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PHYSICAL REVIEW C VOLUME 3, NUMBER 4 APRIL 1971

# Neutron-Capture Gamma Rays from the 14.1-eV Resonance in $Xe^{131}(n, \gamma)Xe^{132}$†

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(Received 30 November 1970)

The $\gamma$ rays from neutron capture in the 14.1-eV resonance in $Xe^{131}$ have been studied. A target of $Na_4XeO_6$ was irradiated in a thermal-neutron beam and in monoenergetic neutron beams of 5.16-, 9.47-, and 14.1-eV energy from a neutron diffraction monochromator. The resulting $\gamma$-ray singles spectra were studied with Ge(Li) detectors of ≈12-, 15-, 20-, and 30-$cm^3$ active volume. $\gamma$ rays were assigned to the $Xe^{131}(n, \gamma)Xe^{132}$ reaction by a comparison of these spectra. Ge(Li)-Ge(Li) coincidence measurements were carried out on resonance with the 20- and 30-$cm^3$ Ge(Li) detectors in combination. 14 $Xe^{132}$ $\gamma$ rays were assigned as primary capture $\gamma$ rays from the 14.1-eV resonance. The energies (in keV) and relative intensities $[I(667.5)=100]$ of these primary $\gamma$ rays are as follows: 8934.2 ±1.0 (0.02), 8268.5 ±0.9 (1.0), 6950.1 ±2.3 (0.14), 6750.1 ± 0.8 (0.13), 6466.8 ±0.5 (13.2), 6380.5 ±0.5 (2.8), 6346.8 ±2.5 (0.09), 6223.0 ±1.0 (0.23), 5755.0 ±1.0 (1.9), 5692.3 ±1.2 (0.4), 4981.1 ±1.7 (0.3), 4910.3 ±2.0 (0.7), 4842.3 ±1.0 (0.7), and 4745.6 ±2.5 (0.09). These data together with the information obtained from the coincidence measurements and earlier radioactive-decay studies indicate levels in $Xe^{132}$ with energies 667.5 ±0.3, 1297.7 ±0.5, 1440.0 ±0.3, 1803.9 ±0.8, 1962.7 ±0.7, 1985.4 ±1.0, 2040.2 ±0.6, 2110.2 ±0.1, 2168.7 ±1.3, 2187.2 ±0.8, 2350.7 ±0.2, 2394.3 ±0.5, 2424.9 ±0.7, 2468.8 ±0.5, 2555.0 ±0.6, 2588.66 ±0.11, 2714.3 ±1.3, 2754.43 ±0.13, 3181.3 ±1.5, 3243.4 ±1.5, 3954.1 ±1.0, 4026.5 ±1.5, 4094.0 ±1.0, and 4189.5 ±1.5 keV. The neutron separation energy of $Xe^{132}$ is 8936.3 ±1.0 keV. The most prominant feature of the $Xe^{132}$ level scheme obtained is the strong feeding of the 2468.8-keV level by the intense 6466.8-keV $\gamma$ ray from the capture state. The observed mode of decay of this level indicates spin and parity $3^-$ for this state although spin 2 cannot be ruled out. If the $3^-$ assignment is correct, then the 14.1-eV neutron resonance in $Xe^{131}$ has spin 2. The properities of the energy levels of $Xe^{132}$ are discussed.

## I. INTRODUCTION

Ewan and Tavendale,[1] in an early paper on the application of Ge(Li) detectors to the study of $\gamma$ rays, recognized that these detectors provided an important new tool for the study of neutron-capture $\gamma$ rays. Since then Ge(Li) detectors have become readily available in many laboratories, and studies of the $\gamma$ rays from both thermal- and resonance-neutron capture have been reported for almost all of the elements. The rapid increase in our knowledge of the neutron-capture $\gamma$ rays, which has resulted from the application of these detectors, is clearly seen in a comparison of the neutron-capture $\gamma$-ray compilations of 1958–1959 (Bartholomew and Higgs[2] and Groshev, Demidov, Lutsenko, and Pelekhov[3]) and 1967–1969 (Bartholomew, Doveika, Eastwood, Monaro, Groshev, Demidov, Pelekhov, and Sokolovskii[4]). One notable exception is the element xenon.

Figure 1 summarizes our knowledge of the Xe-$(n,\gamma)$ reaction in November, 1968. It shows the information contained in the neutron-capture $\gamma$-ray compilation prepared by Bartholomew *et al.*[4] The level scheme shown is based on results obtained by Bartholomew and Naqvi[5] and by Monaro, Kane, and Ikegami.[6] Bartholomew and Naqvi, with a NaI pair spectrometer, measured the energies and intensities of the $\gamma$ rays from a gaseous target of xenon bombarded with thermal neutrons. They also studied $\gamma$-$\gamma$ coincidences with NaI detectors and were able to show that the 8.256- and 6.454-MeV $\gamma$ rays feed levels in $Xe^{132}$ at 0.67 and 2.47 MeV, respectively. Monaro, Kane, and Ikegami also measured the energies and intensities of the Xe capture $\gamma$ rays with a pair spectrometer. These authors used a target of $XeF_4$, which is a rather inconvenient target material, since it may hydrolyze to the highly unstable form $XeO_3$.

We have now undertaken a comprehensive study of the Xe$(n,\gamma)$ reaction with the aim of obtaining information about the level structure of several of the Xe isotopes. We anticipated a considerable improvement on the data obtained in the earlier $(n,\gamma)$ studies for three reasons. First, as discussed above, Ge(Li) detectors with good energy resolution are now available. Secondly, it is now possible to make a stable Xe target of sodium perxenate ($Na_4XeO_6$), thus eliminating the inconvenience of using either the gas target or the potentially unstable $XeF_4$. Thirdly, the difficulties of making a suitable target preclude the use of separated Xe isotopes and hence make thermal-neutron-capture studies very complicated. However, with a sample of natural composition one can use the recently constructed neutron monochromator[7] at the Brookhaven High Flux Beam Reactor (HFBR) to provide neutrons of the energy of a single Xe resonance and hence study the neutron-capture $\gamma$ rays from the individual Xe isotopes.

The neutron monochromator provides a continuous beam of monoenergetic neutrons in the energy range 0.01 to 20 eV. There are three neutron resonances of Xe in this range.[8] These are at 5.16, 9.47, and 14.1 eV and lie in $Xe^{124}$, $Xe^{129}$, and $Xe^{131}$, respectively. We have studied the neutron-capture $\gamma$-ray spectra from all three of these resonances, and we have also studied the thermal-neutron-capture spectrum with a clean filtered thermal-neutron beam.[7] We have begun our analysis of these measurements with the $\gamma$ rays from the 14.1-eV resonance in $Xe^{131}$. These results, which concern the $\gamma$ rays and energy levels of $Xe^{132}$, are reported here.

Almost all of the information currently available on the level scheme of $Xe^{132}$ is derived from studies of the radioactive decay of $Cs^{132}$ and $I^{132}$. The decay of $Cs^{132}$ has been studied by several authors.[9-14] A number of early studies[9] of the energies, intensities, and coincidence relationships of the $Cs^{132}$ $\gamma$ rays were carried out with NaI scintillation spectrometers. NaI detectors were also used by Robinson, Johnson, and Eichler[10] to study $\gamma$-$\gamma$ directional correlations in the $Cs^{132}$ decay. Johnson, Boyd, Eichler, and Hamilton[11] measured

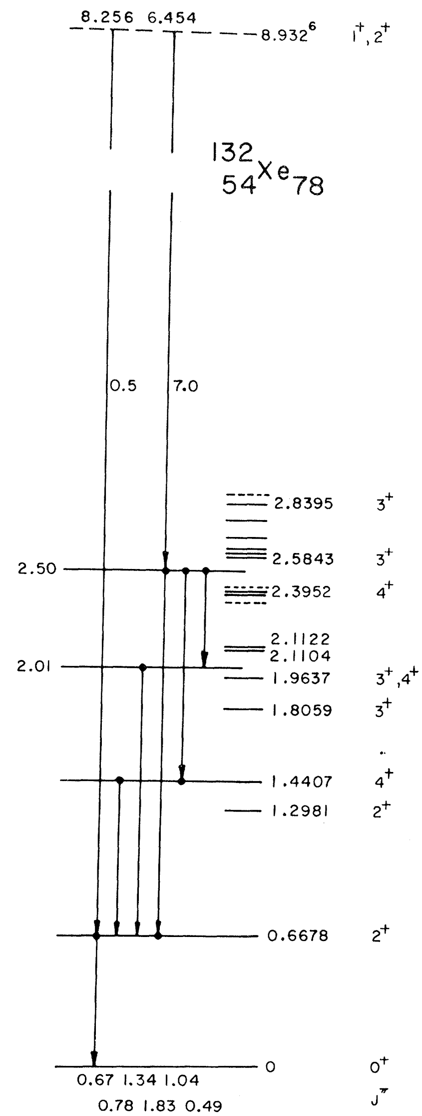


FIG. 1. This figure summarizes our knowledge of the $Xe^{131}(n,\gamma)Xe^{132}$ reaction in November, 1968. The level scheme shown, which is based mainly on the thermal-neutron-capture $\gamma$-ray studies of Bartholomew and Naqvi (see Ref. 5) and Monaro, Kane, and Ikegami (see Ref. 6), is taken from the neutron-capture $\gamma$-ray compilation of Bartholomew *et al* (see Ref. 4).

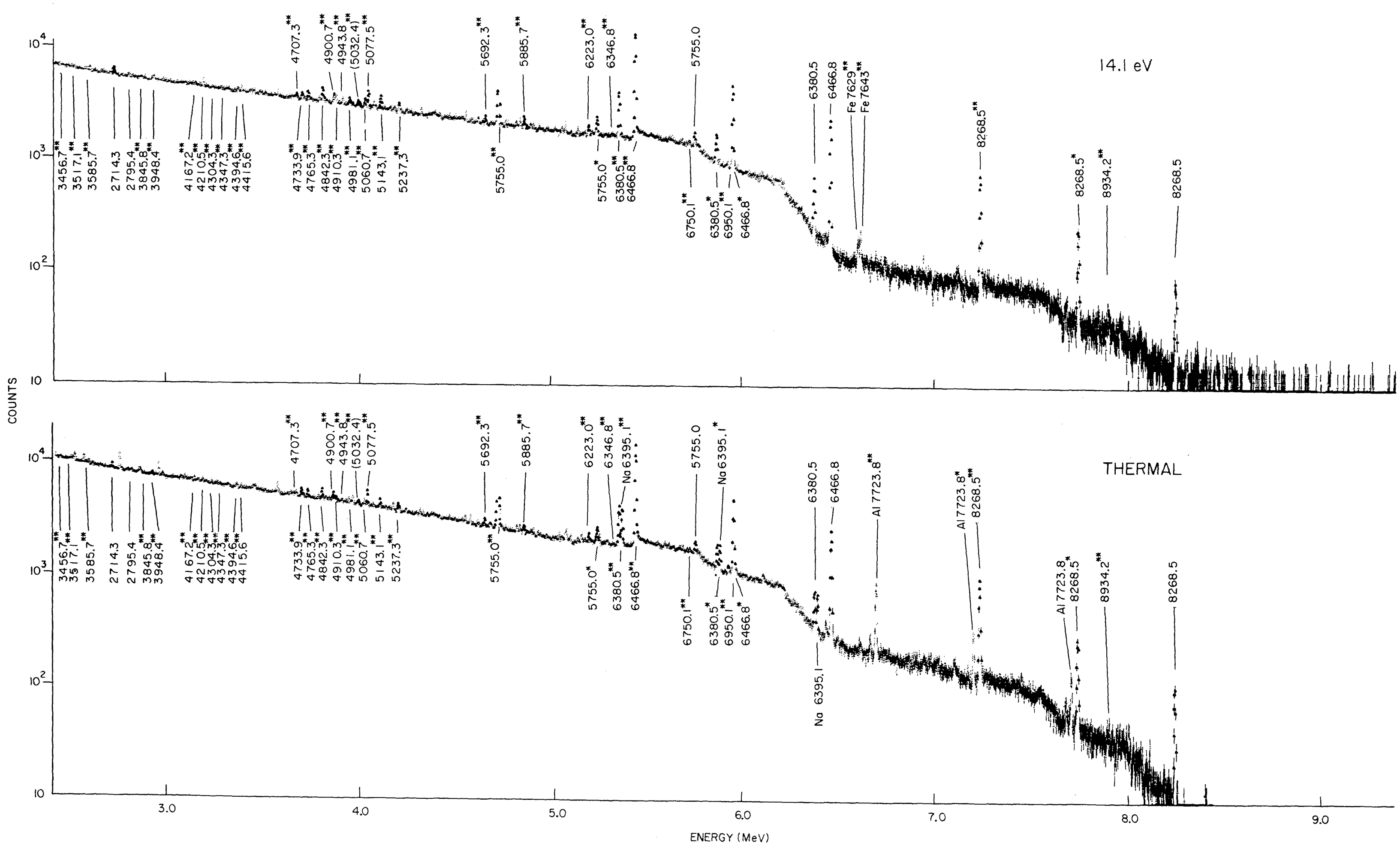


FIG. 2. This figure shows the neutron-capture $\gamma$-ray spectra (~2.4–9.3 MeV) from $Na_4XeO_6$ target irradiated in a monoenergetic neutron beam (14.1-eV energy) from a crystal diffraction monochromator (see Ref. 7, upper half), and a thermal-neutron beam (see Ref. 7, lower half). The energy dispersion is approximately 2.3 keV/channel. Single and double asterisks indicate one- and two-escape peaks, respectively. These spectra were recorded in the same geometry and with the same electronic settings with a Ge(Li) detector of ≈30-$cm^3$ active volume. The spectra were accumulated in runs of 4- and 1- day duration. It should be noted that most of the prominent background lines in the thermal spectrum, such as the peaks from the intense 6395.1- and 7723.8-keV $\gamma$ rays from the $Na^{23}(n,\gamma)Na^{24}$ and $Al^{27}(n,\gamma)Al^{28}$ reactions, do not appear in the 14.1-eV resonance spectrum. A few weak background lines, such as the two-escape peaks of the well-known 7629–7643-keV $\gamma$-ray doublet in the $Fe^{56}(n,\gamma)Fe^{57}$ reaction, appear in the 14.1-eV resonance spectrum only. The most prominent features of both spectra are the peaks due to the intense 6466.8 ±0.5-keV primary $\gamma$ ray in the $Xe^{131}(n,\gamma)Xe^{132}$ reaction. These peaks dominate the thermal spectrum because $Xe^{131}$ contributes 66.9% of the thermal-neutron-capture cross section of Xe.

the energies and intensities of the $\gamma$ rays from $Cs^{132}$ with a small Ge(Li) detector. Later Carter, Hamilton, and Pinajian[12] repeated these measurements after Henck[13] had pointed out some discrepancies between the early results and measurements on $I^{132}$. The new measurements resulted in a consistent decay scheme for $Cs^{132}$ with levels in $Xe^{132}$ at 667.65, 1297.6, 1440.1, 1803.4, and 1985.3 keV. Frana, Rezanka, Spalek, and Mastalka[14] also measured the energies and intensities of the $\gamma$ rays from the decay of $Cs^{132}$ and confirmed the $Cs^{132}$ decay scheme of Carter *et al.*

The $\beta^-$-decay of $I^{132}$ has been studied by a large number of authors.[15-25] Robinson, Eichler, and Johnson (REJ)[15] used scintillation spectrometers to measure $\gamma$-ray energies and intensities; $\gamma$-$\gamma$, $\beta$-$\gamma$, and $\gamma$-$\gamma$-$\gamma$ coincidences; and $\gamma$-$\gamma$ directional correlations. Rao[16] also studied $\gamma$-$\gamma$ directional correlations with NaI scintillation counters. Boyd and Hamilton[17] studied the internal-conversion-electron spectrum below 1.4 MeV with an iron-free double-focusing $\beta$ spectrometer and were able to determine the $K$ conversion coefficients of several prominent transitions. Johnson, Wilsky, Hansen, and Nielsen[18] measured the energies and relative intensities of the $I^{132}$ $\gamma$ rays between 1.14 and 2.68 MeV with a NaI three-crystal pair spectrometer. They also studied the conversion-electron spectrum over the range 100–2200 keV. Hamilton, Boyd, and Johnson[19] summarized the work carried out on $I^{132}$ prior to 1965 and presented a detailed level scheme consistent with the information available at that time. Ardisson and Petit[20] measured the energies and intensities of the $I^{132}$ $\gamma$ rays with a Ge(Li) detector. Ythier, Ardisson, and Lefort[21] then used a pair spectrometer incorporating a Ge(Li) detector to study the $I^{132}$ $\gamma$ rays between 1282 and 2839 keV. Henck, Star, Siffert, and Coche[22] also measured the energies and relative intensities of the $I^{132}$ $\gamma$ rays with Ge(Li) detectors. They also combined their results with the earlier conversion-electron intensity measurements[18,19] to determine the $K$ conversion coefficients of many of the transitions. Their decay scheme differed from that given by Hamilton, Boyd, and Johnson in various respects. Ardisson and Marsol[23] reported Ge(Li)-NaI $\gamma$-$\gamma$ coincidence studies on this decay. Carter, Hamilton, Manthuruthil, Amtey, Pinajian, and Zganjar[24] reported measurements of $\gamma$-ray energies and intensities with Ge(Li) detectors. They also measured selected portions of the conversion-electron spectrum with a high-resolution double-focusing $\beta$ spectrometer and deduced $K$ conversion coefficients for most of the prominent transitions. These authors also tabulated all of the information available on the energies and intensities of the $\gamma$ rays emitted. Hamilton, Carter, and Pinajian[25] studied $\gamma$-$\gamma$ coincidences with Ge(Li) and NaI detectors in a $4096\times4096$-channel format. From their results they were able to place a large fraction of the observed $\gamma$ rays in a level scheme with some 20 levels below 3059 keV.

Very little information on the level structure of $Xe^{132}$ is available from reaction studies. However, Brinckman, Heiser, Fromm, and Hageman[26] and Bergstrom, Herrlander, Kerek, and Luukko[27] have studied the $Te^{130}(\alpha, 2n)Xe^{132}$ reaction. The former authors reported an isomeric level at 2754 keV with a half-life of 8.4 msec and probable spin and parity of $10^+$. This result was confirmed by Bergstrom *et al.*, although their results indicate some doubt about the assignment of spin 10 to the isomeric level.

The present paper reports the results of an investigation of the $\gamma$ rays from the 14.1-eV resonance in $Xe^{131}$ over the energy range 0–9 MeV. Since the $Xe^{131}$ ground state has spin and parity $\frac{3}{2}^+$, this resonance may be $1^+$ or $2^+$. From studies of resonance shapes in neutron-transmission measurements Ribon[28] has concluded that the spin of the 14.1-eV resonance is probably $2^+$. The $(n, \gamma)$ reaction may thus be expected to populate directly low-energy–low-spin states (spins 0–3) in $Xe^{132}$. The experimental procedure and results are described in Sec. II. The construction of the resulting level scheme is discussed in Sec. III. Finally, the level scheme is discussed in Sec. IV.

## II. EXPERIMENTAL METHODS AND RESULTS

### A. Equipment

The target consisted of ~5 g of anhydrous $Na_4XeO_6$ enclosed in an aluminum capsule. The anhydrous $Na_4XeO_6$ was prepared from $XeF_6$ by the method of Appelman and Malm.[29] The only impurity of any significance present in this material was a small amount of NaF. The relative abundances of the Xe isotopes are 0.096% $Xe^{124}$, 0.090% $Xe^{126}$, 1.92% $Xe^{128}$, 26.44% $Xe^{129}$, 4.08% $Xe^{130}$, 21.18% $Xe^{131}$, 26.89% $Xe^{132}$, 10.44% $Xe^{134}$, and 8.87% $Xe^{136}$. In thermal-neutron capture these isotopes contribute 0.39%, 0.007%, <0.36%, 24.6%, <0.76%, 66.9%, <5%, <1.94%, and 0.09%, respectively, to the capture cross section.

The properties of the crystal diffraction neutron monochromator have been fully described in Ref. 7. It is sufficient here to state that it was designed specifically for neutron-capture $\gamma$-ray studies. It provides $2\times10^5$ neutrons/sec on a 1-in.$^2$ target at an energy of 1 eV. The energy dependence of the beam intensity is roughly $1/E$. The angular resolution of the monochromator is 12′, giving an energy resolution $\Delta E/E = 0.14$ at 14.1 eV.

The $Na_4XeO_6$ target was irradiated in the monoenergetic neutron beam at neutron energies of 5.16, 9.47, and 14.1 eV in order to study the resonance-capture $\gamma$-ray spectra. It was also irradiated in the thermal-neutron beam[7] at the HFBR, which has an intensity of $7\times10^7$ neutrons/sec over 1 $cm^2$ with a Cd ratio $>2\times10^4$, in order to study the thermal-neutron-capture spectrum.

The singles $\gamma$-ray spectra were studied with Ge(Li) detectors of ≈12-, 15-, 20-, and 30-$cm^3$ active volume. Coincidences between $\gamma$ rays were studied with the 20- and 30-$cm^3$ detectors in combination. The electronic equipment used in these measurements and the procedures followed in analyzing the data have been described in detail in previous publications.[30]

### B. Energy and Intensity Measurements

The singles spectra of $\gamma$ rays emitted following the bombardment of xenon with neutrons of thermal, 5.16-, 9.47-, and 14.1-eV energy were studied over the energy range 0–9.5 MeV in a number of runs of different dispersion and energy range. The assignment of the observed capture $\gamma$ rays to $Xe^{132}$ was made by a careful comparison of the spectra taken at different neutron energies under identical experimental conditions. An example of part of such a comparison is shown in Fig. 2. The lower half of this figure shows the thermal-neutron-capture $\gamma$-ray spectrum of Xe from ~2.4 to 9.3 MeV. This spectrum was accumulated in 1 day with the 30-$cm^3$ Ge(Li) detector. The upper half of the figure shows the $\gamma$-ray spectrum from the 14.1-eV resonance obtained under the same conditions. This spectrum was accumulated in a run of 4-day duration. In general the peaks belonging to $Xe^{132}$ are readily distinguished from background peaks and those peaks arising from neutron capture in the other xenon isotopes. The majority of the background lines in the thermal spectrum simply disappear in the resonance spectrum. For example, the peaks from the intense 6395.0- and 7723.8-keV $\gamma$ rays, which arise from the $Na^{23}(n,\gamma)Na^{24}$ and $Al^{27}(n,\gamma)Al^{28}$ reactions in the $Na_4XeO_6$ target and Al source holder, respectively, are clearly present in the thermal spectrum but not in the resonance spectrum. Care must be exercized in the assignment of very weak lines, since in some cases background lines appear in the resonance spectrum which are not present at thermal-neutron energies. For example, the two-escape peaks of the well-known 7629-7643-keV $\gamma$-ray doublet in the $Fe^{56}(n,\gamma)Fe^{57}$ reaction are clearly seen in the 14.1-eV resonance spectrum (see Fig. 2). These and other background lines arise from the difference in the experimental configuration when the diffracted and thermal beams are used. For example, the Fe $\gamma$ rays are thought to arise from the steel used in the second collimator of the Bragg monochromator. The energies and intensities of the $\gamma$ rays assigned to $Xe^{132}$ are listed in Table I.

In this high-energy region of the spectrum the following procedure was used to determine the energies of the $\gamma$ rays. The neutron-capture $\gamma$-ray spectrum was recorded together with a set of pulser peaks flanking the $\gamma$-ray peaks. The intervals between the peaks of the strong 6466.8-keV transition and the other $Xe^{132}$ $\gamma$-ray lines could then be determined in terms of pulser units. This step involves the assumption of system linearity over the short intervals between the pulser peaks. The pulser units were then converted into energy units using the well-known energy differences between the full energy, one- and two-escape peaks. The intense peaks of the 6466.8-keV transition (see Fig. 2) were ideal for this purpose. A value of $6466.8\pm0.5$ keV was obtained for the energy of this $\gamma$ ray by comparison with the energy[31] of the $6395.1\pm0.4$-keV $\gamma$ ray from sodium in a thermal-neutron-capture spectrum. The energies of the remaining lines assigned to $Xe^{132}$ could then be obtained by combining this energy with the energy differences measured in the experiment described above. Various other background lines of known energy which appeared in the thermal-neutron-capture spectrum, such as the three peaks due to the 7723.8-keV capture $\gamma$ ray from Al, served as a check on this energy calibration. In the case of very weak lines, which are only observable in those spectra without superimposed pulser peaks, the energy of the peak was measured by comparison with the measured energies of strong neighboring lines. In this case, system linearity is assumed over the interval between these peaks.

Figure 3 shows an example of the $Xe^{132}$ $\gamma$-ray spectrum from the 14.1-eV resonance in the energy interval 0 to 2.3 MeV. This spectrum was accumulated with the ~20-$cm^3$ Ge(Li) detector in a run of 4-day duration. In this region of the spectrum the $\gamma$ rays from radioactive sources of $Ba^{133}$, $Cs^{137}$, and RdTh were recorded together with the $Xe^{132}$ capture $\gamma$ rays. At intervals during the measurement the same spectrum was routed into a separate section of the analyzer memory together with a set of pulser peaks to be used in the correction for the nonlinearity of the electronic system. The energies of the $Xe^{132}$ lines were obtained by comparison with the known energies[32–34] of the lines from the radioactive sources.

The energies of all of the lines assigned to $Xe^{132}$ are listed in column 1 of Table I. The measured intensities of the observed $\gamma$ rays relative to the

TABLE I. Energies, relative intensities, and assignments of $\gamma$ rays observed in the $Xe^{131}(n,\gamma)Xe^{132}$ reaction at the 14.1-eV resonance.

| $E_\gamma$ (keV) | $I_\gamma$ (relative) | Level (keV) From – To | $\Delta L - E_\gamma$ [a] (keV) |
|---|---|---|---|
| 46.5±0.3 | ··· | ··· | ··· |
| 65.8±0.3 | ··· | ··· | ··· |
| 68.2±0.3 | ··· | ··· | ··· |
| 78.8±0.3 | ··· | ··· | ··· |
| 186.7±0.2 | 0.2 ±0.1 | ··· | ··· |
| 313.0±0.5 | 0.2 ±0.1 | ··· | ··· |
| 344.4±0.4 | 0.2 ±0.1 | ··· | ··· |
| 363.6±0.5 | 0.3 ±0.2 | 1803.9–1440.0 | +0.3±0.9 |
| | | 2168.7–1803.9 | +1.2±1.6 |
| | | 2714.3–2350.7 | 0 ±1.4 |
| 403.3±1.0 | 0.3 ±0.2 | ··· | ··· |
| 429.2±0.4 | 0.64±0.15 | 2468.8–2040.2 | −0.6±0.9 |
| 483.7±0.5 | 7.8 ±0.7 | 2468.8–1985.4 | −0.3±1.1 |
| 506.5±0.5 | 3.9 ±0.5 | 1803.9–1297.7 | −0.3±0.6 |
| | | 2468.8–1962.7 | −0.4±1.0 |
| 522.7±0.6 | 2.9 ±0.2 | 1962.7–1440.0 | 0 ±1.0 |
| 536.2±0.4 [b] | 0.7 ±0.2 | ··· | ··· |
| 546.4±0.5 | 0.2 ±0.1 | 1985.4–1440.0 | −1.0±1.2 |
| | | 2350.7–1803.9 | +0.4±1.0 |
| | | 2714.3–2168.7 | +0.2±1.9 |
| 570.1±0.7 | 2.8 ±0.4 | 2555.0–1985.4 | −0.5±1.4 |
| 600.2±0.5 | 6.8 ±0.5 | 2040.2–1440.0 | ··· [c] |
| 608.8±0.6 | 0.3 ±0.05 | ··· | ··· |
| 621.0±0.5 | 0.87±0.2 | 2424.9–1803.9 | 0 ±1.2 |
| 630.2±0.4 | 18.5 ±1.6 | 1297.7–667.6 | ··· [c] |
| 667.5±0.3 | 100 | 667.5–g.s. | ··· [c,d] |
| 707.9±0.4 | 0.3 ±0.1 | ··· | ··· |
| 727.0±0.4 | 0.45±0.12 | 2168.7–1440.0 | +1.7±1.4 |
| | | 2714.3–1985.4 | +1.9±1.7 |
| 772.5±0.3 | 24.4 ±2.0 | 1440.0–667.5 | ··· [c] |
| | | 3954.1–3181.3 | +0.3±1.8 |
| 812.0±0.4 | 1.0 ±0.2 | 2110.2–1297.7 | +0.5±0.5 |
| 832.2±0.4 | 0.6 ±0.2 | 3181.3–2350.7 | −1.6±1.6 |
| 889.2±0.6 | 0.84±0.1 | 2187.2–1297.7 | +0.3±1.1 |
| 910.8±0.7 | 0.4 ±0.2 | 2350.7–1440.0 | −0.1±0.8 |
| | | 2714.3–1803.9 | −0.4±1.7 |
| | | 4094.0–3181.3 | +1.9±1.9 |
| 954.3±0.3 | 0.89±0.1 | 2394.3–1440.0 | 0 ±0.7 |
| 983.7±0.9 | 0.45±0.2 | 2424.9–1440.0 | +1.2±1.2 |
| 1028.7±0.3 | 5.4 ±0.6 | 2468.8–1440.0 | +0.1±0.7 |
| 1114.3±0.5 | 0.4 ±0.05 | 2555.0–1440.0 | +0.7±0.8 |
| 1120.9±0.5 | 0.6 ±0.05 | ··· | ··· |
| 1136.1±0.6 | 2.4 ±0.5 | 1803.9–667.5 | +0.3±1.0 |
| 1141.0±0.8 | 0.4 ±0.3 | 3181.3–2040.2 | +0.1±1.8 |
| 1154.0±0.4 [e] | 0.8 ±0.15 | ··· | ··· |
| 1171.2±0.4 | 0.89±0.15 | 2468.8–1297.7 | −0.1±0.7 |
| 1227.6±1.0 | 0.4 ±0.2 | ··· | ··· |
| 1236.2±0.5 | 0.35±0.1 | ··· | ··· |
| 1280.3±0.3 | 0.6 ±0.1 | 3243.4–1962.7 | +0.4±1.7 |
| 1290.8±0.4 [f] | ··· | 2588.7–1297.7 | ··· |
| 1295.3±0.4 [f] | ··· | 1962.7–667.5 | ··· |
| 1298.2±0.5 [f] | ··· | 1297.7–g.s. | ··· |
| 1317.6±0.3 | 13.2 ±1.0 | 1985.4–667.5 | +0.3±1.1 |
| 1398.8±0.7 | 0.24±0.12 | ··· | ··· |
| | 0.26±0.1 | 2110.2–667.5 | +0.5±0.8 |
| | 0.45±0.1 | 2168.7–667.5 | +0.2±1.5 |

| $E_\gamma$ (keV) | $I_\gamma$ (relative) | Level (keV) From – To | $\Delta L - E_\gamma$ [a] (keV) |
|---|---|---|---|
| 1519.4±0.3 | 1.8 ±0.3 | 2187.2–667.5 | +0.3±0.9 |
| 1539.0±0.5 | 0.38±0.1 | 4094.0–2555.0 | 0 ±1.3 |
| 1620.2±0.4 | 1.4 ±0.2 | ··· | ··· |
| 1669.7±1.1 | 0.23±0.08 | 4094.0–2424.9 | −0.6±1.6 |
| 1719.7±0.4 | 1.2 ±0.3 | 4189.5–2468.8 | +1.0±1.6 |
| 1739.8±0.8 | 0.1 ±0.05 | 3181.3–1440.0 | +1.5±1.7 |
| 1756.6±0.8 | 0.33±0.1 | 2424.9–667.5 | +0.8±1.1 |
| 1786.0±0.8 | 0.34±0.1 | 3954.1–2168.7 | −0.6±1.8 |
| 1801.1±0.3 | 4.4 ±0.8 | 2468.8–667.5 | +0.2±0.7 |
| 1813.7±0.5 | 0.5 ±0.3 | ··· | ··· |
| 1858.3±0.7 | 0.56±0.1 | 4026.5–2168.7 | −0.5±2.1 |
| 1887.6±0.3 | 2.5 ±0.4 | 2555.0–667.5 | −0.1±0.7 |
| 1895.8±0.7 | 0.5 ±0.1 | ··· | ··· |
| 1920.3±1.2 | 0.3 ±0.2 | 2588.7–667.5 | +0.9±1.2 |
| 1926.0±1.2 | 0.5 ±0.3 | 4094.0–2168.7 | −0.7±2.0 |
| 1986.4±0.9 | 1.4 ±0.2 | 1985.4–g.s. | −1.0±1.7 |
| 2027.0±0.6 | 1.3 ±0.2 | ··· | ··· |
| 2055.2±0.7 | 0.6 ±0.2 | 4094.0–2040.2 | −1.4±1.9 |
| 2087.3±0.8 | 0.5 ±0.3 | 2754.4–667.5 | −0.4±0.9 |
| 2149.9±0.8 | 0.3 ±0.1 | 3954.1–1803.9 | +0.3±1.5 |
| | | 4189.5–2040.2 | −0.6±1.8 |
| 2169.8±0.8 | 0.5 ±0.2 | 2168.7–g.s. | −1.2±1.5 |
| 2188.9±1.0 | 0.3 ±0.2 | 2187.2–g.s. | −1.2±1.3 |
| 2384.6±1.2 | 0.2 ±0.1 | 4189.5–1803.9 | +1.0±2.1 |
| 2577.0±1.0 | 0.3 ±0.2 | 3243.4–667.5 | −1.1±1.8 |
| 2592.5±1.0 | 0.5 ±0.2 | ··· | ··· |
| 2615.1±0.6 | 0.3 ±0.2 | ··· | ··· |
| 2698.0±2.0 | 0.2 ±0.1 | ··· | ··· |
| 2714.3±0.5 | 0.7 ±0.2 | 2714.3–g.s. | 0 ±1.4 |
| 2795.4±0.7 | 0.4 ±0.2 | 4094.0–1297.7 | +0.9±1.3 |
| 3456.7±1.0 | 0.3 ±0.2 | ··· | ··· |
| 3517.1±0.7 | 0.4 ±0.2 | ··· | ··· |
| 3585.7±1.8 | 0.2 ±0.1 | ··· | ··· |
| 3845.8±1.5 | 0.2 ±0.1 | ··· | ··· |
| 3948.4±1.5 | 0.5 ±0.2 | ··· | ··· |
| 4167.2±2.5 | 0.2 ±0.1 | ··· | ··· |
| 4210.5±0.7 | 0.4 ±0.2 | ··· | ··· |
| (4304.3±1.0) | 0.2 ±0.1 | ··· | ··· |
| (4347.3±2.0) | 0.2 ±0.1 | ··· | ··· |
| (4394.6±1.0) | 0.3 ±0.1 | ··· | ··· |
| 4415.6±0.9 | 0.5 ±0.2 | ··· | ··· |
| 4707.3±2.0 | 0.2 ±0.1 | ··· | ··· |
| 4733.9±1.9 | 0.3 ±0.1 | ··· | ··· |
| 4745.6±2.5 | 0.09±0.05 | 8936.3–4189.5 | +1.1±3.0 |
| 4765.3±1.9 | 0.4 ±0.1 | ··· | ··· |
| 4842.3±1.0 | 0.7 ±0.2 | 8936.3–4094.0 | −0.1±1.7 |
| (4892.0±2.5) | ≤0.2 | ··· | ··· |
| 4900.7±1.0 | 0.6 ±0.3 | ··· | ··· |
| 4910.3±2.0 | 0.7 ±0.3 | 8936.3–4026.5 | −0.6±2.7 |
| 4943.8±1.8 | 0.3 ±0.1 | ··· | ··· |
| 4981.1±1.7 | 0.3 ±0.1 | 8936.3–3954.1 | +1.0±2.2 |
| (5032.4±2.1) | 0.3 ±0.2 | ··· | ··· |
| 5060.7±1.7 | 0.8 ±0.3 | ··· | ··· |
| 5077.5±1.6 | 1.3 ±0.2 | ··· | ··· |
| 5143.1±1.5 | 0.7 ±0.2 | ··· | ··· |

TABLE I *(Continued)*

| $E_\gamma$ (keV) | $I_\gamma$ (relative) | Level (keV) From | To | $\Delta L - E_\gamma$ [a] (keV) |
|---|---|---|---|---|
| 5237.3 ± 1.5 | 0.5 ± 0.2 | ··· | | ··· |
| 5692.3 ± 1.2 | 0.4 ± 0.2 | 8936.3 | 3243.4 | +0.5 ± 2.2 |
| 5755.0 ± 1.0 | 1.9 ± 0.2 | 8936.3 | 3181.3 | −0.1 ± 2.1 |
| 5885.7 ± 2.5 | 0.4 ± 0.2 | ··· | | ··· |
| 6223.0 ± 1.0 | 0.23 ± 0.10 | 8936.3 | 2714.3 | −1.2 ± 1.9 |
| 6346.8 ± 2.5 | 0.09 ± 0.06 | 8936.3 | 2588.7 | +0.6 ± 2.7 |
| 6380.5 ± 0.5 | 2.8 ± 0.3 | 8936.3 | 2555.0 | +0.6 ± 1.3 |
| 6466.8 ± 0.5 | 13.2 ± 0.8 | 8936.3 | 2468.8 | +0.5 ± 1.2 |
| 6750.1 ± 0.8 | 0.13 ± 0.06 | 8936.3 | 2187.2 | −1.2 ± 1.5 |
| 6950.1 ± 2.3 | 0.14 ± 0.05 | 8936.3 | 1985.4 | +0.6 ± 2.7 |
| 8268.5 ± 0.9 | 1.0 ± 0.1 | 8936.3 | 667.5 | ··· [d] |
| 8934.2 ± 1.0 | 0.02 ± 0.01 | 8936.3 | g.s. | +1.8 ± 1.5 |

[a] $\Delta L$ denotes the difference in energy of the levels between which the transition takes place minus the recoil energy of the $\gamma$ ray.

[b] A $\gamma$ ray of this energy and intensity may exist in the $Xe^{131}(n,\gamma)Xe^{132}$ reaction but it is not possible to tell from our spectra, since it coincides in energy with the most intense $\gamma$ ray emitted in the decay of the neighboring 9.47-eV resonance of $Xe^{129}$.

[c] The energy of this $\gamma$ ray was used, together with the energy of the level which it feeds, to define the energy of the level which it deexcites.

[d] The energy of this $\gamma$ ray was used to determine the neutron separation energy.

[e] Doublet.

[f] These $\gamma$ rays form part of a complicated multiplet involving an intense 1293.6-keV In $\gamma$ ray from the In$(n,\gamma)$ reaction, which results from scattered neutrons reaching the Ge(Li) detector mounting. The $\gamma$ rays in the multiplet are unresolved or only partially resolved in our spectra. The energies given are those reported in Ref. 25.

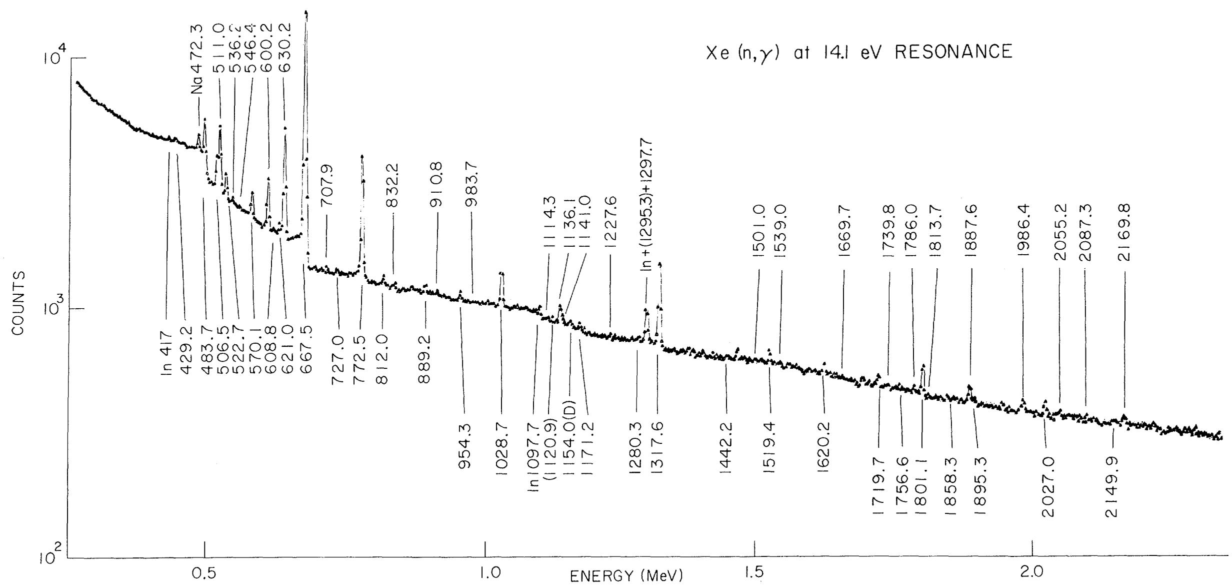


FIG. 3. The neutron-capture $\gamma$-ray spectrum from 0–2.3 MeV from a $Na_4XeO_6$ target irradiated in a monoenergetic neutron beam of 14.1-eV energy from a crystal diffraction neutron monochromator. The energy dispersion is approximately 2.3 keV/channel. This spectrum was accumulated in four days with a ≈20-$cm^3$ Ge(Li) detector.

intensity of the 667.5-keV $\gamma$ ray, which are listed in column 2 of Table I, are mean values obtained from several runs with different detectors. These measurements were made with the aid of relative-efficiency curves for the various detectors, determined by the method of Kane and Mariscotti.[35]

### C. $\gamma$-$\gamma$ Coincidences

To help establish the level scheme of $Xe^{132}$, measurements of $\gamma$-$\gamma$ coincidences were carried out at the 14.1-eV resonance. Two separate runs were made. In the first run the $\gamma$ rays from 180 to 1480 keV were counted in the ~30-$cm^3$ Ge(Li) detector in coincidence with $\gamma$ rays from 80 to 320 keV detected in the ~20-$cm^3$ Ge(Li) detector. In the second run, $\gamma$ rays from ~4.5–7.3 MeV were counted in the 30-$cm^3$ Ge(Li) detector in coincidence with $\gamma$ rays from 440 to 1360 keV detected in the 20-$cm^3$

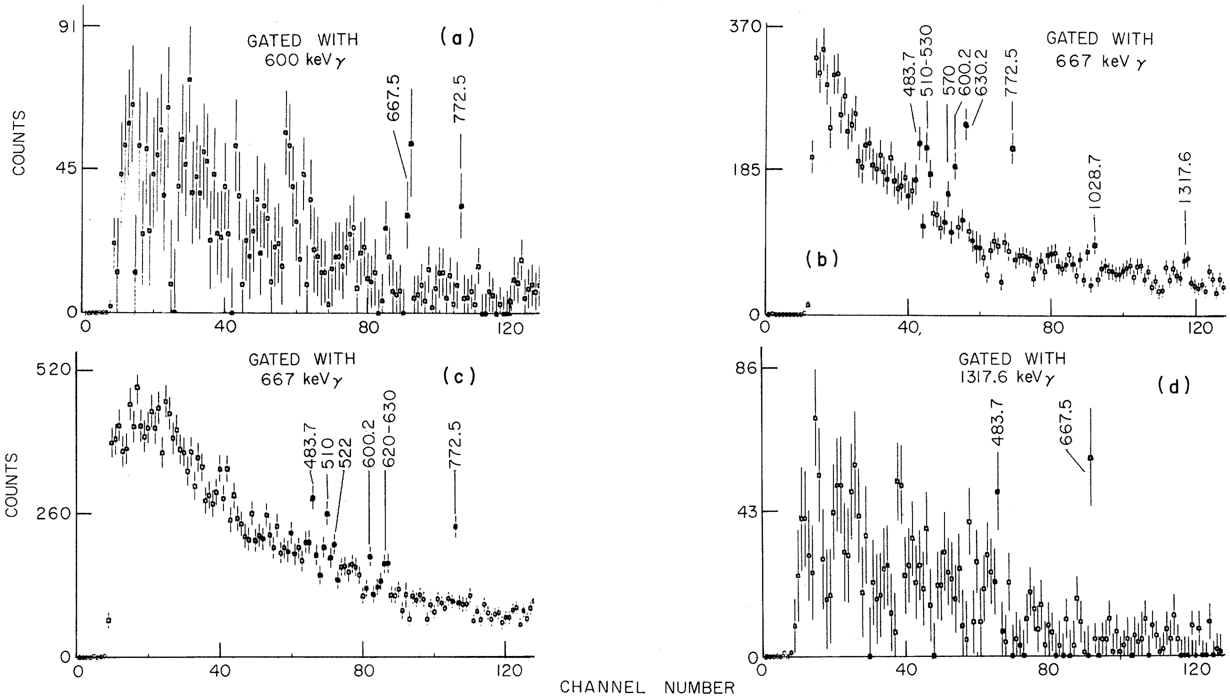


FIG. 4. This figure shows net coincidence spectra in one Ge(Li) detector gated with a single $\gamma$-ray peak in the other. The $\gamma$-$\gamma$ coincidence data were recorded in $128\times128$-channel format. Each spectrum shown here was obtained as a computer output from a program (see Ref. 36) which summed the spectrum slices associated with the gating $\gamma$ ray and subtracted an equal number of background slices. Parts (a), (c), and (d) show the spectra from the 30-$cm^3$ Ge(Li) detector gated with the 600.2-, 667.5-, and 1317.6-keV $\gamma$ rays detected in the 20-$cm^3$ detector. Part (b) shows the 20-$cm^3$ Ge(Li) detector gated with the 667.5-keV $\gamma$ ray detected in the 30-$cm^3$ Ge(Li) detector. It should be noted that the energy dispersion is different in this spectrum. At the energy dispersion used in this run a $\gamma$-ray peak appears in a single channel. It should also be noted that the procedure used to obtain these spectra does not include the subtraction of chance coincidences from the total spectrum. However, chance coincidences are not expected to contribute a significant fraction of the total counts in these spectra. Note, for example, the failure to observe any 667-667-keV coincidences in either part (b) or part (c), both of which are gated with the 667.5-keV $\gamma$ ray.

Ge(Li) detector. In both runs the pulses from the two counters were stored in a $128\times128$-channel format in the 16384-channel memory of a TMC pulse-height analyzer. The total counting times in the two runs were $5\frac{1}{2}$ and 6 day, respectively.

The spectrum in coincidence with each $\gamma$ ray could be obtained with a computer program[36] which permitted the summing of spectrum slices associated with a particular peak and the subtraction of an equal number of background slices to obtain the net coincidence spectrum. Figure 4 shows four examples of such net coincidence spectra taken from the first run. At the energy dispersion used, a $\gamma$-ray peak appears in a single channel. Figure 4(b) shows the spectrum in the 20-$cm^3$ detector gated with the 667.5-keV $\gamma$ ray, which deexcites the first excited state of $Xe^{132}$. We see coincidences with $\gamma$ rays of 483-, 510-, 530-, 570-, 600-, 630-, 772-, 1028-, and 1317-keV energy. Figures 4(a), 4(c), and 4(d) show the $\gamma$-ray spectra in the 30-$cm^3$ Ge(Li) detector gated with the 600.2-, 667.5-, and 1317.6-keV $\gamma$ rays.

These spectra clearly confirm that the 600.2- and 1317.6-keV $\gamma$ rays are in coincidence with the 667.5-keV $\gamma$ ray. It should be noted that the procedure used to obtain these spectra does not involve the subtraction of chance coincidences. They are not expected to be a significant fraction of the total counts in these spectra. This is confirmed by the failure to observe 667-667-keV coincidences in either of the spectra in Fig. 4 gated with the 667-keV $\gamma$ ray.

The coincidence counting rate in the high-energy–low-energy run was very low. As a result the only coincidences observed were between the very strongest $\gamma$ rays. The results of both coincidence runs are summarized in Table II.

## III. CONSTRUCTION OF THE LEVEL SCHEME

The level scheme of $Xe^{132}$ is shown in Fig. 5. It was constructed from the data of Tables I and II together with the information available from previous investigations.

The level scheme of Fig. 1, which was constructed from the results of the earlier $(n, \gamma)$ studies,[5,6] is confirmed in the present work. The observed 6466.8- and 8268.5-keV $\gamma$ rays (see Fig. 2) are readily identified as the 6454- and 8256-keV $\gamma$ rays seen in the earlier $(n, \gamma)$ experiments. Three pieces of evidence identify the 8268.5-keV transition as a primary transition feeding the first excited state of $Xe^{132}$. These are the following: (1) The observation that the difference in energy ($665.7 \pm 1.4$ keV) between the 8268.5-keV $\gamma$ ray and the very weak 8934.2-keV $\gamma$ ray, which was the highest-energy $\gamma$ ray assigned to $Xe^{132}$, is consistent with the known energy ($667.5 \pm 0.3$ keV) of the first excited state of $Xe^{132}$. (2) The observation of coincidences between the 8268.5- and 667.5-keV $\gamma$ rays by Bartholomew and Naqvi.[5] (3) The fact that the neutron separation energy obtained by assuming that the 8268.5-keV transition does feed the 667.5-keV level is $8936.3 \pm 1.0$ keV. This value agrees excellently with the value of $8932 \pm 6$ keV given in the atomic-mass table of Mattauch, Thiele, and Wapstra.[37] These data thus establish the 8934.2- and 8268.5-keV transitions as primary transitions to the ground state and first excited state of $Xe^{132}$ and fix the neutron separation energy as $8936.3 \pm 1.0$ keV.

The remainder of the level scheme was then constructed as follows: (a) It was first assumed that the observed high-energy $\gamma$ rays ($E_\gamma > 4$ MeV) correspond to primary transitions to levels in $Xe^{132}$. The difference in energy between the neutron separation energy and the measured primary $\gamma$-ray energy then gave a preliminary value for the level energy ($E_L$). (b) A search of the $\gamma$-ray singles spectra was then made for the presence of secondary $\gamma$ rays, whose energies equaled the difference in energy between $E_L$ and the energy of a state already established in radioactive-decay studies or the present work. The secondary transitions were ordinarily placed in the level scheme on the basis of the energy fit alone, but in some cases the assignment was supported by other evidence. In the absence of further supporting evidence a level was only placed in the level scheme if three transitions were found which fitted as feeding or deexciting the level, of which two at least did not fit elsewhere in the level scheme. If only two of the transitions found to fit did not fit elsewhere, the level is shown as a dashed line in Fig. 5. (c) A precise value of $E_L$ was then found from the weighted mean of values obtained from all of the transitions into and out of the level. (d) Finally, steps b and c were repeated using these more precise values of $E_L$.

In general it was found that where levels are populated in both the $(n, \gamma)$ reaction and the decay of $I^{132}$ or $Cs^{132}$ the $\gamma$-ray energies and branching ratios measured here are in good agreement with the mean values measured in radioactive-decay studies.[24] The energies measured in the present $(n, \gamma)$ reaction study are, on the whole, less precise than the corresponding values obtained from radioactive-decay studies where the background is lower.

TABLE II. Results of the $\gamma$-$\gamma$ coincidence measurements.

| $\gamma$ Ray (keV) | Coincident peaks [a] (MeV) |
|---|---|
| | **Low-energy–low-energy coincidences** |
| 483.7 | 0.67, 0.77, 1.32 |
| 522.7 | 0.67, 0.77, 0.955, (1.15), (1.295) |
| 570.1 | (0.62), (0.67) |
| 600.2 | (0.42), 0.67, 0.77 |
| 630.2 | (0.51), (0.57), 0.67 |
| 667.5 | 0.48, 0.51, 0.52, (0.57), 0.60, 0.63, 0.77, (1.03), 1.32 |
| 772.5 | (0.43), 0.48, 0.52, 0.60, 0.67, 1.03 |
| 1028.7 | 0.67, 0.77 |
| 1317.6 | 0.48, 0.67 |
| | **High-energy–low-energy coincidences** |
| 483.7 | 6.47 [b] |
| 667.5 | 6.38 [b], 6.47 [b] |
| 772.3 | 6.38 [b], 6.47 [b] |
| 5755.0 [b] | (0.67), (0.77) |
| 6380.5 [b] | 0.67, 0.77 |
| 6466.8 [b] | 0.48, 0.515, 0.67, 0.77, 1.03 |

[a] The error on the quoted energies is ±10 keV.
[b] The observed peak was a two-escape peak.

As noted in the introduction, Ribon[28] has measured the spin of the 14.1-eV resonance as probably $2^+$. However, his measurements do not rule out a value of $1^+$. As a result, the spins assigned to those levels populated directly from the capture state are less well defined than they would be if we knew the spin of the resonance.

Comments on the properties of the individual levels in $Xe^{132}$ follow.

### A. Ground State and 667.5 ± 0.3-keV Level

As discussed above we observe a very weak primary transition ($E_\gamma = 8934.2 \pm 1.0$ keV) to the $0^+$ ground state, and a moderately strong primary transition ($E_\gamma = 8268.5 \pm 0.9$ keV) to the $2^+$ first excited state of $Xe^{132}$. If the capture state is indeed $2^+$ as suggested by Ribon,[28] then the transition to the ground state is a pure $E2$ transition. $E2$ primary transitions have rarely been observed in neutron capture. The relative intensity of this transition is consistent with this multipolarity, but the well-known Porter-Thomas fluctuations of pri-

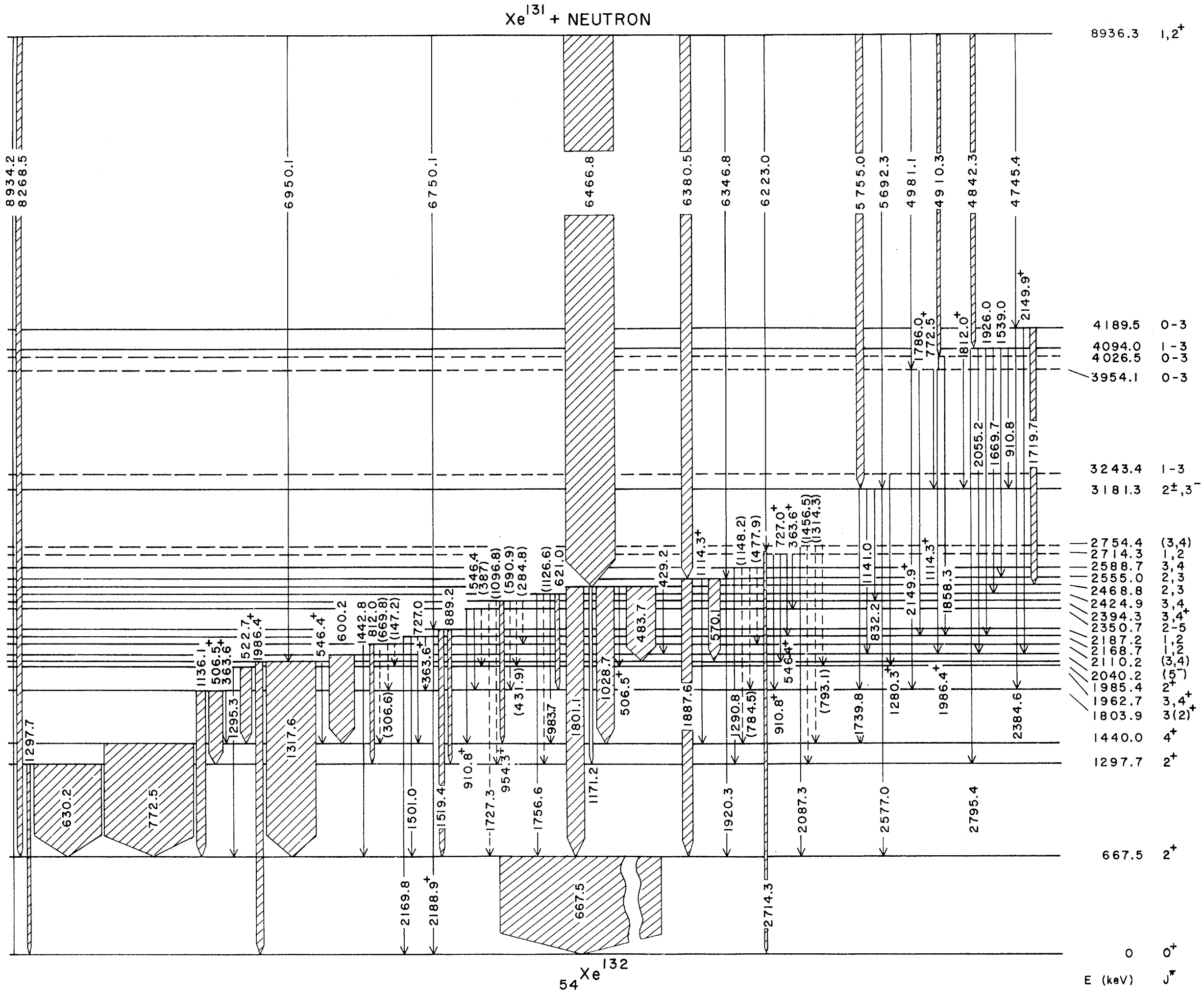


FIG. 5. This figure shows the decay scheme obtained in the present work for the 14.1-eV resonance in the $Xe^{131}(n,\gamma)$-$Xe^{132}$ reaction. The measured level energies (in keV) and assigned spins and parities are indicated on the right. The breadths of the vertical lines representing the observed transitions are proportional to the measured $\gamma$-ray intensities. Transitions represented by dashed lines were observed in radioactive-decay-scheme studies (see Ref. 25) but are thought to be too weak to be observed in the present work. In the absence of further supporting evidence a level was only placed in the level scheme if three transitions were found which fitted as feeding or deexciting the level, of which at least two did not fit elsewhere in the level scheme. If only two of the observed transitions did not fit elsewhere, then the level is shown as a dashed line. $\gamma$ rays noted with a dagger fit in energy in more than one place in the level scheme.

mary capture $\gamma$-ray intensities preclude any more meaningful statement.

The $667.5 \pm 0.3$-keV first excited state of $Xe^{132}$ is well known from studies[9-27] of $I^{132}$ and $Cs^{132}$. The value of the energy obtained here is consistent with the mean values[12,24] $667.67 \pm 0.06$ keV and $667.65 \pm 0.09$ keV measured in studies of the radioactive decay of $I^{132}$ and $Cs^{132}$, respectively. The measured[17] $K$ conversion coefficient of this transition is consistent with pure $E2$ multipolarity, and hence with spin and parity $2^+$ for this level. Spin and parity $2^+$ for the first excited state is consistent with the systematics of the energies of levels in even-even nuclei in this region.

### B. 1297.7 ± 0.5 keV

A level at this energy is well established in radioactive-decay studies.[9-25] It decays to the ground state and first excited states by transitions of energy 1297.7 and 630.2 keV. In the present experiment it was not possible to measure the energy and intensity of the former transition, because it appears as a part of a multiplet involving a strong 1293.6-keV background peak from indium on the Ge(Li) detector and a 1295.3-keV transition in $Xe^{132}$. As a result it is not possible to make a comparison with the branching ratio measured in radioactive decay. The 630.2-keV transition is certainly that observed in the radioactive-decay studies, since it is observed in coincidence with the 667.5-keV $\gamma$ ray (see Fig. 4 and Table II), and the measured intensity clearly indicates that it lies near the ground state. Several transitions are observed to feed this level in the $(n,\gamma)$ reaction.

The energy of a possible primary transition to this level coincides with that of the upper member of the well-known $Fe(n,\gamma)$ doublet at 7629–7643 keV, which is clearly evident in the 14.1-eV resonance spectrum (see Fig. 2). As a result it is not possible to determine whether such a primary $\gamma$ ray is present in the $Xe^{132}$ spectrum. An upper limit on the intensity of this line, relative to $I_\gamma(667.5)=100$, is $I_\gamma \leq 0.2$. The $2^+$ spin and parity assigned to this level is based on the $\gamma$-$\gamma$ directional-correlation measurements of Robinson, Johnson, and Eichler[10] and the $M1$-$E2$ multipolarity assigned[22,24] to the 630.2-keV $\gamma$ ray.

### C. 1440.0 ± 0.3 keV

This level is also firmly established from studies of radioactive decay[9–25] and the $Te(\alpha,2n)$ reaction.[26,27] Coincidence measurements show that it decays by a pure $E2$ transition[22,24] of 772.5 ± 0.3-keV energy to the 667.5-keV first excited state. The level was assigned spin and parity $4^+$ by REJ[15] on the basis of $\gamma$-$\gamma$ directional-correlation measurements, which are consistent with spin 2, 3, or 4, the log$ft$ of the $I^{132}$ $\beta^-$ decay to the level, and the systematics of the energy levels in neighboring even-even nuclei.

Bergström *et al.*[27] have measured the angular distribution of the 772.5-keV $\gamma$ ray with respect to the beam direction in the $(\alpha,2n)$ reaction, which in principle should reflect the change in spin involved in the transition. Unfortunately, the state is strongly fed via a long-lived isomer produced in the $(\alpha,2n)$ reaction, which reduces the measured anisotropy. The value measure is consistent with spin 4 for this state.

A primary transition to a level of spin and parity $4^+$ would have to be of $E2$ or higher multipolarity, and as such would be very weak. No such transition was observed.

### D. 1803.9 ± 0.8 keV

A level at this energy was first proposed by REJ[15] on the basis of the observed coincidence between the 667.5-keV $\gamma$ ray and a $\gamma$ ray at 1.14 MeV. In a private communication to the authors of Ref. 12, Henck[13] pointed out a discrepancy in the energies obtained for this level from studies of $Cs^{132}$ and $I^{132}$. On the basis of his own coincidence measurements he then placed the 506- and 1136-keV transitions assigned as originating with this level elsewhere in the level scheme. Carter, Hamilton, and Pinajian[12] remeasured the energies of the $Cs^{132}$ $\gamma$ rays and showed that the resulting level energy agreed with that obtained in $I^{132}$ decay. They also pointed out that the $\gamma$-ray branching ratio measured for this level in the two decays was the same, which supports the contention that the same level is populated in both decays. The branching ratio measured here for the 1136.1-, 506.5-, and 363.6-keV $\gamma$ rays to the 667.5-, 1297.7-, and 1440.0-keV levels is 0.62 : 1.0 : 0.078, in excellent agreement with the value 0.59 : 1.0 : 0.098 given by Carter *et al.*[24] It is highly unlikely that these three $\gamma$ rays would appear in the same relative intensity when produced in three different ways unless they do indeed deexcite the same level. The $\gamma$-$\gamma$ coincidence studies of Hamilton, Carter, and Pinajian(HCP)[25] add further support for this level. This level and its mode of decay now seem to be firmly established.

Robinson, Johnson, and Eichler[10] assigned spin 2 or 3 for this level from their $\gamma$-$\gamma$ correlation studies on $Cs^{132}$. The $M1$-$E2$ multipolarities[22,24] of the 1136.1- and 506.1-keV transitions indicate even parity. The failure to observe a transition to the $0^+$ ground state favors spin and parity $3^+$, but $2^+$ is not ruled out. The failure to observe a primary $\gamma$ ray to this level is not significant, because of the well-known Porter-Thomas fluctuations in the partial radiation widths of neutron resonances.

### E. 1962.7 ± 0.7 keV

This level was established by the observation of the 522.7–772.5-keV cascade by REJ.[15] This result was confirmed by HCP[25] and by the present experiment. HCP also observed coincidences between the 1295.3-keV transition to the 667.5-keV state and the 667.5-keV $\gamma$ ray. This 1295.3-keV line is part of a complex multiplet in the $(n,\gamma)$ spectrum, so it could not be measured in the spectra obtained here.

The $\gamma$-$\gamma$ correlation studies of REJ[15] indicate spin 3, 4, or 5 for this level. Spin 5 is very unlikely, since the observed transition to the $2^+$ state would be of $M3$ multipolarity in this case. The multipolarity[22,24] of the 522.7-keV transition is $M1$-$E2$, which establishes even parity for this level. Thus the level has spin and parity of $3^+$ or $4^+$.

### F. 1985.4 ± 1.0 keV

This level is populated directly in the $(n,\gamma)$ reaction by the weak 6950.1-keV primary transition. It decays to the ground state and first excited states by the 1986.4- and 1317.6-keV transitions, with a branching ratio of 0.11 ± 0.02. This is in good agreement with the values of $0.12 \pm 0.02$ and $0.09 \pm 0.03$, which were measured[12,24] for this branching ratio in the $Cs^{132}$ and $I^{132}$ decays, respectively.

Henck *et al.*[22] in their study of $I^{132}$ placed these transitions elsewhere. For example, the 1317.6-keV transition was placed as deexciting a level at 2614 keV. However, the transitions placed as deexciting the 2614-keV level in Ref. 22 do not have the same relative intensity in the $(n, \gamma)$ and radioactive-decay studies. As a result, the placing of these $\gamma$ rays suggested by Henck *et al.* seems unlikely.

REJ[15] assigned spin 2 to this level from their $\gamma$-$\gamma$ directional-correlation studies. The decay to the ground state is consistent with spin 1 or 2 and positive parity.

The level is strongly fed from the 2468.8- and 2555.0-keV levels by the 483.7- and 570.1-keV transitions. The observed 483.7-1317.6-keV coincidences confirm the former result (see Table II).

### G. 2040.2 ± 0.6 keV

A level at this energy was observed in studies[26,27] of the decay of $Xe^{132m}$ and the $Te(\alpha, 2n)$ reaction. It was assigned spin and parity $5^-$. The level decays by an intense 600.2-keV transition to the $4^+$ level at 1440.0 keV. This transition is observed to be in coincidence with the 667.5–772.5-keV cascade. There is also weak evidence of coincidences with a $\gamma$ ray of $\approx$0.42-MeV energy which may represent the 429.2-keV transition between the 2468.8- and 2040.2-keV levels. The 1141.0-, 2055.2-, and 2149.9-keV transitions fit in energy as feeding this level from the 3181.3-, 4094.0-, and 4189.5-keV levels. The failure to observe a primary transition to this level is consistent with spin and parity $5^-$.

### H. 2110.18 ± 0.06 keV

A level at this energy is clearly established in studies of the decay of $I^{132}$. HCP[25] have discussed the evidence for the existence of this level and place five transitions of energy 1442.56, 812.2, 669.8, 306.6, and 147.2 keV as deexciting it. We observe $\gamma$ rays of energy 812.0 and 1442.2 keV which agree in energy and relative intensity $[I(1442)/I(812.0) = 0.26 \pm 0.1$ compared with the value[24] of $0.25 \pm 0.03$ for the decay of $I^{132}]$ with the first two of these $\gamma$ rays. Of the three remaining transitions placed as deexciting this level by HCP,[25] two are too weak to be observed in the present experiment and the third has an energy of 669.8 keV and would be masked by the intense 667.5-keV $\gamma$ ray from the first excited state to the ground state. The level may also be weakly fed from levels at 2187.2, 2394.3, and 2588.7 keV.

On balance the evidence suggests that this level is weakly populated in the $(n, \gamma)$ reaction. Accordingly, it is included in Fig. 5. HCP[25] assign spin and parity $(3,4)^+$ on the basis of the measured $\log ft$ in the decay of $I^{132}$ and the observation of $(M1\text{-}E2)$ transitions to $2^+$ states.

### I. 2168.7 ± 1.3 keV

A level at this energy would decay by transitions of energy 2168.7, 1501.2, 728.7, and 364.8 keV to the 0-, 667.5-, 1440.0-, and 1803.9-keV states. $\gamma$ rays of these energies are observed, although the last two may be placed elsewhere in the level scheme. The 363.6-keV transition is well established as deexciting the 1803.9-keV level (see Sec. III D). One cannot exclude the possibility that a weak transition of the same energy may be placed here. A $\gamma$ ray of 727.1-keV energy was observed[24] in the $I^{132}$ decay, but HCP[25] place this transition as deexciting a level at $2838.7 \pm 0.10$ keV. Their results indicate that the 2838.7-keV level decays by four transitions. The energies of two of these coincide with the energies (727.0 and 1398.8 keV) of $\gamma$ rays measured here. These $\gamma$ rays are weak and their intensities are not well measured here, but their relative intensities are consistent with those measured in the decay of $I^{132}$. The other two transitions placed as deexciting the 2838.7-keV level by Hamilton *et al.* would be too weak to be measured in the present experiment. It seems possible then that the 2838.7-keV level is weakly populated in the $(n, \gamma)$ reaction and the 727.1-keV transition properly arises there. However, it is not possible to decide between these possibilities on the basis of the information presently available.

Transitions of energy 546.4, 1786.0, and 1926.0 keV fit as feeding this level from the levels at 2714.3, 3954.1, and 4094.0 keV. No primary transition to this level was observed.

Transitions to the $0^+$ and $2^+$ ground and first excited states indicate spin 1 or 2 for this level. No information on the parity of the level is available.

### J. 2187.2 ± 0.8 keV

This level is populated by a weak primary transition of $6750.1 \pm 0.8$-keV energy. It decays by the 2188.9-, 1519.4-, and 889.2-keV transitions to the ground state, 667.5- and 1297.7-keV levels.

Carter *et al.*[24] report three very weak $\gamma$ rays of energy $2186.9 \pm 2.0$, $1519.7 \pm 0.2$, and $889.0 \pm 2.0$ keV in the $I^{132}$ decay. The relative intensities reported in Ref. 24 for these $\gamma$ rays were $0.13 \pm 0.06 : 1.0 : 0.77 \pm 0.11$, in good agreement with the values reported here, namely $0.17 \pm 0.11 : 1.0 : 0.47$

± 0.09. The $\gamma$ rays were not placed in the level scheme by Carter *et al.* The above results indicate that this level is weakly populated in both the $(n,\gamma)$ reaction and the decay of $I^{132}$.

The observation of transitions to levels with spins $0^+$ and $2^+$ indicates spin 1 or 2 for this level. No evidence is available on the parity of the level.

### K. 2350.7 ± 0.16, 2394.3 ± 0.5, and 2424.9 ± 0.7 keV

Hamilton *et al.*[22] have proposed levels in $Xe^{132}$ at the above energies on the basis of studies of the decay of $I^{132}$. Columns 1 and 2 of Table III list the energies and intensities (relative to the strongest line from each level) of the $\gamma$ rays assigned in Ref. 25 as deexciting these levels. Where $\gamma$ rays of the same energy have been observed in the $(n,\gamma)$ reaction, the measured energy is listed in column 3. We note that in each case the strongest $\gamma$ rays deexciting the level are observed in the $(n,\gamma)$ reaction, the remaining ones being too weak to be seen in the present experiment. A weak $\gamma$ ray of 1669.7-keV energy fits as feeding the 2424.9-keV level from a level at 4094.0 keV, and an 832.2-keV $\gamma$ ray fits between the 3181.3- and 2394.3-keV levels. We conclude that these three levels are very weakly populated in the $(n,\gamma)$ reaction. No primary $\gamma$ rays to these levels were observed.

The evidence available on the spins and parities of these levels can be summarized as follows: (1) 2350.7 keV: The measured log$ft$ in the decay of $I^{132}$ indicates spin 3 to 5. The observed mode of decay is consistent with these spin values. (2) 2394.3 keV: The $\gamma$-$\gamma$ directional-correlation studies of REJ[15] and Rao[16] are consistent with spins 3, 4, or 5. Spin 5 is ruled out by the observation of a transition to the $2^+$ first excited state. The multipolarity of the 954.3-keV transition to the 1440.0-keV level has been measured[22,24] and found to be $M1$-$E2$. Hence the state has even parity. (3) 2424.9 keV: This state is observed to decay to levels with spins ranging from 2 to 4, which limits the probable spin to 2, 3, or 4. The measured[25] log$ft$ for this level in the decay of $I^{132}$ is consistent with spin 3, 4, or 5. The multipolarity of the 621.0-keV transition to the 1803.9-keV level was found[22,24] to be $M1$-$E2$. Hence this level may have spin and parity $3^+$ or $4^+$.

### L. 2468.8 ± 0.5 keV

This level is fed by the very intense 6466.8 ± 0.5-keV primary transition and by the moderately strong 1719.7-keV transition from the level at 4189.5 keV. It decays by the 1801.1-, 1171.2-, 1028.7-, 483.7-, and 429.2-keV transitions to levels at 667.5, 1297.7, 1440.0, 1985.4, and 2040.2 keV. None of these transitions fit elsewhere in the level scheme. They are also not observed in radioactive-decay studies.

In addition to the energy fits there is some support for the placing of these $\gamma$ rays from the coincidence studies. The 6466.8-keV primary $\gamma$ ray is in coincidence with the 483.7- and 1028.7-keV $\gamma$ rays (see Table II). In turn the 483.7-keV $\gamma$ ray to the 1985.4-keV levels is in coincidence with the 667.5-, 772.5-, and 1317.6-keV $\gamma$ rays, all of which are emitted in or following the decay of the 1985.4-keV level. The 1028.7-keV $\gamma$ ray to the 1440.0-keV level is in coincidence with the 667.5- and 772.5-keV $\gamma$ rays, which form a cas-

TABLE III. Energies and relative intensities of $\gamma$ rays from the 2350.7-, 2394.3-, and 2424.9-keV levels.

| Level energy (keV) | $\gamma$-ray energy from $I^{132}$ decay [a] | $I_\gamma$(relative) [b] | $\gamma$-ray energy from $(n,\gamma)$ reaction | $I_\gamma$(relative) [b] |
|---|---|---|---|---|
| 2350.7 ± 0.16 | 387.8 ± 0.4 | 0.13 ± 0.03 | ··· | ··· |
| | 547.1 ± 0.2 | 1.0 | 546.4 ± 0.5 | 0.5 ± 0.35 |
| | 910.3 ± 0.2 | 0.73 ± 0.08 | 910.8 ± 0.7 | 1.0 |
| 2394.3 ± 0.5 | ··· | ··· | 44.9 ± 0.3 | 0.56 ± 0.23 |
| | 284.8 ± 0.1 | 0.044 ± 0.004 | ··· | ··· |
| | 431.9 ± 0.4 | 0.025 ± 0.005 | ··· | ··· |
| | 590.9 ± 2.0 | 0.0033 ± 0.0022 | ··· | ··· |
| | 954.55 ± 0.09 | 1.0 | 954.3 ± 0.3 | 1.0 |
| | 1096.8 ± 0.7 | 0.0019 ± 0.0007 | ··· | ··· |
| | 1727.3 ± 0.5 | 0.0034 ± 0.0005 | ··· | ··· |
| 2424.9 ± 0.7 | 621.0 ± 0.2 | 1.0 | 621.0 ± 0.5 | 1.0 |
| | 984.5 ± 0.2 | 0.28 ± 0.03 | 983.7 ± 0.9 | 0.52 ± 0.26 |
| | 1126.6 ± 0.7 | 0.026 ± 0.012 | ··· | ··· |
| | 1757.5 ± 0.2 | 0.19 ± 0.02 | 1756.6 ± 0.8 | 0.38 ± 0.14 |

[a] Taken from Ref. 25.

[b] Relative to intensity of strongest line from each level.

cade from this level to the ground state. The 6466.8-keV primary $\gamma$ ray was also observed in coincidence with the 667.5- and 772.5-keV $\gamma$ rays. Evidence for the 429.2-keV transition, which is thought to proceed to the $5^-$ state at 2040.2 keV, consists of a peak at $420 \pm 10$ keV seen weakly in coincidence with the 600.2-keV transition, which in turn, deexcites that level.

The strong primary $\gamma$ ray is almost certainly of dipole character, thus indicating spin 0 to 3 for the 2468.8-keV level. If the 429.2-keV transition to the $5^-$ state at 2040.2 keV is correctly placed, then the spin and parity of the 2468.8-keV level must be $3^-$, since any other value would imply a multipolarity higher than $E2$ for this transition, which would be unlikely to compete with dipole and quadrupole transitions to other levels. Since the 429.2-keV transition is placed tentatively on the basis of the energy fit and the evidence of weak 420-600 keV coincidences discussed above, we cannot rule out the possibility of spins and parities $2^{\pm}$ and $3^+$. It should be noted that if this level does have spin and parity $3^-$, then it implies $2^+$ spin and parity for the 14.1-eV resonance, since a $1^+$ assignment would require $M2$ multipolarity for the 6466.8-keV primary transition, which is most unlikely.

### M. 2555.0 ± 0.6 keV

This level is fed by the strong $6380.5 \pm 0.5$-keV primary transition and the 1539.0-keV transition from the level at 4094.0 keV. It decays via the 1887.6-, 1114.3-, and 570.1-keV transitions to levels at 667.5, 1440.0, and 1985.4 keV. The 1114.3-keV $\gamma$ ray may be placed elsewhere in the level scheme.

The 6380.5-keV primary transition was observed to be in coincidence with the 667.5- and 772.5-keV transitions from the 667.5- and 1440.0-keV levels, respectively. The strength of the primary transition establishes it as a dipole transition and hence restricts the level spin to values from 0 to 3. Decay to levels of spin 2 and 4 further restricts the spin to 2 or 3. There is no evidence concerning the parity of the state.

### N. 2588.66 ± 0.11 keV

As in the cases of the levels discussed in Secs. III H and K this level, which was established[25] in studies of $I^{132}$, appears to be populated weakly in the decay of the 14.1-eV resonance. A weak $6346.8 \pm 2.5$-keV primary transition to this level is observed. The level is thought[25] to decay by five transitions, of which the two most intense coincide in energy with the $1920.3 \pm 1.2$- and 1290.8-keV $\gamma$ rays observed here. The remaining three $\gamma$ rays would be too weak to be observed in the present experiment. It seems reasonable to conclude that this level is also weakly fed in the $(n,\gamma)$ reaction.

The measured $\log ft$ in the $I^{132}$ $\beta^-$ decay is consistent with spins 3, 4, and 5. The observed decay to states of spin 2 rules out spin 5. The observation of a primary $\gamma$ ray in this reaction strongly favors spin 3 but spin 4 cannot be ruled out. No evidence is available on the parity of this state.

### O. 2714.3 ± 1.3 keV

This level is populated by a primary transition of energy $6223.0 \pm 1.0$ keV. Observed $\gamma$ rays of energy 2714.3, 910.8, 727.0, 546.4, and 363.6 keV may represent transitions to levels at 0, 1803.9, 1985.4, 2168.7, and 2350.7 keV. With the exception of the 2714.3-keV transition, however, all of these transitions fit elsewhere in the level scheme, and $\gamma$ rays of the same energy were also observed in the radioactive-decay studies.[24] Hence the level appears as a dashed line in Fig. 5.

The observation of a primary transition and a 2714.3-keV transition to the $0^+$ ground state limits the spin of the level to 1 or 2. If the spin is 2, odd parity is also ruled out, since it would imply $M2$ multipolarity for the 2714.3-keV transition, which is unlikely to compete with dipole transitions to other levels.

### P. 2754.43 ± 0.13 keV

The case of this level is similar to those discussed in Secs. III K and N. HCP[25] show a level decaying by four transitions, of which one ($E_\gamma = 2086.8 \pm 0.15$ keV) is much more intense than the others. We observe a very weak line of energy $2087.3 \pm 0.8$ keV. Again the level may be weakly populated in the $(n,\gamma)$ reaction. The remaining three $\gamma$ rays assigned to this level in Refs. 24 and 25 would be too weak to be observed here. As pointed out by HCP[25] the level at $2754 \pm 3$ keV observed[26,27] in the $Te^{130}(\alpha, 2n)Xe^{132}$ reaction is clearly not that under discussion.

### Q. 3181.3 ± 1.5 keV

This level is fed by the strong $5755.0 \pm 1.0$-keV primary transition. It may also be fed by transitions of 772.5- and 910.8-keV energy from the 3954.1- and 4094-0-keV levels but these transitions fit elsewhere in the level scheme. It decays via transitions of 1739.8-, 1141.0-, and 832.2-keV energy to the 1440.0-, 2040.2-, and 2350.7-keV levels. All three of these transitions are weak. As a result no evidence concerning their positions in the level scheme was obtained from the coincidence measurements described in Sec. II C. It is noteworthy that in contrast to the other levels populated in this reaction the total incoming intensity exceeds the total outgoing intensity.

The strength of the primary transition indicates that it has dipole character, thus limiting the level spin to the values 0 to 3. If the 1141.0-keV transition to the $5^-$ level at 2040.2 keV is correctly placed, then spin and parity $3^-$ is the only choice for this level. The alternative would be $E3$ or higher multipolarity for this transition, which is unlikely. If the 1141.0-keV transition is incorrectly placed, spins and parities $2^{\pm}$ are allowed.

### R. 3243.4 ± 1.5 keV

This level is fed by a weak 5692.3 ± 1.2-keV primary transition and decays by 2577.0- and 1280.3-keV transitions to the 667.5- and 1962.7-keV levels. The 1280.3-keV transition may be placed elsewhere. Hence the level appears as a dashed line in Fig. 5. No information was obtained from the coincidence measurements concerning these transitions.

The observed feeding and decay of this level limit the possible spin to 1, 2, or 3. The parity of the state is unknown.

### S. 3954.1 ± 1.0 keV

This level is fed by a weak 4981.1 ± 1.7-keV primary transition. It decays to the 1803.9- and 2168.7-keV levels by transitions of 2149.9- and 1786.0-keV energy. The former may be placed elsewhere in the level scheme. Hence the level appears as a dashed line in Fig. 5.

The transition from the capture state, spin 1 or 2, and the observed transitions to states with spins of $3(2)^+$ and 1 or 2 restrict the spin to the values 0 to 3. The parity is unknown.

### T. 4026.5 ± 1.5 keV

A primary transition of energy 4910.3 ± 2.0 keV feeds this level. While the 1986.4- and 1858.3-keV transitions fit in energy between this level and the 2040.2- and 2168.7-keV levels, the former transition is firmly established as deexciting the 1985.4-keV level. It is perhaps worth noting that the intensities of the 4910.3- and 1858.3-keV $\gamma$ rays are equal within the errors.

The observation of a primary transition to the level restricts the range of possible spin values to 0 to 3. No evidence concerning the parity of the state is available.

### U. 4094.0 ± 1.0 keV

This level is fed by the 4842.3 ± 1.0-keV primary transition. It decays by the 2795.4-, 2055.2-, 1926.0-, 1669.7-, and 1539.0-keV transitions to levels at 1297.7, 2040.2, 2168.7, 2424.9, and 2555.0 keV. In addition the 910.8-keV transition, which may be placed elsewhere, fits in energy between this level and the 3181.3-keV level. No evidence on the placing of these transitions is available from the coincidence studies.

If the 2055.2-keV transition is correctly placed then the level spin is $3^-$, since it is unlikely that this transition is of higher multipolarity than $E2$. If it is not correctly placed then spins 1 to 3 are possible. No evidence is available concerning the parity of this state.

### V. 4189.5 ± 1.5 keV

This level is fed by a very weak primary transition of energy 4745.6 ± 2.5 keV. It decays to the 1803.9- and 2468.8-keV levels by the 2384.6- and 1719.7-keV transitions. In addition, the 2149.9-keV transition fits between this level and the level at 2040.2 keV, but, alternatively, may also be placed as deexciting the 3954.1-keV level.

If the 2149.9-keV transition does lie here then this level has spin and parity $3^-$. If not the spin of this state may have any value from 0 to 3. No evidence is available on the parity of this level.

### W. Possible Levels Not Included in the Level Scheme

In addition to the levels discussed above, which have been included in the level scheme (Fig. 5), there is weak evidence from the present neutron-capture studies for the existence of a number of other levels in $Xe^{132}$. This evidence does not meet the criteria outlined at the beginning of Sec. III for the inclusion of a level in the level scheme. Comments on the evidence for these possible levels follow:

*Level at 2838.7 ± 0.10 keV.* HCP[25] place a level at this energy in $Xe^{132}$, which deexcites by four transitions, of which the 1398.57- and 727.1-keV $\gamma$ rays are considerably stronger than the others. Weak $\gamma$ rays of these energies are observed in the present experiment. Both these transitions may be placed elsewhere in the level scheme (see Sec. III I).

We conclude that this level may be weakly populated in the $(n, \gamma)$ reaction.

*Level at 2693.3 ± 0.7 keV.* The energies of the 2027.0-, 889.2-, 707.9-, and 506.5-keV $\gamma$ rays sum with the 667.5-, 1803.9-, 1985.4-, and 2187.2-keV level energies to equal 2693.3 keV within the combined errors, thus suggesting a level in $Xe^{132}$ at this energy. With the exception of the 707.9-keV transition these transitions may be placed elsewhere in the level scheme. The 506.5- and 889.2-keV $\gamma$ rays are firmly established as deexciting the 1803.9- and 2187.2-keV levels (see Secs. III D and J). No primary transition to a level at this energy was observed.

*Levels at 3698.9 ± 0.8 and 3859.0 ± 0.8 keV.* Levels at these energies are suggested by the observation of possible primary transitions of 5237.3 ± 1.5- and 5077.5 ± 1.6-keV energy. In the case of the 3698.9-keV level we observe 812.0- and 1114.3-keV transitions which would fit between such a level and levels at 2583.75 and 2886.2 keV. Levels at these energies are known from studies of the decay of $I^{132}$, but no other evidence was obtained in the present work that they are populated in the $(n,\gamma)$ reaction. Both of these transitions also fit elsewhere in the level scheme. A very weak peak at 3699.2 ± 2.5 keV was also observed in our $\gamma$ ray spectra.

This peak may be a full-energy peak and hence may represent a weak ground-state transition from a level at 3698.9 keV. We also observe an 1895.8-keV $\gamma$ ray which would fit as a transition from the 3698.9-keV level to the 1803.9-keV level.

This transition fits equally well between the possible 3859.0-keV level and the 1962.7-keV level. In addition, we observe a 2055.2-keV $\gamma$ ray which could be a transition from the 3859.0-keV level to the 1803.9-keV level, but this transition fits elsewhere in the level scheme. The available evidence on these two levels is too weak for either to be included in the level scheme.

*Level at 3875.0 ± 1.0 keV.* A level at this energy is suggested by the observation of a possible primary $\gamma$ ray of 5060.7 ± 1.7-keV energy. The 2577.0- and 1887.6-keV transitions would fit between such a level and the 1297.7- and 1985.4-keV levels. Both of these transitions fit elsewhere in the level scheme.

*Level at 3992.8 ± 1.0 keV.* The 4943.8 ± 1.8-keV $\gamma$ ray assigned to $Xe^{132}$ may be a primary capture $\gamma$ ray to a level at this energy. The 2188.9-, 1280.3-, and 812.0-keV transitions would fit between such a level and the 1803.9-, 2714.3-, and 3181.3-keV levels. All three of these transitions fit elsewhere in the level scheme.

*Level at 4172.5 ± 1.0 keV.* The 4765.3 ± 1.9-keV $\gamma$ ray may be a primary capture $\gamma$ ray to a level at this energy. The 1986.4- and 78.8-keV transitions fit between such a level and the levels at 2187.2 and 4094.0 keV. It is perhaps worth noting that the weak 1280.3-keV transition would fit between a level at this energy and the level at 2886.2 keV which is populated[25] in the decay of $I^{132}$. In addition, the 313.0-keV transition fits between such a level and the possible level at 3859.0 keV. All four of the above mentioned transitions fit elsewhere in the level scheme.

## IV. DISCUSSION

In general, where a level is populated in both the $(n,\gamma)$ reaction and the radioactive decay of $I^{132}$ or $Cs^{132}$, the results of the present investigation confirm the results obtained by earlier authors[9–25] who studied these decays. At the same time we have also obtained a considerable amount of new information about the level structure of $Xe^{132}$. In particular, a number of new levels have been discovered above 2-MeV excitation energy and their decay modes have been determined. No evidence was found for levels at 2111.8, 2583.75, 2613.50, 2669.95, 2762.4, 2840.29, 2886.2, 2890.74, and 3058.7 keV, which have been reported[22,25] in studies of the decay of $I^{132}$. Both the $Xe^{131}(n,\gamma)$-$Xe^{132}$ reaction and the decay of $I^{132}$ are expected to populate low-spin states in $Xe^{132}$, but it is not surprising that some levels are populated in one process but not in the other. For example, the predominately statistical nature of the slow-neutron-capture reaction leads to strong fluctuations, the Porter-Thomas fluctuations, in the partial $\gamma$-ray widths of neutron resonances. As a result a particular level may not be populated in the decay of a single neutron resonance such as the one studied here.

The most striking feature of the level scheme obtained here is the intense feeding of the state at 2468.8 keV from the capture state. As discussed in Sec. III L the present results favor spin and parity $3^-$ for this level, but this assignment rests heavily on the placing of the 429.2-keV transition to the $5^-$ level at 2040.2 keV. If this transition is incorrectly placed then spin 2 cannot be ruled out. A $3^-$ octupole vibration is expected[38] at roughly this energy in $Xe^{132}$ and other neighboring even-even nuclei. However, such a level would be expected to decay predominantly to the collective, $2^+$ first excited state. Although there is a moderately strong transition to the first excited state, the 2468.8-keV level prefers to decay to the $4^+$ state at 1440.0 keV and the $2^+$ state at 1985.4 keV. Hence the nature of this level is unclear even if it does have spin and parity $3^-$.

It was hoped that the present experiment would yield an unambiguous value for the spin of the 14.1-eV neutron resonance in $Xe^{131}$ as well as provide information about the level structure of $Xe^{132}$. $s$-wave neutron capture on the $\frac{3}{2}^+$ ground state of $Xe^{131}$ leads to a capture state with spin 1 or 2. The observation of a strong primary transition (presumed dipole) to a known level of spin 0 or 3 should determine which value is correct. A primary transition was observed to the ground state, the only known $0^+$ state, but it is extremely weak (see Sec. III A) and may be an $E2$ transition. Since its multipolarity is uncertain, it is not significant in this context. No strong primary transitions were observed to feed levels with an established spin of 3. However, strong or moderately strong primary transitions were observed to levels at 2468.8, 3181.3, and 4094.0 keV, which decay to the $5^-$ state at 2040.2 keV. It is unlikely that the transitions deexciting these levels are of higher multipolarity than $E2$. If these transitions are correctly placed then the spins and parities of these levels must be $3^-$. Since they are also fed by dipole transitions from the capture state, the spin of the 14.1-eV resonance must then be 2. A weak primary transition was also observed to the 2488.7-keV level, which is thought to have spin 3 or 4 (see Sec. III N). Again the multipolarity of this transition is uncertain. Hence its observation does not determine the resonance spin. On balance the evidence from the present experiment favors spin 2 for the 14.1-eV resonance, in agreement with Ribon,[28] but it is not conclusive.

REJ[15] have compared the observed level structure of $Xe^{132}$ with the predictions of a number[39-43] of nuclear models for even-even nuclei in this mass region. They pointed out that all of these models, with the exception of the axially symmetric model of Davydov and Filippov,[41] predict the $2^+$ and $4^+$ states observed at approximately twice the energy of the first excited state. In addition, they predict a $0^+$ state in the same energy region. A careful search of the neutron-capture $\gamma$-ray spectrum was made for evidence of such a level. No such evidence was found. It is noteworthy that, thus far, the $0^+$ member of the two-phonon triplet has also escaped detection in the other neighboring even-even Xe nuclei. HCP[25] have speculated that the group of levels at ≈2-MeV excitation energy is the three-phonon quintuplet of levels predicted by the vibrational model at three times the energy of the first excited state. Unfortunately our knowledge of the properties of these levels remains too limited to make this comparison fully meaningful.

A detailed comparison with the predictions of the various models must await further experiments and more exact information on the spins, parities, and lifetimes of the known levels and on the mixing ratios of the observed transitions.

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†Work performed under the auspices of the U. S. Atomic Energy Commission.

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