Erratum: Thermal Consequences of the Capture of Neutrinos by the Earth

[Phys. Rev. 74, 621 (1948)]

A. E. BENFIELD
Department of Engineering Sciences and Applied Physics, Harvard University, Cambridge, Massachusetts

THE Editor regrets that two mistakes were made in printing the above-named Letter to the Editor.

(i) The second sentence of the first paragraph should read, "He argues that neutrinos originating at the center of the *sun* would produce a maximum heating effect in the earth. . . ." The word *sum* was mistakenly printed for *sun*.

(ii) The denominator of the first term of Eq. (1) should be $6k$, not 61.

A Search for Gamma-Rays from He^6 and F^{18}

WILLIAM J. KNOX
Radiation Laboratory, Department of Physics, University of California, Berkeley, California

September 17, 1948

THE series of beta-active nuclei He^6, Be^{10}, C^{14}, F^{18}, Na^{22}, etc., has created much discussion because some of its members show allowed transitions while others are forbidden. It seemed possible that the allowed cases might represent transitions to excited states; if so, a consistent rule would govern the transitions to the ground states. However, the results given below seem to exclude this explanation, unless the unlikely assumption of a very low energy gamma-ray is made.

Absorption measurements on F^{18} have shown a penetrating radiation which has the expected annihilation radiation energy of about 0.5 Mev. In order to exclude further the possibility of a true gamma-ray of about 0.5-Mev energy, which would not be detected by half-thickness measurements, absorption curves on F^{18} and C^{11} have been compared to see if the ratio of positrons to photons is the same. C^{11} is assumed to have no gamma-ray, since the upper energy limit of its positron spectrum[1] corresponds very closely to both the mass difference[2] and the computed Coulomb energy difference[1] between B^{11} and C^{11}, and the spectrum is apparently simple. The C^{11} and F^{18} on which the measurements were made were produced by $(n,2n)$ reactions on polystyrene foils and LiF using 90-Mev neutrons produced by the 184-inch cyclotron. The shorter-lived activities (O^{15}, N^{13}, C^{11}) were allowed to decay out of the F^{18} samples before making measurements. The ratio of the number of counts coming from the sample when surrounded by 400 mg/cm² of Al to the number of beta-counts extrapolated to zero absorber was observed to be 0.011 for C^{11} and 0.010 for F^{18}, both values with a probable error of about ten percent. These values are consistent with the known counting efficiency for annihilation radiation of the Geiger tubes used. There is no evidence from these measurements that there is a nuclear gamma-ray associated with F^{18}.

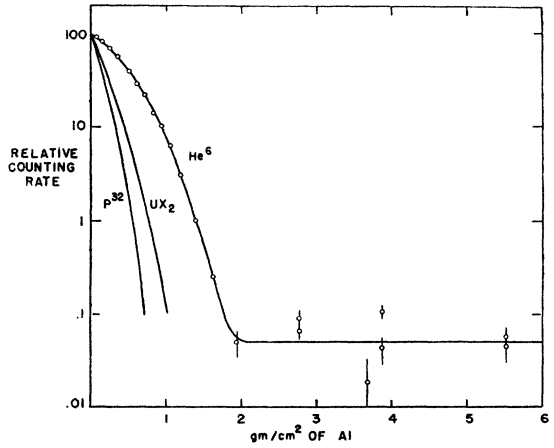

FIG. 1. Absorption of He^6 betas in aluminum and comparison curves on P^{32} and UX_2.

He^6 was obtained by bombarding powdered Be in a brass vessel with 11-Mev neutrons produced by the 60-inch cyclotron. For the purpose of identification the half-life was measured on an automatic photographic short half-life measuring apparatus,[3] and five determinations gave a value of 0.82 ± 0.06 second in agreement with previously reported values.[4,5] For absorption measurements a continuous flow method was used in which the He^6 was swept from the vessel with helium, filtered through a fine glass wool plug, and transported through about 85 ft. of $\frac{3}{16}$-in. tubing to the cyclotron control room, where background radiation was low enough to make measurements while the cyclotron was operating. An end window Geiger tube suspended above a graphite block and surrounded by a lead shield was used for counting. The He^6 was swept through a chamber in the graphite block which was covered by a 1.5-mil Al window situated directly beneath the Geiger tube. In this manner essentially all of the He^6 beta-particles emitted in the vicinity of the counter, with the exception of those actually counted, were absorbed in carbon, thus minimizing bremsstrahlung. Flat aluminum absorbers were interposed between the counting tube and the gas chamber, and counting was done with the cyclotron operating at a constant level and with the He flowing at a constant rate. Under these operating conditions the reproducibility of a monitoring count using some standard amount of absorber was within ± four percent for a given set of measurements. The absorption curve obtained is reproduced in Fig. 1, together with comparison curves taken under similar conditions of geometry and absorber arrangement on samples of P^{32} and UX_2. The initial portion of the curve was obtained with a zero absorber counting rate of about 10,000 c.p.m. while the final portion was obtained with about five times this intensity. Coincidence corrections were made and all points were normalized to 100 at zero absorber. Probable errors due to counting are shown on the lowest points. The amount of radiation penetrating more than 2 g/cm² of absorber is about 0.05 percent of the total number of counts, which is the magnitude expected due to production of bremsstrahlung. Hence, it is concluded that there is no gamma-ray associated with the disintegration of He^6 unless it is of very low

energy (<100 kev) or of low intensity (< ten percent of disintegrations if gamma-ray were of 1 Mev). Further comparison of the He^6 curve with the P^{32} and UX_2 curves gives ranges of 1.85 and 1.88 g/cm² of aluminum, respectively. This corresponds to a maximum energy of 3.7 Mev, using the range-energy relationship $E_{max}=1.85R+0.245$,[6] with an estimated possible error of ±0.2 Mev. This value for the energy is in close agreement with previously reported values.[4,5]

Appreciation is expressed to Professor E. M. McMillan for suggesting this problem. This paper is based on work performed under the auspices of the Atomic Energy Commission in connection with the Radiation Laboratory, University of California, Berkeley, California.

[1] Delsasso, White, Barkas, and Creutz, Phys. Rev. **58**, 586 (1940).
[2] Haxby, Shoupp, Stephens, and Wells, Phys. Rev. **58**, 1035 (1940).
[3] T. M. Putnam, to be published.
[4] Bjerge and Brøstrom, Kgl. Danske Vid. Sels. Math.-Fys. Medd. **16**, No. 8 (1938).
[5] H. S. Sommers, Jr. and R. Sherr, Phys. Rev. **69**, 21 (1946).
[6] L. E. Glendenin, Nucleonics **2**, No. 1 (Jan. 1948).

The Nuclear Spin and Magnetic Moment of Na^{22} *

LUTHER DAVIS, JR.
Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Massachusetts
September 13, 1948

THE atomic beam magnetic resonance method,[1] as used by Zacharias[2] to determine the nuclear spin and magnetic moment of K^{40}, has been modified to permit similar observations to be made with radioactive nuclei having considerably shorter half-lives. These modifications involve the use of a mass spectrometer for separating the Na^{22} peaks from the large background of Na^{23} and a beryllium copper multistage electron multiplier[3,4] for detecting the Na^{22}. The source of atoms for the beam is a monel metal oven with an exit canal long compared with its width, designed so as to conserve radioactive material. A sample of NaN_3 containing 330 microcuries of Na^{22} (3×10^{-9} mole) in a dilution of one part in 10^4 of $Na^{23}N_3$ was placed in the oven. Decomposition occurs at 320°C, providing an atomic sodium beam. A 16-hour run was sufficient for all present determinations and required the evaporation of only 4×10^{-10} mole of Na^{22} out of the oven. The beam intensity of Na^{22} was naturally small, a few thousand atoms/sec., and the radiofrequency transition intensities were less than 100 atoms/sec.

Two types of transitions were observed, first at low frequency with $\Delta m_f=\pm1$ and $\Delta F=0$. These permit direct comparison of g_F for Na^{22}, with g_F for Na^{23}. For an unexcited alkali atom, $F=I+\frac{1}{2}$, and the spin of the Na^{22} is obtained as soon as a transition is observed at the mass position 22 of the mass spectrograph.

Search was made for resonances with the homogeneous field (as determined by the Na^{23} transition) and radiofrequency set for transitions corresponding to $I=0$, 1, 2, 3, 4, 5, and 6, and with the mass spectrometer set for 22. Resonances were observed only for spin 3 at mass 22.

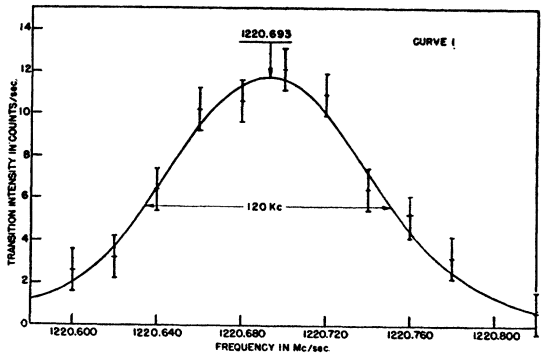

FIG. 1. Transition intensity *vs.* frequency of oscillating field for the two Na^{22} lines $F=7/2$, $M_f=\pm1/2\leftrightarrow F=5/2$, $M_f=\pm1/2$ at a field of 6.17 gauss. One count/sec. is equivalent to about 7 atoms/sec.

These peaks faded out for mass numbers $22\frac{1}{3}$ and $21\frac{2}{3}$ and could not possibly have been a spurious effect from the more abundant Na^{23}. These low frequency resonances were followed as the magnetic field was increased to permit an evaluation of the h.f.s. $\Delta\nu$ of Na^{22}. The second type of transition can then be made in which $\Delta F=\pm1$. Curve 1 shows the result of an experiment in which a $\Delta F=\pm1$ transition was made in almost zero field.

The results show that the spin of Na^{22} is 3 in units of $h/2\pi$, and its h.f.s. $\Delta\nu$ is 1220.64 ± 0.04 mgc/sec. By comparison with the value of the nuclear magnetic moment of Na^{23}, given by Millman and Kusch,[5] we obtain for Na^{22}, 1.746 ± 0.003 nuclear magnetons. The sign of this nuclear moment was also shown to be positive in just the way that was used by Zacharias on K^{40}.

Good, Peaslee, and Deutsch[6] report that the disintegration of Na^{22} goes by 100 percent positron emission to an excited state of Ne^{22}, and they conclude also that the spin of this excited state differs from that of Na^{22} by at most one unit. The spin of Ne^{22}* is therefore either 2, 3, or 4. Further unpublished data by Professor Deutsch indicate that the effective half-life for the possible transition to the ground state of Ne^{22} is at least 5000 years, consistent with a spin change of three units.

I am greatly indebted to Dr. E. T. Clarke who prepared the Na^{22} by a $Mg^{24}(d,\alpha)Na^{22}$ reaction in the M. I. T. cyclotron, to Professor J. W. Irvine, Jr., for the separation[7] of the Na^{22} from the cyclotron target and for the conversion of the $Na^{22}Cl$ to $Na^{22}N_3$, to Dr. Darragh Nagle for the design and construction of the molecular beam apparatus adapted for use in this experiment, and to Professor J. R. Zacharias who suggested the problem and some of the methods, and with whom constant discussions of the problems involved led to the successful conclusion of this experiment.

* This work has been supported in part by the Signal Corps, the Air Materiel Command, and the Office of Naval Research.
[1] P. Kusch, S. Millman, and I. I. Rabi, Phys. Rev. **57**, 765 (1940).
[2] J. R. Zacharias, Phys. Rev. **61**, 270 (1942).
[3] J. S. Allen, Phys. Rev. **55**, 967 (1939).
[4] Hin Lew, *Hyperfine Structure of Aluminum by Atomic Beam Method* (M. I. T. thesis, 1948).
[5] S. Millman and P. Kusch, Phys. Rev. **58**, 438 (1940).
[6] W. M. Good, D. Peaslee, and M. Deutsch, Phys. Rev. **69**, 813 (1946).
[7] J. W. Irvine, Jr. and E. T. Clarke, J. Chem. Phys. **16**, 686 (1948).