THE ORBIT CYCLOTRON

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ORBIT, Inc., has constructed an 8 MeV proton cyclotron and installed it at the Medical Sciences Division of the Oak Ridge Associated Universities. Figure 1 shows the installation in a vault with open floor area of 8.5'x9'. The cyclotron is a positive ion accelerator with a vertical beam plane.[1] Internal beam current of 100 μA has been obtained. Efforts are now underway to improve the orbital optics and the extraction efficiency. The anticipated extracted energy is 8.4 MeV.

The vertical beam plane was chosen to permit targets to be recessed into the floor and reduce the required volume of above floor neutron shielding material. However, in this installation the vault provides adequate shielding so there is no need to recess the targets. The cyclotron has therefore been raised on tracks to permit greater movement inside the small vault to facilitate servicing. A target material transport tube connects the vault with an adjacent radiochemistry processing laboratory. The length over which the target product material must be transported is approximately 5 m.

At the time of the design of this cyclotron, some uncertainty existed over the adequacy of an 8 MeV proton beam for producing sufficiently high precursor activity levels of the proper quality needed to synthesize the positron-emitting radiopharmaceuticals used in clinical PET. Subsequent developments have eliminated this uncertainty for the radiopharmaceuticals that have so far been shown to be clinically useful, i.e., ^{18}FDG, $^{13}NH_3$, $^{15}O_2$, and $H_2{}^{15}O$.

The end of bombardment saturation yield for the (p,n) reaction using 10.7 MeV protons on $H_2{}^{18}O$ is 120 mCi/μA.[2] With a 1-hr. bombardment of 20 μA, an ^{18}FDG yield of 150 mCi has been routinely achieved.[3] Based on these data and the reaction yield curve[4], a 1 hr bombardment with a 20 μA beam of 8 MeV protons will yield at least 300 mCi of $^{18}F^-$, which is sufficient to produce 100 mCi of ^{18}FDG using an equivalent automated synthesis process.

The production of $^{13}NH_3$ via the (p,n) reaction on a ^{13}C-powder slurry target has been demonstrated to be approximately 25 mCi/μA at saturation for a 5 μA beam and a 20 minute bombardment.[2] From these data and the yield curve[4], an estimated 40 mCi of $^{13}NH_3$ can be obtained from a 5 μA, 8 MeV proton beam with a bombardment of 20 minutes.[3]

The production of ^{15}O from the (p,n) reaction on enriched $^{15}N_2$ by low energy protons has been amply demonstrated by C.T.I., Inc.[2] The 11 MeV proton beam of the RDS cyclotron is reduced to 8.5 MeV by a beam energy degrader prior to entrance into the target. Clinically adequate batch and continuous flow productions have been obtained at low cost target gas consumption rates.

The above radiopharmaceuticals are sufficient to perform the clinical studies cited in the report by the ACNP/SNM Task Force on Clinical PET.[5] Clinical PET centers are now fully operational using only these radiopharmaceuticals.

The production of clinically adequate ^{11}C-labeled radiopharmaceuticals with an 8 MeV proton beam remains somewhat questionable due to the lack of a definition of the compound required and the synthesis procedure to be employed. Wolf[6] shows an $^{11}CO_2$ production yield of 28 mCi/μA for 8 MeV protons via the (p,α) reaction on $^{14}N_2$. One can reasonably expect to irradiate this gas target with 20-30 μA beams for 1-hr thereby producing 500-750 mCi of $^{11}CO_2$.

Once the ORBIT cyclotron is operational and producing extracted beam, collaborative efforts with the Medical Sciences Division of the Oak Ridge Associated Universities will attempt to demonstrate the ability to produce sufficient ^{11}C-amino acids to permit clinical PET studies. This complex synthesis procedure will serve as a benchmark for evaluating the clinical utility of an 8 MeV proton beam for producing ^{11}C-labeled radiopharmaceuticals for PET.

1. Highfill RR: Design and status of a specialized cyclotron for positron tomography. IEEE Trans on Nuc Sci. NS30 1982:1765-1767.

2. Hendry GO, Straatmann MG, Carroll LR, et al: Design and performance of a compact radioisotope delivery system. Siemens Medical Systems, Inc.

3. Kam J, U. Tennessee: private communication.

4. Highfill RR and Wieland BW: A choice of targetry to significantly reduce the size of medical cyclotrons for positron tomography. Proc of 2nd Int Conf of World Fed of Nucl Med & Biol, 1978.

5. Kuhl DE, Wagner HN, et al: Positron Emission Tomography: Clinical status in the United States in 1987. J. Nucl. Med. 29:1136-1143, 1988.

6. Wolf AP: Special characteristics and potential for radiopharmacaeuticals for positron emission tomography. Sem. Nucl. Med., XI:1, 1981.