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A HIGHLY NEUTRON-DEFICIENT VANADIUM ISOTOPE: ^{44}V[†]

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Vanadium-44, with a half-life of 90±25 msec, has been produced by the $^{40}Ca(^{6}Li,2n)^{44}V$ reaction induced by 18.5 MeV lithium ions; beta-delayed α-particles of 3.05±0.2 MeV (c.m.) were observed with a production cross-section $\approx$ 100 nb.

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With the exception of ^{16}F, all of the members of the $A = 4n$, $T_Z = \frac{1}{2}(N - Z) = -1$ series from ^{8}B through ^{40}Sc are nucleon stable and their decay properties have been fairly well established. However, no technique for investigating higher A nuclei of this series has been demonstrated. We wish to report the observation of ^{44}V, following the $^{40}Ca(^{6}Li,2n)$ reaction, by utilizing the weak beta-delayed particle emission frequently observed in the decay of nuclei in this mass series; in principle, extension of this approach

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to other heavy ions should permit observation of heavier unknown $T_Z = -1$ nuclei. Characterization of these highly neutron-deficient isotopes is a prerequisite for detailed exploration of the expected limits of nucleon stability in the $f_{7/2}$ shell.

Mechanically chopped beams of 18.5 and 21.5 MeV ^{6}Li ions (3+) from the second tandem of the Brookhaven National Laboratory three-stage MP tandem Van de Graaff facility were used to irradiate 0.86 ± 0.06 mg/cm^2 natural calcium targets. Beam intensities incident on the target averaged 0.4 μA. The 21.5 MeV beam was employed to investigate the well-known beta-delayed α-particle emission of ^{20}Na [1] for orientation and calibration purposes; ^{20}Na was produced by the ^{16}O(^{6}Li,2n) reaction on oxygen target impurities. The 18.5 MeV beam was required to investigate ^{44}V, since this energy lies just below the threshold for the production of ^{20}Na which would otherwise present a severe background problem due to its prolific yield. (Due to the nucleon instability of ^{16}F, reactions on ^{12}C target impurities are of no concern.)

Simple calculations lead one to expect ^{44}V to most probably be a weak beta-delayed α-particle emitter with a half-life $\lesssim$ 150 msec. In order to detect fairly low-energy α-particle groups in an intense beta background, a semiconductor telescope consisting of surface barrier detectors was employed. This telescope utilized a 5-μ ΔE detector followed by a 31-μ E detector and subtended a solid angle of 0.15 sr. The targets were placed at an angle of 30° to the beam while the telescope was positioned perpendicular to the beam axis.

A timing device triggered both the pneumatic beam interceptor and a shutter which dropped in between the target and the ΔE counter during the irradiation periods. Summed coincidence pulses between the two detectors were stored in a two-parameter analyzer as a function of time. As a further aid in reducing the background from beta-particle pile-up, only those events losing more than 600 keV in the ΔE detector were accepted. (This restriction also eliminates protons; however, beta-delayed proton emission from ^{44}V was expected to be extremely weak at best.) Alpha-particles between 1.6 and 6.5 MeV could have been linearly detected by this system; a ^{241}Am α-source and a precision pulser established the energy scale. Energy spectra were recorded in four successive time groups, each of 100 msec duration.

Figure 1(a) presents data from the bombardment of the calcium target with 21.5 MeV ^{6}Li ions. Comparison of this α-particle spectrum with the results of Polichar et al. [1] shows that it is dominated by, and consistent with, the decay of ^{20}Na produced from oxygen target impurities. (The primary α-particle branch in this decay has a center-of-mass (c.m.) energy of 2.70 MeV; due to our relatively thick target, most of the yield of this group lies below the telescope cut-off.) Further, the observed half-life of these beta-delayed α-particles agrees well with the known 446 msec half-life of ^{20}Na [2].

Figure 1(b) presents an α-particle spectrum following the decay of the new isotope ^{44}V. A peak corresponding to a c.m. energy of 3.05±0.20 MeV, after correction for energy loss in the target, dominates the observed spectrum. The data are consistent with the assumption that this fairly broad peak arises primarily from a single α-particle group and have been so treated; however, due to the low yield of this group and the various assumptions necessary for the energy analysis, the possibility that such a peak could arise from two moderately-spaced α-particle groups can not be completely eliminated. The half-life of this peak is 90±25 msec and its production cross section is of the order of 100 nb. Events in the shaded region arise from beta-particle pile-up and have a half-life longer than one second.

This low yield for beta-delayed particle decay from ^{44}V coupled with the overwhelming yield of ^{20}Na from oxygen target impurities precluded determination of an excitation function for the ^{40}Ca(^{6}Li,2n)^{44}V reaction. However, at this relatively low bombarding energy for ^{6}Li on calcium, no other nuclide including the unknown isotope ^{45}V can be formed which can be a source of beta-delayed α-particles of this energy. (Unknown masses of relevant $f_{7/2}$ shell nuclei are taken from the predictions of Harchol et al. [3].)

A preliminary decay scheme for ^{44}V is presented in fig. 2. Data on ^{44}Ti were taken from refs. 4 and 5. The spin and parity of ^{44}V are taken to be 2+ based on its mirror nuclide ^{44}Sc [6]. (Similarly, based on this mirror comparison, one would also expect a beta-decaying isomer $^{44}V^{m}$ (6+) of comparable half-life. For simplicity, we have attributed the observed decays to the ground state; several weak arguments, none of them convincing, favor this choice.) As can be seen in fig. 2, the α-particles must originate from a state at 8.17 MeV in ^{44}Ti which, if populated by allowed beta-decay, is restricted to a J^{π} of 2+ by angular momentum and parity conservation [7]. Superallowed beta-decay populates the 2+, T = 1 state at 6.72 MeV [5]. Even though this state is unstable to (isospin-forbidden) α-particle emission, penetrability calculations alone show that such α-emission is far too slow to compete with γ-ray de-excitation; no evidence for any such α-particle group was observed in the ΔE singles spectra.

Although extremely few Z > N nuclei above the titanium isotopes are known, these results suggest that the heavier A = 4n, T_Z = -1 nuclides ^{48}Mn and ^{52}Co can also be characterized. Both these nuclides could be weak beta-delayed proton or α-particle emitters and can similarly be produced by employing ^{10}B and ^{14}N projectiles on appropriate targets.

We wish to thank Michael G. Littman for his assistance with this experiment.

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7. No isospin assignment is possible since the level scheme of ^{44}Ti is unknown and that of ^{44}Sc poorly characterized (see H. Ohnuma and A. M. Sourkes, Phys. Rev. C 3 (1971) 158) in the appropriate regions of excitation.

Figure Captions

Fig. 1. (a) An α-particle spectrum following the decay of ^{20}Na produced by the ^{16}O(^{6}Li,2n) reaction on oxygen target impurities. The center-of-mass energy of the major peak unaffected by the telescope cut-off is shown. For both (a) and (b), the data shown correspond to sums of all four time channels; cross-hatched events below the arrow at 1.6 MeV can only arise from beta-particle pile-up.

(b) An α-particle spectrum following the decay of ^{44}V produced by the ^{40}Ca(^{6}Li,2n) reaction.

Fig. 2. A preliminary decay scheme for ^{44}V. Decays that have not been directly observed are shown as dashed lines. Energies are given in MeV. The spin-parity assignments are discussed in the text.

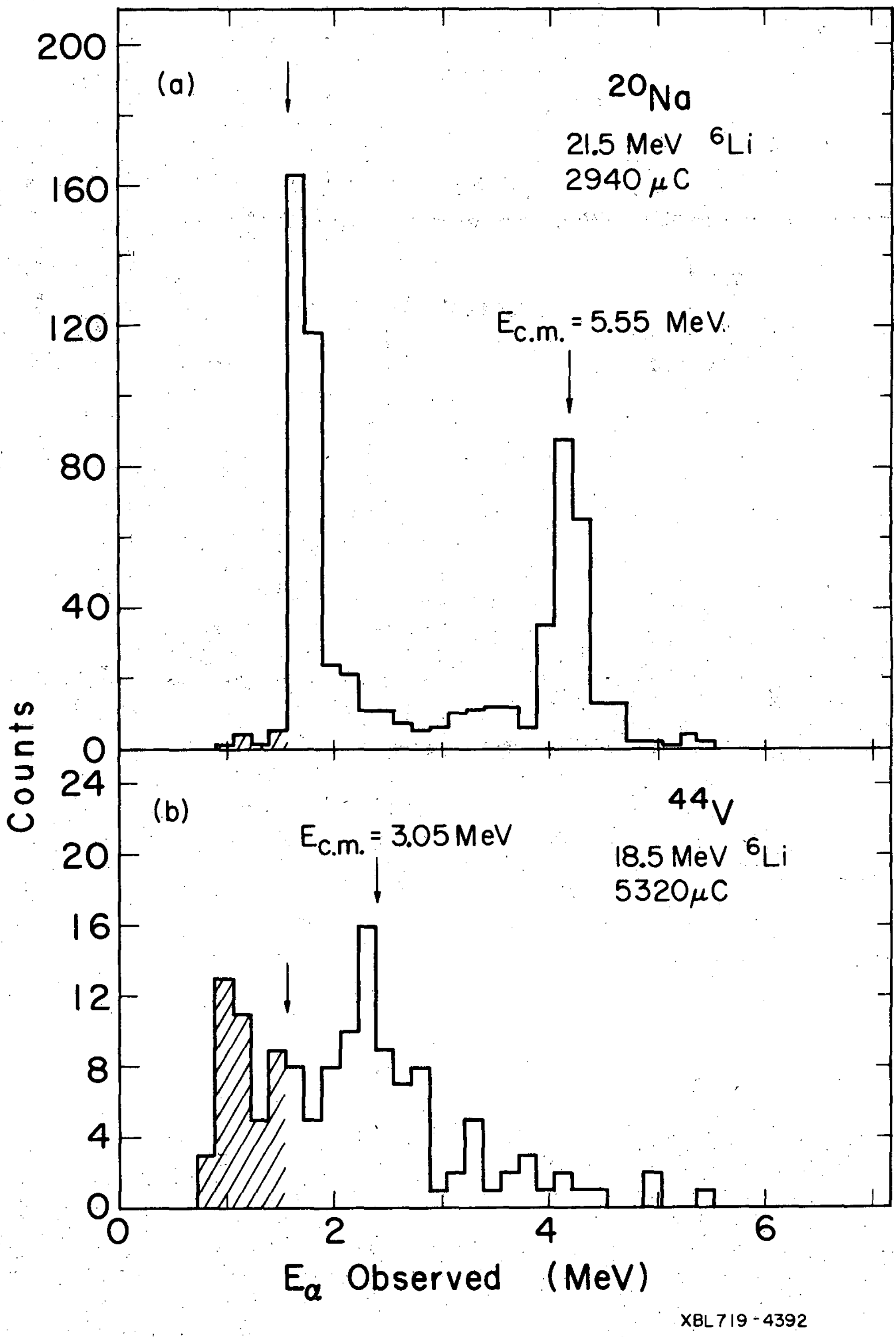

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Fig. 1

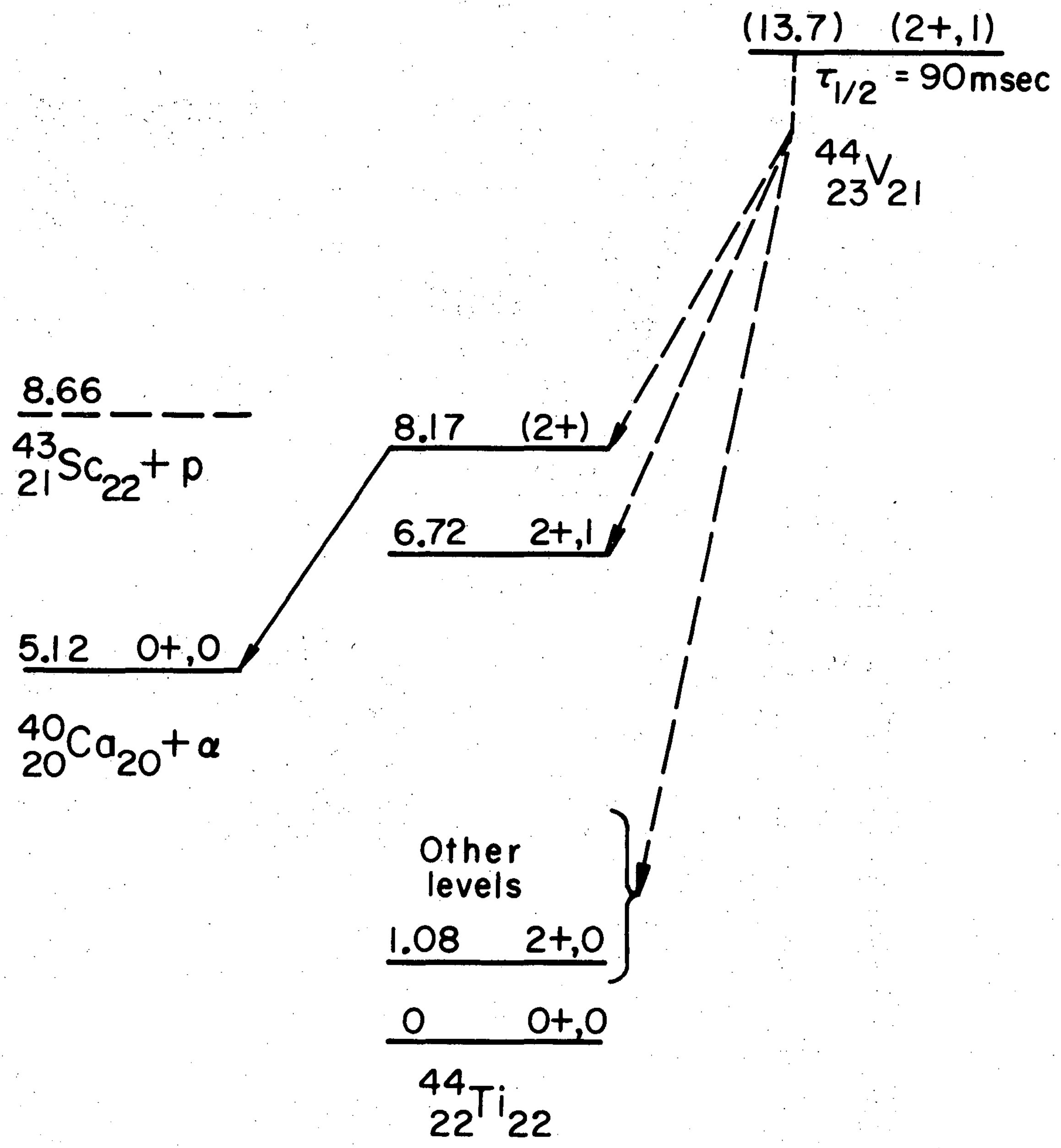

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Fig. 2

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