# Thermal Energy Relaxation Length of Ra-Be Neutrons in Water

JAY TITTMAN
*Research Laboratory, Schlumberger Well Surveying Corporation, Ridgefield, Connecticut*
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Measurement of the density of thermal neutrons about a point Ra—Be source in infinite water medium has been extended to one meter. The thermal relaxation length is found to be constant at 9.58±0.2 cm over a range in which neutron density changes by $10^5$.

PREVIOUS published investigations[1–5] of the distribution of thermal neutrons about a point source in an infinite water medium have been limited to distances <50 cm by the difficulty of measuring the small flux densities at larger distances. For the purpose of determining $\langle r^2\rangle_{Av}$, it has been assumed that the thermal neutron density continues to fall off as $r^{-2}\exp(-r/L_r)$, where $L_r$ is the relaxation length.[6] The present measurements extend these data to one meter.

A 1 g Ra-Be source contained in a small stainless steel housing was located at the center of a water-filled cubic pit 8 feet on an edge. Measurements out to 35 cm were made with 1-inch diameter In foils (104 mg/cm²) both with and without 0.005-inch Cd covers, using standard techniques. After applying small corrections for background and counter dead time, the measured activities were converted into $A_{th}$, the thermal neutron induced activity after infinite exposure. Beyond ~15 cm the ratio $A_{epithermal}/A_{th}$ was very closely constant at the value 0.063 so that no correction for Cd overlap of the lowest In resonance[7] was required.

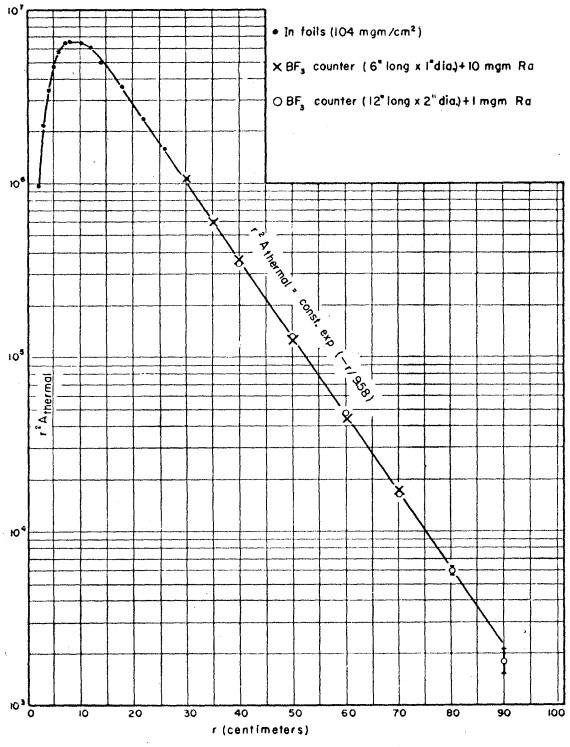


FIG. 1. Thermal neutron density as a function of distance. $BF_3$ counter data are normalized to the In foil points at 30 and 35 cm.

At positions $r>30$ cm, $BF_3$ proportional counters were used as detectors. As in the case of the foil measurements, counts were taken both with and without watertight Cd sleeves surrounding the counters. In order to evaluate the effect of detector size on the measurements, two counters with the dimensions indicated in Fig. 1 were used. Table I indicates the ranges in which data were taken with each detector. The data, normalized end to end, are shown in Fig. 1. The consistency of the results in the ranges of overlap indicates that effects of water displacement and spatial resolution are negligible. This feature was further checked by orienting the counters with their center wires along the radius vector from the source. The net effect appeared, within experimental error, as a constant factor applied to the counting rate, leaving the measured value of $L_r$ unaffected.

Early in the course of the measurements it was found that the neutron integral bias curves were sensitive to the $\gamma$-flux to which the counters were exposed. Since the $\gamma$-intensity from the Ra—Be source falls off rapidly with distance, this variation in $\gamma$-flux would have affected the relative values of neutron counting rates at different distances. In order to eliminate this effect, auxiliary Ra sources were attached to the $BF_3$ counters

TABLE I. Results using different detectors.

| Detector | Auxiliary source | Range in which used (cm) | $L_r$ (cm) |
|---|---|---|---|
| In foils | ··· | 18–35 | 9.57 |
| Small $BF_3$ counter | 10 mg Ra | 30–70 | 9.65 |
| Larg $BF_3$ counter | 1 mg Ra | 40–90 | 9.52 |
| | | Average | 9.58 |

[1] E. Amaldi and E. Fermi, Phys. Rev. **50**, 899 (1936).
[2] A. M. Munn and B. Pontecorvo, Can. J. Research **A25**, 157 (1947).
[3] J. H. Rush, Phys. Rev. **73**, 271 (1948).
[4] Tittle, Faul, Secrest, and Goodman, Technical Report No. 21 (Laboratory for Nuclear Science and Engineering, Massachusetts Institute of Technology, 1949).
[5] Dacey, Paine, and Goodman, Technical Report No. 23 (Laboratory for Nuclear Science and Engineering, Massachusetts Institute of Technology, 1949).
[6] S. Flügge, Physik. Z. **44**, 445 (1943).
[7] C. W. Tittle, Nucleonics **9**, No. 1, 60 (1951).

so that the latter were in a constant $\gamma$-ray bath compared to which the variation in $\gamma$-flux from the 1 g Ra—Be source some distance away was negligible. The $BF_3$ counters were later replaced by a small G-M tube, and the constancy of the $\gamma$-flux was established experimentally.

The average value $L_r = 9.58$ cm is in agreement with previous measurements at smaller distances[1,3–5] to within experimental error of ~2 percent and justifies the use of a simple exponential decay out to at least 1 meter.

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# Radioactivity of $Pt^{191}$ and $Pt^{193m}$†

J. B. SWAN,* W. M. PORTNOY, AND R. D. HILL
*Physics Department, University of Illinois, Urbana, Illinois*
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A 3.2-day activity of $Pt^{191}$ and a 4.5-day activity of $Pt^{193}$ have been investigated. Electron-capture of $Pt^{191}$ is followed by a complex spectrum of gamma-radiation. The 4.5-day $Pt^{193m}$ activity is a characteristic $M4$ isomeric transition of 135-kev.

FOLLOWING recent experiments[1] with osmium, an investigation of the electron-capture decay of $_{78}Pt^{191}$ and $_{78}Pt^{193}$ was undertaken to determine whether there were any features of these decays in common with the beta-decays of $_{76}Os^{191}$ and $_{76}Os^{193}$.

Iridium metal (38.5 percent $Ir^{191}$, 61.5 percent $Ir^{193}$) was bombarded with 10-Mev deuterons, and the platinum fraction containing $Pt^{191}$ and $Pt^{193}$ produced by a $(d,2n)$ reaction was chemically separated. The internal-conversion spectrum of the platinum was investigated using 180°- and lens-spectrometers. Conversion lines corresponding to the following gamma-transitions were obtained: 62, 82, 94, 125, 129, 135, 171, 178, 267, 350, 359, 408, 455, and 537 kev.

Lifetime tests on individual conversion lines showed that, with the exception of the 135-kev transition, all transitions had approximately the same half-life. The best measurement of this half-life was 3.2±0.2 days. The observed half-life of the 135-kev transition was 4.5±0.2 days.

Foils of platinum (0.012 percent $Pt^{190}$, 0.8 percent $Pt^{192}$, 32.8 percent $Pt^{194}$, 33.7 percent $Pt^{195}$, 25.4 percent $Pt^{196}$, 7.2 percent $Pt^{198}$) were irradiated by gamma-rays from a 22-Mev betatron. The conversion-electron spectrum again showed strong lines of the 135-kev transition. However, none of the other lines listed above was observed. Since relatively little $Pt^{191}$ is produced by a $(\gamma,n)$ reaction on platinum, the 135-kev gamma-transition is, therefore, to be assigned to $Pt^{193}$. The assignments of 3.2-day and 4.5-day half-lives to $Pt^{191}$ and $Pt^{193}$ are in accord with those already made by Wilkinson.[2] Also observed in the gamma-irradiated sources were the 129- and 97-kev transitions of 3.8-day $Pt^{195m}$, the 337-kev transition of 80-minute $Pt^{197m}$, and the 77-kev transition and 0.7-Mev beta-spectrum of 18-hour $Pt^{197}$. The 129-kev transition of $Pt^{195m}$ is characteristically an isomeric $M4$ transition, and cannot be confused with the 129-kev gamma-transition of the platinum source separated from the irradiated iridium. An isotopic chart of platinum and neighboring elements is shown in Fig. 1.

## $Pt^{191}$. DISCUSSION

Of the thirteen gamma-transitions which are now to be allocated to $Pt^{191}$, measurements of conversion-electron energies show that the 82- and 129-kev transitions are converted in iridium. It is probable that all of the transitions follow the electron-capture of $Pt^{191}$. Further, the 129-kev transition is found to be identical with the already-observed[1] 129-kev transition following the beta-decay of $Os^{191}$. However, the 42-kev transition observed in the decay of $Os^{191}$ is not observed in the decay of $Pt^{191}$ and, relative to the 129-kev transition, is certainly not present to the extent of one-fourth of the intensity that it has in the $Os^{191}$ decay.

No thorough experimental analysis of the complex $Pt^{191}$ decay scheme was attempted. However, it is apparent from the transition energies that certain transitions combine to give common energy values. In particular, 455 plus 82, 408 plus 129, 359 plus 178, combine to yield an energy of 537 kev, for which energy a transition is itself found. Other combinations are: 94 plus 82 (178); 94 plus 171 (267); 267 plus 82 (350); 62 plus 125 plus 267 (455); 62 plus 125 plus 350 (537). Although a feasible decay scheme might easily be con-

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* Fulbright Fellow. On leave from University of Western Australia, Perth, Australia.
[1] J. B. Swan and R. D. Hill, Phys. Rev. 88, 831 (1952).
[2] G. Wilkinson, Phys. Rev. 73, 252 (1948).