PHYSICAL REVIEW VOLUME 101, NUMBER 3 FEBRUARY 1, 1956

Investigations of I^{128}

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(Received August 5, 1955)

The β^-, γ and electron capture processes of I^{128} were investigated with the solenoidal magnetic spectrometer, a single-channel scintillation spectrometer, a multiple-channel selective coincidence scintillation spectrometer, and a proportional counter spectrometer. Three β^- groups with energies 2.120, 1.665, and 1.125 Mev and relative abundance 76.0:15.5:2.0, and four γ radiations with energies 0.455, 0.540, 0.750, and 0.990 Mev and relative intensities 100:9.7:1.7:1.8 were found. The electron capture branch was determined to be 6.4% of the total disintegration. The ratio of electron capture to the ground to that to the first excited state of Te^{128} is 19:1. Spin and parity were assigned to the ground and excited states of the daughter nuclei Te^{128} and Xe^{128}, and a decay scheme was proposed for I^{128}.

INTRODUCTION

One of the main objectives of the study of β and γ spectroscopy is to investigate the properties of selected states of nulcides and to discover regularities of nuclear structure. Once certain regularities of the states are recognized and confirmed, they in turn serve as valuable guides in further investigations of energy level schemes. The most outstanding example of this is shown by the discovery and identification[1,2] of the rotational level of nuclei in the rare earth region for $90 \leq N \leq 108$. Recently it has been pointed out[3] that there is a second group of even-even nuclei in the region $66 < A < 150$ where the ratio E_2/E_1 of the energy of the second excited state to that of the first excited state is surprisingly constant, fluctuating around 2.2.

Xenon and tellurium both have a long series of stable even-even nuclides. Most of these nuclides are well investigated, and their level schemes are indeed confined to the regularities mentioned above. However, the low-lying excited states of Xe^{128} and Te^{128} are not well investigated and their position could be learned through the investigation of the β and γ radiations of I^{128}. I^{128} can be easily produced by the $I^{127}(n,\gamma)I^{128}$ reaction. However, because of its short half-life of 24.99 min,[4] its decay scheme was not thoroughly studied. It was known only that it decays by both β^- and electron-capture processes.[5] The maximum energy of the β^- spectrum is 2.02 Mev.[6] One gamma-ray with an intensity of 7% at 0.428 Mev was reported by spectrometer investigation,[5] and more recently another γ line was reported at 0.98 Mev.[7] Our investigations[8] revealed that there are four γ lines of energies 0.455, 0.540, 0.750 and 0.990 Mev with relative intensities 100:9.7:1.7:1.8 respectively. Three β^- groups were found with energies 2.120, 1.665 and 1.125 Mev and their relative abundances are 80.0%, 16.3%, and 3.7% respectively. Using the more accurate value for $\beta_2/\beta_3 = 7.8$ as obtained from the γ-ray intensities, the following relative intensities for the three β^- groups were obtained: 81.3:16.5:2.1. The electron capture branch is only 6.4% of the total decay and the 0.750-Mev line is in the electron capture branch. Furthermore, our findings are in excellent agreement with the predictions[3] based on the regularities of the even-even nuclei in the region of $66 < A < 150$ as mentioned above.

CHEMICAL PREPARATION

I^{128} was prepared by bombarding ethyl iodide with slow neutrons from the Columbia cyclotron. The Szilard-Chalmers method was used for the separation. The activated ethyl iodide was shaken with 10 cc of $0.05M$ $Na_2S_2O_5$ for at least 15 seconds. The aqueous solution was then separated and warmed slightly. Approximately 20 μg of Ag^+ was added to the solution and AgI precipitated. To attain very high specific activity of I^{128}, the minute quantity of iodine in the ethyl iodide due to photodissociation was always removed prior to bombardment.

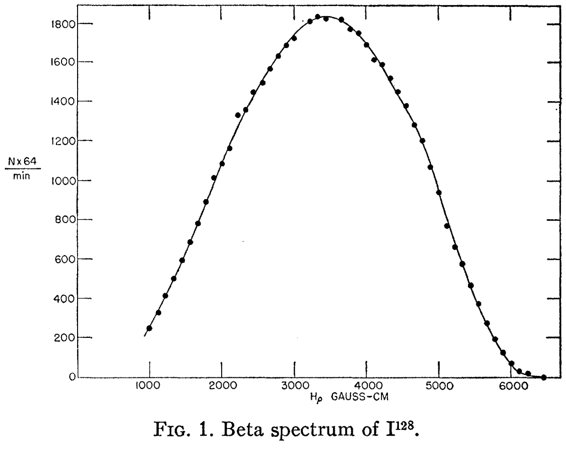

Fig. 1. Beta spectrum of I^{128}.

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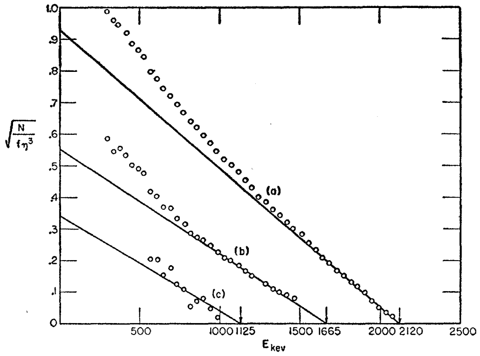


FIG. 2. Kurie analysis of the β^- spectrum. (a) Kurie plot showing high-energy β^- group with end-point energy of 2120±10 kev. (b) Kurie plot of remaining β^- groups obtained after subtraction of highest energy group from the composite spectrum showing a second β^- group with end-point energy of 1665±15 kev. (c) Kurie plot of lowest energy β^- group also obtained by subtraction methods, with end-point energy of 1125±20 kev.

β^- SPECTRA

The distribution of β^- particles of I^{128} was investigated in the magnetic solenoidal spectrometer. The measured spectrum was corrected for decay ($T_{\frac{1}{2}}=24.99$ min) and is plotted in Fig. 1. The Kurie analysis of the highest energy portion of the β^- spectrum as shown in Fig. 2(a) reveals a linear Kurie plot with an end point of 2120±10 kev. After subtracting the highest energy β^- group from the composite spectrum, the remainder can again be resolved into two linear Kurie plots. One has an end point of 1665±15 kev [Fig. 2(b)] and the lowest energy one has an end point of 1125±20 kev [Fig. 2(c)]. This value was obtained from the difference between the maximum energy of β_2^- and the energy of γ_2.

The relative intensities of the two highest energy β^- transitions as determined by comparing the area under these two component spectra are $\beta_1:\beta_2=4.9:1$ as shown in Fig. 3. The intensity ratio of the two lower energy groups was not calculated by comparing the area under the two corresponding spectra, as it is felt that the area of the lowest energy group might have been distorted by the scattering and absorption effects. To obtain the ratio of β_2/β_3, the measured gamma-ray intensities are used instead. It is found that $\beta_2/\beta_3=(\gamma_1-\gamma_2)/(\gamma_2+\gamma_4)=7.8$.

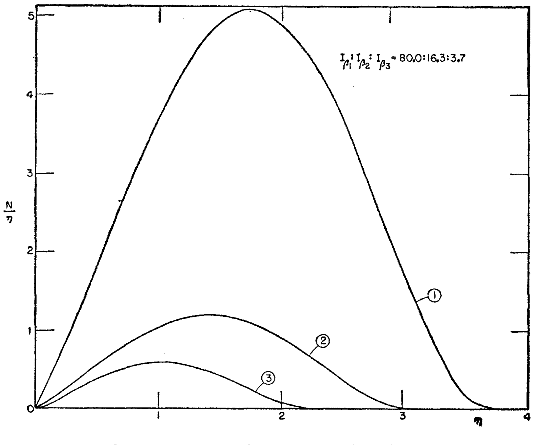


FIG. 3. Resolved momentum distribution for the three β^- spectra.

GAMMA-RAY SPECTRUM

(A) Spectrum Analysis

The gamma-ray spectrum was investigated using the conventional single-channel NaI scintillation spectrometer. The spectrum obtained after correction for decay is plotted in Fig. 4. Four gamma rays associated with I^{128} are identified at the energies 455±5, 540±5, 750±7, and 990±10 kev. After suitable corrections were made for background, Compton radiations from higher gamma rays, and variations in efficiency with energy, the relative intensities of the gamma rays are determined with an accuracy of about 10% and listed in Table I. The possibility of the 990-kev radiations arising from the summation of the 455-kev and the 540-kev gamma rays was eliminated by taking several spectra at varying source-detector distances and comparing the ratios of the corresponding peak heights.

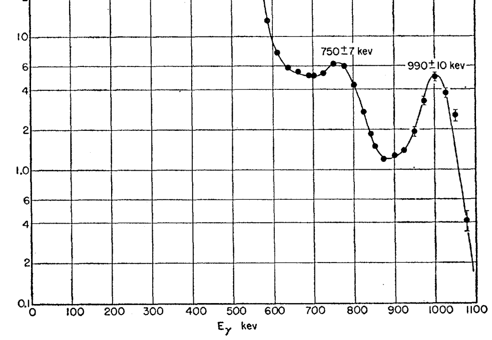


FIG. 4. γ-ray spectrum of I^{128}.

(B) Coincidence Measurements

The gamma rays and the x-rays emitted in the decay of I^{128} were investigated further by using the selective coincidence spectrometer. The results show that the 455-kev and the 540-kev gamma rays are coincident [Fig. 5(a)] and also that the 750-kev gamma rays are coincident with the Te x-rays and thus belong to the electron-capture branch [Fig. 5(b)]. The relative intensity of the 455-kev gamma ray to the 540-kev gamma ray was also calculated from the coincidence data. The result is listed in Table I and agrees well with the analysis of the spectrum obtained with the single-channel spectrometer. No attempt was made to determine the intensity ratio for the 750-kev gamma ray and the Te x-rays from the coincidence data.

INTENSITY OF THE 455-kEV RADIATION RELATIVE TO THE INTENSITY OF THE β^- RADIATIONS

In order to tabulate the relative intensities of the various branches, one must calculate the intensity of the 455-kev gamma radiation relative to the intensity of the β^- radiations. This ratio can be directly calculated from the relative intensity of the three groups of β^- particles and the relative intensity of the 455- and 540-kev lines.

$$\frac{\gamma_1}{\beta_1+\beta_2+\beta_3}=\frac{\gamma_1}{\beta_2(4.9+1+1/7.8)}=\frac{\gamma_1}{6.0(\gamma_1-\gamma_2)}=18.4\%.$$

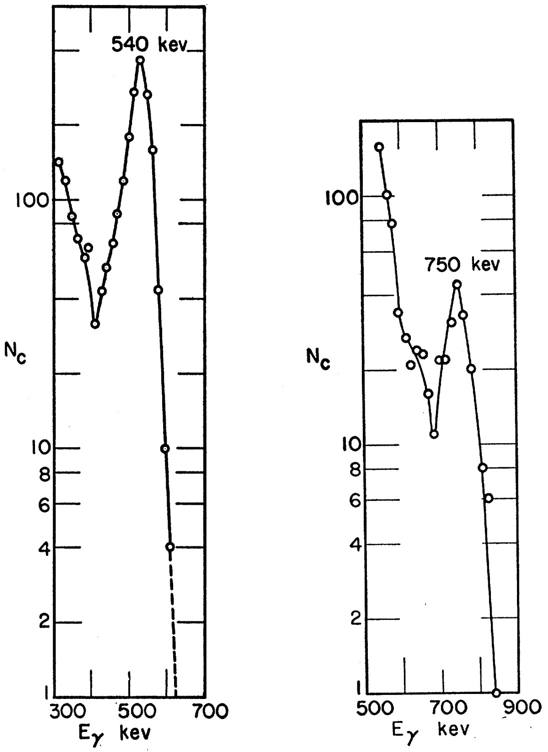
An independent auxiliary experiment with the use of Au^{198} was carried out to check this relative intensity ratio. First the β^- spectrum of Au^{198} was investigated in the magnetic solenoidal spectrometer under exactly the same condition as that for I^{128}, and the ratio of the areas under the two spectra (Au^{198}, I^{128}) was thus obtained. The relative intensities of the 455-kev line of I^{128} and the 411-kev line of Au^{198} were compared on the NaI scintillation spectrometer. Since the decay scheme and the conversion coefficient of Au^{198} are well known, the intensity of the 455-kev radiation relative to the intensity of the β radiations in I^{128} can be calculated. It yielded a value for $\gamma_1/(\beta_1+\beta_2+\beta_3)=20\pm2\%$, which is in good agreement with that derived from the first method described above.

TABLE I. Relative intensities of the gamma radiations.

Energy of γ radiation kev	Relative intensities from single-channel analyzer	Relative intensities from coincidence spectrometer
455	100	100
540	9.7	9.1
750	1.7	
990	1.8	

DETERMINATION OF THE RELATIVE INTENSITY OF THE ELECTRON CAPTURE PROCESS

The electron capture process in I^{128} should lead both to the first excited state and to the ground state of Te^{128} with the emission of the characteristic Te x-rays. The intensity ratio of the Te x-rays to the 455-kev gamma radiation may be determined by a comparison method which has been employed in the investigation of I^{126} [9] and Sb^{122}.[10] The basic principle of the method involves the measurements of the relative intensities of the 455-kev gamma line of I^{128} to the 661-kev gamma line of Cs^{137} with a scintillation spectrometer and that of the Te x-ray to the Ba x-ray of the same sources with a proportional counter. The intensity of *K*-capture transitions relative to the intensity of the 455-kev gamma radiations was thus determined to be 31.6%. Since the ratio of the intensity of the 455-kev gamma radiation to the intensity of the total β^- radiations was determined to be around 20%, one gets for the ratio of *K*-capture to β^- emission a value of 6.3%. If one assumes *L*-capture to be about 10% of the *K*-capture,



(a) (b)

FIG. 5. γ-ray coincidence spectra of I^{128}. (a) Radiation in coincidence with the 455-kev line. (b) Radiation in coincidence with the Te x-rays.

TABLE II. Relative abundance and log *ft* values of the three β^- radiations, the two electron-capture branches, and relative intensities of the γ radiations (normalized to the β^-).

	Radiation (Mev)	Abundance (%)	log *ft*
β_1	2.120 ± 0.010	76.0 ± 3.0	6.12
β_2	1.665 ± 0.015	15.5 ± 0.7	6.31
β_3	1.125 ± 0.020[a]	2.0 ± 0.2	6.58
β_+	Not observed		
E.C.$_1$	$=0.550$	0.32 ± 0.03	5.72
E.C.$_2$	$=1.300$	6.08 ± 0.60	5.17
γ_1	0.455 ± 0.005	17.16 ± 1.7	
γ_2	0.540 ± 0.005	1.78 ± 0.18	
γ_3	0.750 ± 0.007	0.31 ± 0.03	
γ_4	0.990 ± 0.010	0.29 ± 0.03	

[a] This energy was obtained by taking the difference between the maximum energy of β_2^- and the energy of γ_2.

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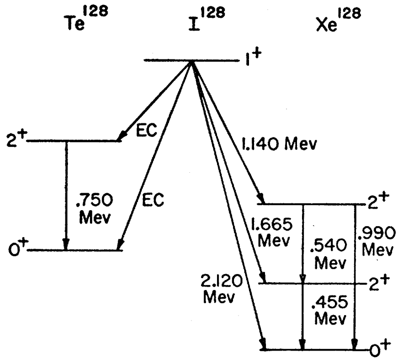

FIG. 6. Proposed decay scheme of I^{128}.

then the ratio of $(K+L)$ capture to total β^- emission is about 6.9%.

The branching ratio for $K+L$ capture to the excited state and to the ground state of Te^{128} can be estimated from the intensity ratio of the 455-kev and the 750-kev lines. Since the total intensity of the $K+L$ capture transitions is 35% of that of 455-kev line and the intensity of 750-kev lines is only 1.7% of that of 455-kev line, it follows that the ratio of electron capture processes to the excited state relative to those to the ground state is 1:19.

RESULTS AND CONCLUSIONS

The final results of the investigation of I^{128} are tabulated in Table II. The proposed decay scheme is shown in Fig. 6. The log ft value for the three β^- transitions varies from 6.12 to 6.58. The log ft values for the electron capture branches are calculated on the basis that the Q value of $I^{128} \rightarrow Te^{128}$ is probably very close to the value predicted from the energy-systematics curve of Way.[11] Since the log ft is very sensitive to the value of the maximum energy, the inaccuracy in the value of Q could contribute a large error in the calculated log ft values of the electron capture process. The log ft values are rather near the upper limit permitted for allowed transitions in that region but they are still less than that for the first forbidden ones (about 7).[12] The spin and parity of the ground states of the even-even nuclei Xe^{128} and Te^{128} must be 0^+. A first forbidden transition would require that I^{128} has odd parity and spin 1. The shell model predicts even parity for all levels for N and Z between 50 and 82, with the single exception of the $h_{11/2}$ level. If one assigns $h_{11/2}$ to the odd neutron to give the required odd parity, one still cannot obtain a spin value $J=1$ with the two plausible assignments $d_{5/2}$ or $g_{7/2}$ for the 53rd proton. However, if one assumes the transition as an allowed one, then the parity and spin of ${}_{53}I^{128}{}_{75}$ should be 1^+. It could be due to the configuration of $(d_{5/2},d_{3/2})$. This is indeed different from the spin and parity assignments of ${}_{53}I^{126}{}_{73}$ and ${}_{53}I^{130}{}_{77}$ which are $2^-(g_{7/2},h_{11/2})$ and $6^-(d_{5/2},h_{11/2})$. With only a few exceptions the spin and parity of the ground, first and second excited states of even-even nuclei are in general 0^+, 2^+, 2^+ or 0^+, 2^+, 4^+. In the case of ${}_{54}Xe^{128}{}_{74}$, since the three β^- transitions from the ground state of I^{128} to the first three levels of Xe^{128} are all allowed, the most logical assignments for the spin and parity of these three levels should be 0^+, 2^+, 2^+. A 4^+ level for the second excited state would make the β transition an unique second forbidden transition of log f_2t around 12. Therefore it is ruled out.

In the introduction, we have pointed out that a well-established regularity in the nuclear level structure could serve as a useful guide in further investigations. It is particularly valuable when one works with a short-lived radioactive substance because much time could thus be saved. Figure 7 shows the four energy-systematics curves for the first and second excited states of Xe and Te, with Xe^{128} and Te^{128} indicated by open circles "o". It is interesting to see that the experimental findings are in excellent agreement with the values indicated by the open circles. The energy of the second excited state of Te^{128} must be larger than 1.4 Mev which is beyond the reach of the Q value of $I^{128} \rightarrow Te^{128}$.

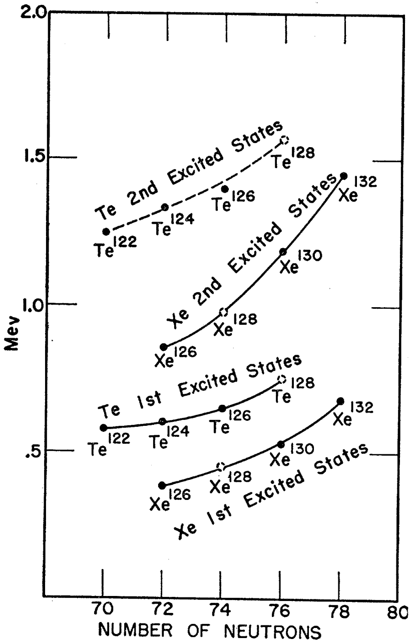

FIG. 7. Energy-systematics curves for the first and second excited states of Xe and Te. The open circles represent the predicted positions of the first and second excited states of Xe^{128} and Te^{128}. The actually observed values of these states are listed in Table II.

ACKNOWLEDGMENTS

We wish to thank Dr. R. van Lieshout for his valuable discussions throughout this investigation. We are also indebted to Dr. V. Fischer for her advice on the chemical procedure. The kind cooperation of Mrs. M. Melkonian in operating the cyclotron is deeply appreciated.

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