0^+ STATE AT 6.24 MeV IN ^{22}Ne EXCITED BY THE REACTION ^{18}O(^{7}Li, t)^{22}Ne *

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The reaction ^{18}O(^{7}Li, t)^{22}Ne has been studied at 12-MeV incident energy. A 0^+ state at 6.24 MeV, which has been associated with the (4,4) representation of SU(3), is strongly excited.

Previous work on the (^{7}Li, t) reaction in light nuclei at intermediate bombarding energies has shown strong evidence for the direct nature of this reaction.[1-3] In addition, in the reaction ^{16}O(^{7}Li, t)^{20}Ne a selectivity was observed[3] such that only the ground-state rotational band and one negative-parity band were strongly populated. These results, together with the applicability of the SU(3) coupling scheme to nuclei at the beginning of the $2s$-$1d$ shell,[4-7] have given support to the proposition[8] that cluster-model states carry representations of SU(3). In this Letter we report on some results obtained from the reaction ^{18}O(^{7}Li, t)^{22}Ne, in particular, that a 0^+ state at 6.24 MeV is strongly excited. We propose that in the framework of the above-mentioned scheme this state can be associated with a specific representation of SU(3).

The reaction was studied using a 12-MeV ^{7}Li^{3+} beam from the University of Pennsylvania tandem accelerator. The targets were prepared by oxidizing 50- to 70-μg/cm^2 calcium evaporated onto 100-μg/cm^2 gold with water enriched in O^{18} to 99.9 %. The outgoing tritons were analyzed at 23 angles ranging from $3\frac{3}{4}$ to $168\frac{3}{4}$° with the University of Pennsylvania multigap spectrograph using nuclear emulsions to detect the tritons.

A triton spectrum measured at $11\frac{1}{4}$° is shown in Fig. 1. The width of the groups (45 keV width at half-maximum) is mainly due to target thickness. Transitions to members of the ^{22}Ne ground-state rotational band are weak compared with transitions to levels above 6.24 MeV. Groups arising from ^{12}C and ^{16}O contaminants are indicated by ^{16}O$_0$, ^{20}Ne$_0$, and ^{20}Ne$_1$.

Angular distributions for triton groups corresponding to transitions to the 0^+, 2^+, 4^+, and 6^+ members[9-11] of the ground-state rotational band at 0, 1.28, 3.34, and 6.35 MeV are shown in Fig. 2 along with distributions leading to states at 4.47 and 6.24 MeV. Because of kinematical shifts only partial angular distributions could be measured for the higher excited states. The experimental angular distributions are forward

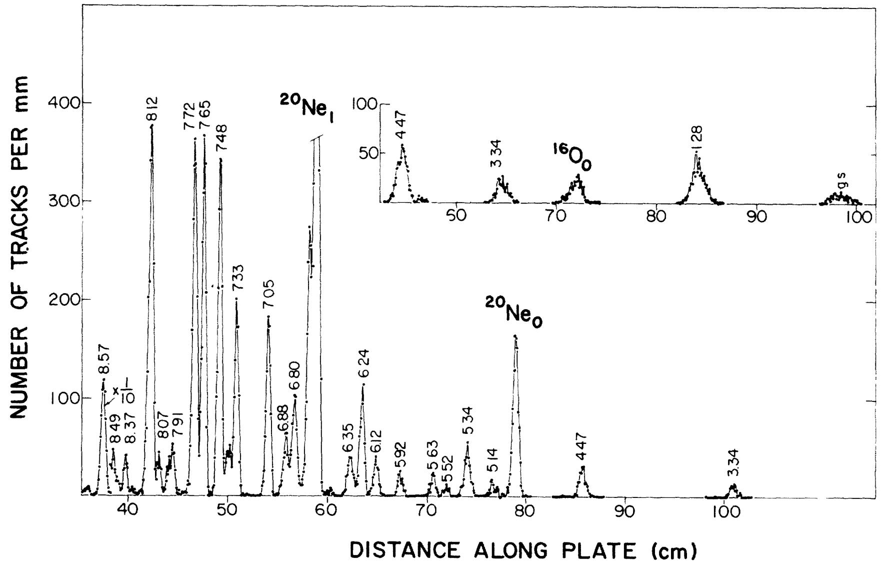

FIG. 1. Triton spectrum obtained from the reaction ^{18}O(^{7}Li, t)^{22}Ne measured at a laboratory angle of $11\frac{1}{4}$°. The inset in the upper right corner shows the results of a separate exposure for the lowest four states. Groups corresponding to states in ^{22}Ne are labeled according to the level excitation energy. Groups arising from ^{12}C and ^{16}O contaminants are labeled ^{16}O and ^{20}Ne, respectively.

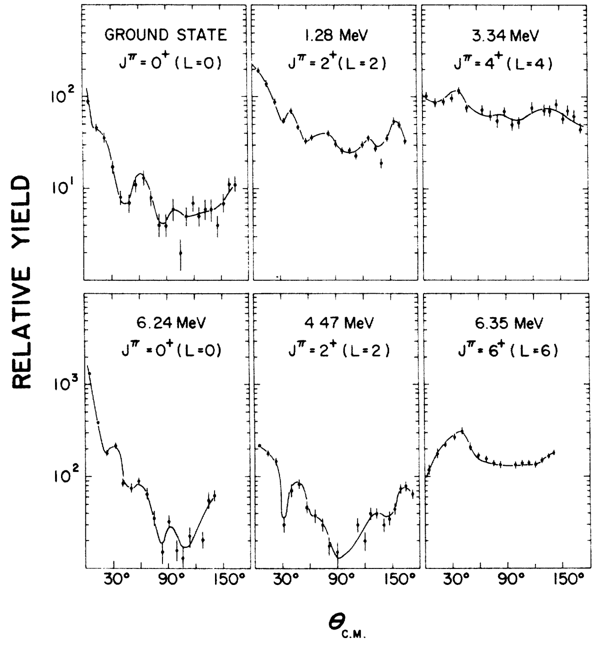

FIG. 2. Triton angular distributions measured from the reaction $^{18}\mathrm{O}(^7\mathrm{Li},t)^{22}\mathrm{Ne}$. The curves drawn are intended to serve only as a guide to the eye. The angular distributions shown are normalized to each other (note change of scale from upper to lower row).

peaked and indicative of a direct alpha-particle transfer. However, the distributions for transitions leading to the members of the ground-state rotational band mentioned above do not fall off as rapidly at large angles as do their counterparts in the reaction $^{16}\mathrm{O}(^7\mathrm{Li},t)^{20}\mathrm{Ne}$,[3] indicating a less favorable ratio between direct and competing nondirect capture processes. Nevertheless, there is a good agreement in the position of the first forward maximum for corresponding L values in the two reactions. Therefore, these transitions may be regarded to show the salient features for the ^{7}Li-induced direct capture of a spinless alpha cluster into orbits of angular momenta $L = 0$, 2, 4, and 6 relative to the 0^+ target nucleus. The transition to the third excited state at 4.47 MeV shows an $L = 2$ stripping pattern and thus confirms the previously[9] suggested most probable spin and parity assignment of $J^\Pi = 2^+$. Of particular interest, however, is the angular distribution of the strong transition to the 6.24-MeV state, which shows an unambiguous $L = 0$ pattern (Fig. 2). Thus the 6.24-MeV state can be assigned $J^\Pi = 0^+$. No excited 0^+ state has been found previously in ^{22}Ne, even though an extensive search has been made up to 5.92-MeV excitation energy.[12]

It has been shown that the SU(3) classification is a useful first-order approximation for the description of nuclei at the beginning of the $2s$-$1d$ shell.[4-7] Furthermore, it has been pointed out[8] that cluster-model states carry certain representations of SU(3). Therefore, the transfer of a spinless alpha cluster will populate predominantly those states in the final nucleus which contain a large fraction of these particular SU(3) representations in their wave functions. Applied to the reaction $^{18}\mathrm{O}(^7\mathrm{Li},t)^{22}\mathrm{Ne}$ this yields the following results: Inasmuch as the ^{18}O ground state has a [2] supermultiplet character, the alpha-cluster states in ^{22}Ne must belong to the [42] partition.[8] The cluster-model states associated with the $(1s)^4(1p)^{12}(2s,1d)^6$ configuration require eight quanta of relative motion between the unexcited O^{18} nucleus and the alpha particle. In the SU(3) model this corresponds to the $(\lambda,\mu) = (8,0)$ representation. Similarly, the ^{18}O ground state belongs predominantly to the (4,0) representation[4,5] and thus the SU(3) representations in ^{22}Ne which can be carried by the cluster-model state are obtained from the outer product[13] of these two representations $(8,0)\otimes(4,0) = (12,0)\oplus(10,1)\oplus(8,2)\oplus(6,3)\oplus(4,4)$. The (12,0) and (10,1) representations, however, do not appear in the [42] partition,[4] thus leaving only the last three terms of the outer product. It should be mentioned that the outer product implies no statement about the relative amplitudes of the (8,2), (6,3), and (4,4) representations in the cluster-model state. For this a more detailed calculation would be necessary which is beyond the scope of this Letter.

In the SU(3) model the angular momentum states belonging to representations with largest values of $\lambda + \mu$ are expected to be lowest in energy.[4-6] Furthermore, as shown by Elliott,[4] these states can be arranged in a way resembling that of rotational bands. Thus, for ^{22}Ne the (8,2) representation contains the ground-state rotational band and a $K = 2^+$ band which starts with the 2^+ state at 4.47 MeV. Because there can be no 0^+ state in the (6,3) representation,[4-6] we may conclude that the wave function of the 6.24-MeV 0^+ state is to a large extent characterized by the (4,4) representation. This would place the bandhead of the (4,4) representation about 6 MeV above that of the leading (8,2) ground-state band representation. A 0^+ state has been predicted at about 6 MeV in a calculation using a truncated set of SU(3) wave functions as unperturbed basis.[7] An analysis of the other strongly excited states above 6.24 MeV is in progress and will hopefully shed more light on the structure of ^{22}Ne.

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[1] G. C. Morrison, Phys. Rev. 121, 182 (1961).

[2] K. Bethge, K. Meier-Ewert, K. Pfeiffer, and R. Bock, Phys. Letters 24B, 663 (1967).

[3] R. Middleton, B. Rosner, D. J. Pullen, and L. Polsky, Phys. Rev. Letters 20, 118 (1968).

[4] J. P. Elliott, Proc. Roy. Soc. (London), Ser. A 245, 128, 562 (1958).

[5] J. P. Elliott and M. Harvey, Proc. Roy. Soc. (London), Ser. A 272, 557 (1963).

[6] M. Harvey, in Advances in Nuclear Physics, edited by M. Baranger and E. Vogt (Plenum Press, Inc., New York, 1968), p. 67.

[7] Y. Akiyama, A. Arima, H. Horiuchi, T. Inoue, and T. Sebe, J. Phys. Soc. Japan Suppl. 24, 108 (1968).

[8] B. F. Bayman and A. Bohr, Nucl. Phys. 9, 596 (1958).

[9] D. Pelte, B. Povh, and W. Scholz, Nucl. Phys. 52, 333 (1964).

[10] M. A. Eswaran and C. Broude, Can. J. Phys. 42, 1311 (1964).

[11] S. Buhl, D. Pelte, and B. Povh, Nucl. Phys. A91, 319 (1967).

[12] W. Kutschera, D. Pelte, and G. Schrieder, Nucl. Phys. A111, 529 (1968).

[13] M. Hamermesh, Group Theory (Addison-Wesley Publishing Company, Inc., Reading, Mass., 1964).

NUCLEAR HEAVY-ION-HEAVY-ION COLLISIONS AND THE INTERMEDIATE-STATE MODEL

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Five excitation functions from 50 to 90° (c.m. system) for O^{16}-O^{16} elastic scattering can be accounted for by a nuclear molecular potential. The parameters of this potential are estimated from the two-nucleon potential in a model of the transient nuclear matter state.

The classical optical model applied to O^{16}-O^{16} scattering has proven to be deficient in several respects.[1-3] These calculations fail to reproduce the extremely low cross sections seen in the valleys of the excitation function. The calculated peak-to-valley ratios of the cross section are much too small at energies above the Coulomb threshold. The optical model also fails to produce the first peak seen at about 17 MeV. In particular, the deep valleys and the large peak-to-valley ratios motivated an attempt to describe the scattering in terms of an average nonmonotonic potential containing a short-range repulsion, which is the lowest approximation to the general nonlocal potential originating from the Pauli principle. Applying the model of Kerlee, Blair, and Farwell,[4] the large peak-to-valley ratios of the 90° excitation function could be reproduced in the energy range 20-26 MeV.[5]

In this note, we shall present an effective nonmonotonic potential describing the excitation functions at 49.3°, 60°, 69.8°, 80.3°, and 90° (c.m.) in the energy range 10-22 MeV (c.m.), thus demonstrating that the low-energy data are compatible with the concept of a "core." Further, we develop a model to estimate important quan-