Os^{186*} cannot be determined accurately from the slope of curve (1) at a large positive delay time.

Newton[1] has given a general discussion of the evaluation of delayed coincidence experiments. In the ideal experiment one desires to excite one channel of the apparatus by the radiation announcing an excited state in a nucleus and to excite the other channel by the radiation emitted in the decay of the excited state whose lifetime is to be measured. If the excited state has a lifetime much too short to be measured by the coincidence apparatus, one obtains a prompt coincidence curve $P(T)$, where T is the delay time introduced in the delayed coincidence apparatus. If there is a measurable lifetime, one obtains a delayed coincidence resolution curve $F(T, \lambda)$ given by

$$F(T, \lambda)=\int_0^\infty \lambda e^{-\lambda t}P(T-t)dt.$$

Since the energy resolution of the scintillation spectrometer is relatively poor compared to the best magnetic beta-ray spectrometers, the delayed coincidence resolution curve in Fig. 1 for $Re^{186}\rightarrow Os^{186}$ is $F(T, \lambda)$ plus possibly some prompt events not related to the $Re^{186}\rightarrow Os^{186*}$ decay and prompt events due to scattering from one to the other detector. Prompt events from scattering are, of course, greatly reduced in number when the delayed coincidence scintillation spectrometer is used.

Delayed coincidence resolution curves $F(T, \lambda)$ were computed graphically using, for $P(T)$, curve (2) of Fig. 1 and values of λ equal to or near that obtained in the usual way from the slope of curve (1) at a large positive value of T. The prompt curve $P(T)$ represents the response of the apparatus to simultaneous emission of radiation of the same energy that gave curve (1). The computed curves $F(T, \lambda)$ for $T_{\frac{1}{2}}=(9.0, 8.0, \text{and } 7.0)\times10^{-10}$ are shown in Fig. 2 and have been normalized to the experimental delayed coincidence resolution curve at $T=6\times10^{-9}$ sec. The agreement between the computed curve for $T_{\frac{1}{2}}=8.0\times10^{-10}$ sec, and the experimental data is good. The difference between the two curves for $T<5\times10^{-9}$ sec yields a resolution curve of prompt events not related to the $Re^{186}\rightarrow Os^{186*}$ decay; the shape of the resulting residual curve agrees with the experimental resolution curve for prompt events of Fig. 1. It appears that the initial state of the 137-kev γ-ray transition from Os^{186} is metastable with a half-life of 8.0×10^{-10} sec.

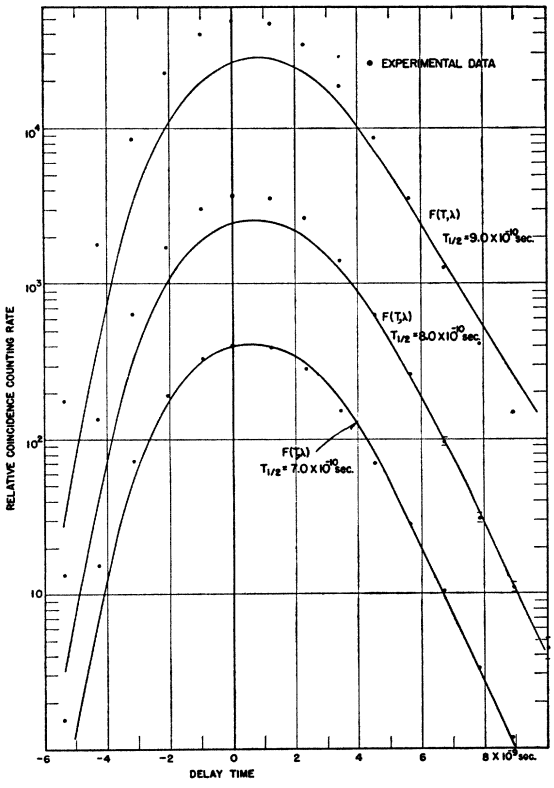

FIG. 2. Comparison of computed delayed coincidence resolution curves $F(T, \lambda)$ for $T_{\frac{1}{2}}=9.0$, 8.0, and 7.0×10^{-10} sec with experimental data obtained with a Re^{186} source. The computed curves $F(T, \lambda)$ are normalized to the experimental data at $T=6\times10^{-9}$ sec.

The energy and half-life of this isomeric state suggests that the transition corresponds to forbiddenness $l=2$. Recently, a few relativistic calculations without screening for L_I shell internal conversion[3] have been completed for $Z=92$, 84, and 49 for electric and magnetic dipole and electric quadrupole radiation. For a γ-ray energy of 137 kev and $Z=84$, the computed ratios[4] (N_K/N_{L_I}) for electric dipole, electric quadrupole, and magnetic dipole radiation are 8.5, 2.0, and 19, respectively. Since Metzger and Hill measured $N_K/N_L=0.6$ for the 137-kev transition in $_{76}Os^{186}$, it appears that electric quadrupole radiation occurs.

* This document is based on work performed for the AEC at Oak Ridge National Laboratory.

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On the Spin and Magnetic Moment of O^{17}

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NUCLEAR induction signals of O^{17} have been observed from H_2O and D_2O and also from some other liquids (methanol, ethanol, and acetic acid) containing oxygen, using the spectrometer described by Proctor.[1] The resonance occurs at a frequency of 5.8 Mc in an external magnetic field of 10,000 gauss. That this resonance originated from O^{17} was confirmed by observing it also in water in which the abundance of O^{17} was enriched from its natural value of 0.037 percent to 0.185 ± 0.006 percent, and by noticing that the signal amplitude observed under the same conditions was increased over that in natural water in proportion to the above abundances.

The ratio of the resonance frequency of O^{17} from H_2O to the resonance frequency of D^2 from D_2O was determined to be

$$\nu(O^{17})/\nu(D^2)=0.88313\pm0.00004. \quad (1)$$

The sign of the magnetic moment of O^{17} was observed to be opposite to that of D^2, i.e. to be negative. A shift of about 1/4000 towards higher frequency was found for the O^{17} resonance from acetic acid.

Although the gyromagnetic ratio of O^{17} is about seven times smaller, it was observed that the thermal relaxation time of O^{17} in pure water is about one-hundred times shorter than that of protons. This short thermal relaxation time can hardly be accounted for by the dipole-dipole interaction. As in other liquids containing nuclei with a finite quadrupole moment, it suggests that the relaxation is due to the interaction with the molecular electric fields and, therefore, that the spin of O^{17} is larger than $\frac{1}{2}$.

According to Bloch's phenomenological theory[2] of nuclear induction, the spin of O^{17} can be determined by comparing its signal amplitude and width with the signal amplitude and width of deuterium whose spin is known, provided that the experimental conditions are so adjusted to achieve the slow passage conditions. If the absorption mode is observed and the amplitude of the sweep field is small compared to the line width of the signal, the signal amplitude recorded by the dc milliammeter will be proportional to

$$nI(I+1)H_s H_1 T_2^2\gamma^3\omega_0^2/(1+\gamma^2T_1T_2H_1^2)^{\frac{1}{2}}, \quad (2)$$

where n is the number of nuclei per unit volume of the sample, I the

spin value, γ the gyromagnetic ratio, ω_0 the resonance frequency, H_s the amplitude of the sweep field, H_1 the half-amplitude of the rf exciting field, and T_1 and T_2 the longitudinal and transversal relaxation times, respectively. Based on the expression (2), the spin determination for O^{17} was carried out with samples of natural water and of O^{17}-enriched water in solutions of either 0.0002-molar concentration of $MnSO_4$ or 0.025-molar concentration of $Fe(NO_3)_3$. A sample of 1.5 percent D_2O in 3-molar concentration of $MnSO_4$ was used for the comparison. In all experiments H_s was chosen as 0.085 gauss and was considerably smaller than the line widths of O^{17} and D^2 signals (about 0.4 gauss) which were mostly due to the field inhomogeneity of the magnet. The dependence of the signal amplitudes of O^{17} and D^2 on the rf field H_1 was found to fit the theoretical expression (2) very well and was used to determine the value T_1T_2. The value of T_2 was given by the measured line width of the signal. Three independent measurements with different samples in different magnetic fields yielded the value 2.44 ± 0.25 for the spin of O^{17}. Considering that the nearest other possible spin values 3/2 and 7/2 are well outside the experimental value, this result indicates that the spin of O^{17} is

$$I(O^{17})=2.5=5/2. \quad (3)$$

In deriving this result it has evidently been assumed that the signal amplitude is, under otherwise identical conditions, proportional to the expression (2). Although there are certainly cases (for example, in the presence of a line structure) where the underlying simplified theory would not hold, it seems experimentally well supported in this case both by the observed line shapes and by the fact that the observed dependence on H_1 of the signal amplitude is in very good agreement with (2).

Because of the large field inhomogeneity over the sample region (about 0.3 gauss) the signals were sufficiently broad for both O^{17} and D^2. In the case of O^{17} the ratio of T_1/T_2 was about 7 for the samples used for the spin determination. It was observed further that the addition of paramagnetic ions does not much affect the thermal relaxation time T_1 of O^{17} nuclei, but that it broadens the line considerably. A 0.001-molar concentration of $MnSO_4$ would give a line width of about 1 gauss for O^{17}, but did not give an appreciable effect on D^2. A further investigation of this abnormal relaxation mechanism of O^{17} in the presence of paramagnetic ions is in progress.

Using the frequency ratio (1), the spin value (3), and the observed negative sign, the value

$$\mu(O^{17})=-1.8928\pm0.00019 \text{ nm} \quad (4)$$

was obtained for the magnetic moment of O^{17}. In deriving the value (4) we have further used the value 2.79245 ± 0.00020 nm for the proton moment recently determined by Bloch and Jeffries[8] and the ratio of the deuteron moment to the proton moment obtained by Levinthal.[4]

The spin value 5/2 with the negative moment approximately equal to the neutron moment assigns a $d_{5/2}$ orbit to the odd neutron of O^{17} as one would expect from the shell model proposed by Mayer[5] and Haxel, Jensen, and Suess.[6] This assignment disagrees with that of Feenberg and Hammack[7] who predicted an $s_{1/2}$ orbit for the ground state of O^{17}.

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† Assisted by the joint program of the AEC and ONR.

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Scintillation Counting of Cosmic-Ray Particles*

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SCINTILLATION counters have the property of producing pulses of amplitude proportional to the energy lost in the scintillator. In order to use scintillators to study the primary heavy nuclei in cosmic rays, we have investigated several experimental arrangements. When a scintillation counter is used as one of the counters in a telescope, the distribution of pulse amplitudes is broadened by the following factors: (a) The statistical fluctuation in energy loss; (*b*) the variation in light collection in the counter; (*c*) the variation in path length through the counter; and (*d*) the statistics of the photo-electrons in the multiplier.

The effect of photo-electron statistics can usually be made very small by good light collection and by the use of a good scintillator. We have found that pyrene dissolved in xylene is a very satisfactory scintillation material. This solution gives pulses with a 5819 multiplier which are about half the size of those from terphenyl in xylene. The fluorescent light from pyrene is light green, however, and suffers negligible absorption in the xylene or in impurities in the zylene. The maximum light output is obtained at a pyrene concentration of 8 g/liter of zylene.

The geometrical arrangement of the scintillation counter is shown in Fig. 1. The multiplier looks into the glass "T" tube which

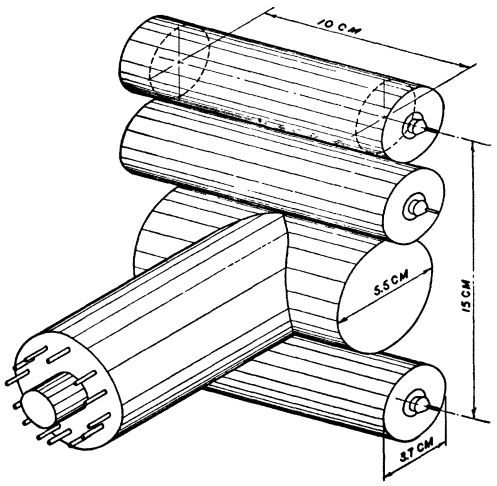

FIG. 1. Scintillation counter geometry.

is painted with magnesium oxide on the outside of the glass. Whenever a triple coincidence occurs in the Geiger counter telescope, the pulse from the scintillation counter is measured. The geometry can be improved by making the active region of the scintillation counter square instead of round in cross section and by decreasing the angle subtended by the Geiger counters.

It has been shown by Landau[1] and by Symon[2] that large fluctuations in the energy loss of monoenergetic charged particles are to be expected if the particles lose only a fraction of their energy in the detector. Whittemore and Street[3] have shown that the experimental distribution obtained with a crystal counter resembles the theoretical curve. In their case, nonuniform parts of the crystal apparently gave more small pulses than were expected from the theory. Figure 2 shows a distribution of sea-level mesons obtained with the scintillation counter telescope. The curve of Fig. 2 was taken with a smaller solid angle than that represented by the telescope of Fig. 1. The contribution to the spread in pulse heights by photo-electron statistics, geometry, and light collection was less than 8 percent. The average energy loss in Fig. 2 corresponds to 9 Mev. The shape and half-width of the distribution agree quite well with the theoretical calculation. Professor Charles