Level Structure in ^{145}Eu†

E. Newman, K. S. Toth, R. L. Auble, R. M. Gaedke,* and M. F. Roche‡
Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830
and
B. H. Wildenthal
Michigan State University, East Lansing, Michigan 48823
(Received 31 October 1969)

Levels in ^{145}Eu were investigated by the ^{144}Sm(^{3}He, d) reaction and by the decay of 25-min ^{145}Gd. At the ^{3}He energy used, i.e., 40.33 MeV, the angular distributions for the stripping reaction were found to be highly structured. This fact permitted reliable assignments of transferred orbital angular momenta to the residual levels. Singles γ-ray spectra for the decay of ^{145}Gd were measured with a 20-cm^3 Ge(Li) detector. The two sets of experimental data were then used to propose the following sequence of ^{145}Eu levels: 0 ($\frac{5}{2}^+$), 330.1 ($\frac{7}{2}^+$), 716 ($\frac{11}{2}^-$), 808.4 ($\frac{1}{2}^+$), 1041.9 ($\frac{3}{2}^+$), 1599.9 ($\frac{7}{2}^+$), 1757.9 ($\frac{3}{2}^+$), 1844.7 ($\frac{3}{2}$, $\frac{5}{2}^+$), 1880.6 ($\frac{1}{2}$, $\frac{3}{2}^+$), 2112.0 ($\frac{3}{2}$, $\frac{5}{2}^+$), and a ($\frac{1}{2}^+$), ($\frac{3}{2}$, $\frac{5}{2}^+$) doublet at ~2480 keV. The salient features of this level scheme are that (1) the (^{3}He, d) reaction predominantly populates the first five energy levels, and (2) the decay from ^{145}Gd ($\frac{1}{2}^+$) proceeds mainly to the levels at 1757.9 and 1880.6 keV and not to the single-particle states at 808.4 and 1041.9 keV. The present results were compared with experimental systematics available for $N=82$ isotones and with the implications of a recent shell-model calculation for nuclei in this region.

I. INTRODUCTION

The nuclei with a closed shell of 82 neutrons are of particular interest since their low-lying level structure should arise mainly from proton excitations. The assumption of a doubly magic $N=82$, $Z=50$ core for these nuclei makes possible a variety of detailed microscopic calculations of the properties of their energy levels.[1,2] In the present study, levels in ^{145}Eu were investigated by the ^{144}Sm(^{3}He, d) reaction and by the decay of 25-min ^{145}Gd. The results were then compared with experimental systematics available for $N=82$ isotones and with the implications of a recent shell-model calculation[3] for nuclei in the same region.

II. γ RAYS IN ^{145}Gd DECAY

A radioactive source that contained ^{145}Gd was produced by bombarding 5 mg of Sm_2O_3 (enriched in ^{144}Sm to 95.1%) with helium ions accelerated in the ORIC. The bombarding energy (~45 MeV) was selected so as to correspond to the peak of the (α, $3n$) excitation function. Since the highly enriched samarium oxide powder was spread over a 2-cm^2 area, ^{145}Gd was the main rare-earth product. Chemical separations were not made.

γ-ray spectra were measured with a 20-cm^3 coaxial Ge(Li) detector connected via a field-effect-transistor preamplifier and an amplifier to a 1600-channel analyzer. Measurements were begun within 5 min after the end of bombardment. The relative photopeak efficiency of the detector system was determined prior to the spectral measurements with the use of standard ^{182}Ta, ^{207}Bi, and ^{226}Ra sources.

A portion of the γ-ray spectra (0.71–1.89 MeV) measured during the first hour of decay time is shown in Fig. 1. All peaks that are identified by energy only are assigned to ^{145}Gd decay. Note that the 721-keV transition in ^{145}Gd due to the 80-sec isomeric state[4] was also observed. This peak, prominent during the first few minutes of counting, was later overwhelmed by Compton distributions due to the higher-energy γ rays seen in Fig. 1. In Fig. 2, we display another spectrum taken during the second hour of counting with a higher amplifier gain. This spectrum shows the doublets at ~950 and ~1070 keV partially resolved. The 894.1-keV γ ray due to the decay[5] of the daughter nuclide ^{145}Eu (5.9 day) is more intense in Fig. 2 than in Fig. 1.

Table I summarizes the γ-ray data for ^{145}Gd. Transition energies are based on the energies of γ rays observed in the standard sources listed above and on the energies of the annihilation radiation and the 894.1-keV transition in ^{145}Sm. The energy values listed in Table I are estimated to be accurate to within ±1 keV. Relative intensities are based on a value of 100 for the 1757.9-keV γ-ray intensity. The absolute intensities given in column 3 were determined by assuming no direct decay to the ^{145}Eu ground state and by taking the sum of intensities for all ground-state transitions in ^{145}Eu to be equal to 100%. (See Sec. IV for the discussion of

† Research sponsored by the U.S. Atomic Energy Commission under contract with Union Carbide Corporation.
* Present address: Trinity University, San Antonio, Tex.
‡ Present address: Argonne National Laboratory, Argonne, Ill.
[1] R. J. Lombard, Nucl. Phys. **A117**, 365 (1968); M. Rho, *ibid.* **65**, 497 (1965); L. S. Kisslinger and R. A. Sorensen, Kgl. Danke Videnskab. Selskab, Mat.-Phys. Medd. **32**, No. 9 (1960).
[2] K. S. Toth, E. Newman, B. H. Wildenthal, R. L. Auble, R. M. Gaedke, and M. F. Roche, in *International Conference on Radioactivity in Nuclear Spectroscopy: Techniques and Applications* (Gordon and Breach Science Publishers, Inc., New York, to be published).
[3] B. H. Wildenthal, Phys. Rev. Letters **22**, 1118 (1969).
[4] G. Jansen, H. Morinaga, and C. Signorini, Nucl. Phys. **A128**, 247 (1969).
[5] I. Adam, K. S. Toth, and M. F. Roche, Nucl. Phys. **A121**, 289 (1968).

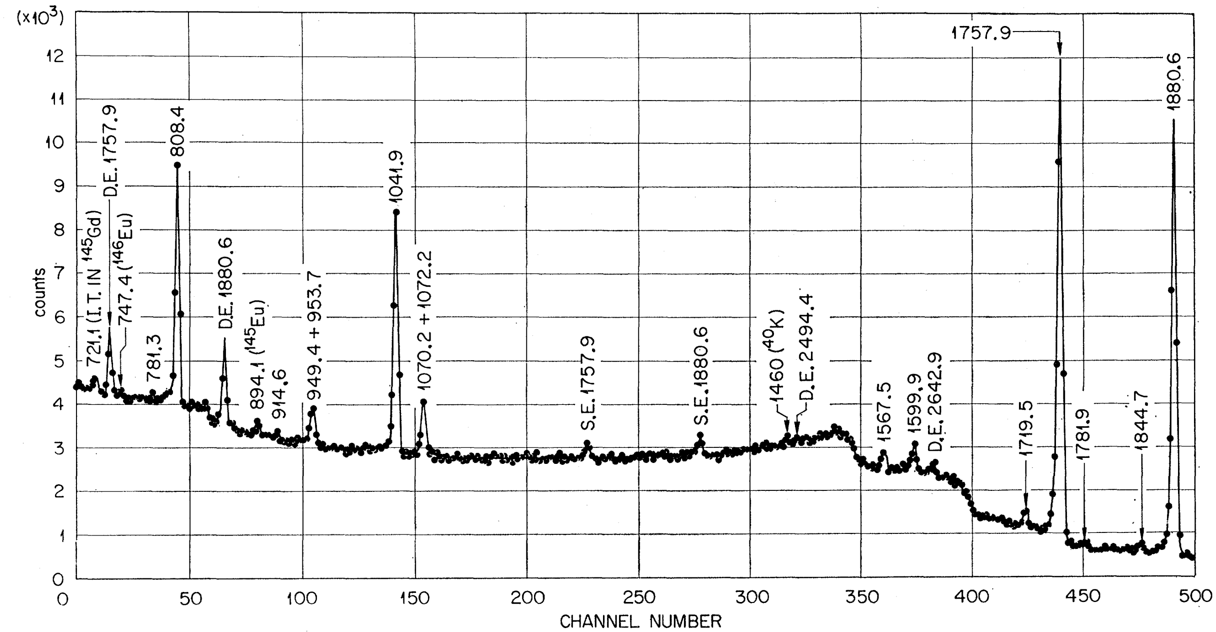

FIG. 1. Portion of the ^{145}Gd γ-ray spectrum (0.71–1.89 MeV) measured during the first hour of decay. Peaks identified by energy only are assigned to ^{145}Gd decay.

the ^{145}Gd decay scheme.) The assumption of no direct decay to the ground state was based on the following evidence: Within the experimental uncertainties, the 25-min component of the annihilation radiation was found to be twice as intense as the 1757.9-keV γ ray. This means that the ^{145}Gd positron intensity on our relative-intensity basis is ~100. Grover[6] measured the intensity ratio $[\beta^+/(K \text{ x rays})]$ to be 0.6, which gives a relative K–x-ray intensity of ~167. The intensity sum ($\beta^+ + K$ x ray) of 267 is, within error limits, equal to 270, the relative-intensity sum for transitions that proceed to the ^{145}Eu ground state. It would appear, therefore, that there is little or no direct ^{145}Gd decay to the ground state.

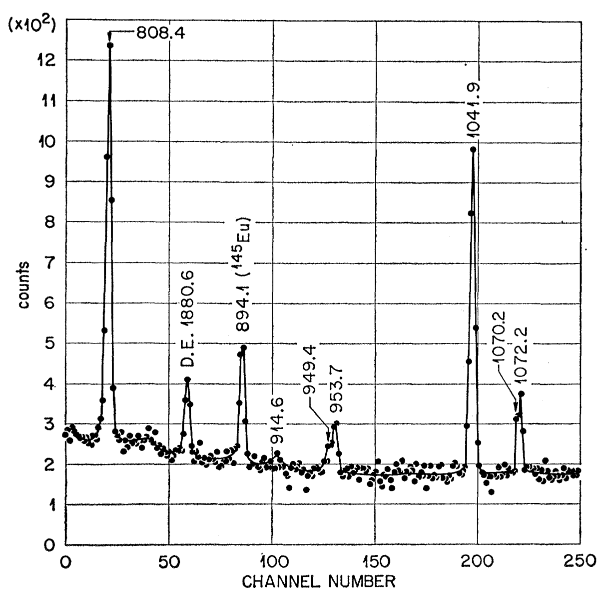

FIG. 2. Portion of the ^{145}Gd γ-ray spectrum (0.80–1.08 MeV) taken with a higher amplifier gain during the second hour of decay. Peaks identified by energy only are assigned to ^{145}Gd decay.

III. PROTON LEVELS IN ^{145}Eu

The single-particle levels in ^{145}Eu were investigated by using the (^{3}He, d) proton stripping reaction on a target of ^{144}Sm. At the incident energy used (40.33 MeV), the differential cross sections are markedly oscillatory with unique angular patterns,[7] thus permitting reliable assignment of the transferred orbital angular momentum to the various residual levels. From these results, a knowledge of the sequence of shell-model orbitals in the region, the appropriate distorted-wave (DW) calculations, the spins, and the configurations of many of the observed levels could be deduced.

The ^{144}Sm target was an enriched (94.5%) rolled metallic foil of 460-μg/cm^2 areal density. The deuteron spectra were recorded with photographic emulsions located in the focal plane of the broad-range magnetic spectrograph. The energy resolution was about 35 keV, attributable mainly to target thickness. A deuteron

[6] J. R. Grover, Phys. Rev. **116**, 406 (1959).
[7] B. H. Wildenthal, E. Newman, and R. L. Auble, Phys. Letters **27B**, 628 (1968).

TABLE I. γ rays in ^{145}Eu.

Energy (keV)	Relative intensity[a]	Absolute intensity[b]
330.1	7.9	2.9
781.3	0.8	0.3
808.4	25.5	9.4
914.6	0.7	0.3
949.4	1.5	0.5
953.7[c]	3.0	1.1
1041.9	27.3	10.1
1070.2	2.5	0.9
1072.2	4.5	1.7
1567.5	2.6	1.0
1599.9	5.0	1.8
1719.5[c]	3.0	1.1
1757.9	100	37.0
1781.9	1.8	0.7
1844.7	1.2	0.4
1880.6	98	36.3
2202.8[c]	1.8	0.7
2494.3	3.9	1.4
2642.9[c]	6.6	2.4
2663.2	0.9	0.3
2674.0	0.6	0.2
2837.7	2.5	0.9

[a] Based on a value of 100 for the 1757.9-keV γ-ray intensity.
[b] Calculated by assuming no direct decay to the ^{145}Eu ground state.
[c] Not placed in decay scheme.

spectrum at 21° (L) is shown in Fig. 3. The peaks are identified by the energies obtained from the spectrograph calibration, and the errors for these determinations are also indicated. Differential cross sections for the various states were measured between 5° and 36° in the laboratory system. The absolute cross sections are based on the ^{3}He elastic scattering yield between 36° and 40° (L) as measured in the spectrograph. The absolute cross sections are then determined by assuming that the observed elastic scattering cross section is equal to that calculated by the optical model. The parameters used in the optical-model calculation are based on those found by Gibson *et al.*[8] It is believed that the absolute cross sections obtained in this way are accurate to better than 20%. The angular distributions are presented in Fig. 4. The errors shown are the statistical uncertainty only and do not reflect the absolute uncertainty discussed above. The curves associated with each distribution are the results of a DW calculation (JULIE) assuming the orbital angular momentum transfer noted on the figure. The curves were calculated using the separation-energy prescription. The bound-state wave function was calculated using a nuclear radius parameter $r_0 = 1.24$ F, a spin-orbit term with a radius parameter[9] $r_{so} = 1.14$ F, and strength $\lambda = 20$. The distorted waves in the entrance and exit channels were calculated from the parameters of Ref. 8 and from an optical-model analysis of 34.4-MeV deuteron elastic scattering,[10] respectively. The curve labeled as the sum of two values of the transferred angular momentum was arrived at by summing, incoherently, the appropriately weighted single-l-transfer calculations. The group requiring this summation was assumed to arise from the excitation of two levels whose spacing was less than the experimental resolution.

In Table II, we present the spectroscopic information derived from the analysis discussed above. Although the orbital angular momentum for a level is determined by experiment, the total angular momentum is not. For the present study, this, in principle, leads to uncertainty in allocating the observed $l=2$ levels between $J=\frac{3}{2}$ and $\frac{5}{2}$. In fact, however, the J assignment can be made with a reasonable degree of certainty from a knowledge of the sequence of shell-model orbitals. Since the ground state is $\frac{5}{2}^+$, the strongly excited $l=2$ level at 1042 keV is probably $\frac{3}{2}^+$ since a $\frac{5}{2}^+$ assignment would imply a total $d_{5/2}$ spectroscopic factor in excess of unity and an empty $d_{5/2}$ orbital is untenable for the wave function of the ^{144}Sm ground state.[7] The $l=2$ levels above 1042 keV have been assumed to be $\frac{3}{2}^+$ for the purpose of calculating spectroscopic factors. It is seen that the first five observed levels contain the major portion of the single-particle strength for the single-particle orbits that are being filled between $Z=50$ and $Z=82$.

TABLE II. Level parameters derived from the ^{144}Sm(^{3}He, d)^{145}Eu reaction.

^{145}Eu level (keV)	l transfer	J^π	C^2S
g.s.	2	5/2+	0.33
329	4	7/2+	0.17
716	5	11/2−	0.82
809	0	1/2+	0.98
1042	2	3/2+	1.01
1599	4	7/2+	0.02
1757	2	3/2+	0.02
1843	2	3/2+	0.10
2108	2	3/2+	0.04
2480[a]	2	3/2+	0.04
	0	1/2+	0.02

[a] Unresolved doublet.

[8] E. F. Gibson, B. W. Ridley, J. J. Kraushaar, M. E. Rickey, and R. H. Bassel, Phys. Rev. **155**, 1194 (1967).

[9] E. Newman and B. H. Wildenthal, Bull. Am. Phys. Soc. **13**, 1463 (1968).

[10] E. Newman, L. C. Becker, B. M. Preedom, and J. C. Hiebert, Nucl. Phys. **A100**, 225 (1967).

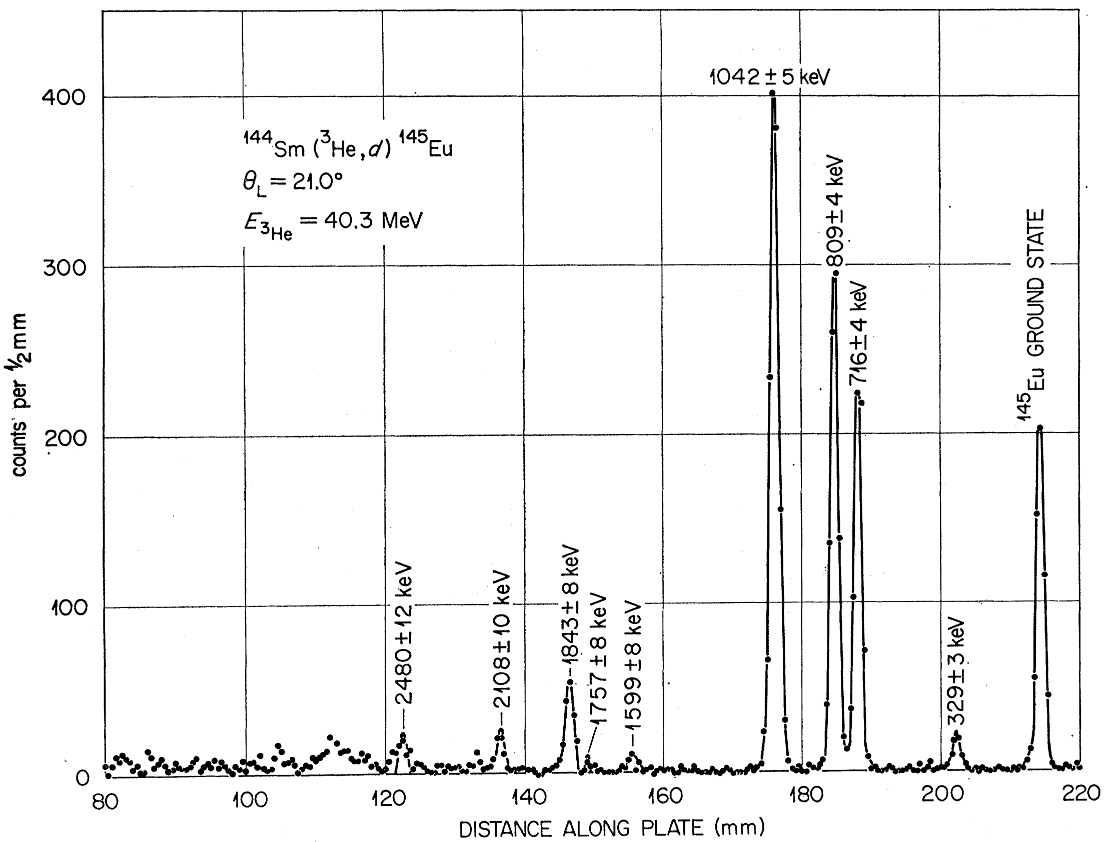

FIG. 3. Deuteron spectrum recorded at 21° (L) from the ^{144}Sm(^{3}He, d)^{145}Eu reaction.

IV. DISCUSSION

The ^{145}Eu level scheme based on the two sets of data is shown in Fig. 5. Note that the 1880.6-keV state was not excited by the (^{3}He, d) reaction, while the high-spin $\frac{11}{2}^-$ 716-keV state was not observed in the decay study. The 2494.3-keV state shown in the decay scheme is proposed as being the $\frac{1}{2}^+$ member of the doublet observed in the stripping reaction at ~2480 keV. Levels above 2.5 MeV are tentatively proposed on the basis of sums and differences of transition energies. Previous information on the low-lying states of ^{145}Eu has been summarized in a recent nuclear data sheets compilation[11] that showed only excited states at 330, 809, 1760, and 1882 keV.

Because of uncertainties in the measured photon intensities and the fact that not all of the observed γ rays were included in the decay scheme, percentages of direct decay were determined only for the states most strongly populated in decay, i.e., those at 808.4, 1041.9, 1757.9, and 1880.6 keV. Logft values based on these decay rates were calculated by using a decay energy[6] of 5.3 MeV and the curves of Moszkowski[12] in a slightly modified version.[13]

The salient features of the experimentally determined ^{145}Eu level scheme are (1) the (^{3}He, d) reaction predominantly populates the first five energy levels, (2) the level density between 1 and 2 MeV is much lower than for the lighter odd-mass $N=82$ nuclei (see, e.g., Refs. 14 and 15), (3) the $\frac{5}{2}^+$ ground state is not appreciably fed by the direct decay of ^{145}Gd, and (4) the ^{145}Gd decay, in contrast to the stripping results, populates mainly the levels at 1757.9 and 1880.6 keV.

Let us turn our attention first to items 1 and 2. The (^{3}He, d) results for the first five levels of ^{145}Eu are consistent with those of similar experiments on lighter $N=82$ nuclei,[7] and the entire set of phenomena can be understood in the following theoretical framework: The 82 neutrons, together with 50 of the protons, form

[11] L. W. Chiao and M. J. Martin, in *Nuclear Data Sheets*, compiled by K. Way *et al.* (Printing and Publishing Office, National Academy of Sciences—National Research Council, Washington, D.C. 20025, 1967), NRC B2-1-81 (for $A=145$).

[12] S. Moszkowski, Phys. Rev. **82**, 35 (1951).

[13] G. J. Nijgh, A. H. Wapstra, and R. Van Lieshout, in *Nuclear Spectroscopy Tables* (North-Holland Publishing Co., Amsterdam, 1959), Chap. 5, Sec. 4, pp. 58–65.

[14] D. DeFrenne, K. Heyde, L. Dorikens-Vanpraet, M. Dorikens, and J. Demuynck, Nucl. Phys. **A110**, 273 (1968).

[15] D. B. Beery, W. H. Kelly, and W. C. McHarris, Phys. Rev. **171**, 1284 (1968).

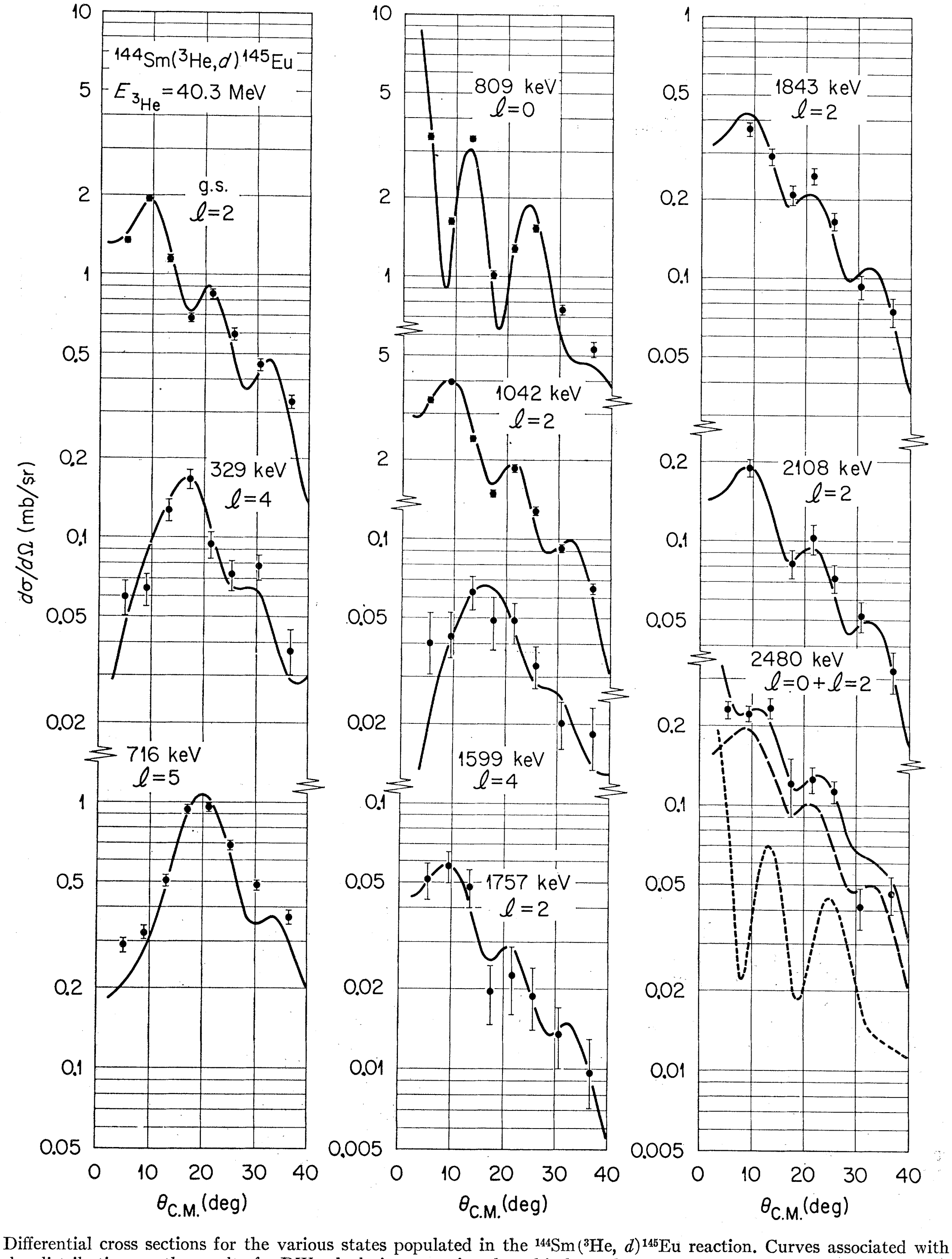

FIG. 4. Differential cross sections for the various states populated in the ^{144}Sm(^{3}He, d)^{145}Eu reaction. Curves associated with each angular distribution are the result of a DW calculation assuming the orbital angular momentum transfer shown in the figure.

major closed shells and can be neglected in considering the structural details of the low-lying energy levels. The protons in excess of 50 occupy the "*sdgh*" major shell, composed of five single-particle orbits, of which the $1g_{7/2}$ and $2d_{5/2}$ energies lie significantly lower than do those of the $1h_{11/2}$, $2d_{3/2}$, and $3s_{1/2}$ orbits. Thus, the active protons in the ground states of even $N=82$ nuclei ($Z=52$–64) tend to occupy $1g_{7/2}$ and $2d_{5/2}$ orbits. Proton stripping reactions on these targets do show $l=2$ and $l=4$ transitions to low-lying states of $J^\pi=\frac{5}{2}^+$ and $\frac{7}{2}^+$.

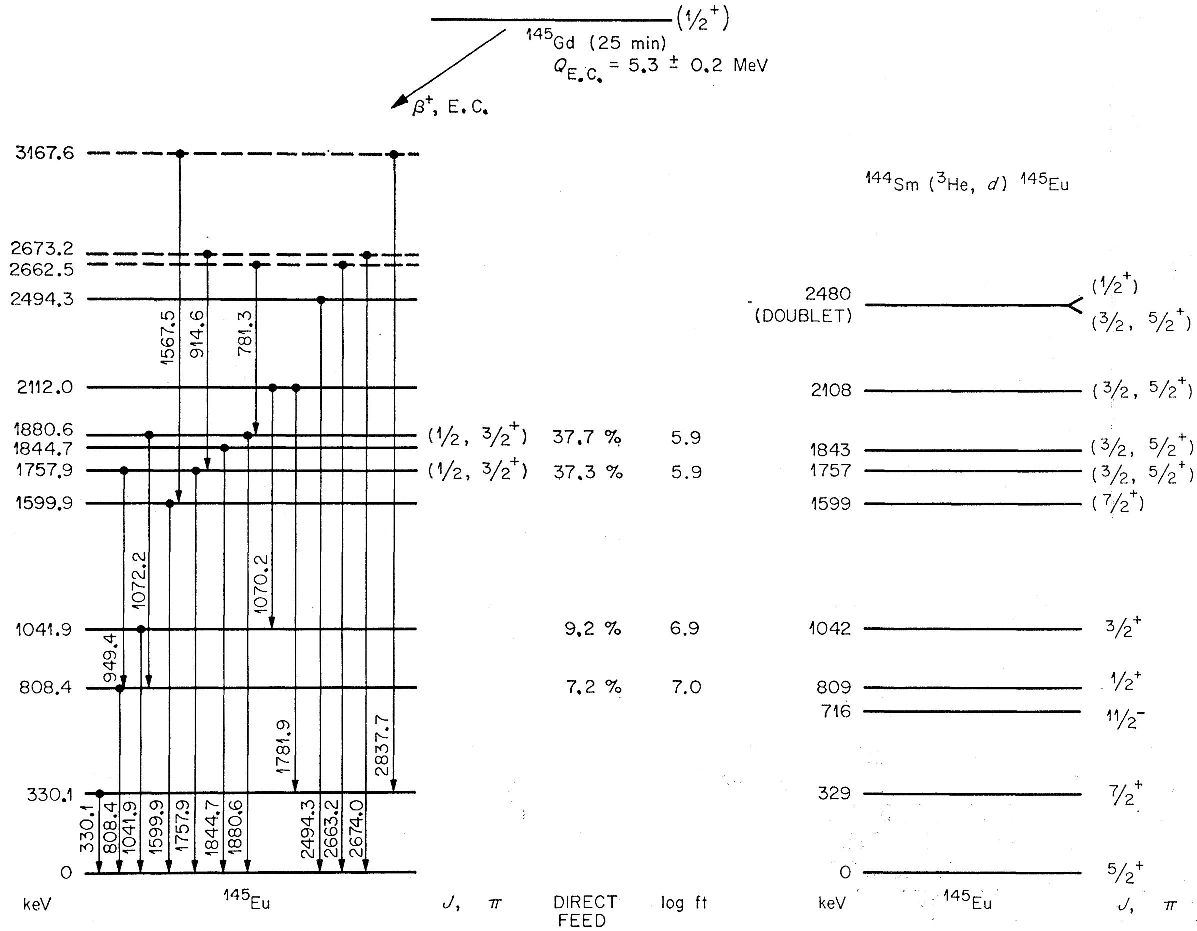

FIG. 5. Europium-145 level scheme based on experimental data obtained from the study of (1) the decay of ^{145}Gd and (2) the ^{144}Sm(^{3}He, d)^{145}Eu reaction.

Similarly, $l=5$, 0, and 2 transitions populate higher excited states of $J^\pi=\frac{11}{2}^-$, $\frac{1}{2}^+$, and $\frac{3}{2}^+$, respectively. The spectroscopic factors for the transitions to the two lowest states should be reduced in proportion to the occupancy of these orbits in the target ground state, while the transitions to the higher three states should proceed with almost the maximum limit of intensity, reflecting the vacancy of these orbits in the target ground state. The systematics of the single-particle centroids in the odd-mass isotones determined via (^{3}He, d) reaction experiments are presented in Fig. 6. These states can be understood as the coupling of the unpaired proton in one of the five "*sdgh*" orbits with the 0^+ ground state of the target nucleus. It is clear from Fig. 6 that the results for ^{145}Eu follow the trends established in the lighter nuclei.

The details of Fig. 6 agree with the results of a shell-model calculation[3] based on the ideas of the preceding paragraph. The basis space of the model encompasses four classes of configurations for the Z' active protons (those in excess of 50). For the odd-A nuclei these are type (1), in which all particles occupy the $1g_{7/2}$ and $2d_{5/2}$ subshell, and all but one are $J=0$ coupled pairs; type (2), in which one particle occupies either the $3s_{1/2}$ or $2d_{3/2}$ orbit and is coupled to a completely paired mixture of $d_{5/2}$ and $g_{7/2}$ protons; type (3), where a $g_{7/2}$ or $d_{5/2}$ particle is coupled to a mixture of $d_{5/2}$ and $g_{7/2}$ particles that include at least one broken pair; and type (4), involving *both* at least one broken pair in the $\frac{7}{2}-\frac{5}{2}$ space *and* the elevation of a single particle into the $\frac{1}{2}-\frac{3}{2}$ space. Thus, the $g_{7/2}$ and $d_{5/2}$ orbits are treated as a subshell, and the model considers all states in that subshell together with one-particle excitations into the higher two positive-parity orbits. Two-particle excitations into these higher orbits have, for the present, been excluded. This appears to be a good approximation for most of the $N=82$ chain. However, such configurations may be expected to become important as the $g_{7/2}$–$d_{5/2}$ space closes out, as it does for the nuclei of present interest, ^{144}Sm, ^{145}Eu, and ^{145}Gd. Excitations into the $1h_{11/2}$ orbit have not yet been included in the calculation. There seems no reason, however, not to extrapolate the model systematics for the positive-parity orbits to help understand the behavior of the $1h_{11/2}$ single-particle state.

In the lighter odd-mass $N=82$ isotones, as observed

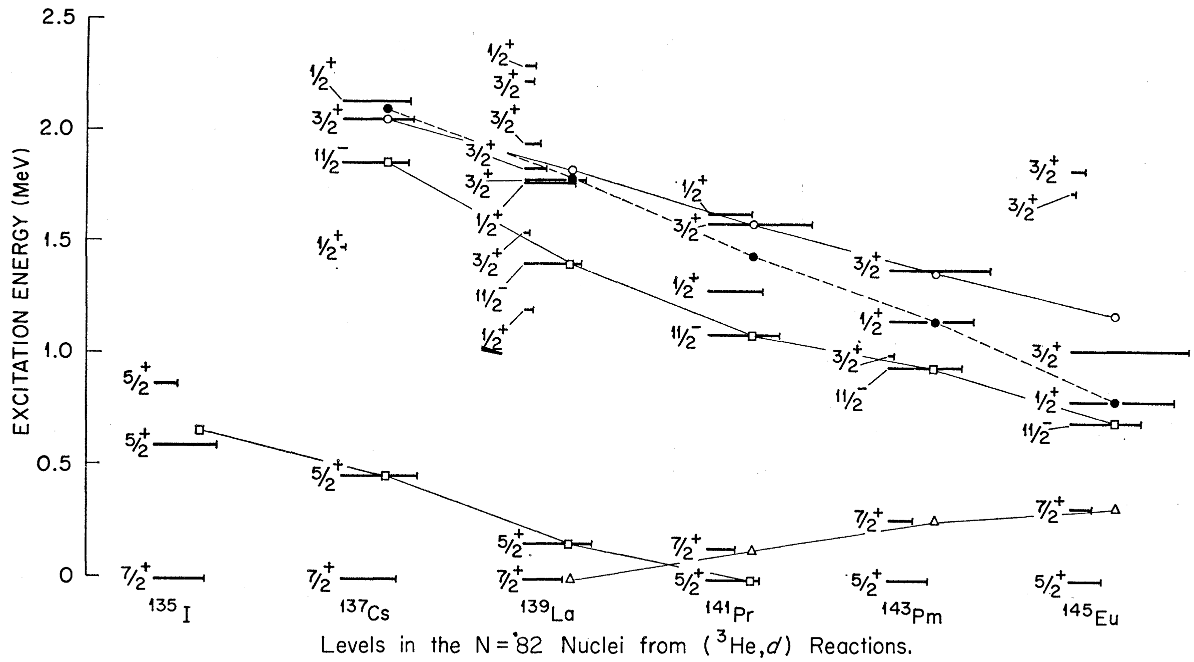

FIG. 6. Systematics of the single-particle centroids in odd-mass $N=82$ iostones as determined via (^{3}He, d) reactions.

experimentally, the shell-model calculation just described predicts the occurrence of many levels between 1- and 2-MeV excitation. It indicates that their wave functions have the character of either type (2) or type (3). States of type (4) lie above 2 MeV. That is to say, states between 1 and 2 MeV involve *either* elevation to a higher single-particle orbit *or* the breaking of a $J=0$ pair in the $g_{7/2}$–$d_{5/2}$ space.

In the model space just described, ^{145}Eu is essentially a "one-hole" nucleus. Specifically, it is no longer possible to construct type-(3) states. Single-particle states of type (2) have, in fact, moved below 1-MeV excitation (see the trend in Fig. 6). Thus, the model spectrum between 1 and 2 MeV becomes vacant. The model spectrum of ^{145}Eu is compared to our composite experimental spectrum in Fig 7. We note that the measured and predicted energies of the first four positive-parity states are in good agreement and that the stripping reaction labels them as the single-particle states. Between 1 and 2 MeV, the experimental level density is indeed reduced in comparison to lighter nuclei. There is, however, a multiplet of levels between 1.6 and 1.9 MeV that seems too far removed from the closest model states at ~2.2 MeV to justify it being associated with them. The higher model states arise from the type-(4) configurations previously mentioned. Thus, the model results appear successful in accounting for the simple "single-particle" states and the general decrease in the density of the higher excited states. There is, however, experimental evidence for the existence of states below 2 MeV whose origins appear to lie outside the model basis.

The third important feature of the experimental results, the absence of observable direct decay to the ^{145}Eu ($\frac{5}{2}^+$) ground state, is at variance with what occurs[13,14] in the ostensibly similar decays of ^{141}Nd ($\frac{3}{2}^+$) and ^{143}Sm ($\frac{3}{2}^+$) to ^{141}Pr and ^{143}Pm, respectively. In each of the latter cases, the transition to the $\frac{5}{2}^+$ ground state of the residual nucleus dominates the decay with a log*ft* value of ~5. The nature of these decays is easily interpreted. The decaying state can be pictured as a $2d_{3/2}$ neutron hole. The active protons in the state, arranged in $J=0$ coupled pairs, primarily occupy the *g*-*d* subshell; but, as experiment shows[7] and BCS theory implies, small admixtures of $J=0$ proton pairs in the $1h_{11/2}$, $2d_{3/2}$, and $3s_{1/2}$ orbits are also present. The β decay could then proceed via an allowed transition $\pi d_{5/2}\rightarrow\nu d_{3/2}$ leaving a $d_{5/2}$ proton coupled to the remaining proton core. For the case of ^{145}Eu, on the other hand, the $\frac{1}{2}^+$ and $\frac{3}{2}^+$ states at 808.4 and 1041.9 keV are significantly fed in the direct decay of ^{145}Gd but not the $\frac{5}{2}^+$ ground and the $\frac{7}{2}^+$ first excited states. Therefore, on the basis of β-decay selection rules, it appears that the spin of the parent cannot be $\geq\frac{3}{2}^+$. Thus, a spin of $\frac{1}{2}^+$ is the only assignment compatible with the experimental data.

The simplest representation of the ^{145}Gd ground state, under the assumption of $J=\frac{1}{2}^+$, would then be a $3s_{1/2}$ neutron hole coupled to a 14-proton state in which the $g_{7/2}$ and $d_{5/2}$ orbits are predominantly occupied. Now, however, insofar as the β-decay process is concerned, the $d_{5/2}$ protons are essentially inactivated because of the $\Delta J=2$ barrier. The transition must, therefore, proceed via the decay of one of a pair of $s_{1/2}$ (or with less probability $d_{3/2}$) protons that are mixed into the dominant $g_{7/2}$–$d_{5/2}$ proton structure. The transition rate would then be expected to be slower than for the $A=141$ and $A=143$ cases. This retardation is indeed observed.

The proposed assignment of $J^{\pi}=\frac{1}{2}^{+}$ to the ground state of ^{145}Gd does not resolve all of the problems posed by the experimental decay data. As noted in Fig. 5, the levels at 1757.9 and 1880.6 keV are populated with significantly more intensity than are the single-particle levels at 808.4 and 1041.9 keV. Since the 1757.9- and 1880.6-keV levels are reached via the β^{+} decay, their spins are $\frac{1}{2}$ or $\frac{3}{2}$ with our assumption of $\frac{1}{2}^{+}$ for the ^{145}Gd ground state. The 1757.9-keV level is also characterized by an $l=2$ (^{3}He, d) angular distribution; it must have $J^{\pi}=\frac{3}{2}^{+}$. It should be recalled that the states between 1600 and 2000 keV were those that apparently could not be accounted for by the shell-model calculation.

We emphasize that it is the ^{145}Eu single-particle states that are expected to be fed most strongly by decay from the ^{145}Gd ground state. It is generally assumed that the ground states of the even-mass $N=82$ isotones with Z and $Z+2$ protons are related to each other by the simple addition of a zero-coupled pair of protons in the "*sdgh*" space. The single-particle states of the $Z+1$ system would then be reached either by adding a proton to the Z proton ground state or by annihilating one from the $Z+2$ ground state. For the lighter $N=82$ nuclei, this assumption accounts for the observed phenomena. Failure of the ^{145}Gd decay (i.e., the annihilation of a proton in the $Z'=14$ ground state) to populate the same levels a does the (^{3}He, d) reaction (i.e., the addition of a proton to the $Z'=12$ ground state) strongly suggests that the $Z'=14$ ground state is not related to the $Z'=12$ ground state in the same fashion that the $Z'=12$ ground state is related to that of $Z'=10$, etc. The $Z'=14$ ground state seems to have more overlap with the active core of the ^{145}Eu states at 1600–2000-keV excitation. We have suggested that these states in ^{145}Eu involve the occupation of the $h_{11/2}$, $d_{3/2}$, and $s_{1/2}$ orbits to a qualitatively greater extent than do the lower known levels of ^{145}Eu. Thus, one is led to speculate that the lowest-energy configuration of 14 active protons also involves this qualitatively greater amount of excitation into these orbits than do the ground and low excited states of the lighter numbers of the chain.

To go beyond these qualitative speculations, it will be necessary to have more experimental information, particularly about the $Z'=14$ system. In addition, detailed theoretical studies of the behavior in the vicinity of the transition from the $1g_{7/2}$–$2d_{5/2}$ region to the $1h_{11/2}$–$3s_{1/2}$ region is also highly desirable.

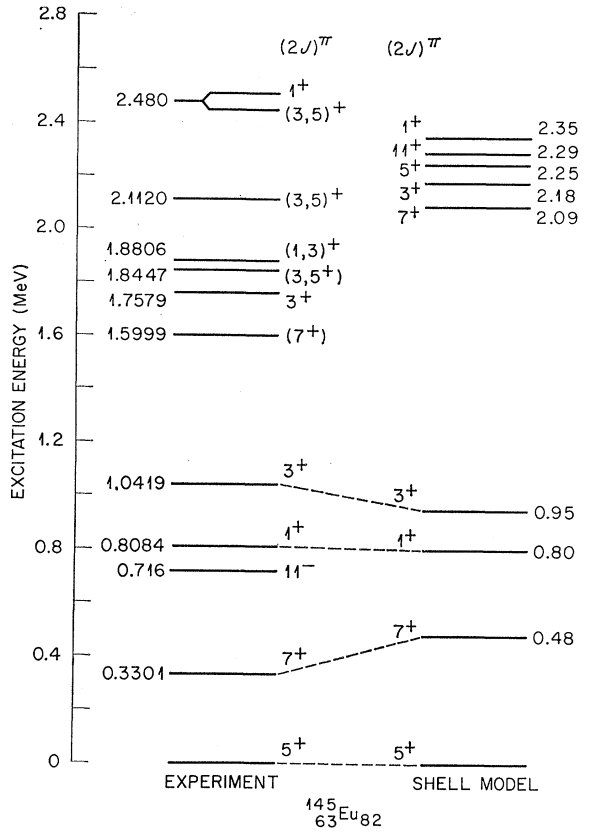

FIG. 7. Composite experimental level scheme for ^{145}Eu compared with the results of the shell-model calculation.

ACKNOWLEDGMENTS

Two of us (B.H.W. and R.L.A.) wish to thank the Oak Ridge Associated Universities for the support of an Atomic Energy Commission Special Postdoctoral Fellowship. The authors wish to thank Ruby Shelton for scanning the nuclear emulsions and the cyclotron crew for their help in performing the bombardments.