Half-lives of some $T = 1/2$ mirror decays*

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Precision measurements of the half-lives of the decay of some $T = \frac{1}{2}$ mirror nuclei have been determined. The results are ^{11}C (1222.9 ± 1.2 sec), ^{19}Ne (17.219 ± 0.017 sec), ^{21}Na (22.47 ± 0.03 sec), ^{23}Mg (11.327 ± 0.014 sec), ^{25}Al (7.174 ± 0.007 sec), ^{27}Si (4.109 ± 0.004 sec), and ^{29}P (4.083 ± 0.012 sec). In addition, the half-life of ^{26}Al^m, which proceeds by a pure Fermi decay, has been determined to be 6.346 ± 0.005 sec.

[RADIOACTIVITY ^{11}C, ^{19}Ne, ^{21}Na, ^{23}Mg, ^{25}Al, ^{26}Al^m, ^{27}Si, ^{29}P; measured $T_{1/2}$; calculated ft.]

I. INTRODUCTION

The decay of $T = \frac{1}{2}$ mirror nuclei is describable in terms of both Fermi and Gamow-Teller decays. While the vector coupling strength G_v is now believed to be constant[1] [conserved vector current (CVC) theory], the axial vector strength G_A undergoes renormalization in the presence of nuclear matter and may be A dependent.[2] If one assumes a knowledge of the Fermi coupling constant G_v, then in principle the G_A coupling strength should be obtainable from the β decay of mirror nuclei. Unfortunately, the problem is vastly complicated by the extreme sensitivity of the Gamow-Teller matrix element to the details of the wave functions of the states involved. One way around the problem, or at least to partially overcome it, is to make use of the close similarity of the magnetic moment and Gamow-Teller matrix elements. Thus magnetic moment measurements may be useful in the evaluation of the axial vector coupling constant.[3]

II. EXPERIMENTAL METHOD

Samples were prepared by irradiation in the internal beam of the McGill synchrocyclotron. The targets were encapsulated in thin-walled beryllium cylinders which contained less than 0.02% oxygen and were transported between the synchrocyclotron and the low background counting area some 15 m distant by a pneumatic system (transit time 2 sec).

β counting methods were employed to monitor the various nuclei under study. The detector was a NE101 plastic scintillator coupled to an RCA 6342A photomultiplier tube. The dynode system was selected to yield a minimum gain shift with count rate and was current-stabilized and temperature controlled.

The logic system is schematically outlined in Fig. 1 and is based on dead-time corrections being obtained from a constant rate pulser.[4] The essential features of the system are the pileup gate which has a known response to count rate and a crystal clock pulser unit which is used to monitor the dead time. The method employed has been analyzed and its accuracy reported elsewhere.[5] Data were taken as single samples in the multiscale mode with accumulation occurring in four groups of 1024 or 256 channels simultaneously. The bin width of each channel was always less than $\frac{1}{10}$ of the half-life under study. The accumulation process was initialized automatically at an integral count rate of 80 000 c.p.s. by a logic pulse from a rate meter.

A low level 100 MHz discriminator provides input to the pileup gate which in turn selects events for further processing only if they are uncontaminated by any other pulse falling within 600 nsec. This time interval both eliminates pileup and allows the dynode chain to completely recover from any previous pulse and hence eliminates gain shifts. A crystal clock pulser, held in coincidence

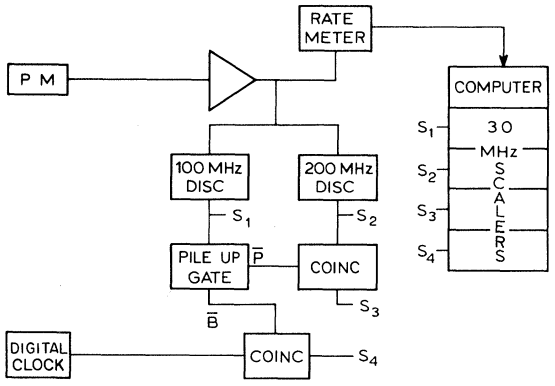

FIG. 1. Schematic outline of the circuit used in the accumulation of half-life data. The essential feature is the pileup gate which selects events for processing which are spaced at least 600 nsec from any other event.

with the busy signal from the pileup gate, provides data for the dead-time correction. A 200 MHz discriminator is positioned to view uncontaminated portions of the β spectrum. Data from the four outputs shown were accumulated in four dual 30 MHz scalers.

Each sample was recorded and corrected for counting losses and then subjected to analysis. The analysis was carried out using the method of maximum likelihood[6] based on both normal and Poisson distributions. Little differences in the choice of distribution was found except for data of poor statistical quality for which the Poisson distribution was found to be superior. The analysis technique could take account of several components.

III. RESULTS

Table I summarizes the present results.

$^{11}_{6}C_5$

The ^{11}C activity was produced by bombarding enriched ^{11}B with 13 MeV protons. A 10-min delay was followed by data accumulation. The data analysis revealed a weak 598 sec component which was traced to the $^{16}O(p, \alpha)^{17}N$ reaction arising from the 0.02% oxygen content of the beryllium encapsulation, as well as a very weak 45 min component associated with a target impurity. The average of seven runs is 1222.9 ± 1.2 sec. This result is in excellent agreement with the weighted average of several previous results.[14]

$^{19}_{10}Ne_9$

The $^{19}F(p, n)^{19}Ne$ reaction was employed at 13 MeV using spectroscopically pure LiF. A delay of 20 to 40 sec preceded data accumulation. In the analysis a weak 122 sec activity arising from the $^{19}F(p, \alpha n)^{15}O$ reaction was detected. A total of 19 runs were accumulated with thresholds varying from 0.8 to 2.0 MeV. The average of these was found to be 17.219 ± 0.017 sec.

$^{21}_{11}Na_{10}$

The ^{21}Na activity was produced by bombarding natural magnesium with 14 MeV protons to induce the $^{24}Mg(p, \alpha)^{21}Na$ reaction. The presence of small amounts of ^{25}Al (7.175 sec) and $^{26}Al^m$ (6.346 sec) dictated a 20 to 45 sec delay before the commencement of data accumulation. The analysis of several sets of data yielded a half-life for ^{21}Na of 22.47 ± 0.03 sec. This result is in agreement with the recent result of Wilkinson and Alburger.[8] The results were confirmed by use of an isotopically enriched ^{24}MgO target.

$^{23}_{12}Mg_{11}$

A target of enriched $Na^{35}Cl$ served in the production of ^{23}Mg through the reaction $^{23}Na(p, n)^{23}Mg$. A delay of 20 to 30 sec preceded data accumulation. In addition, spectroscopically pure $NaO_2C_2H_3$ was used as a target but gave rise to long-lived activities. The result of many runs using mainly the $Na^{35}Cl$ target gave rise to a half-life of 11.327 ± 0.014 sec, in good agreement with the 11.26 ± 0.08 sec result from γ-ray techniques previously reported.[10]

$^{25}_{13}Al_{12}$

The $^{25}Mg(p, n)^{25}Al$ reaction was carried out at 13 MeV. A series of 24 runs with varying thres-

TABLE I. Summary of the present experimental results.

Nucleus	$T_{1/2}$ (sec) Present work	Recent result	Previous value
$^{11}_{6}C_5$	1222.9 ± 1.2	1189 ± 45 [a]	1223 ± 4 [b]
$^{19}_{10}Ne_9$	17.219 ± 0.017	17.36 ± 0.06 [c]	17.40 ± 0.04 [d]
$^{21}_{11}Na_{10}$	22.47 ± 0.03	22.55 ± 0.10 [e]	22.8 ± 0.3 [f]
$^{23}_{12}Mg_{11}$	11.327 ± 0.014	11.26 ± 0.08 [g]	11.57 ± 0.13 [f]
$^{25}_{13}Al_{12}$	7.174 ± 0.007	7.177 ± 0.023 [h]	7.23 ± 0.02 [f]
$^{26}_{13}Al^m_{13}$	6.346 ± 0.005	6.351 ± 0.010 [i]	6.346 ± 0.005 [j]
$^{27}_{14}Si_{13}$	4.109 ± 0.004	4.17 ± 0.01 [k]	4.18 ± 0.02 [f]
$^{29}_{15}P_{14}$	4.083 ± 0.012	4.149 ± 0.005 [h]	4.21 ± 0.04 [f]

[a] Reference 7.
[b] Reference 14.
[c] Reference 8.
[d] Reference 16.
[e] Reference 9.
[f] Reference 15.
[g] Reference 10.
[h] Reference 11.
[i] Reference 12.
[j] Reference 17.
[k] Reference 13.

TABLE II. The present results are employed in the extraction of ft values for the various mirror decays.

	E_B^+ Max.[a] (keV)	$T_{1/2}$[b] (sec)	Branching ratio (%)	Electron capture (%)	T (sec)	f[c]	ft
$^{11}_{6}C_5$	960 ± 1.0	1222.9 ± 1.2			1222.9 ± 1.2	3.232 ± 0.015	3952.4 ± 18.7
$^{19}_{10}Ne_9$	2216.2 ± 0.4	17.219 ± 0.017			17.219 ± 0.010	99.56 ± 0.34	1714.3 ± 6.0
$^{21}_{12}Na_{11}$	2526 ± 9	22.47 ± 0.03	94.9 ± 0.2[d]	0.087	23.698 ± 0.060	173.0 ± 2.7	4099.7 ± 64.8
$^{23}_{12}Mg_{11}$	3034.6 ± 2.2	11.327 ± 0.014	91.3 ± 0.3[e]	0.035	12.411 ± 0.044	386.9 ± 1.9	4801.7 ± 29.0
$^{25}_{13}Al_{12}$	3257.2 ± 1.5	7.174 ± 0.007	99.14 ± 0.09[f]	0.084	7.242 ± 0.010	515.4 ± 1.1	3732.3 ± 9.5
$^{27}_{14}Si_{13}$	3787.6 ± 1.7	4.109 ± 0.004	99.82 ± 0.05[g]	0.074	4.119 ± 0.004	999.4 ± 2.0	4116.5 ± 9.2
$^{29}_{15}P_{14}$	3922 ± 8	4.083 ± 0.012	98.6 ± 0.4[f]	0.083	4.144 ± 0.021	1148.7 ± 11.0	4760.2 ± 51.6

[a] A. H. Wapstra and N. B. Gove, Nucl. Data A9, 267 (1971).
[b] Present result.
[c] Reference 19.
[d] Reference 9.
[e] Average of Refs. 9, 15, and 18.
[f] Reference 15.
[g] Reference 18.

holds gave rise to a half-life value of 7.174 ± 0.007 sec. This value has been corrected for $^{26}Al^m$ (6.346 sec) arising from the 0.4% ^{26}Mg contamination in the ^{25}Mg sample. This contaminant tends to shorten the observed half-life by 3 msec under the present conditions.

$^{26}_{13}Al^m_{13}$

Enriched ^{26}Mg was bombarded with 13 MeV protons to produce the $^{26}Al^m$ activity. The present result, based on 12 runs, yielded a half-life of 6.348 ± 0.004 sec. The 0.19% ^{25}Mg contaminant in the ^{26}Mg sample introduces a 2 msec adjustment and hence a final half-life value of 6.346 ± 0.005 sec is adopted.

$^{27}_{14}Si_{13}$

High purity aluminum (99.999%) was irradiated with protons of various energies (11–15 MeV) to produce the activity through the $^{27}Al(p, n)^{27}Si$ reaction. A result of 4.109 ± 0.004 sec was found, based on 14 runs with the discriminator set to minimize any small random sum effects which may occur. The present result differs greatly from previous values.

$^{29}_{15}P_{14}$

The ^{29}P activity was produced from the bombardment of 13 MeV protons on ^{29}Si. The 4.36% ^{28}Si and 0.36% ^{30}Si contaminants in the sample gave rise to 6.346 sec $^{26}Al^m$ activity and 149.8 sec ^{30}P activity. In addition, the $^{32}S(p, \alpha)$ reaction was employed to produce the ^{29}P activity. In this case a weak 12 sec component was observed. The present results are based on many runs and yield a half-life of 4.083 ± 0.012 sec, a result differing considerably from the 4.149 ± 0.005 sec value reported recently.[11]

IV. DISCUSSION

The present half-life results are combined with Q value and branching ratio data in order to extract ft values. These results are summarized in Table II.

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