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^{23}Na via ^{20}Ne(^{7}Li,α)

H. T. Fortune and J. R. Powers*
Physics Department, University of Pennsylvania, Philadelphia, Pennsylvania 19104

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At $E(^{7}\mathrm{Li})=22.0$ MeV, forward-angle angular distributions have been measured for 37 states (or groups of states) up to an excitation energy of 9.1 MeV, using a multiangle spectrograph and a gas target.

The nuclear structure of ^{23}Na is reviewed by Endt and van der Leun.[1] Additional information is available from investigations of the reactions ^{25}Mg(d,α) (Ref. 2), ^{21}Ne(^{3}He,p) (Ref. 3), ^{19}F(^{6}Li,d) (Refs. 4 and 5), and ^{20}Ne(α,p) (Ref. 6).

We report here the results of the ^{20}Ne(^{7}Li,α) reaction at a bombarding energy of 22.0 MeV. The target was enriched ^{20}Ne gas contained in a gas cell with no entrance window. Outgoing α particles were momentum analyzed in a multiangle spectrograph and detected in nuclear emulsion plates. Mylar foils directly in front of the emulsions stopped all particles heavier than α's.

Data were collected at six angles from 7.5° (laboratory) to 45° in steps of 7.5°. A typical spectrum is displayed in Fig. 1. Peak positions and peak areas were extracted for all identifiable groups up to just above 9 MeV excitation. Excitation energies were calculated from the observed peak locations and the known magnet calibration. These are listed in Table I, where they are compared with values from Endt and van der Leun. In general the agreement is quite good, but our resolution of about 50 keV prevents separation of some doublets or groups of levels. Above 7 MeV excitation the present reaction is quite selective. Even though many levels are known between 7 and 9 MeV, we observe only a few strong peaks. Most of the states are only weakly populated.

Angular distributions were extracted for 37 states (or groups of states) between 2.0 and 9.1 MeV of excitation. These are plotted in Figs. 2 and 3. Maximum measured cross sections are listed in Table I. The mechanism of the (^{7}Li,α) reaction is undoubtedly not simply direct at 22 MeV, but rather contains one-step direct components, together with inelastic two-step routes, and perhaps even some compound-nucleus formation and decay.

In ^{20}Ne(α,p), the results were analyzed[6] in a direct formalism, even though their angular-distribution shapes were not clearly representative of the angular momentum transfer. We have investigated a possible correlation be-

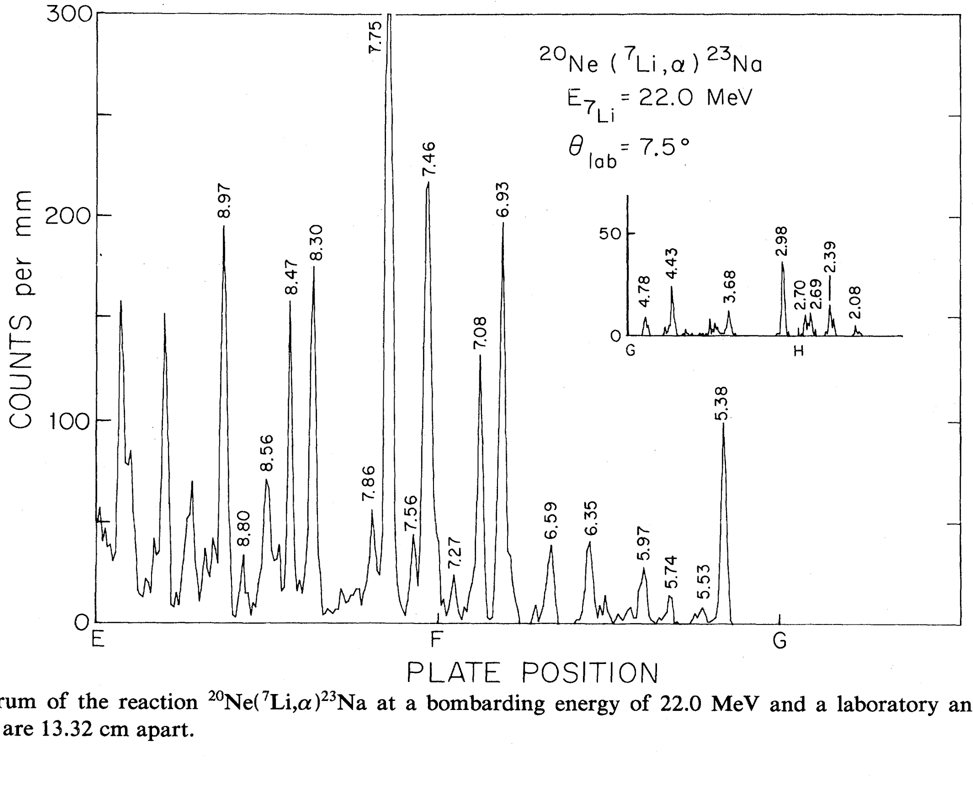

FIG. 1. Spectrum of the reaction ^{20}Ne(^{7}Li,α)^{23}Na at a bombarding energy of 22.0 MeV and a laboratory angle of 7.5°. Index marks (E, F, etc.) are 13.32 cm apart.

TABLE I. Results of the ^{20}Ne(^{7}Li,α)^{23}Na reaction.

J^{π}[a]	E_x (MeV±keV) Literature[b]	Present	$\sigma_{\max}$ (μb/sr)
$\frac{7}{2}^{+}$	2.076	2.082±7	12.3
$\frac{1}{2}^{+}$	2.391	2.389±2	39.6
$\frac{1}{2}^{-}$	2.640	2.647±8	11.2
$\frac{9}{2}^{+}$	2.704	2.705±6	8.5
$\frac{3}{2}^{+}$	2.982	2.984±2	42.8
$\frac{3}{2}^{-}$	3.678	3.668±5	24.5
$\frac{5}{2}^{-}$	3.848	3.842±7	13.1
$\frac{5}{2}^{+}$	3.915	3.914±5	8.2
$\frac{1}{2}^{+}$	4.432	4.426±3	29.2
$\frac{7}{2}^{+}$	4.776	4.770±3	24.4
$\frac{5}{2}^{+}$	5.377	5.378±2	
$\frac{11}{2}^{+}$	5.533	5.528±6	17.1
$(\frac{3}{2},\frac{5}{2})^{+}$	5.741	5.742±4	29.4
$(\frac{1}{2}^{+}\text{-}\frac{5}{2})^{+}$	5.766		
	(5.781±8)		
$\frac{5}{2}$ or $\frac{7}{2}$	5.929	5.923±10	14.5
$(\frac{1}{2},\frac{3}{2})^{-}$	5.967	5.958±14	13.3
$(\frac{3}{2}\text{-}\frac{7}{2})^{-}$	6.042	6.030±8	10.1
$(\frac{5}{2}^{+}\text{-}\frac{11}{2}^{+})$	6.117	6.117±6	5.2
$(\frac{3}{2}\text{-}\frac{7}{2}^{+})$	6.193	6.182±10	11.2
$(\frac{9}{2},\frac{13}{2})^{+}$	6.237	6.235±6	14.6
$\frac{1}{2}^{+}$	6.306	6.320±5	67.4
$\frac{9}{2}^{-}$	6.348		
$(\frac{5}{2},\frac{9}{2}^{+})$	6.577	6.588±10	55.0
	6.617		
$(\frac{3}{2},\frac{5}{2})^{+}$	6.733	6.729±12	12.7
	6.819		
$(\frac{3}{2},\frac{5}{2})^{+}$	6.866		
$\frac{3}{2}^{-}$	6.918	6.928±9	275
$(\frac{1}{2}^{+}\text{-}\frac{5}{2}^{+})$	6.946		
$(\frac{3}{2}\text{-}\frac{7}{2}^{+})$	7.070	7.079±13	142
$\frac{3}{2}^{-}$	7.080		
	7.122		
$\frac{5}{2}^{+}$	7.132		
	7.166±5		
	7.185		
	7.267	7.279±10	33.4
	7.273		
	7.393		
	7.412		
$\frac{5}{2}^{+}$	7.448	7.463±8	348
$(\frac{1}{2},\frac{3}{2})^{-}$	7.489		
	7.563	7.575±7	52.6

TABLE I. (*Continued*).

$J^{\pi a}$	E_x (MeV±keV) Literature[b]	Present	$\sigma_{\max}$ (μb/sr)
	7.685		
$(\frac{1}{2}\text{-}\frac{5}{2}^{+})$	7.720		
	7.747	7.751±10	655
	7.833		
	7.872	7.862±10	72.6
$\frac{5}{2}^{+};T=\frac{3}{2}$	7.888		
	7.965		
	7.990		
	8.061		
	8.106±7		
	8.128±6		
	8.155±5		
	8.178±6		
	8.226±5		
	8.260		
	8.300	8.304±10	208
	8.329		
$(\frac{3}{2}^{+}\text{-}\frac{7}{2}^{+})$	8.359		
	8.416		
$(\frac{3}{2},\frac{5}{2})^{+}$	8.469	8.478±8	165
	8.505		
	8.560	8.570±14	43.9
	8.610		
	8.630		
	8.648	8.644±11	105
$\frac{1}{2}^{+};T=\frac{3}{2}$	8.663		
	8.720		
	8.799	8.801±19	37.4
$\frac{1}{2}^{+}$	8.822		
	(8.862)		
	(8.894)		
$\frac{7}{2}^{-}$	8.945	8.965±10	223
	8.972		
	(9.000)		
	9.041	9.024±17	37.4
	9.072		
	9.103	9.107±14	39.8
	9.113		
	9.147±5		

[a] References 1, 2, and 6, and references therein.

[b] Reference 1. Uncertainties are listed whenever they exceed 3 keV.

tween results of (^{7}Li,α) and (α,p) by plotting in Fig. 4 our maximum measured cross sections versus those measured in (α,p). The data appear to be divided into two distinct groups—one having σ(^{7}Li,α) large and proportional to σ(α,p), the other having σ(^{7}Li,α) small and only weakly increasing with σ(α,p). There is a third set of states with only moderately large (^{7}Li,α) cross sections, but with no measurable strength in (α,p). We know of no simple nuclear-structure characteristic that levels in a given set have in common. Each grouping contains both high- and low-spin states, and states of both positive and negative

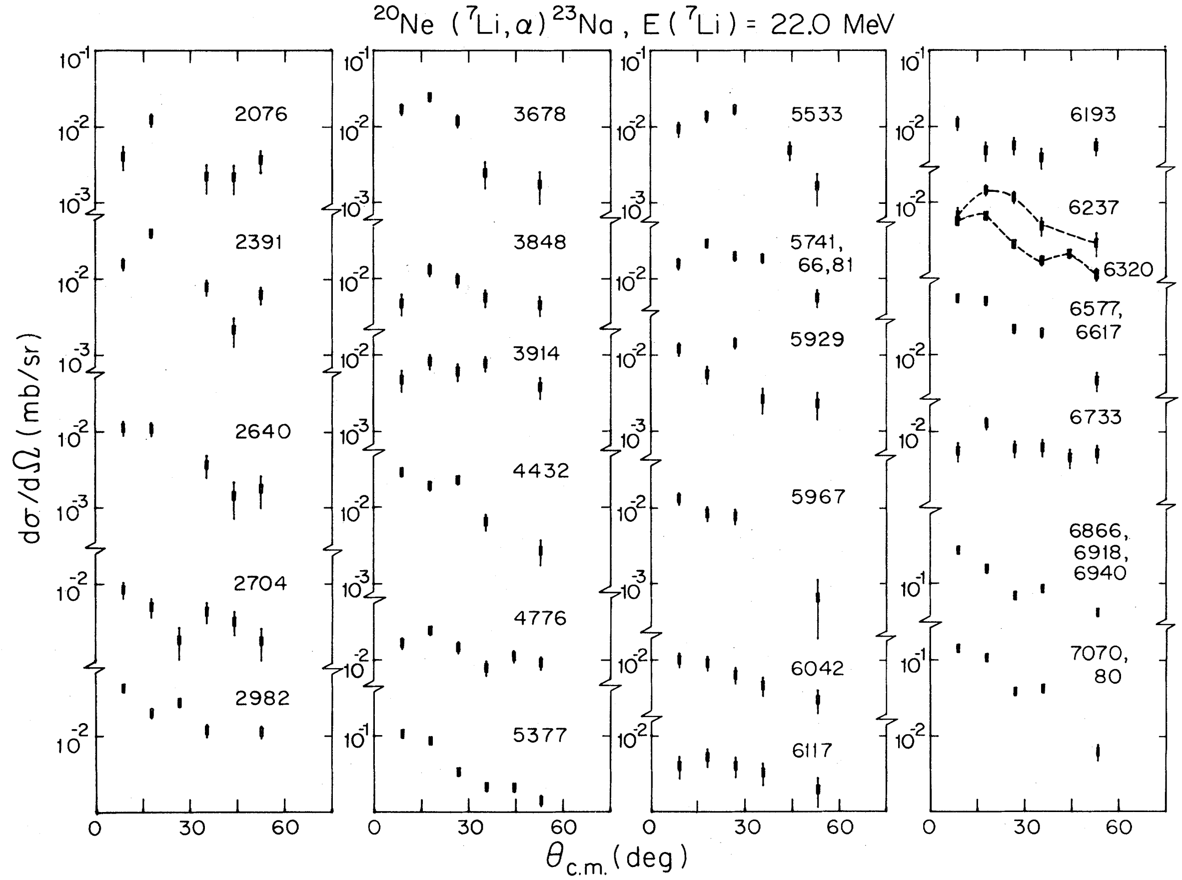

FIG. 2. Angular distributions for the reaction ^{20}Ne(^{7}Li,α)^{23}Na leading to states with E_x between 2.07 and 7.08 MeV.

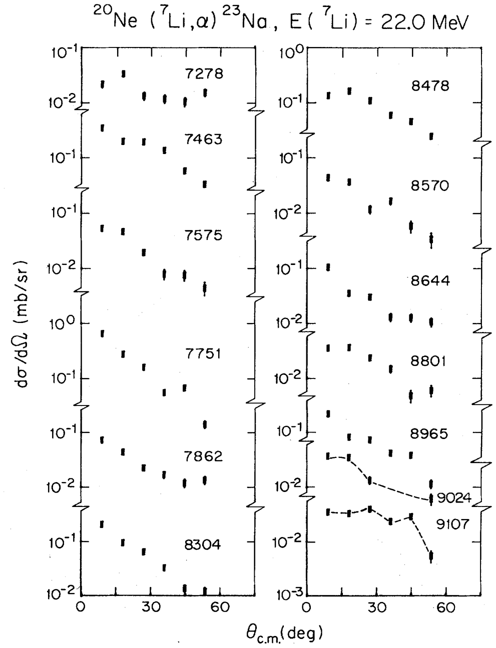

FIG. 3. Same as Fig. 2, but for states between 7.1 and 9.1 MeV.

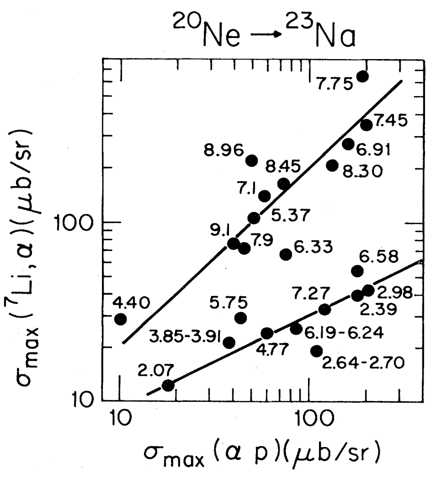

FIG. 4. Maximum differential cross sections measured in (^{7}Li,α) (present work) versus those for (α,p) (Ref. 6). The upper line is for $\sigma(^7\mathrm{Li},\alpha)\propto\sigma(\alpha,\mathrm{p})$; the lower line has $\sigma(^7\mathrm{Li},\alpha)\propto[\sigma(\alpha,\mathrm{p})]^{1/2}$.

parity. For most of the strong states in (^{7}Li,α), the three-nucleon spectroscopic factor measured in (α,p) is smaller than for other states of the same J^{π}. This anticorrelation might suggest that nondirect mechanisms are dominating for the strongest states observed in (^{7}Li,α), and that direct and nondirect processes, on the average, interfere destructively for states with large direct transfer strengths.

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*Present address: FEMA, 500 C Street, SW, Washington, D.C. 20472.

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