PRODUCTION OF ^{11}C-CARBON DIOXIDE AND ^{18}F-FLUORIDE AT THE UNIVERSITY OF KENTUCKY 6.5 MV VAN DE GRAAFF ACCELERATOR

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INTRODUCTION

The aim of our work has been to establish an isotope production facility at the University of Kentucky HVEC CN Van de Graaff accelerator. These radionuclides will be used in medical and biological research at the Chandler Medical Center of the university. The accelerator has a capacity of being operated at 6.5 MV and has been in operation since 1964., mainly for nuclear physics research. Recently the machine was upgraded to increase the operating voltage to 7.5 MV. With funding from the Kentucky EPSCoR (Experimental Program to Stimulate Competitive Research) program, production of short-lived positron emitters (^{11}C, ^{18}F) was started in 1987. These isotopes are currently being used for radiopharmaceutical development in collaboration with various groups in the College of Pharmacy and Department of Nuclear Medicine.

^{11}C-PRODUCTION

1. ^{11}C was produced by the ^{11}B(p,n)^{11}C reaction, using natural B_2O_3 as target material.
2. The aluminum target system (Figure 1) consists of a target holder, a water cooling jacket and a target chamber which is bolted to a brass plate for quick mounting/dismounting using a triclamp. The target chamber has an entrance window, beam viewing window and inlet/outlet ports for gas circulation.
3. Thickness of the Havar entrance foil proved to be important. A 3 micrometer foil was too thin and made the maintenance of a vacuum difficult. Such a thin foil also was subject to developing pinholes. A 6 micrometer foil was subsequently used and worked well.
4. The diameter of the entrance foil window was 1 cm.
5. The distance from the foil to the target was 7 cm. When the beam passes through the Havar foil and the helium column, its diameter increases to as much as 1 cm from 2-3 mm before entering through the foil; this is due to charged particle scattering. However, the beam on target often had a diameter as small as 5-6 mm.
6. A 2.5 cm diameter viewing window (equipped with a television camera for remote viewing) was employed to ensure that the beam not only activates but also melts the B_2O_3 for the release of ^{11}CO and $^{11}CO_2$ from the target material.
7. For the recovery of most of the produced activity a beam current of at least 4 microampere was necessary; this ensured the collection of approximately 85% of the activity from the target. Occasionally some of the B_2O_3 target material evaporates (viewed as a bright glow filling the chamber, and causes a redeposition inside the target chamber).
8. Both water cooling (ice in water) or air cooling with a Hilsch vortex tube at 75 psig (in this technique the air flow splits through a pressure reduction port to a cooler flow and warmer flow in opposite direction; the cooler flow is used for cooling) worked well in our system, and we continued to use the former method in all experiments. A flow of helium through the target was used to cool the target and the foil from inside (flow rate 60-70 ml/min). Helium was mixed with 3% oxygen to convert ^{11}CO to $^{11}CO_2$.

9. A stairstep circular cavity in the target plate with 3 or 4 steps is used to hold the molten B_2O_3 in the target area.
10. One B_2O_3 target could be used for 2 to 3 runs of 30 min. duration at 6 MeV and 4-6 microampere current. That maximum beam current that was used was 8 microampere.
11. The foils were used for 8-10 runs, although the foil life can be longer (we didn't test the exact time for foil remains intact).

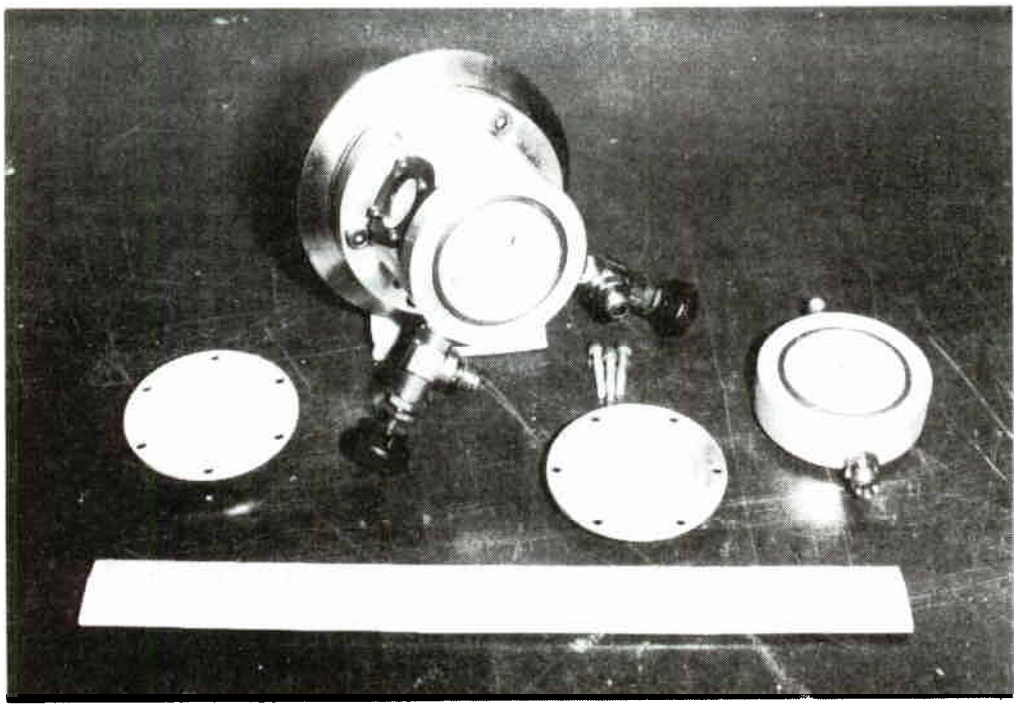

Figure 1 - ^{11}C Target

12. A proton energy of 5.2 or 6.0 MeV incident on the foil resulted in an attenuated energy on the target of 4.8 or 5.73 MeV respectively after passing through the 6 micrometer Havar window and 7 cm long helium column (at one atmosphere pressure). When the above energies were used at a proton current of 3.5 microampere, the following yields were obtained (theoretical yields were estimated from the neutron yields as in Reference 1).

Proton energy on target (MeV)	Time Irradiated in min.	Yield in mCi Exp.	Theor.
4.8	20	16	21
5.73	40	50	88

14. The trapped $^{11}CO_2$ has been converted to ^{11}C-acetate, ^{11}C-benzoate ^{11}C-formaldehyde and ^{11}C-urea.

^{18}F-PRODUCTION

1. ^{18}F is produced as the fluoride ion from [^{18}O]H_2O via the $^{18}O(p,n)^{18}F$ reaction.
2. The target design was similar to that used by Wieland et al.[2]
3. The target (Fig. 2) was machined from a single piece of nickel with a target area of 1 cm diameter and 1.8 mm depth.
4. The reflux area, drilled at the top, connects a 0.8 mm ID tubing for venting (at an angle of 45 degree), and a 2.67 mm ID refluxing tube which extends to 0.8 mm ID tubing to connect to the N_2-gas supply. The total volume of the reflux area is about 300 microliter.
5. A 0.8 mm tubing is connected at the bottom of the target (at an angle of 45 degree) for loading and unloading of the [^{18}0]H_2O.
6. We employ ice water to cool the back of the target. Initially, the cooling was not sufficient and target water was partially lost due to evaporation. To prevent this loss, the back portion of the target was thinned from 2.5 mm thickness to 1 mm. Subsequently, water cooling at the back of the target and Hilsch air cooling at the reflux tube was used and proved satisfactory. Evaporation of [^{18}O]H_2O from the target area became negligible even after a 90 minute irradiation. The loss was indirectly monitored during irradiation with a neutron detector at a fixed distance.
7. The target water was pressurized at the top by nitrogen at 16 psig. Nitrogen pressure at 20 psig or helium pressurization did not improve our yield.
8. Although the target volume is only 145 microliter, we inject about 220 microliter [^{18}O]H_2O into the target. About 50 microliter remains in the loading tubing, and 25 microliter compensates for evaporation, radiolysis loss and the out ward bulging of the foil.
9. Loading of the [^{18}0]H_20 from the top either through venting or reflux tubing was difficult due to its capillary action. Therefore, both loading and unloading of the water was done through the lower part of the target.

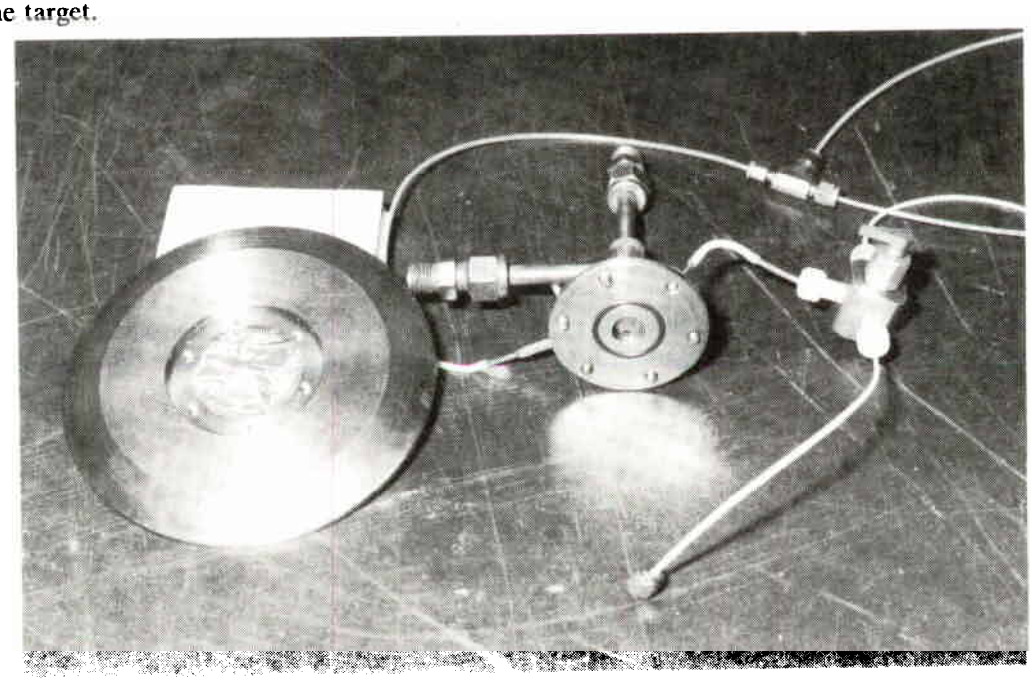

Figure 2 - ^{18}F Target

10. The target was mounted on a brass flange with a 6 micrometer Havar foil separating the vacuum system from the target water; this assembly was mounted at the end of the beamline with a triclamp.

11. After irradiations at 3.0 microampere, the following activity was obtained:

Proton energy on target (MeV)	%[^{18}O]H_2O	Time irradiated in min.	Yield in mCi Exp.*	Theor.
5.8	55	70	19	24
5.8	65	80	24	32

* Recovered activity at the end of beam.

SUMMARY

We are now successfully producing ^{11}C and ^{18}F nuclides at the University of Kentucky Van de Graaff accelerator. Useful amounts of activity for radio-pharmaceutical research and for some clinical applications can be reliably produced on a routine basis. The major problem encountered when running the machine at high energies is that of sparking. We therefore, operate the accelerator for our purposes only after it has been run at high energy for a day or more. Alternatively, the machine is conditioned for a long time by gradually increasing the energy of the protons.

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