short range,[10] the increased value of $\epsilon$ found at 30,000 feet (3rd series) could be partially due to $\pi$-mesons slowed down in the absorber. Indeed, the excess of ordinary mesons would be still 20 percent at 30,000 feet if 13 percent of the delayed coincidences registered with C were due to positive $\pi$-mesons.

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* Assisted by the joint program of the ONR and AEC.
** On leave from the University of Rome, Italy.
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## Measurement of a $2.3\times10^{-8}$-Second Metastable State in $Hg^{198}$

W. J. MacIntyre
*Sloane Physics Laboratory, Yale University,* New Haven, Connecticut*
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METASTABLE nuclear states of half-lives ranging from a millisecond to 0.65 microsecond have been investigated in detail by De Benedetti and McGowan[1] by the delayed coincidence method. In addition Bittencourt and Goldhaber[2] have reported a $5\pm2\times10^{-8}$ second state of $Te^{121}$ and Stevenson and Deutsch[3] have reported a state of $Cd^{111}$ with a half-life of $8\pm1\times10^{-8}$ second.

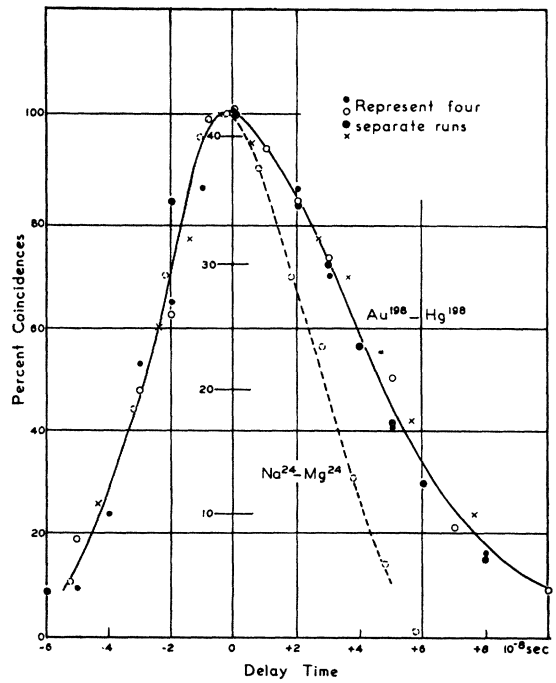


FIG. 1. Coincidence rate *versus* delay curve for $Na^{24}$ and $Au^{198}$ decay. Plus values of delay refer to additions to $\beta$-channel. First two sets of data on $Au^{198}$ taken with $\beta$-detection by proportional counter and second two by scintillation counter.

By use of detectors and coincidence circuits of combined resolving time of $5.6\times10^{-8}$ second, states of $\beta-\gamma$-coincidences have been investigated in the region of $1-30\times10^{-8}$ second. Determinations on the decay of calcium fluoride and naphthalene crystals as previously reported[4] have shown the measurements possible with the circuits. The long decay time of these phosphors, however, prevent their use and so for a scintillation counter for gamma-detection, polystyrene was selected. When used in conjunction with a 931A and the usual circuits this has a resolving time of $2.8\times10^{-8}$ second[5] and the decay is faster than can be detected with the coincidence circuit used.

For detection of the beta-particles both proportional counters of resolving time of $2.8\times10^{-8}$ second and polystyrene scintillation counters have been used. Results obtained with the polystyrene counter and the proportional counter were identical, thus verifying that the polystyrene decay time is negligible.

In the search for short-lived isomers the isotope was placed between the two counters with an absorber screening the gamma-scintillation counter from the beta-particles. Since the proportional counter has a low efficiency for gamma-rays this results in the proportional counter detecting only the beta-particles and the scintillation counter detecting only the gamma-rays. This is important in the case of cascaded gamma-rays as it proves the data obtained are for $\beta-\gamma$-coincidences and not $\gamma-\gamma$.

The simultaneous stimulation of both counters will result in the familiar resolution curve as the delay time of one channel with respect to the other is varied. Thus identification of isomers is accomplished by searching for departure of the usual symmetric resolution curve to one of asymmetry. The simultaneous stimulation of both counters may be obtained by projecting a beam of beta-particles through the proportional counter into the scintillation counter or by a $\beta-\gamma$-coincidence of a state so fast that no variation of symmetry appears.

Such a state is shown in Fig. 1 for the case of $\beta-\gamma$-coincidences from $Na^{24}$. Although there is perhaps a slight asymmetry to the traling edge it appears too fast for this equipment to measure and shows the state of $Mg^{24}$ found from $Na^{24}$ decay to be faster than a $2\times10^{-8}$ second half-life. These measurements were obtained with both a proportional counter and polystyrene counter detecting the beta-particles with no variation observed.

In the case of the decay of $Au^{198}$, as shown also in Fig. 1, a distinct asymmetry is observed. This shows the existence of a lag in the detection of the gamma-rays and consequently a metastable state of the newly-formed $Hg^{198}$. A compilation of four separate measurements plotted on the figure all show the same asymmetry and approximate decay time.

According to the analysis of Van Name[6] this trailing edge should fall off in value as the exponential of the decay constant, providing the first point is beyond the half-width pulse distribution. The variation of the logarithm of the coincidence against time is shown in Fig. 2 to give a straight line, with half-life $2.3\times10^{-8}$ second. From variations of several curves and the limitation of the range to three half-lives the error is estimated to be $\pm0.2\times10^{-8}$ second.

Previously, Madansky and Wiedenbeck[7] had estimated a state in $Hg^{198}$ of 0.2~0.3 microsecond half-life. Mandeville and Scherb[8] have also investigated $Hg^{198}$ for a possible metastable state by looking for loss in $\beta-\gamma$-coincidences from $Au^{198}$, while reducing the resolving time of their coincidence circuit from 1.0 microsecond to $0.035\pm0.002$ microsecond and reported no state apparent. De Benedetti and McGowan also reported negative results for the range previously mentioned.

An attempt was made to identify the type of gamma-ray transition by use of Segrè's formula.[9] Using the value of the

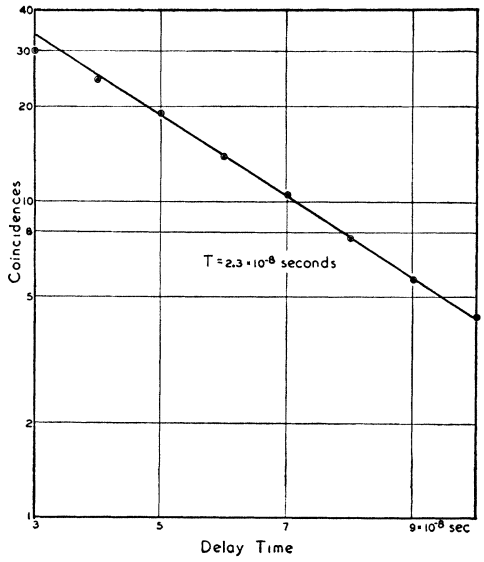


FIG. 2. Semi-logarithmic plot of $Au^{198}$ coincidences *versus* delay time.

gamma-ray energy of 0.41 Mev this predicts a half-life of the order of $1.7\times10^{-11}$ second for electric quadrupole and $1.5\times10^{-6}$ second for electric octupole. The observed value falls between these two values of $l$ equal to 2 or 3 and is thus probably a quadrupole transition.

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## Mass Assignment of the 43-Minute Hg Isomer

INGMAR BERGSTRÖM AND SIGVARD THULIN
*Nobel Institute for Physics, Stockholm, Sweden*
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THE electromagnetic isotope separator, recently built at our Institute,[1] has been used to determine the mass number of the $43^m$ activity of Hg. This activity has been known before to be due to an isomeric state and our results, which will be reported here, show that this activity can be uniquely ascribed to mass number 199.

When performing a determination of this kind, one can proceed principally in two different ways. One can either start by irradiation of unseparated Hg and then make the isotope separation of the irradiated sample, whereafter the activity of each mass number is determined, or one can make the separation first and then irradiate the different isotopes separately. In the first case the active isotope assignment will be unique, while the other procedure, though it does not always give an unique answer, may be advantageous when the isotope is very short-lived. In the present case both methods have been used.

One gram Hg was irradiated in a small glass container by fast Be-neutrons from our 6.5-Mev cyclotron for about 2 hours (current 50–100 $\mu$a). Immediately after irradiation the container was introduced into the ion source of the separator by means of a vacuum lock device. The mercury ion current was 10–15 $\mu$a and the time of separation 40 min., giving about 60 $\mu$g stable Hg isotopes. The separation could be started a few minutes after the irradiation in the cyclotron. The Hg spectrum was deposited on a thin Al plate, which could be taken out quickly after a convenient separation time. The Al plate was cut into strips, each corresponding to a mass number and 4 mm wide. The activity of each strip was then measured with a small bell $\beta$-counter (background 6 counts/min.). Figure 1 shows the results of such an investigation. On the abscissa axis the mass number scale is given, which is found by the visual deposition on the plate of the stable isotopes. The distance between the centers of two subsequent mass numbers on the plate is 4 mm. According to Fig. 1 the $43^m$ activity evidently has the mass number 199. The half-life of the activity of this mass number was also checked. Another investigation with better focusing showed an activity of 6 c/m at mass number 199 and no counts above the background for the mass numbers 198 and 200.

In order to investigate different reactions leading to the metastable level in $Hg^{199}$ the previously mentioned second method was used. The stable isotopes of Hg were separated and deposited on a Fe plate, which was cut into strips as mentioned above. The strips were irradiated in the cyclotron and then separately treated with a diluted solution of hydrochloric acid. It was found that the isotope deposits on the strips left the active plates and flowed up to the surface of the solution. The isotopes were then filtered off, washed with water and alcohol and then dried. In this way the activity measurements could be started 10 min. after irradiation. The mass numbers 199 and 200 showed a weak activity above background with a half-life of the order of 40 min. This may mean that both the reaction $Hg^{199}(n,n)Hg^{199*}$ and $Hg^{200}(n,2n)Hg^{199*}$ occur, since earlier investigations have shown that no hydrogen compounds occur in the mass spectrum that can disturb the measurements.

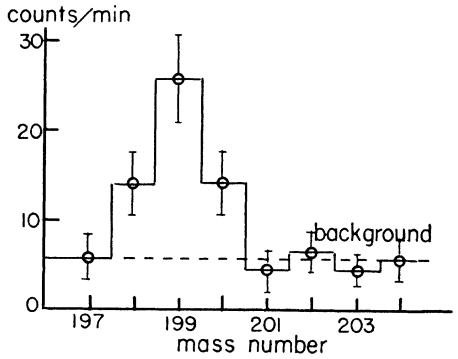


FIG. 1. Histogram showing that activity is to be assigned to mass number 199.

Our mass assignment fits well with the experiments performed by Sherr *et al.*,[2] who observed a 43 min. Hg activity obtained from a $(\alpha,n)$-reaction on Pt. The mass assignment also explains why the 43 min. activity cannot be produced by a $(n,\alpha)$-reaction on Pb as shown by Wu and Friedländer,[3] since there is no stable $Pb^{202}$ isotope.

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