USE OF ^{244}Cm AND ^{145}Pm AS SOURCES FOR BONE MINERALIZATION STUDIES

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Both the 17.6-year ^{244}Cm and the 17.7-year ^{145}Pm are useful x-ray sources for bone mineral determination in vivo and in vitro. Their long half-lives also make them much more convenient than 60-day ^{125}I.

Photon absorptiometric measurement of bone mineral has been described by Cameron, et al (*1,2*) and by Sorenson, et al (*3*). In this method the transmission of a monoenergetic x-ray beam through a bone sample is measured at intervals across the sample. The transmission data can be used to determine the actual bone mineral content through a suitable algorithm (*4*).

Whereas ^{125}I, the usual source, has proved suitable for many determinations, in many other cases there is a need for lower energy x-ray sources for scanning small bones or for higher energy sources for larger bones and heavier patients. For this reason we have built and tested two sources: ^{244}Cm (L x-ray energy 14–22 keV) and ^{145}Pm (K x-ray energies of 39 and 44 keV). This paper reports the results of these tests and compares them with those obtained with ^{125}I (K x-ray energy 27 keV).

CURIUM-244 SOURCE

With its usual ^{125}I source, the bone scanning instrument used for human adults is unsuitable for scanning small bones such as the bones of children or the femur of a mouse or other small animals. In the scanning instrument we designed for this type of measurement, L x-rays from a ^{244}Cm-source are counted by a Si(Li) detector—a lithium-drifted silicon diode—although either NaI or CsI detectors gave acceptable results.

The decay schemes of these isotopes are found in the compilation of Lederer, et al (*5*). Curium-244 is primarily an alpha emitter of 17.6-year half-life, and the only photon radiation emitted by the source at a level greater than 0.1% are the L x-rays of the ^{240}Pu daughter. These are of comparable intensity, have energies of 14.3, 18.3, and 21.4 keV, respectively, and are emitted in a total of 18% of the decays. No alpha activity, of course, can penetrate the source case or 15-mg/cm^2 beryllium window. A 100-mCi source was encased in a double-walled container made largely of beryllium metal which allowed the low-energy L x-rays to emerge with little attenuation. The source holder was also designed to give a fair degree of collimation with a 3-mm aperture at the source and 2-mm aperture at the detector 17 cm away. The effective source strength including self-absorption was about 20 mCi of x-rays.

The Si(Li) detector was coupled to a multichannel scalar in such a way that the channel number corresponded to the transverse scan position. The high resolution of the Si(Li) detector enabled it to resolve the L x-rays of ^{244}Cm into three major lines whose energies were approximately 14, 18, and 21 keV and whose respective intensities were in the ratio 0.68:1.00:0.24. To measure with any one of these three x-ray lines, the window of a single-channel analyzer was set to select it. The data analysis, performed with a computer program written by A. M. Strash (*4*), determined the bone diameter and mineral content, provided an error analysis based on counting statistics, and produced a graphical output of the transmission data.

The performance of the instrument to scan small bones in vitro is illustrated in Fig. 1 which allows four scans of a mouse femur—one with each of the three ^{244}Cm-L x-ray lines readily resolved by the Si(Li) detector and, for comparison, one with the conventional ^{125}I source. The high spatial resolution

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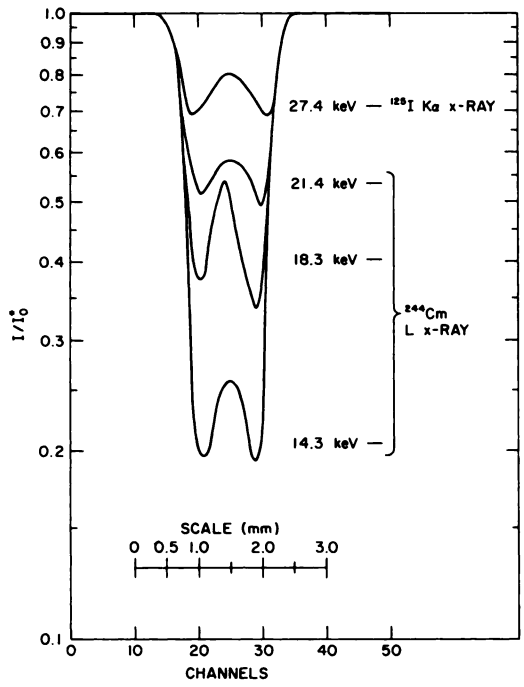

FIG. 1. Four scans of mouse femur in vitro. X-ray lines used for scans were three prominent L x-rays from our ^{244}Cm source and Kα line from conventional ^{125}I source. Scans were made using Si(Li) detector.

of the system and the merits of the lower scanning energy are readily apparent. The higher resolution of the lower energy lines is probably due in part to the lower scattering at these energies.

PROMETHEUM-145 SOURCE

The ^{145}Pm source was made by irradiating 150 mg of enriched ^{144}Sm for 1 year in a high-flux reactor (flux $> 10^{15}$ neutrons/sec). At the end of the irradiation, the samarium was purified and the ^{145}Sm (half-life = 340 days) was allowed to decay for 1 year. At the end of this time the prometheum that had grown into the sample was purified and was found to be isotopically pure ^{145}Pm. This sample of pure ^{145}Pm was absorbed onto a bed of cation-exchange resin filling a recess 1-mm wide, 5-mm long, and about 1-mm deep in a steel holder, the bed was covered with a beryllium window, and the detector was covered by a 2-mm collimator, 17-cm from the source.

The decay scheme (*5*) of ^{145}Pm indicates that ^{145}Pm decays by electron capture with a 17.7-year half-life. In its decay it emits 67-keV gamma rays with an intensity of 1% and 72-keV gamma rays with an intensity of 2.3%. It also emits Nd K x-rays with an apparent intensity of 116% (due to conversion of the gamma radiation). The energies of the major K x-rays are 36.9, 37.4, and 42.2 keV and in our NaI or CsI detectors appear to be a single peak at 37 keV. In this case our source contained 25 mCi of ^{145}Pm.

Two scans of the mid-shaft of a human right arm, in vivo, the upper one taken with a standard ^{125}I source purchased from New England Nuclear and the lower with our ^{145}Pm source, are compared in Fig. 2. For both sources we used a CsI detector. The two dips are due to absorption in the radius and ulna. The absorption for the ^{145}Pm source, though smaller, is still quite satisfactory for bone mineral studies of the two bones. In the soft-tissue background, the irregularities due to the difference between the absorption in fat and in other soft tissue are considerably less pronounced in the data taken with the higher energy x-rays from our ^{145}Pm source.

Our sources were prepared at Argonne National Laboratory from isotopes obtained through the Isotope Division of Oak Ridge National Laboratory. If these sources are not available commercially, then, with AEC approval, the sources may be obtained from the Isotopes Division of Oak Ridge National Laboratory, Oak Ridge, Tenn. The present price of ^{244}Cm (*6*) as oxide is about $100/100 mCi plus packaging and handling costs of about $260. The estimated cost of ^{145}Pm is about $3,600 (*7*) for 25 mCi if 8–10 such sources could be produced at the same time. In addition to these isotope costs, there would be full recovery charges on source-holder fabrication and loading.

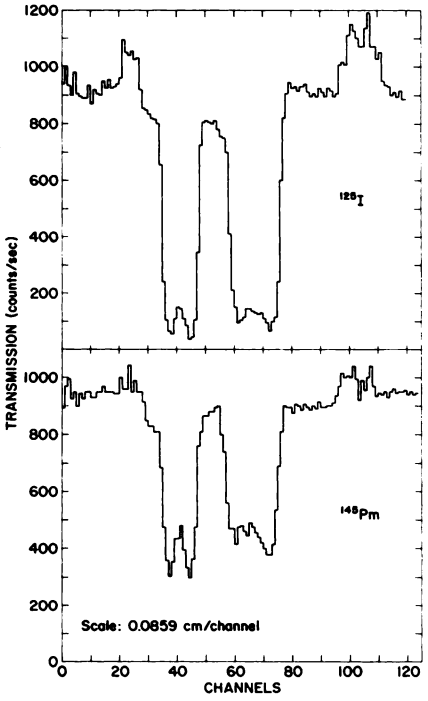

FIG. 2. Scans of mid-shaft of human right arm in vivo. Lower scan was obtained with 44-keV x-ray from our ^{145}Pm source, upper with 27 keV x-ray from standard ^{125}I source. Scans were made using CsI scintillation detector and are qualitatively same as obtained with NaI or Si-Li detector.

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