THE $^{23}Na(p, \alpha_0)^{20}Ne$ REACTION BETWEEN E_t = 1.8 AND 2.2 MeV

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ABSTRACT: The excitation curve for the reaction $^{23}Na(p, \alpha_0)^{20}Ne$ has been measured for proton energies between 1.8 and 2.2 MeV. In order to study states in ^{24}Mg, angular distributions were measured on three of the five resonances that exist in this interval, and which had not previously been studied. Spin and parity as well as mixing parameters are proposed for two of these resonances (E_p = 2.170 and 2.129). The third at E_p = 2.080 is a double level, which became clear when the angular distributions were measured at the two edges of the wide resonance at E_p = 2.076 and 2.088. A table is given of possible analog resonances in this reaction.

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INTRODUCTION

Excited states in ^{24}Mg formed by the proton bombardmenr of ^{23}Na have been studied using different outgoing radiations,[1] for example $^{23}Na(p,\gamma)^{24}Mg$. In the energy range where resonances are well separated, the angular distributions may be analyzed using angular correlation theory in order to extract information concerning the compound nucleus and the reaction mechanism.

The $^{23}Na(p,\alpha_0)^{20}Ne$ reaction has been previously studied by P.H. Stelson[2], who analyzed angular distributions of some resonances in the region E_p = 1 to 1.9 MeV. On the other hand, the region E_p = 2.2 to 4.5 MeV has been studied by Hirabate et al[3]. In this paper the gap was filled, and the resonances at 2.080, 2.129 and 2.170 MeV (levels 30, 40, 41, 42 of Ref. 1) were studied through angular distributions from 90° to 160°.

EXPERIMENT

The proton beam with a resolution of about 3 keV was obtained from the 12 MeV EN Tandem at the Instituto Nacional de Energía Nuclear, México. The beam energy was calibrated with the $^{12}C(p,p)^{12}C$ resonance at 4.806 ± .005 MeV energy[4]. The target NaBr evaporated on a Formvar backing and about 20 μugr/cm^2 thick, was placed in a scattering chamber[5]. Two surface barrier detectors were used, one fixed at 150° for monitoring, and one movable for taking the angular distributions. Pulses were analyzed in a 2048 channel Nuclear Data analyzer.

Figure 1 shows the excitation curve at 150° and 90° taken in 10 keV intervals outside of resonance and at 3 keV intervals on resonance. The charge accumulated at each point was 50 μucoul.

Angular distributions were measured from 90° to 160° in 10° steps at the maxima of the two resonances at 2.129 and 2.170 MeV. For the double resonance at 2.080 MeV, the angular distributions were taken at 2.076 and 2.088 MeV.

The results are shown in Table 1.

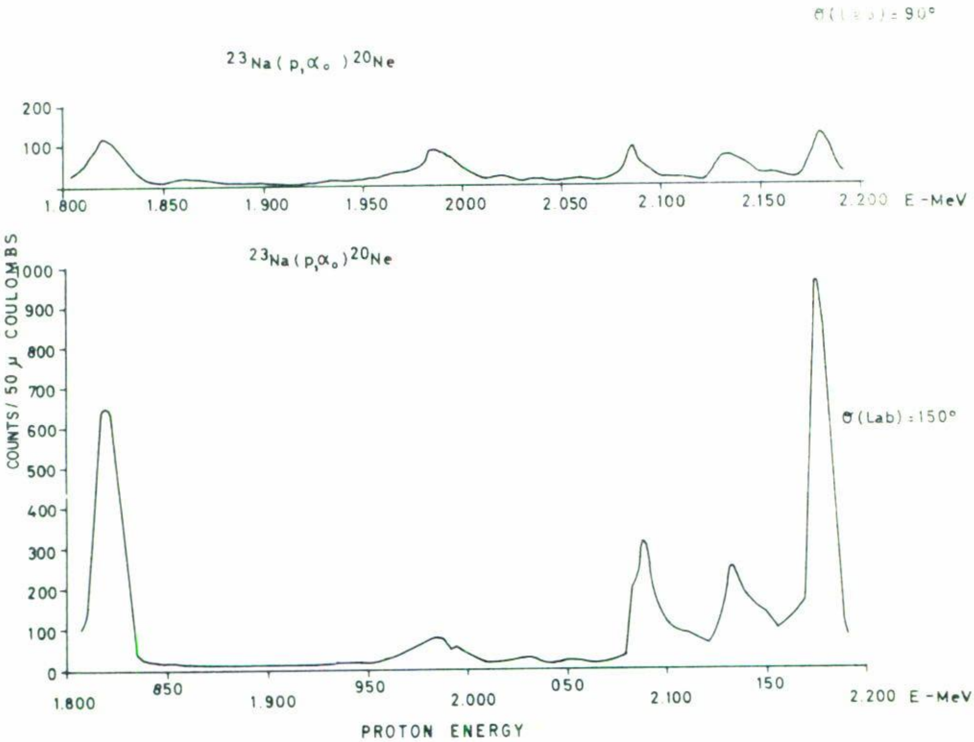


Fig. 1. Excitation curves at two different angles for the energy interval studied.

ANALYSIS

The method used to determine possible J^{π} assignments has been described previously[6]. Based on addition of angular momentum and on the fact that the outgoing channel is well defined (the channel spin is 0 in this case), the only possible J^{π} values for the compound state b are 0^+, 1^-, 2^+, 3^-, etc. From the shape of the angular distributions of the resonance, probable J^{π} values are given and mixing parameters extracted. The mixing parameters are defined by Ferguson[7] as

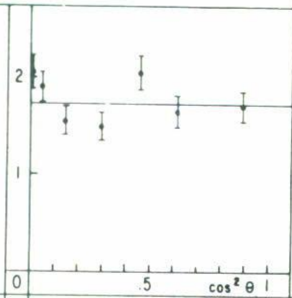
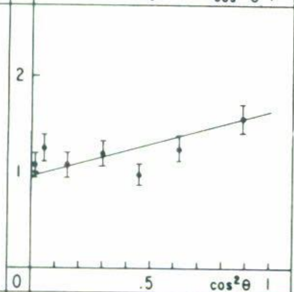
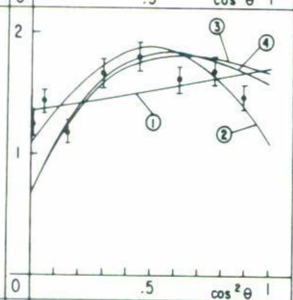
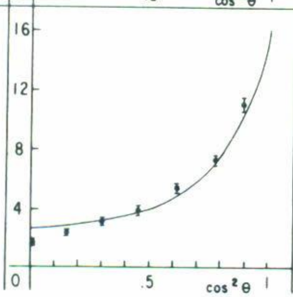
Level No.1)	Ep	Present Results	Possible configurations	δ
39	2.076		no assignment	
40	2.088		no assignment	
41	2.129		1) ${}^{2}_{1}$ (1) 1^- (1) 0^+	$\delta_0 = 26.7$
			2) ${}^{2}_{1}$ (2) 2^+ (2) 0^+	$\delta_0 = 1.$
			3) ${}^{2}_{1}$ (3) 3^- (3) 0^+	$\delta_0 = 2.2$
			4) 2 $\binom{3}{1}$ 3^- (3) 0^+	$\delta_1 = .33$
42	2.170		2^+ $\binom{4}{2}$ 4^+ (4) 0^+	$\delta_1 = .30$

Table 1. Results and possible assignments to states in ^{24}Mg from the $^{23}Na(p, \alpha_0)$ reaction.

$$\delta_1 = \frac{<b||l_1'|a>}{<b||l_1|a>}$$

for mixing of the relative incoming angular momentum l_1, and

$$\delta_0 = \left| \frac{<b||l_1|a'>}{<b||l_1|a>} \right|^2$$

for mixing of the incoming channel spin a (since the ground state of ^{23}Na is $3/2^+$, a is 1 or 2). Table 1 summarizes our results and assignments. The first two columns give the level number[1] and the measured proton energy. The third column gives the experimental result for the angular distributions. and also th calculated curves, adjusted by least squares, to give the corresponding configurations of the fourth column and mixing parameters shown in the fifth column. Only angular momenta up to 4 have been considered.

From the $^{23}Na(p, \gamma)^{24}Mg$ reaction it is established that the level at 2.080 MeV bombarding energy consists of two closely spaced levels. In order to verify this, angular distributions were measured at the extremes of the peak, and they were found to be different. N spin assignments were tried for these distributions because of the high probability of mixing.

The only level that has an unambiguous assignment is that at 2.170 MeV. The compound state is clearly 4^+ due to the strong anisotropy, and the reaction proceeds via channel spin 2 and preferably via angular momentum 2.

The excitation energy of ^{24}Na levels is known from several reactions[8], so it is simple to calculate the energy of analog states in ^{24}Mg. The Coulomb energy difference was taken as $E_C = 4783.5$ keV[9]. Table 2 points out how the excitation energy in ^{24}Na calculated from the resonance energy of certain states in the $^{23}Na + p$ reaction coincide with measured excitations, suggesting possible analog states.

Table 2. Possibility of analog states in the $^{23}Na + p$ reaction.

E (Lab)* MeV	E_p (CM) MeV	E_x ^{24}Mg MeV	E_x ^{24}Na (Calc.) MeV	E_x ^{24}Na** (Exper.) MeV
1.0871	1.0404	12.7344	3.2179	3.219 ± .005
1.2875	1.2321	12.9261	3.4096	3.409 ± .008
1.511	1.446	13.14	3.6235	3.625 ± .009
1.6379	1.5675	13.2615	3.745	3.738 ± .008
1.7486	1.6734	13.3674	3.8509	3.850 ± .008
1.8023	1.7248	13.4188	3.9023	3.899 ± .008
1.8324	1.7536	13.4476	3.9311	3.929 ± .008
2.0752	1.986	13.680	4.1635	4.16 ± .020
2.1216	2.03	13.724	4.2075	4.219 ± .008
2.3544	2.2531	13.9471	4.4306	4.44 ± .020
2.4359	2.3312	14.0252	4.5087	4.53 ± .020

* Reference 1

** Reference 7

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RESUMEN

Se midió la curva de excitación para la reacción $^{23}Na(p, \alpha_0)^{20}Ne$ en el rango de energías de protón 1.8-2.2 MeV. Con objeto de estudiar los estados excitados de ^{24}Mg se midieron las distribuciones angulares en tres de las cinco resonancias que aparecen en este intervalo y que no habían sido analizadas anteriormente. Se proponen posibles asignaciones de espín y paridad y parámetros de formación para dos de las resonancias (E_p = 2.129 y 2.170 MeV). La tercera a E_p = 2.080 MeV corresponde a un nivel doble lo cual resultó evidente al hacer las distribuciones angulares en los extremos de la aparente resonancia a E_p = 2.076 y 2.088 MeV. Se presenta también una tabla de posibles resonancias análogas en esta reacción.