Convenient ^{77}Kr Production Method for Medical Use

Ren IWATA, Minoru MONMA, Kazuhiko TAMATE* and Tatsuo IDO

Cyclotron and Radioisotope Center, Tohoku University
Aoba, Aramaki, Sendai-shi, 980

*National Institute of Radiological Sciences
4-9-1, Anagawa, Chiba-shi, 260

Received July 16, 1982

A convenient method of ^{77}Kr production has been developed for its routine medical use in cerebral blood flow measurement. An aqueous solution of NaBr (40 wt%) was used as the target and ^{77}Kr produced by the $^{79}\text{Br}(p, 3n)^{77}\text{Kr}$ reaction was rapidly recovered from the target under a He stream. The optimal target thickness was determined to be 5~6 mm by investigating radionuclidic purity and proton current effect on the yield. About 740 MBq (20 mCi) of ^{77}Kr with a radionuclidic purity of 92% was obtained within 5 min after a 5 μA -20 min irradiation. The present method has been demonstrated to be suitable for routine ^{77}Kr production.

Key Words: krypton-77, radioisotope production, radiopharmaceutical

1. Introduction

Among the krypton isotopes, ^{77}Kr has some excellent characteristics. It has a rather short half-life (74.7 min) and a high positron branching ratio (~80%). It is used for regional cerebral blood flow measurement by positron tomography¹⁾. The $^{79}\text{Br}(p, 3n)^{77}\text{Kr}$ reaction on natural bromine seems suitable for the routine production of ^{77}Kr ²⁾. The separation of ^{77}Kr from a target, however, may not be so convenient when a pellet target of NaBr is used as previously reported³⁾. ^{77}Kr produced in a matrix of the pellet is recovered by melting it in a quartz tube. As an alternative method, the use of an aqueous solution of NaBr as the target has been investigated for a rapid and easy separation. In the present paper we describe the ^{77}Kr production method suitable for its routine medical use.

2. Methods

The irradiation was carried out with 38 MeV protons for various currents and target thickness using the cyclotrons of Cyclotron and Radioisotope Center of Tohoku University and National Institute of Radiological Sciences. The concentration of NaBr in water was selected as 40 wt% because the solvent quantity might be

decreased by radiation decomposition or evaporation resulting in the deposition of NaBr in the target vessel during the irradiation when a saturated solution (about 48 wt %) was used. In general, when a thin liquid target is irradiated with a high current of charged particles, gas bubbles are formed in the beam path by local evaporation or radiation decomposition of the target water, and the decrease in the effective target thickness is observed. The target vessel made of titanium was specially designed

Fig. 1 Sectional side view of the target vessel.

Fig. 2 Flow chart of the remote-controlled ^{77}Kr production system.

to suppress the above current effect. Its design is shown in Fig. 1. The net volume of the target was about 30 ml but that of the beam path only about 4 ml (in the case of 5.0 mm of thickness). It could thus be expected that when a vacancy is formed by the gas bubbles in the beam path the surrounding target filled it swiftly.

Figure 2 shows the flow chart of the remote-controlled production system. The gas transfer tube was well swept with a He stream before the irradiation because ^{13}N simultaneously produced by the $^{16}\text{O}(p, \alpha)^{13}\text{N}$ reaction might contaminate ^{77}Kr by taking the chemical form of ^{13}NN , if the air was present in the system. During the irradiation, solenoid valves of EV-2 and EV-3 were kept open, and after the irradiation the ^{77}Kr produced was carried from the target under a He stream with a controlled flow rate (usually 30 ml/min) and collected in a balloon. The yield and the radionuclidic purity were measured with a Ge(Li) or pure Ge detector.

3. Results and Discussion

The separation of the ^{77}Kr from the aqueous target could be performed simply by sweeping it with a He stream through the target vessel. As seen in Fig. 3, it was collected within 5 min after the irradiation corresponding to about 150 ml of He carrier. No contaminant derived from the target water was observed on the decay curve of the collected radioactive gas.

Fig. 3 Typical ^{77}Kr elution curve obtained by monitoring radioactive gas flow in the transfer tube.

The threshold energy of the $^{79}\text{Br}(p, 3n)^{77}\text{Kr}$ reaction was calculated to be 23.0 MeV, to which the incident proton energy was degraded after passing through the target thickness of 6.5 mm. In Fig. 4, a decrease in the yield of ^{77}Kr is observed at the thickness of 5 mm though it is constant over that of 6 mm. Figure 5 shows the effect of the proton current on the yield. Over the current of $5\ \mu\text{A}$, the current effect becomes remarkable and the yield in a $10\ \mu\text{A}$ -irradiation is reduced to about 80% of the expected value. From this result, it is not definitely certain whether the present design of

Fig. 4 Correlation between the ^{77}Kr yield and the target thickness.

Fig. 5 Effect of the proton current on the ^{77}Kr yield.

Fig. 6 Correlation between the ^{77}Kr purity and the target thickness.

the target vessel is the best or still improvable.

When natural bromine is used as the target instead of enriched ^{79}Br , the contamination of a long-lived ^{79}Kr (half-life: 35 h) is inevitable owing to the simultaneous reaction of $^{81}\text{Br}(p, 3n)^{79}\text{Kr}$. It is also produced by the $^{79}\text{Br}(p, n)^{79}\text{Kr}$ reaction when a thick target is used. For medical use, the contamination with a long-lived radioisotope should be minimized. Figure 6 shows the radionuclidic purity of ^{77}Kr as a function of the target thickness. At the thickness of 5 mm, the purity was 92% and this value agreed with that of the literature which was obtained with a thinner NaBr pellet target

Fig. 7 Gamma ray spectrum of the ^{77}Kr collected at 5 min after the irradiation.

($34.8 \leq E_p \leq 40$ MeV)²⁾, showing that the ^{79}Kr formation by the $^{79}\text{Br}(p, n)^{79}\text{Kr}$ reaction has no contribution to the purity. Another long-lived krypton radioisotope of ^{76}Kr (half-life: 14.8 h), produced by the $^{79}\text{Br}(p, 4n)^{76}\text{Kr}$ reaction, was not observed on the gamma ray spectrum obtained with a pure Ge detector as shown in Fig. 7.

4. Conclusion

From the results obtained, the optimal target thickness is determined to be 5~6 mm on the basis of the yield and the radionuclidic purity. When the aqueous NaBr solution of 40 wt% with 5 mm thickness is irradiated with 38 MeV protons at a current of $5 \mu\text{A}$ for 20 min, about 740 MBq (20 mCi) of ^{77}Kr can be obtained

within 5 min after the irradiation. This value is about 1/3 times less than that of using a pellet target, but it is thought to be sufficient for medical use. In addition, the same target can be used for a repeated production by this method. It can be concluded that the method of using the aqueous NaBr solution as the target is very suitable for the routine production of ^{77}Kr .

References

- 1) Yamamoto, Y.L., et al.: *J. Nucl. Med.*, **17**, 546 (1976)
- 2) Dikšić, M., et al.: *Int. J. Appl. Radiat. Isotopes*, **28**, 885 (1977)
- 3) Houdayer, A.J., et al.: *Int. J. Nucl. Med. and Biology*, **4**, 83 (1977)

要 旨

医学利用のための ^{77}Kr の簡便な製造法

岩田 鍊, 門間 稔, 玉手和彦*, 井戸達雄

東北大学サイクロトロン・ラジオアイソトープセンター 980 仙台市荒巻字青葉

*放射線医学総合研究所 260 千葉市穴川4-9-1

脳血流量測定におけるルーチン的な医学利用のための ^{77}Kr の簡便な製造法を開発した。40 wt% の NaBr 水溶液をターゲットとして $^{79}\text{Br}(p, 3n)^{77}\text{Kr}$ 反応により製造された ^{77}Kr は、照射容器中に He を通じることによりターゲットから迅速に取り出された。ターゲットの厚さは、核種純度およびプロトン電流値の収量に対する影響を検討した結果、5~6 mm が最適であった。5 μA , 20 分の照射の後 5 分以内で、核種純度 92% の ^{77}Kr を約 740 MBq (20 mCi) 取り出すことができた。本法は、 ^{77}Kr のルーチン生産に適することが示された。