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Reactor Produced ^{202}Tl: Determination of Half-life and Gamma Energies

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The production of ^{202}Tl in a nuclear reactor is discussed. We describe the experimental method followed for the determination of the half-life and the gamma energies. The following data were obtained: Half-life: (12·23 ± 0·02) days—Energies: (439·56 ± 0·01) keV and (520·13 ± 0·07) keV.

INTRODUCTION

^{202}Tl is a well known nuclide which has been studied by several authors.[1–4] Various methods have been reported for its production, none of them being based on the $(n, 2n)$ reaction in a nuclear reactor. The reported value for its cross section is 4 mb in a fission neutron spectrum,[4] which suggests the possibility of obtaining ^{202}Tl with not too small a yield. Our main interest in this method is its application to activation analysis of thallium from ^{202}Tl, considering the known fact that the isotopes originated by (n, γ) reactions have no gamma radiations, excepting the Hg X-rays from ^{204}Tl. As ^{203}Tl $(n, 2n)$ ^{202}Tl is a reaction almost free of interferences, its use in neutron flux measurements above its threshold energy of 8·8 MeV would also be interesting.

We have determined the half-life and the energies of ^{202}Tl with good accuracy as a part of a more general work on thallium.

EXPERIMENTAL

Source preparation

Samples of Spec-Pure metallic thallium (Johnson, Matthey & Co., London) were treated with diluted NO_3H in order to remove surfacial impurities, mainly the thallium oxide formed on the metal; washed with distilled water, dried, rapidly weighed and sealed in quartz ampoules. A 96 hr irradiation was carried out in one of the irradiation boxes of the RA-3 Reactor (thermal flux: $8{\cdot}2 \times 10^{12}$ n/cm^2 sec; fast flux: $1{\cdot}7 \times 10^{12}$ n/cm^2 sec). As we intended to study both ^{202}Tl and ^{204}Tl the sample was irradiated without cadmium cover.

Twenty-four hr after the end of the irradiation the gamma spectrum of the irradiated thallium showed small peaks due to interferences, such as ^{122}Sb, ^{124}Sb and ^{198}Au as well as the expected ^{202}Tl and ^{204}Tl. Purification was performed as follows: the sample was dissolved in fuming HNO_3 and H_2SO_4 was added. $BaSO_4$, acting as a scavenger, was precipitated with $BaCl_2$ and filtered. A gamma spectrum of this precipitate showed that in it almost all ^{198}Au, as well as part of ^{122}Sb and ^{124}Sb activities were present. The hot solution was treated with metallic zinc to assure that thallium was in the Tl(I) state. Under these conditions, part of the antimony present escapes from the solution as volatile compounds. Finally the solution was diluted and TlI precipitated, by adding a NaI solution. The TlI was filtered, washed with NH_4OH, distilled water and dried. A small portion was placed in the center of a lucite disk, in order to form a near-point source. Measuring the gamma spectrum of this source, we could see that ^{122}Sb and ^{124}Sb activities had not been completely removed but what remained might be considered as negligible; Fig. I shows a spectrum of the source.

Measurements

All measurements were performed with a 40-cm^3 Ge(Li) detector, with a 2·3-keV resolution for the 1332·5 keV of ^{60}Co, coupled to a 4096-multichannel analyzer. The value of the ^{202}Tl half-life was obtained following its decay during 38 days by measuring its 439 keV radiation. The thallium source was placed in an automatic sample changer, to assure geometry reproducibility and measurement times were sufficiently long to accumulate statistically good

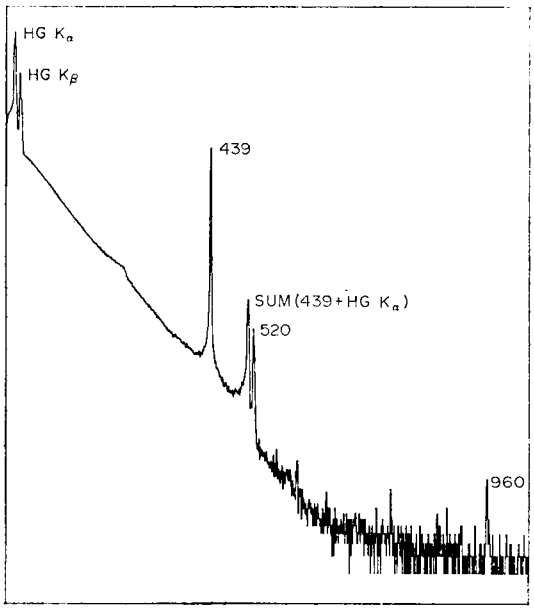

FIG. 1. Gamma spectrum of ^{202}Tl–^{204}Tl source, 14 days after the end of the irradiation.

numbers of counts. Immediately afterwards each measurement, a source of ^{152}Eu ($T_{\frac{1}{2}}$: 13 yr) was measured to detect accidental variations of equipment experimental conditions through its 444 keV peak. The coincidence losses due to sums of 439 keV radiation and Hg X-rays from the source were less than three per cent of the total number of counts obtained for the 439 keV. Source geometry was adjusted in such a way that dead time was very small in all measurements.

The most outstanding energies, corresponding to 439 and 520 keV levels were measured using standards of well known energy. These standards and their energy are listed in Tables 1 and 2, for 439 and 520 keV, respectively. Determination procedure was as follows: thallium source and standards were measured simultaneously in such a geometrical arrangement so as to accumulate the

TABLE 1

Nuclide	Energy (keV)	Intensity (%)	Reference
^{133}Ba	383·851 ± 0·020	9·0	(6)
^{75}Se	400·640 ± 0·015	11·4	(6)
^{152}Eu	411·13 ± 0·05	2·3	(7)
^{152}Eu	443·98 ± 0·05	3·0	(7)
^{192}Ir	468·053 ± 0·014	49·5	(8)
^{22}Na	511·006 ± 0·002	180	(9)

TABLE 2

Nuclide	Energy (keV)	Intensity (%)	Reference
^{152}Eu	443·98 ± 0·05	3·0	(7)
^{192}Ir	468·053 ± 0·014	49·5	(8)
^{85}Sr	513·98 ± 0·03	100	(10)
^{207}Bi	569·62 ± 0·06	98	(11)
^{192}Ir	588·557 ± 0·017	4·6	(8)
^{192}Ir	612·435 ± 0·017	5·0	(8)

same number of counts for each peak concerned. This condition was fulfilled for the 439 keV level, but not when measuring the 520 keV one, due to intensity differences for the transitions of the ^{192}Ir standard. Therefore, when the number of counts accumulated over the 588 and 612 keV peaks equalled those of the other sources, the 468 keV peak shows a much larger number of counts. Assembly geometry was such that the fraction of the total activity entering the detector was low, avoiding any possible peak shape and localization distortion. Spectra of standards without the thallium source were also measured, to prove that no disturbance existed in the ^{202}Tl peaks region.

Calculations

Peak areas were calculated by Covell's method and their Neperian logarithms as a function of decay time were adjusted to a straight line using the least squares method. From the slope of this curve the value of ^{202}Tl half-life was obtained analytically.

Locations of peaks were found by a program [12] which smooths out data and then fits them into a Gaussian curve, determining the position of its maximum. Energy, as a function of a channel number, proved to be a straight line for the considered range. Values of energies were obtained from the least squares adjusted curves. The determination of the two energies was carried out separately, calculating different values for each.

RESULTS AND DISCUSSION

For the half-life of ^{202}Tl we have obtained a value of (12·23 ± 0·02) days, in accordance with previously published values, although with better precision. Determination factor for the adjusted straight line was 0·9995. The values of the measured energies were (439·56 ± 0·01) keV and (520·13 ± 0.07) keV. The cascade peak, corresponding to the sum of

the two quoted peaks can not be directly measured because of its low intensity. For a proper measure, a very long accumulation time would be necessary, and errors caused by shifts during this accumulation time would be too large. The errors expressed for the energies were calculated from the average of four different runs for each.

The fact that the width of the annhilation radiation peak is larger than those of the other peaks did not seem to have a great influence on the error of its localization, but there would be a source of error in the disturbance produced by the (439 keV + HgKα X-ray) sum peak, which has almost the same energy. This complication was serious when the 520 keV peak was measured, due to the condition that source and standards would accumulate an approximately equal number of counts, so that the area of the sum peak would be as large as that for 511·006 keV. For this reason, we used ^{85}Sr instead of ^{22}Na.

The situation was different when measuring the 439 keV peak, because of the little importance of the sum peak compared with ^{22}Na, which was measured so as to produce a similar number of counts to the 439 keV peak. We have performed four runs with a ^{85}Sr standard, in order to confirm the preceding, obtaining a new value of (439·55 $\pm$ 0·02) keV.

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