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ALLOWED ELECTRON-CAPTURE BRANCHES IN THE DECAY OF ^{34m}Cl

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Abstract: The decay of ^{34m}Cl has been studied with 36 and 100 cm^3 Ge(Li) detectors and with a high-resolution large volume Ge(Li)-NaI(Tl) Compton-suppression spectrometer. The ^{34m}Cl activity was produced with the reaction ^{24}Mg(^{12}C, pn)^{34}Cl at $E(^{12}C) = 35$ MeV by bombarding thick natural Mg targets. The half-life was measured to be $\tau_{\frac{1}{2}} = 32.06 \pm 0.08$ min. Nine γ-ray transitions were observed including four γ-rays not seen previously. The measured γ-ray intensities determine new electron-capture branches of (0.030 ± 0.006) % and (0.032 ± 0.003) % to ^{34}S levels at 4.69 and 4.88 MeV with $\log ft$ values of 5.48 ± 0.08 and 5.26 ± 0.04, respectively. These $\log ft$ values imply allowed transitions and are consistent with the known J^π values of $J^\pi = 4^+$ and 3^+ of the 4.69 and 4.88 MeV levels, respectively. A lower limit of $\log ft > 6.9$ is obtained for the allowed electron-capture branch to the $J^\pi = 2^+$, 4.89 MeV level. Other previously observed decay branches have been confirmed. Since the decay of ^{34m}Cl proceeds (46.9 ± 1.0) % to the ^{34}Cl ground state, the latter decay was studied concurrently; ^{34}Cl(0) with $J^\pi = 0^+$, $T = 1$ decays exclusively to its analog ^{34}S(0) and the sum of the intensities of four other allowed branches is less than 1.2×10^{-4} of the intensity of the ground-state branch. The experimental results are compared with recent shell-model calculations performed in a large configuration space.

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RADIOACTIVITY ^{34m}Cl [from ^{24}Mg(^{12}C, pn)]; measured $T_{\frac{1}{2}}$, E_γ, I_γ; deduced decay scheme, β-branches, $\log ft$ values. ^{34}S levels deduced γ-branching ratios.

1. Introduction

Beta-decay studies in which reactions with a large cross section are combined with sensitive detection techniques can reveal weak β-ray branches not observed previously. These experimentally weak branches may well be of allowed character and thus correspond to large matrix elements, the determination of which offers useful constraints for the description of the low-lying states involved in β-decay.

The present study of the ^{24}Mg(^{12}C, pn)^{34m}Cl(β^+)^{34}S reaction with a large volume Ge(Li)-NaI(Tl) Compton-suppression spectrometer reports on two new allowed electron-capture branches, gives improved values for γ- and β-branching ratios and discriminates between two reported accurate half-life determinations, which differ from each other by more than six standard deviations.

Previous studies of the ^{34m}Cl decay are reported in refs. $^{1-4}$).

2. Experimental methods and results

The $^{34\mathrm{m}}$Cl activity with a half-life of about 32 min and a Q-value of 5637.2 ± 2.2 keV [ref. [5])] was produced by bombarding 0.2 mm thick natural Mg targets with 35 MeV, 0.9 μA (electrical) $^{12}C^{5+}$ ions from the Utrecht EN tandem accelerator. After bombardments of about 1 h, the targets were carried to a large volume Ge(Li)-NaI(Tl) Compton-suppression spectrometer in a low-background room.

The spectrometer consists of a 100 cm^3 Ge(Li) detector combined with a 23 cm × 28 cm NaI(Tl) crystal as shown in fig. 1. The source, at 9.5 cm distance from the Ge(Li) crystal, irradiates a volume of 18 cm^3. Pulses from the spectrometer were analyzed with an 8192 channel ADC coupled to a CDC 1700 computer.

The measurement of an activated target consisted of a run with the following cycle: wait 15 min, count 20 min, wait 2 min, count 20 min, wait 2 min, count 20 min. The three 8k spectra, generated in this way, made it possible to follow the time dependence of the intensity of the observed γ-rays. The count rate of the Ge(Li) detector of about 5 kHz at the beginning of the counting period was reduced to a rate of about 0.7 kHz at the computer by the vetos from the NaI crystal. The vetos were generated for pulses above a threshold of about 20 keV. A total of 18 runs was accumulated and for each run a fresh target was used to avoid the build-up of long-lived contaminants (e.g. ^{24}Na).

The grand sum of all spectra is shown in fig. 2. In addition to the γ-rays connected with the $^{34\mathrm{m}}$Cl decay, only four contaminant γ-rays are visible. The 59 and 68 keV lines are the K_α and K_β X-rays of W and originate from the tungsten collimator (see fig. 1), while the 1461 and 2615 keV γ-rays are background radiations of ^{40}K and ^{208}Tl, respectively.

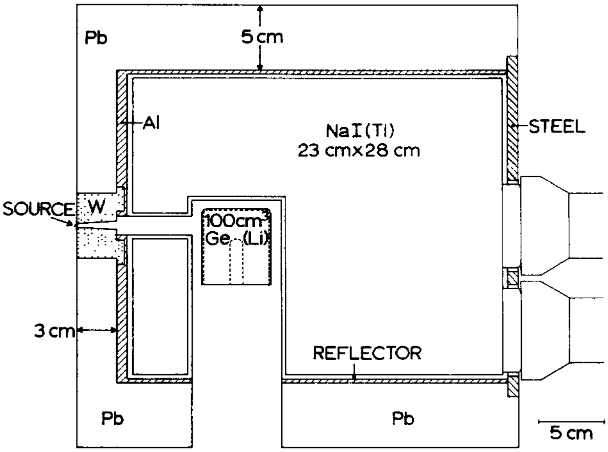

Fig. 1. Schematic cross-sectional view of the large-volume Ge(Li)-NaI(Tl) Compton-suppression spectrometer. The well in the NaI(Tl) crystal houses a 100 cm^3 Ge(Li) detector. The source is at a distance of 9.5 cm from the Ge(Li) crystal and irradiates a volume of 18 cm^3.

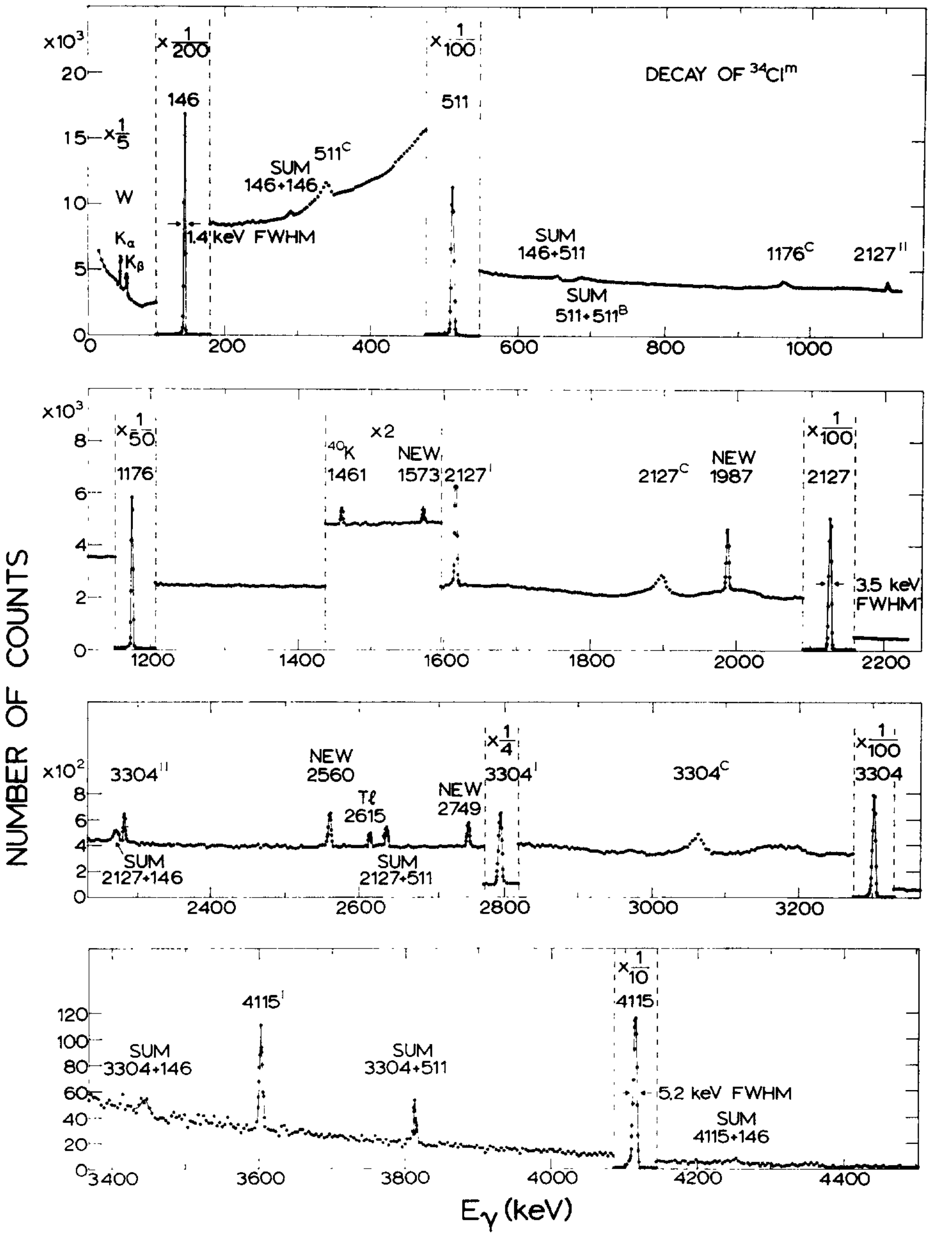

Fig. 2. Delayed γ-rays from the ^{24}Mg(^{12}C, pn)^{34m}Cl(β^+)^{34}S reaction observed with the experimental set-up shown in fig. 1. The spectrum is recorded with an 8192 channel ADC and has a dispersion of 0.731 keV/ch. Between peaks the average of five consecutive channels is plotted. The peaks are labeled with the corresponding γ-ray energies in keV; primes and double primes indicate single- and double-escape peaks, respectively. A superscript C denotes the Compton edge.

In the following, some of the features of this spectrum are discussed. The 2127 keV peak has an area of 2.66×10^6 counts. The number of counts in the 146, 511, 1176, 2127 and 3304 keV peaks amounts to 52 % of all counts in the 8k spectrum. Due to the relatively high count rate and the enhanced detection sensitivity a number of sum peaks are visible of which the 2127+146, 3304+146 and 4115+146 keV peaks are random sum peaks, since the γ-rays involved belong to different nuclei. Their widths are relatively large as can be seen clearly from the 2127+146 sum peak.

The structures labeled with a C at $511/(2+511/E_\gamma)$ keV below the corresponding full-energy peak of E_γ keV are the Compton edges which correspond to γ-rays scattered over 180° by the Ge(Li) crystal escaping through the 19 mm diameter entrance hole of the NaI crystal. The width and shape of the Compton peaks is determined by the dimensions of this hole (see fig. 1).

The peak labeled $511+511^{\mathrm{B}}$ is the sum of 511 keV and backscattered 511 keV radiation. The large number of positrons irradiating the W-collimator transform the latter into a strong source of 511 and 511^{B} keV γ-quanta. The difference in energy of the 511^{C} and $511+511^{\mathrm{B}}$ peaks with the annihilation peak is the same.

The wide bell-shaped structures visible, e.g., just below the 2127 and 3304 keV full-energy peaks are partly due to Compton-scattering from the W-collimator.

The full-energy, single-escape and double-escape peaks of the 2127 keV γ-ray have in this set-up relative areas of 100 : 0.79 : 0.05 compared to 100 : 7 : 6 for the 100 cm^3 Ge(Li) detector alone. The strong suppression of the double-escape peak is due to the absence of collinear holes in the NaI crystal.

Apart from the well-known [5]) γ-rays from the ^{34m}Cl decay with energies of 146, 1176, 2127, 3304 and 4115 keV, four new γ-rays are observed at 1573, 1987, 2560 and 2749 keV. Their recoil corrected energies are listed in table 1.

Since the data pertaining to fig. 2 are also available as three 8k spectra, the relative time dependence of the peaks could be investigated. The results are shown in fig. 3 where areas of peaks relative to the area of the 2127 keV peak are plotted as a function of time. The constancy of the measured ratios strongly supports the conclusion that all nine γ-rays arise from the ^{34m}Cl decay as was known previously for the five strongest γ-rays.

2.1. HALF-LIFE MEASUREMENT

In order to measure the half-life of ^{34m}Cl, thirteen consecutive γ-ray spectra were taken for recording times between 7 and 60 min over a 7.7 h period after the end of the bombardment. The source was placed at a distance of 7 cm from the 100 cm^3 Ge(Li) detector, shielded with 1.5 cm Pb. To minimize the necessary ADC dead-time corrections, a biased amplifier was used with the bias set to exclude pulses corresponding to energies $<$ 1100 keV. The actual correction was determined by recording a pulser peak simultaneously with the γ-ray spectra of interest. The pulser count rate was scaled separately.

The analysis proceeded in the following way. The area A_i of the 2127 keV peak

TABLE 1

Delayed γ-rays from the decay of $^{34\text{m}}$Cl

Energy a) (keV)	Assignment in ^{34}S a) ($E_i \rightarrow E_f$ in keV)	Relative γ-ray intensity c)
42	$4115 \rightarrow 4072$	< 0.6
146	^{34}Cl$(1 \rightarrow 0)$	1010 ± 40 d)
201	$4115 \rightarrow 3914$	< 0.10
610	$3914 \rightarrow 3304$	< 0.09
769	$4072 \rightarrow 3304$	< 0.10
811	$4115 \rightarrow 3304$	< 0.11
1155	$5227 \rightarrow 4072$	< 0.08
1176	$3304 \rightarrow 2127$	322 ± 10
1319	$4622 \rightarrow 3304$	< 0.15
1572.5 ± 0.7 b, e)	$4875 \rightarrow 3304$	0.26 ± 0.05
1588	$4891 \rightarrow 3304$	< 0.15
1787	$3914 \rightarrow 2127$	< 0.13
1945	$4072 \rightarrow 2127$	< 0.14
1987.2 ± 0.5 b)	$4115 \rightarrow 2127$	4.09 ± 0.11
2127	$2127 \rightarrow 0$	1000
2495	$4622 \rightarrow 2127$	< 0.07
2560.3 ± 0.6 b)	$4688 \rightarrow 2127$	0.72 ± 0.14
2748.8 ± 0.7 b, e)	$4875 \rightarrow 2127$	0.49 ± 0.05
3191	$5318 \rightarrow 2127$	< 0.09
3256	$5383 \rightarrow 2127$	< 0.09
3304	$3304 \rightarrow 0$	254 ± 8
4072	$4072 \rightarrow 0$	< 0.02
4115	$4115 \rightarrow 0$	5.2 ± 0.3
4875	$4875 \rightarrow 0$	< 0.008
4891	$4891 \rightarrow 0$	< 0.008
5383	$5383 \rightarrow 0$	< 0.008
$5400 < E_\gamma < 5700$		< 0.008

a) Energies taken from ref. 5) unless indicated otherwise.

b) Energy (including recoil) determined in the present work.

c) The upper limits are given at the 95 % confidence level.

d) $I_\gamma + I_e \equiv I_\gamma(1+\alpha_T) = I_\gamma(1.100 \pm 0.009) = 1111 \pm 45$.
The total conversion coefficient α_T is taken from ref. 5).

e) These energies lead to an excitation energy of $E_x = 4876.1 \pm 0.5$ keV.

in spectrum i taken between t_{1i} and t_{2i} can be written as

$$A_i = N \int_{t_{1i}}^{t_{2i}} \{1 - D(t)\} \frac{1}{\tau} \, \mathrm{e}^{-t/\tau} \, \mathrm{d}t, \tag{1}$$

where τ is the mean life wanted, N a constant related to the intensity at the end of bombardment and $D(t)$ the dead-time function. The average count rate in the 2127 keV peak in the first spectrum of 7 min duration was about 5200 counts/min. The error ΔA_i in A_i increased monotonically with i from about 0.5 % for the first few spectra to 5 % for the last but one, and 34 % for the last spectrum. From the results obtained with the pulser followed that in very good approximation $D(t)$

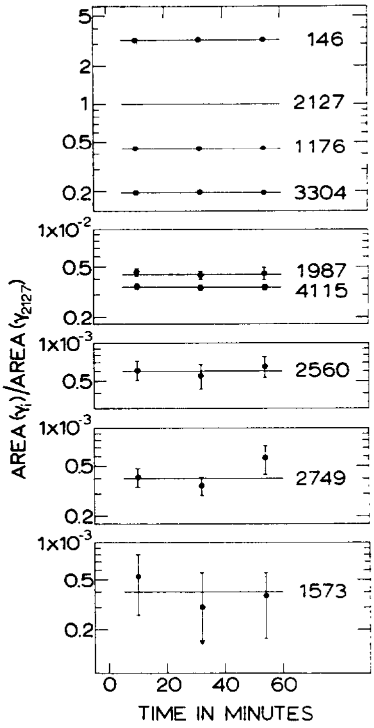

Fig. 3. Relative time dependence of the intensity of the nine γ-rays observed in the reaction ^{24}Mg(^{12}C, pn)^{34m}Cl(β^+)^{34}S.

could be written as

$$D(t) = D_0 e^{-t/\tau_D} + D_\infty, \tag{2}$$

with $D_0 = 0.080$, $D_\infty = 0.0038$ and $\tau_D = 49 \pm 4$ min. The latter value corresponds to a half-life of 34 ± 3 min. Minimizing the nonlinear least-squares expression

$$\sum_{i=1}^{13} (A_i - A_i^{\text{th}})^2 / (\Delta A_i)^2 \tag{3}$$

[where A_i^{th} denotes the right-hand side of eq. (1)], gives the best values for τ and N. For each trial value of τ the calculation of the corresponding value for N is straightforward since the expression for A_i [eq. (1)] is linear in the parameter N.

The result obtained from the 2127 keV peak is $\tau_{\frac{1}{2}} = 32.06 \pm 0.08$ min with a chi-squared value of $\chi^2 = 0.65$. The influence of the uncertainty in τ_D [see eq. (2)] is found to be negligible. The initial amplitude of $D(t)$ can be reduced by deleting the first few spectra, albeit at the cost of an increased error in the final result. Omission of the first five values of A_i, e.g., yields $D_0 = 0.026$ and $\tau_{\frac{1}{2}} = 32.12 \pm 0.13$ min, in good agreement with the value above. A systematic deletion of A_i values from the beginning or from the end did not show any systematic change of $\tau_{\frac{1}{2}}$. So the value

$\tau_{\frac{1}{2}} = 32.06 \pm 0.08$ min is adopted for the half-life of $^{34\text{m}}$Cl. This result agrees with the value of 31.99 ± 0.05 min given in ref. [6]) but is in outspoken disagreement with the older result of 32.40 ± 0.04 min in ref. [7]).

2.2. RELATIVE INTENSITIES

The relative intensities for the observed γ-rays are obtained in two steps. In the first step the intensities of the strong 146, 1176, 2127, 3304 and 4115 keV γ-rays are determined with 36 and 100 cm^3 Ge(Li) detectors. For that purpose a weaker source was produced and counted with the 100 cm^3 Ge(Li) detector at a distance of 8.3 cm. Efficiency calibration spectra were recorded in the same geometry and the relative full-energy peak efficiency curve was determined by means of γ-rays of known intensities from radioactive sources of ^{133}Ba [ref. [8])], ^{182}Ta[ref. [9])], ^{56}Co[ref. [10])] and ^{208}Tl[ref. [11])]. The self-absorption was negligible for the thin sources used. For this detector the efficiency curve bends over at about $E_\gamma = 125$ keV, due primarily to absorption in the 1.0 mm dead layer in front of the single open-ended Ge(Li) crystal.

The intensity ratio I_{146}/I_{2127} for the 146 and 2127 keV γ-rays was also determined with a 36 cm^3 true-coaxial Ge(Li) detector for which the bend in the efficiency curve occurs at about $E_\gamma = 85$ keV. The efficiency ratio $\varepsilon_{146}/\varepsilon_{2127}$ was written as $\varepsilon_{146}/\varepsilon_{2127} = (\varepsilon_{146}/\varepsilon_{1221})(\varepsilon_{1221}/\varepsilon_{2127})$, of which the first factor followed from the calibration measurement with the ^{182}Ta source, while the second factor is given by the measurement with the ^{56}Co source. Although the ratios of the areas of the 146 and 2127 keV peaks for the 36 and 100 cm^3 detectors differed by a factor of 2.2, the intensity ratios agreed within 3 % and lead to the adopted value of $I_{146}/I_{2127} = 1.01 \pm 0.04$. The relative γ-ray intensities of the 146, 1176, 2127, 3304 and 4115 keV transitions, determined in this way, are given in table 1.

In the second step the intensities of these γ-rays are used to construct an internal efficiency curve for the spectrum accumulated with the Compton-suppression spectrometer (see fig. 2). The resulting relative intensities for the weaker γ-rays are also listed in table 1. The upper limits given for unobserved peaks were taken as $4(N \times \text{FWHM})^{\frac{1}{2}}$, where N denotes the spectrum intensity in a particular region and values for the FWHM (full-width at half-maximum) were estimated from neighbouring peak widths. This particular limit corresponds to two standard deviations in a result not significantly different from zero.

It should be remarked that, due to the collimated irradiation from the side, the efficiency curve of the Compton-suppression spectrometer for the higher γ-ray energies is lifted with respect to the efficiency curve of the 100 cm^3 Ge(Li) detector alone, in which case the front is irradiated. For the 146, 1176 and 4115 keV peaks the area ratios $A_{146} : A_{1176} : A_{4115}$ amount to $100 : 13.8 : 0.11$ for collimated irradiation from the side and to $100 : 6.1 : 0.04$ for irradiation from the front.

A comparison of the present intensities with the results obtained in four previous studies is given in table 2. The present intensity of the 146 keV γ-ray agrees with the (less accurate) result of Konijn [2]) but differs by five standard deviations from the result of Ward and Kuroda [4]). For the 1176, 2127, 3304 and 4115 keV γ-rays the agreement with ref. [3]) is excellent.

TABLE 2

Comparison of relative intensities of γ-rays in the decay of ^{34m}Cl

E_γ (keV)	I_γ				
	[a])	[b])	[c])	[d])	[e])
146	101 ± 4	74 ± 4		104 ± 15	
640	< 0.012	< 0.3		< 0.3	< 0.5
770	< 0.010	< 0.3		< 0.3	< 0.5
1176	32.2 ± 1.0	29 ± 2	32 ± 2	30 ± 2	47 ± 8
1573	0.026 ± 0.005				
1987	0.409 ± 0.011				
2127	100	100	100	100	100
2560	0.072 ± 0.014				
2749	0.049 ± 0.005				
3304	25.4 ± 0.8	24 ± 3	26 ± 2	36.5 ± 3.0	34 ± 5
4115	0.52 ± 0.03	0.4 ± 0.2	0.54 ± 0.10	1.1 ± 0.5	1.2 ± 0.5

[a]) Present work. [b]) Ref. [4]). [c]) Ref. [3]). [d]) Ref. [2]). [e]) Ref. [1]).

2.3. ASSIGNMENTS OF THE NEW γ-RAYS

The assignments of the new γ-rays are, apart from the time behaviour of the intensities, shown in fig. 3, based on the arguments given below.

2.3.1. The 1573 and 2749 keV γ-rays. The energy (including recoil) of the 1573 keV γ-ray leads in combination with the excitation energy of the 3303.5±0.4 keV level [5]) to $E_x = 4876.0\pm0.8$ keV, while the 2749 keV γ-ray in combination with the 2127.4±0.2 keV level [5]) yields $E_x = 4876.2\pm0.7$ keV. The two values agree and combine to $E_x = 4876.1\pm0.5$ keV, to be compared with 4875.1±0.6 keV given in ref. [5]). The intensities from table 1 lead to branching ratios of (65±7)% and (35±7)% also in agreement with the known [5]) ratios of (64±3)% and (36±3)%, respectively.

2.3.2. The 1987 keV γ-ray. The γ-ray energy leads, together with the excitation energy of the 2127.4±0.2 keV level [5]) to $E_x = 4114.6\pm0.5$ keV in good agreement with $E_x = 4114.6\pm0.7$ keV listed in ref. [5]). The intensities from table 1 yield the branching ratios given in table 3. They agree with results listed in ref. [5]) but are more accurate. It should be noted that the existence of the 1987 keV transition is already implied by the spectroscopic information available in ref. [5]).

2.3.3. The 2560 keV γ-ray. The γ-ray energy combines with the excitation energy of the first excited state to $E_x = 4687.7\pm0.6$ keV in agreement with 4687.5±0.6 keV given in ref. [5]). The absence of other decay γ-rays is consistent with the 100 % decay of this level to the 2.13 MeV level given in ref. [5]).

2.4. BETA-DECAY BRANCHES

The assignments and intensities of the γ-rays from table 1 lead to the β-decay branches given in table 4.

TABLE 3

Gamma-ray branching ratios [a] of the 3.30 and 4.11 MeV ^{34}S levels (E_x in MeV)

To \ From	3.30	4.11
0	44.1±1.1	56±2
2.13	55.9±1.1	44±2
3.30		< 2
3.91		< 2 [b]
4.07		< 7 [c]

[a] The upper limits are given at the 95 % confidence level.

[b] An upper limit of 100 W.u. for this E2 transition [5] would correspond to a branching ratio of 0.003 %.

[c] An upper limit of 10 W.u. for this M1 transition [5] would correspond to a branching ratio of 0.002 %.

The Q-value for the decay of ^{34m}Cl with $J^\pi = 3^+, T = 0$ is 5637.2±2.2 keV [ref. [5]] and the values for $\log f$ and for the ratio of electron capture to β^+ decay are taken from the tables of Gove and Martin [12].

With the internal conversion process included, the partial decay of ^{34}Cl(1) to ^{34}Cl(0) amounts to (46.9±1.0)% corresponding to a width of $\Gamma_{\gamma+e} = 0.111\pm0.002$ aeV.

The newly observed γ-rays determine electron-capture branches of (0.030±0.006)% and (0.032±0.003)% to ^{34}S levels at 4.69 and 4.88 MeV with $\log ft$ values of 5.48±0.08 and 5.26±0.04, respectively. These $\log ft$ values imply allowed transitions and are consistent with the known spins of $J^\pi = 4^+$ and 3^+ of the 4.69 and 4.88 MeV

TABLE 4

^{34m}Cl(β^++EC)^{34}S: allowed and first-forbidden transitions

E_x(^{34}S) [a] (keV)	J^π [a]	$\frac{I(\text{EC})}{I(\beta^+)}$ [b]	$\log f$ [b]	Branch [c] (%)	$\log ft$ [d]
2127	2^+	0.0045	2.16	28.4±0.7	5.99±0.02
3304	2^+	0.032	0.96	24.3±0.7	4.86±0.02
4115	2^+	0.74	−0.54	0.392±0.015	5.15±0.02
4622	3^-	∞	−1.27	< 0.008	> 6.1
4688	4^+	∞	−1.33	0.030±0.006	5.48±0.08
4875	3^+	∞	−1.52	0.032±0.003	5.26±0.04
4891	2^+	∞	−1.53	< 0.0007	> 6.9
5318	2^-	∞	−2.28	< 0.004	> 5.4 [e]

[a] The excitation energies, J^π assignments and Q-value (5637.2±2.2 keV) are taken from ref. [5].

[b] Ref. [12].

[c] $I_\gamma(146)+I_e(146) = (46.9\pm1.0)$ %.

[d] *The half-life is taken as* $\tau_{\frac{1}{2}} = 32.06\pm0.08$ *min, see text.*

[e] A first-forbidden β-transition in a nucleus with $Z < 80$ should have a $\log ft$ value larger than 5.9, see ref. [13].

levels, respectively. The only other possible allowed branch, *viz.* to the $J^\pi = 2^+$, 4.89 MeV level, is not observed but a (rather high) lower limit of log *ft* > 6.9 is obtained.

The experimental results are summarized in fig. 4.

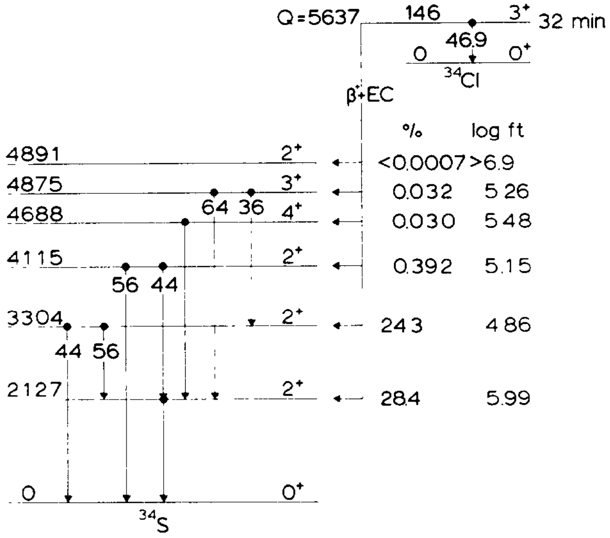

Fig. 4. Summary of the experimental results. Detailed information is found in tables 3 and 4.

Since the decay of ^{34m}Cl populates the ^{34}Cl ground state appreciably, its decay is studied concurrently. The $J^\pi = 0^+, T = 1$ ^{34}Cl ground state decays 100 % to the analog ^{34}S ground state and possible allowed branches to the 3.91, 4.07, 5.23 and 5.38 MeV levels with spins of $0^+, 1^+, 0^+$ and 1^+ are less than 0.006 %, 0.002 %, 0.003 % and 0.0009 %, respectively. The sum of the intensities of these four branches is thus less than 1.2×10^{-4} of the intensity of the ^{34}S ground-state branch.

The experimentally low upper limit of 0.006 % for the branch to the lowest excited $J^\pi = 0^+$ state corresponds only to log*ft* > 4.0, due to the relatively low β^+ endpoint energy of 555 keV. The expected intensity of a branch due to charge dependent effects would be a factor of about 100 lower than the present limit.

3. Comparison with shell-model calculations

Since the β-decay operators connect low-lying states in neighbouring isobaric nuclei, their matrix elements tend to be sensitive to aspects of the wave functions not tested in nucleon transfer or γ-decay data.

A comparison between present experimental results and theoretical calculations by Lanford and Wildenthal [14]) is given in table 5. The wave functions used were

TABLE 5

Comparison of experimental and calculated values for allowed branches in the β-decay of ^{34}Cl

Initial state	$E_x(^{34}S)$ (keV)	J^π	log *ft*	
			expt. [a]	calc. [b]
^{34m}Cl	2127	2^+	5.99 ± 0.02	5.88
	3304	2^+	4.86 ± 0.02	4.26
	4115	2^+	5.15 ± 0.02	8.14
	4688	4^+	5.48 ± 0.08	6.48
	4875	3^+	5.26 ± 0.04	4.93
	4891	2^+	> 6.9	
^{34}Cl(0)	0	0^+	3.48 ± 0.02	3.48
	4072	1^+	> 4.1	4.46

[a] Present work.

[b] Ref. [14]).

generated in the large $1d_{\frac{5}{2}}, 2s_{\frac{1}{2}}$ and $1d_{\frac{3}{2}}$ shell-model base with the configurations restricted to $(1d_{\frac{5}{2}})^{n_1}(2s_{\frac{1}{2}})^{n_2}(1d_{\frac{3}{2}})^{n_3}$ with $n_1 \geqq 10$. A mixture of free and modified surface δ-interaction matrix elements was employed.

As shown in table 5, the two worst discrepancies occur for the branches to the third $J^\pi = 2^+$ and the lowest $J^\pi = 4^+$ level, which intensities are calculated too low by factors of 1000 and 10, respectively.

The discrepancy for the third $J^\pi = 2^+$ level may reflect the general inadequacy of these calculations in providing a description for more than the lowest eigenvectors of an energy matrix only. The prediction of log *ft* = 4.93 for the electron-capture branch to the 4875 keV level is borne out quite well by the present experiment.

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