α,n reaction) of Nb^{92}(10 day) and Nb^{92m} do not differ by more than a factor of 2, then the half-life of Nb^{92m} must be <1 h or >350 yr. The latter value is based on observation of the γ-ray spectrum for a period of 130 days.

An attempt was also made to produce Nb^{92m} by the reaction $Nb^{93}(\gamma,n)$, using the beam from a 22-MeV betatron. The only niobium activity detected in the irradiated sample was 10-day Nb^{92}. Silva *et al.*[38] have reported a similar result. The reported 5.9-μsec, 0.088-MeV level of Nb^{92},[39] which is excited in the reaction $Nb^{93}(\gamma,n)$ is probably a 2− state, resulting from the configuration $(p_{1/2}d_{5/2})$.[40]

[38] E. Silva, J. Goldemberg, P. B. Smith, and L. Marquez, Nuovo cimento **9**, 17 (1958).
[39] R. B. Duffield and S. H. Vegors, Jr., Phys. Rev. **112**, 1958 (1958).
[40] *Note added in proof*. The reported 13-h niobium activity has recently been shown to result from an impurity (communication from E. T. Bramlitt and R. W. Fink to the Nuclear Data Group; reported in *Nuclear Data Pink Sheet* No. 3, February, 1962).

It is quite possible that the expected low-lying high-spin isomer, with configuration $(g_{9/2}d_{5/2})_{6+,7+}$, is the ground state of Nb^{92}, analogous to the case of Nb^{94}, which has a 6+ ground state. If this were the situation, the dominant decay mode would be an electron-capture transition to the 1.492-MeV (4+) level of Zr^{92}. This second-forbidden transition would be expected to have a half-life of $\geq 5\times10^5$ yr.

VI. ACKNOWLEDGMENTS

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Decay of Sr^{85}†

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A gamma ray of 0.878 MeV was found in the decay of Sr^{85} in addition to the well-known 0.514-MeV gamma ray. The half-lives of both gamma rays were measured. The half-life of the 0.878-MeV gamma ray was found to be 64.9±1.99 days and the half-life of the 0.514-MeV gamma ray was found to be 63.9±0.27 days. There is good evidence of a gamma ray of 0.356±0.015 MeV in coincidence with the 0.514-MeV gamma ray. The 0.878-MeV gamma ray has also been found to be in coincidence with the characteristic x ray of Rb due to orbital electron capture. The relative intensities of the 0.878-, 0.356-, and 0.514-MeV gamma rays are about 1.07×10^{-4}, 0.2×10^{-4}, and 1.0, respectively. A decay scheme is proposed on the basis of these results.

INTRODUCTION

THE ground state of Sr^{85} decays to Rb^{85} by orbital electron capture usually followed by emission of a 0.514-MeV gamma ray.[1,2] The detection of any weak gamma ray of energy lower than 0.514 MeV is very difficult because of the predominance of the 0.514-MeV gamma ray. It is also difficult to discern weak gamma rays of energy less than 1.02 MeV in Sr^{85}. The use of a strong source to look for such gamma rays results in a "pile up" phenomenon; two 0.514-MeV gamma rays strike the detector simultaneously and appear as a 1.02-MeV gamma ray in a spectrometer. This effect is proportional to the square of the source strength.

† This work was supported by the U. S. Atomic Energy Commission.
[1] W. S. Emmerich and J. D. Kurbatov, Phys. Rev. **85**, 148 (1952).
[2] A. W. Sunyar, J. W. Mihelich, G. Scharff-Goldhaber, and M. Goldhabe, Phys. Rev. **86**, 1023 (1952).

The investigation of a 1-mC sample of Sr^{85} indicated[3] possible gamma radiation above the known 0.514-MeV gamma ray but because of the pile-up phenomenon it was difficult to discern the intensity or the energy of this radiation. Moving the source from the detector definitely indicated pile up, as the intensity of the 1.02-MeV photopeak decreased as the inverse fourth power of the distance from the source to the detector. A gamma ray of 0.878 MeV appeared as the source was moved further back from the detector. Its intensity fell off only as the square of the distance from the source to the detector. When an appropriate quantity of lead absorber was placed between the source and the detector, the 1.02-MeV "pile-up photopeak" could be caused to disappear and again a 0.878±0.012-MeV gamma ray did appear.

[3] All Strontium samples used in this investigation were purchased from the Oak Ridge National Laboratory.

The intensity of pile-up due to a high flux of monoenergetic gamma rays passing through lead diminishes as $e^{-2\sigma(E)\rho l}$ whereas the gamma-ray intensity decreases as $e^{-\sigma(E)\rho l}$ as it passes through lead. As the absorption cross section for lead is about 0.15 cm^2/g for 0.514-MeV gamma rays and is only about 0.08 cm^2/g for 0.878-MeV gamma rays, it is possible, by inserting a thick absorber between source and detector, to use a relatively strong source fairly close to the detector without an appreciable appearance of pile up.

The half-life measurements were made using 2.86 cm of lead placed between source and detector. This amount of lead will increase the relative intensity of the weak 0.878-MeV gamma ray compared with the 0.514-MeV gamma ray by a factor of 10.5. More important, however, is the fact that the relative intensity of the pile-up phenomenon compared to the 0.878-MeV gamma ray is decreased by a factor of one thousand because of the lead. No pile up was detected with the 2.86 cm of lead. Even though the use of lead allowed the source to be placed close to the detector counting times from 2 to 16 h were necessary for half-life measurements.

To determine further whether the 0.878-MeV gamma radiation was due to the decay of Sr^{85} coincidence measurements were made in order to determine what gamma rays, if any, were in coincidence with the Rb x-ray due to electron capture, the 0.514-MeV gamma ray, and a 0.150-MeV gamma ray which is present in the decay of Sr^{85m},[2,4] and might have been present in a very small amount in Sr^{85} and detectable in coincidence measurements.

In the course of the investigation the energy of the predominant gamma radiation of Sr^{85} was found to be 0.514±0.004 MeV. This agrees with other reported results.[1,2]

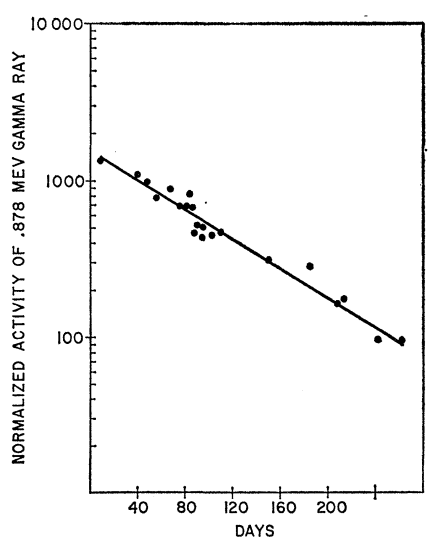

FIG. 1. Half-life measurement of the 0.878-MeV gamma-ray activity of Sr^{85}.

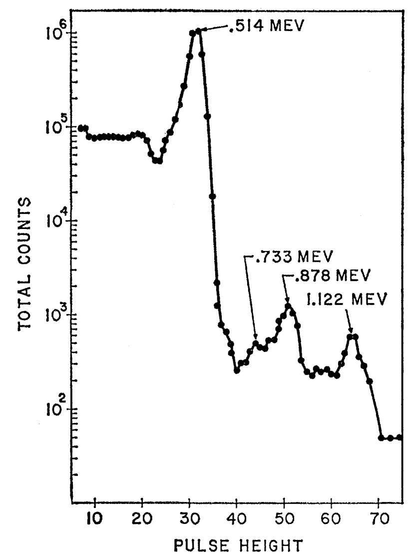

FIG. 2. Gamma-ray spectrum of Sr^{85} taken in the course of half-life measurements (2.8 cm of lead inserted between the source and the detector).

DECAY OF Sr^{85}

The gamma rays and x-rays were measured with scintillation detectors. A Harshaw Chemical Company integral line assembly containing a 3-in. diam×3-in. thickness NaI crystal mounted on a 6369 photomultiplier tube and another NaI crystal, 3-in. diam×3-in. thickness, mounted on a 6369 photomultiplier tube were used in the investigation for the detection of gamma rays. The detection of x rays and the coincidence gating in the 0.150-MeV range were made with a Harshaw integral line assembly with a NaI crystal $1\frac{1}{2}$-in. diam ×$\frac{1}{4}$-in. thickness.

A Radiation Counter Laboratories 128-channel analyzer was used for gamma-ray spectroscopy. An Atomic Instrument Company 20-channel analyzer gated by a fast slow coincidence circuit was used for coincidence measurements. Resolving times 2τ were around 0.5×10^{-6} sec.

The half-life measurements of Sr^{85} were followed for 255 days. If the 0.878-MeV gamma-ray activity were due to a pile-up phenomenon in spite of the absorber placed between the source and the detector, it would have decayed much more rapidly than the 0.514-MeV gamma ray. Instead this activity of 0.878-MeV decayed with a half-life of 64.9±1.99 days (Fig. 1 and 2) while the predominant gamma-ray activity of 0.514-MeV decayed with a half-life of 63.9±0.27 days, in good agreement with other reported values.[4,5]

The Sr^{85} sample was produced at the Oak Ridge National Laboratory by bombarding Sr^{84}, enriched to 46.1%, with neutrons. Less than 0.5% of the activity of the enriched source was due to Sr^{89} produced from

[4] D. Strominger, J. M. Hollander and G. T. Seaborg, Revs. Modern Phys. **30**, 585 (1958).

[5] K. Way, *Nuclear Data Sheets,* National Academy of Sciences, National Research Council (U. S. Government Printing Office, Washington, D. C.).

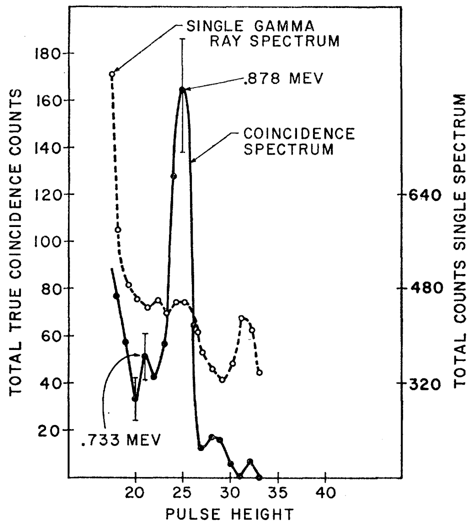

FIG. 3. Gamma-ray spectrum in coincidence with the Rb x-ray characteristic of electron capture.

the 31.8% Sr^{88} remaining in the sample.[6] A comparison of the Sr^{85} source was made with a Sr^{89} source of equal strength. The 0.878-MeV gamma-ray activity in Sr^{85} was at least 200 times too strong to be attribuetd to the Sr^{89} impurity in the Sr^{85} sample.[4,5,7]

Bombarding Sr^{84} with neutrons may produce a minute amount of Rb^{84} from the (n,p) reaction. Rb^{84} is a positron emitter with a half-life of about 33 days.[4] While Rb^{84} emits an 0.890-MeV gamma ray, no appreciable 33-day activity characteristic of this isotope was found in the decay of the 0.878-MeV gamma-ray activity. Since there was a delay of about 5 months from the time the sample was prepared to the commencement of the half-life measurements, any Rb^{84} present initially as a small impurity might have decayed sufficiently in that time to escape detection in a sample of Sr^{85} whose half-life is 63.9 days.

Measurements were made in order to ascertain if the gamma ray of 0.878 MeV was in coincidence with the Rb x-ray characteristic of electron caputre (Fig. 3). In this measurement 1.91 cm of lead were placed in front of the gamma-ray detector to eliminate pile up. The source used for coincidence was $\sim$10 mC. This amount of lead increased the relative intensity of the 0.878-MeV gamma ray to the 0.514-MeV gamma ray by about a factor of 4.5. More important again however, is the fact that the lead decreases the relative intensity of the pile up phenomenon from the 0.514-MeV gamma ray compared to the 0.878-MeV gamma ray by about a factor of one hundred. Use of the lead in front of the 3-in. crystal detecting the gamma radiation permitted both detectors to be placed close together subtending relatively large solid angles for coincidence measurements. A gamma ray of 0.878 MeV was indeed in coincidence with the x-rays as was the 0.514-MeV gamma ray (Fig. 3). Repeated runs were made with counting times of about 12 h as the intensity of the 0.878-MeV gamma-ray activity in coincidence with the x-ray was very low. Half-life measurements of this coincidence were not attempted.

The Sr^{85} sources used for coincidence measurements were somewhat fresher than the source used for the half-life experiments as coincidence measurements were made within 90 days after the source was prepared. Some Rb^{84} may have been present. This isotope, which decays by electron capture as well as positron emission to Kr^{84}, could have been detected in the gamma-ray—x-ray coincidence measurements as the Rb x ray and the Kr x ray are very close in energy.

Due to the possible presence of Rb^{84} as an impurity, the results of the gamma-ray—x-ray coincidence measurements are not conclusive in themselves. It is felt that they do add strength to the argument of a 0.878-MeV gamma-ray activity in the decay of Sr^{85} when considered with other evidence reported here. No conclusions involving spin assignments, in the subsequent discussion, are based solely on the results of this experiment.

This experiment, however, further eliminates Sr^{89} as a source of this 0.878-MeV activity. A $\frac{1}{8}$-in. sheet of polyethylene was placed in front of the x-ray counter and no appreciable decrease was noticed in the gamma-ray—x-ray coincidence rate. If the coincidence registered by the 0.878-MeV gamma ray were due to a Sr^{89} beta ray, end-point energy $\sim$0.6 MeV, entering the x-ray detector instead of an x ray, the coincidence rate would be materially decreased by placing the polyethylene sheet in front of the x-ray detector.

The presence of a 0.878-MeV gamma ray in the decay of Sr^{85} suggests that there could be a 0.514–0.364 MeV gamma-ray cascade and a 0.728–0.150-MeV gamma-ray cascade. The Q for the decay of Sr^{85} is[8] $1.11\pm.03$ MeV and this prohibits a 0.878–0.514-MeV gamma-ray cascade.

A 0.356 ± 0.015 gamma ray was found in coincidence with the well-known 0.514-MeV gamma ray. In order to be able to detect this gamma ray, a source was used which was much weaker than that used in the other parts of the investigation. This was necessary in order to keep accidental coincidences, resulting from the predominant 0.514-MeV gamma radiation, to a minimum. No pile up was seen from this weak source. Because of this the counting times had to be very large, around 12 h, and it was necessary to combine the data of individual runs. The gamma-gamma coincidence measurements were made with detectors and angles of 180° to each other and also with the detectors at angles of 90° to each other (Figs. 4 and 5).

Positron annihilation was detected in the 180° case, but in both cases the presence of a gamma ray at 0.356 MeV was apparent. The sample used here was from the

[6] Analysis made at Oak Ridge National Laboratory before source was delivered.

[7] Work is presently being done on the decay scheme of Sr^{89} which is believed to emit a weak 0.913-MeV gamma ray.

[8] A. J. Elwyn, H. H. London, Sophie Oleksa, and G. N. Glasoe Phys. Rev. **112**, 1200 (1958).

same Oak Ridge sample of Sr^{85} from which gamma-ray–x-ray measurements were made. The positron activity is tentatively ascribed to the presence of a small Rb^{84} or other positron-emitting impurity. Due to the weakness of the positron activity, half-life measurements of it were not deemed feasible. A difficulty always present in detecting possible positrons in this isotope is the presence of the dominant 0.514-MeV gamma rays. The presence of the positron activity is discussed further in a subsequent section of this paper.

Coincidence measurements were made to determine the possible presence of a 0.728–0.150-MeV gamma-ray cascade. The $\frac{1}{4}$-in.-thick[9] NaI crystal was used to detect any 0.150-MeV gamma radiation and a 3-in. crystal was used to detect the proposed 0.728-MeV gamma ray. Detection of a very low intensity 0.150-MeV gamma ray in coincidence with a 0.728-MeV gamma ray would be very difficult, due to the predominance of the 0.514-MeV gamma radiation of Sr^{85}. The source was so weak that no noticeable pile up occurred. The coincidence experiment did not give any definite indication of the presence of a gamma ray at 0.728 MeV. The upper limit of the fraction of Sr^{85} decaying by such a 0.728–0.150 MeV gamma cascade is estimated to be $<6\times10^{-6}$.

Traces of gamma radiation of 0.733 ± 0.020 MeV often appeared in the gamma-ray spectra taken in the course of half-life experiments, however, (see Fig. 2). This 0.733-MeV activity was too weak to have half-life measurements undertaken. In addition traces of gamma radiation of this energy often appeared in coincidence with the Rb x ray due to electron capture (Fig. 3).

As lead was placed between source and detector in

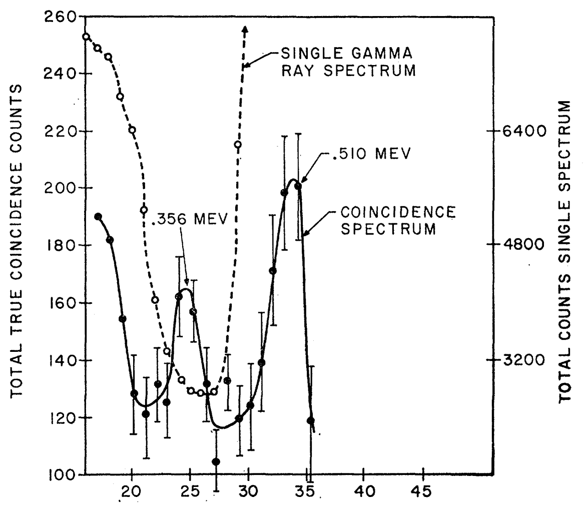

FIG. 4. Gamma-ray spectrum in coincidence with the 0.514-MeV gamma ray of Sr^{85} (detectors 180° apart).

[9] This crystal has about a 74% intrinsic efficiency for 0.150-MeV gamma rays whereas the intrinsic efficiency for the 0.514-MeV gamma rays is only about 19%. Thus, accidental coincidences resulting from the Compton tail of the 0.514-MeV gamma ray are reduced as about 4/5 of this predominant radiation passes through the thin crystal without detection. P. R. Bell, in *Beta- and Gamma-Ray Spectroscopy*, edited by K. Siegbahn (North-Holland Publishing Company, Amsterdam, 1955), pp. 133–154.

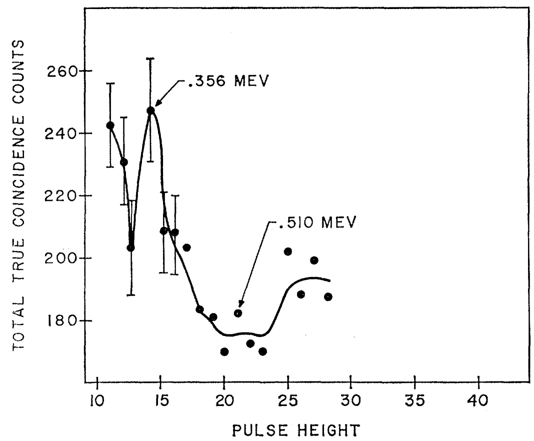

FIG. 5. Gamma-ray spectrum in coincidence with the 0.514-MeV gamma ray of Sr^{85} (detectors 90° apart).

both of these experiments, 2.86 cm in the half-life measurement, and 1.91 cm in the coincidence experiment, a gamma ray of 0.728 MeV would be attenuated about 1.8 times as much as an 0.878-MeV gamma ray in the half-life experiment and about 1.4 as much as the 0.878-MeV gamma ray in the gamma ray–x ray coincidence experiment. Efforts to improve the appearance of this possible gamma radiation by removing some of the lead absorber between the source and the detector in both the coincidence and the single gamma-ray spectrum were not conclusive as the pile-up events became marked. A 0.728-MeV gamma ray is tentatively assigned to the decay scheme of Sr^{85}. The evidence is not strong enough to make any definite conclusion however.

A 1.122 ± 0.088-MeV gamma ray of very low intensity was found in the gamma-ray spectrum of the Sr^{85} sample (Fig. 2). This gamma ray, however, had a measured half-life of over 100 days and it was not detected in any coincidence measurements. This gamma ray is not attributed to the decay of Sr^{85}. Its presence, however, along with the presence of the 0.878- and 0.514-MeV gamma rays would render very difficult measurement of internal brehmsstrahlung from any possible decay of Sr^{85} directly to the ground state of Rb^{85}.

The decay of Sr^{85m} [2,4,5] was re-examined in view of finding a 0.875-MeV gamma ray in the decay of Sr^{85}. It was thought there may be some decay of Sr^{85m} to the 0.878-MeV level of Rb^{85} (Fig. 6). A natural strontium source was bombarded with neutrons in the Pennsylvania State Universtiy Research Reactor. Measurements were made of the gamma-ray spectrum in coincidence with the 0.150-MeV γ ray in Rb^{85} due to the decay of 70-min Sr^{85m} as well as with the Rb x ray due to electron capture. No appreciable decay of Sr^{85m} to levels of Rb^{85} was found other than that previously reported.

DISCUSSION

On the basis of the above experiments a decay scheme of Sr^{85} is proposed (Fig. 6). Included is a postulated 0.878-MeV state in Rb^{85}, the 0.514- and 0.150-

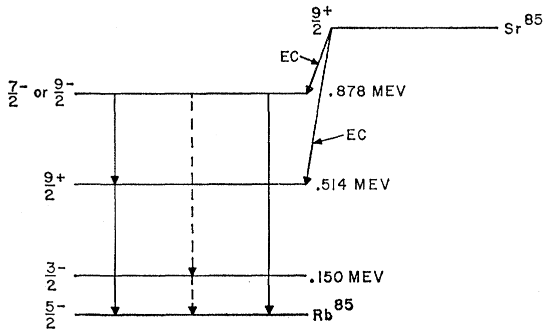

FIG. 6. Proposed decay scheme for Sr^{85}.

MeV states of Rb^{85}, the gamma rays of 0.878 ± 0.012 MeV, 0.356 ± 0.015 MeV, a possible gamma ray 0.733 ± 0.020 MeV and the predominant gamma ray of 0.514 ± 0.004 MeV.

Sr^{89}, a negatron emitter, is eliminated as the cause of the 0.878-MeV gamma ray because of the half-life measurements; the 0.878-MeV activity is 200 times too strong to be accounted for by any Sr^{89} impurity, and the 0.878-MeV activity is in coincidence with an x ray characteristic of orbital electron capture. Rb^{84} is eliminated as the cause of the 0.878-MeV gamma activity from the half-life measurement and the fact that the gamma-gamma coincidence measurements revealed a cascade which is not characteristic of the decay of Rb^{84}.[4]

The intensity of the 0.878-MeV gamma ray relative to that of the 0.514-MeV is about 1.7×10^{-4}. It is difficult to obtain the branching ratio for the two gamma rays emitted from the 0.878-MeV state as they were not able to be observed simultaneously in one experiment. However, by comparison of source strengths, efficiencies of the gamma-ray and x-ray detector, and the geometries of the experiments in which the 0.875- and 0.356-MeV gamma rays were seen, it is estimated[10] that the intensity of the 0.356-MeV gamma ray is slightly greater than one tenth the intensity of the 0.878-MeV gamma ray. Thus, the branching ratio of the decay of Sr^{85} to the 0.878-MeV state relative to the 0.514-MeV state is about 1.9×10^{-4}.

The log *ft* value for the decay of Sr^{85} to the 0.514-MeV state of Rb^{85}, based on the Q of 1.11 MeV and virtually 100% branching ratio, is 6.06. The log *ft* value is about 9.0 for the decay of Sr^{85} to the 0.878-MeV state of Rb^{85} based on the above branching ratio of 1.9×10^{-4}.[11] It is felt that any refinements of this branching ratio determination would leave the log *ft* value for the transition to the 0.878-MeV state $8.3\leq \log ft\leq9.7$.

It is quite likely that such a log *ft* value is indicative of a first forbidden transition. The limits imposed by such a transition on the J of the 0.878-MeV state of Rb^{85} then would be $5/2^-\leq J\leq 13/2^-$, since J of the 0.514-MeV state of Sr^{85} is $9/2^+$.[4] If a first-forbidden transition is postulated the following arguments can be made about the spin of the 0.878-MeV state of Rb^{85}.

It is quite unlikely that spins of $13/2^-$ or $11/2^-$ could be assigned to this state. In the former case the 0.878-MeV gamma-ray transition would be an $E4$ transition while the 0.356-MeV gamma-ray transition would be an $M2$ transition. The spins of the ground state, the 0.150-MeV state, and the 0.514-MeV state of Rb^{85} are known[4] and are shown in Fig. 6. The calculated branching ratio based on the Weisskopf formula for transition probabilities[12] is

$$\Gamma_{M2(0.356\mathrm{MeV})}/\Gamma_{E4(0.878\mathrm{MeV})}\sim6\times10^{7}.$$

If a lower limit is put on this ratio based on the largest deviations from these types of transitions that have been tabulated,[13] then

$$\Gamma_{M2(0.356\mathrm{MeV})}/\Gamma_{E4(0.878\mathrm{MeV})}\gtrsim6\times10^{3}.$$

The fact that these gamma rays have intensities within an order of magnitude of each other would appear to eliminate this choice of spin.

The same argument is, in effect, repeated for the latter choice mentioned above, assignment of spin $11/2^-$ to this state. Here the 0.878-MeV gamma ray would be an $M3$ transition and the 0.356-MeV gamma ray would be an $E1$ transition. Here the Weisskopf formula gives a ratio of[14]

$$\Gamma_{E1(0.356\mathrm{MeV})}/\Gamma_{M3(0.878\mathrm{MeV})}\approx1.6\times10^{+11}.$$

Again, since the intensities of these gamma rays are within an order of magnitude of each other, it is felt safe to eliminate this choice of spin.

A similar argument seems to cast doubt on $5/2^-$ as a spin choice. If a 0.728-MeV gamma-ray transition did take place between the 0.878-MeV level and the 0.150-MeV level, it would be an $M1$ transition according to this spin choice. The 0.356-MeV gamma ray would be an $M2$ transition. For gamma rays of these energies, the Weisskopf formula for transition probabilities gives

$$\Gamma_{M2(0.356\mathrm{MeV})}/\Gamma_{M1(0.728\mathrm{MeV})}\approx2.3\times10^{-7}.$$

Assigning a lower limit on this ratio based on the largest deviations from these types of transitions that have been tabulated,[13] we have

$$\Gamma_{M2(0.356\mathrm{MeV})}/\Gamma_{M1(0.728\mathrm{MeV})}\lesssim2\times10^{-3}.$$

If this limit were to hold, the 0.728-MeV gamma ray should have been detected with more certainty than is reported here; thus, other spin choices should be sought.

[10] It was also necessary to consider the fact that true coincidences were lost in this experiemnt as the mean life, τ, of the 0.514-MeV state is 0.9×10^{-6} sec (reference 2) and the resolving time, 2τ of the coincidence circuit used in the experiment was about 0.5×10^{-6} sec.

[11] Based on the nomographs of S. R. Moszkowski, Phys. Rev. **82**, 35 (1951).

[12] V. F. Weisskopf, Phys. Rev. **83**, 1073 (1951).

[13] D. H. Wilkinson, in *Nuclear Spectroscopy*, edited by Fay Ajzenberg-Selove (Academic Press Inc., New York, 1960), Part B, pp. 852–859.

[14] This argument and the other similar arguments remain essentially unchanged if the Moszkowski refinement of the Weisskopf formula is used. S. R. Moszkowski, in *Beta- and Gamma-Ray Spectroscopy*, edited by K. Siegbahn (North-Holland Publishing Company, Amsterdam, 1955), pp. 373–395.

There is little to choose between a $7/2^-$ and a $9/2^-$ spin assignment for the proposed 0.878-MeV state of Rb^{85} based upon the data available. The branching ratios calculated in a similar way for these two spin choices, considered with tabulated experimental deviations of these branching ratios from the predictions of Weisskopf formula,[15] are consistent with the experimental data for both spin choices.

The above discussion is consistent with the failure to find any appreciable transitions from the $1/2^-$ state of Sr^{85m} to the 0.878-MeV state of Rb^{85}. It is also consistent with the decay scheme of Kr^{85} and[4] Kr^{85m} which have not shown a 0.878-MeV level in Rb^{85}. This 0.878-MeV level is not accessible to the ground state of Kr^{85} and Kr^{85m} has a spin of $1/2^-$. A transition by beta decay between a $1/2^-$ and $7/2^-$ or $9/2^-$ state would be very highly forbidden.

The positrons found in the coincidence experiment are attributed to Rb^{84} or another positron-emitting impurity in the Sr^{85} sample. No transitions directly to the ground state have been found in the decay of Sr^{85}. Such a transition would be a first-forbidden unique transition. All tabulated first forbidden unique transitions have log ft values $\geqslant 8.16$ for odd-A nuclei[16] Assigning, for the sake of argument, a log ft value of 8.16 for the transition to the ground state of Rb^{85} gives a ratio (ground-state decay)/(decay to 0.514-MeV state) $<3\times10^{-2}$. The ratio of β^+/K for this transition to the ground state would be $\lesssim 2\times10^{-5}$.[17] Thus, the branching ratio for the decay of Sr^{85} by positron emission relative to electron capture (or relative to the observable 0.514-MeV gamma ray) is very likely to be $<6\times10^{-7}$. It is therefore unlikely that the positron activity seen is due to Sr^{85}.

ACKNOWLEDGMENTS

I wish to give acknowledgment to Dr. W. W. Pratt of The Pennsylvania State University for his suggestions and discussions which were an immeasurable aid in carrying out this investigation. I wish also to give acknowledgment to Douglas S. Vonada of The Pennsylvania State University Research Reactor staff for his innovations, aid, and suggestions concerning the electronic apparatus used in this investigation.

[15] W. W. Pratt, Nuclear Phys. **28**, 598 (1961).

[16] C. S. Wu, in *Nuclear Spectroscopy*, edited by Fay Ajzenberg-Selove (Academic Press Inc., New York, 1960), Part A, pp. 139–169.

[17] Based on extrapolating curves of P. F. Zweifel, in *Proceedings of The Rehovoth Conference on Nuclear Structure, Rehovoth, Israel, 1957*, (Interscience Publishers, Inc., New York, 1958), pp. 300–315.

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Endothermic Deuteron Stripping Reactions. III. The $C^{14}(d,p\gamma)C^{15}$ and $Li^7(d,p\gamma)Li^8$ Reactions*

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The cross section of the $C^{14}(d,p)C^{15*}$ reaction ($Q=-1.76$ MeV) to the first excited state of C^{15} at 0.75 MeV was measured for deuteron energies between 2.7 and 3.4 MeV. The cross section was obtained from the yield of the γ ray to the C^{15} ground state. The energy of this γ ray was measured to be 0.750 ± 0.007 MeV. The γ-ray angular distribution relative to the deuteron beam was measured at five deuteron energies between 2.9 and 3.4 MeV. The presence of a $P_4(\cos\theta)$ term in the distributions together with previous work establishes the C^{15} 0.75-MeV level as $5/2^+$. The measured angular distributions were found to be in agreement with predictions based on stripping theory. The cross section for the $Li^7(d,p)Li^{8*}$ reaction ($Q=-1.17$ MeV) to the first excited state of Li^8 at 0.98 MeV was measured for deuteron energies between 1.9 and 3.3 MeV. The cross section was obtained from the yield of the γ ray to the Li^8 ground state. The γ-ray energy was measured to be 0.980 ± 0.010 MeV. The anisotropy of this γ ray was measured at 23 deuteron energies between 1.9 and 3.3 MeV. These results were also consistent with the predictions of stripping theory if assignments of 1^+ for the Li^8 0.98-MeV level and $M1$ for the 0.98-MeV γ ray are assumed.

I. INTRODUCTION

In the first paper[1] of this series it was argued that the stripping mechanism should contribute all or nearly all of the cross section for many endothermic (d,p) or (d,n) reactions near threshold. Several methods of investigating the relative contribution of the stripping and compound nucleus mechanisms to the cross section near threshold in endothermic (d,p) or (d,n) reactions were discussed. In particular, the angular distribution of the γ rays relative to the deuteron beam (intermediate particle unobserved) in a $(d,p\gamma)$ or $(d,n\gamma)$ reaction was considered in some detail.

In the second paper[2] of this series the method of

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[1] E. K. Warburton and L. F. Chase, Jr., Phys. Rev. **120**, 2095 (1960); hereafter referred to as I.

[2] L. F. Chase, Jr., R. G. Johnson, and E. K. Warburton, Phys. Rev. **120**, 2103 (1960); hereafter referred to as II.