true of the theoretical calculations. In fact, the orbit-orbit corrections (as well as the more certain electrodynamical corrections and those for the motion of the nucleus) cancel out entirely from $\Delta g_1 - \Delta g_2$ [see Eq. (18)], and these were the only corrections in which we had to resort to modified Slater wave functions. The deviations from Russell-Saunders coupling are involved solely in the difference $\Delta g_1 - \Delta g_2$, and it is natural to blame them for the discrepancy. However, the spin-orbit parameter involved therein can be estimated quite accurately by extrapolation from atomic spectra [unless perchance, the nondiagonal element $(^3P_2|\zeta_{2p}|^1D_2)$ differs markedly from the diagonal elements[11] $(^1P|\zeta_{2p}|^1P)$ or $(^3P|\zeta_{2p}|^3P)$]. In any case, a discrepancy of only 5×10^{-6} is, after all, very small. Complete reliance cannot be placed on even the most perfect Hartree-Fock wave functions used to compute F^k, etc., because of approximations basic to the self-consistent field model. The HHS wave functions, for instance, give a spin-orbit parameter about 10 percent too high. (The discrepancy in $\Delta g_1 - \Delta g_2$ would, incidentally, disappear almost completely if we used the HHS rather than spectroscopic value of ζ_{2p} in calculating the deviations from Russell-Saunders coupling, but there appears to be no logical grounds for so doing.) We are hence probably hoping for too much precision, and it certainly does not seem repaying to push further any calculations based on the Hartree-Fock model. The experimental measurements of Rawson and Beringer were originally essayed to see whether there was experimental evidence for the Schwinger electrodynamical corrections in complex atoms. As a result of the present paper we can certainly say that these corrections are confirmed in oxygen, though of necessity with less precision than in atoms with a single valence electron.

[11] G. W. King and J. H. Van Vleck, Phys. Rev. **56**, 464 (1939), find that the diagonal and off-diagonal elements of ζ are appreciably different in mercury, but in light atoms like oxygen the difference may not be as great.

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Decay Scheme of I^{132}*

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The radiations of 2.33-hr I^{132} have been investigated with magnetic lens and scintillation spectrometers. Beta rays of 2.12 (18 percent), 1.53 (24 percent), 1.16 (23 percent), and 0.9 (20 percent) Mev have been identified. Gamma rays of 0.528 (25 percent), 0.624 (6 percent), 0.673 (100 percent), 0.777 (75 percent), 0.96 (20 percent), 1.16 (8 percent), 1.40 (11 percent), 1.96 (5 percent), and 2.2 (2 percent) Mev have been observed, and their coincidences are tabulated. A possible decay scheme is proposed which is consistent with the experimental data.

INTRODUCTION

THE routine production[1] of 77-hr Te^{132}—2.33-hr I^{132} has made available high purity, high specific activity I^{132} sources for the first time. Previous investigations reported β rays[2] with maximum energies of 2.2 and 0.9 Mev, and γ rays[3] of 0.67, 1.41, and 1.99 Mev. A γ ray of energy greater than 2.23 Mev was reported[4] since photoneutron production in D_2O was observed. In view of the uncertainty in the existing information, it seemed advisable to undertake the present investigation.

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

[1] Stang, Tucker, Banks, Doering, and Mills, Nucleonics (to be published).

[2] Novey, Sullivan, Coryell, Newton, Sleight, and Johnson, in *Radiochemical Studies: The Fission Products* (McGraw-Hill Book Company, Inc., New York, 1951), Paper No. 135, National Nuclear Energy Series, Plutonium Project Record, Vol. 9, Book 2, part 5, p. 958.

[3] Maienschein, Bair, and Baker, Phys. Rev. **83**, 477 (1951).

[4] L. S. Goldring, Brookhaven National Laboratory Quarterly Progress Report, July 1–September 30, 1951 (unpublished); Brookhaven National Laboratory Report BNL-132 (S-11) (unpublished).

Source Preparation

The radioactive Te was separated with carrier Te from pile-irradiated U by a series of hydrolytic precipitations of TeO_2 alternated with precipitation of elemental Te by means of $NaHSO_3$ solution. The final solution consisted of Na_2TeO_3 in NaOH.

Since the half-life of I^{132} is short, it was desirable to use a Te^{132}—I^{132} equilibrium source for the β-ray energy measurements. This source was prepared by evaporating a small aliquot of the above solution on 0.1 mg/cm^2 nylon one week after the initial Te separation; the I which had grown in during the one-week delay was driven off during the evaporation. Sufficient time was then allowed for the I^{132} to attain equilibrium with the Te^{132} before the measurements were begun. The one-week delay before the separation of Te from I allowed

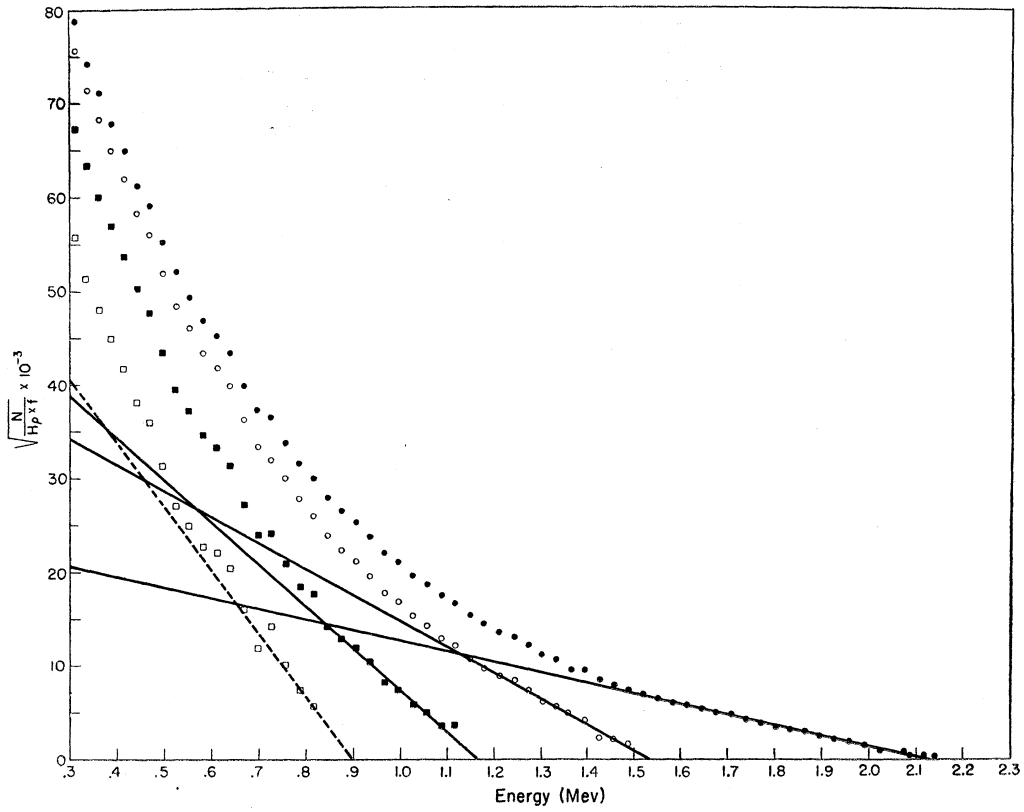

FIG. 1. Kurie plot analysis of the I^{132} β-ray spectrum.

for the decay of the primary short-lived Te fission product activities (2-min Te^{133}, 44-min Te^{134}, 2-min Te^{135}, 25-min Te^{131}, 72-min Te^{129}, and 9.3-hr Te^{127}). The Te isomers, 115-day Te^{127m}, 33-day Te^{129m} and 30-hr Te^{131m}, which are the parents of 9.3-hr Te^{127}, 72-min Te^{129} and 25-min Te^{131}, respectively, were not removed by this procedure. However, a consideration of the fission yields[5] and the half-lives indicates that the contribution from these activities could not be greater than 2 percent of that due to the I^{132}. The 77-hr Te^{132}, which was of course present, did not obscure the results for reasons which will be discussed later. A similar source was mounted in a stainless steel cup for investigation of the externally converted γ-ray spectrum.

In order to obtain an unambiguous picture of the I^{132} γ-ray spectrum, it was desirable to use "pure" I^{132} sources for these measurements. These sources were prepared from the final Te solution in the following manner: After an initial delay of at least 48 hours, which permitted the short-lived Te activities to decay, the daughter products were separated from the Te solution. Since this separation was performed at varying times after the initial Te separation, variable amounts of Te^{131m} and Te^{132} were present in the solution. A 2–4 hour growth period, after which the I was separated from the Te solution, resulted in a negligible contribution from the 8-day I^{131} arising from the Te^{131m} which may have been present. The I^{132} was precipitated as AgI and mounted.

β-RAY MEASUREMENTS

The β-ray spectrum was investigated using a lens spectrometer with a resolution of 2.7 percent. Figure 1 shows a Kurie plot analysis of the I^{132} β-ray spectrum. The experimental points were corrected for the decay during the experiment. Analysis of the Kurie plot gave the following β-ray energies and approximate intensities: 2.12 ± 0.04 Mev (18 percent), 1.53 ± 0.07 Mev (24 percent), and 1.16 ± 0.07 Mev (23 percent). A more doubtful β-ray group with an energy of 0.9 ± 0.1 Mev and an intensity of approximately 20 percent was also observed. The K-shell internal conversion electrons from the 0.673-Mev γ ray were carefully determined; the sources were too weak to permit accurate measurement of the other internal conversion electrons. It is obvious that the Te^{132} β rays, which are of much lower energy[6] (approximately 0.22 Mev), did not interfere with these energy and intensity determinations.

[5] A. C. Pappas, Technical Report No. 63, Laboratory for Nuclear Science, Massachusetts Institute of Technology, 1953 (unpublished).

[6] L. M. Langer and G. Ford, Atomic Energy Commission Report WASH-62, December, 1951 (unpublished), referred to in "Table of Isotopes" by Hollander, Perlman, and Seaborg, Revs. Modern Phys. **25**, 469 (1953).

γ-RAY MEASUREMENTS

The energies and intensities of the γ rays were investigated with a scintillation spectrometer which consisted of a 1-in. high×1½-in. diameter cylindrical NaI(Tl) crystal, a DuMont K1186 photomultiplier tube, non-overloading amplifier,[7] stable high-voltage supply,[8] and a single-channel pulse-height analyzer.[9] The source was placed approximately six inches from the crystal to minimize spurious addition effects which result from the simultaneous detection of two cascaded γ rays. Be absorber was used to remove the β rays.

The γ-ray spectrum was divided into three overlapping regions to insure that all points were determined in the region of good amplifier linearity and constant channel width. The normalized composite curve is shown in Fig. 2. The experimental points were all corrected for the decay which had occurred during the run. Energy calibration was made with Co^{60}, Na^{22}, Cs^{137}, and Ce^{144}-Pr^{144} γ rays. Although there was a slight asymmetry in the shape of the 0.665-Mev γ-ray photoline, the resolution was too poor to identify another γ ray. However, a γ ray of 0.624 Mev, which is not seen in Fig. 2, was observed in the electron spectrum from a thin lead converter with the lens spectrometer; the resolution was again set to 2.7 percent. No γ rays with energy less than 0.500 Mev were observed; the absence of a 0.364-Mev γ ray indicates that the 8-day I^{131} contamination was negligible. Since no x-rays were observed, there are no abundant γ rays present which are converted to an appreciable extent.

The relative intensities of the individual γ rays were obtained in the following manner. The areas under each of the individual photolines were integrated after subtraction of the background and the Compton distribution from each of the higher energy γ rays. These areas, after correction for the crystal efficiency and yield in the photoline,[10] are proportional to the relative intensities of the γ rays. In the case of the 1.96- and 2.2-Mev γ rays, the efficiency curves were extrapolated to these energies. Although some error was introduced by this procedure, it is probably small compared to the other errors in obtaining the intensities of these lines. The intensity of the 0.624-Mev γ ray is estimated to be approximately 6 percent of the 0.673-Mev γ ray from the external conversion electron data. The energies and intensities of the γ rays are tabulated in columns 1 and 2, Table I.

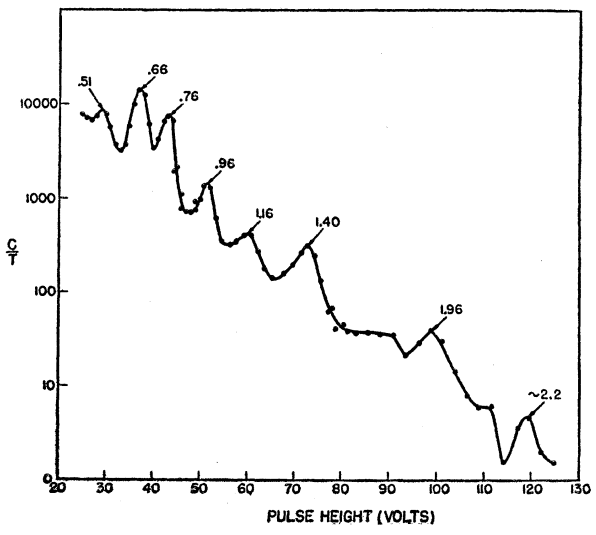

FIG. 2. I^{132} γ-ray spectrum observed with a scintillation spectrometer.

TABLE I. Energies, intensities, and γ-γ "coincidences" of I^{132} γ rays observed with scintillation spectrometers.

	Selecting γ-ray energy (Mev)	Rel. intensity (%) (including efficiency corrections)	γ rays observed in "coincidence" spectrum (Mev)
γ_1	0.510±0.03	25±5	0.665, 0.768
γ_2	0.665±0.03	100	0.510, 0.665, 0.768, 0.96, 1.16, 1.40, 1.96
γ_3	0.768±0.04	75±10	0.510, 0.665, 0.96, 1.16, 1.40
γ_4	0.96 ±0.05	20±4	0.665, 0.768
γ_5	1.16 ±0.06	8±3	0.665, 0.768
γ_6	1.40 ±0.07	11±4	0.665, 0.768
γ_7	1.96 ±0.10	~5	0.665
γ_8	2.2 ±0.10	~2	...

An equilibrium Te^{132}-I^{132} source was supplied to Dr. E. Church at the Argonne National Laboratory, who examined the internal conversion electrons in a 440-gauss β-ray spectrograph. He obtained the following more accurate energy measurements: 0.528±0.006 Mev, 0.673±0.006 Mev, 0.777±0.006 Mev. No significant data were obtained for the higher-energy γ rays because the source intensity was too low.

γ-γ AND β-γ COINCIDENCE MEASUREMENTS

The γ-γ and β-γ coincidence data were obtained using a coincidence scintillation spectrometer, the components of which were identical with those previously described, except that a gray-wedge coincidence spectrometer[11] replaced the single-channel analyzer. An anthracene crystal was used as the β-ray detector for the β-γ coincidence measurement. The essential feature of this coincidence spectrometer is that it displays either all events detected in one crystal, or only those events which occur in time coincidence (0.1 μsec) with events of a selected amplitude observed in another detector. Accidental effects were evaluated by the introduction of a 0.5-μsec delay line in one leg of the coincidence circuit. The γ-γ coincidences are tabulated in column 3, Table I.

[7] R. L. Chase and W. A. Higinbotham, Rev. Sci. Instr. **23**, 34 (1952).
[8] W. A. Higinbotham, Rev. Sci. Instr. **22**, 133 (1951).
[9] Model 510, Single Channel Pulse-Height Analyzer, Atomic Instrument Company, Cambridge, Massachusetts.
[10] P. R. Bell (unpublished).
[11] Bernstein, Chase, and Schardt, Rev. Sci. Instr. **24**, 437 (1953). R. L. Chase, Brookhaven National Laboratory Report BNL 262 (T-42), 1953 (unpublished).

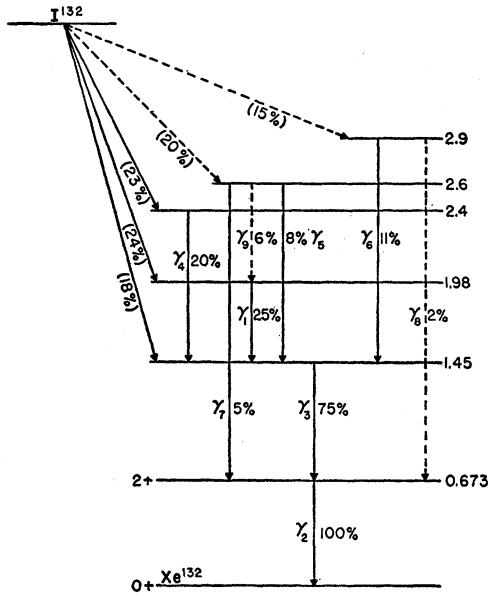

FIG. 3. Proposed decay scheme of I^{132}. The energies and intensities are the experimentally observed values.

By making intense exposures, it is possible to define the end point of a β-ray spectrum fairly accurately. Photographs were taken of the β rays in coincidence with each of the γ rays. The 2.12-Mev β ray was observed to be in coincidence with both the 0.665- and 0.768-Mev γ rays. Evidence for the other β-γ coincidences could not be obtained. The available source strength required that good geometry be used for these measurements, and consequently the intensity of the addition spectrum of the 0.665- and 0.768-Mev γ rays was comparable with that of the other γ rays. Although stronger sources could have been prepared, they would have been extremely difficult to work with, and it was felt that the Kurie plot analysis provided sufficient evidence for the proposed decay scheme. The β-γ coincidences obtained with the 1.96- and 2.2-Mev γ rays were doubtful because the low intensity of these γ rays limited the statistical accuracy of these measurements.

DISCUSSION

The decay scheme postulated in Fig. 3 is consistent with the experimental evidence; the indicated intensities and energies are the experimentally determined values. Doubtful or unobserved transitions are indicated by the dashed lines. The locations of both the 2.2- and 0.624-Mev (γ_9, Fig. 3) γ rays in the decay scheme are not implicit in the coincidence data. However, the 2.2-Mev γ ray, which is probably the γ ray observed to produce photoneutrons in D_2O, represents within the experimental error the crossover transition for the 1.4- and 0.77-Mev γ rays. The 1.16-Mev γ ray represents, within the experimental error, the crossover transition for the 0.53- and 0.62-Mev γ rays.

The energy and intensity of the 0.97-Mev β ray which was uncertain, and the 0.73-Mev β ray which was not observed in the Kurie plot analysis of the β-ray spectrum, are postulated on the basis of the γ rays. The β-γ coincidence data indicate that there are no β-ray transitions to either the ground state or the 0.67-Mev level, and that the 2.12-Mev β ray leads to the 1.45-Mev level. The $\log(ft)$ values for the 2.13, 1.53, 1.16, 0.97, and 0.73 Mev β-ray transitions are 7.5, 6.9, 6.4, 6.1, and 5.8, respectively; this indicates that all the β-ray transitions are probably first forbidden, with the possible exception of the 0.73-Mev β ray.

The K-shell internal conversion coefficient for the 0.673-Mev γ ray was determined to be 2.7×10^{-3}; this value appears to be in best agreement with the theoretical values for an $E2$ transition.[12]

The coincidence and intensity data indicate that the 0.673-Mev level represents the first excited state of Xe^{132}. The 2+ assignment for this level is consistent with the predictions of the systematics[13] of the first excited states of even-even nuclei. The spin assignment of the 1.45-Mev level is probably larger than 2, since no β-ray transitions to the 2+, 0.673-Mev level or the 0+ ground state are observed, and crossover transitions from the 1.45-Mev level to the ground state are absent.

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[12] Rose, Goertzel, and Perry, Oak Ridge National Laboratory Report ORNL-1023 (unpublished).
[13] G. Scharff-Goldhaber, Phys. Rev. **90**, 587 (1953).