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THE FORMATION OF STRONGLY POPULATED LEVELS OF $(d_{5/2})^2_5$ AND $(f_{7/2})^2_7$ CONFIGURATION IN (α, d) REACTIONS

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The Formation of Strongly Populated Levels of $(d_{5/2})^2_5$ and $(f_{7/2})^2_7$ Configuration in (α,d) Reactions

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ABSTRACT

The (α,α) stripping reaction has been studied with 45 and 50 MeV heluim ions for targets of Ne^{20}, Mg^{24}, Ar^{40}, and Ca^{40} as part of a continuing study[1] of two-nucleon transfer reactions. Deuteron energy spectra from each target studied were dominated by highly populated levels with characteristic angular distributions. believed to correspond to insertion of the captured nucleons into a $(d_{5/2})^2$ $J = 5$ or $(f_{7/2})^2$ $J = 7$ configuration. The Q values of the $(d_{5/2})^2_5$ transitions, observed at excitations of 1.53 and 0 MeV in Na^{22} and Al^{26}, respectively, fall on the line extrapolated from the Q-value-recoil mass number relationship established for (α,d) reactions forming $(d_{5/2})^2_5$ lighter targets.[1] The highly populated levels observed at excitations of 0.60 MeV in Sc^{42}, 1.87 MeV in K^{42}, 6.91 MeV in Al^{26}, and 7.45 MeV in Na^{22} have been assigned $(f_{7/2})^2_7$ configurations.

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THE FORMATION OF STRONGLY POPULATED LEVELS OF $(d_{5/2})^2_5$ AND $(f_{7/2})^2_7$ CONFIGURATION IN THE (α,d) REACTION

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INTRODUCTION

The preferential excitation of certain nuclear levels in (α,d) reactions was first observed using the 48 MeV helium ion beam of the 60 inch cyclotron. The spectra from the product nuclei N^{14}, O^{16}, O^{17} and F^{18} showed one or more very large peaks.

These strongly excited levels were reported[1] to be the J=5 levels of the $(d_{5/2})^2$ configuration. The target core is unchanged during the reaction while the captured proton and neutron each enter the $d_{5/2}$ shell. It was shown that in such cases the state of highest allowable total angular momentum will be preferentially populated. The investigation of these strongly excited $(d_{5/2})^2_5$ levels has been continued and a similar investigation has been started in the region where the $f_{7/2}$ shell should be populated.

EXPERIMENTAL PROCEDURE

The (α,d) reaction was observed from C^{12}, Ne^{20}, Mg^{24}, Ar^{40} and Ca^{40} target nuclei. The preparation of the carbon target has been described previously.[2] The 2.6 mg/cm^2 thick natural magnesium target

was prepared by evaporation. Rolling chips of natural calcium in an inert atmosphere provided calcium foils about 1 mg/cm^2 thick. Ar^{40} and Ne^{20} gases were bombarded in a 3-inch-diameter gas holder equipped with .001-inch-thick Dural windows.

External beams of 45 or 50 MeV helium ions from the 88-inch cyclotron were used. The outgoing particles were identified by a semiconductor counter telescope feeding a pulse multiplier. Pulses from a .050-inch-thick lithium drifted silicon transmission counter were added to the pulses from .090 inch lithium drifted stopping detector and the sum was analyzed by a 400 channel RIDL pulse height analyzer. The experimental conditions allowed a deuteron energy resolution of about 230 KeV from a solid target.

RESULTS AND DISCUSSION

Energy spectra and angular distributions of deuterons were measured for the product nuclei Na^{22}, Al^{26}, K^{42} and Sc^{42}. Figure 1 shows typical deuteron energy spectra for each reaction. The deuteron energy scale was established by measuring deuteron spectra from $C^{12}(\alpha,d)N^{14}$. Enough oxygen was present in the Ca^{40} and Mg^{24} targets to identify the strong deuteron line from $O^{16}(\alpha,d)F^{18*}$(1.1 MeV). Thus, providing an additional energy calibration point.

At least one, and in some cases two, levels of the product nucleus were very highly populated, as Figure 1 shows. Several of the angular distributions of deuterons corresponding to the strong levels are shown in Figure 2: they are all very similar to one another.

The Q-values for the formation of the highly populated levels

are shown in Table 1. The results of previously reported experiments are also included. Figure 3 shows that the Q-values for formation of the 1.53 MeV level of Na^{22} and the ground state of Al^{26} fall on a smooth line with the Q-values for excitation of the previously reported $(d_{5/2})^2$ J=5 levels when plotted as a function of mass number. It is therefore very probable that these two levels have also the configuration $(d_{5/2})^2$ J=5. In fact the spin of the ground state of Al^{26} is already known to be 5+, and the strongly excited level is either the ground state or very close to the ground state.

The level of Sc^{42} at 0.6 MeV must have high spin (since it is a long-lived isomeric state[3]). Since selection rules forbid formation by (α,d) reactions of even-spin levels of a $(j)^2$ configuration, it is most likely that the level has spin and parity 7+ arising from the $(f_{7/2})^2$ configuration. Since the Q-value for its formation falls on a smooth curve (as a function of mass number) with the level at 7.45 MeV in Na^{22}, 6.91 MeV in Al^{26}, 5.2 MeV in Cl^{34} and 1.87 MeV in K^{42}, it is very probable that these levels also are the J=7 members of the $(f_{7/2})^2$ configuration.

Levels of Sc^{42} at 0.60, 1.43, 2.25, 3.00 and 3.55 MeV were identified. The (He^3,p) reaction, which can excite both odd and even spin members of the $(f_{7/2})^2$ configuration, excited levels of Sc^{42} at 0, 0.617, 1.035, 1.509, 1.958, 2.248 and 2.998 MeV.[4] It is thus very likely that the 0, 1.035 and 1.958 MeV levels are states of even spin, since (He^3,p) excites them but (α,d) does not.

TABLE I

Nucleus	Energy Level	Q-values	JπT	Configuration
N^{14}	9.0	-22.6	5 + 0	$(d_{5/2})^2$
O^{16} a)	14.7	-17.8	(4)+ 0	$(d_{5/2})^2$
	16.2	-19.3	(5,6)+ 0	$(d_{5/2})^2$
	(17.2)	(-20.3)	(5,6)+ 0	$(d_{5/2})^2$
O^{17} a)	7.6	-17.4	11/2- 0	$(d_{5/2})^2$
	9.0	-18.8	9/2- 0	$(d_{5/2})^2$
F^{18}	1.1	-17.4	5+ 0	$(d_{5/2})^2$
Na^{22}	1.53	-14.1	(5+)0	$(d_{5/2})^2$
Al^{26}	0.0	-12.4	5+ 0	$(d_{5/2})^2$
Na^{22}	7.45	-19.9	(7+)0	$(f_{7/2})^2$
Al^{26}	6.91	-19.3	(7+)0	$(f_{7/2})^2$
Cl^{34} b)	5.2	-17.4	(7+)0	$(f_{7/2})^2$
K^{42}	1.87	-12.7	(7+)0	$(f_{7/2})^2$
Sc^{42}	.60	-13.9	7+ 0	$(f_{7/2})^2$

a) The angular momentum of the captured deuteron is coupled to the angular momentum of the core producing multiple peaks in the case of the 1+ N^{14} and the 1/2- N^{15} cores.

b) From an unpublished $S^{32}(\alpha,d)Cl^{34}$ investigation using the 48 MeV alpha beam of the 60 inch cyclotron.

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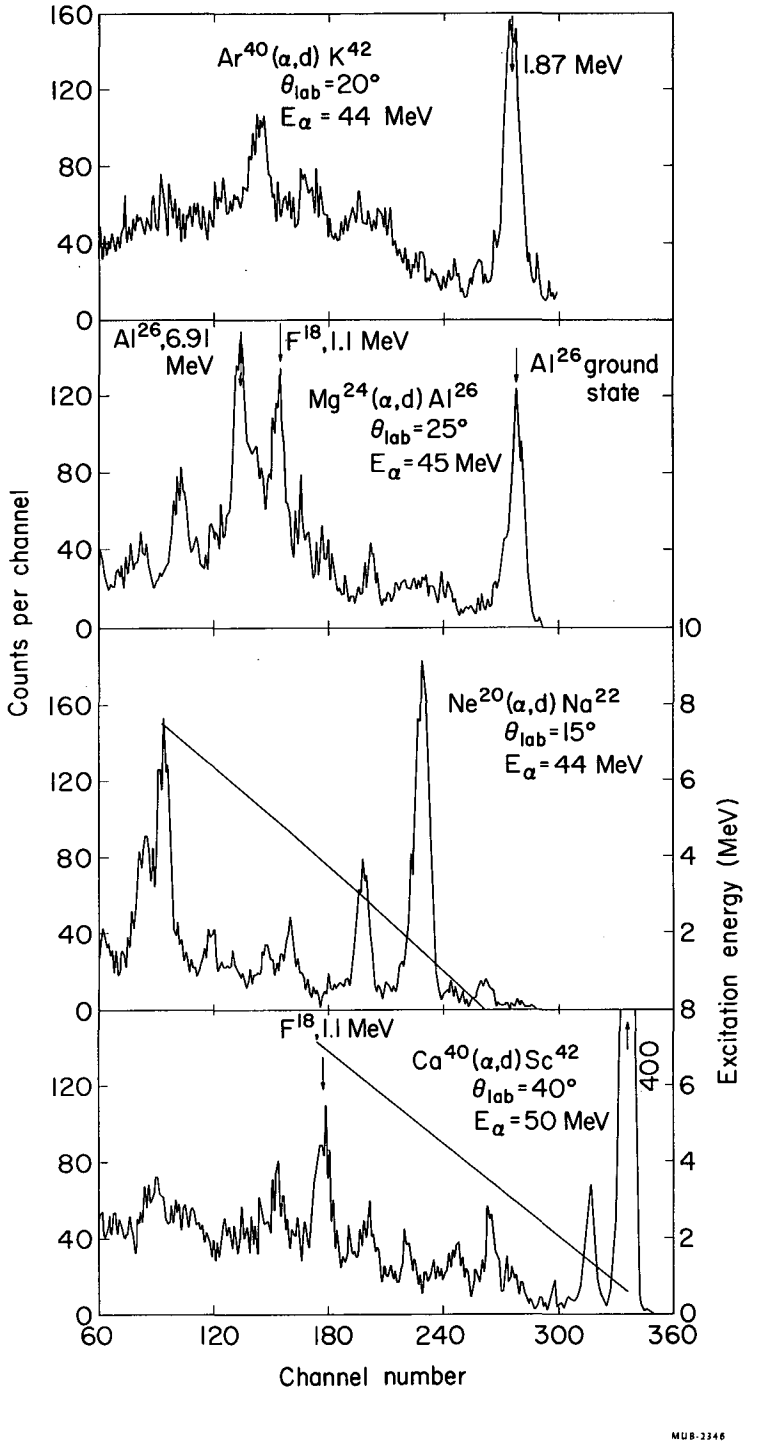

Fig. 1. Deuteron energy spectra from the $Ar^{40}(\alpha, d)K^{42}$, the $Mg^{24}(\alpha, d)Al^{26}$, the $Ne^{20}(\alpha, d)Na^{22}$, and the $Ca^{40}(\alpha, d)Sc^{42}$ reactions.

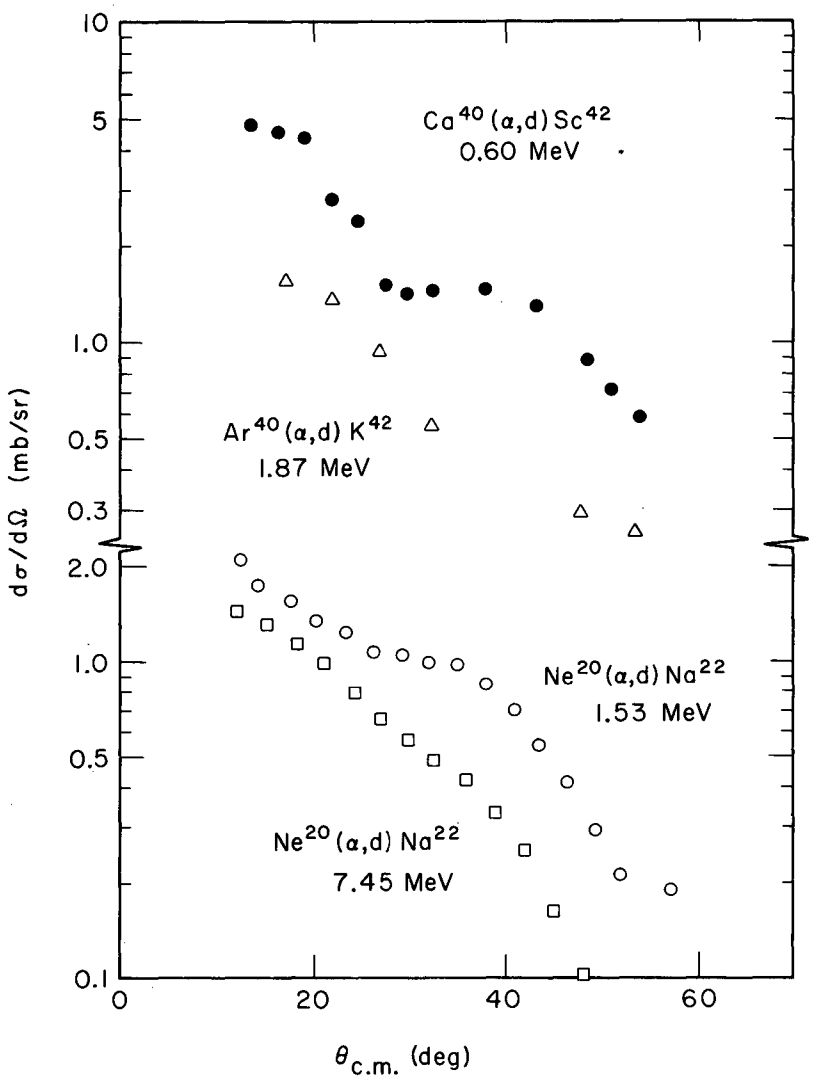

Fig. 2. Angular distribution of the strongly populated levels in the K^{42}, Na^{22} and Sc^{42} nuclei.

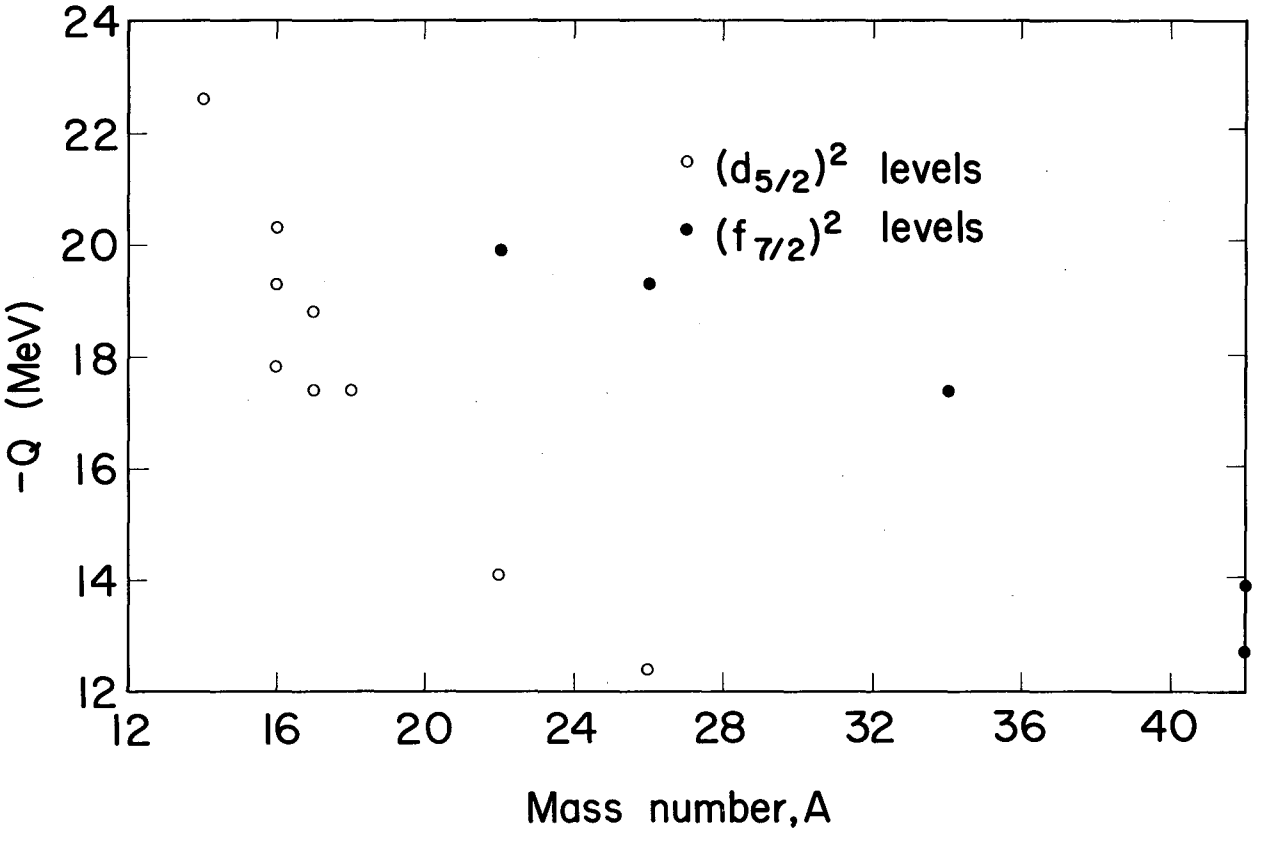

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Fig. 3. Dependence of Q on Mass number A, for (α, d) reaction to $(d_{5/2})^2_5$ and $(f_{7/2})^2_7$ levels.