OPTIMIZATION OF THE PRODUCTION OF Na$^{18}$F BY USE OF THE SZILARD-CHALMERS REACTION FOLLOWING IRRADIATION OF FLUORINE COMPOUNDS WITH 14 MeV NEUTRONS

Z. B. ALFASSI,* A. P. KUSHELEVSKY,* W. WOLF**

*Department of Nuclear Engineering, Ben-Gurion University of the Negev, Beersheva (Israel)
**Radiopharmacy Program, School of Pharmacy University of Southern California, Los Angeles, California (USA)

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Studies intended to optimize the production of Na$^{18}$F in aqueous solution following irradiation of organic fluorine compounds with 14 MeV neutrons are described. The use of Szilard-Chamers conditions was chosen to enhance the yield of $^{18}$F, given the low fluxes available and the inherently low cross section of the (n, 2n) reaction. Twenty five potential target compounds were tested. The most suitable one, both in terms of the cost of the target material and of the efficiency of production of water-soluble Na$^{18}$F was found to be perfluoro n-hexane. A simple production method for $^{18}$F$^-$ is outlined.

Introduction

Na$^{18}$F has been used in the past as a popular agent for bone scanning. However, because of its short half-life of 110 minutes, and the inherent difficulties in the logistics of its distribution, its cost was relatively high. The $^{99m}$Tc phosphates can provide good bone scans at a much lower cost and with materials that are today readily available in all nuclear medicine departments, and hence they have practically eliminated the use of $^{18}$F$^-$ in clinical bone scanning. Recent increased interest in positron imaging may change this picture once more, inasmuch as $^{18}$F is a positron emitter (while $^{99m}$Tc is not). This may allow a much better spatial definition of the bone lesion; also, the F$^-$ ion replaces a hydroxy group in the hydroxyapatite crystal lattice, whereas the $^{99m}$Tc containing species are deposited on the bone by a mechanism that has not been fully clarified. Interest in other $^{18}$F labeled compounds is growing. A number of $^{18}$F labeled agents are currently being studied clinically. Due to its short half-life, $^{18}$F must be produced and used within a few hours. Consequently, only centers that possess (or sometimes are near) a cyclotron or a reactor can make extensive use of this radionuclide.
With the recently increasing interest in fast neutron generators for radiation therapy, and the wider availability of such machines, a new source of short-lived radionuclides, $^{18}\text{F}$ in particular, has become available. $^{18}\text{F}$ can be produced via the $(\text{n}, 2\text{n})$ reaction on $^{19}\text{F}$; however, because the cross-section of this reaction is only 55 mb for 14 MeV neutrons, material of very low specific activity will be obtained unless the resulting $^{18}\text{F}$ is further enriched by the use of Szilard–Chalmers conditions. The present paper describes our preliminary results using this method of $^{18}\text{F}$ production.

**Materials and methods**

*Neutron source*

The 14 MeV neutrons were generated using a D, T Walden-Cockroft accelerator yielding a flux of $5 \times 10^8 \text{ n s}^{-1}$ having in average energy of 14.1 MeV and a maximum energy of 14.8 MeV.

The test target consisted of a polyethylene tube 0.8 cm in radius, 0.1 cm wall thickness and 2.25 cm height of liquid target that was placed in the neutron beam.

The production target is a cylindrical vessel made of pyrex of 0.1 cm thickness, 4.3 cm radius and 4.2 cm depth.

*Materials*

The fluorinated compounds used in this work were obtained from Fluorochem (UK), Pierce Co. (USA) and Fluka, Ltd. (Switzerland), and used without further purification. All materials were reagent grade.

*Experimental conditions*

The determination of total $^{18}\text{F}$ production yields were performed by irradiating 4 cm$^3$ of the target compound in the polyethylene tubes, followed by extraction of the irradiated material with 4 cm$^3$ of one of the aqueous solutions. The yields were calculated by measuring the total activities in both the organic and aqueous phases. In a typical production experiment, 20 cm$^3$ of a 0.01M NaOH solution in water was mixed with 370 g of perfluorohexane and placed in the irradiation vessel. This target was then placed at about 0.5 cm from the D, T neutron generator and irradiated for 30 minutes with no cooling. The target was removed after 10 minutes from the irradiation assembly and the irradiated mixture was shaken and the two phases allowed to separate. The organic phase was then washed with 5 cm$^3$ of 0.01M NaOH solution and the washing combined with the first extract. The aqueous phase was then concentrated