the viscosity and diffusion coefficient using the Lennard-Jones 12-6 potential function, and also using the modified Buckingham exp-6 potential function. The constants used in the potential functions are given in Table II; the results are plotted in Fig. 4. It can be shown that no choice of parameters for either potential function can give better agreement between classical calculations and measurements for both viscosity and diffusion coefficient, in the 14 to 20°K temperature range.

Cohen, Offerhaus, van Leeuwen, Roos, and de Boer[12] have made quantum mechanical calculations up to 22°K of $\eta(H_2)$ and ρD(ortho-para-H_2), using the Lennard-Jones potential. Their viscosity calculation is shown in Fig. 4. Their diffusion coefficient results have been multiplied by $n\mu/\rho$ and by the mass correction factor, Eq. (7), before plotting in Fig. 4. According to the principle of corresponding states, the mass correction factor applies to the quantum mechanical calculation, since the diffraction effects depend in this manner on the masses of the colliding particles. Since H_2 and D_2 are different molecules, just as ortho-H_2 and para-H_2 are different molecules, the quantum mechanical symmetry effects should be the same, and the calculation of Cohen *et al.* should apply to the H_2-D_2 diffusion coefficient. The measurements at 13.9 and 19.5°K are about 20% below the quantum mechanical calculations.

Classical calculations in second approximation indicate the dependence of the diffusion coefficient on H_2-D_2 isotopic ratio increases with temperature. At 300°K, the change in diffusion coefficient between a 50%-50% mixture and a 95%-5% mixture is about 0.7%. The experiment is not sufficiently precise to look profitably for this effect.

ACKNOWLEDGMENTS

The author gratefully acknowledges the encouragement and assistance of Dr. E. F. Hammel, Dr. W. E. Keller, and Dr. T. R. Roberts.

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[12] Cohen, Offerhaus, van Leeuwen, Roos, and de Boer, Physica **22**, 791 (1956).

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Nuclear Levels in P^{30}, S^{33}, and S^{35}†

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Targets of natural antimony sulfide have been bombarded with deuterons accelerated by the MIT-ONR electrostatic generator to energies of 6.0 and 6.5 Mev. Charged reaction products, protons, alpha particles, and elastically scattered deuterons, were observed at angles of 50, 90, and 130 degrees to the deuteron beam with a high-resolution, broad-range magnetic spectrograph.

The ground-state Q value of the $S^{32}(d,\alpha)P^{30}$ reaction is measured as 4.887 ± 0.010 Mev. The previously reported first level in P^{30} appears to be a doublet with components at 0.680 and 0.708 Mev. On intensity grounds, an isobaric spin $T=1$ is assigned to the lower level. Twenty-eight additional levels in P^{30} are observed in a region of excitation up to 5.8 Mev.

The ground-state Q value of the $S^{32}(d,p)S^{33}$ reaction is 6.413 ± 0.006 Mev, and one hundred four levels are observed up to an excitation energy of 8.0 Mev. Some levels stand out as single-particle states because of the high intensities of the corresponding proton groups.

Six weak proton groups were assigned to the $S^{34}(d,p)S^{35}$ reaction. The ground-state Q value is 4.757 ± 0.010 Mev.

I. INTRODUCTION

In the last few years, there has been a considerable interest in the level schemes of self-conjugated odd-odd nuclei. Of prime importance is the position of the lowest $J=0^+$, $T=1$, state. Strong evidence[1,2] has been collected from the $Si^{29}(p,\gamma)P^{30}$ reaction, showing that in P^{30} this state is to be found at an excitation energy of 0.69 Mev. Recently, however, the $T=1$ character of this state has been questioned, because an intense alpha-particle group proceeding to this level has been observed from the $S^{32}(d,\alpha)P^{30}$ reaction.[3] The isobaric spin-selection rule only allows transitions to $T=0$ levels in this reaction.

Ground-state Q-value measurements of reactions

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† This work has been supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

[1] Endt, Kluyver, and van der Leun, Phys. Rev. **95**, 580 (1954).

[2] Broude, Green, Singh, and Willmott, Phys. Rev. **101**, 1052 (1956).

[3] L. L. Lee and F. P. Mooring, Phys. Rev. **104**, 1342 (1956).

leading to and from P^{30} also yield conflicting results. While the P^{30} mass found from the P^{30} beta decay[4] is in good agreement with an earlier less accurate determination from the $Si^{29}(p,\gamma)P^{30}$ reaction,[1] it is not in agreement with the values computed from the recently reported $Al^{27}(\alpha,n)P^{30}$ threshold[5] or from the $S^{32}(d,\alpha)P^{30}$ reaction energy.[3]

The reasons given above made it interesting to start a new investigation of the $S^{32}(d,\alpha)P^{30}$ reaction by high-resolution magnetic analysis. In addition to alpha particles, protons from the $S^{32}(d,p)S^{33}$ reaction were also observed in the deuteron bombardment of sulfur targets. With the latter reaction, the S^{33} level scheme as found earlier from the $Cl^{35}(d,\alpha)S^{33}$ reaction[6] could be checked; furthermore, this level scheme could be investigated to much higher excitation energy.

Finally, some weak proton groups were observed that were assigned to the $S^{34}(d,p)S^{35}$ reaction.

II. EXPERIMENTAL PROCEDURE

Deuterons accelerated with the MIT-ONR electrostatic generator[7] were used to bombard thin antimony sulfide targets obtained by evaporation onto Formvar films strengthened by a thin evaporated gold layer. The sulfur was of natural isotopic constitution. Energies of charged reaction products emitted from the target at angles of 50, 90, and 130 degrees to the deuteron beam were determined with a broad-range magnetic spectrograph.[8] Nuclear emulsions served for particle detection.

Two bombardments were performed at a deuteron energy of 6.542 Mev and at detection angles of 90 and 130 degrees. Both exposures were made at a spectrograph field setting so that the secondary particles, corresponding with an excitation energy up to 4.4 Mev in P^{30} and up to 6.9 Mev in S^{33}, were focused on the nuclear emulsions. Weak proton groups were observed in these exposures that might be attributed to the (d,p) reaction from one or both of the antimony isotopes. To diminish their intensity still more, six bombardments were performed at a lower deuteron energy ($E_d=6.006$ Mev) at detection angles of 50, 90, and 130 degrees. At this deuteron energy, two different spectrograph field settings were used so that the secondary particles, corresponding either with an excitation energy up to 4.6 Mev in P^{30} and up to 7.0 Mev in S^{33} or with an excitation energy up to 5.8 Mev in P^{30} and up to 8.0 Mev in S^{33}, were focused on the nuclear emulsions. At the last field setting of the spectrograph, only the four most energetic proton groups from the $S^{32}(d,p)S^{33}$ reaction were not recorded.

The bombardment at $E_d=6.542$ Mev, $\theta=90$ degrees, was on a rather thick target, yielding relatively poor resolution with alpha-particle groups of about 40-kev half-width. The resolution was not optimal in the bombardment at $E_d=6.006$ Mev, $\theta=50$ degrees, where the secondary particles had to penetrate the target backing, which probably was not of uniform thickness. The latter exposures were not used for (d,α) Q-value determinations. In all other exposures, the half-width of the alpha-particle groups was about 20 kev, while that of the proton groups did not exceed 9 kev.

The energy shift as a function of angle and of bombarding energy was used to distinguish S^{32} groups from S^{34} and contaminant groups.

The actual bombarding energy used in Q-value calculations was computed from observation of the deuteron group elastically scattered from S^{32}. In all cases, the bombarding energy thus found agreed within 3 kev with the value computed from the field setting of the 90-degree beam-deflecting magnet.

III. THE $S^{32}(d,\alpha)P^{30}$ REACTION

The alpha-particle spectrum obtained from the bombardment at $E_d=6.006$ Mev, $\theta=50$ degrees, is shown in Fig. 1. Thirty-one groups are assigned to the $S^{32}(d,\alpha)P^{30}$ reaction, while other groups result from C^{13} and O^{16} in the Formvar. The large width of group (22) and the high background between groups (26) and (27) are also ascribed to the $C^{13}(d,\alpha)B^{11}$ reaction. The low broad groups at $d=41.7$ and 31.4 cm were not identified. They do not appear in other exposures. No groups could be found from the $S^{34}(d,\alpha)P^{30}$ reaction.

The Q value of the $S^{32}(d,\alpha)P^{30}$ reaction is determined to be 4.887 ± 0.010 Mev. It can be used to compute the P^{30} mass excess. In Table I, the value thus obtained is compared with values of the P^{30} mass found by other authors[3–5,9] from several nuclear reactions. The masses taken for n, p, d, α, Al^{27}, Si^{29}, Si^{30}, and S^{32} are those adopted in the review article by Endt and Braams.[10] It is seen that the P^{30} mass, as determined from the present measurement, is in very good agreement with the values found from the $Si^{29}(p,\gamma)P^{30}$ and $P^{30}(\beta^+)Si^{30}$ reactions, while the $S^{32}(d,\alpha)P^{30}$ measurements given in

TABLE I. The P^{30} mass excess as computed from different nuclear reactions.

Reaction	Q-value (Mev)	P^{30} mass excess (Mev)	Reference
$Si^{29}(p,\gamma)P^{30}$	5.570 ± 0.030	-11.315 ± 0.030	9
$P^{30}(\beta^+)Si^{30}$	$4.26\ \pm0.04$	$-11.31\ \pm0.04$	4
$Al^{27}(\alpha,n)P^{30}$	-2.969	-11.011	5
$S^{32}(d,\alpha)P^{30}$	4.831 ± 0.013	-11.262 ± 0.013	3
$S^{32}(d,\alpha)P^{30}$	4.887 ± 0.010	-11.308 ± 0.010	Present measurement

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[4] D. Green and J. R. Richardson, Phys. Rev. **101**, 776 (1956).

[5] B. S. Burton and R. M. Williamson, Bull. Am. Phys. Soc. Ser. II, **1**, 264 (1956).

[6] Paris, Buechner, and Endt, Phys. Rev. **100**, 1317 (1955).

[7] Buechner, Sperduto, Browne, and Bockelman, Phys. Rev. **91**, 1502 (1953).

[8] Buechner, Mazari, and Sperduto, Phys. Rev. **101**, 188 (1956); C. P. Browne and W. W. Buechner, Rev. Sci. Instr. **27**, 899 (1956).

[9] C. van der Leun and P. M. Endt, Phys. Rev. **110**, 96 (1958), following paper.

[10] P. M. Endt and C. M. Braams, Revs. Modern Phys. **29**, 683 (1957).

reference 3 and those of the $Al^{27}(\alpha,n)P^{30}$ reaction give widely different results.

Excitation energies of P^{30} levels observed in the present investigation are given in Table II. All values are averages of at least two, but mostly four, separate determinations. No single measurement deviated by more than 4 kev from the average.

It is seen in Fig. 1 that levels (1) and (2) in P^{30} form a close doublet. The transition to level (1) is very weak. The intensity relative to the transition to level (2) is 0.15 at $E_d=6.0$ Mev, $\theta=50$ degrees (Fig. 1), while it is 0.08 at 6.0 Mev, $\theta=90$ degrees; 0.20 at 6.0 Mev, $\theta=130$ degrees; and only 0.02 at 6.5 Mev, $\theta=130$ degrees. Thus, level (1) should presumably be identified with the $J=0^+$, $T=1$, state found from the $Si^{29}(p,\gamma)P^{30}$ reaction.[1,2] That in the $S^{32}(d,\alpha)P^{30}$ reaction a transition to this level has been observed at all implies a breakdown of the isobaric spin-selection rule, which also has been found recently in other analogous cases.[11] Level (2), which presumably has $T=0$ character, is probably the level observed by Lee and Mooring[3] in their investigation of the $S^{32}(d,\alpha)P^{30}$ reaction at relatively low resolution. More evidence as to the doublet character of the first level in P^{30} is given in the following paper.

In P^{30} there must also exist $T=1$ states, corresponding to the known Si^{30} levels at 2.24, 3.51, and 3.79 Mev.[10] After correcting these values for the Coulomb energy and neutron-proton mass difference, the analogous states in P^{30} should be expected at 2.92, 4.19, and 4.47 Mev. They should probably be identified with levels (8), (14), and (19) at 2.937, 4.181, and 4.501, respectively. The violation of the isobaric spin-selection rule is more pronounced in these cases, the average intensities of the corresponding (d,α) groups being about 50% of that of neighboring groups corresponding to $T=0$ final states. Evidence for the $T=1$ character of levels (8) and (14) is also found from the $Si^{29}(p,\gamma)P^{30}$ reaction.[9]

The excitation energies of levels (2), (3), and (4), which were measured here as 0.708±0.008, 1.451 ±0.010, and 1.972±0.010 Mev, respectively, are in reasonable agreement with the values of 0.693, 1.440,

TABLE II. Excitation energies (in Mev) of P^{30} levels as observed from the $S^{32}(d,\alpha)P^{30}$ reaction.

(1)	0.680±0.010	(11)	3.836±0.010	(21)	4.734±0.010
(2)	0.708±0.008	(12)	3.926±0.010	(22)	4.929±0.010
(3)	1.451±0.010	(13)	4.141±0.010	(23)	5.024±0.010
(4)	1.972±0.010	(14)	4.181±0.010	(24)	5.200±0.010
(5)	2.538±0.010	(15)	4.230±0.010	(25)	(5.233±0.010)
(6)	2.723±0.010	(16)	4.296±0.010	(26)	5.412±0.010
(7)	2.839±0.010	(17)	4.342±0.010	(27)	5.504±0.010
(8)	2.937±0.010	(18)	4.421±0.010	(28)	5.598±0.110
(9)	3.018±0.010	(19)	4.501±0.010	(29)	5.700±0.010
(10)	3.734±0.010	(20)	4.625±0.010	(30)	5.790±0.010

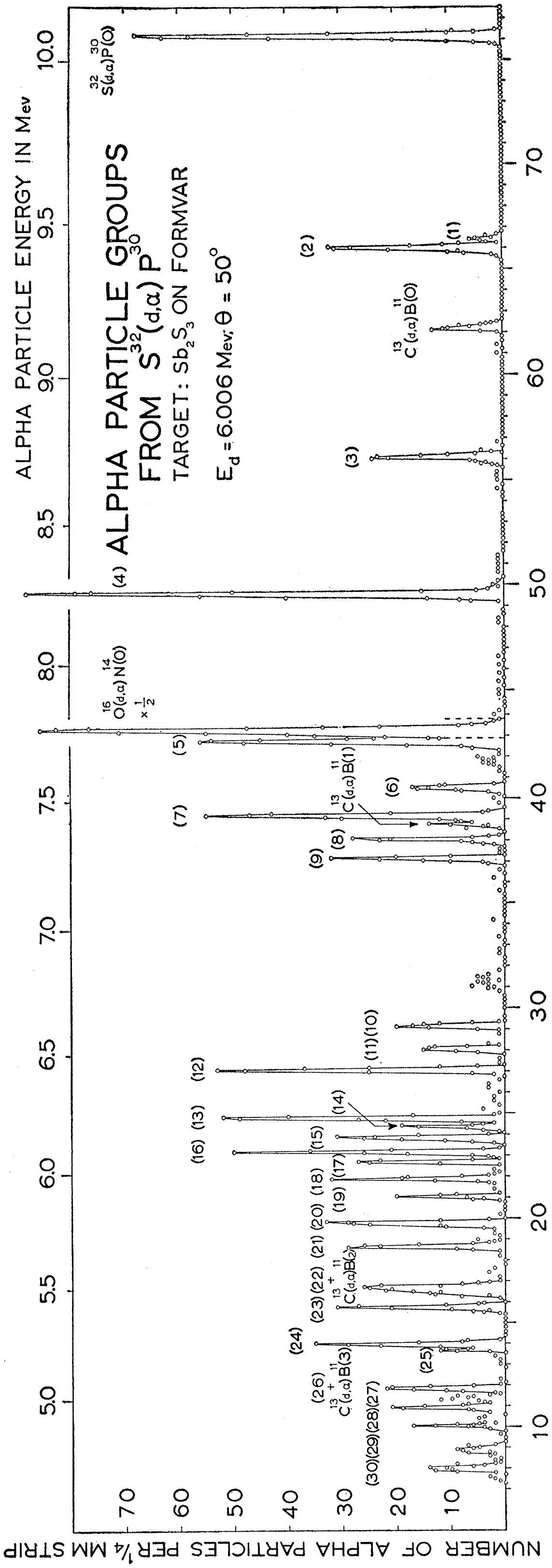

FIG. 1. Alpha-particle groups from the deuteron bombardment of a thin Sb_2S_3 target on Formvar backing at $E_d=6.006$ Mev, $\theta=50°$.

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[11] C. P. Browne, Phys. Rev. **104**, 1598 (1956); and Bull. Am. Phys. Soc. Ser. II, **1**, 212 (1956).

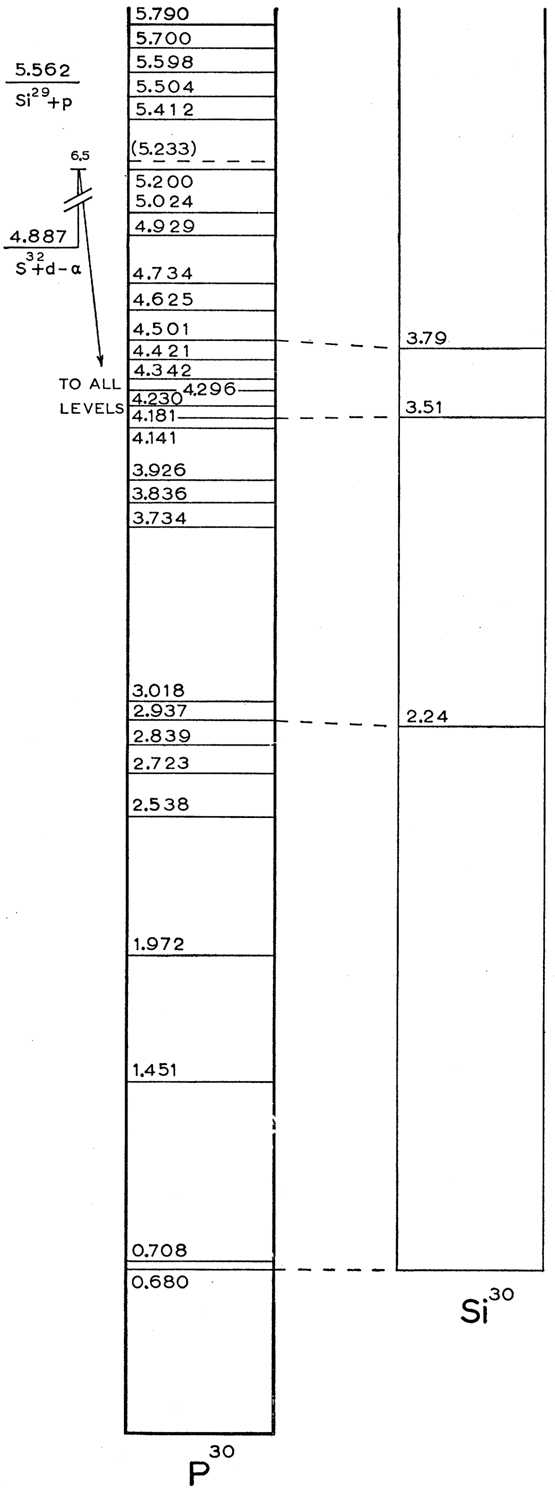

FIG. 2. Level scheme of P^{30}, in comparison with known level scheme of Si^{30}.

and 1.97 Mev found by Lee and Mooring.[3] A comparison with excitation energies obtained from the $Si^{29}(p,\gamma)P^{30}$ reaction will be given in the following paper.[9]

The P^{30} level scheme, as observed from the $S^{32}(d,\alpha)P^{30}$ reaction, is shown in Fig. 2. To compare the excitation energies of $T=1$ states, the level scheme of Si^{30}, as given in the review paper by Endt and Braams,[10] has also been drawn. The Si^{30} ground state has been aligned with the 0.680-Mev level in P^{30}.

IV. THE $S^{32}(d,p)S^{33}$ REACTION

The proton spectrum, as observed from the bombardment at $E_d=6.006$ Mev, $\theta=90$ degrees, is given in Fig. 3. It contains groups (4) through (104) resulting from the $S^{32}(d,p)S^{33}$ reaction. Groups (0), (1), (2), and (3) are shown in the insert of Fig. 3. This part of the spectrum was taken at a higher spectrograph field setting. Two intense groups, marked C^{13}, are attributed to the $C^{12}(d,p)C^{13}$ reaction, and two others, indicated as O^{17}, are attributed to the $O^{16}(d,p)O^{17}$ reaction. The weak groups marked S^{35}, which are ascribed to the $S^{34}(d,p)S^{35}$ reaction, will be dealt with in Sec. V. Some other quite weak groups, visible between the $S^{32}(d,p)S^{33}$ groups (1) and (2) in Fig. 3, probably result from the Sb(d,p) reaction, but it is impossible to say from which of the two stable antimony isotopes these groups originate.

Not all one hundred and five proton groups finally assigned to the $S^{32}(d,p)S^{33}$ reaction are evident in Fig. 3. Group (34) and groups (83) through (87) coincide with intense contaminant groups. These groups were observed in the exposures at $E_d=6.006$ Mev, $\theta=130$ degrees and $\theta=50$ degrees. Other groups, for example (47) and (48), (67) and (68), and some groups in the (70) to (82) region, are poorly resolved in Fig. 3. The most detailed information was obtained from the spectrum taken at $E_d=6.006$ Mev, $\theta=130$ degrees, where the resolution was still slightly better than in Fig. 3, although the exposure was shorter, making the statistics somewhat worse. In this spectrum, groups could be separated leading to S^{33} levels with only 5-kev difference in excitation energy. If it assumed, however, that levels are distributed at random, it must be expected that, even with this high resolution, an appreciable number of levels are missed because they are closer than 5 kev to other levels. It is estimated that, up to an excitation energy of 5 Mev, essentially all levels have been detected, while approximately one level might have been missed in the 5- to 6-Mev region, four levels in the 6- and 7-Mev region, and twelve levels in the 7- to 8-Mev region.

The ground-state Q value of the $S^{32}(d,p)S^{33}$ reaction is measured as 6.413 ± 0.006 Mev. Other measurements by magnetic analysis have yielded values of 6.422 ± 0.011 Mev[12] and 6.408 ± 0.020 Mev.[3] Another comparison value can be found by subtraction of the measured Q value of the $Cl^{35}(p,\alpha)S^{32}$ reaction from that of the $Cl^{35}(d,\alpha)S^{33}$ reaction. For the former

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[12] Strait, Van Patter, Buechner, and Sperduto, Phys. Rev. **81**, 747 (1951).

reaction, Q values are published of 1.865 ± 0.015 Mev,[13] 1.863 ± 0.008 Mev,[14] and 1.860 ± 0.005 Mev,[15] yielding an average value of 1.861 ± 0.004 Mev. The Q value given for the $Cl^{35}(d,\alpha)S^{33}$ reaction is 8.277 ± 0.010 Mev.[6] From these, the Q value of the $S^{32}(d,p)S^{33}$ reaction is computed as 6.416 ± 0.012 Mev, in very good agreement with the value measured here.

The excitation energies of S^{33} levels as found from the present measurements are given in Table III. They cover the region from the S^{33} ground state up to an excitation energy of 8 Mev. Originally it had been the intention to extend the measurements to the neutron binding energy at 8.646 Mev, but the high level density about 8 Mev made an exploration of this region impossible. Again, the values given in Table III are averages of from two to five separate determinations with no single measurement deviating by more than 5 kev from the mean.

No previous high-resolution investigation has been performed of the $S^{32}(d,p)S^{33}$ reaction. By absorption methods, Smith and Pollard[16] found S^{33} levels at 1.05, 2.17, 3.22, 4.33, and 5.32 Mev, while Davison[17] reported levels at 0.79, 1.90, 2.17, 2.85, 3.15, 3.88, 4.15, 4.42, 4.70, 5.11, 5.63, and 6.30 Mev, all ±0.05 Mev. The strongest proton groups observed by Holt and Marsham[18]

TABLE III. Excitation energies (in Mev) of S^{33} levels observed from the $S^{32}(d,p)S^{33}$ reaction.

(1)	0.839[a]	(27)	5.399	(53)	6.616	(79)	7.475
(2)	1.965	(28)	5.479	(54)	6.676	(80)	7.482
(3)	2.314	(29)	5.597	(55)	6.689	(81)	7.487
(4)	2.869	(30)	5.613	(56)	6.710	(82)	7.503
(5)	2.936	(31)	5.622	(57)	6.720	(83)	(7.560)
(6)	2.971	(32)	5.711	(58)	6.788	(84)	(7.579)
(7)	3.222	(33)	5.864	(59)	6.892	(85)	(7.589)
(8)	3.832	(34)	5.888	(60)	6.903	(86)	(7.595)
(9)	3.935	(35)	5.915	(61)	6.965	(87)	(7.601)
(10)	4.049	(36)	5.982	(62)	6.999	(88)	7.615
(11)	4.095	(37)	6.067	(63)	7.017	(89)	7.629
(12)	4.145	(38)	(6.079)	(64)	7.037	(90)	7.658
(13)	4.211	(39)	6.101	(65)	7.133	(91)	7.693
(14)	4.377	(40)	6.131	(66)	7.164	(92)	7.711
(15)	4.425	(41)	6.234	(67)	7.183	(93)	7.749
(16)	4.732	(42)	6.261	(68)	7.190	(94)	7.766
(17)	4.747	(43)	6.310	(69)	7.254	(95)	7.779
(18)	4.869	(44)	6.326	(70)	7.330	(96)	7.797
(19)	4.919	(45)	6.360	(71)	(7.335)	(97)	7.828
(20)	4.941	(46)	6.372	(72)	7.353	(98)	7.840
(21)	5.177	(47)	6.416	(73)	7.359	(99)	7.862
(22)	5.210	(48)	6.427	(74)	7.369	(100)	7.892
(23)	5.272	(49)	6.487	(75)	7.401	(101)	7.906
(24)	5.287	(50)	6.513	(76)	7.413	(102)	7.983
(25)	5.340	(51)	6.526	(77)	7.452	(103)	7.991
(26)	5.351	(52)	6.559	(78)	7.460	(104)	8.015

[a] The experimental error amounts to 6 kev for all levels, except for (1), to which was assigned an error of 5 kev.

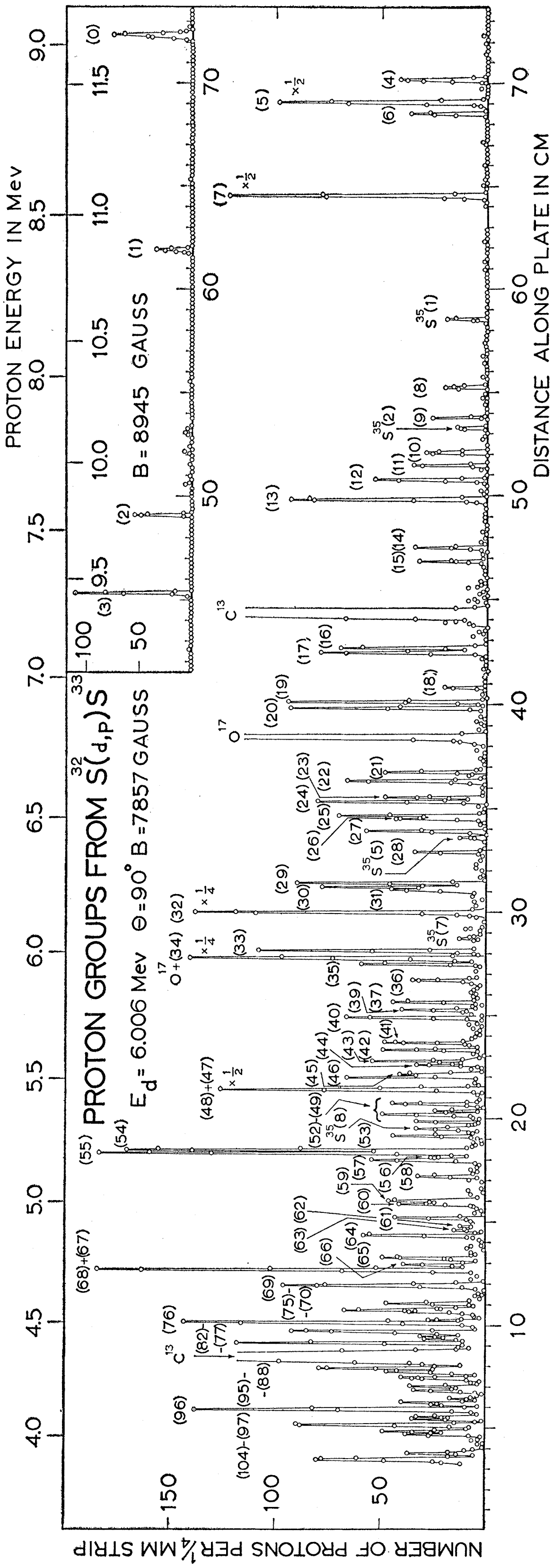

FIG. 3. Proton groups from the deuteron bombardment of a thin Sb_2S_3 target on Formvar backing at $E_d=6.006$ Mev, $\theta=90°$, and at two different spectrograph field settings.

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[13] Almqvist, Clarke, and Paul, Phys. Rev. **100**, 1265(A) (1955).

[14] Endt, Paris, Sperduto, and Buechner, Phys. Rev. **103**, 961 (1956).

[15] Van Patter, Porter, and Rothman, Phys. Rev. **106**, 1016 (1957).

[16] E. Smith and E. Pollard, Phys. Rev. **59**, 942(A) (1941).

[17] P. W. Davidson, Phys. Rev. **75**, 757 (1949).

[18] J. R. Holt and T. N. Marsham, Proc. Phys. Soc. (London) **A66**, 467 (1953).

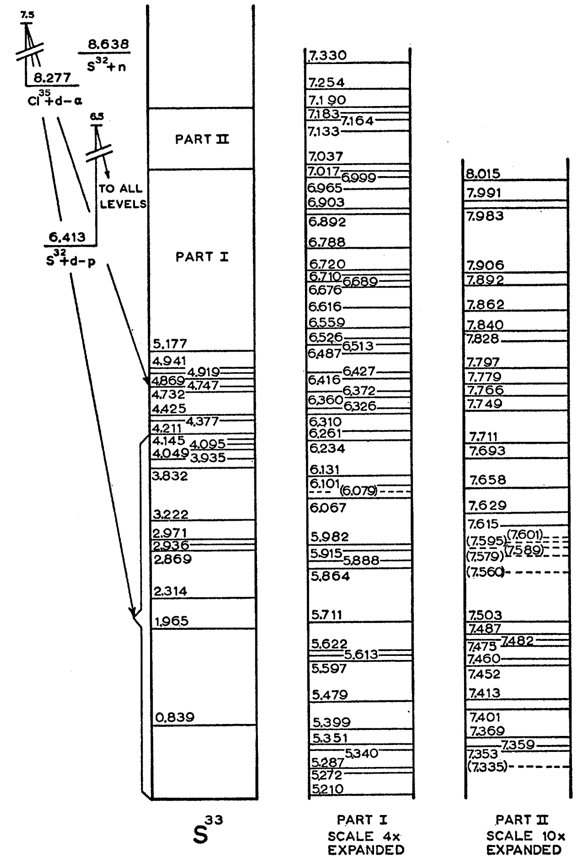

FIG. 4. Level scheme of S^{33}.

correspond to levels at 0.85, 2.90, 3.26, 4.21, 4.89, and 5.72 Mev.

A better comparison is possible with the levels found from magnetic analysis of the alpha-particle groups from the $Cl^{35}(d,\alpha)S^{33}$ reaction.[6] Levels were reported at 0.844±0.006; 1.966±0.007; 2.312; 2.869; 2.938; 2.969; 3.227; 3.365; all ±0.008; 3.840; 3.947; 4.060; 4.105; 4.159; 4.224; all ±0.009; and 4.749±0.010 Mev. On the whole, these values are in good agreement with the values given in Table III, although there seems to be some small systematic difference increasing with excitation energy to about 13 kev. The level found from the $Cl^{35}(d,\alpha)S^{33}$ reaction at 3.365 Mev has not been observed in the present investigation. After re-examination of the original $Cl(d,\alpha)$ data, it can now be stated with certainty that the corresponding weak alpha-particle group should have been assigned to the $Cl^{37}(d,\alpha)S^{35}$ reaction leading to a new S^{35} level at 2.955±0.010 Mev. The alpha-particle groups leading to the S^{33} levels (14) and (15) at 4.377 and 4.425 Mev have been missed in the $Cl(d,\alpha)$ investigation. These groups were weak and partly hidden by contaminant groups.

It is seen in Fig. 3 that the intensities of the $S^{32}(d,p)S^{33}$ proton groups differ widely. In general, the strongest groups [for example, (5), (7), (13), (32), (34), (48), (54), and (55)] are relatively most intense at $\theta=50$ degrees and weakest at $\theta=130$ degrees. It seems probable that these groups show relatively pronounced stripping angular distributions, indicating transitions to relatively pure S^{33} single-particle final states. It is interesting to compare the present results with the angular distribution measurements of Holt and Marsham.[8] They found an $l_n=3$ stripping pattern for groups (4), (5), and (6) (unresolved). Because (5) is so much more intense than (4) or (6), it can now be said that level (5) must be the $f_{7/2}$ state to be expected in this region. One of the other two levels must be the mirror state of the $\frac{3}{2}^+$ level observed in Cl^{33} at 2.861 ±0.011 Mev.[19]

For the extremely strong groups (7) and (32), Holt and Marsham found an $l_n=1$ stripping distribution. The p-state character of these levels is confirmed by consideration of the x-ray intensities observed in the $S^{32}(n,\gamma)S^{33}$ reaction.[20] At least 80% of all thermal neutron captures in S^{32} are followed by a gamma-ray transition to either (7) or (32) with an intensity ratio of about 1:3. These transitions have $E1$ character leading from the $\frac{1}{2}^+$ capturing state to $\frac{1}{2}^-$ or $\frac{3}{2}^-$ levels. It is tempting to identify levels (7) and (32) with the expected $p_{\frac{3}{2}}$ and $p_{\frac{1}{2}}$ single-particle states.

The character of level (13) is problematic. The (d,p) stripping distribution fits $l_n=1$,[18] but no gamma transition to this level is observed in the $S^{32}(n,\gamma)S^{33}$ reaction.

In Fig. 4, the S^{33} level scheme is shown, incorporating the data from the $S^{32}(d,p)S^{33}$ and $Cl^{35}(d,\alpha)S^{33}$ reactions.

V. THE $S^{34}(d,p)S^{35}$ REACTION

The Sb_2S_3 targets used in the present investigation were of natural isotopic constitution. The sulfur thus contained 4.2% of S^{34}. Since in (d,p) reactions the intensity ratio of strong-to-weak groups may be very high, it had to be expected that the stronger $S^{34}(d,p)S^{35}$

TABLE IV. Excitation energies (in Mev) of S^{35} levels as observed from different reactions.

Level	$S^{34}(d,p)S^{35}$ present work	$Cl^{37}(d,\alpha)S^{35}$ [a]
(1)	1.992±0.008	(1.992±0.010)
(2)	2.346±0.008	(2.348±0.010)
(3)	···	2.714±0.010
(4)	···	2.955±0.010[b]
(5)	3.803±0.010	···
(6)	···	(4.025±0.010)
(7)	4.192±0.010	
(8)	4.961±0.010	

[a] See reference 6.
[b] For this level, see Sec. IV of present paper.

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[19] C. van der Leun and P. M. Endt, Physica 22, 1234(L) (1956).

[20] Kinsey, Bartholomew, and Walker, Phys. Rev. 85, 1012 (1952); B. B. Kinsey and G. A. Bartholomew, Phys. Rev. 93, 1260 (1954); and Groshev, Adyasevich, and Demidov, *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1955* (United Nations, New York, 1956), Vol. 2, p. 39.

groups could compete in intensity with the weaker $S^{32}(d,p)S^{33}$ groups, especially at the smaller angles of observation. However, in order to distinguish the S^{33} and the S^{35} proton groups, a shift of angle of observation was used. For a change in the angle of observation from 50 to 130 degrees, the relative energy shift between $S^{32}(d,p)S^{33}$ and $S^{34}(d,p)S^{35}$ proton groups is, on the average, 37 kev.

A very weak group corresponding to the $S^{34}(d,p)S^{35}$ ground-state transition has been found in three different exposures. It is not seen in Fig. 3. The average Q value is 4.757 ± 0.010 Mev. This is in exact agreement with a value of 4.757 ± 0.013 Mev, which is computed from the known Q values of the $Cl^{37}(d,\alpha)S^{35}$ and $Cl^{37}(p,\alpha)S^{34}$ reactions.[6,13–15]

Relatively intense groups have been seen corresponding to the S^{35} levels given in Table IV. Groups (1) and (2) were found in three different exposures, while groups (5), (7), and (8) were seen in only two spectra. For comparison, the S^{35} levels found from the $Cl^{37}(d,\alpha)S^{35}$ reaction have also been given in Table IV.

From the combined $S^{34}(d,p)S^{35}$ and $Cl^{37}(d,\alpha)S^{35}$ reactions, the existence of levels (1) and (2) must be regarded as definitely established. The same holds for levels (3) and (4) if it is remembered that only intense $S^{34}(d,p)S^{35}$ groups are expected to show up in the present investigation. That level (5) has not been found from the $Cl^{37}(d,\alpha)S^{35}$ reaction is caused by the fact that, at different exposures, the corresponding alpha-particle group would have coincided with one or the other of two intense $Cl^{35}(d,\alpha)S^{33}$ groups. Levels (7) and (8) fell outside the range of the $Cl^{37}(d,\alpha)S^{35}$ investigation.

In Fig. 5 is presented the present information on S^{35} as obtained from the $S^{34}(d,p)S^{35}$ and $Cl^{37}(d,\alpha)S^{35}$ reactions. Although probably the most important S^{35} levels have now been found, enriched-target work is apparently necessary to investigate the S^{35} level scheme more nearly completely.

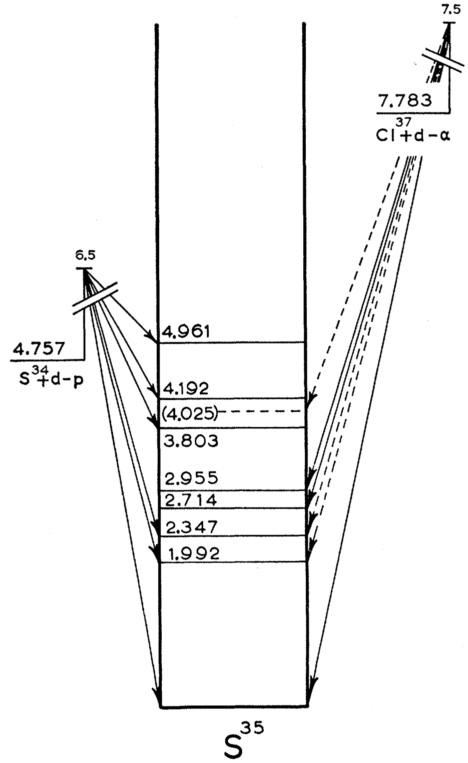

FIG. 5. Level scheme of S^{35}.

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