

EXTRACTION OF ^{11}C FROM THE TRIUMF 500 MeV ISOTOPE PRODUCTION FACILITY COOLING WATER

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Summary

The cooling water of the TRIUMF 500 MeV Isotope Production Facility¹ represents a potential source of large quantities of ^{11}C that can be used in radiopharmaceutical research and in positron emission tomography (PET) studies of the living human brain.

Positron emission tomography²⁻⁴ permits non-invasive *in vivo* autoradiography of human and animal tissues to be taken. The possible array of compounds that could be imaged *in vivo* is large considering that positron emitting radionuclides exist for the biologically important elements C, N and O and also for other elements (e.g. F, Br and I) which can be attached to molecules of biochemical interest. Nevertheless, incorporation of such radionuclides into components whose metabolism in tissue could yield vital information about disease processes requires highly sophisticated chemistry.^{5,6}

The major obstacle to the development of new radiopharmaceuticals is that the most desirable positron emitting radionuclides are so short-lived (^{15}O $t_{1/2}=2.05$ min; ^{13}N $t_{1/2}=9.96$ min; ^{11}C $t_{1/2}=20.3$ min; ^{18}F $t_{1/2}=110$ min) that an accelerator dedicated to their production must be available relatively close to the laboratories where they will be used.

The University of British Columbia/TRIUMF Program on Positron Emission Tomography has reached a point where routine studies are performed using 2-deoxy-2-[^{18}F]fluoro-D-glucose for glucose metabolism, H_2^{15}O for blood flow and L-6-[^{18}F]fluorodopa for regional dopamine synthesis. These agents have been developed using the CP-42 cyclotron (11-42 MeV proton only cyclotron) and a single target chamber for $^{18}\text{F}\text{-F}_2$ and $^{15}\text{O}\text{-O}_2$ production.⁷ Because the cyclotron is used as a source of radionuclides for commercial sales, its operating schedule has limited the development of ^{11}C containing compounds. In the development of complex organic compounds with ^{11}C , frequent preparations of ^{11}C are necessitated by its short half-life. Otherwise the characterization of products, purity and yields are nearly impossible to determine because of the ultra small quantities ($<10^{-3}$ - 10^{-8} g) with which the chemist must work. Thus it has become important for us to find a source of ^{11}C that can be used independent of the CP-42 operating schedule.

The cooling water of the 500 MeV isotope facility provides that potential. The facility has been built to take advantage of the abundant radionuclide production capabilities of the 100 μA beam via the proton-induced spallation reactions.¹ The solid targets are completely submerged in cooling water, which also acts as shielding. Target cooling is provided by a closed water circulation system that is completely contained within the irradiation thimble (8.6 m long vertical tank with target holders at the bottom where the proton beam passes through it). The total flow in the system is 114 ℓ/min , which is shared equally by eight circuits; six for the target holders and two for the thimble windows. The proton beam passes through 19-25 layers of cooling water with a total maximum thickness of almost 50 mm. Calculations estimated that 33 Ci of ^{11}C are present at saturation with 100 μA beam.¹

Initial experiments involved taking samples from the cooling water system during beam operation at

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60 μA . The samples were divided into two portions, one for following radioactive decay and the other for processing. This second sample was subjected to vacuum, He flushing, heating and the addition of acid with trapping of the effluent gas in soda lime after each step. The trapped radioactivity was continuously monitored.

The liquid sample had three components with half-lives corresponding to ^{11}C , ^{13}N and ^{15}O (see Fig. 1). The activity in soda lime did not start to increase until the sample was acidified. At that point approximately half of the ^{11}C activity was liberated from the solution and was trapped in the soda lime.

A previous report⁸ indicated that an efficient separation of $^{11}\text{CO}_2$ from water could be achieved by the addition of carrier CO_2 and sulfuric acid followed by heating. Since it was our intention to remove the $^{11}\text{CO}_2$ from the cooling water and allow the water to return to the cooling water loop, any chemicals added must be removed. Therefore our first attempts were aimed at using only physical means for separation.

The procedure that worked best and was also simple was to take the irradiated water and heat it at 90-95°C while passing a stream of He gas through it. The separated $^{11}\text{CO}_2$, carried by the He gas, passed through a cold water condenser and two dry ice/2-propanol baths and was trapped by 5A molecular sieve trap at room temperature. A soda lime trap placed after the molecular sieves indicated that all of the ^{11}C was trapped by the sieves. Decay studies of the remaining water, the dry ice traps and the molecular sieves indicated that only ^{13}N remained in the water, only ^{11}C was in the molecular sieve trap and a trace of ^{11}C was present in the dry ice traps. The decay corrected separation yield was determined to be 70%. Presumably the

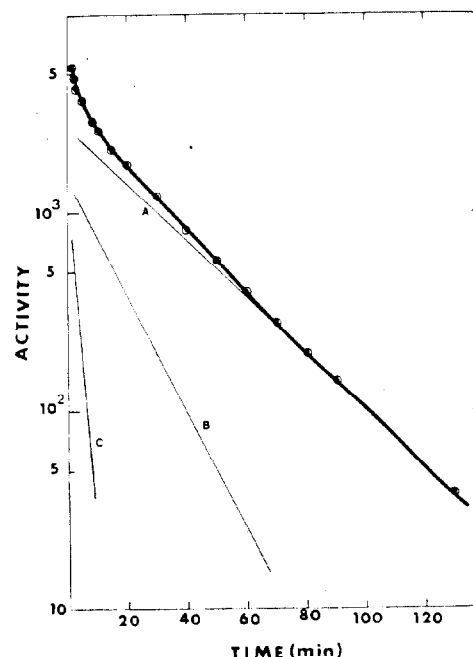


Fig. 1. Decay curve for sample taken from cooling water. Components A, B and C have half-lives of 21, 10, and 2 minutes respectively.

remaining ^{11}C was entrained throughout the system in water droplets.

Heating the molecular sieve trap to 200°C resulted in the immediate release of the $^{11}\text{CO}_2$.

Results from the $^{11}\text{CO}_2$ separations experiments indicate that almost all of $^{11}\text{CO}_2$ dissolved in the cooling water can be separated by heating the water to near boiling with He purge gas. The $^{11}\text{CO}_2$ can be reversibly trapped with molecular sieves. This $^{11}\text{CO}_2$ -water separation method, by physical means, is efficient, rapid and can be easily extended to a large scale operation by TRIUMF and the Gustaf Werner Institute.

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