β^+ decay of 15.2-min ^{114}Te

B. E. Zimmerman
Department of Chemistry and Biochemistry, University of Maryland, College Park, Maryland 20742
and Department of Physics, University of Tennessee, Knoxville, Tennessee 37996

W. B. Walters
Department of Chemistry and Biochemistry, University of Maryland, College Park, Maryland 20742

Zs. Dombrádi and Z. Gácsi
Institute for Nuclear Research of the Hungarian Academy of Sciences, H-4001 Debrecen 51, Hungary

P. F. Mantica, H. K. Carter, and J. Kormicki
Oak Ridge Institute for Science and Education, Oak Ridge, Tennessee 37831
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The β^+ decay of 15.2 min ^{114}Te into levels of ^{114}Sb was studied through γ-ray and conversion electron spectroscopy at the UNISOR on-line isotope mass separator. Multiscaled γ-ray and electron singles provided for the determination of energies and intensities for 94 transitions (68 new) and of internal conversion coefficients for 12 of these transitions. The level scheme was deduced from γ-γ and γ-e coincidence measurements and extended to 2.1 MeV. The energy spectrum and electromagnetic properties of levels and associated transitions were calculated in the interacting boson-fermion-fermion model (IBFFM), with good agreement between experimental and theoretical results.

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I. INTRODUCTION

The study of odd-odd nuclei near the $Z=50$ closed shell provides an excellent basis for an investigation of the effective interaction between neutrons and protons. Such investigations [1–5] have been carried out in the neutron-deficient $Z=51$ nuclides ^{116,118,120}Sb. Until recently, interpretation of the low-energy level structure of ^{114}Sb has suffered from insufficient transition data and lack of definite spin and parity assignments.

The only previously reported investigation of the decay of ^{114}Te into ^{114}Sb is that of Wigmans *et al.* [6]. Several levels up to 1.9 MeV were reported, but few level spins have been firmly established. Those that were proposed remained tentative and transition intensities remained unreported due to a lack of a suitable normalization. Many transition sequences were also incorrectly deduced, possibly due to a lack of sufficient coincidence data.

The presence of a negative parity $I=8$ isomer was first proposed by Gil *et al.* [7], who reported a 275-μs level at 422 keV decaying via an $E3$ transition to a level at 96 keV, followed by an $E2$ transition to ground. Subsequent works of Van Nes *et al.* [8], Kamermans *et al.* [9], and Duffait *et al.* [10] established the position of the isomer at 495 keV with decay by a 322-keV $E3$ transition and cascades through low-energy levels to ground. Much of this work, however, concentrated on feeding into the isomer from high-energy states and nearly all of the reported structure information below the isomer has been based on the level scheme of Wigmans *et al.* A study of collective structures at high spin (up to $I=35$) and high excitation energy (18 MeV) was recently reported [12], with only two out of seven observed bands having established decay routes to the isomer.

A recent study using the $(p,n\gamma)$ reaction has been conducted by Gácsi and Dombrádi [11] and the low-energy level scheme deduced to 1.0 MeV with population of levels up to $I=5$.

The magnetic dipole moment of the 3^+ ground state of ^{114}Sb was measured by Zimmerman *et al.* [13] to be $1.72(8)\mu_N$ and interpreted to be an indication of the onset of mixing of 3^+ members of the two lowest-lying energy level multiplets, with the major contribution coming from the $\pi d_{5/2}\nu g_{7/2}$ configuration.

II. EXPERIMENTAL TECHNIQUES

The experiments performed in this investigation were carried out at the UNISOR (University Isotope Separator at Oak Ridge) mass separator, on line to the 25-MV tandem accelerator at the Holifield Heavy Ion Research Facility. Ions of ^{114}Te were produced in a FEBIAD (Forced Electron Beam-Induced Arc Discharge) type ion source using the reaction of 220-MeV ^{32}S ions on a series of isotopically enriched ^{92}Mo foils with a combined thickness of 6 mg/cm^2. The ions were then mass separated and the $A=114$ products deposited into a Mylar tape to be moved sequentially to two shielded counting stations via a computer-controlled moving tape transport system.

The detector setup at the first counting station consisted of two Ge γ-ray detectors and a Si electron detector, which was used in conjunction with a miniorange filter. The miniorange was placed 4 cm from the tape, and the detector positioned 1 cm from the miniorange. This arrangement was used to maximize the count rate of conversion electrons below 1 MeV. A large (44%) Ge detector was placed at 90° relative to the beam axis beneath the tape. A 2.5-cm Al disk was placed between the source and the detector to minimize the β background. A smaller (15%) detector was placed in a horizontal

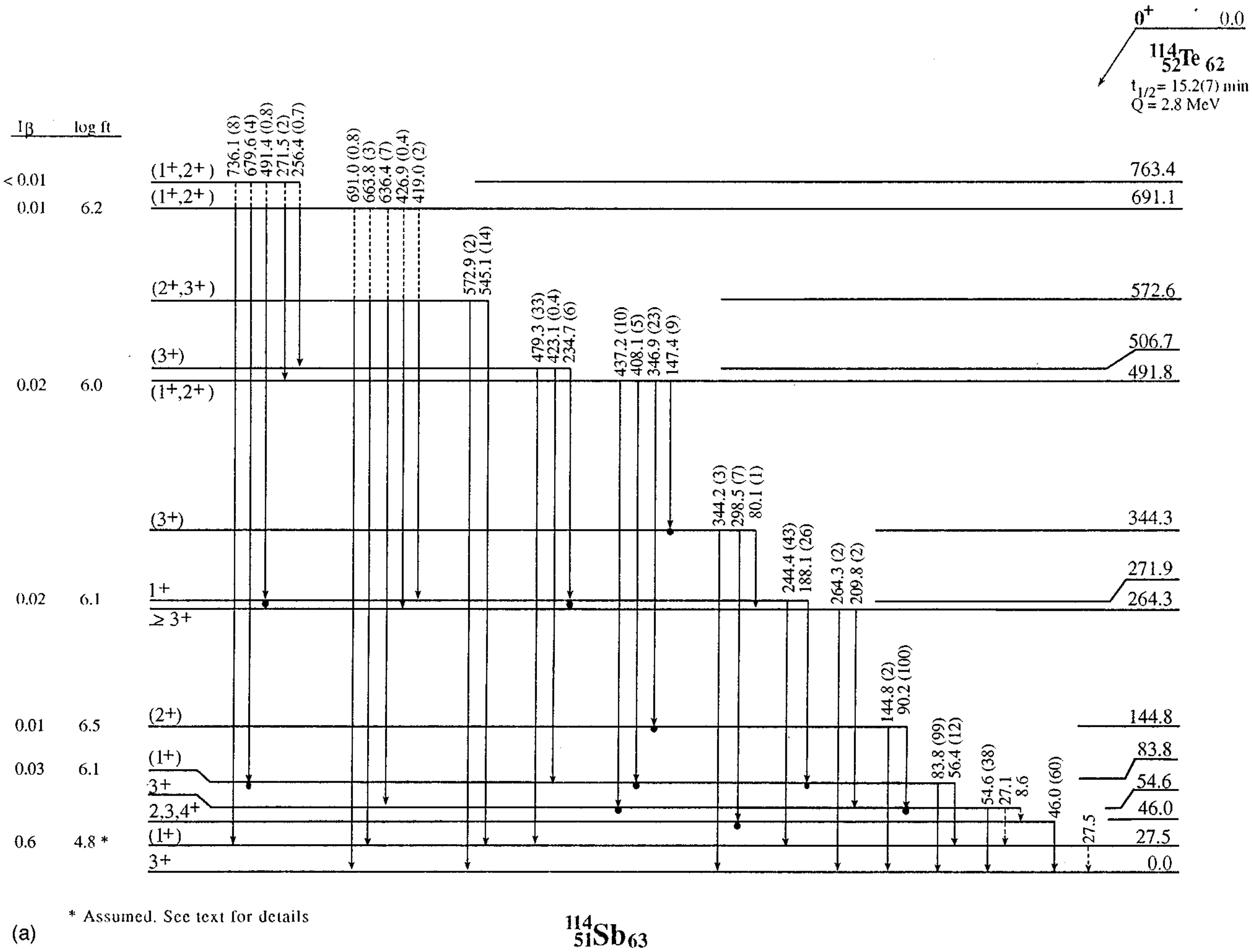

FIG. 1. Proposed level scheme for the decay of ^{114}Te, showing decay from levels from 763 to 28 keV (a), 1670 to 806 keV (b), and 2140 to 1757 keV (c). Intensities include internal conversion. Transitions placed via coincidence relationships are marked with solid circles; other transitions placed via energy sum relationships. Decay branching ratios and log ft values are also given. See main text for details of log ft calculations.

position at 90° relative to both the beam axis and the large Ge detector and at 180° relative to the Si detector.

The detector arrangement at the second station was identical to that of the first station with the exception that the miniorange was not used with the electron detector, resulting in better low-energy efficiency which complemented the Si +miniorange combination at the first station.

Absolute detector efficiency and energy calibrations for the Ge detectors were obtained both prior and subsequent to the experiment through the use of a standard mixed ^{125}Sb/^{154,155}Eu source placed in the beamline at the exact source position. Relative efficiency and energy calibrations for the electron detectors were obtained from a ^{137}Cs/^{207}Bi source placed in the beamline at the position of the implanted source.

Singles γ and electron data were collected in all of the detectors at both stations with a Nuclear Data ND9900 acquisition system based on a DEC Micro Vax II. Multiscaled γ singles spectra were also collected to allow for half-life determination of the observed transitions. Multiscaled data were collected in a series of eight 60-s planes with a 1-s tape move and 0.5 s between planes, for a total cycle time of 484.5 s at each station and 969 s (16.15 min) for each source at both stations.

Dual coincidence data were collected throughout the experiment among all three detectors at both stations with a Concurrent Computer Corp. 3230 computer. A total of 1.3×10^6 γ-γ coincidences were recorded over the duration of the experiment.

III. EXPERIMENTAL RESULTS

Figure 1 shows the proposed level scheme derived from the data collected from the decay of ^{114}Te. Tables of γ-ray singles and coincidence results are presented in material deposited with the Physics Auxiliary Publication Service [14]. Portions of the summed γ-ray and electron singles spectra are presented in Fig. 2. With the exception of the levels at 28, 264, 691, and 1109 keV, all of the levels are proposed on the basis of at least one γ ray having a coincidence relationship. The levels at 84, 272, 763, 806, 1017, 1924, and 1986 keV are all established primarily through observed coincidences with the 83.8-keV γ ray. The level at 1924 keV is further confirmed by strong coincidences with γ rays from other established levels such as shown in Fig. 3.

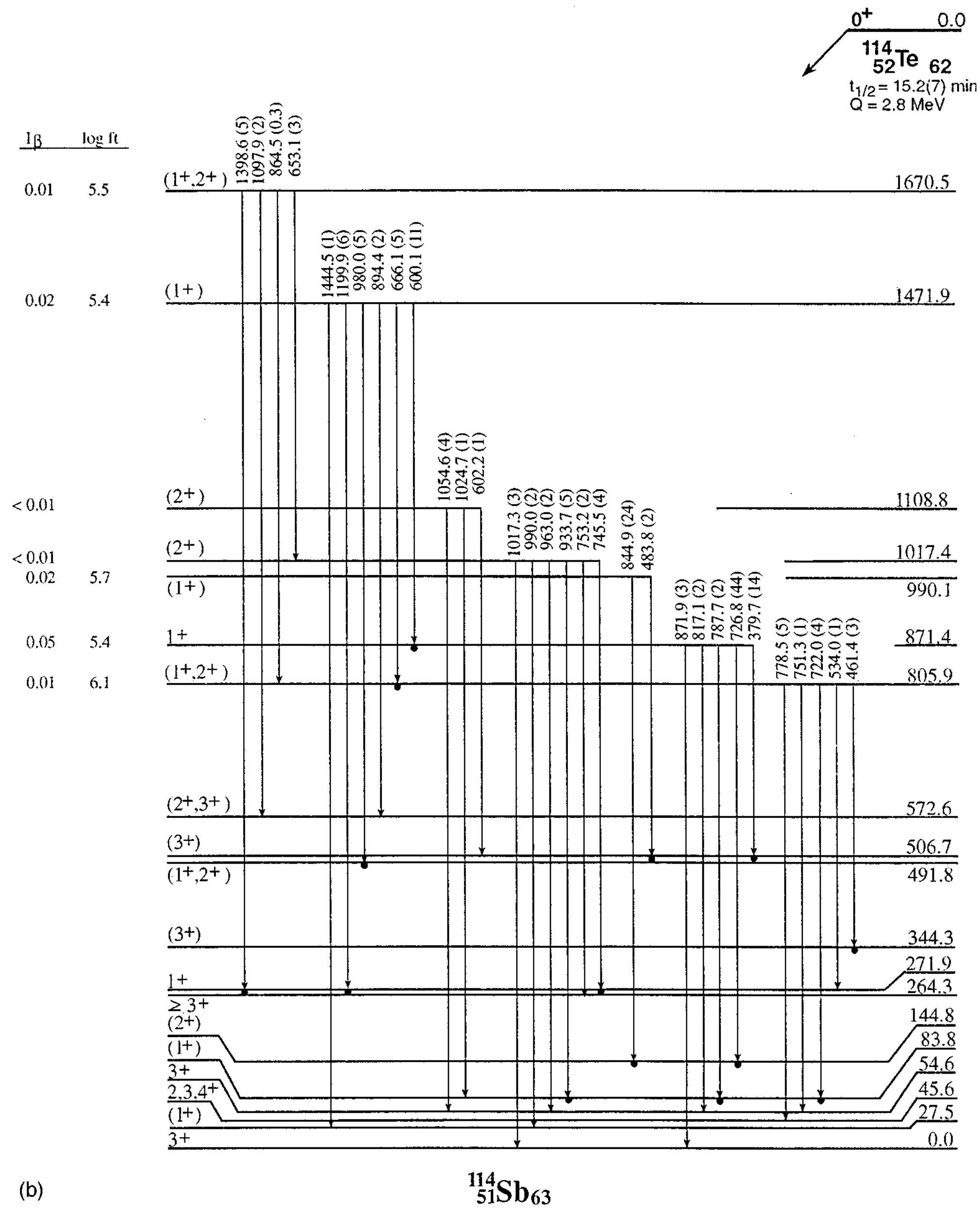

FIG. 1 (*Continued*).

The level at 507 keV is placed due to the observed strong coincidence between the 234.7- and 188.1-keV γ rays. The observed coincidence between the 234.7-keV γ ray and the 188.1-and 244.4-keV γ rays, along with the lack of a 244.4-keV transition in the 188.1-keV gate, first suggested a level at 27.5 keV. This level is also suggested by an energy-sum relationship with the 56.6-keV γ ray, which is in coincidence with the 188.1-keV γ ray. The intensity of the 27.5-keV de-exciting transition could not be determined due to an inability to resolve it from the Te, Sb, and Sn x rays and its energy is determined by a weighted average of the energy differences of transitions which decay from levels which feed both this level and the ground state.

The levels at 46 and 55 keV are proposed on the basis of observed coincidences with the 90.2-keV γ ray (shown in Fig. 4), as well as with the 726.8-keV γ ray. Gates on these transitions show that the ratio of the intensities of the 46.0- and 54.6-keV γ rays is the same as that observed in the singles spectrum, suggesting that the transitions are not in cascade. The presence of both the 54.6- and 46.0-keV transitions in the 90-keV gate indicates an (unobserved) intervening transition with energy 8.6 keV. An imbalance in the decay intensity feeding into and decaying out of the 54.6-keV level requires that an additional (unobserved) transition decay out of the level. Thus a 27.1-keV transition is proposed on this basis.

Time spectra obtained by gating the γ-γ time-to-amplitude converter (TAC) on energy in one detector while requiring a coincidence with any other γ ray are shown in Fig. 5. The time spectra gated on the 83.8- and 90.2-keV γ rays show characteristic prompt responses, while the 46.0- and 54.6-keV gated spectra are clearly delayed. Fits of the slopes of the decay curves show half-lives of 26(3) and 20.4(9) ns for the 45.96- and 54.64-keV transitions, respectively. These are consistent with the upper limit of 24(5) ns

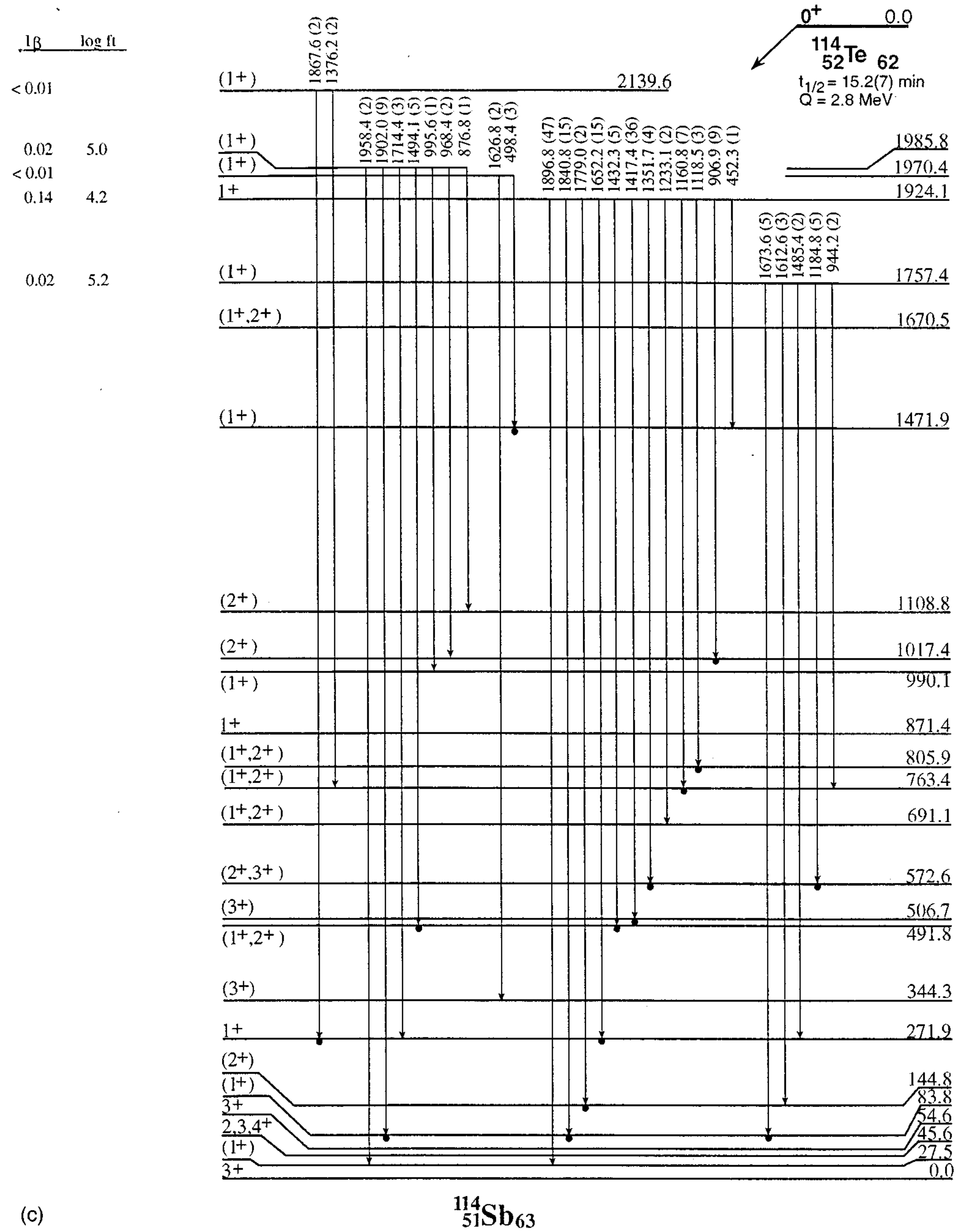

FIG. 1 (*Continued*).

for the 45.6- and 54.6-keV transitions reported by Wigmans *et al.*

Because they were unable to observe the coincidence between the 726.8- and the 46.0- and 54.6-keV transitions, Wigmans *et al.* had placed the low-energy γ rays *above* the 90-keV γ ray and were unable to assign the half-lives to levels in the scheme. This would have required that the 90.2-keV transition have a delayed component in the time spectrum, but this was observed in neither the present work nor that of Gácsi and Dombrádi [11]. However, by placing the transitions *below* the 90.2-keV γ ray, we are now able to reconcile both the half-lives and the coincidences. Thus half-lives of 26(3) and 20.4(9) ns can be assigned to the levels at 46 and 55 keV, respectively.

The 264-keV level is proposed due to a coincidence observed between the 80.1-, 264.3-, and 147.4-keV γ rays. The 209.8-keV γ ray is placed by energy sums, but is confirmed by the coincidence data of Gácsi and Dombrádi [11].

The level at 492 keV is proposed based on an observed coincidence between the 437.2-, 408.1-, 346.9-, and 147.4-keV γ rays with the 54.6-, 83.8-, 90.2-, and 298.5-keV γ rays, respectively. The level at 573 keV is proposed based on coincidences between the 545.1- and 1184.8-keV transitions.

The level at 871 keV is based on a 726.8-keV/90.22-keV coincidence. The level at 990 keV is proposed based on coincidence relationships between the 90.2- and 844.9-keV γ rays.

Where necessary to place weak γ rays or ones for which a clean coincidence gate was not possible, we have adopted the coincidence relations observed by Gácsi and Dombrádi. We have placed the 483.8-keV γ ray as deexciting the level at 990 keV based on their observed coincidence with the

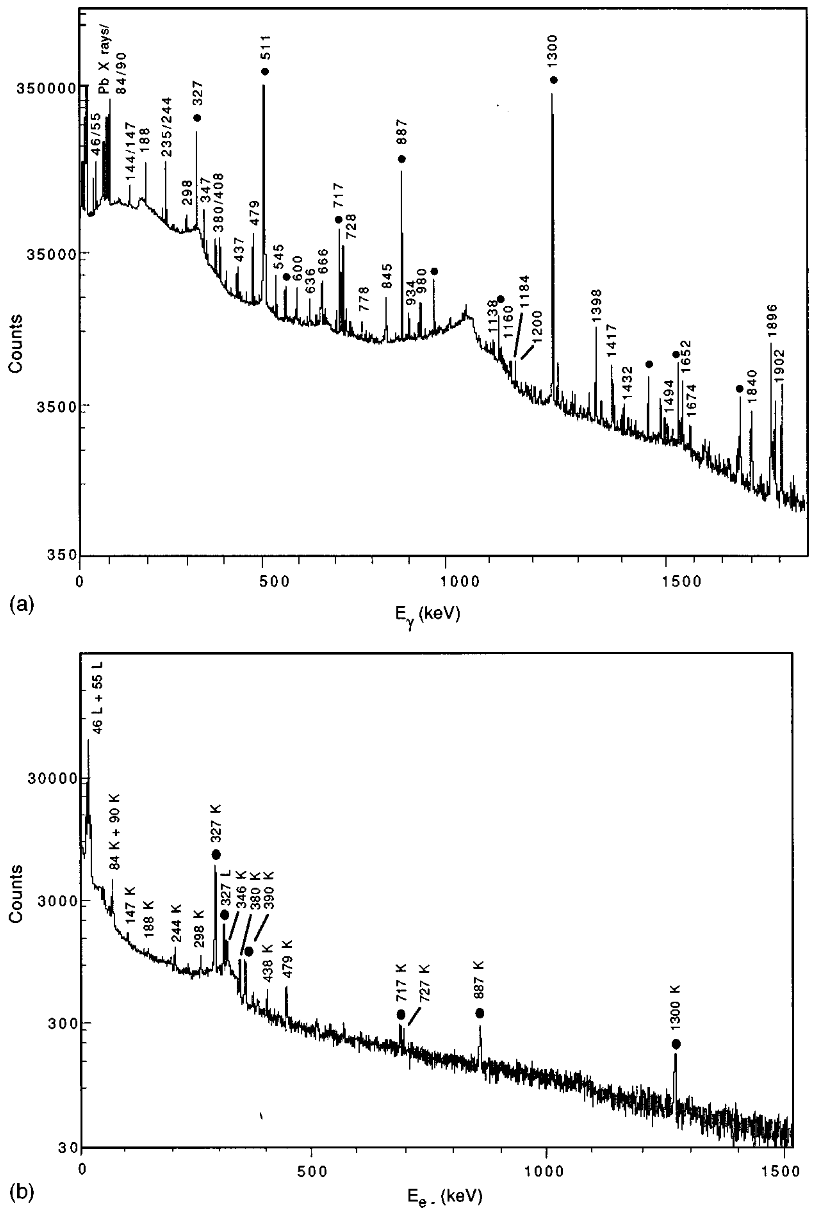

FIG. 2. Portions of the γ-ray (a) and electron (b) singles spectra obtained from the decay of ^{114}Te. All multiscaled planes are summed.

479.3-keV transition. Similarly, our placements of the 419.0- and 636.4-keV transitions are based on their coincidence relationships.

The results of the conversion electron measurements are presented in Fig. 6, along with plots of the theoretical internal conversion coefficients for $E1$, $E2$, and $M1$ multipolarities [15]. Experimental values for K- and L-shell internal conversion coefficients were normalized to those determined by Gácsi and Dombrádi [11] for the 188-keV γ ray. All transitions were observed to be of $E2/M1$ character.

Determination of the absolute β population of the levels is not possible, owing to the probable high intensity of direct population of the 1^+ level at 27 keV, whose intensity we were unable to measure. Moreover, the low count rates in the coincidence spectra made placement of many γ transitions uncertain; hence determination of β feeding by the difference between population and depopulation of levels only gives upper limits. In addition, depopulation of the levels below 200 keV is also uncertain owning to the uncertainties of the conversion electron coefficients.

The β decay to the 1^+ level at 27 keV has been estimated by assuming a log*ft* value of 4.8, which is comparable to that observed in the population of the low-energy 1^+ level in the decay of ^{116}Te to levels of ^{116}Sb [16]. In spite of small intensity imbalances, the conversion coefficients are sufficiently well established for the 83.8- and 90.2-keV transitions to be certain that neither is a pure $E2$ transition, implying that the 83-keV level does not have spin and parity 1^+.

We can be certain of the 1^+ assignments for the levels at 1986, 1924, 1472, and 871 keV. There are several other levels for which a β population imbalance is present, but not such that unplaced γ rays could account for the imbalance. The levels at 272 and 492 keV are examples of such population balances. Gácsi and Dombrádi [11] assign the former as a 1^+ level, and the latter as a 2^+ level on the basis of angular distribution measurements. The level at 990 keV is also most likely to be a 1^+ level. It does not appear to be the same level as that shown by Gácsi and Dombrádi at the same energy, inasmuch as we do not observe the γ ray at 719 keV that they place as the strongest depopulating γ transition

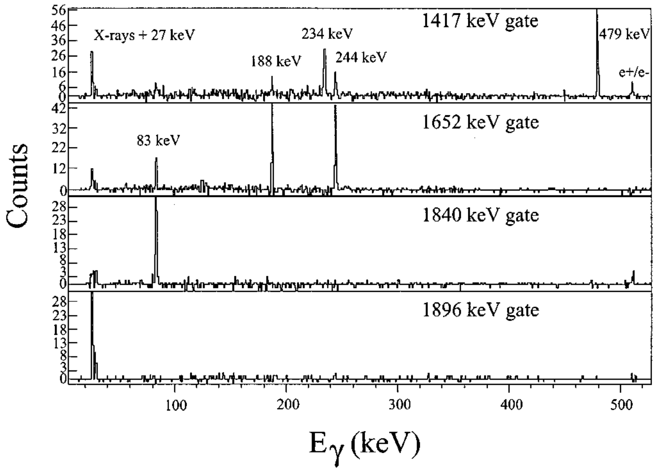

FIG. 3. Low-energy portions of gates on the 1417.4-, 1652.2-, and 1840.8-keV transitions which establish the level at 1924 keV.

from that level. Thus there is most likely a level doublet at that energy.

The strong β decay to the 1^+ level at 1924 keV is of some interest, as the log*ft* value of 4.2 implies a strong Gamow-Teller allowed transition. The strong transition to the low-energy 1^+ level has been clearly observed in the decay of ^{116}Te and found to have a log*ft* of 4.8. The theoretical analysis [1,2] of the daughter 1^+ state shows the neutron configuration to be largely $d_{3/2}$; hence the strong β transition would be the Gamow-Teller allowed transition that converts the $d_{5/2}$ proton in ^{114}Te to the $d_{3/2}$ neutron in ^{114}Sb. It is highly unlikely that a fragment of that transition could lie at 2 MeV. Therefore we suggest that the rapid β transition to the 1924-keV level must imply the decay of a core $g_{9/2}$ proton to a $g_{7/2}$ neutron via the Gamow-Teller spin-flip transition. Such a transition at this energy is possible given that the location of the $g_{9/2}$ proton intruder hole state is known to lie at 1461 keV in ^{113}Sb.

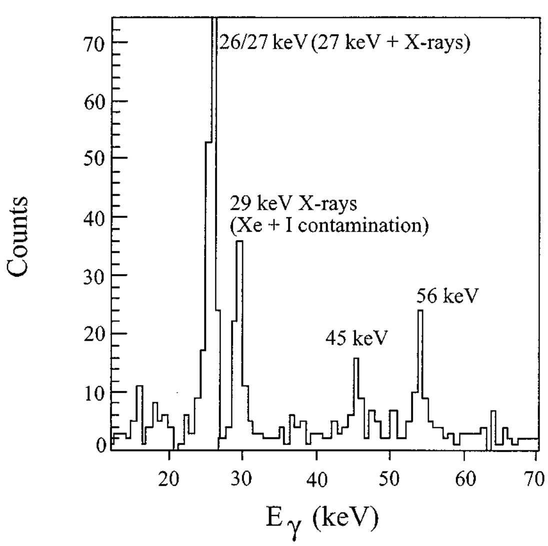

FIG. 4. Low-energy portion of coincidence spectrum gated on the 90.2-keV γ ray.

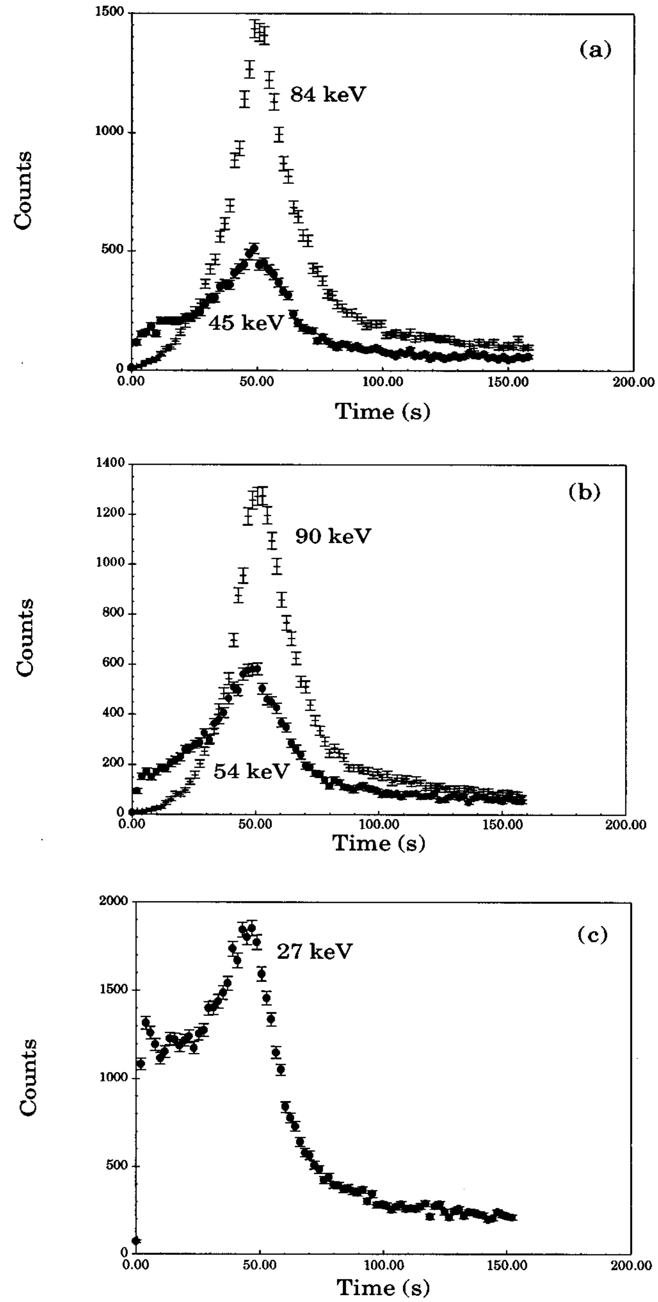

FIG. 5. Time spectra gated by the 83-, 90-, (prompt) and 45-, 54-, and 27-keV (delayed) transitions, requiring a coincidence with any other γ ray.

IV. INTERACTING BOSON-FERMION-FERMION MODEL DESCRIPTION

A. Hamiltonian

The Hamiltonian of the interacting boson-fermion-fermion model [17] is

$$H_{\mathrm{IBFFM}} = H_{\mathrm{IBFM}}(\pi) + H_{\mathrm{IBFM}}(\nu) - H_{\mathrm{IBM}} + H_{\mathrm{eff}},$$

where $H_{\mathrm{IBFM}}(\pi)$ and $H_{\mathrm{IBFM}}(\nu)$ denote the interacting boson-fermion model (IBFM) Hamiltonians for the neighboring odd-even nuclei with an odd proton and odd neutron, respec-

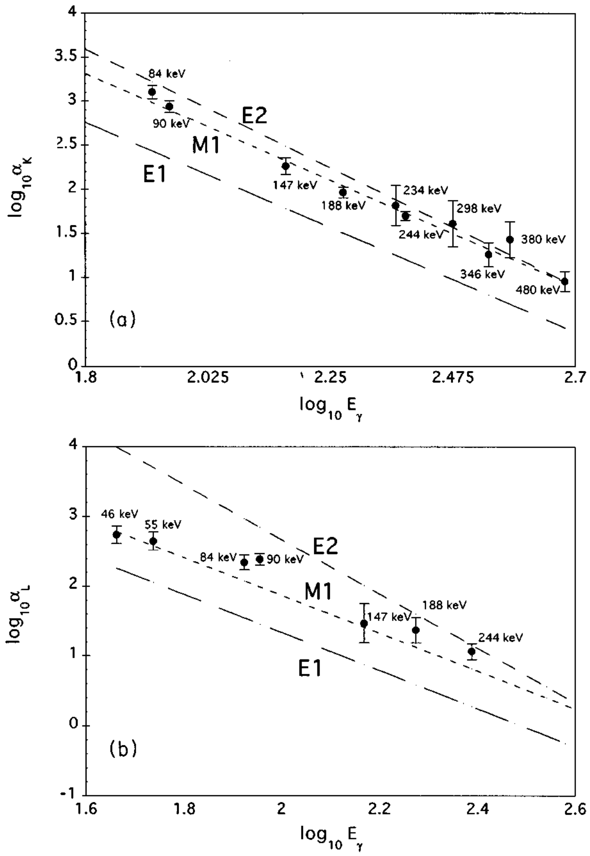

FIG. 6. Experimentally determined internal K- and L-electron conversion coefficients observed in the decay of ^{114}Te. Experimental values are normalized to the α_K for the 188-keV transition as measured by Gácsi and Dombrádi [11]. Theoretical $E1$, $M1$, and $E2$ curves are also shown.

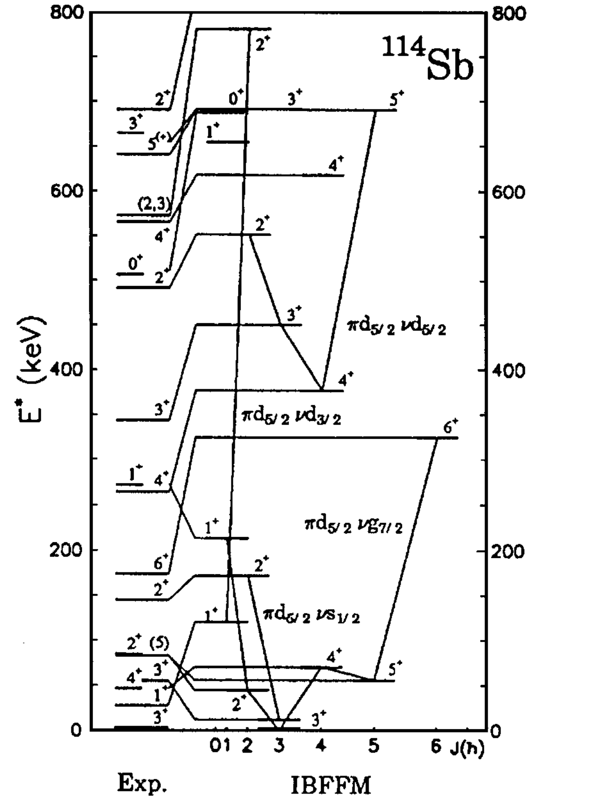

FIG. 7. IBFFM and experimental energy spectra of low-lying ^{114}Sb states. The abscissa is scaled according to $I(I+1)$, where I is the spin of the state.

tively [18]. H_{IBM} denotes the IBM Hamiltonian [19] for the even-even core nucleus. H_{eff} denotes the effective proton-neutron interaction.

The IBFFM Hamiltonian was diagonalized in the proton-neutron-boson basis:

$$|(j_\pi, j_\nu)J, n_d R; I\rangle,$$

where j_π and j_ν stand for the proton and neutron angular momenta coupled to J, n_d is the number of d bosons, R is their total angular momentum, and I is the spin of the state. The computer code IBFFM, used for the calculations, was written by Brant, Paar, and Vretenar [20].

B. Parameters

In this work the core Hamiltonian was approximated with its SU(5) limit, which is reasonable for spherical nuclei. Since the introduction of anharmonicities, allowed in the SU(5) limit, had negligible effects on the states investigated, they were neglected. The only parameter of the core, the *d-boson energy* (ϵ_d), was taken as the energy of the 2_1^+ states of the neighboring even-even ^{112}Sn isotope to be 1.257 MeV. Because reduced boson number can be used in the SU(5) limit, we restricted the maximal number of the d bosons to 2, which largely simplified the calculations. The present calculations show that the total contribution even of the two d-boson components was weak in the wave functions of the states investigated, which suggests that there is no need for further d bosons.

The *model space* consisted of the $s_{1/2}$, $d_{3/2}$, $d_{5/2}$, $g_{7/2}$, and $h_{11/2}$ states for both the protons and neutrons. The single proton was assumed to be a particle, while the neutrons were treated as quasiparticles. The *occupation probabilities* for the neutrons were calculated in the BCS approximation using the parametrization proposed by Kisslinger and Sorensen [21] as in Ref. [11]. The V^2 values deduced are consistent with the experimental systematics. We had to renormalize the relative energies of the quasineutron states slightly (max 200 keV) to get better agreement in the odd-odd nuclei.

The quasiparticle energies and occupation probabilities used in the calculations are given below:

$$V^2(\tilde{s}_{1/2}) = 0.412, \quad E(\tilde{s}_{1/2}) = 0.125 \text{ MeV},$$

$$V^2(\tilde{d}_{3/2}) = 0.091, \quad E(\tilde{d}_{3/2}) = 1.15 \text{ MeV},$$

$$V^2(\tilde{d}_{5/2}) = 0.836, \quad E(\tilde{d}_{5/2}) = 0.30 \text{ MeV},$$

$$V^2(\tilde{g}_{7/2}) = 0.671, \quad E(\tilde{g}_{7/2}) = 0.00 \text{ MeV},$$

$$V^2(\tilde{h}_{11/2}) = 0.119, \quad E(\tilde{h}_{11/2}) = 0.60 \text{ MeV}.$$

The *single particle energies* for the proton states were taken as 2.3, 2.6, 0.0, 0.9, and 2.4 MeV for the $s_{1/2}$, $d_{3/2}$, $d_{5/2}$, $g_{7/2}$, and $h_{11/2}$ states, respectively. The 0.9-MeV $g_{7/2}$ energy is in agreement with experiment if the self-energy correction

TABLE I. Wave functions of low-lying states of ^{114}Sb. For the given J^π states, the $\vert(j_\pi,j_\nu)I;NR\rangle$ wave function components and the corresponding amplitudes are given. Only amplitudes larger than 0.2 are shown.

0_1^+		3_1^+	
$\vert(d_{5/2},g_{7/2})2;12\rangle$	0.847	$\vert(d_{5/2},g_{7/2})3;00\rangle$	−0.751
$\vert(d_{5/2},g_{7/2})4;24\rangle$	−0.299	$\vert(d_{5/2},s_{1/2})3;00\rangle$	−0.349
$\vert(d_{5/2},g_{7/2})2;22\rangle$	0.274	$\vert(d_{5/2},g_{7/2})5;12\rangle$	0.248
1_1^+		$\vert(d_{5/2},g_{7/2})4;12\rangle$	−0.245
$\vert(d_{5/2},d_{3/2})1;00\rangle$	0.750	$\vert(d_{5/2},g_{7/2})3;12\rangle$	−0.223
$\vert(d_{5/2},g_{7/2})1;00\rangle$	−0.311	3_2^+	
$\vert(d_{5/2},d_{3/2})2;12\rangle$	0.216	$\vert(d_{5/2},s_{1/2})3;00\rangle$	−0.781
1_2^+		$\vert(d_{5/2},g_{7/2})3;00\rangle$	0.336
$\vert(d_{5/2},g_{7/2})1;00\rangle$	−0.772	$\vert(d_{5/2},s_{1/2})3;12\rangle$	0.264
$\vert(d_{5/2},g_{7/2})3;12\rangle$	0.378	3_3^+	
$\vert(d_{5/2},d_{3/2})1;00\rangle$	−0.345	$\vert(d_{5/2},d_{5/2})3;00\rangle$	−0.801
1_3^+		$\vert(d_{5/2},d_{5/2})4;12\rangle$	−0.434
$\vert(d_{5/2},d_{5/2})1;00\rangle$	0.532	$\vert(d_{5/2},d_{5/2})2;12\rangle$	0.207
$\vert(d_{5/2},s_{1/2})3;12\rangle$	−0.450	3_4^+	
$\vert(s_{1/2},s_{1/2})1;00\rangle$	−0.325	$\vert(d_{5/2},g_{7/2})5;12\rangle$	−0.479
$\vert(d_{5/2},g_{7/2})2;12\rangle$	0.211	$\vert(d_{5/2},g_{7/2})4;12\rangle$	−0.456
$\vert(d_{5/2},g_{7/2})1;00\rangle$	−0.205	$\vert(d_{5/2},g_{7/2})2;12\rangle$	−0.447
2_1^+		$\vert(s_{1/2},g_{7/2})3;00\rangle$	−0.269
$\vert(d_{5/2},g_{7/2})2;00\rangle$	0.780	4_1^+	
$\vert(d_{5/2},g_{7/2})4;12\rangle$	−0.337	$\vert(d_{5/2},g_{7/2})4;00\rangle$	−0.847
$\vert(d_{5/2},g_{7/2})2;12\rangle$	0.293	$\vert(d_{5/2},g_{7/2})5;12\rangle$	−0.366
$\vert(d_{5/2},s_{1/2})2;00\rangle$	−0.205	4_2^+	
2_2^+		$\vert(d_{5/2},d_{5/2})4;00\rangle$	0.846
$\vert(d_{5/2},s_{1/2})2;00\rangle$	−0.809	$\vert(d_{5/2},d_{5/2})5;12\rangle$	0.352
$\vert(d_{5/2},s_{1/2})2;12\rangle$	0.253	$\vert(d_{5/2},d_{5/2})3;12\rangle$	−0.233
$\vert(d_{5/2},g_{7/2})2;00\rangle$	−0.211	4_3^+	
2_3		$\vert(d_{5/2},g_{7/2})6;12\rangle$	0.469
$\vert(d_{5/2},d_{5/2})2;00\rangle$	−0.688	$\vert(d_{5/2},g_{7/2})5;12\rangle$	0.457
$\vert(d_{5/2},d_{5/2})3;12\rangle$	−0.368	$\vert(d_{5/2},g_{7/2})3;12\rangle$	0.314
$\vert(d_{5/2},d_{3/2})2;00\rangle$	0.336	$\vert(d_{5/2},d_{3/2})4;00\rangle$	−0.295
2_4^+		$\vert(d_{5/2},g_{7/2})4;12\rangle$	−0.282
$\vert(d_{5/2},d_{3/2})2;00\rangle$	0.704	$\vert(s_{1/2},g_{7/2})4;00\rangle$	0.256
$\vert(d_{5/2},d_{5/2})2;00\rangle$	0.377	$\vert(d_{5/2},d_{3/2})4;12\rangle$	0.223
$\vert(d_{5/2},d_{3/2})1;12\rangle$	−0.372	5_1^+	
2_5^+		$\vert(d_{5/2},g_{7/2})5;00\rangle$	0.857
$\vert(d_{5/2},g_{7/2})2;12\rangle$	0.506	$\vert(d_{5/2},g_{7/2})6;12\rangle$	0.365
$\vert(d_{5/2},g_{7/2})3;12\rangle$	−0.438	$\vert(d_{5/2},g_{7/2})4;12\rangle$	−0.200
$\vert(d_{5/2},g_{7/2})1;12\rangle$	−0.415	5_2^+	
$\vert(d_{5/2},s_{1/2})3;12\rangle$	0.220	$\vert(d_{5/2},d_{5/2})5;00\rangle$	−0.809
$\vert(d_{5/2},g_{7/2})4;24\rangle$	−0.215	$\vert(d_{5/2},d_{5/2})4;12\rangle$	0.363
		6_1^+	
		$\vert(d_{5/2},g_{7/2})6;00\rangle$	0.800
		$\vert(d_{5/2},g_{7/2})5;12\rangle$	−0.352

of the particle-vibration coupling is taken into account. The other states are so high in energy that their exact energy only slightly influences the results of the IBFFM calculations.

The proton and the neutron *boson-fermion coupling strength parameters* were fitted to the level energies and electromagnetic moments of the neighboring odd ^{113}Sb and ^{113}Sn isotopes by IBFM calculations. The dynamical and monopole proton interaction strengths were Γ_π=0.65 and A_π=0.05 MeV, respectively. The exchange interaction strength was neglected, as the boson consists of neutron excitations. The neutron dynamical, monopole, and exchange interaction strengths were Γ_ν=0.6, A_ν=0.05, and Λ_ν=1.5 MeV, respectively, in accordance with the strength parameters used for the description of heavier Sb nuclei [22].

A spin-dependent δ interaction with an additional spin polarization term was used for the effective proton-neutron interaction:

$$H_{\rm eff}=V_0\,\delta(\mathbf{r}_\pi-\mathbf{r}_\nu)(1+\alpha\sigma_\pi\sigma_\nu)+V_{\rm SP}[\sigma_\pi\sigma_\nu]_0\,.$$

TABLE II. Transitions between low-lying ^{114}Sb states. The experimental data marked with asterisks were taken from Ref. [10]. The index C indicates calculated in the frame of IBFFM values.

E_i (keV)	I_i	E_f (keV)	I_f	I_γ/E_γ^3 (Rel.)	$B(M1)_C$ (Rel.)
83	2_1^+	0	3_1^+	100	100
		27	1_1^+	39	16
145	2_2^+	0	3_1^+	4	85
		55	3_2^+	100	100
265	4_2^+	0	3_1^+	62	98
		55	3_2^+	100	100
		84	5_1^{+*}	25	118
272	1_2^+	27	1_1^+	77	44
		83	2_1^+	100	100
344	3_3^+	0	3_1^+	3	<1
		46	$4_1(2)^+$	12	1
		264	4_2^+	100	100
492	2_3^+	55	3_2^+	5	<1
		83	2_1^+	3	1
		145	2_2^+	23	<1
		344	3_3^+	100	100
507	0_1^+	27	1_1^+	69	146
		272	1_2^+	100	100
573	$(2_4,3)$	0	3_1^+	10	9
		27	1_1^+	100	100
		272	1_2^+	36	68
665	3_4^{+*}	83	2_1^{+*}	50	183
		145	2_2^{+*}	100	100
		344	3_3^{+*}	90	10
691	2_5^+	0	3_1^+	9	101
		27	1_1^+	33	24
		55	3_2^+	100	100
		272	1_2^+	73	24
		344	3_3^{+*}	167	30

The short-range proton-neutron effective interaction strengths $V_0=-500$ MeV fm^3 and $\alpha=0.15$ are deduced from the doubly closed shell nuclei [23]. The radial matrix elements were calculated using harmonic oscillator wave functions with oscillator parameter $b=2.29$ fm. The spin polarization interaction with a strength of $V_{\rm sp}=0.06$ MeV was used. The strength of the effective spin-spin interaction, which simulates the admixing of $M1$ giant resonance to the low-lying states, was estimated from the effective spin gyromagnetic ratios applying the relations given by Bohr and Mottelson [24].

The applied effective charges and gyromagnetic ratios were the commonly used, standard values in the mass region [25]: $e_p=1.5e$, $e_n=0.5e$, $e_{\rm vib}=1.6e$, $g_{lp}=1$, $g_{ln}=0$, $g_{sp}=0.6g_{sp}^{\rm free}$, $g_{sn}=0.5g_{sn}^{\rm free}$, and $g_R=Z/A$.

C. Results

The energy spectrum of ^{114}Sb calculated in the IBFFM is compared with the experimental data in Fig. 7. The connection of the experimental and theoretical states is based mainly on the analysis of the decay properties of the states. The rms deviation from the experiment for the identified states is better than 100 keV. The description of the energy correlation of the states within a p-n multiplet is also reasonable.

The main components of the wave functions of the lowest-lying states are given in Table I. Most of the states investigated have a dominant component of one proton-neutron multiplet, but the majority of them are mixed somewhat. The dominant components of the wave functions are in agreement with the identifications made on the basis of the parabolic rule [11] except the 3^+ and 4^+ members of the $\pi d_{5/2}\nu d_{3/2}$ multiplet, which are at higher energy in the IBFFM calculations. For the pure states the strongest component in the wave function is the proton-neutron multiplet state with about 70% weight, while the summed weight of the one-d-boson components is about 25%. Only 5% is left for the two-d-boson components, what justifies our two-boson approach.

The result of the calculations of the *electromagnetic properties* is summarized in Table II. The magnetic moment is known only for the ground state to be $1.72(8)\mu_N$ [13]. Its value is somewhat larger than expected for a pure $\pi d_{5/2}\nu g_{7/2}$ multiplet. The 15% mixing from the 3^+ member of the $\pi d_{5/2}\nu s_{1/2}$ multiplet shifted the calculated $\mu_{3_1^+}=1.71\mu_N$ value close enough to the measured one.

For the γ rays from levels below 700 keV, all the known mixing ratios are less than 5% [11], so a pure $M1$ approximation seems reasonable. According to the selection rules for the $M1$ transitions practically only the intermultiplet transitions are allowed. Thus the $M1$ branching ratios are characteristic for the mixing of the multiplets. The description of the branching ratios is reasonable except for the 2_2^+, 2_3^+, and 3_3^+ states. The 2_3^+ and 3_3^+ states have $\pi d_{5/2}\nu d_{5/2}$ character. It seems that their wave function is too pure. Some $\pi d_{5/2}\nu s_{1/2}$ mixing is absent from both states, and some more $\pi d_{5/2}\nu g_{2/2}$ component is missing from the 3_3^+ state. The 2_2^+ state has $\pi d_{5/2}\nu s_{1/2}$ nature. It decays to the 3_1^+ and 3_2^+ states having mixed $\pi d_{5/2}\nu s_{1/2}$ and $\pi d_{5/2}\nu g_{7/2}$ character. If the 2_2^+ state were pure, only 1% mixing would have been allowed by the branching ratios. The larger mixing required by the magnetic moment is reasonable if there are other components in the wave function of the 2_2^+ state, as well. The IBFFM fulfills this requirement. Unfortunately, the phases of the mixed components sum up coherently and produce a too strong transition. If they were out of phase, the branching could be reproduced.

The branching ratio of the stretched $E2$ transition from the 0_1^+ to the 2_1^+ state is also well described. This transition has a 12 Weiskopf unit strength, which is very close to the strength of the $2_1^+\rightarrow 0_1^+$ transition in the Sn core, in agreement with the fact that this transition connects a one-phonon state with a zero-phonon state in the Sb nucleus.

The predicted lifetimes by the IBFFM calculations are 3 ms for the 27-keV, 0.7 ns for the 46-keV, and 5.6 ns for the 56-keV state. The latter two numbers are somewhat shorter than the experimental values obtained in this work, but the long lifetime for the 27-keV state is in agreement with both this work and the coincidence measurements of Ref. [11], where no coincidence relations were found with the 27-keV transition, even with 100-ns time window width, which suggests a lifetime longer than 100–200 ns.

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