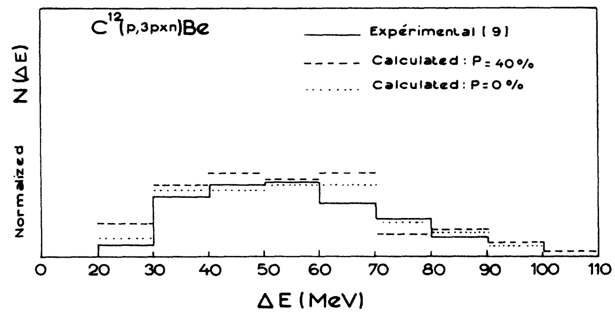

FIG. 1. Number of $(p, 3pxn)$ events against $\Delta E = E^* + (n-1)B$.

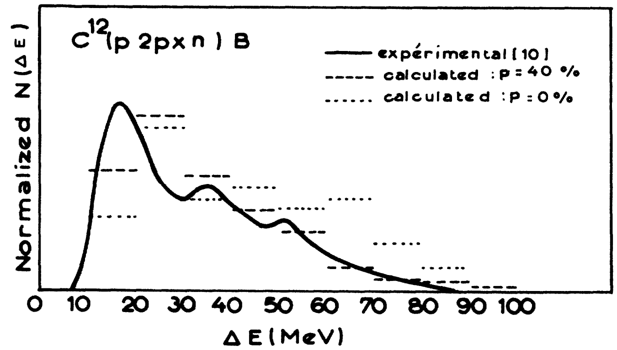

FIG. 2. Number of $(p, 2pxn)$ events against $\Delta E = E^* + (n-1)B$.

periment.

The calculations of $(p,p\alpha)$, $(p,2pxn)$ and $(p, 3pxn)$ cascades, taking into account the p-α collisions, give good values for the cross sections and ΔE spectra, but results still compatible with experiment can be obtained with $P = 0\%$ for the last two.

Other Monte Carlo calculations are in progress for several other light nuclei and various reactions.

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LIFETIMES OF $d_{3/2}$ HOLE STATES IN SCANDIUM ISOTOPES*

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The location of $d_{3/2}$ hole states in the odd-A isotopes of scandium has been inferred from the angular distributions of pickup reactions by Yntema and Satchler.[1] They observed such states in Sc^{45}, Sc^{47}, and Sc^{49}, and on this basis French[2] predicted that such a $d_{3/2}$ "hole" state (formed by promoting a $d_{3/2}$ proton to the $f_{7/2}$ shell) should also occur in Sc^{43} near the ground state. We therefore concluded that the first excited state of Sc^{43}, which we had previously shown to be metastable with a lifetime 190 times the single-particle estimate for an $M2$ transition,[3] is the predicted $d_{3/2}$ "hole" state and that the transition is $M2$. The "hole" level in Sc^{45} was observed by Yntema and Erskine[4] with the reaction $Ti^{48}(p,\alpha)Sc^{45}$ and the excitation energy was found to be 13 keV. In Sc^{47}, Yntema and Satchler[1] found the hole state at about 800-keV excitation with the reaction $Ti^{48}(d, He^3)Sc^{47}$; and in Sc^{49}, which we have not investigated, they found the hole state at 2.4 MeV.

We have now observed the gamma rays (which were not previously seen) from these levels in Sc^{43}, Sc^{45}, and Sc^{47} and measured their lifetimes. Our results show that the first excited states of all three isotopes are indeed metastable (corresponding to $M2$ transitions) so they may be explained as $d_{3/2}$ hole states formed by promoting a $d_{3/2}$ proton to the $f_{7/2}$ shell. The level diagrams for these nuclei are given in Fig. 1.

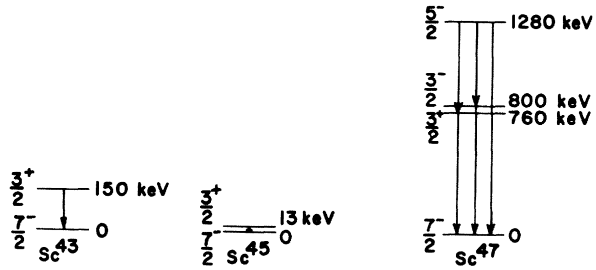

FIG. 1. Level schemes for the scandium isotopes in which the lifetimes of the $d_{3/2}$ hole states have been measured.

The level structure of Sc^{43} has been studied by McCallum, Ferguson, and Mani,[5] who observed the threshold for production of neutrons from the reaction $Ca^{43}(p,n)Sc^{43}$ and found the first excited state to be at 138 ± 8 keV. We have produced this state with 8-MeV alpha particles on a thick target with the reaction $Ca^{40}(\alpha,p)Sc^{43}$ and with 6-MeV protons on a thick target with the reaction $Ca^{43}(p,n)Sc^{43}$. With both reactions we observed an intense gamma ray of 150 ± 3 keV with a NaI(Tl) scintillator and believe it to be the gamma ray from the first excited state of Sc^{43}. The lifetime was measured by pulsing the beam from the accelerator. Events corresponding to the photopeak of the 150-keV gamma ray were stored according to their time of occurence in a multichannel analyzer in the multiscaler mode. Data from both reactions gave a mean life of 628 ± 10 μsec. From the calculations of Rose,[6] we expect a total conversion coefficient of 0.045. The partial mean life for emission of a gamma ray is given by $\tau_\gamma = \tau_{\mathrm{obs}}(1+\alpha)$, where τ_{obs} is the observed mean life and α is the total conversion coefficient. In this case the value is $\tau_\gamma = 656$ μsec.

From the work of Yntema and Erskine[4] with the reaction $Ti^{48}(p,\alpha)Sc^{45}$, the first excited state of Sc^{45} was known to be at 13 keV. We excited this state by the reaction $Sc^{45}(p,p')Sc^{45*}$ induced by a pulsed beam of 2.7-MeV protons on a thick metallic scandium target. Pulse-height spectra from a NaI(Tl) scintillator 1 mm thick and 12.7 mm in diameter were recorded during the period between beam pulses. During the period when the proton beam was striking the target, a very intense pulse of characteristic x rays of scandium was formed. To reduce the number of these x rays relative to the 13-keV gamma ray, a filter of Lucite 12.5 mm thick was inserted between the target and detector. The pulse-height spectra were calibrated by recording the pulse-height spectra due to the characteristic x rays from selenium (mean energy 11.4 keV) and niobium (mean energy 16.9 keV). The energy of the gamma ray as determined in this way is 13 ± 1 keV. The decay of this state was observed by recording pulses corresponding to the photopeak of the 13-keV gamma ray on a multichannel analyzer in the multiscaler mode. The mean life was 0.44 ± 0.02 sec. By extrapolating the conversion coefficients calculated by Rose[6] to lower energy and lower Z, we obtain a total conversion coefficient of 330 for an $M2$ transition of this energy. The corresponding partial mean lifetime for gamma emission is then 132 sec, which is 210 times Moszkowski's[7] single-particle estimate.

The position of the hole state in Sc^{47} is known to be near 800-keV excitation from the work of Yntema and Satchler[1] who measured the angular distribution of the reaction $Ti^{48}(d,He^3)$ leading to this state and concluded that the reaction proceeded by pickup of an $l=2$ proton. Accordingly, one expects that this state should be metastable. Bjerregaard et al.[8] have shown that there are two states near this excitation energy in Sc^{47}, one at 760 keV, and one at 800 keV. The upper one is known to be populated by the decay of Ca^{47}, but its lifetime[9] is much too short to be the metastable state. We have found, however, that the lower state (at 760 keV) is also populated in about 0.05% of the decays of Ca^{47}. It has a lifetime appropriate for an $M2$ transition and it therefore must be the state that was seen by Yntema and Satchler. We measured the lifetime of this state by observing a weak source of Ca^{47} with two NaI(Tl) scintillators ($1\frac{1}{2}$ in. thick$\times 1\frac{1}{2}$ in. in diameter). Fast pulses from each scintillator were sent to a time-to-pulse-height converter[10] whose output was gated by a slow coincidence between gamma rays of energies 760 keV and 520 keV. A very large prompt peak was formed by coincidences from the more intense 480- to 800-keV cascade. A tail observed on the prompt peak corresponded to the process in which a 520-keV event in one scintillator was followed by a 760-keV event in the other. The mean life for this 760-keV transition was 0.40 ± 0.06 μsec. The conversion coefficient is so small in this case that one may also use this value for the partial mean life for gamma emission.

Table I summarizes the data. The transitions are considerably slower than the single-particle estimate, but all are inhibited by about the same

Table I. Summary of data on the lifetimes of $M2$ transitions from $d_{3/2}$ hole states in scandium isotopes.

Isotope	Excitation energy (keV)	Observed mean life (μsec)	Conversion coefficient	Partial γ-ray mean life τ_γ (μsec)	Moszkowski estimate, τ_M (μsec)	Ratio τ_γ/τ_M
Sc^{43}	150 ± 3	628 ± 10	0.045	656	3.49	190
Sc^{45}	13 ± 1	$(0.44 \pm 0.025) \times 10^6$	330	145×10^6	0.6915×10^6	210
Sc^{47}	760 ± 20	0.40 ± 0.06	≈ 0	0.40	0.00098	410

factor. A calculation by Lawson,[11] based on the admittedly somewhat unrealistic assumption that seniority is a good quantum number in this region, predicts that the transition rates should be only one quarter of the single-particle estimate.

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SEARCH FOR CP NONCONSERVATION IN K_2^0 DECAYS*

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Neutral K mesons are especially convenient for studying CP invariance in strangeness-changing decays. The K_1^0 meson, the even CP state, decays into two pions. The K_2^0 meson, the odd state of CP, is not allowed to decay into two pions if CP is conserved. The published experimental upper limit on the $K_2^0 \to \pi^+ + \pi^-$ mode is 0.3% of all K_2^0 decays.[1-5]

In an experiment designed to look primarily at $K_{\mu 3}^0$ and K_{e3}^0 decays, we have also looked for cases of K_2^0 mesons decaying into two pions. The experiment was performed 60 feet from the target in a 30° neutral beam at the Brookhaven AGS. Neutral particles decaying in a vacuum pipe placed in a magnetic field of 10 kG were detected with the counter and spark-chamber arrangement shown in Fig. 1. To trigger the spark chambers, during the portion of the run devoted to $K_{\mu 3}$ decays, a coincidence $ME_1E_2E_3P\bar{A}$ was required. This insured a high probability for selecting $K_{\mu 3}$ events since only about 10% of the pions from the other modes of K_2^0 decay would be able to penetrate the 11 in. of Pb without interacting. The triggering during the K_{e3} portion of the run was the same as before except that the Pb was removed and the bias levels on the E counters raised so that electron showers would trigger the chambers. The E counters consisted of alternate layers of $\frac{1}{8}$-in. plastic scintillator and $\frac{3}{32}$-in. Pb, a total of about two radiation lengths of Pb in each counter.

To analyze the events, a search was made for pictures of the magnet spark chambers which contained two oppositely charged tracks whose intersection point was in the vacuum pipe. The identity of one of these two particles was established as being a muon during the $K_{\mu 3}$ run by observing the range of the particle in the exterior