ELECTRON LINEAR ACCELERATOR PRODUCTION OF ^{43}K

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Carrier-free radiopharmaceutical ^{43}K as KCl was produced by the $^{44}Ca(\gamma,p)^{43}K$ reaction induced by bremsstrahlung radiation from an electron linear accelerator. An irradiation of 1 hr using 5.4 kW of 45-MeV electrons passing through a thick tantalum converter produced yields in excess of 1.5 mCi/gm ^{44}CaO. The ^{43}K was separated from the target material and prepared as ^{43}KCl using ion-exchange chromatography. This radiopharmaceutical is now being prepared in millicurie quantities for myocardial imaging, electrolyte studies, and other uses for which ^{40}K and ^{42}K are unsuited.

The radionuclide ^{43}K, in the form of KCl, has been found to be an effective agent for myocardial imaging and electrolyte studies (*1–4*). Clinically usable quantities of this radioisotope have been produced in high-flux nuclear reactors by the $^{43}Ca(n,p)^{43}K$ reaction and in cyclotrons by the $^{40}A(\alpha,p)^{43}K$ reaction (*1,4,5*). An alternate reaction is $^{44}Ca(\gamma,p)^{43}K$ induced by bremsstrahlung radiation developed by the electron beam of a linear accelerator (*6,7*). In a practical application of this photonuclear reaction we have routinely produced carrier-free ^{43}K. Our method uses a moderately priced, enriched (94%) ^{44}Ca target and requires no elaborate irradiation or handling equipment to produce sufficient quantities for clinical investigations.

METHODS

A quantity of 94%-enriched ^{44}Ca was purchased as $CaCO_3$ and converted to the oxide to eliminate the photoproduction of ^{11}C during irradiation. For each production exposure, approximately 0.30 gm of ^{44}CaO was sealed in a quartz ampule and inserted into an air-cooled quartz target holder (Fig. 1). High-energy bremsstrahlung was produced by passing the electron beam of the AFRRI electron linear accelerator through a thick (0.7 radiation length), water-cooled tantalum converter. The target was placed approximately 2.5 cm from the converter exit window. An irradiation of 1 hr using 5.4 kW of 45-MeV electrons produced ^{43}K activities greater than 450 μCi in 0.3 gm of ^{44}CaO. Targets were manually transferred to a lead container after irradiation and carried to the hot lab for chemical processing.

Chemical separation of potassium from calcium was performed on a Bio-Rad AG 50W-X8 in H^+ form ion-exchange column using a procedure developed at ORNL (*5*), modified to incorporate a

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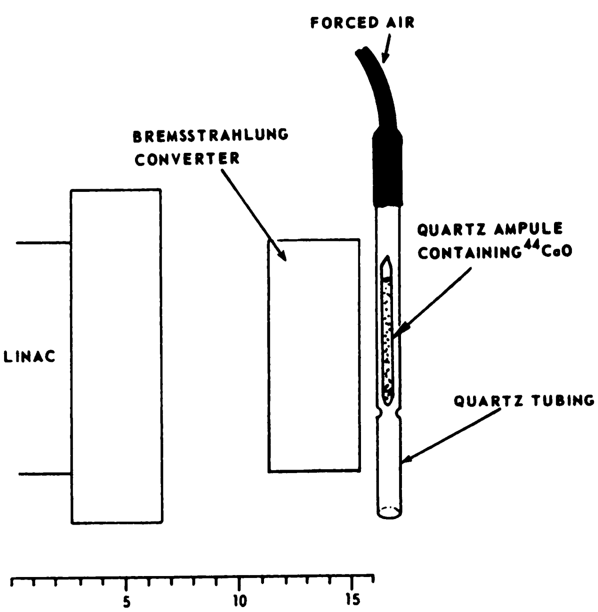

FIG. 1. Diagram of irradiation arrangement. Electron beam from Linac passes through bremsstrahlung converter, producing high-energy photons which induce photonuclear reactions in target material.

simple pneumatic pressure system to elute the ^{43}K from the column. A standard nitrogen or helium tank was regulated at about 4 psi to maintain a flow rate of 3 ml/min. The exchange column was maintained at approximately 80°C by a hot water jacket and an infrared heating lamp directed onto the column head reservoir. At this elevated temperature, the difference between the selectivity coefficients of K^+ and Ca^{2+} increases, thereby enhancing the separation of the two ions. The selectivity coefficients were unaffected by the operating pressure of the column (*8*). The eluted KCl was taken to dryness, dissolved in normal saline, and passed through a 0.22-micron Millipore filter. After elution from the column, the target material was then recovered by precipitation with saturated ammonium oxalate, furnaced in a nitrogen atmosphere at 950° for 6 hr, and encapsulated for reactivation. Recovery of the enriched calcium was 98% or better. The recovered CaO contained minimal amounts of radionuclides derived from other stable calcium isotopes present in the target material. No special handling precautions were required.

DISCUSSION

No direct cross-section data appear to be available for the reaction $^{44}Ca(\gamma,p)^{43}K$. Brix, et al (*6*) have reported a value for the integrated cross section of 120 MeV-mb over the energy interval 12.2–31 MeV. Wu, et al (9) measured the differential cross section at 90 deg for the reaction $^{40}Ca(\gamma,p)^{39}K$ finding a maximum at approximately 20 MeV and a half-width of about 4 MeV. We assumed these parameters to describe the giant resonance peak for the $^{44}Ca(\gamma,p)^{43}K$ reaction. The bremsstrahlung converter thickness was optimized for the production of photons of energy 15–25 MeV by a computer simulation technique, making use of bremsstrahlung formulas suggested by Hansen and Fultz (*10*). A new tungsten converter of 1.3 radiation length thickness is being constructed. Using 45-MeV electrons, it is expected to increase the radionuclide yields by more than 40%.

Irradiation of ^{44}Ca with photons of energy greater than 20 MeV produces ^{42}K by the competing γ,np reaction. The gamma and beta energies from decay of ^{42}K are higher than those from ^{43}K, resulting in a higher body dose and hindering conventional gamma scanning techniques. It is thus desirable to reduce the level of ^{42}K in most preparations of ^{43}K. The $^{44}Ca(\gamma,np)^{42}K$ reaction threshold has been computed to be higher than that for the $^{44}Ca(\gamma,p)^{43}K$ reaction (*11*). It is therefore possible to reduce the ratio of ^{42}K to ^{43}K activities by reducing the energy of the electron beam although the reduction also reduces the yield of ^{43}K as shown in Table 1. Myocardial scans on beagles were performed at the AFRRI using 100–150 μCi per visualization. For such use, 0.30 gm of ^{44}CaO exposed to 35.7-MeV bremsstrahlung for 1 hr produced ample ^{43}K with only 12% ^{42}K contamination. Much larger amounts of ^{43}K may be produced by using larger amounts of ^{44}CaO target material although targets greater than 1 gm would require a longer ion-exchange column for separation.

TABLE 1. YIELDS OF ^{43}K AND ^{42}K FOR SEVERAL ELECTRON BEAM ENERGIES

Beam energy (MeV)	Yield (μCi/gm^{44}CaO-hr)		
	^{43}K	^{42}K	Ratio $^{42}K/^{43}K$
30.0	370	23	0.062
35.7	770	92	0.12
40.4	1100	230	0.21
44.5	1500	390	0.26

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