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Experimental yields of PET radioisotopes from a prototype 7.8 MeV cyclotron

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Introduction

The worldwide use of PET has proven beyond dispute the importance for both routine diagnosis and physiological, oncological and pharmacological research. In many ways the present success of PET relies on the mature technology of PET compact medical cyclotrons. As long time developers of new targets, isotopes and compounds, we have been inclined to look for new block-buster applications, high power targets and sustainable ways of embracing the GMP and regional distribution, but recent pioneering development [1] around very small cyclotrons and "embedded synthesis and qc" has pointed out an old, but important nuclear physics lesson now halfway forgotten: that many PET isotopes can be made in high yields with proton energies far below 10 MeV [2]. This has opened a new interest in small cyclotrons and their targets.

We have been testing the first GE Healthcare Prototype for a 7.8 MeV negative ion, internal ion source cyclotron with 3 production targets mounted on a short beamline. Here we present the first experimental yields of some of the important PET radionuclides.

FIGURE 1. Prototype cyclotron; the beamline and targets extending to the right

Materials and methods

The prototype cyclotron (FIG. 1) has been installed and tested without self-shield in designated experimental area in order to establish the neutron field around accelerator and targets in order to qualify design calculations for a future integrated shield.

The cyclotron energy is fixed by the radial position of the extraction foil, while the azimuth determines which of the 3 targets are being irradiated. The beam energy at front of target foil was determined on several occasions: 7.8 ± 0.1 MeV by a 2 copper-foil sandwich method (adopted from [3]). The available beam inside the cyclotron at extractor position is > 50 µA, and 35 µA are easily and long term reliably extracted (> 90 %) on to any of the 3 target positions. The prototype is capable of delivering more than 40 µA to target, but target current was limited to 35 µA under present unshielded conditions.

Results ^{18}F

We have tested the prototype gridded (> 80 % transmission) niobium body target with 10µm Havar foil using 95 % ^{18}O water and 35 µA on target + grid with yields given in TABLE 1. The observed yields corrected for stopping in foil, grid loss and water enrichment are 75 % of theoretical. One Fastlab FDG run using 2 h irradiation yielded 16 GBq FDG EOS, confirming the "usual" ^{18}F activity.

T_b (h)	I (µA)	A^{EOB} (GBq) ^{18}F	No. of runs.
0.5	35	10.3 ± 0.8	15
1	35	14.5 ± 1.3	3
2	30–35	22.5	1

TABLE 1. ^{18}F EOB activity

Results ^{11}C

Using gridded target and a 10µm foil with 99% N_2 + 1 % O_2 at 10 bar followed by trapping into ascarite gave EOB activity as shown in TABLE 2.

T_b (h)	I (µA)	A^{EOB} (GBq) ^{11}C	No.of runs.
0.5	35	13.6–14.0	2

TABLE 2. ^{11}C activities recovered at EOB

Results ^{13}N

We know that the ^{16}O(p,alpha)^{13}N cross section is a very steep function of energy around 7.8 MeV. In the hope of using the simple water target route to ^{13}N NH_3 we have measured the ^{13}N yields (corrected for ^{18}F contribution). It is still unclear if these yields can be improved to make useful single doses of ammonia.

T_b (h)	I (µA)	A Saturation(MBq) ^{13}N	No.of runs.
0.33	30	220+/-35	4

TABLE 3. ^{13}N activities (liq + gas) corrected to steady state yields

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Results for other isotopes

We have used solid targets to make ^{45}Ti, ^{64}Cu, ^{68}Ga and ^{89}Zr. The development of these solid targets is still in progress, but especially the ^{68}Ga yield looks promising (3 GBq EOB after 1 h on natural Zn will give > 15 GBq on enriched ^{68}Zn).

References

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