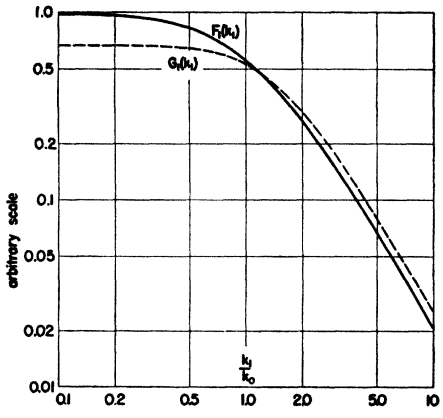

FIG. 1.

In an isotropic scalar fluctuation field (e.g., temperature fluctuations) the corresponding transformation can, of course, be derived in the same way. This is simply a special case in which no vector component need be taken, and the above factor does not enter. The result is

$$G_1(k_1)=\tfrac{1}{2}\int_{k_1}^{\infty}[G(k)/k]dk. \tag{2}$$

The inverse formulas are easily found to be

$$F(k_1)=2k_1[k_1F_1''(k_1)-F_1'(k_1)] \tag{3}$$

and

$$G(k_1)=-2k_1G_1'(k_1). \tag{4}$$

To see the physical consequences of the difference between (1) and (2), suppose an isotropic turbulence field with both vector (velocity) and scalar (e.g., temperature) fluctuations present, and suppose that their three-dimensional power spectra are proportional. Purely for the sake of computation, we assume that in the low wave numbers range they both follow the von Kármán interpolation formula[2] proposed for three-dimensional velocity spectrum:

$$F(k)\sim(k/k_0)^4/[1+(k/k_0)^2]^{17/6}. \tag{5}$$

Then the resulting one-dimensional spectra differ basically as shown in Fig. 1.

The integral scales are proportional to the ordinate intercepts of the one-dimensional power spectra:

$$L_x=C\cdot F_1(0);\quad \Lambda_x=C\cdot G_1(0). \tag{6}$$

In this case $L_x/\Lambda_x=1.50$. Furthermore, for isotropic turbulence, the lateral integral scales are related to the longitudinal ones by

$$L_y=\tfrac{1}{2}L_x;\quad \Lambda_y=\Lambda_x. \tag{7}$$

Hence

$$L_y/\Lambda_y=0.75.$$

If some appropriate high wave number extrapolation for the three-dimensional spectra is postulated, the microscale relation can be deduced in similar fashion.

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Erratum: Determination of Nuclear Gyromagnetic Ratios I

[Phys. Rev. **76**, 350 (1949)]

JOHN R. ZIMMERMAN AND DUDLEY WILLIAMS
Mendenhall Laboratory of Physics, Ohio State University, Columbus, Ohio

THE following typographical error has been noted in the above paper:

Page 354, the first expression of Eq. (6) should read

$$(k+1)^2=(\nu_A{}^r\nu_A{}^s/\nu_B{}^r\nu_B{}^s).$$

A New Gamma-Ray Resonance in the Reaction $C^{12}(p,\gamma)N^{13}$ *

D. M. VAN PATTER
Laboratory for Nuclear Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts

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A PREVIOUSLY unreported gamma-ray resonance has been found for the reaction $C^{12}(p,\gamma)N^{13}$. It was first located by the measurement of the gamma-rays from a thick graphite target bombarded by protons. The detector consisted of thin-walled beta-counters in coincidence, which measured the secondary electrons from a thick aluminum converter. The resonance was definitely assigned to the reaction $C^{12}(p,\gamma)$ by taking a thick-target excitation curve of the N^{13} positron activity which showed the same resonance. A thin-target excitation curve for the N^{13} positron activity was also measured, using a 7-kv Formvar target, and the experimental points agreed with a symmetrical Breit-Wigner curve. The different excitation curves gave a resonance at an average proton bombarding energy of 1.697 ± 0.012 Mev with a half-width of 74 ± 9 kev. The absolute voltage scale was established from known $F^{19}(p\alpha',\gamma)$ resonances and also from measurements of the energy of elastically scattered protons and deuterons by deflection in the field of a 180-degree focusing magnet (using the energy of polonium alphas as a standard).

The ratio of thick-target yields from the 1.70, 0.456-Mev $C^{12}(p,\gamma)$ resonances was measured as 1.3 ± 0.2 from the N^{13} activity. Assuming the value of Fowler and Lauritsen[1] for the thick-target yield of the 0.456-Mev resonance as 7.2×10^{-10} quanta per incident proton, we obtain $9.4\pm1.4\times10^{-10}$ quanta per incident proton for the thick-target yield of the 1.70-Mev resonance. This thick-target yield gives a value for the radiation breadth Γ_γ of 1.3 ± 0.2 ev.

A search was made for additional resonances, using a 50-kev lampblack target but without success. In the energy range 0.95- to 1.6-Mev proton bombarding energy, no resonance was found with a peak intensity greater than 0.04 of the peak intensity of the 1.70-Mev resonance. From 1.6 to 2.1 Mev, no resonance occurred greater than 0.12 of the maximum intensity of the 1.70-Mev resonance.

In order to determine the position of the energy level of N^{13} corresponding to this gamma-ray resonance, it is necessary to know the mass difference $C^{12}+p-N^{13}$ given by Hornyak and Lauritsen[2] as 1.92 Mev, which they calculated by using Bethe's mass values. Analysis of more recent data indicates that this value should be altered. Let us first make use of the $C^{12}(d,n)N^{13}$ reaction as measured by Bennett and Richards.[3]

$$C^{12}+d=N^{13}+n+Q_1,\quad C^{12}+p-N^{13}=(p+n-d)+Q_1,$$
$$Q_1=-0.27\pm0.02\text{ Mev}^3,\quad (p+n-d)=2.237\pm0.005\text{ Mev}^4.$$

We obtain $C^{12}+p-N^{13}=1.967\pm0.025$ Mev.

It is also possible to use the two following reactions:

$$C^{12}+d=C^{13}+p+Q_2,\quad N^{13}=C^{13}+Q_3,$$
$$C^{12}+p-N^{13}=(p+n-d)-(n-p)+Q_2-Q_3,$$
$$Q_2=2.729\pm0.009\text{ Mev}^5,\quad (n-p)=0.782\pm0.002\text{ Mev}^6.$$

The latest value for the maximum energy of the N^{13} positrons is 1.202 ± 0.005 Mev[7], so that

$$Q_3=1.202\pm0.005+2m_0c^2=2.223\pm0.005\text{ Mev}.$$

We obtain

$$C^{12}+p-N^{13}=1.961\pm0.021\text{ Mev}.$$

The weighted average of the two determinations of $C^{12}+p-N^{13}$ is 1.963 ± 0.015 Mev. We find, then, corresponding to gamma-ray resonances at 0.456 ± 0.002[1] and 1.697 ± 0.012 Mev, energy levels in N^{13} at 2.383 ± 0.018 and 3.53 ± 0.027 Mev.

Grosskreutz[8] has just recently measured the energy of the neutron groups from the $C^{12}(d,n)N^{13}$ reaction using 10-Mev deuterons. In addition to the ground-state neutrons, he finds only two other groups which go to energy levels in N^{13} measured at

2.29±0.12 and 3.48±0.12 Mev. These results are in complete agreement with the energy levels in N^{13} found by the $C^{12}(p,\gamma)$ reaction, which is a strong indication that there are no additional levels in N^{13} below 3.8 Mev.

It is of theoretical interest to compare these energy levels of N^{13} to those of the mirror nucleus C^{13}. The first three levels of C^{13} known at present are at 0.9±0.2 Mev,[9-11] 3.098±0.008 Mev[5], and 3.91 Mev.[12] The existence of the lowest level is not yet firmly established. However, it is evident that the energy levels of these mirror nuclei do not correspond, as would be expected for equal neutron-neutron and proton-proton forces.

The author is indebted to Professor W. W. Buechner and to Dr. John Blatt for their invaluable guidance, and to A. Sperduto for the measurement of the energy of elastically scattered protons.

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On the Double Beta-Process

MARK G. INGHRAM AND JOHN H. REYNOLDS
University of Chicago and Argonne National Laboratory, Chicago, Illinois
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A STUDY has been made of the isotopic constitution of xenon extracted from a pre-Cambrian tellurium ore, in order to determine the half-lives of the double beta-transitions $Te^{128} \rightarrow Xe^{128}$ and $Te^{130} \rightarrow Xe^{130}$. In this ore, measurable amounts of these two isotopes of xenon should have accumulated during geological time if the transitions take place at a rate comparable to that reported by Fireman[1] for the similar transition $Sn^{124} \rightarrow Te^{124}$. The importance of double beta-studies lies in the fact that the half-lives calculated from the Majorana theory of the neutrino[2] and the Dirac theory of the neutrino[3] differ by a large factor. Table I gives half-lives

TABLE I. Theoretical half-lives for allowed double beta-disintegrations.

Transition	$Te^{128} \rightarrow Xe^{128}$	$Te^{130} \rightarrow Xe^{130}$
Atomic mass difference in Mev	0.5	1.6
Majorana half-life in years	2×10^{16}	6.0×10^{14}
Dirac half-life in years	3×10^{27}	1.1×10^{24}

so calculated; the energies available for the transitions have been estimated from the decay schemes of the intermediate nuclei and from considerations of the nuclear energy surface[4] and are conservative.

The ore used for this study was the mineral tellurobismuthite (Bi_2Te_3) in andalusite and sericite rock blasted from an outcrop in Mångfallberget, near Boliden, Sweden. This telluride deposit has been described in detail by Grip and Ödman.[5] A rough estimate by Dr. K. Rankama places the age of the original sulfide mineralization at 1500±500 million years.

TABLE III. Measured minimum half-lives based on crystal age of 1.5×10^9 years.

Transition	$Te^{128} \rightarrow Xe^{128}$	$Te^{130} \rightarrow Xe^{130}$
Max. no. radiogenic xenon atoms per atom of Xe^{134}	0.07	0.014
Max. no. radiogenic xenon atoms in sample	3.0×10^{12}	5.0×10^{11}
No. of parent atoms in sample	3.8×10^{22}	4.2×10^{22}
Minimum half-life in years	1.3×10^{19}	8.0×10^{19}

The sample (430 grams containing 6 percent tellurium) was crushed in an iron mortar and transferred to a quartz bottle which was then evacuated and heated to well above the melting point of Bi_2Te_3. The gas evolved was collected and purified in an apparatus patterned closely after that of Epstein and co-workers[6] in their experiments with fission xenon. The final rare gas mixture was analyzed in a conventional 60° single-focusing mass spectrometer. By calibrating with artificially prepared mixtures of argon and xenon, it was possible to measure both the chemical composition and the isotopic constitution of the gas.

The mixture was found to consist of $1.3\pm0.3\times10^{-5}$ cc S.T.P. xenon plus $1.3\pm0.3\times10^{-2}$ cc S.T.P. argon. The results of the isotopic analysis are represented in Table II together with Nier's values[7] for normal xenon. All abundances are referred to mass 134. It will be noted that the only evidence for the presence of radiogenic xenon occurs at mass 130. For this minute sample of xenon, however, the accuracy of the measurements is such that the apparent excess xenon at this mass can only be viewed as intriguing (even though a measurement of normal xenon immediately thereafter checked Nier's value of 0.386 exactly). At masses 124, 126 and 128 the recorder peaks were so close to background level that only upper limits for these abundances can be given.

These data can be used, however, to place lower limits on the half-lives of the double beta-transitions. The results are presented in Table III. A corresponding calculation for the energetically questionable transition $Te^{126} \rightarrow Xe^{126}$ gives a minimum half-life of 6×10^{19} years.

On comparison with the half-lives presented in Table I, it appears that these results support the Dirac antineutrino theory. However, the values are subject to qualification on two counts. First, the possibility exists that radiogenic xenon may have escaped from the crystals of ore since the time of the original mineralization, either by simple diffusion or during later alteration of the mineral. Considering the retentivity of helium by various minerals,[8,9] it appears that the former possibility is remote. A hydrothermal alteration of the telluride, on the other hand, would certainly result in loss of xenon, and this possibility cannot be dismissed for the present ore. If this has occurred, the accumulation of daughter xenon dates only from the time of alteration and the half-lives in Table III must be reduced in proportion. Secondly, the theoretical half-lives presented in Table I are essentially minimum values; favorable forms of the interaction terms have been assumed and the calculations have been made for completely allowed transitions. As a result, the Majorana half-lives may be longer in the particular transitions we have investigated, due, for example, to a possible difference in parity between the ground states of Te^{130} and Xe^{130}. That these two effects, acting in combination, could overpower the factor of 10^5 by which the measured minimum half-life exceeds the calculated Majorana half-life in the transition at mass 130 is improbable, but it must be admitted as a possibility.

TABLE II. Relative abundances of the xenon isotopes.

Mass	124	126	128	129	130	131	132	134	136
Present study	<0.015	<0.018	<0.25	2.47 ±0.03	0.394 ±0.004	2.00 ±0.02	2.55 ±0.02	1.000	0.847 ±0.008
Normal xenon*	0.0089	0.0083	0.180	2.49	0.386	2.009	2.558	1.000	0.849

* See reference 7.