppo, A. Di Pietro, P. Figuera, M. Gulino, M. Lattuada, D. Miljanic, A. Musumarra, M.G. Pellegriti et al., Nucl. Phys. A719 (2003) 99c
- 2003SU04 T. Suzuki, R. Fujimoto and T. Otsuka, Phys. Rev. C67 (2003) 044302.
- 2003TI13 N.K. Timofeyuk, R.C. Johnson and A.M. Mukhamedzhanov, Phys. Rev. Lett. 91 (2003) 232501
- 2003TR04 L. Trache, A. Azhari, F. Carstoiu, H.L. Clark, C.A. Gagliardi, Y.-W. Lui, A.M. Mukhamedzhanov, X. Tang, N. Timofeyuk and R.E. Tribble, Phys. Rev. C67 (2003) 062801
- 2003UT02 H. Utsunomiya, H. Akimune, S. Goko, T. Hayakawa, Y.-W. Lui, H. Ohgaki, M. Ohta, T. Shizuma, H. Toyokawa and T. Yamagata, Nucl. Phys. A718 (2003) 199c
- 2003VO02 V.T. Voronchev and Y. Nakao, J. Phys. (London) G29 (2003) 431
- 2003VO08 V.T. Voronchev and Y. Nakao, J. Phys. Soc. Jpn. 72 (2003) 1292
- 2003WI16 W.T. Winter, S.J. Freedman, K.E. Rehm, I. Ahmad, J.P. Greene, A. Heinz, D. Henderson, R.V.F. Janssens, C.L. Jiang, E.F. Moore et al., Phys. Rev. Lett. 91 (2003) 252501
- 2003WO13 R. Wolski, S.I. Sidorchuk, G.M. Ter-Akopian, A.S. Fomichev, A.M. Rodin, S.V. Stepantsov, W. Mittig, P. Roussel-Chomaz, H. Savajols, N. Alamanos et al., Nucl. Phys. A722 (2003) 55c
- 2004TA17 W.P. Tan, W.G. Lynch, T.X. Liu, X.D. Liu, M.B. Tsang, G. Verde, A. Wagner, H.S. Xu, B. Davin, R.T. de Souza et al., Phys. Rev. C69 (2004) 061304
- 2004TR06 L. Trache, F. Carstoiu, C.A. Gagliardi and R.E. Tribble, Phys. Rev. C69 (2004) 032802