Differential Cross Sections of (α,α) and (α,α') Scattering from B^{11}, C^{12}, C^{13}, O^{16}, Ne^{20}, Mg^{24}, Si^{28} and P^{31}

Jun Kokame*, Kiyoji Fukunaga*, Hitoshi Nakamura**
and Nobuyuki Inoue***

(Kimura Laboratory)

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Numerical differential cross sections of elastically and inelastically scattered alpha-particles are presented. Target nuclei are B^{11}, C^{12}, C^{13}, O^{16}, Ne^{20}, Mg^{24}, Si^{28} and P^{31}. The energy of the incident particles is about 28.5 Mev and the beam of alpha-particles was obtained from a 105 cm cyclotron of Kyoto University.

1. INTRODUCTION

Elastic and inelastic scattering of alpha-particles are useful reactions to investigate the structure of nuclear levels and the mechanisms of the scattering. Recently, the (α, α') scattering was intensively investigated by many researchers for intermediate nuclei ($A \sim 50$) in the vibrational region. According to the development in methods of analysis using electronic computers operated by a code of DWBA or other theories[1~4], the excited states of the nuclei and the mechanism of the scattering have been successfully analyzed in many cases.

As the (α, α') scattering excites the nucleus preferentially in a collective mode, this property seems to be useful to investigate collective levels in light nuclei, because recent theoretical analyses show a considerable success in understanding levels in light nuclei by collective models as well as in heavy nuclei.

We have been investigating the (α, α') scattering of light nuclei, and the numerical values of differential corss sections of some nuclei obtained up-to-date are presented here with a brief description and discussion on each result.

2. EXPERIMENTAL PROCEDURES

An alpha-particle beam accelerated up to 28.5 MeV by a 105 cm F. F. cyclotron in our laboratory was brought to a 52 cm scattering chamber through a pair of quadrupole magnets. The energy spread of the beam is considered to be less than 150 keV.

Scattered alpha-particles were detected with a solid state detector, RCA C-4-250-2.0. A charge sensitive low noise preamplifier for the detector was designed and made by ourselves. Usual electronics were used to analyze the energy spectrum of scattered alpha-particles.

* 小亀 淳, 福永清二
** 中村 黜, Department of Physics, Faculty of Science,Kyoto University, Kyoto.
*** 井上信幸, Present address: Institute of Plasma Physics, Nagoya University, Nagoya.

The target nuclei in the present results are B^{11}, C^{12}, C^{13}, O^{16}, Ne^{20}, Mg^{24}, Si^{28} and P^{31}.

For boron, a target was made by sedimentation of 96.7% enriched B^{11} powder on a thin gold backing of which thickness is 0.2 mg/cm². The thickness was estimated by weighing as 1.5 mg/cm².

For carbon (C^{12}), a self-supporting carbon foil was made by a cracking method[5] from methane gas. The thickness of the foil was 0.50 mg/cm². A Mylar film was also used.

The target of C^{13} was made by the cracking method using 56% enriched methane gas. The thickness was 0.38 mg/cm².

Natural gas of oxygen and neon were used for O^{16} and Ne^{20} in a gas target chamber in which the pressure was about 30 cmHg.

For magnesium, a foil of which thickness was 1.00 mg/cm² was made by evapolation in vacuum from metalic powder in natural abundance.

As a silicon target, unbacked silicon foil made by etching obtained from Toshiba Co. was used. This foil had relatively poor uniformity so that the absolute value of the measurement was calibrated by comparison with results obtained from SiO_2-foils of which thickness were 3.25 and 2.14 mg/cm².

In last, a phosphorous target (3.50 mg/cm²) was made by sedimentation of red-phosphorous powder in alcohol on a thin gold foil.

3. RESULTS AND DISCUSSIONS

Numerical differential cross sections are shown in the following tables.

As the results and discussions had been reported elsewhere[6~8] in detail for each nucleus, here we discuss only on some interesting results.

3-1. Results on B^{11}, C^{12} and C^{13}

The yield from the second level (4.46 MeV, $5/2^-$) and the fourth level (6.76 MeV, $7/2^-$) in B^{11} are relatively large compared with that of the first and the third level. Their shapes of the angular distribution are quite close to each other.

These aspects can be understood reasonably by the unified model[17] of the B^{11} nucleus, in which model the second and the third state are belonging to a rotational band of the ground state $K=3/2^-$. Thus the levels at 4.46 and 6.76 MeV seem to have collective nature and the relatively large yield.

As for the result for C^{12}, the scattering from the first excited state 2^+, is interesting in comparison with inelastic scatterings from B^{11}. The latter nucleus can be considered alternatively by a model of the excited core[8,18]. In this model the four low-lying levels of B^{11} could be considered to the multiplet split out from the first excited state of C^{12} (the core nucleus) coupled to a hole of which spin is 3/2 in the lp-orbit in the core. The both scatterings from B^{11} and C^{12} would have some resemblances in the shape of the angular distrbutions and their magnitude of the elastic and inelastic scattering. However, the experimental results show poor correspondence by each other so that the excited core model would be an over simplified model for such a light nucleus as boron.

As for C^{13}, the second excited state at 3.68 MeV ($3/2^-$) seems to be the first excited state of the ground-state rotational band with $K=1/2^-$.

There is two positive parity states nearby the level, namely 3.09 MeV ($1/2^+$) and 3.85 MeV ($5/2^+$). These levels had been understood as single particle levels having one nucleon in 2s- and ld-shell respectively, because a large reduced width in the stripping reaction C^{12} (d,p) C^{13} [9~11] had been obtained. In the latter reaction the yield leading the residual nucleus to the second level (3.68 MeV, negative parity) is small.

In (α, α') scattering, an enhanced excitation of collective levels can be expected. If the second state is actually collective, the yield from this level in the (α, α') scattering would be larger than that from other levels in contrast with the case of the stripping reaction. The result showed that the prediction is valid, and the second level of C^{13} seems to be a collective one belonging to the rotational band of the ground state.

3-2. Results on O^{16}, Ne^{20}, Mg^{24} and Si^{28}

These four nuclei, of which atomic numbers are 4n (n=4,5,6 and 7, respectively), have low-lying levels of which the spin-parity is relatively well established[12]. Among others, these nuclei have unnatural-parity states (e. g. 2^-, 3^+ etc.). The excitation of an unnatural-parity state of even-even nuclei by alpha-particles is very interesting to investigate the scattering mechanisms and the structure of the level, because the level can not be excited by ordinary direct interactions in a single step transition.

The experimental results show some appreciable yield from these unnatural-parity levels (2^- at 8.88 MeV in O^{16} and at 4.97 MeV in Ne^{20}: 3^+ at 5.22 MeV in Mg^{24} and at 6.27 MeV in Si^{28}). The angular distributions show clear diffraction pattern. We are considering that the yields from these levels would be brought by a successive multiple excitations and/or an exchange process most probably (see detailed discussion in ref 6.).

For other levels of natural parity, the phase rule in Blair's inelastic diffraction scattering[13] seems to be fairly well satisfied with some exception. In general, a clear out-of-phase relation in the angular distribution was observed between the scattering from ground state (0^+) and the lowest excited level of 2^+. Where the level has, or seems to have, odd spin-parity, the phase relation is in-phase.

The exception is 4^+ level, at 10.34 MeV in O^{16}, at 4.25 MeV in Ne^{20} and at 6.00 MeV in Mg^{24}. They show some systematic deviations from the phase rule and resemble to each other in the shape of the angular distribution. These facts are considered to be showing some common nature in the structure of the 4^+ levels in the light nuclei, but a clear explanation has not been made.

Some anomalously large yields were observed in Si^{28} (from a doublet at 6.88 MeV), contradicting current assignment of spin parities by the β-γ spectroscopy. The doublet (6.88 MeV and 6.89-MeV) is considered to consist of two states of 4^+ and 2^-,[16] respectively. As mentioned above, the yield from unnatural-parity states is relatively small. The large cross section of the (α, α') scattering from the doublet should be considered to be mainly brought from the level of which spin is 4^+. The yield from 4^+ levels are relatively small in other cases in light unclei[7]. Moreover the out-of-phase relation of the yield from this level to that of ground state seems to inhibit an even parity to this level. Considering from relatively large yield and the phase relation, one of the doublet seems to prefer an negative parity and an odd number of spin, e. g. collective octupole vibration (3^-) from the result of the (α,α') scattering. However, the assignment of such a spin-parity has not been reported from experiments of β-γ decays.

3-3. The Result on P^{31}

Experiments of the (α,α') scattering from odd-A nuclei in the mass region 20 to 30 are relatively little. The nucleus P^{31} was investigated in the (α,α') scattering for comparison with the (p,p') scattering. The latter scattering had been intensively examined by our group in the energy region of 6.5～14 MeV[14,15].

The yields from the first excited level at 1.265 Mey $(3/2^+)$ at angles of 32.5^0 to 45^0 were overlapped with that from carbon contaminations. The differential cross sections at these angles were obtained by a subtraction of contaminated peaks using the angular distribution of carbon measured separately at the same incident energy.

The integrated cross sections of α_1' and α_2' from 20^0 to 102.5^0 CM are 2.6 mb and 2.4 mb respectively of which errors are $\pm$ 10%. They have in-phase relation to each other and out-of-phase to the pattern of the elastic scattering.

The yield from the first and the second level in the (p,p') scattering resemble each other in the angular distribution as well as in the case of the (α,α') scattering. The integrated cross section of p_1' and p_2' are almost the same, but the former is slightly larger than the latter in the low energy regions and is smaller than the latter in higher regions.

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TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
B^{11}	28.3	0	3/2 −
θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error* in mb/ster.	
20.4	137.1	1.1	
23.8	19.9	0.4	
27.1	69.1	0.4	
30.5	99.9	0.4	
33.8	95.4	0.4	
37.2	85.4	0.4	
40.5	27.1	0.2	
43.8	12.5	0.1	
47.0	6.13	0.10	
50.3	7.50	0.10	
53.5	8.82	0.10	
56.7	8.37	0.11	
59.9	5.92	0.08	
63.0	3.46	0.07	
66.2	1.66	0.04	
69.2	1.57	0.05	
72.3	2.86	0.05	
75.3	5.48	0.06	
78.3	6.97	0.09	
81.3	6.61	0.11	
84.2	5.74	0.10	
87.1	3.25	0.09	

*The statistical error.

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
B^{11}	28.3	−2.14	1/2 −
θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.	
20.7	0.93	0.16	
24.1	0.792	0.079	
27.5	0.564	0.065	
30.9	0.582	0.067	
34.3	0.596	0.060	
37.7	0.801	0.054	
41.1	0.751	0.049	
44.4	0.670	0.032	
47.7	0.535	0.034	
51.0	0.425	0.037	
54.3	0.551	0.030	
57.5	0.510	0.029	
60.7	0.381	0.024	
63.9	0.191	0.022	
67.1	0.126	0.015	
70.2	0.207	0.027	
73.3	0.335	0.021	
76.4	0.514	0.029	
79.4	0.597	0.034	
82.4	0.425	0.044	
88.2	0.522	0.048	

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
B^{11}	28.3	−4.46	5/2 −
θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.	
21.1	10.4	0.3	
24.6	8.89	0.13	
28.1	6.81	0.12	
31.5	4.34	0.10	
35.0	3.37	0.09	
38.4	3.28	0.09	
41.8	3.18	0.08	
45.2	3.55	0.07	
48.6	3.22	0.08	
52.0	2.69	0.07	
55.3	1.93	0.06	

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
B^{11}	28.3	−5.03	(1/2, 3/2) −
θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.	
21.2	1.84	0.18	
24.7	1.92	0.11	
28.2	1.85	0.12	
31.7	1.57	0.10	
35.2	1.54	0.09	
38.6	1.28	0.07	
42.1	1.39	0.07	
45.5	1.22	0.06	
48.9	1.14	0.07	
52.2	1.55	0.08	
55.6	1.51	0.07	

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
B^{11}	28.3	−6.76 −6.81	7/2 − (3/2 +)

θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.
21.6	7.35	0.21
25.2	6.20	0.12
28.7	4.44	0.10
32.3	2.96	0.09
35.8	2.90	0.09
39.3	2.66	0.09
42.8	2.68	0.08
46.3	3.35	0.07
49.7	2.60	0.08
53.1	2.30	0.08
56.5	2.14	0.06

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
B^{11}	28.3	−7.30	(5/2 −)

θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.
21.7	1.59	0.19
25.3	1.98	0.11
28.9	1.76	0.10
32.5	1.20	0.08
36.0	1.12	0.08
39.5	0.688	0.07
43.1	0.692	0.07
46.5	0.295	0.06
50.0	0.306	0.05
53.5	0.722	0.07
56.9	0.347	0.06

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
C^{12}	28.4	0	0 +

θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.
20.0	—	—
23.3	—	—
26.5	189.4	0.96
29.8	274.8	1.2
33.1	230.8	1.1
36.3	167.5	0.8
39.5	93.0	0.5
42.8	45.8	0.4
46.0	33.1	0.3
49.2	38.3	0.3
52.4	40.0	0.5
55.5	34.0	0.3
58.6	25.9	0.2
61.7	15.8	0.08
64.8	7.91	0.06
67.8	2.86	0.05
70.8	0.461	0.018
73.8	0.740	0.026
76.8	2.69	0.051
79.7	4.99	0.067
82.6	5.66	0.05
85.4	5.32	0.08
88.2	3.64	0.07
91.0	1.60	0.05
93.8	2.11	0.05
96.5	3.31	0.14
99.2	6.26	0.15

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
C^{12}	28.4	−4.43	2 +

θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.
20.6	24.8	0.6
24.0	30.1	0.6
27.4	22.9	0.4
30.7	18.3	0.4
34.1	14.4	0.4
37.4	16.5	0.3
40.8	21.4	0.4
44.1	27.9	0.4
47.4	31.2	0.4
50.7	32.9	0.4
53.9	27.8	0.4
57.1	22.0	0.3
60.3	18.6	0.3
63.5	18.4	0.3
66.7	22.4	0.4
69.8	24.8	0.4
72.9	25.7	0.4
75.9	21.8	0.4
78.9	16.8	0.3
81.9	12.6	0.5
84.8	10.5	0.3
87.7	12.6	0.3
90.6	17.1	0.3
93.4	21.5	0.4
96.2	21.8	0.4
98.9	19.7	0.4
101.6	13.7	0.2

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
C^{13}	28.4	0	1/2 −
θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.	
19.6	—	—	
22.8	—	—	
26.1	97.6	1.2	
29.3	196.4	1.6	
32.5	176.5	1.4	
36.6	76.5	1.2	
38.9	17.4	0.8	
42.0	9.24	0.58	
45.2	22.4	0.6	
48.3	29.1	0.6	
51.4	27.3	0.6	
54.5	17.9	0.6	
57.6	6.90	0.46	
60.6	3.82	0.36	
63.7	2.86	0.26	
66.6	3.89	0.19	
69.6	6.47	0.18	
72.6	9.77	0.22	
75.5	13.7	0.3	
78.4	15.7	0.3	
81.2	15.3	0.3	
84.0	10.8	0.3	
86.8	7.48	0.21	
89.6	6.29	0.19	
92.3	8.92	0.23	
95.0	13.6	0.3	
97.7	18.4	0.3	

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
C^{13}	28.4	−3.09	1/2 +
θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.	
19.9	2.08	0.31	
23.2	2.75	0.22	
26.5	2.76	0.19	
29.8	2.92	0.21	
33.1	1.38	0.16	
36.3	0.81	0.13	
39.6	0.45	0.13	
42.8	1.03	0.12	
46.0	1.32	0.13	
49.1	2.00	0.14	
52.3	1.58	0.11	
55.4	1.45	0.11	
58.6	0.90	0.11	
61.6	0.441	0.078	
64.7	0.675	0.048	
67.7	1.58	0.14	
70.8	1.61	0.13	
73.7	1.41	0.13	
76.7	1.01	0.12	
79.6	0.500	0.099	
82.5	0.277	0.052	
85.3	0.161	0.029	
88.2	0.161	0.051	
90.9	0.205	0.047	
93.7	0.252	0.047	
96.4	0.275	0.059	
99.1	0.436	0.060	

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
C^{13}	28.4	−3.68 −3.85	3/2 − 5/2 +
θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.	
20.0	23.3	0.6	
23.3	17.9	0.4	
26.6	12.6	0.3	
29.9	7.14	0.27	
33.2	5.37	0.26	
36.5	7.41	0.23	
39.7	9.28	0.27	
42.9	9.17	0.23	
46.2	8.33	0.22	
49.4	5.50	0.20	
52.5	4.05	0.15	
55.7	3.49	0.14	
58.8	3.79	0.16	
61.9	4.28	0.16	
65.0	4.18	0.17	
68.0	4.23	0.17	
71.1	4.74	0.18	
74.0	5.52	0.19	
77.0	6.80	0.20	
79.9	7.38	0.20	
82.8	6.73	0.19	
85.7	4.97	0.16	
88.5	4.15	0.14	
91.3	3.77	0.14	
94.0	4.81	0.17	
96.7	6.91	0.20	
99.4	8.17	0.17	

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
C^{13}	28.4	−6.87	5/2 +
θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.	
20.5	3.17	0.38	
23.9	4.35	0.33	
27.3	2.87	0.22	
30.7	2.19	0.18	
34.0	1.00	0.17	
37.4	0.99	0.13	
40.7	1.07	0.14	
44.0	0.99	0.12	
47.3	1.04	0.11	
50.6	0.71	0.11	
53.8	1.01	0.12	
57.0	0.92	0.11	
60.2	0.83	0.11	
63.4	1.15	0.12	
66.5	1.32	0.13	
69.6	1.15	0.13	
72.7	0.93	0.12	
75.7	0.86	0.13	
78.8	0.92	0.10	
81.7	0.91	0.11	
84.7	0.97	0.11	
87.6	1.01	0.11	
90.4	0.580	0.094	
93.2	0.722	0.093	
96.0	0.647	0.093	
98.7	0.427	0.088	
101.5	0.555	0.083	

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
C^{13}	28.4	−7.50 −7.55 −7.68	3/2 +

θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.
20.7	18.0	0.6
24.1	20.4	0.5
27.5	17.7	0.3
30.9	16.2	0.4
34.3	11.5	0.3
37.6	8.53	0.24
41.0	6.89	0.23
44.3	6.21	0.20
47.6	5.24	0.19
50.9	5.44	0.19
54.2	4.79	0.17
57.4	4.17	0.17
60.6	3.95	0.18
63.8	3.77	0.17
67.0	4.94	0.18
70.1	5.75	0.19
73.2	7.02	0.21
76.2	7.38	0.22
79.3	6.35	0.21
82.2	5.82	0.19
85.2	4.46	0.17
88.1	3.84	0.18
91.0	4.07	0.18
93.8	5.41	0.20
96.6	5.94	0.23
99.3	7.13	0.23
102.0	7.52	0.18

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
O^{16}	27.3	0	0 +

θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.
18.7	176.3	1.2
21.8	51.9	0.5
24.9	93.5	0.5
27.9	117.3	0.6
31.1	89.9	0.52
34.2	37.6	0.4
37.2	7.81	0.17
40.2	4.87	0.11
43.2	16.4	0.2
46.2	25.3	0.2
49.2	25.7	0.2
52.2	15.1	0.1
55.2	8.18	0.03
58.1	2.34	0.06
61.0	0.549	0.029
63.9	1.49	0.07
66.8	3.64	0.09
69.7	4.18	0.11
72.5	3.49	0.10
75.3	1.89	0.07
78.1	0.825	0.040
80.9	1.06	0.05
83.6	2.02	0.06
86.3	3.79	0.09

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
O^{16}	27.3	(−6.06 −6.14	0 +)* 3 −

θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.
19.4	13.5	0.4
22.6	14.2	0.3
25.8	13.6	0.2
28.9	10.4	0.2
32.1	7.91	0.17
35.3	4.04	0.13
38.4	1.92	0.09
41.6	2.02	0.07
44.7	2.92	0.08
47.8	3.89	0.10
50.9	4.37	0.09
53.9	3.69	0.07
57.0	3.56	0.07
60.0	3.14	0.07
63.0	3.37	0.07
65.9	3.17	0.10
68.9	3.27	0.09
71.8	3.40	0.11
74.7	2.84	0.10
77.6	2.41	0.08
80.4	1.88	0.06
83.2	1.82	0.06
86.0	1.87	0.06

* Contributions from the level are considered to be small.

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
O^{16}	27.3	−6.92 (−7.12	2 + 1 −)

θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.
19.5	12.5	0.4
22.7	7.31	0.23
25.9	4.92	0.16
29.1	4.89	0.16
32.3	6.62	0.16
35.5	6.70	0.16
38.7	5.87	0.15
41.8	3.88	0.10
45.0	2.62	0.08
48.1	2.16	0.08
51.2	2.55	0.07
54.3	2.97	0.07
57.3	3.29	0.07
60.3	2.95	0.07
63.4	2.63	0.06
66.3	2.34	0.09
69.3	2.62	0.08
72.2	2.79	0.10
75.1	3.36	0.10
78.0	3.22	0.09
80.9	2.82	0.08
83.7	2.00	0.07
86.5	1.56	0.06

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
O^{16}	27.3	−8.88	2 −
θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.	
19.8	4.68	0.37	
23.1	4.65	0.21	
26.3	3.21	0.14	
29.6	2.07	0.12	
32.8	1.10	0.10	
36.0	0.283	0.065	
39.2	0.338	0.060	
42.4	0.536	0.046	
45.6	0.875	0.055	
48.8	1.04	0.06	
51.9	0.849	0.050	
55.0	0.526	0.038	
58.1	0.281	0.031	
61.2	0.243	0.027	
64.2	0.210	0.018	
67.3	0.651	0.057	
70.3	0.795	0.055	
73.3	1.04	0.07	
76.2	0.895	0.060	
79.1	0.692	0.054	
81.9	0.333	0.039	

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
O^{16}	27.3	−9.84 (−9.58	2 + 1 −)
θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.	
19.9	2.24	0.32	
23.2	1.90	0.16	
26.5	1.89	0.12	
29.8	1.98	0.13	
33.1	2.47	0.13	
36.3	2.04	0.11	
39.6	1.62	0.09	
42.8	1.38	0.07	
46.0	1.03	0.07	
49.1	0.673	0.064	
52.3	0.594	0.051	
55.4	0.620	0.041	
58.6	0.811	0.042	
61.6	0.925	0.045	
64.7	0.780	0.046	
67.7	0.599	0.062	
70.8	0.391	0.053	
—	—	—	
76.7	0.210	0.054	
79.6	0.509	0.075	

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
O^{16}	27.3	−10.34	4 +
θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.	
20.1	0.824	0.256	
23.4	1.14	0.16	
26.7	1.38	0.14	
30.0	1.33	0.12	
33.3	1.27	0.11	
36.5	1.18	0.09	
39.8	0.903	0.085	
43.0	0.883	0.070	
46.3	1.16	0.08	
49.5	1.20	0.05	
52.7	0.921	0.058	
55.8	0.678	0.048	
58.9	0.355	0.035	
62.0	0.273	0.033	
65.1	0.202	0.033	
68.2	0.234	0.057	
71.2	0.397	0.059	
—	—	—	
77.2	1.77	0.11	
80.1	1.97	0.12	

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	-QVALUE OF THE LEVEL (MeV)	SPIN & PARITY
Ne^{20}	27.3	0	0 +
θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.	
14.5	547.1	2.6	
18.0	209.0	1.0	
21.0	140.4	0.8	
23.9	175.3	0.9	
26.9	142.1	0.8	
29.9	55.0	0.3	
32.8	6.51	0.11	
35.7	5.94	0.10	
38.7	23.7	0.2	
41.6	33.7	0.3	
44.5	23.0	0.2	
47.4	10.3	0.1	
50.3	2.26	0.05	
53.1	0.877	0.032	
56.0	2.78	0.05	
58.8	4.27	0.07	
61.6	4.02	0.06	
64.4	2.51	0.05	
67.2	1.19	0.04	
70.0	0.573	0.022	
72.2	0.847	0.032	

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
Ne^{20}	27.3	−1.63	2 +
θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.	
15.1	30.1	0.8	
18.1	60.9	0.6	
21.1	47.0	0.5	
24.1	9.81	0.24	
27.1	4.16	0.20	
30.0	12.0	0.2	
33.0	19.5	0.2	
36.0	17.8	0.2	
38.9	10.2	0.1	
41.9	4.06	0.11	
44.8	2.61	0.09	
47.7	5.94	0.10	
50.6	9.23	0.10	
53.4	9.67	0.11	
56.3	6.81	0.08	
59.1	3.14	0.06	
62.0	1.19	0.03	
64.8	0.915	0.032	
67.6	1.72	0.04	
70.4	2.39	0.04	
73.1	2.39	0.05	

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
Ne^{20}	27.3	−4.25	4 +
θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.	
18.3	2.06	0.18	
21.3	3.86	0.21	
24.3	3.29	0.19	
27.4	4.02	0.19	
30.4	3.04	0.11	
33.4	2.02	0.07	
36.4	1.34	0.06	
39.4	1.14	0.05	
42.3	1.02	0.07	
45.3	0.967	0.061	
48.2	0.686	0.040	
51.1	0.367	0.026	
54.0	0.232	0.023	
56.9	0.0934	0.0211	
59.8	0.274	0.021	
62.6	0.491	0.025	
65.4	0.778	0.031	
68.3	0.858	0.033	
71.1	0.807	0.026	
73.9	0.667	0.029	

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
Ne^{20}	27.3	−4.97	2 −
θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.	
18.3	0.54	0.23	
21.3	0.41	0.12	
24.4	0.21	0.15	
27.5	0.41	0.11	
30.5	0.53	0.06	
33.5	0.87	0.06	
36.5	0.75	0.05	
39.5	0.46	0.04	
42.4	0.15	0.05	
45.4	0.10	0.04	
48.3	0.077	0.024	
51.3	0.18	0.02	
54.2	0.20	0.02	
57.1	0.26	0.03	
60.0	0.20	0.02	
62.8	0.18	0.02	
65.7	0.26	0.02	
68.5	0.28	0.02	
71.3	0.31	0.02	
74.1	0.33	0.03	

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
Ne^{20}	27.3	−5.63 (−5.80	3 − 1 −)
θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.	
18.4	7.39	0.37	
21.5	9.88	0.28	
24.5	9.17	0.26	
27.6	8.41	0.24	
30.6	4.55	0.13	
33.6	2.14	0.09	
36.6	1.41	0.07	
39.6	1.81	0.07	
42.6	2.48	0.10	
45.6	2.44	0.09	
48.5	1.72	0.06	
51.5	1.34	0.05	
54.4	1.47	0.05	
57.3	1.72	0.05	
60.2	2.04	0.05	
63.1	1.91	0.05	
65.9	1.74	0.05	
68.7	1.03	0.04	
71.5	0.969	0.032	
74.3	0.888	0.040	

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
Mg^{24}	28.4	0	0 +

θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.
23.3	252.3	0.5
26.1	193.2	0.7
29.0	114.4	0.4
31.9	18.9	0.2
34.8	10.1	0.1
37.6	39.4	0.2
40.5	52.2	0.3
43.3	35.3	0.2
46.2	15.9	0.1
49.0	3.60	0.04
51.8	3.54	0.04
54.6	8.70	0.05
57.3	10.8	0.1
60.1	8.24	0.05
62.9	3.98	0.03
65.6	1.12	0.02
68.3	0.636	0.010
71.0	1.56	0.02
73.7	2.35	0.03
76.4	2.20	0.02
79.1	1.46	0.03
81.6	0.792	0.019
84.3	0.578	0.016
86.9	0.838	0.013
89.5	1.29	0.02

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
Mg^{24}	28.4	−1.368	2 +

θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.
23.4	13.1	0.2
26.3	6.02	0.16
29.2	14.2	0.2
32.1	22.3	0.2
34.9	18.8	0.1
37.8	9.60	0.07
40.7	3.35	0.09
43.5	3.61	0.08
46.3	6.70	0.07
49.2	10.3	0.1
52.0	9.55	0.06
54.8	5.88	0.04
57.6	2.45	0.02
60.3	1.28	0.02
63.1	1.83	0.02
65.8	2.55	0.02
68.6	2.83	0.02
71.0	2.31	0.02
73.5	1.22	0.02
76.4	0.556	0.011
79.3	0.536	0.017
81.9	0.769	0.019
84.6	1.04	0.02
87.2	1.02	0.01
89.7	0.934	0.020

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
Mg^{24}	28.4	−4.12 −4.23	4 + 2 +

θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.
23.6	4.43	0.08
26.5	4.36	0.09
29.4	4.51	0.08
32.4	5.00	0.09
35.3	5.01	0.08
38.1	3.78	0.06
41.0	2.85	0.07
43.9	1.59	0.04
46.8	1.42	0.04
49.6	1.79	0.04
52.4	1.94	0.03
55.3	1.96	0.03
58.1	1.46	0.02
60.9	0.946	0.020
63.6	0.606	0.015
66.3	0.696	0.017
69.1	0.984	0.013
71.8	1.26	0.017
74.6	1.28	0.02
77.2	0.922	0.015
79.9	0.842	0.023
82.6	0.917	0.022
85.2	1.04	0.02
87.8	1.19	0.02
90.4	1.18	0.02

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
Mg^{24}	28.4	−5.22	3 +

θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.
23.7	1.33	0.04
26.6	1.20	0.04
29.6	0.949	0.033
32.5	0.466	0.018
35.4	0.370	0.035
38.3	0.553	0.028
41.2	0.569	0.041
44.1	0.505	0.027
47.0	0.400	0.029
49.8	0.315	0.022
52.7	0.265	0.019
55.5	0.293	0.017
58.3	0.245	0.015
61.1	0.198	0.009
63.9	0.139	0.012
66.6	0.0677	0.0104
69.4	0.103	0.007
72.1	0.169	0.010
74.8	0.213	0.012
77.5	0.164	0.005
80.2	0.278	0.012
82.8	0.241	0.013
85.5	0.187	0.013
88.1	0.106	0.008
90.7	0.118	0.011

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
Mg^{24}	28.4	−6.00	4 +

θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.
23.8	2.55	0.08
26.7	2.17	0.09
29.7	2.19	0.06
32.6	1.73	0.07
35.5	1.04	0.05
38.4	1.09	0.04
41.3	1.25	0.06
44.2	—	—
47.1	0.810	0.047
49.8	0.628	0.030
52.8	0.484	0.019
55.7	0.295	0.016
58.5	0.179	0.012
61.3	0.223	0.014
64.1	0.324	0.014
66.8	0.434	0.016
69.6	0.605	0.013
72.3	0.648	0.017
75.0	0.483	0.017
77.7	0.372	0.011
80.4	0.275	0.019
83.1	0.245	0.015
85.7	0.240	0.014

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
Mg^{24}	28.4	−6.44	0 +

θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.
23.8	2.67	0.07
26.8	1.31	0.06
29.7	1.48	0.06
32.7	1.74	0.07
35.6	1.05	0.05
38.5	0.776	0.035
41.4	0.395	0.054
44.3	—	—
47.2	—	—
50.1	0.531	0.019
52.9	—	—
55.8	0.295	0.019
58.6	—	—
61.4	0.0927	0.0122
64.2	0.0541	0.0100
67.0	0.0675	0.0115
69.7	0.144	0.009
72.5	0.176	0.013
75.2	0.141	0.012
77.9	0.110	0.009
80.6	0.0616	0.0098
83.2	0.0330	0.0083
85.9	0.0255	0.0072

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
Si^{28}	28.3	0	0 +

θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.
17.1	936.3	6.2
20.0	448.2	4.3
22.8	463.4	1.8
25.7	296.0	1.0
28.5	109.2	0.5
31.3	19.8	0.2
34.1	21.1	0.2
36.9	56.6	0.4
39.7	63.5	0.4
42.5	35.0	0.3
45.2	11.8	0.2
48.0	1.46	0.04
50.8	5.91	0.09
53.6	11.7	0.1
56.3	12.9	0.1
59.0	8.72	0.10
61.7	3.53	0.06
64.4	0.848	0.025
67.1	0.698	0.023
69.8	1.56	0.03
72.4	2.28	0.04
75.1	2.11	0.04
77.7	1.30	0.03
80.3	0.686	0.023
82.9	0.461	0.017

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
Si^{28}	28.3	−1.772	2 +

θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.
14.3	117.2	2.0
17.2	61.9	1.1
20.1	35.8	0.8
22.9	12.8	0.3
25.8	5.86	0.15
28.6	12.3	0.2
31.5	20.3	0.4
34.3	16.9	0.2
37.1	9.10	0.20
39.9	4.25	0.10
41.3	3.21	0.09
42.7	4.07	0.09
45.5	6.33	0.12
48.3	7.57	0.10
51.0	5.94	0.08
53.8	3.26	0.07
56.5	2.17	0.05
59.3	1.99	0.05
62.0	2.79	0.05
64.7	3.06	0.05
67.4	3.11	0.05
70.1	2.71	0.05
72.7	2.10	0.04
75.4	1.05	0.03
78.0	0.740	0.024
80.6	0.736	0.024
83.2	1.23	0.03
85.8	1.69	0.03
88.4	1.73	0.04
91.0	1.29	0.03
93.5	0.719	0.024
96.0	0.536	0.018
98.5	0.885	0.025

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
Si^{28}	28.3	−3.61 −4.97	4 + 0 +

θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.
17.4	—	—
20.2	—	—
23.1	—	—
26.0	2.14	0.14
28.8	2.32	0.09
31.7	2.36	0.09
34.6	2.23	0.09
37.4	1.82	0.08
40.2	1.30	0.07
43.0	1.09	0.06
45.8	1.10	0.06
48.6	1.25	0.04
51.4	1.38	0.05
54.2	1.09	0.04
56.9	0.879	0.040
59.7	0.891	0.038
62.4	0.985	0.034
65.2	1.15	0.03
67.9	1.17	0.03
70.6	0.990	0.030
73.2	0.717	0.026
75.9	0.574	0.024
78.5	0.623	0.025
81.2	0.841	0.030
83.8	1.02	0.03
86.4	1.03	0.03
89.0	0.749	0.027
91.5	0.609	0.023

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
Si^{28}	28.3	−6.88 −6.89	2 − & 4 +

θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.
17.5	19.0	0.8
20.4	18.4	0.7
23.2	15.8	0.4
26.1	11.5	0.3
29.0	7.18	0.15
31.9	5.83	0.15
34.7	5.04	0.14
37.6	6.27	0.15
40.4	6.28	0.15
43.3	5.19	0.12
46.1	3.33	0.09
48.9	1.89	0.06
51.7	1.66	0.06
54.5	1.28	0.06
57.3	1.71	0.06
60.1	1.72	0.07
62.8	1.33	0.05
65.5	1.12	0.04
68.2	0.830	0.040
70.9	0.969	0.040
73.6	1.12	0.04
76.3	1.47	0.05

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
Si^{28}	28.3	−6.27	3 +

θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.
17.5	0.527	0.432
20.4	0.698	0.691
23.2	0.909	0.382
26.1	0.417	0.213
29.0	0.278	0.158
31.9	0.369	0.248
34.7	0.301	0.160
37.6	0.445	0.193
40.4	0.466	0.149
43.3	0.408	0.230
46.1	0.248	0.171
48.9	0.127	0.057
51.7	0.114	0.072
54.5	0.139	0.057
57.3	0.202	0.055
60.1	0.164	0.064
62.8	0.112	0.041
65.5	0.0919	0.0404
68.2	0.0451	0.0298
70.9	0.0478	0.0292
73.6	0.106	0.042
76.3	0.157	0.042

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
P^{31}	28.3	0	1/2 +

θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.
22.6	138.8	0.2
25.4	105.1	0.2
28.2	36.3	0.3
31.0	8.37	0.05
33.7	12.6	0.1
36.5	19.5	0.1
39.3	17.7	0.1
42.1	8.96	0.05
44.8	2.60	0.03
47.6	0.913	0.012
50.3	2.86	0.03
53.0	3.92	0.03
55.7	3.68	0.04
58.4	1.29	0.02
61.1	0.257	0.009
63.8	0.219	0.006
66.5	0.607	0.010
69.1	0.845	0.011
71.8	0.670	0.010
74.4	0.366	0.008
77.0	0.143	0.005
79.6	0.148	0.004
82.2	0.304	0.006
—	—	—
87.4	0.501	0.007
—	—	—
92.5	0.351	0.006
—	—	—
97.5	0.211	0.004
—	—	—
102.5	0.117	0.003

$(\alpha,\alpha),(\alpha,\alpha')$ Scattering from B^{11}, C^{12}, C^{13}, O^{16}, Ne^{20}, Mg^{24}, Si^{28} and P^{31}

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
P^{31}	28.3	−1.256	3/2 +
θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.	
22.5	4.15	0.05	
25.3	4.37	0.06	
28.1	2.36	0.08	
30.9	1.57	0.04	
33.6	0.835	0.04	
36.4	0.797	0.030	
39.2	1.13	0.03	
41.6	1.29	0.04	
44.7	1.27	0.04	
47.4	0.426	0.008	
50.1	0.272	0.009	
52.9	0.115	0.006	
55.6	0.159	0.007	
58.3	0.187	0.006	
61.0	0.253	0.009	
63.6	0.199	0.006	
66.3	0.130	0.005	
68.9	0.0630	0.0031	
71.6	0.0438	0.0026	
74.2	0.0619	0.0032	
76.8	0.0790	0.0036	
79.4	0.0638	0.0026	
82.0	0.0456	0.0029	
—	—	—	
87.2	0.0260	0.0015	
—	—	—	
92.2	0.0484	0.0021	
—	—	—	
97.3	0.0421	0.0020	
—	—	—	
102.2	0.0985	0.0030	

TARGET NUCLEUS	INCIDENT ENERGY (MeV)	Q-VALUE OF THE LEVEL (MeV)	SPIN & PARITY
P^{31}	28.3	−2.232	5/2 +
θ_{cm} in degrees	$(d\sigma/d\Omega)_{cm}$ in mb/ster.	Error in mb/ster.	
22.4	1.97	0.04	
25.2	1.28	0.02	
28.0	2.02	0.02	
30.7	2.07	0.02	
33.5	1.31	0.02	
36.3	0.573	0.013	
39.0	0.334	0.018	
41.8	0.451	0.019	
44.5	0.640	0.021	
47.3	0.429	0.008	
50.0	0.314	0.021	
52.7	0.114	0.010	
55.4	0.125	0.007	
58.1	0.288	0.015	
60.8	0.354	0.010	
63.4	0.329	0.007	
66.1	0.250	0.006	
68.7	0.139	0.005	
71.4	0.0895	0.0038	
74.0	0.0741	0.0035	
76.6	0.0839	0.0038	
79.2	0.0909	0.0031	
81.8	0.0938	0.0033	
—	—	—	
86.9	0.0730	0.0025	
—	—	—	
92.0	0.0742	0.0026	
—	—	—	
97.0	0.0809	0.0027	
—	—	—	
102.0	0.1025	0.0031	

REFERENCES

(1) N. Austern, R. M. Drisko, E. Rose and G. R. Satchler, *Phys. Rev.* **128**, 733 (1962).
(2) R. H. Bassel, G. R. Satchler, R. M. Drisko and E. Rost, *Phys. Rev.* **128**, 2693 (1962).
(3) E. Rost, *Phys. Rev.* **128**, 2708 (1962).
(4) B. Buck, *Phys. Rev.* **127**, 940 (1962).
(5) H. Taketani, "Genshikaku Kenkyu" -circular in Japan- 8, 604 (1964).
(6) J. Kokame, K. Fukunaga, N. Inoue and H. Nakamura, *Phys. Letters*, 8, 342 (1964).
(7) J. Kokame, K. Fukunaga, N. Inoue and H. Nakamura, to be published in *J. Phys. Soc. Japan*, **20**, No. 4 (1965).
(8) J. Kokame, K. Fukunaga and H. Nakamura. *Phys. Letters*. **14**, 234(1965).
(9) J. N. McGruer, E. K. Warburton and R. S. Bender, *Phys. Rev.* **100**, 235 (1956).
(10) S. Hinds and R. Middleton, *Proc. Phys. Soc, (London)* **74**, 775 (1959).
(11) M. H. MacFarlane and J. B. French, *Rev. Mod. Phys.* **32**, 567 (1960).
(12) T. Lauritzen and F. Ajzenberg-Selove, "Nuclear Data Sheet, Energy Levels of Light Nuclei", May 1962.
P. M. Endt and C. Van der Leun, *Nuclear Physics*, **34**, 1 (1962),
(13) J. S. Blair, *Phys. Rev.* **115**, 982 (1959).
(14) J. Kokame, *J. Phys. Soc. Japan*, **16**, 2101 (1961).
(15) J. Kokame, R. Ishiwari, K. Miyake, J. Muto, H. Itoh, T. Ohama, K. Ueda, S. Tahira and K. Baba, "Genshikaku Kenkyu" -circ[ar in Japan-, **7**, 73, 340 (1963).
(16) Y. P. Antoutiev, D. A. E Darwish, O. E. Badawy, L. M. El-Nadi and P. V. Sorokin, *Nuclear Physics*, **56**, 401 (1964).
(17) S. G. Nilsson, *Danske Vid. Selsk. Fys. Mat. Medd.* **29**, No. 16 (1955).
(18) A. De-Shalit, *Phys. Rev.* **122**, 1530 (1961).