for much assistance with the apparatus.

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CLUSTER MODEL INTERPRETATION OF THE ISOTOPIC SPIN SELECTION RULE IN CERTAIN NUCLEAR REACTIONS

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In this note we wish to present results concerning the operation of the isotopic spin selection rule in nuclear reactions which have resulted from a study of some lithium-induced reactions. Experimental verification of such selection rules has previously been obtained from the study of (d,α)[1] and (α,d)[2] reactions, from the study of inelastic deuteron scattering,[3] and recently from the work of Halbert and Zucker[4] on the inelastic scattering of N^{14} by C^{12}. In the present work we have been concerned with the reactions $Li^6(Li^6, d)B^{10}$ and $Li^6(Li^7, t)B^{10}$ with particular reference to the reactions leading to the $T=1$, second excited state of B^{10} at 1.74 Mev. In the first reaction it was to be expected, since both Li^6 and the deuteron have $T=0$, that the probability of deuteron emission leading to the $T=1$ level in B^{10} would be reduced by virtue of the isotopic spin selection rule; the second reaction was studied for purposes of comparison.

In Fig. 1 the spectrum of deuterons observed at a laboratory angle of 9.5° from the reaction $Li^6(Li^6, d)B^{10}$ is presented. The positions of the levels in B^{10} are as calculated from the observed position of the deuterons leading to the first 1+ level in B^{10} and the variation of its position with the angle of observation. As can be seen from the observed spectrum, deuterons leading to the $T=1$ level in B^{10} are very much inhibited, and over the angular range where one could observe this deuteron group, the situation persisted. As discussed above, this result can be interpreted as confirmation of the isotopic spin selection rule. However, it is the purpose of this note to suggest that the observed inhibition may be considered on a different basis.

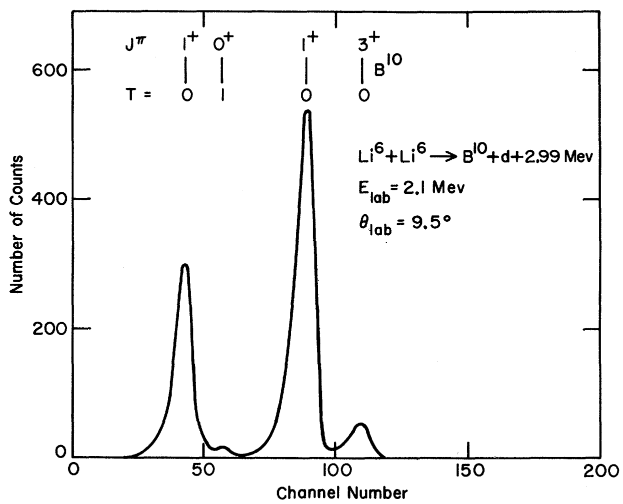

FIG. 1. The spectrum of deuterons observed in the reaction $Li^6(Li^6, d)B^{10}$ at a laboratory angle of 9.5° and incident energy of 2.1 Mev. The positions of the corresponding levels in B^{10} are indicated above.

As part of the reaction studies using lithium ions, evidence has been obtained that both the reactions (Li^6, d) and (Li^7, t) are favored and proceed in part by a stripping mechanism with capture of the alpha-particle substructure.[5] In the reaction $Li^6(Li^6, d)B^{10}$, if only the J^π of the final states in B^{10} are considered, there is no reason why the 0+ level should be reduced except possibly by a $(2J+1)$ weighting factor. However, we see from Fig. 1 that the deuterons leading to the 3+ level in B^{10} are reduced also relative to those leading to the 1+ levels. If now the situation is considered from the viewpoint of B^{10}

being formed as a result of the capture of an alpha particle by Li^6, the following considerations apply. The formation of B^{10} in a 1+ level can proceed by $l=0$ capture of the alpha particle, while the formation of the 3+ level can only proceed by at least $l=2$ capture and might be expected to be reduced as is observed. And now when we consider the formation of the $0+(T=1)$ level of B^{10} on this basis, there is no way by which an alpha particle ($J=0+$) can be captured by $Li^6(J=1+)$ to form a 0+ state.

Up to this point, the discussion has only been an alternative way of explaining the inhibition of the deuteron group leading to the $T=1$ level, since the usual one concerning isotopic spin conservation leads to the same conclusion. However, in the comparison study of the reaction $Li^6(Li^7, t)B^{10}$ essentially no tritons leading to the $T=1$ level were observed. In the reaction, there is now no restriction due to isotopic spin conservation which can inhibit the formation of the $T=1$ level in B^{10}. Likewise there is no consideration due to the available angular momentum for the reaction to proceed.

The spectrum of tritons observed at 14.5° from the reaction $Li^6(Li^7, t)B^{10}$ is shown in Fig. 2, with the calculated positions of the levels in B^{10}

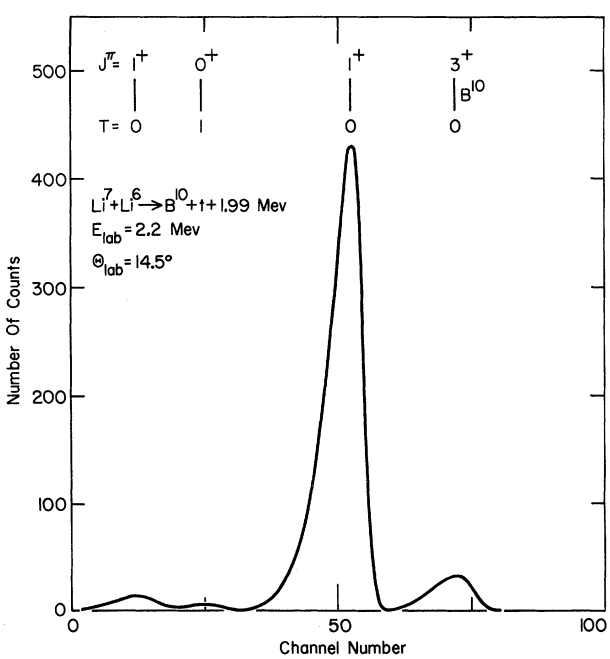

FIG. 2. The spectrum of tritons observed in the reaction $Li^6(Li^7, t)B^{10}$ at a laboratory angle of 14.5° and incident energy of 2.2 Mev. The positions of the corresponding levels in B^{10} are indicated above.

shown above. The similarity in the relative intensities of the tritons and deuterons leading to the same low-lying levels in B^{10} can be noted. That the second 1+ level in B^{10} is not more strongly excited may be due in part to the low Q value (-0.16 Mev) for the $Li^6(Li^7, t)B^{10}$ reaction leading to this level. With such small energy available in the center-of-mass system the transfer of an alpha particle to Li^6 may be inhibited by the Coulomb field, although it is realized that this argument also may account for some of the reduction observed in the tritons leading to the 0+ level where the Q value is only 0.25 Mev. A clarification of this point awaits detailed calculations involving the proposed reaction mechanism involving alpha-particle transfer. At this time, however, the most likely explanation of the inhibition of the triton group leading to the $T=1$ level appears to be the impossibility of Li^6 capturing an alpha particle to form a 0+ state of B^{10} as discussed for the $Li^6(Li^6, d)B^{10}$ reaction.

Of course this description of the reaction is just what the $T=1$ nature of the state implies insofar as this state in B^{10} corresponds to a nucleus with six neutrons and four protons or vice versa, where the two extra neutrons or protons are necessarily in a singlet state. Thus if one thinks of the $T=1$ level of B^{10} at 1.74 Mev as having the character of Be^8 plus a deuteron in the singlet $T=1$ state which is consistent with the 2-Mev difference in binding energy of the singlet and triplet states of the deuteron, the formation of this level when Li^6 captures an alpha particle would require a rearrangement of the deuteron in the target nucleus Li^6. That it is the $T=1$ state of the deuteron which is involved in both reactions studied and not a $T=1$ state arising from a $Li^7 + He^3$ configuration can be seen from considerations of the nuclear masses involved which would predict a $T=1$ level of this nature at much higher excitation energies in B^{10}.

It would seem therefore that such heavy-particle stripping considerations together with such a "cluster" model[6] of the nucleus as discussed here are capable of explaining the observed isotopic spin conservation in the $Li^6(Li^6, d)B^{10}$ reaction in a very simple way. Furthermore one sees that in addition to the (Li^6, d) reaction, the (Li^6, α) reaction and the (α, d) and (d, α) reactions, at energies where heavy-particle stripping involving the transfer of a deuteron is expected to play an important reaction role, also fit into this scheme, since the observation of the isotopic spin selection rule involves a 0+ initial and final state and the deuteron has spin 1. In addition, the conservation of isotopic spin observed in the inelastic scattering of deuterons, alpha particles, or more recently C^{12} ions from N^{14} can be understood as arising from the improbability of the deuteron in the target nucleus undergoing an internal spin flip to form its $T=1$ state.

It would appear then that at energies where stripping is expected to be important, one does not require the introduction of the formal concept of isotopic spin conservation to describe the inhibition observed in reactions leading to such 0+, $T=1$ levels. That isotopic spin selection rules are experimentally satisfied at high energies has also been pointed out by Wilkinson,[7] who suggests that the reason for their validity is the overlapping of many levels in the compound system which break up before isotopic spin mixing occurs. In this connection it would be of interest to examine the situation in a reaction leading to a higher $T=1$ level where $J\neq 0$, to see whether the transition is allowed or not. It will also be of interest to carry out a study of the reaction $B^{10}(Li^6, d)N^{14*}(T=1)$ and $B^{10}(Li^7, t)N^{14*}(T=1)$ to verify further the results obtained here. It can be pointed out that a study of the latter reaction in conjunction with the reaction $B^{10}(Li^7, He^3)C^{14}$(g.s.) should also provide a sensitive test of the relations between the cross sections predicted by the isotopic spin selection rules.

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SEARCH FOR RESONANCE IN π-π INTERACTION IN π-N SCATTERING AT 0.96 Bev

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Photographs of interactions in a hydrogen bubble chamber exposed to the 0.96-Bev negative pion beam from the Brookhaven Cosmotron were kindly supplied by Professor Steinberger and have been measured and analyzed.[1] This Letter reports a detailed examination of 110 events of the type

$$\pi^- + p \rightarrow p + \pi^- + \pi^0$$

for evidence of a resonance in the pion-pion interaction.

Other photographs of the same exposure have been measured by Alles-Borelli, Bergia, Ferreira, and Waloschek[2] at Bologna, and some by Pickup, Ayer, and Salant[3] at Brookhaven. Center-of-mass momuntum spectra of the π^- and π^0 mesons from the above reaction were found[3,4] to be in reasonable accord with the extended isobaric nucleon model of Lindenbaum and Sternheimer,[4] which includes contributions from the $T'=\frac{1}{2}$ isobaric state (corresponding to the $T=\frac{1}{2}$ resonance in the π-N system at $T_\pi = 600$ Mev) as well as from the $T'=3/2$ state.

Laboratory kinetic energy spectra of protons were found to possess a low-energy peak which has been interpreted by Bonsignori and Selleri[5] and Derado[6] as evidence for a strong pion-pion interaction. This interpretation is based on an estimate of the "pole part" of the pion-nucleon scattering cross section by the method of Chew and Low.[7] Their formula, valid when the square of the four-momentum transfer Δ^2 to the spectator nucleon approaches the unphysical limit $-\mu^2$, where μ is the pion mass, becomes in the case of the reaction considered,

$$\frac{\partial^2\sigma}{\partial\Delta^2\partial\omega^2} = \frac{f^2}{2\pi}\,\frac{\Delta^2/\mu^2}{(\Delta^2+\mu^2)^2}\,\frac{1}{{q_{1L}}^2}\,\omega(\tfrac{1}{4}\omega^2-\mu^2)^{1/2}\sigma_{\pi\pi}(\omega), \tag{1}$$

where f^2 is the renormalized pion-nucleon coupling constant, q_{1L} the laboratory momentum of the incident pion, and $\sigma_{\pi\pi}(\omega)$ the total cross sec-