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Gamma Decays, Lifetimes and Spins of ^{47}V Excited States

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Abstract

The nucleus ^{47}V has been studied using the ^{47}Ti(p, nγ)^{47}V reaction, with isotopically enriched ^{47}Ti targets, incident proton energies from 4·7 to 5·4 MeV, and Ge(Li) γ-ray detectors. The previously unreported γ-decay of the second excited state was observed. Energies of the first seven excited states were deduced to be $87\cdot5\pm0\cdot1$, $145\cdot7\pm0\cdot2$, $259\cdot6\pm0\cdot4$, $660\cdot1\pm0\cdot3$, $1138\cdot3\pm0\cdot4$, $1272\cdot2\pm0\cdot4$ and $1295\cdot1\pm0\cdot4$ keV. Their γ-decay branching ratios were measured. The lifetimes of the last four mentioned states were deduced from attenuated Doppler shifts to be 680^{+1400}_{-340}, 960^{+1700}_{-440}, 390^{+390}_{-150} and >750 fs respectively. Angular distribution measurements resulted in the assignment of $J^{\pi} = 9/2^-$ to the 1272 keV level and $J = 9/2$ or $11/2$ to the 1295 keV level. The results are discussed in the light of the Coriolis-coupling model.

Introduction

The level structure of ^{47}V has been well established by a variety of methods. The ground state spin has been shown to be $3/2^-$ by stripping reactions (Rosner and Pullen 1967*a*, 1967*b*) and atomic beam techniques (Redi and Graber 1967). The low energy levels ($E_x < 700$ keV) were initially investigated via the (p, n) reaction (McCallum *et al.* 1960), but the majority of levels have been established using the ^{46}Ti(τ, d) reaction (Dorenbusch *et al.* 1967; St. Pierre *et al.* 1967; Čujec and Szöghy 1969). For the latter reaction, l_p values were assigned to the transferred proton and parities were assigned to levels in the residual nucleus. In some cases the assignment of spins was possible. Further studies by Brown *et al.* (1966) using the ^{50}Cr(p, α) reaction revealed levels not populated in the (τ, d) reaction. Proton capture studies by Albinsson and Dubois (1965, 1967), McCallum and Pohl (1970), Willmes (1970) and Schrader *et al.* (1973) served to confirm previous J^{π} assignments of the low lying states, and measurements of branching ratios of some of these levels were made. In addition, conversion-electron studies of the 88 keV level have been made by Menti (1967).

Prior to the work reported here, no γ-ray data other than those from the (p, γ) experiments have been available, and no measurements of the lifetimes of excited states below $E_x = 1300$ keV have been made. It was the aim of the present experiment to measure these lifetimes and to assign J^{π} values using the ^{47}Ti(p, nγ) reaction ($Q = -3\cdot699$ MeV). In particular, a search for the low lying $9/2^-$ and $11/2^-$ states predicted by Malik and Scholz (1966) was made, as the (p, nγ) process should prove suitable for population of these high spin states. The ground state of the ^{47}Ti target nucleus has $J^{\pi} = 5/2^-$, and so protons with l values as low as 2 should give substantial population of the levels of interest.

In addition to the above, a special effort was made here to observe the previously unseen γ-decay of the 146 keV level. This level is populated in the (p, n) and stripping reactions, but was not observed in the (p, γ) experiments.

Experimental Procedure and Data Analysis

Unless otherwise noted, all targets used in this work were prepared by vacuum evaporation of isotopically enriched titanium metal ($75\cdot5\%$ ^{47}Ti) onto $0\cdot5$ mm thick tungsten backings. Proton beams for this study were provided by the A.N.U. Tandem Van de Graaff accelerator. The collimation system, target chamber and rotatable correlation table have been described previously (Bell *et al.* 1974). Two 36 cm^3 Ge(Li) spectrometers, with resolutions of about 3 keV (FWHM) for $E_\gamma = 1332$ keV, were used for all γ-ray detection. Their respective spectra were accumulated in two 2048-channel arrays of an IBM 1800 computer system. Peak areas and centroids were extracted using standard programs available in this laboratory.

Excitation Function

The energies of new levels and their modes of decay were established by the measurement of a γ-ray excitation function between $4\cdot15$ and $5\cdot25$ MeV incident proton energy. The appearance of new peaks in the γ-spectra was taken to indicate the population of new levels in ^{47}V.

Lifetime Measurements

A thin (150 $\mu g\,cm^{-2}$) titanium target was bombarded with protons of $4\cdot7$, $5\cdot1$ and $5\cdot4$ MeV, the energies being chosen to accentuate direct feeding of the state being studied, and to minimize population via γ-cascades from higher levels. Beam currents were typically 200 nA.

The two Ge(Li) detectors were placed at 120° relative to each other, 5 cm from the target. Combinations of ^{88}Y, ^{60}Co, ^{65}Zn and ^{54}Mn sources were placed near the target during data collection to provide standard reference energies appropriate to the level being studied. Spectra were recorded with one counter at 0°, 30°, 90° and 120° (the other then at 120°, 90°, 30° and 0°), each measurement being repeated at least once. Energies of peaks were calculated by linear interpolation between the reference source peaks, assuming the γ-energies tabulated by Marion (1968). Individual γ-ray energies were least-squares fitted with the expression

$$E(\theta) = E_0 + \Delta E \cos\theta$$

to yield the unshifted energy E_0, and the 0° to 90° Doppler shift ΔE. Energies calculated from both counters were always in excellent agreement (Table 1).

The experimental Doppler shift attenuation factor $F(\tau)_{exp}$ was derived from the ratio of the observed Doppler shift to the full shift calculated for the recoil velocity of the centre of mass. That this velocity is appropriate when a compound nucleus reaction mechanism is expected to dominate has been shown by Carlson *et al.* (1974), following Hausser *et al.* (1968).

A calculation of $F(\tau)_{theor}$ versus the mean life τ was made using the theoretical treatment of Lindhard *et al.* (1963), as modified by Blaugrund (1966), and the experimental half-life was deduced from the resulting curves. The correction factors

f_e and f_n introduced by Blaugrund were both taken to be unity. Extrapolation of measurements by Hvelplund and Fastrup (1968) suggests that $f_e = 1 \cdot 1$ should be used for vanadium ions recoiling in titanium, and this would introduce a maximum of 5% reduction in the reported lifetime. However, in the absence of reliable estimates of f_n, no corrections were applied to the present data. The errors thus introduced are small compared with the error of 15% assigned to the $F(\tau)_{\text{theor}}$ calculated from the Lindhard–Blaugrund formulae. Results of Doppler shift measurements for the 660, 1138, 1272 and 1295 keV levels are presented in Table 2.

Table 1. Excitation energies and branching ratios for ^{47}V levels

Level No.	E_x (keV)	Decay	Branching ratios (%) Present work	Previous results*
1	$87 \cdot 5 \pm 0 \cdot 1$	$87 \cdot 5 \to 0$		100
2	$145 \cdot 7 \pm 0 \cdot 2$	$145 \cdot 7 \to 0$	$(1 \cdot 0 \pm 0 \cdot 5)$	
		$\to 87 \cdot 5$	$99 \cdot 0 \pm 0 \cdot 5$	
3	$259 \cdot 6 \pm 0 \cdot 4$	$259 \cdot 6 \to 0$	87 ± 1	85^{A}
		$\to 87 \cdot 5$	13 ± 1	15^{A}
4	$660 \cdot 1 \pm 0 \cdot 3$	$660 \cdot 1 \to 0$	45 ± 5	50 ± 17^{B}, 50^{A}
		$\to 87 \cdot 5$	17 ± 5	20 ± 7^{B}, 30^{A}
		$\to 259 \cdot 6$	38 ± 10	30 ± 10^{B}, 20^{A}
5	$1138 \cdot 3 \pm 0 \cdot 4$	$1138 \cdot 3 \to 0$	4 ± 3	
		$\to 87 \cdot 5$	44 ± 5	40^{C}
		$\to 145 \cdot 7$	4 ± 2	5^{C}
		$\to 259 \cdot 6$	30 ± 5	36^{C}
		$\to 660 \cdot 1$	18 ± 5	19^{C}
6	$1272 \cdot 2 \pm 0 \cdot 4$	$1272 \cdot 2 \to 87 \cdot 5$	18 ± 2	
		$\to 145 \cdot 7$	82 ± 2	
7	$1295 \cdot 1 \pm 0 \cdot 4$	$1295 \cdot 1 \to 87 \cdot 5$	< 10	
		$\to 145 \cdot 7$	100	
		$\to 660 \cdot 1$	< 10	

* From: A, Albinsson and Dubois (1967); B, McCallum and Pohl (1970); C, Schrader *et al.* (1973).

Table 2. Results of Doppler shift attenuation measurements for ^{47}V

The correction factors f_e and f_n were both taken to be $1 \cdot 0 \pm 0 \cdot 15$

E_p (MeV)	V_{cm}/c (%)	E_x (keV)	E_γ (keV)	Shift $\Delta E(0°–90°)$	Attenuation factor $F(\tau)$	Lifetime τ (ps)
$4 \cdot 7$	$0 \cdot 211$	660	$660 \cdot 1 \pm 0 \cdot 3$	$0 \cdot 13 \pm 0 \cdot 08$	$0 \cdot 09 \pm 0 \cdot 06$	$0 \cdot 68^{+1 \cdot 4}_{-0 \cdot 34}$
$5 \cdot 1$	$0 \cdot 220$	1138	$878 \cdot 7 \pm 0 \cdot 3$	$0 \cdot 18 \pm 0 \cdot 10$	$0 \cdot 07 \pm 0 \cdot 04$	$0 \cdot 96^{+1 \cdot 7}_{-0 \cdot 44}$
$5 \cdot 4$	$0 \cdot 227$	1272	$1184 \cdot 5 \pm 0 \cdot 3$	$0 \cdot 43 \pm 0 \cdot 15$	$0 \cdot 16 \pm 0 \cdot 06$	$0 \cdot 39^{+0 \cdot 39}_{-0 \cdot 15}$
$5 \cdot 4$	$0 \cdot 227$	1295	$1149 \cdot 4 \pm 0 \cdot 4$	$0 \cdot 02 \pm 0 \cdot 17$	$0 \cdot 01 \pm 0 \cdot 07$	$> 0 \cdot 75$

Angular Distribution Measurements

The angular distributions of γ-rays decaying from levels populated in the (p, n) reaction just above threshold may be analysed using statistical compound nucleus theory if the target is thick enough to provide energy averaging over many compound nuclear states. The quantity of enriched titanium available at the time of the experiment allowed the fabrication of a 600 $\mu g\,cm^{-2}$ target, which would only average over a 30 keV interval. This was considered insufficient for a statistical analysis and therefore a 'thick beam' was produced by utilizing the energy straggling of the incident proton beam introduced by placing a 5 μm tantalum foil on the front face of the titanium target. Measurements indicated that such a foil would induce approximately 100 keV straggling width in a 5 MeV incident proton beam. This, in conjunction with the target thickness, gave energy averaging over about 1000 levels of the compound nucleus (Thompson 1973), which was adequate.

Resonances in the (p, n) reaction which are due to isobaric analogues of levels in ^{48}Ti are not expected to interfere with this work as the analogue of the ^{48}Ti ground state lies about 3 MeV below the ^{47}Ti+p threshold in the ^{48}V system. With incident proton energies of 4–5 MeV, only levels near 8 MeV excitation in ^{48}Ti might be seen as resonances. The level density of ^{48}Ti is high in this region of excitation and, unless a level has a large spectroscopic factor relative to its immediate neighbours, no analogue resonances will be seen and the situation will revert to the statistical case.

Proton beams of 4·8 and 5·5 MeV incident energy (giving mean energies at the centre of the target of 4·4 and 5·1 MeV respectively) were used. Beam currents of 400 nA required typical data collection times of $2\frac{1}{2}$ h.

One Ge(Li) detector, positioned to look through the target backing, was placed on the rotatable table 18 cm from the target. The second detector, used as a monitor of reaction yield, was placed 25 cm from the target at a constant angle of 90° to the beam direction. Data were recorded at 15° intervals between 0° and 90°, the yield at each angle being measured at least twice. The live times associated with each counter and ADC combination, and the total time, were automatically recorded, as were the integrated live charge and total charge. Gamma-ray yields were individually corrected for dead time loss, and the yield in the moving counter was corrected for relative absorption (corrections $<2\%$) in the tungsten backing using the data of Davisson and Evans (1950). The normalized angular distributions were compared with the predictions of the MANDY compound nucleus program of Sheldon and Strang (1969) and normalized χ^2 fits were evaluated. A 0·1% confidence limit was used as the criterion for excluding unacceptable fits. Errors for mixing ratios were evaluated using the procedure of Archer *et al.* (1966). Angular distributions were measured for the decay of the 660, 1138, 1272 and 1295 keV levels.

Low Energy γ-ray Measurements

The data of McCallum *et al.* (1960) indicated that the 146 keV level ($J^\pi = 7/2^-$) is strongly populated in the ^{47}Ti(p, n) reaction, and this was confirmed by our measurements using a resonant scattering spectrometer (Bell *et al.* 1972). X-rays produced in the tungsten target backing used for our previous (p, nγ) studies obscured the possible 58 keV γ-decay from this level to the 88 keV level ($J^\pi = 5/2^-$). Substitution of uranium as the target backing left the region $E_x < 95$ keV free from X-rays and permitted the search for this previously unreported γ-decay.

A target, isotopically enriched in ^{47}Ti, was prepared by painting a thick slurry of titanium dioxide onto a 0·5 mm thick natural uranium disc. The resulting target thickness was 7 mg cm^{-2} of TiO_2. The target chamber arrangement was as used previously except that the copper cold shroud was omitted to reduce the attenuation of low energy radiation.

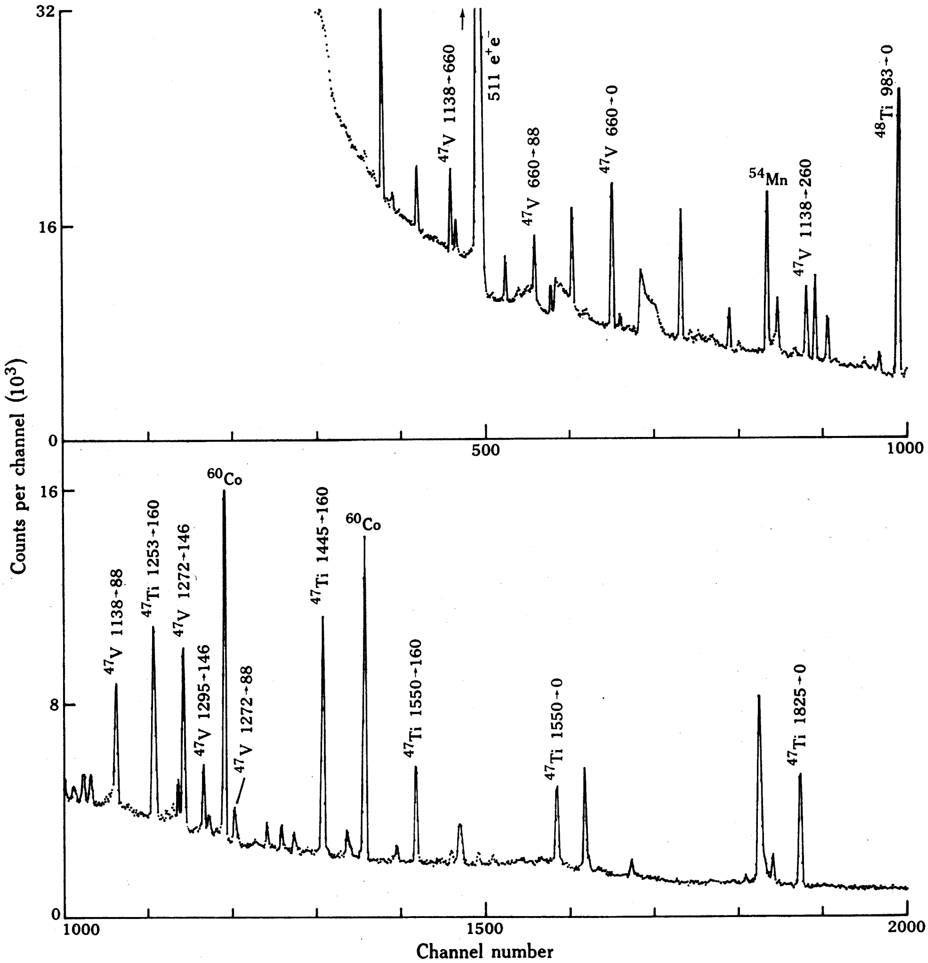

Fig. 1. Gamma-ray spectrum for the reaction ^{47}Ti(p, nγ) ^{47}V measured at 0° for an incident proton energy of 5·4 MeV. ^{54}Mn and ^{60}Co source peaks used for calibration purposes in the Doppler shift measurements are indicated, as are the major ^{47}V and ^{47}Ti γ-decays (all energies are in keV). Other γ-ray peaks were identified satisfactorily: they arise from inelastic proton scattering in the target and backing materials, from inelastic neutron scattering in the Ge(Li) detector and surrounding materials, and from background radiation in the laboratory.

It was found that the efficiency and resolution of the coaxial germanium detector for low energy radiation was much improved when the γ-rays were incident on the side of the detector. This arrangement was therefore adopted for the present work. The efficiency curve for the system was measured by replacing the target with standard sources. A 5 MeV incident proton beam was used for this study to ensure adequate population of the 146 keV state.

Results

Typical spectra recorded in this experiment are presented in Figs 1 and 2. Combination of results from the measurements reported here allows the assignment of new excitation energies, branching ratios, and lifetimes for levels in ^{47}V. These are summarized in Tables 1 and 2, and are compared with previous results where possible.

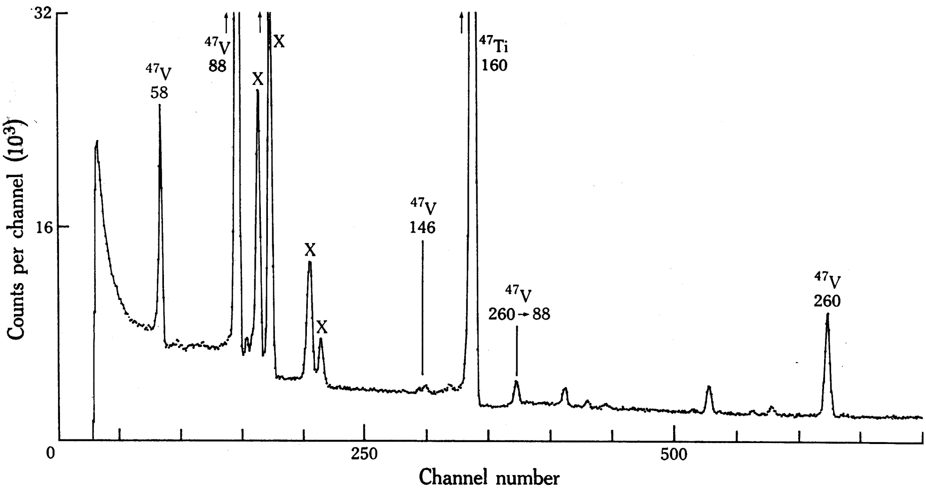

Fig. 2. Low energy γ-ray spectrum obtained from the ^{47}Ti(p, nγ)^{47}V reaction for an incident proton energy of 5·0 MeV. The major peaks from ^{47}V and ^{47}Ti levels (keV) are indicated. An enriched target on a uranium backing was used; the uranium X-rays are each marked with an 'X'. The 146→0 keV transition in ^{47}V is a tentative assignment.

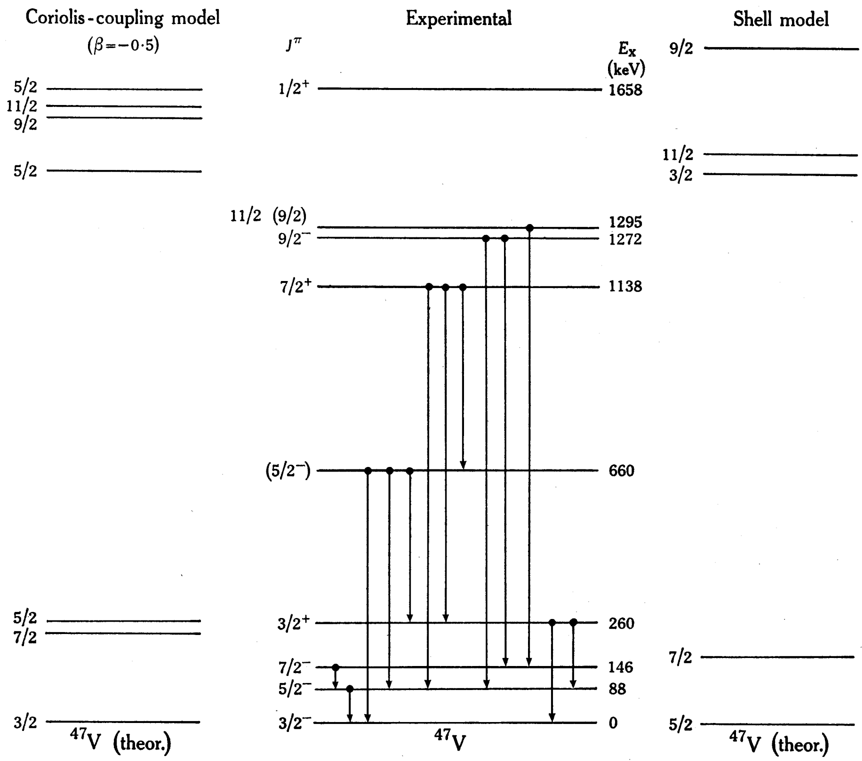

Fig. 3. Energy level scheme for ^{47}V constructed from this work and the compilation of Lewis (1970). The theoretical predictions of the shell model (McCullen et al. 1964) and rotational-particle (Coriolis-coupling) model (Malik and Scholz 1966) are presented for comparison. Only γ-decay branches exceeding 10% intensity are shown (cf. Table 1).

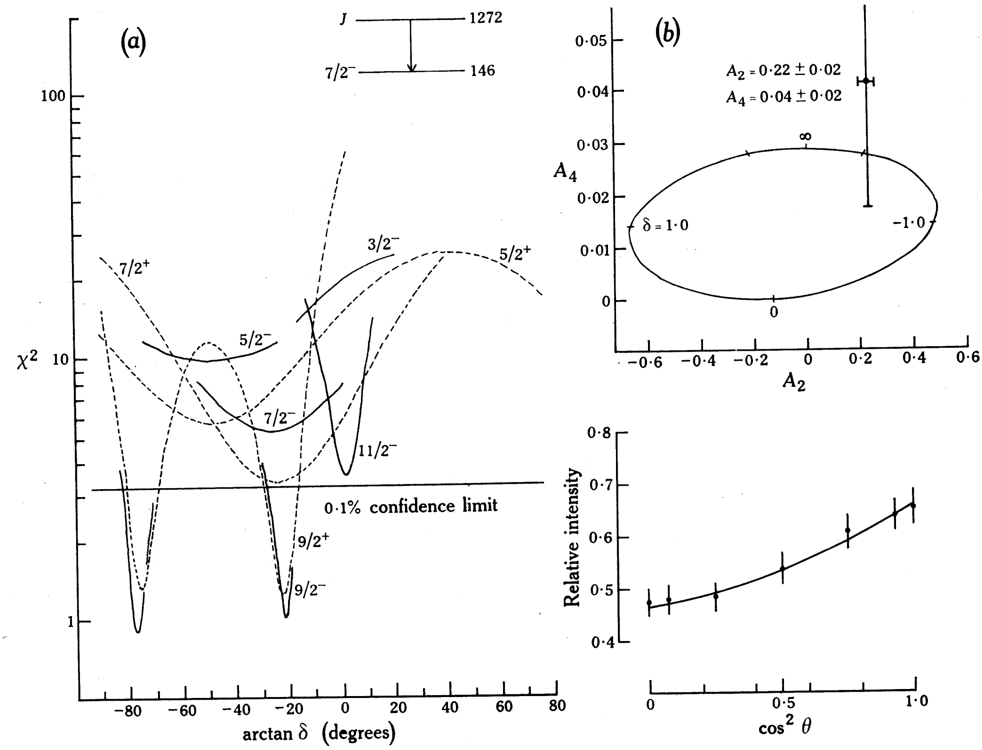

Fig. 4. Experimental angular distribution and the results of the MANDY program calculations for the 1272→146 keV transition in ^{47}V from the reaction ^{47}Ti(p, nγ)^{47}V at $E_p = 5 \cdot 162$ MeV. In (*b*) the theoretical ellipse in A_2–A_4 space for a $9/2^- \rightarrow 7/2^-$ transition is compared with a Legendre fit to the angular distribution data. The plots of χ^2 versus arctan δ in (*a*) are for different values of initial spin and parity of the 1272 keV level. The phase convention for δ is that of Rose and Brink (1967).

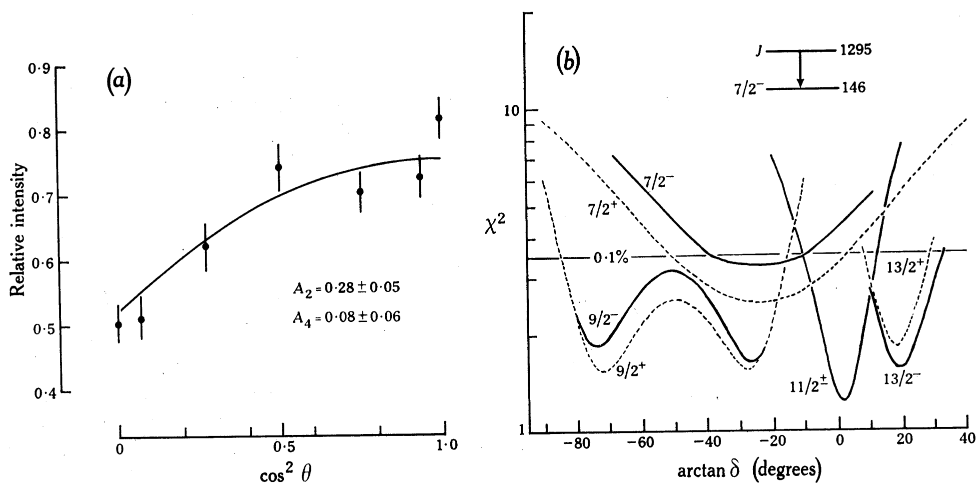

Fig. 5. Showing (*a*) the measured angular distribution for the 1295→146 keV transition in ^{47}V from the reaction ^{47}Ti(p, nγ)^{47}V at $E_p = 5 \cdot 162$ MeV, together with the curve of the Legendre polynomial fit to the data, and (*b*) the plots of χ^2 versus arctan δ obtained by comparing the experimental data with the predictions of the MANDY program.

In the following, all results are interpreted with reference to individual states. An energy level scheme is presented in Fig. 3. Limits on transition strengths accord with the survey by Skorka *et al.* (1966).

87·5 keV Level

The decay of this level was prominent in the low energy spectrum (Fig. 2), and an excitation energy of $87\cdot5 \pm 0\cdot1$ keV was assigned, in excellent agreement with the energy inferred from the Doppler shift studies. Earlier workers have assigned $J^{\pi} = 5/2^{-}$ to this state.

145·7 keV Level

This level has been established as $J^{\pi} = 7/2^{-}$ in previous studies. The γ-decay energy to the 87·5 keV level was measured to be $58\cdot2 \pm 0\cdot1$ keV, from which the excitation energy is $145\cdot7 \pm 0\cdot2$ keV. A small peak is evident in Fig. 2 at the correct energy for the $146 \rightarrow 0$ keV transition. After allowance for summing of the $146 \rightarrow 88 \rightarrow 0$ keV cascade γ-rays, this peak implies a branch of $(1\cdot0 \pm 0\cdot5)\%$. Independent confirmation of this tentative assignment by, say, observation in particle–gamma coincidence is clearly desirable.

660·1 keV Level

The observed γ-decay of this level to the $J^{\pi} = 3/2^{+}$ (259·6 keV), $5/2^{-}$ (87·5 keV) and $3/2^{-}$ (g.s.) levels effectively limits its spin to $J \leqslant 7/2$. McCallum and Pohl (1970) have further limited J to $\leqslant 5/2$, and favour a $5/2^{-}$ assignment. The angular distributions measured in this experiment did not change the restriction on the possible spin values. However, the transition strengths calculated using the branching ratios and lifetime reported herein preclude $J^{\pi} = 1/2^{\pm}$. Such an assignment would necessitate an implausibly strong quadrupole decay to the $5/2^{-}$ (87·5 keV) state (if $J^{\pi}(660) = 1/2^{-}$ then $\Gamma(\mathrm{E2}) > 80$ W.u.; if $J^{\pi} = 1/2^{+}$ then $\Gamma(\mathrm{M2}) > 3000$ W.u.).

1138 keV Level

This state has recently been assigned $J = 7/2$ by Schrader *et al.* (1973). Consideration of the present lifetime and branching ratios for the quadrupole transition to the 260 keV ($3/2^{+}$) level allows the rejection of negative parity ($\Gamma(\mathrm{M2}) > 600$ W.u. but $\Gamma(\mathrm{E2}) = 50 \pm 30$ W.u.).

1272·2 keV Level

Gamma decays to the 87·5 ($5/2^{-}$) and 145·7 ($7/2^{-}$) keV levels were observed, and the former branch was measured to be $(18 \pm 2)\%$. The angular distribution of the 1126 keV γ-ray (Fig. 4) allowed the exclusion of all spins except 9/2 for this level, with two possible values of the quadrupole–dipole mixing ratio ($\arctan\delta = -78° \pm 2°$ or $-22° \pm 2°$). The measured lifetime ($\tau = 0\cdot39$ ps) shows that positive parity for this level may be rejected as it would lead to an unacceptable M2 strength ($\Gamma(\mathrm{M2}) > 200$ W.u.) for the M2–E1 decay to the $7/2^{-}$ (145·7 keV) level. However, no discrimination between the values of δ is possible; the E2–M1 strengths derived from the lifetime are:

δ	Γ(M1) (W.u.)	Γ(E2) (W.u.)
$-0\cdot41 \pm 0\cdot05$	$0\cdot040 \pm 0\cdot022$	14 ± 8
$-4\cdot7 \pm 1\cdot0$	$0\cdot0020 \pm 0\cdot0012$	90 ± 50

The latter E2 strength is much stronger than average but may not be excluded. The $1272\cdot2 \rightarrow 87\cdot5$ keV ($J^\pi = 9/2^- \rightarrow 5/2^-$) decay has an E2 strength of 16 ± 9 W.u., which is typical of such transitions in this mass region (Nomura and Yamazaki 1971).

The $1272\cdot2$ keV level is presumed to be the low lying $9/2^-$ level predicted by Malik and Scholz (1966) and Ginocchio (1966).

1295·1 keV Level

This level appears to decay entirely to the $J^\pi = 7/2^-$ state at $145\cdot7$ keV, but we were unable to eliminate the possibility of low intensity branches ($<10\%$) to the $87\cdot5$ ($5/2^-$) and $660\cdot1$ ($5/2^-$) keV levels. The measured $F(\tau)$ for this decay is almost exactly zero but, because of the large errors associated with this measurement, all that can be said with certainty is that $\tau > 0\cdot75$ ps.

The measured angular distribution (Fig. 5) could not be fitted with better than $0\cdot1\%$ confidence for any spin less than 7/2. The most likely spins are 9/2 (with $\arctan\delta = -28° \pm 5°$ or $-72° \pm 6°$) or 11/2 (with $\arctan\delta = 2° \pm 3°$). The solutions for $J = 13/2$ require significant hexadecapole components in the transition. If one conservatively assumes hexadecapole strengths not exceeding 100 W.u. the level lifetime must exceed 1 ms. Nuclear spin relaxation times are expected to be several orders of magnitude shorter than this, so that our observation of anisotropy precludes $J^\pi \geqslant 13/2$. The solution $J^\pi = 7/2^+$ has only 1% confidence, and corresponds to a large, and unlikely, M2–E1 admixture; the $J^\pi = 7/2^-$ solution is even less likely. Thus we conclude $J = 9/2$ or $11/2$ for this level.

Discussion

Knowledge of the low lying states of ^{47}V has been considerably extended by the present measurements. Determinations of branching ratios, lifetimes and spins have been made for several levels, but comparison with theory is still tentative as no model calculations of transition strengths have yet been published.

The predicted energy level schemes for negative parity states in ^{47}V, based on a pure $1f_{7/2}$ shell model (Ginocchio 1966) and a Coriolis-coupling model (Malik and Scholz 1966), are compared with the measured decay scheme in Fig. 3. As noted by the above authors, the pure shell model fails to explain even the broad features of the ^{47}V level scheme (McCullen *et al.* 1964). The wrong ground state spin is predicted, and the triplet of low lying negative parity states is missing. However, in a deformed ($\beta > 0$) shell model, the ground state of ^{47}V ($Z = 23$, $N = 24$) would correspond to the last proton being in Nilsson orbital number 13 ($K^\pi = 3/2^-$), thus giving the correct ground state J^π.

No band structure is apparent in the energy level scheme of ^{47}V, indicating some mixing of the rotational bands based upon the 10 available single-particle or hole excited states in the 1f–2p shell. Using the wavefunctions of the 10 bands as a basis, Malik and Scholz (1966, 1967) exactly diagonalized the Hamiltonian containing the RPC term. These calculations showed that the band mixing in ^{47}V is such that a $3/2^-$ ground state is predicted only for large deformations ($\beta \leqslant -0\cdot4$ or $>0\cdot5$).

The model of Malik and Scholz, for a choice of deformation parameter $\beta = -0\cdot5$, is particularly successful in explaining the distribution of negative parity levels. The correct ground state spin is predicted and the presence of the low lying triplet, which eluded a pure shell model calculation, is explained. The high spin $9/2^-$

and $11/2^-$ levels have been found at a slightly lower energy than predicted by either model, but the ordering of these levels is as predicted by Malik and Scholz. The $5/2^-$ level predicted by the Coriolis-coupling model near 1·4 MeV probably corresponds to the 660 keV level. McCallum and Pohl (1970) tentatively assigned this level as $5/2^-$ on the basis of (p, γ) work.

With a large positive deformation parameter ($\beta > 0 \cdot 5$) the energy level spectrum is once again well reproduced. The characteristic ground state triplet is predicted, and the low lying $9/2^-$ and $11/2^-$ levels are again near 1 MeV, although in the reverse order to that observed experimentally.

The low lying positive parity states are not predicted by either model, and are probably due to core excitation of $d_{3/2}$ and $s_{1/2}$ hole states. The spherical shell model calculations of Ginocchio (1966) and Bansal and French (1964) place these states near 1·4 and 1·5 MeV respectively, but it seems likely that they are associated with the 260 ($3/2^+$) and 1658 ($1/2^+$) keV levels. The large deformation, which seems to be needed to explain the negative parity levels of this nucleus theoretically, would be sufficient to depress the $3/2^+$ level to the observed 260 keV excitation. The energy gap between the $d_{3/2}$ and $s_{1/2}$ Nilsson orbitals and the $f_{7/2}$ orbitals decreases as the nuclear deformation is increased ($\beta > 0$), thus decreasing the hole excitation energies. This phenomenon has been observed by Plendl *et al.* (1965) and Blasi *et al.* (1970) for the odd mass scandium isotopes where the excitation energy of the low lying $3/2^+$ levels decreases with increasing nuclear deformation.

The ordering of the positive parity states also indicates that the ^{47}V nucleus might have a positive deformation parameter. Only for $\beta > 0$ is the $3/2^+$ state (Nilsson orbital 8) closer to the $f_{7/2}$ levels than is the $1/2^+$ state (orbitals 9 and 11), indicating that for $\beta > 0$ the $3/2^+$ core-excited state would be at a lower excitation energy than the $1/2^+$ state. Experimentally the $3/2^+$ level is found at a lower excitation than the $1/2^+$ level. There is, however, the possibility that this ordering may be destroyed by the RPC, in which case nothing could be inferred from the positive parity level sequence, but the $1/2^+$ and $3/2^+$ states are well separated and the RPC effect would need to be very strong to change their ordering.

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