Gamma Rays from I^{128}

H. Bosch, R. Radicella,* P. Reyes, and T. Urstein
Nuclear Spectroscopy Laboratories, Comisión Nacional de Energía Atómica, Buenos Aires, Argentina
(Received February 10, 1958)

The gamma radiation following the decay of I^{128} was studied by means of a single-channel analyzer. Four gamma rays of energies 0.445, 0.530, 0.740, and 0.975 Mev and relative intensities 100:9.3:0.9:1.8 were found. Three methods of preparing the source were employed in order to check the purity of the sample. Using published data together with our results, we propose a level sequence for Xe^{128}, which is of vibrational type.

I. INTRODUCTION

THE I^{128} nucleus disintegrates by K capture and β^- emission to two stable isobars, Te^{128} and Xe^{128}, respectively. A half-life of 24.99 min[1] was assigned to this disintegration. The K-capture branch is $6.3\pm0.7\%$ of that of electron branch.[2] According to Mims and Halban,[2] the x-rays appearing in the disintegration of I^{128} belong to the Te isotope.

Wapstra *et al.*[3] observed two gamma rays of 0.445 and 0.980 Mev, Germagnoli[4] one of 0.430 Mev. The β^- and γ radiations following the decay of I^{128} have been studied in detail by Benczer, Farrelly, Koerts, and Wu.[5] They observed gamma rays of energies 0.455, 0.540, 0.750, and 0.990 Mev. Gupta and Jha[6] have also studied the gamma-ray spectrum and observed 0.440- and 0.980-Mev gamma rays.

We continued the investigation of I^{128} because, as Xe^{128} is an even-even nucleus whose neutron number lies between 36 and 88, one of the vibrational bands according to Scharff-Goldhaber and Weneser[7] and Wilets and Jean,[8] there should exist at approximately twice the energy of the first excited state, three levels with character 0+, 2+, and 4+. As the β^- transitions from I^{128} to the levels 0+ and 2+ of Xe^{128} are allowed (as will be seen later on), it is logical to expect the observation of the levels 0+ and 2+ of the triplet. This is of particular interest because one does not know with certainty the position of the 0+ with respect to the 2+ and 4+ levels of the triplet.[9] Recent theoretical work of Raz[10] indicates that the 0+ level lies higher in energy than the 2+ and 4+ levels and that the 2+ level is always below the 4+. There is only one example in which the three sublevels appear[11] (Cd^{114}) and one in which the sequence 2+, 0+ was found[1] (Pd^{106}). In the latter case, the energy of the corresponding two levels is the same within the experimental errors.

II. EXPERIMENTAL

(A) Source Preparation

Different methods of preparing the source were employed in order to check the purity of the sample. I^{128} was prepared by bombarding ethyl iodide with slow neutrons from the synchrocyclotron of this Institute, and the iodide separated by Szilard-Chalmers method. I^{128} was also prepared by bombarding resublimed iodide with slow neutrons. Finally, NaI was irradiated with slow neutrons and the iodine separated. A half-life determination for the total β^- activity was performed with a scintillation spectrometer with anthracene in the three cases, and the same results were obtained. In Fig. 1 the decay curve of the β^- activity is plotted.

(B) Single Measurements

For the measurements of energies and relative intensities of the gamma radiations, a single scintillation spectrometer with crystals of different sizes was used.

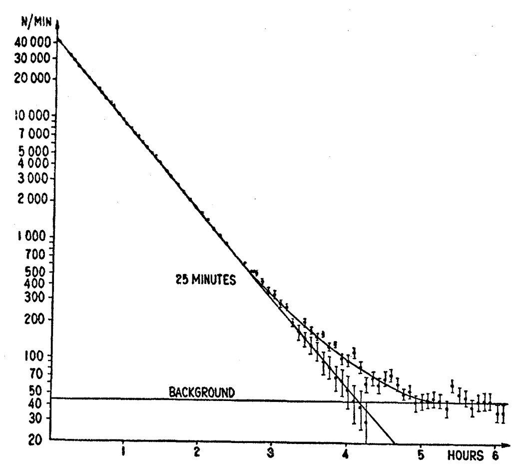

Fig. 1. Decay curve of the β^- activity corresponding to I^{128}.

* Radiochemical Laboratories.
[1] D. Hull and H. Seeling, Phys. Rev. **60**, 553 (1941).
[2] J. Reynolds, Phys. Rev. **79**, 745 (1950); H. Mims and H. Halban, Proc. Phys. Soc. (London) **A64**, 753 (1953).
[3] H. Wapstra *et al.*, Physica **19**, 138 (1953).
[4] E. Germagnoli *et al.*, Nuovo cimento **10**, 1388 (1953).
[5] Benczer, Farrelly, Koerts, and Wu, Phys. Rev. **101**, 1027 (1956).
[6] R. K. Gupta and S. Jha, Nuclear Phys. **1**, 2 (1956).
[7] G. Scharff-Goldhaber and J. Weneser, Phys. Rev. **98**, 212 (1955).
[8] L. Wilets and M. Jean, Phys. Rev. **102**, 788 (1956).
[9] C. A. Mallmann (to be published).
[10] B. J. Raz (to be published).
[11] H. T. Motz, Phys. Rev. **104**, 1352 (1956).
[12] D. E. Alburger and B. J. Toppel, Phys. Rev. **100**, 1457 (1955).

Final measurements were made with a 2-in.×2-in. NaI(Tl) crystal and a DuMont 6364 photomultiplier. Many observations at different source-to-crystal distances were performed in order to estimate the sumup between the gamma rays.

A typical gamma-ray spectrum of I^{128} after correction for decay is plotted in Fig. 2. In the insert is represented the spectrum for low energies. The following energies, in Mev, were established: 0.0275 (Te x-rays), 0.445 ±0.005, 0.530±0.005, 0.740±0.010, and 0.975±0.015.

In order to reduce the pileup to a few percent between the 0.445-Mev gamma ray and its Compton background and the sumup between the 0.445- and 0.530-Mev gamma rays, the source-to-crystal distance was fixed at 13 cm. The relative intensities of the gamma rays are listed in Table I.

III. DISCUSSION

It is possible to conclude from the series of measurements that there are four gamma rays following the decay of I^{128} whose energies are, in Mev: 0.0275 (Te x-rays), 0.445±0.005, 0.530±0.005, 0.740±0.010, and 0.975±0.015.

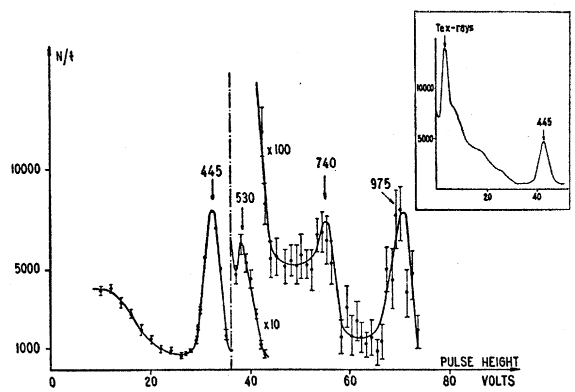

FIG. 2. Gamma-ray spectrum of I^{128} after correction for decay. In the insert is represented the spectrum for low energies.

The ground state of even-even nuclei always has the character 0+.[9,10] The first excited state, with few exceptions, has the character 2+.[9–11] The energy of the first excited level was plotted as a function of neutron number for a series of Te and Xe nuclei (Fig. 3). It appears reasonable to compare these energies, as the first excited states of all these nuclei have the character 2+. This is not the case with the second excited states where the character is generally 2+ or 4+ and occasionally 0+ or odd.[9,11]

From the results of Temmer and Heydenburg[13] and the plot of Fig. 3, we may assert that the 0.740-Mev gamma ray corresponds to the Te branch. According to that plot, the 0.445-Mev gamma ray is the corresponding transition between the first and ground states of Xe^{128}.

TABLE I. Relative intensities of the gamma radiations.

Energy of the gamma radiation (Mev)	Relative intensities
0.445	100
0.530	9.3
0.740	0.9
0.975	1.8

According to the energy and relative intensities of the β^- radiations from I^{128} inferred by other authors,[5] all the β^- transitions are allowed. As was stated before, the character of the ground and first excited levels of Xe^{128} are 0+ and 2+, respectively; consequently, the character of the ground state of I^{128} should be 1+. This can be explained by the shell model: we can assign a configuration $d_{\frac{5}{2}}$ for protons and $d_{\frac{3}{2}}$ for neutrons. Then the character of the second excited level of Xe^{128} could be 0+, 1+, or 2+.

In general the second excited levels (collective levels) of even-even nuclei have the character 2+ or 4+.[8–10] The character 1+ for the second excited state of even-even nuclei has not been observed. This was pointed out by Glaubman and Morinaga[14] who asserted that in even-even nuclei the low-lying odd-parity states have odd spin. With this assumption we can exclude the possibility 1+ for the second excited level of Xe^{128}. Owing to the fact that the energy of the 0.975-Mev gamma ray is 2.2 times that of the 0.445-Mev gamma ray and is the sum of 0.445 and 0.530 Mev, we are tempted to consider that radiation as the crossover between these two. This corresponds to a transition from the second excited level to the ground state, and the possibility 0+ must be ruled out.

We did not observe any splitting in the second excited state of Xe^{128}, even though the 0+ sublevel could be fed by an allowed β^- transition. In order to estimate the energy and relative intensity of the possible transition from this sublevel to the 2+ first excited state, we have made a rough calculation, obtaining the following results: If we suppose a β^- transition to the

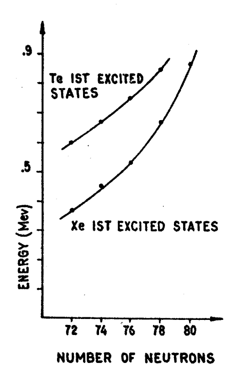

FIG. 3. Energy of the first excited level of a series of Te and Xe nuclei, as a function of neutron number.

[13] G. M. Temmer and N. P. Heydenburg, Phys. Rev. **104**, 967 (1956).

[14] M. J. Glaubman, Phys. Rev. **90**, 1000 (1953); H. Morinaga, Phys. Rev. **103**, 503 (1956).

0+ second excited sublevel with a logft value from 6.5 to 7 and a gamma transition of intensity at most 10% of that of the 0.445-Mev gamma ray, its corresponding energy would lie between 0.230 and 0.440 Mev. On the other hand, if we suppose that the gamma transition has an intensity of 1% or less of that of the 0.445-Mev gamma ray, its corresponding energy would lie between 0.530 and 0.740 Mev. These rough calculations are not in contradiction with our experimental results, since these relative intensities at the corresponding energy ranges cannot be observed.

We shall attempt to perform the external conversion of the gamma rays from I^{128} and observe the corresponding electron lines in our orange-type beta-ray spectrometer.

ACKNOWLEDGMENTS

We are very much indebted to Dr. C. A. Mallmann for his valuable discussions throughout this work, especially for his advice about the systematics of even-even nuclei. We wish also to thank the synchrocyclotron group for their cooperation.

PHYSICAL REVIEW VOLUME 111, NUMBER 3 AUGUST 1, 1958

Fusion Chain Reaction—Chain Reaction with Charged Particles

MICHAŁ GRYZIŃSKI
Institute of Experimental Physics, Warsaw University, Warsaw, Poland, and
Institute of Nuclear Research, Warsaw, Poland

(Received November 17, 1957; revised manuscript received March 4, 1958)

It is shown that in the case of a medium which is an exoergic nuclear mixture (a mixture of nuclei which can lead to an exoenergetic reaction) and which possesses a high temperature ($\sim10^7$ °K) or a relatively high density ($\sim10^4$ g/cc), a fusion chain reaction can take place. This is due to the decrease in the stopping power of the medium under the conditions given above. Equations for determining the multiplication factor for a binary mixture under various physical conditions are derived. The multiplication factor is calculated for a DT mixture. It is concluded that for an exoergic nuclear mixture there exists a critical temperature or a critical density which limits the slow release of fusion nuclear energy. For an infinite medium of 50% DT mixture the critical temperature and the critical density are $\sim10^7$ °K and $\sim10^3$ g/cc, respectively. In a finite medium the values are higher and there exists a critical mass which limits the possibility for the development of a fusion chain reaction. This critical mass was estimated and in first approximation is m_{cr} (in grams) $=1/(\text{density of the medium in g/cc})^2$.

I. INTRODUCTION

SIMULTANEOUSLY with discovery of the fission chain reaction with neutrons, the possibility of obtaining a chain reaction with charged praticles was abandoned, because of the small efficiency of charged particles in nuclear reactions. In the most advantageous case, $D+T\rightarrow He^4+n$, the efficiency attained is only $\sim5\times10^{-3}$ reaction per 14-Mev deuteron. But no note was taken of the fact that the efficiency depends on the physical conditions and in some cases it may be greatly increased. This is especially true for nuclei of small charge, where the Coulomb barrier penetration factor is not too high. The development of a chain reaction with charged particles is, therefore, possible only for light nuclei, where the release of nuclear energy is due to the process of fusion. Only highly exoenergetic reactions of large cross sections may lead to the fusion chain reaction; these are the same reactions which are involved in thermonuclear reaction.[1]

II. FORMULATION OF THE PROBLEM

The mechanism of a fusion chain reaction, which is due to *in statu nascendi* reactions, is as follows. In an exoergic reaction $A+B$ in which weakly bound groups of nucleons of nuclei A and B form strongly bound groups of reaction products, we obtain particles of high kinetic energy. Part of their kinetic energy is transferred in elastic collisions directly to the A and B nuclei of the medium. The recoiling A and B nuclei, in the process of slowing down to thermal energy, have some probability of leading again to the reaction $A+B$. Under normal physical conditions, the dissipation of energy of charged particles in collisions with electrons is so large that their range (L) in the medium is much smaller than the mean free path (λ) with respect to nuclear processes. Therefore, only a small fraction of the recoil nuclei lead again to the $A+B$ reaction. The development of the avalanche is possible when the sum of the ranges of the recoil nuclei $\sum_i L_i$ is comparable to λ. Since $\sum_i L_i \simeq E_Q/\langle(dE/dx)\rangle_{\text{Av}}$ and $\lambda\simeq1/N\bar{\sigma}$, where E_Q = the kinetic energy released in the $A+B$ reaction, $\langle(dE/dx)\rangle_{\text{Av}}$ = the average energy losses of recoiling nuclei per unit path, N = the density of reacting nuclei of the medium, and $\bar{\sigma}$ = the mean cross section for the $A+B$ reaction, we can write

$$E_Q\bar{\sigma}/[(1/N)\langle(dE/dx)\rangle_{\text{Av}}]\sim1. \tag{1}$$

[1] W. B. Thompson, Proc. Phys. Soc. (London) **B70**, 1 (1957).