

## ABSTRACT

Production of radioactive scandium by irradiating natural titanium metal in Pakistan Research Reactor-1 was evaluated. The production rate of scandium-47 ( $^{47}\text{Sc}$ ) and other radioactive scandium was estimated. High specific activity  $^{47}\text{Sc}$  can be produced by irradiating enriched titanium-47 in sufficient quantities needed for therapeutic applications. A new separation technique based on column chromatography was developed. Neutron irradiated titanium was dissolved in hydrofluoric acid, which was evaporated and taken in distilled water. The resulting solution was loaded on silica gel column. The radioactive scandium comes out first and the inactive titanium is removed with 2 M HCl. More than 95% radioactive scandium was recovered, while chemical impurity of titanium determined by optical emission spectroscopy was less than 0.01  $\mu\text{g} / \text{mL}$  in final product of  $^{47}\text{Sc}$ .

Production of Copper-64 ( $^{64}\text{Cu}$ ) by irradiating copper and zinc metals in a reactor was evaluated. Low specific activity  $^{64}\text{Cu}$  can be easily produced using thermal neutrons via  $^{63}\text{Cu} (n, \gamma) ^{64}\text{Cu}$  reaction, while use of fast neutrons are mandatory for high specific activity  $^{64}\text{Cu}$  via  $^{64}\text{Zn} (n, p) ^{64}\text{Cu}$  reaction. Natural copper and zinc targets were irradiated in Pakistan Research Reactor-1. Radionuclidic impurities produced by thermal and fast neutrons were determined. Commonly available organic anion exchange resin (AG 1-X8) was used for the separation of no-carrier-added radiocopper from neutron irradiated zinc. More than 95 %  $^{64,67}\text{Cu}$  was recovered. The radionuclidic and chemical purity of  $^{64}\text{Cu}$  was determined. The specific activity of  $^{64}\text{Cu}$  produced by  $^{63}\text{Cu} (n, \gamma)$  and  $^{64}\text{Zn} (n, p)$  was compared.

The metallic cation,  $^{68}\text{Ga}$  (III) is suitable for complexation with chelators either naked or conjugated with biological macromolecules, however, such labeling procedure requires high chemical purity and concentrated solutions of  $^{68}\text{Ga}$  (III), which cannot be sufficiently fulfilled by the presently available  $^{68}\text{Ge}/^{68}\text{Ga}$  generator eluate. A method to increase the concentration and purity of  $^{68}\text{Ga}$  obtained from a commercial  $^{68}\text{Ge}/^{68}\text{Ga}$  generator has been developed. The  $^{68}\text{Ga}$  eluate (1M HCl) is extracted in methyl ethyl ketone, which is evaporated and taken in a small volume of buffer.

Arsenic-77 ( $T_{1/2} = 1.6$  d) was produced by irradiating natural germanium in Pakistan Research Reactor-1. The nuclear reaction  $^{76}\text{Ge} (n, \gamma)$  produces  $^{77}\text{Ge}$ , which decays by emission of  $\beta^-$  particles into  $^{77}\text{As}$ . The neutron irradiated target was dissolved in aqua regia, excess of acid was removed by evaporation and finally the solution in basic media was passed through hydrous zirconium oxide (HZO) column. The Ge was quantitatively retained on HZO, while  $^{77}\text{As}$  was present in the effluent. More than 90 %  $^{77}\text{As}$  was recovered. The chemical impurity of Ge in  $^{77}\text{As}$  was  $<0.01\mu\text{g/mL}$ .

Large columns containing aluminum oxide ( $\text{Al}_2\text{O}_3$ ) or gel (e.g. zirconium molybdate) are needed to prepare  $^{98}\text{Mo}(n,\gamma)^{99}\text{Mo}\rightarrow^{99\text{m}}\text{Tc}$  column chromatographic generators that results in large elution volumes containing relatively high  $^{99}\text{Mo}$  impurity and low concentrations of  $^{99\text{m}}\text{Tc}$ . Post elution concentration of  $^{99\text{m}}\text{Tc}$  using in house prepared lead cation exchange and alumina column was developed. The principle of the method developed is trapping of anionic pertechnetate on tiny alumina column. This can be only achieved in the absence of sulfate ions. These sulfate ions are removed from the eluate by reaction with lead ions loaded onto a cation exchange column, to precipitate lead sulfate, which is filtered out by the column packing. Using these columns high bolus

volumes (10-60 ml 0.02 M sodium sulfate) of  $^{99m}\text{Tc}$  can conveniently be concentrated in 1 mL of physiological saline. This approach also works very effectively to prepare high specific volume solutions of  $^{99m}\text{Tc}$ -pertechnetate from a fission based  $^{99}\text{Mo}/^{99m}\text{Tc}$  generator in the second week of its normal working life. Rhenium-188 is also obtained from alumina based  $^{188}\text{W}\rightarrow^{188}\text{Re}$  generator, and developed technique can also be used for the concentration of  $^{188}\text{Re}$ .

Because of the high content of inactive molybdenum in neutron irradiated  $\text{MoO}_3$ , large columns containing alumina or gel are needed to produce chromatographic  $^{99}\text{Mo}\rightarrow^{99m}\text{Tc}$  generator. This results in large elution volumes containing relatively high  $^{99}\text{Mo}$  breakthrough and low concentrations of  $^{99m}\text{TcO}_4^-$ . The decrease in specific volume of  $^{99m}\text{Tc}$  places a limitation on reconstitution of some kits for  $^{99m}\text{Tc}$  radiopharmaceuticals applied in diagnostic nuclear medicine. Hence concentration technique is mandatory for effective utilization of (n, $\gamma$ ) produced  $^{99}\text{Mo}/^{99m}\text{Tc}$  generators at the start of its life whereas in case of fission  $^{99}\text{Mo}/^{99m}\text{Tc}$  generator the technique may be quite useful at the end of first week of its life. Post elution concentration of  $^{99m}\text{Tc}$  using in house prepared lead (Pb) column was developed. The high bolus volumes (10-60 ml saline) can conveniently be concentrated in ~1 ml of saline. The adsorption behavior of  $\text{Na}^{188}\text{ReO}_4$  is quite different from  $\text{Na}^{99m}\text{TcO}_4$  on lead column. Sodium perrhenate did not adsorb on Lead column and found quantitatively in effluent. Thus Lead column may also be used for the separation of  $\text{Na}^{99m}\text{TcO}_4$  from  $\text{Na}^{188}\text{ReO}_4$ .

The high bolus volumes (20–40 mL) of the generator-produced Rhenium-188 require post elution concentration of the eluate for the preparation of a dissolved  $\beta^-$  source and radiopharmaceuticals labeled with Re-188 for radiotherapy. Solvent extraction

of  $^{188}\text{Re}$  in methyl ethyl ketone was studied. With the increase of organic phase volume, extraction of  $^{188}\text{Re}$  was enhanced while mixing time of aqueous and organic phases did not show any significant effect on the extractability of  $^{188}\text{Re}$  in the organic phase. Almost 80% of  $^{188}\text{Re}$  was extracted in methyl ethyl ketone at a volume ratio of 1 : 2 for aqueous and organic phases. By evaporation/distillation of methyl ethyl ketone,  $^{188}\text{Re}$  was concentrated and dissolved in the desired volume of physiological saline.