Title
ENERGY DEPENDENCE OF 26Mg(p,t)22**fe AND 12C(p,t)10C L = 0 AND L = 2 ANGULAR DISTRIBUTION SHAPES

Authors
Cosper, S.W.
Brunnader, H.
Cerny, Joseph
et al.

Publication Date
1967-08-01

University of California

Ernest O. Lawrence Radiation Laboratory

ENERGY DEPENDENCE OF $^{26}Mg(p,t)^{24}Mg$ AND $^{12}C(p,t)^{10}C$
L = 0 AND L = 2 ANGULAR DISTRIBUTION SHAPES

S. W. Cosper, H. Brunnader, Joseph Cerny, and Robert L. McGrath

August 1967

Submitted to Phys. Letters

UCRL-17709
Preprint

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

ENERGY DEPENDENCE OF $^{26}Mg(p,t)^{24}Mg$ AND $^{12}C(p,t)^{10}C$ L = 0 AND L = 2 ANGULAR DISTRIBUTION SHAPES

S. W. Cosper, H. Brunnader, Joseph Cerny, and Robert L. McGrath

August 1967

ENERGY DEPENDENCE OF $^{26}Mg(p,t)^{24}Mg$ AND $^{12}C(p,t)^{10}C$ L = 0 AND L = 2 ANGULAR DISTRIBUTION SHAPES*

S. W. Cosper,† H. Brunnader, Joseph Cerny, and Robert L. McGrath

Lawrence Radiation Laboratory and Department of Chemistry
University of California
Berkeley, California

August 1967

Abstract: Though (p,t) angular distributions with L = 0 and 2 normally show a static behavior, their measurement on ^{26}Mg and ^{12}C targets for proton energies between 20 and 54 MeV shows a marked shape and magnitude deterioration at the lower energies. These results are compared to two-nucleon transfer DWBA theory.

- - - - - - - - - -

During a recent experiment[1)] in which the lowest T = 2 (15.43 MeV; 0^+) state in ^{24}Mg was populated via the $^{26}Mg(p,t)$ reaction, it was noted that the typical L = 0 triton angular distribution of this state[2)] showed a marked magnitude and shape deterioration when the incident proton energy was lowered from 38.7 to 32.5 MeV. That both the magnitude and shape of this angular distribution could undergo such a drastic change with only a 6 MeV change in incident proton energy near $E_p \approx 35$ MeV appeared to be of considerable interest for three reasons: a) Most other L = 0 and L = 2 (p,t) angular distributions, primarily involving relatively high c.m. energy tritons, had shown a nearly static shape which changed slowly with target mass number (compare refs. 3) and 4))— a fact which had been used to assign L = 0 or L = 2 transfer to unknown (p,t) and (p,^{3}He) angular distributions; b) This magnitude and shape deterioration, if not predicted by current two-nucleon transfer theory, could cause uncertainties in the spectroscopic information extracted from some (p,t) reaction data; and c) Any experiments directed toward establishing the location[2] or decay properties[1] of $T = |T_z| + 2$ states via (p,t) investigations would require knowledge of the conditions under which the cross section to these high isospin states was a maximum.

In order to obtain further data concerning this phenomenon, the external proton beam of the Berkeley 88-in. cyclotron was used to bombard targets of ^{26}Mg and ^{12}C. The resulting tritons were identified by means of a ΔE-E detector telescope and a power-law type particle identifier[5]. Angular distributions of tritons leaving ^{24}Mg in its ground and first excited (1.37 MeV, 2^+) states (L = 0 and 2, respectively) were obtained at eight incident proton energies between 20.0 and 50.0 MeV. L = 0 triton angular distributions resulting from the formation of the 15.43 MeV 0^+, T = 2 state in ^{24}Mg were obtained at six proton energies between 32.5 and 50.0 MeV. In addition, L = 0 and 2 angular distributions from the ^{12}C(p,t)^{10}C ground and first excited (3.35 MeV, 2^+) states, respectively, were investigated at six proton energies between 30.0 and 54.1 MeV.

These L = 0 (p,t) data are shown in fig. 1 and the L = 2 data in fig. 2. The solid curves in both figures represent two-nucleon transfer[6] distorted-wave born approximation (DWBA) fits to the data[7], where each fit has been individually normalized. Real and imaginary well depths were allowed to vary smoothly with energy[8], the actual values of the parameters used followed quite closely the approximate expressions presented in fig. 1. The two-nucleon transfer DWBA clearly reproduces the general features of the observed shape variation of these (p,t) angular distributions with incident proton energy.

The magnitude and shape deterioration of the angular distribution of the 15.43 MeV ^{24}Mg state at low energies is readily apparent in fig. 1. The first maximum, beyond zero degrees, of the characteristic L = 0 shape, clearly seen from 50.0 down to 38.7 MeV, has disappeared at E_p = 32.5 MeV— the cross section in that angular region having decreased almost a factor of 8. The other two L = 0 distributions in fig. 1 also show comparable magnitude and shape deterioration at the lower incident proton energies. The nearly static L = 0 shape referred to earlier is clearly evident in the data of fig. 1. The L = 2 angular distributions shown in fig. 2 likewise show an almost static shape for $E_p \gtrsim 38.7$ MeV, however, like the L = 0 shapes they tend to deteriorate at lower proton energies. It is interesting to note that the L = 2 transition to the ^{24}Mg (1.37 MeV) state does not show the cross section reduction seen in the L = 2 transition to the ^{10}C (3.35 MeV) state at the lower proton energies.

Figure 3 presents a summary of these data and their DWBA fits. In the left portion of the figure are plotted the integrated cross sections versus the outgoing triton c.m. energy, while the right portion of the figure shows the first maximum peak cross section[9] plotted against triton c.m. energy. The points connected with dashed lines represent the experimental data and the solid curves the DWBA predictions.

The most striking property of the three L = 0 transitions is that they all seem to reach a maximum integrated and first maximum cross section at E_t (c.m.) ≈ 17±2 MeV. The L = 2 transition to the ^{10}C (3.35 MeV) state also shows this behavior. In contrast, both the integrated and first maximum cross sections for the ^{24}Mg (1.37 MeV) state are still rising at E_t (c.m.) $\approx$ 8 MeV. An intercomparison of figs. 1, 2, and 3 shows that the characteristic (p,t) L = 0 and 2 shapes begin to deteriorate below E_t (c.m.) $\approx$ 10 MeV. Hence assignment of L-transfer values to unknown (p,t) transitions by comparing their angular distribution shapes to known transitions could possibly be misleading if the incident energy is such that E_t (c.m.) $\leq$ 10 MeV. Since the DWBA appears to reproduce the observed energy dependence of these (p,t) cross sections quite well, spectroscopic information extracted from (p,t) reaction data using the DWBA should not be affected by this observed strong energy dependence.

REFERENCES

*Work performed under the auspices of the U.S. Atomic Energy Commission.

†Present address: Physics Department, University of Southwestern Louisiana, Lafayette, Louisiana, 70501.

1) R. L. McGrath, S. W. Cosper, and J. Cerny, Phys. Rev. Letters 18 (1967) 243

2) G. T. Garvey, J. Cerny, and R. H. Pehl, Phys. Rev. Letters 12 (1964) 726

3) J. Cerny, C. Détraz, and R. H. Pehl, Phys. Rev. 152 (1966) 950

4) G. Bassani, N. M. Hintz, and C. D. Kavaloski, Phys. Rev. 136 (1964) B1006; and G. Bassani, N. M. Hintz, C. D. Kavaloski, J. R. Maxwell, and G. M. Reynolds, Phys. Rev. 139 (1965) B830

5) F. S. Goulding, D. A. Landis, J. Cerny, and R. H. Pehl, Nucl. Instr. Methods 31 (1964) 1

6) N. K. Glendenning, Phys. Rev. 137 (1965) B102

7) For a more complete discussion of this DWBA code, see D. G. Fleming, J. Cerny, C. C. Maples, and N. K. Glendenning, (to be published).

8) For examples of optical model parameter variation with energy, see: F. G. Perey, Phys. Rev. 131 (1963) 745; and F. Bjorklund, Proceeding of the International Conference on the Nuclear Optical Model, The Florida State University (Rose Printing Co.), Tallahassee, Florida, p. 1, 1959.

9) If the angular distribution shape had deteriorated to the point that no clear first maximum was observable, the peak angle was chosen to be that last observed.

Figure Captions

Fig. 1. Some L = 0 triton angular distributions resulting from the proton bombardment of ^{26}Mg and ^{12}C at various incident energies. The solid curves are two-nucleon transfer DWBA fits which were generated using the parameters shown in the figure plus a real and imaginary radius parameter of 1.25 f. (E_p and E_{exc} are the incident proton energy and the excitation of the state being fit in MeV, respectively.) Each fit has been independently normalized to the data.

Fig. 2. Some L = 2 triton angular distributions from the $^{26}Mg(p,t)$ and $^{12}C(p,t)$ reactions at various incident proton energies. See caption of Fig. 1.

Fig. 3. Integrated (10°-60° c.m.) and first maximum (past 0°) peak cross sections plotted versus triton c.m. energy for some L = 0 and L = 2 (p,t) transitions to states in ^{24}Mg and ^{10}C. The data points are connected with dashed lines, while the solid curves are DWBA predictions. All DWBA values for a given state have the same normalization.

APPENDIX

This appendix contains three tables which present data considered too lengthy for inclusion in the body of the paper submitted to the journal.

Table A-I. $^{26}Mg(p,t)^{24}Mg$ (Q = -9.94 MeV) D.W.B.A. Parameters

Entrance Channel			Exit Channel					
$V \sim 74.0 - 0.5\,E_p$ [a]			$V \sim 182.5 - 0.5\,(E_p - E_{exc})$ [b]					
$W_s \sim 10.0 + 0.2\,E_p$			$W_s \sim 29.6 + 0.2\,(E_p - E_{exc})$					
$a_r = a_i = 0.50$ f			$a_r = a_i = 0.60$ f					
$r_r = r_i = 1.25$ f			$r_r = r_i = 1.25$ f					
$r_c = 1.30$ f			$r_c = 1.30$ f					
E_p (MeV)	V	W_s	Ground State V	Ground State W_s	1.37 MeV State V	1.37 MeV State W_s	15.43 MeV State V	15.43 MeV State W_s
20.0	64.0	14.0	172.6	33.6	173.3	33.3	---	---
25.0	62.0	15.0	170.0	34.6	170.7	34.3	---	---
30.0	60.0	16.0	167.5	35.6	168.2	35.3	---	---
32.5	58.5	16.5	---	---	---	---	174.3	33.0
35.0	57.0	17.0	165.0	36.6	165.7	36.3	173.0	33.4
38.7	53.0	17.5	163.7	37.3	164.0	37.1	171.1	34.0
42.0	50.0	18.4	162.0	38.0	162.7	37.7	169.5	34.8
46.0	50.0	19.0	159.5	38.8	160.2	38.5	167.5	35.6
50.0	48.0	20.0	157.5	39.6	158.2	39.3	165.5	36.4

a. E_p = Incident Proton Lab Energy (MeV)

b. E_{exc} = Excitation of State Being Fit (MeV)

Table A-II. $^{12}C(p,t)^{10}C$ (Q = - 23.32 MeV) D.W.B.A. Parameters

Entrance Channel	Exit Channel
$V \sim 85.0 - 0.5\ E_p$ [a]	$V \sim 180.0 - 0.5\ E_p + 0.6\ E_{exc}$ [b]
$W_s \sim 19.0 + 0.2\ E_p$	$W_s \sim 27.0 + 0.2\ E_p - 0.3\ E_{exc}$
$a_r = a_i = 0.40$ f	$a_r = a_i = 0.60$ f
$r_r = r_i = 1.25$ f	$r_r = r_i = 1.25$ f
$r_c = 1.30$ f	$r_c = 1.30$ f

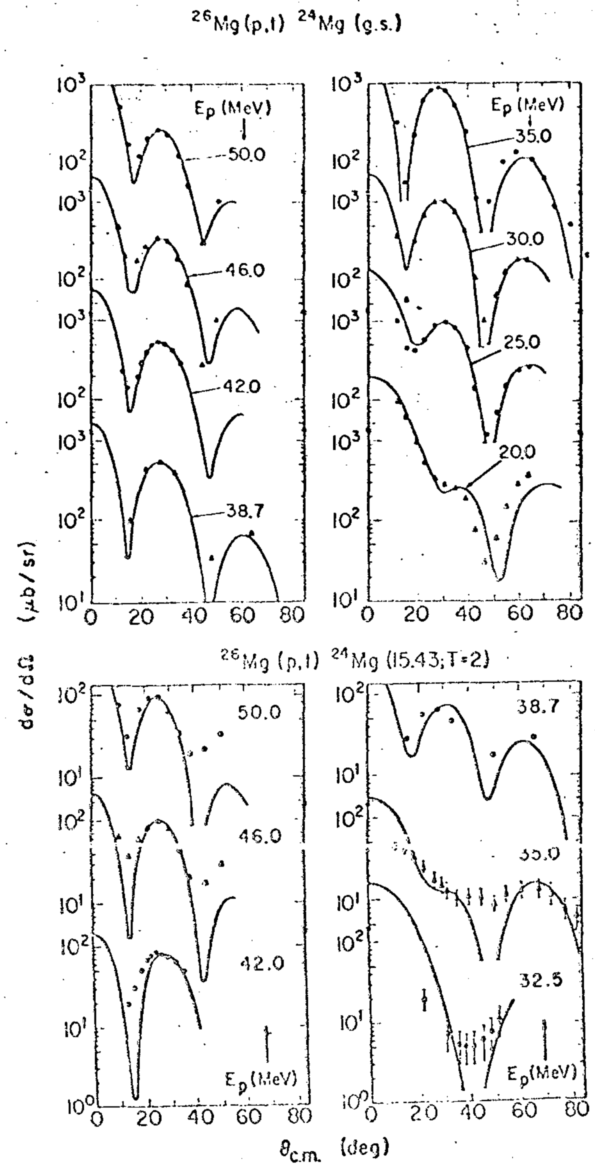
E_p (MeV)	V	W_s	Ground State V	Ground State W_s	3.35 MeV State V	3.35 MeV State W_s
30.0	70.0	25.0	165.0	33.0	---	---
32.5	68.3	25.5	---	---	165.3	32.6
35.0	67.5	26.0	162.5	34.0	164.5	33.2
43.7	63.0	27.8	158.0	35.6	160.0	35.0
46.0	62.0	28.2	157.0	36.2	159.0	35.4
50.0	60.0	29.0	155.0	37.0	157.0	36.2
54.1	58.0	29.8	153.0	37.8	155.0	37.0

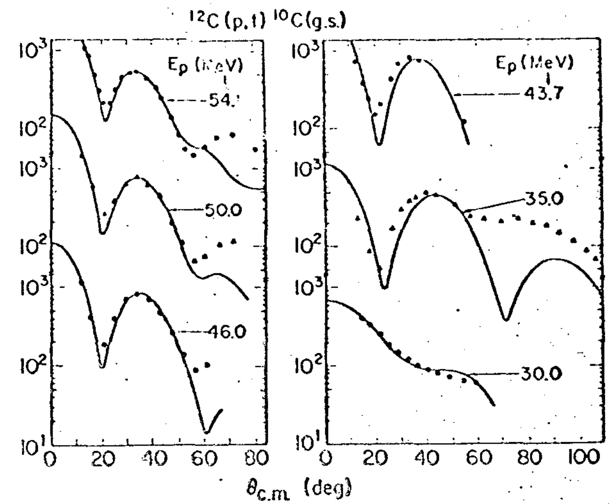
a. E_p = Incident Proton Lab Energy (MeV)

b. E_{exc} = Excitation of State Being Fit (MeV)

Table A-III. Comparison of experimental and predicted integrated (10°-60° c.m.) cross sections for some L = 0 and L = 2 (p,t) reactions on ^{26}Mg and ^{12}C.

Proton Energy (MeV)	^{24}Mg g.s. $\sigma_t(\mu b)$		^{24}Mg (1.37 MeV) $\sigma_t(\mu b)$		^{24}Mg (15.43 MeV) $\sigma_t(\mu b)$		^{10}C g.s. $\sigma_t(\mu b)$		^{10}C (3.35 MeV) $\sigma_t(\mu b)$	
	Exp.	DWBA	Exp.	DWBA	Exp.	DWBA	Exp.	DWBA	Exp.	DWBA
20.0	1055	1350	810	640	---	---	---	---	---	---
25.0	1210	1275	570	500	---	---	---	---	---	---
30.0	1005	1065	420	425	---	---	390	705	---	---
32.5	---	---	---	---	~ 35	40	---	---	---	105
35.0	780	790	370	375	45	60	965	1380	265	265
38.7	~ 570	590	~340	335	~105	110	---	---	---	---
42.0	~ 525	460	~260	285	~130	130	---	---	---	---
43.7	---	---	---	---	---	---	~1105	1285	~465	420
46.0	380	345	200	240	140	120	1315	1145	555	470
50.0	300	250	160	195	130	95	1175	890	555	555
54.1	---	---	---	---	---	---	900	695	495	610





PARAMETERS FOR DWBA FITS

NUCLEUS	REAL AND IMAG. DIFFUSENESS (f)	REAL AND IMAG. (SURFACE ABSORPTION) WELL DEPTHS (MeV)
^{26}Mg	0.50	$V \sim 74.0 - 0.5\ E_p$ $W_s \sim 10.0 + 0.2\ E_p$
^{24}Mg	0.60	$V \sim 182.5 - 0.5\ (E_p - E_{exc})$ $W_s \sim 29.6 + 0.2\ (E_p - E_{exc})$
^{12}C	0.40	$V \sim 85.0 - 0.5\ E_p$ $W_s \sim 19.0 + 0.2\ E_p$
^{10}C	0.60	$V \sim 180.0 - 0.5\ E_p + 0.6\ E_{exc}$ $W_s \sim 27.0 + 0.2\ E_p - 0.3\ E_{exc}$

XBL 677-3577

Fig. 1.

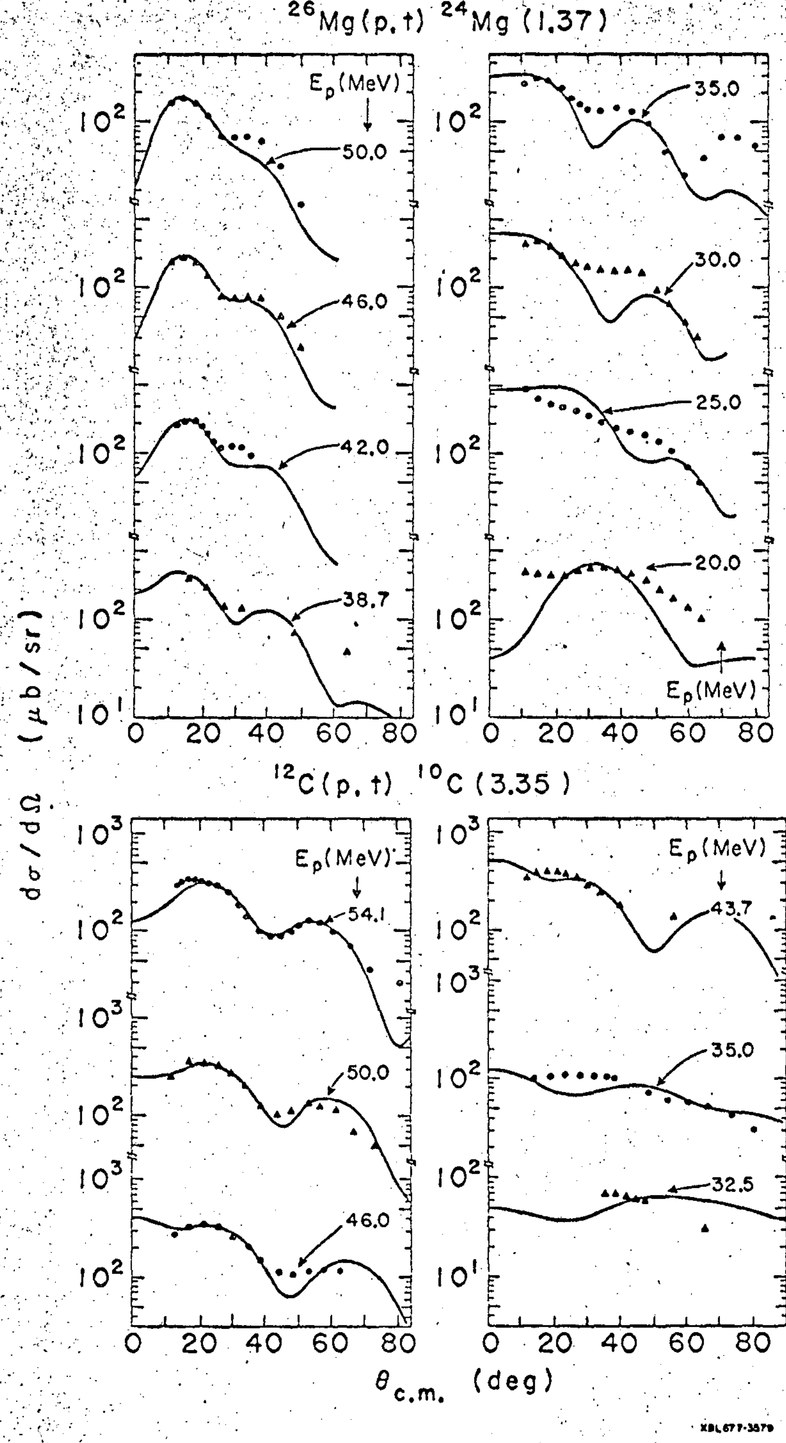

^{26}Mg(p,t) ^{24}Mg (1.37)
E$_p$(MeV)
50.0
46.0
42.0
38.7
35.0
30.0
25.0
20.0
^{12}C(p,t) ^{10}C (3.35)
54.1
50.0
46.0
43.7
35.0
32.5
dσ/dΩ (μb/sr)
θ$_{c.m.}$ (deg)
XBL677-3379

Fig. 2.

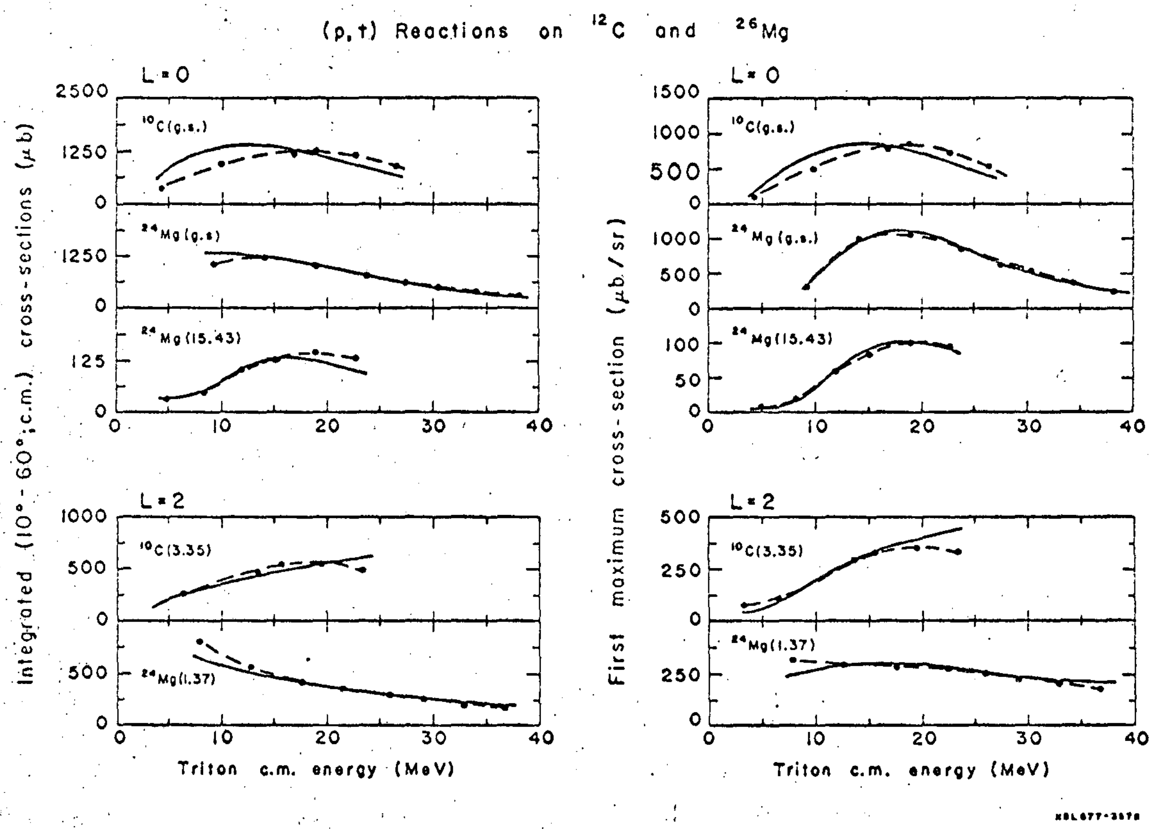

(p,t) Reactions on 12C and 26Mg
L = 0
L = 2
10C(g.s.)
24Mg(g.s.)
24Mg(15.43)
10C(3.35)
24Mg(1.37)
Integrated (10°- 60°; c.m.) cross-sections (μb)
First maximum cross-section (μb/sr)
Triton c.m. energy (MeV)
2500
1250
125
1000
500
1500
100
50
250
0
10
20
30
40

Fig. 3.