parameter ζ larger than 0.03 are required to fit the data at this energy. The effect of using values of ζ of 0.1 or 0.2 in calculating the curves of Fig. 2 is to smooth out the fluctuations and decrease the agreement between theory and experiment. A slightly better fit at 1.55 Mev might be obtained by using a value of ζ between 0.03 and 0.1. Such an energy dependence of the value of ζ necessary to fit the data has been suggested, and is indicated by several experiments.[9]

It has been suggested[4] that agreement between measured and predicted cross sections may be improved by using the formula $R^*=(1.26A^{\frac{1}{3}}+0.70)\times10^{-13}$ cm to determine nuclear radii. Values of R^* corresponding to the elements used in this experiment are listed in Table I. The effect of using R^* instead of R is to shift the points in Fig. 2 to smaller radius values as well as to raise them slightly. The shift is greatest for the heaviest elements. Although a slight change in this direction improves the agreement with theory for Pb, Bi, and Th, the effect of using R^* is to worsen the over-all agreement.

The present results for $\sigma(30°)$ at 1.00 Mev are about 12% larger on the average than the results of Walt and Barschall.[2] Since the uncertainty in the absolute cross sections is about 15% in both experiments, this difference is within the quoted errors.

The theoretical three-dimensional plot of $\sigma(\theta)$ at 1-Mev neutron energy shown in reference 1 indicates a sharp peak in $\sigma(0°)$ for atomic weights around 200, which corresponds to a value of R of about 8.5×10^{-13} cm. The failure of the curves in Fig. 2 for $E_n=1.00$ Mev to show this peak may be caused by the fact that values of orbital angular momentum only up to and including 5 units were considered in the present calculations.

TABLE I. Elements investigated and corresponding values of R and R^* in 10^{-13} cm. R is given by $1.45\ A^{\frac{1}{3}}\times10^{-13}$ cm and $R^*=(1.26\ A^{\frac{1}{3}}+0.70)\times10^{-13}$ cm.

Element	R	R^*	Element	R	R^*
Ti	5.26	5.28	Sn	7.12	6.90
Fe	5.53	5.52	Sb	7.18	6.94
Ni	5.63	5.60	Ce	7.53	7.24
Cu	5.79	5.73	Ta	8.20	7.83
Zn	5.84	5.78	Pb	8.57	8.15
Zr	6.52	6.37	Bi	8.60	8.18
Ag	6.90	6.70	Th	8.89	8.44
Cd	7.00	6.77			

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Energy Levels of S^{33}, S^{35}, Cl^{36}, Cl^{38}, and Ba^{139}†

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Barium-chloride targets have been bombarded with deuterons accelerated by an electrostatic generator to energies between 3.0 and 7.5 Mev. Charged reaction products have been observed with a high-resolution magnetic analyzer. The following ground-state Q-values have been measured: $Cl^{35}(d,\alpha)S^{33}$, 8.277±0.010 Mev; $Cl^{37}(d,\alpha)S^{35}$, 7.783±0.012 Mev; $Cl^{35}(d,p)Cl^{36}$, 6.354±0.008 Mev; and $Cl^{37}(d,p)Cl^{38}$, 3.881±0.008 Mev. Fifteen levels have been observed in S^{33}, four in S^{35}, twenty-three in Cl^{36}, and six in Cl^{38}. From the intensities of the observed proton groups and other considerations, a spin of $J=2^-$ can be assigned to the Cl^{38} ground state, and a spin of $J=5^-$ to the lowest (isomeric) level in Cl^{38} at 672±5 kev.

The $Ba^{138}(d,p)$ Ba^{139} ground-state Q-value is 2.493±0.010 Mev, and a level in Ba^{139} is observed at 623±8 kev.

I. INTRODUCTION

THIS work has been undertaken primarily to obtain accurate ground-state Q-values for the chlorine (d,α) and (d,p) reactions. Together with other nuclear reaction data, chiefly beta-decay energies, they establish mass links between many sulfur, chlorine, and argon isotopes, and S^{33}, the heaviest nucleus included in Li's mass survey.[1] The masses to be computed from them will be published in a separate paper, awaiting the measurement of the $K^{39}(p,\alpha)A^{36}$ ground-state Q-value, which is now being undertaken. This Q-value will establish a link with the masses of several potassium, calcium, and scandium isotopes.

In the course of this investigation, alpha-particle and proton groups have been observed corresponding

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[1] C. W. Li, Phys. Rev. 88, 1038 (1952).

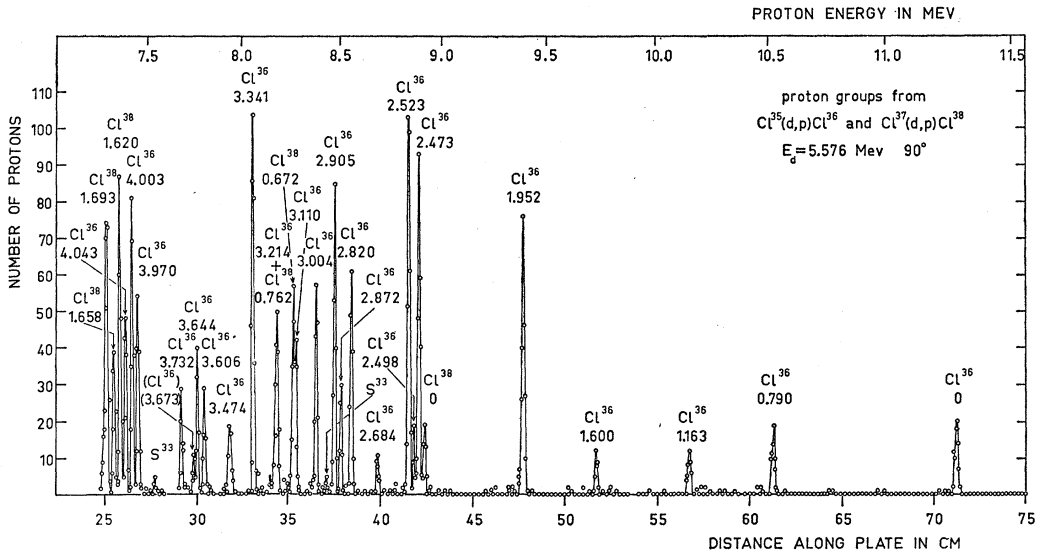

FIG. 1. Proton spectrum from a $BaCl_2$ target at 5.6-Mev deuteron bombarding energy. The final nucleus and its excitation energy have been indicated for each proton group.

to transitions to excited states in S^{33}, S^{35}, Cl^{36}, and Cl^{38}. Previous work on the energy levels of these nuclei has been reviewed by Endt and Kluyver.[2]

As a by-product, two proton groups were found which have been assigned to the $Ba^{138}(d,p)Ba^{139}$ reaction. Nothing is known on the level scheme of Ba^{139}. Kinsey and Bartholomew[3] observed a great number of gamma rays from thermal neutron capture in natural barium, but they could not establish their isotopic assignment.

II. APPARATUS AND EXPERIMENTAL PROCEDURE

The deuteron beam was obtained from the MIT-ONR electrostatic generator.[4] The broad-range spectrograph[5] was used for the magnetic analysis of charged reaction products emitted at an angle of 90 degrees with the deuteron beam.

Barium-chloride targets were prepared by evaporation onto formvar films strengthened by a thin evaporated gold layer. Both thin and relatively thick targets have been used, with thicknesses of about 80 and 300 $\mu g/cm^2$, respectively. The chlorine in the barium chloride was of natural isotopic composition; 75.4% Cl^{35}, and 24.6% Cl^{37}.

Bombardments were performed at deuteron energies of 3.0, 5.6, 6.0, 7.0, and 7.5 Mev and at exposures ranging from 500 to 3000 microcoulombs. Deuterons of 3.0 Mev were obtained by making use of the mass four molecular beam at 6.0 Mev. For proton detection, after magnetic analysis, 50-micron Eastman N. T. A. nuclear emulsions were used covered with aluminum foil of sufficient thickness to stop all alpha particles and all deuterons, scattered elastically or inelastically, from the target. Uncovered plates served for alpha-particle detection. They were also counted for protons; because, although the deuteron background on these plates was fairly intense, it was possible to discriminate between protons and deuterons from the difference in grain density of the tracks. An advantage of the presence of deuteron groups scattered elastically from Cl^{35} and Cl^{37} was the possibility of using them to determine the input deuteron energy, giving a valuable check on the deuteron energy computed from the field setting of the analyzing magnet used as an energy selector.

The assignment of observed particle groups to the responsible isotope is of special importance. It can be effected in several ways. Contaminants in the target backing can be sorted out by comparison of the spectra obtained from thin and thick targets. A critical test of the assignment of an observed particle group to a particular contaminant is the computation of its Q-value. The Q-values of most ordinary low-mass contaminants, such as C^{12}, C^{13}, N^{14}, O^{16}, Na^{23}, and Si^{28}, are now well known up to sufficiently high excitation energies. Also, S^{32} was present on or in the target. The ground-state Q-value of the $S^{32}(d,p)S^{33}$ reaction is accurately known,[6] and the Q-values corresponding to transitions to S^{33} excited states can now be computed from the excitation energies found in the present investigation of the $Cl^{35}(d,\alpha)S^{33}$ reaction.

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[3] B. B. Kinsey and G. A. Bartholomew, Can. J. Phys. **31**, 1051 (1953).
[4] Buechner, Sperduto, Browne, and Bockelman, Phys. Rev. **81**, 1502 (1953).
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[6] Strait, Van Patter, Buechner, and Sperduto, Phys. Rev. **81**, 747 (1951).

A third method for the identification of a contaminant group is to observe its energy shift caused by a change in bombarding energy. This method was used to distinguish between Cl^{35} and Cl^{37} groups. For a change in deuteron energy from 3.0 to 7.5 Mev, the relative energy shift between $Cl^{35}(d,p)Cl^{36}$ and $Cl^{37}(d,p)Cl^{38}$ proton groups is 19.7 kev. For alpha-particle groups from $Cl^{35}(d,\alpha)S^{33}$ and $Cl^{37}(d,\alpha)S^{35}$, it is 47.0 kev. For particle groups of reasonable intensity, this is quite sufficient for a correct assignment.

III. RESULTS

A typical proton spectrum at $E_d=5.6$ Mev is shown in Fig. 1. The number of protons, counted in 0.5-mm strips of the plate, is plotted as a function of the distance along the plate. The latter can be converted by means of polonium alpha calibrations into ρ, the radius of the proton orbit in the spectrograph, and is thus at a given field setting a measure of proton energy. The plate was also counted in the region from 3- to 25-cm plate distance, but in this region the spectrum is so complicated that many weaker groups are no longer resolved.

Actually, three plates each 25-cm long are used instead of one plate of 75 cm. Small parts of the spectrum on the edges of the plates cannot be counted. In the exposure for Fig. 1, a prominent group associated with the 1.312-Mev state in Cl^{38} fell in one of these gaps (from 28.2 and 29.0 cm). This group was observed at other field settings and other deuteron energies.

For each proton group the final nucleus and the excitation energy of the corresponding level have been indicated. All groups with a maximum intensity of more than 10 protons per 0.5-mm strip can be assigned to either $Cl^{35}(d,p)Cl^{36}$ or to $Cl^{37}(d,p)Cl^{38}$. Contaminant groups are very weak at $E_d=5.6$ Mev. Two groups (maximum intensity=5 protons per strip) are very probably due to $S^{32}(d,p)S^{33}$, and other groups of the same or lower intensity have also been assigned to contaminants, because they either disappear at other deuteron energies or show an energy shift different from that expected for the chlorine groups. Contaminant groups from light elements, for example C^{13}, Na^{23}, and Si^{28}, are relatively more intense at $E_d=3.0$ Mev, while at $E_d=7.5$ Mev there appears a more or less continuous proton background that may well be caused by (d,p) reactions from contaminants of higher atomic number. Because of this background, it is possible that some lower intensity groups, particularly from $Cl^{37}(d,p)Cl^{38}$, were not detected.

The $Cl^{37}(d,p)Cl^{38}$ ground-state group, at a plate distance $d=42.4$ cm, is well resolved from the $Cl^{35}(d,p)Cl^{36}$ triplet, a few millimeters more to the left. At $E_d=7.5$ Mev the separation is still larger, while at $E_d=3.0$ Mev this group almost coincides with the right-hand triplet member, being visible only as an irregularity on the high-energy slope of the latter.

TABLE I. Levels in Cl^{36} and Cl^{38}.

The $Cl^{35}(d,p)Cl^{36}$ reaction			The $Cl^{37}(d,p)Cl^{38}$ reaction		
Level	Q-value in Mev ±0.008	Cl^{36} level in Mev	Level	Q-value in Mev ±0.008	Cl^{38} level in Mev
(0)	6.354	0	(0)	3.877	0
(1)	5.564	0.790±0.005	(1)	3.205	0.672±0.005
(2)	5.191	1.163±0.006	(2)	3.115	0.762±0.005
(3)	4.754	1.600±0.007	(3)	2.565	1.312±0.006
(4)	4.402	1.952±0.007	(4)	2.257	1.620±0.007
(5)	3.881	2.473±0.007	(5)	2.219	1.658±0.007
(6)	3.856	2.498±0.007	(6)	2.184	1.693±0.007
(7)	3.831	2.523±0.007			
(8)	3.670	2.684±0.007			
(9)	3.534	2.820±0.007			
(10)	3.482	2.872±0.007			
(11)	3.449	2.905±0.007			
(12)	3.350	3.004±0.007			
(13)	3.244	3.110±0.008			
(14)	3.140	3.214±0.008			
(15)	3.013	3.341±0.008			
(16)	2.880	3.474±0.008			
(17)	2.748	3.606±0.008			
(18)	2.710	3.644±0.008			
(19)	(2.681)	(3.673±0.008)			
(20)	2.622	3.732±0.008			
(21)	2.384	3.970±0.008			
(22)	2.351	4.003±0.008			
(23)	2.311	4.043±0.008			

The proton group at $d=35.4$ cm is broader than others and shows a faint doublet structure. At $E_d=3.0$ Mev, the intensity in the valley between the two peaks comes down to one-third of the peak height, while at 7.5 Mev the two peaks have merged into one with the same width as other groups.

The proton group at $d=34.4$ cm, with the same width as other groups at $E_d=5.6$ Mev, has separated into two incompletely resolved groups at $E_d=7.0$ and 7.5 Mev, while no comparison is possible with the bombardment at $E_d=3.0$ Mev, since this region of the plate is blackened by deuterons scattered elastically from the gold target backing. No plates covered with aluminum foil had been exposed at $E_d=3.0$ Mev.

This discussion indicates that the assignment of proton groups to $Cl^{35}(d,p)$ or $Cl^{37}(d,p)$, respectively, can be regarded as unambiguous, although the relative energy shifts between these groups are certainly not very large. There is only one proton group, at $d=29.8$ cm, for which the assignment is dubious. It is weak at $E_d=7.5$ Mev and is covered by elastic deuterons at $E_d=3.0$ Mev.

In Table I the Q-values are given, computed for the $Cl^{35}(d,p)Cl^{36}$ and $Cl^{37}(d,p)Cl^{38}$ reactions, and the excitation energies of the corresponding Cl^{36} and Cl^{38} levels. The errors given are standard errors. To all Q-values an error has been assigned of 8 kev. Actually, the random part is dependent on the statistics of the corresponding proton group and on the number of times the group has been observed; while the estimated systematic part, mainly arising from uncertainties in the magnet calibrations, depends on deuteron and proton energy. The fluctuations of the individual errors, however, are so small as to warrant the assignment of a constant error.

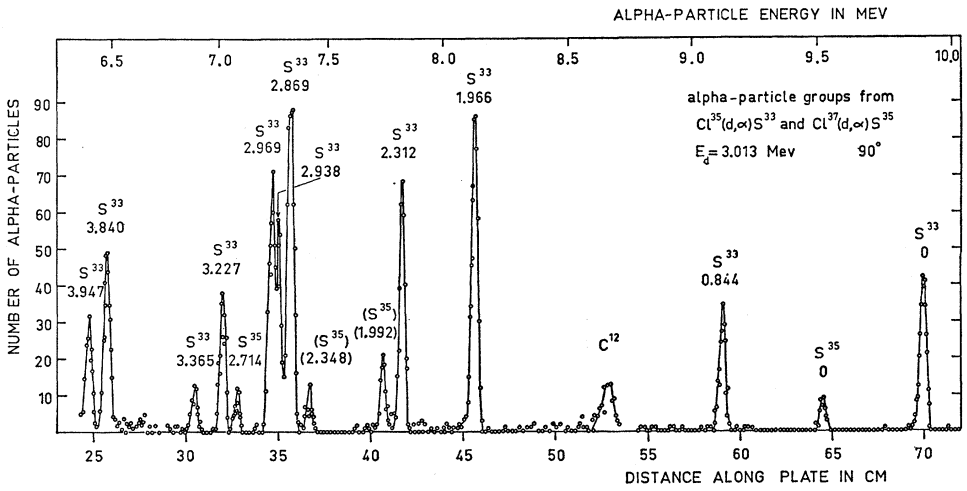

FIG. 2. Alpha-particle spectrum from a $BaCl_2$ target at $E_d=3.0$ Mev. The final nucleus and its excitation energy have been indicated for each alpha-particle group.

At $E_d=7.0$ and 7.5 Mev, two proton groups appeared surpassing in intensity all chlorine groups. They were also observed by Braams[7] from a BaO target at $E_d=6.5$ Mev. They have been assigned to the $Ba^{138}(d,p)Ba^{139}$ reaction, which also agrees with the observed energy shift. The abundance of Ba^{138} (71.7%) in natural barium is roughly six times larger than that of any of the other six stable barium isotopes. The Q-values computed for these groups were 2.493±0.010 Mev and 1.870±0.010 Mev, corresponding to transitions to the Ba^{139} ground state and to a level at 623±8 kev. At $E_d=7.0$ Mev and at $\theta=90$ degrees, the intensity of the excited-state group is about 1.5 times that of the ground-state group. The energies of eleven gamma rays from the capture of thermal neutrons in natural barium were measured by Kinsey and Bartholomew.[3] Their strong gamma rays, I and J, with intensities of 3 and 13 photons, respectively, per 100 captures, after subtraction of the deuteron binding energy of 2.23 Mev correspond to $Ba^{138}(d,p)Ba^{139}$ Q-values of 2.47±0.03 and 1.87±0.03 Mev, in excellent agreement with our values.

TABLE II. Levels in S^{33} and S^{35}.

The $Cl^{35}(d,\alpha)S^{33}$ reaction			The $Cl^{37}(d,\alpha)S^{35}$ reaction		
Level	Q-value in Mev ±0.010	S^{33} level in Mev	Level	Q-value in Mev ±0.012	S^{35} level in Mev
(0)	8.277	0	(0)	7.783	0
(1)	7.433	0.844±0.006	(1)	(5.791)	(1.992±0.010)
(2)	6.311	1.966±0.007	(2)	(5.435)	(2.348±0.010)
(3)	5.965	2.312±0.008	(3)	5.069	2.714±0.010
(4)	5.408	2.869±0.008	(4)	(3.758)	(4.025±0.010)
(5)	5.339	2.938±0.008			
(6)	5.308	2.969±0.008			
(7)	5.050	3.227±0.008			
(8)	4.912	3.365±0.008			
(9)	4.437	3.840±0.009			
(10)	4.330	3.947±0.009			
(11)	4.217	4.060±0.009			
(12)	4.172	4.105±0.009			
(13)	4.118	4.159±0.009			
(14)	4.053	4.224±0.009			
(15)	3.528	4.749±0.010			

The alpha-particle spectrum at $E_d=3.0$ Mev is shown in Fig. 2. The plate is blackened by elastic deuterons below $d=24$ cm. At $E_d=5.6$ and 7.5 Mev, six alpha-particle groups, not presented in Fig. 2, were found in this region of excitation. On the whole, the alpha-particle yield, averaged over all observed groups, decreases with increasing deuteron energy. At $E_d=5.6$ Mev, it is only 30% of that at $E_d=3.0$ Mev and at $E_d=7.5$ Mev, only 20%. This is perhaps caused by the fact that the intensity of a particular alpha-particle group is roughly inversely proportional to the number of decay channels of the compound nucleus, which increases steeply with the excitation energy of the latter. The groups seen in Fig. 2 at $d=40.6$ and 36.7 cm were so weak at higher deuteron energy that the energy shift could not be measured accurately enough to regard the isotopic assignment as unique. In view of the weakness of alpha-particle groups, especially from $Cl^{37}(d,\alpha)S^{35}$, it cannot be excluded that groups from this reaction have been missed.

Only one group was assigned to a contaminant: the broad group at $d=52.8$ cm, which must be due to the $N^{14}(d,\alpha)C^{12}$ reaction proceeding to the C^{12} level at 4.43 Mev. The group at $d=59.0$ cm appeared exceptionally broad when first counted. It proved to coincide with the triton group from the $C^{13}(d,t)C^{12}$ ground-state transition. At the same $H\rho$, triton tracks are only 10% shorter than those of alpha-particles, but the grain density is much smaller. By recounting with a 20× microscope objective, instead of the usual 10×, it was possible to discriminate between alphas and tritons.

In Table II, the Q-values are collected, computed for the $Cl^{35}(d,\alpha)S^{33}$ and $Cl^{37}(d,\alpha)S^{35}$ reactions, together with the excitation energies of the corresponding levels in S^{33} and S^{35}.

[7] C. M. Braams (unpublished).

TABLE III. Gamma rays from thermal neutron capture in chlorine.

Method:	Pair spectrometer[a]		Scintillation spectrometer[b]	Two-crystal scintillation spectrometer[c]		Two-crystal scintillation spectrometer[d]
Line	Energy in Mev	Intensity per 100 captures	Energy in Mev	Energy in Mev	Rel. Int.	Energy in Mev
A	8.56±0.03	3				
B	7.77±0.03	10	7.7 ±0.2			
C	7.42±0.03	8				
D	6.98±0.03	1				
E	6.62±0.06	4				
F	6.12±0.03	6	6.2 ±0.2			
G	5.72±0.03	2				
H	5.51±0.03	1				
I	5.01±0.03	4				
J	4.46±0.04	2		4.67±0.10		
K	4.06±0.04	3				
L	3.62±0.05	2		3.71±0.10	(23)	
				2.68±0.10	(10)	2.84
				2.40±0.10	(14)	2.45
			2.00 ±0.025	2.03±0.10		
			1.59 ±0.013	1.77±0.10	(19)	
			1.15 ±0.010	1.12±0.10	(29)	1.14
			0.784±0.010	0.70±0.10	(35)	0.75
						0.48

[a] See reference 10.
[b] See reference 11.
[c] See reference 12.
[d] See reference 13.

IV. DISCUSSION

$Cl^{35}(d,p)Cl^{36}$ and $Cl^{37}(d,p)Cl^{38}$

The only other data on the $Cl(d,p)$ reactions have been obtained with a cyclotron beam and proton energy measurement by aluminum absorption. Thus, Shrader and Pollard,[8] using enriched targets, measured Q-values of 6.31, 5.35, and 1.50 Mev for the $Cl^{35}(d,p)Cl^{36}$ reaction and 4.02, 3.02, and 2.10 Mev for the $Cl^{37}(d,p)Cl^{38}$ reaction. Only the Q-value of the $Cl^{35}(d,p)Cl^{36}$ ground-state transition is in reasonable agreement with our value. From natural chlorine targets at $E_d=3.5$ Mev, Ennis[9] observed ten proton groups with Q-values of 6.26, 3.94, 3.46, 3.03, 2.76, 2.40, 1.84, 1.18, 0.69, and 0.44 Mev. The ground-state Q-value again agrees with our value. The other proton groups have spacings of about 0.4 Mev, corresponding to the energy resolution to be obtained in range measurements. It is seen in Table I that the actual proton spectrum is far more complicated, as is to be expected for odd-odd final nuclei.

A better comparison of the Cl^{36} level scheme, as found from the present measurements, is possible with the energy determinations of gamma rays from thermal neutron capture in chlorine.[10–13] These are given in Table III. Coincidence measurements[14] have shown the existence of two-step cascades formed by the 7.77- and 0.784-Mev, 7.42- and 1.15-Mev, 6.98- and 1.59-Mev, and 6.62- and 2.00-Mev gamma rays. The gamma rays *A* through *I* found by Kinsey *et al.*[10] can be explained as direct transitions from the capturing state to levels in Cl^{36}, while most of the low-energy gamma rays observed correspond to transitions from various levels to the ground state. The 0.48-Mev gamma ray found by Braid[13] would fit, for example, approximately between levels (17) and (13), although there are also several other possibilities. A 0.735-Mev gamma ray,[14] in coincidence with the 7.77-Mev gamma ray, does not fit in the Cl^{36} level scheme found in the present investigation. This level scheme is presented in Fig. 3.

The first level in Cl^{38} at 672 kev can be identified with the isomeric state found by Scharff-Goldhaber and

TABLE IV. Gamma rays from thermal neutron capture in sulfur.[10]

γ ray	Energy in Mev	Intensity in photons per 100 captures
A	8.64±0.02	1.2
B	7.78±0.03	1.6
C	7.42±0.03	(0.7)
D	7.19±0.03	(0.5)
E	6.64±0.03	0.25
F	5.97±0.06	(1.0)
G	5.43±0.02	60
H	5.03±0.06	(5)
I	4.84±0.06	11
J	4.60±0.06	(5)
K	4.38±0.03	7
L	3.69±0.05	4
M	3.36±0.05	7
N	3.21±0.03	20
O	2.94±0.05	20

[8] E. F. Shrader and E. Pollard, Phys. Rev. **59**, 277 (1941).
[9] W. W. Ennis, Phys. Rev. **82**, 304 (1951).
[10] Kinsey, Bartholomew, and Walker, Phys. Rev. **85**, 1012 (1952); B. B. Kinsey and G. A. Bartholomew, Phys. Rev. **93**, 1260 (1954).
[11] B. Hamermesh and V. Hummel, Phys. Rev. **88**, 916 (1952).
[12] Reardon, Krone, and Stump, Phys. Rev. **91**, 334 (1953).
[13] T. H. Braid, Phys. Rev. **90**, 355 (1953).
[14] A. L. Recksiedler and B. Hamersmesh, Phys. Rev. **96**, 109 (1954).

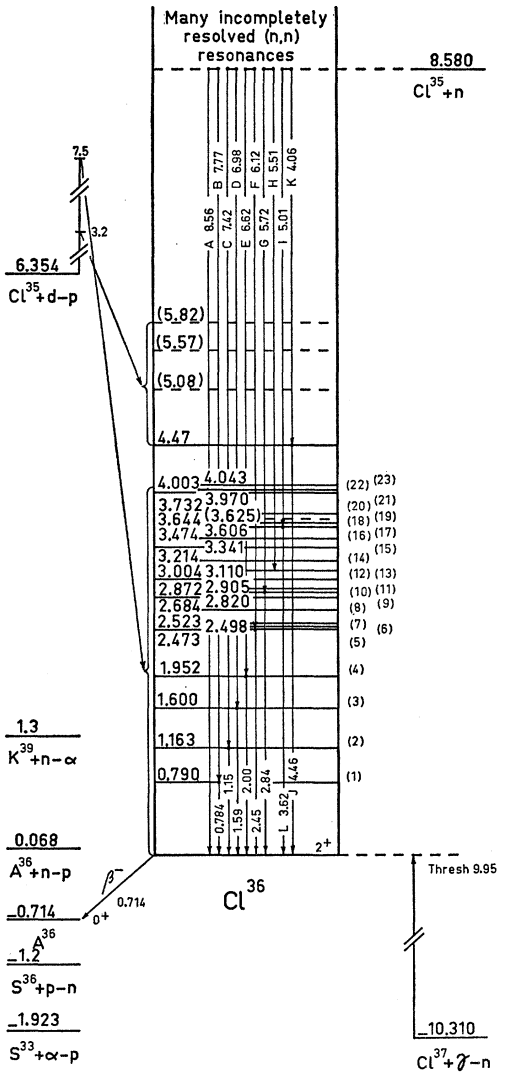

FIG. 3. Level scheme of Cl^{36}.

McKeown[15] at 660±20 kev with a half-life of 1.0±0.2 sec. The shell model predicts a $(d_{3/2},f_{7/2})$ configuration for the lower states of Cl^{38} with spin $J=2^-$, 3^-, 4^-, and 5^-. In K^{40}, where the situation is analogous, these states have been detected, and their spins could be determined as $J=4^-$, 3^-, 2^-, and 5^-, in order of increasing excitation energy.[2,16] The ground-state spin of Cl^{38} is very probably $J=2^-$ as follows from the $Cl^{38}(\beta^-)A^{38}$ decay.[2] The spin of the isomeric state must then be $J=5^-$, because a lower spin would result in a half-life much shorter than 1 second. The Weisskopf estimate yields 4×10^{-3} second for an $M3$ transition and 25 seconds for $E4$.

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The spin assignment given above is borne out by the present experiment. The $Cl^{37}(d,p)Cl^{38}$ transitions leading to the ground state and the first level should have the same stripping angular distribution determined by $l_n=3$. The corresponding proton groups measured at $\theta=90°$ should have the same intensity apart from a factor $(2J_f+1)$. These intensities should then have a ratio $5/11=0.45$. The experimental intensity ratio at $E_d=5.6$ Mev is 0.43 ± 0.04, in very good agreement with theory. It was not possible to apply the same method for the determination of the spin order of the $J=3^-$ and 4^- levels expected at higher excitation energy, because interference from neighboring $Cl^{35}(d,p)Cl^{36}$ proton groups excludes an accurate intensity comparison. The Cl^{38} level scheme is given in Fig. 4.

$Cl^{35}(d,\alpha)S^{33}$ and $Cl^{37}(d,\alpha)S^{35}$

The only earlier work on these reactions has been that of Shrader and Pollard.[8] They observed an alpha-particle group at $E_d=3.2$ Mev, and, from its range, they determined the Q-value as 9.1 Mev.

The levels in S^{33}, given in Table II, can be compared with those observed from the $S^{32}(d,p)S^{33}$ reaction by

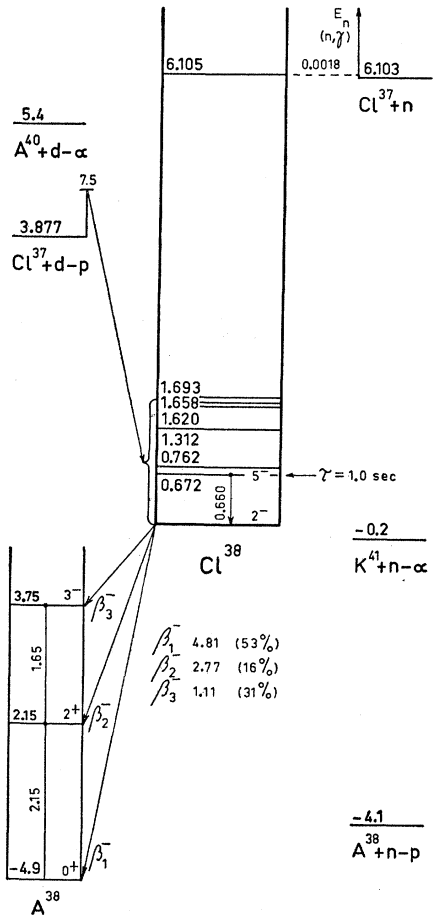

FIG. 4. Level scheme of Cl^{38}.

aluminum absorption methods. At $E_d=3.1$ Mev, Smith and Pollard[17] found levels at 1.05, 2.67, 3.32, 4.33, and 5.33 Mev; while at $E_d=3.2$ Mev, Davison[18] observed 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. Proton angular distributions were measured by Holt and Marsham[19] for transitions proceeding to levels at 0.85, 2.90, 3.26, 4.21, 4.89, and 5.72 Mev. Keeping in mind the lower energy resolution, it can be seen that these data agree well with those of Table II. The level at 4.42 Mev given by Davison was not observed in the present investigation. The same was stated explicitly by Holt and Marsham. They did observe the other groups given by Davison, although their intensity was too small for an angular distribution measurement.

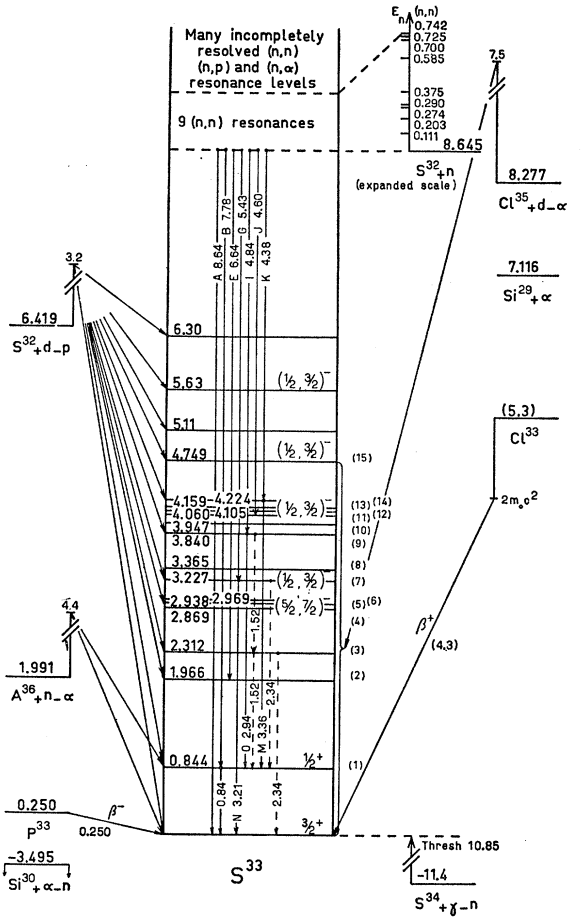

FIG. 5. Level scheme of S^{33}.

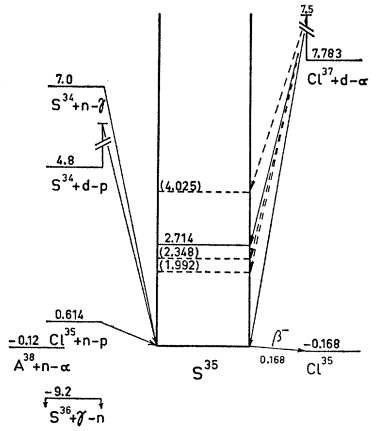

FIG. 6. Level scheme of S^{35}.

The gamma rays found by Kinsey *et al.*[10] from thermal neutron capture in natural sulfur are given in Table IV. Many of these gamma rays can be fitted into the level scheme determined from the present experiment. Gamma rays *A*, *B*, *E*, *G*, *I*, *J*, and *K* correspond to transitions from the capturing state to levels (0), (1), (2), (7), (9), (11), and (14), respectively. Gamma ray *N* de-excites level (7) to ground, but might also be partly responsible for the de-excitation of level (11) to (1). Gamma rays *M* and *O* probably de-excite levels (14) and (9), respectively, to level (1). They would also correspond to ground-state transitions from levels (8) to (5), but these levels are not excited from the capturing state. Gamma rays *C*, *D*, *F*, *H*, and *L* do not seem to fit into the present level scheme. At least, *C* and *D* probably result from capture in S^{33} or S^{34}. A unique assignment is not yet possible as the mass of S^{34} is still very poorly known.

Low-energy gamma rays of $E_\gamma=0.84$, 1.52, and 2.34 Mev have been observed by Braid.[13] The first corresponds to the de-excitation of level (1) to ground. The second can be a transition from level (3) to (1), or from (9) to (3), or both. The third is probably the transition from (7) to (1), but it might also de-excite level (3) to ground. The S^{33} and S^{35} level schemes are presented in Figs. 5 and 6.

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