Considerations concerning the energy of a small PET cyclotron

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To an appreciable extent, the PET–technique owes its feasibility and spreading to the availability of small and reliable compact cyclotrons which can be operated with very little staff (if support is given by the manufacturer). The purely economic consideration to offer low cost cyclotrons initiated the design of very small "baby–cyclotrons" with restricted capabilities adapted to the production of the low Z positron emitters exclusively, i.e. for protons of about 10 MeV. This limitation soon turned out to be impractical. Thus most manufacturers' (exception: CTI west) "mini–cyclotrons" today accelerate protons to 17 MeV (MC–16F from Scanditronix, model 325 from CGR–MeV, models BC 168, BC 1710 from the Japan Steel Works).

We are sometimes asked to give recommendation to institutes or scientists who propose to purchase a PET–facility. Today, I would argue in the following way: From a survey of some characterisitic cross–sections a mini–cyclotron of 17 MeV protons seems to have sufficient potential. On the other hand, some surplus energy, i.e. a bigger accelerator could be required from several reasons:

1. The half–lives of the prominent positron emitters preclude medical investigations of processes with biological time constants greater than a few hours. It is to be expected that at least in the field of labelled antibodies, PET will need longer–lived radioisotopes with maybe more ease of preparation like ^{76}Br, ^{121}I, or eventually ^{127}Cs. Looking at the cross–sections shows that about 25–30 MeV protons are needed for effective production of these nuclides.

2. A PET group working successfully – and who does not aim at that? – will attract scientists and institutes near by with nuclear medical instrumentation for cooperation. This would mean either more batches per day or higher activities per batch of short–lived radioisotopes or even radioisotopes with longer half–lives as mentioned above, depending on the distance and transport facilities.

3. If several nuclear medical departments in one region would develop interest in positron emission tomography, the individual decision in favour of a PET device could be facilitated if only one institute would need to install a powerful, jointly operated cyclotron.

4. To optimize the yields of positron emitters from gas targets, which is the most elegant way to do it, one could think of just raising gas pressure or using tandem targets. For safe handling of pressurized gas targets, entrance foil thicknesses around

setting) so that one person can control the bombardment directly from the radiochemistry lab. This is of great utility during continuous radiogas production.

The installation went into operation on September 1985 and the preliminary values of the recovered activities so far obtained are given in the Table.

The installation should be working on routine basis starting summer 1986.

Table

Radionuclide	Labeled product	target no.	target material	recovered activity
Oxygen-15	CO_2	1	N_2 + 2 % CO_2	9.2 mCi/μAmin [c,e]
	CO	1		8.6 mCi/μAmin [c,e]
	H_2O [a]	2	N_2 + 2 % O_2	not tested
	O_2	2		10.4 mCi/μAmin [c,e]
Nitrogen-13	N_2	3	CO_2	not tested
	NH_3 [b]	4	H_2	46.5 mCi, EOB+9min[f]
Carbon-11	CO	4		1.8 mCi/μAmin [c,d]
	CO_2	5	$N_2(O_2)$	2.4 mCi/μAmin [c,d]
	HCN	6	N_2 + 2 % H_2	not tested
Fluorine-18	F_2	7	Ne + 1 % F_2	not tested

a) Catalytic reduction of O_2 with H_2 on Pd/Al_2O_3 at 150°C;
b) Obtained via DeVarda's reduction;
c) Outlet flow 0.5 l/min;
d) Target pressure 6 bar;
e) Target pressure 0.6 bar;
f) Target volume 20 ml, 15 μA for 20 minutes

1 mm and thus energy losses in the foil or the first target section, respectively, of several MeV have to be allowed for by the energy of the accelerator.

To a group who likes to have some reserve for future developmental work I would thus recommend to aim at proton energies between 25 and 30 MeV. It has to be taken into account, however, that the costs for the cyclotron itself is nearly linearly depending on its energy and that the cost for the whole facility including space for laboratories etc. (the PET-device excluded) will go up correspondingly - about linearly by a factor of 2.5.