ACTIVATION RATES AND CHEMICAL RECOVERY OF $^{67}\text{Cu}$ PRODUCED WITH LOW ENERGY PROTON IRRADIATION OF ENRICHED $^{70}\text{Zn}$ TARGETS

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Copper-$^{67}$ is a radioisotope with significant potential for diagnostic and therapeutic applications in nuclear medicine. Despite its promise, $^{67}\text{Cu}$ has failed to make an impact in clinical nuclear medicine, primarily because it is available sporadically, and in limited quantities. Common methods of production rely on high energy proton irradiation of natural zinc targets or on induced reactions using high energy neutrons at nuclear reactors. We have evaluated alternative production methods that could provide year-round adequate supply of this isotope. Using a low energy accelerator, we have studied the production of $^{67}\text{Cu}$ by proton reactions on enriched $^{70}\text{Zn}$. Our results indicate that it is possible to produce useful quantities of $^{67}\text{Cu}$ from the irradiation of enriched $^{70}\text{Zn}$ with protons that have energies of less than 20 MeV. Production rates are higher than currently used methods at high energy accelerators or reactors. This isotope can be made available throughout the year as a result of this research.
supply of the $^{67}$Cu used for preparation of the porphyrins/monoclonal antibodies. At present, accelerator produced $^{67}$Cu is only available in quantity from Los Alamos National Laboratory and Brookhaven National Laboratory for 6-8 months of the year. Reactor production via the $^{67}$Zn($n,p$)$^{67}$Cu reaction is possible but production rates are too low to be financially feasible for long range treatment protocols.\(^8\)

We have examined a number of possible methods of production using the Los Alamos National Laboratory Van de Graaff accelerator. Our initial research centered on the use of the epithermal/fast neutrons produced by proton reactions on Ge and W targets to simulate reactor production methods. Although measurable amounts of $^{67}$Cu were produced, expensive ($>10$ gram) enriched $^{67}$Zn targets would have been required to produce the desired quantities. Investigations into other possible production methods at LAMPF indicated that some of our total $^{67}$Cu production may be resulting from high energy ($p,t\sim$) reactions on the $^{70}$Zn fraction of our natural zinc targets. Theoretical calculations using the ALICE computer code\(^9\) and our experimental results indicated that a useful cross section for $^{67}$Cu production at proton energies less than 25 MeV does exist. Thus, it should be possible to produce $^{67}$Cu at any suitable low energy ($<30$ MeV) proton accelerator throughout the year.

**Experimental**

*Targets and Irradiations:* Irradiations were performed using the tandem Van de Graaff accelerator at the Ion Beam Facility at the Los Alamos National Laboratory. This accelerator has a maximum energy of 20.4 MeV for protons and can provide up to 17 $\mu$A of current on target for isotope production. Actual beam intensity varied from 2 to 6 $\mu$A and proton energies ranged from 19.6 MeV to 18.1 MeV at the face of the target material. Targets, 0.95 cm in diameter, were prepared from both natural zinc and enriched $^{70}$Zn. The targets were fabricated from compressed oxide, electrodeposited zinc metal, or stacked zinc metal foils. Four of the six targets were covered with 0.05 mm thick copper monitor foils to measure beam intensity. Table 1 lists the target compositions. Table 2 lists the parameters for each irradiation. Figure 1 is a diagram of the target geometry used for these experiments.

Calculations using ALICE\(^9\) generated cross section curves indicate a maximum cross section for the ($p,\alpha$) reaction at $\sim 17$ MeV. Recently acquired data from Levkovskii,\(^{11}\) place the maximum at 14.8 MeV and with a cross section more than twice that estimated from ALICE calculations. Data from Barbier also indicate that ($p,\alpha$) reactions on Zn are possible\(^{12}\). Figure 2 shows the comparision between the data of Levkovskii and ALICE.

*Activity Measurements:* The radioisotopes of interest and their major decay properties are listed in Table 3. All radioassays were made using a HPGE detector coupled to a 4000 channel pulse height analyzer which had been calibrated using NIST traceable standards to determine the detector efficiency curve. Data was processed using the computer codes Specanl and Raygun.