Poster Discussion

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Yields and Impurities in Several Production Reactions for ^{124}I

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Summary
The yields and radionuclide impurities of 4.15-d ^{124}I were measured in a compact cyclotron under realistic high-current production conditions by the nuclear processes $^{124}Te(d,2n)^{124}I$ (E_d = 14 MeV) using 89.6 % $^{124}TeO_2$ and $^{124}Te(p,n)^{124}I$ (E_p = 12.2 MeV) using 89.6 % and 99.8 % enriched $^{124}TeO_2$. The (d,2n) process showed the highest yield. The impurity level of ≤ 5 % relative to the ^{124}I activity, as requested for clinical trials, was observed in all three reactions but within different time windows. The (p,n) process can advantageously be performed in low-energy "baby"-cyclotrons resulting in good yields and high purity. However, this production method also requires a distinct time for the decay of ^{123}I.

Introduction
Iodine-124 ($T_{1/2}$ = 4.15 d) decays simultaneously by positron emission (21.6 %) and by electron capture (78.4 %). Consequently, this radionuclide is becoming increasingly significant in diagnostics by positron emission tomography (PET) [1,2], and, due to its amount of short-ranged Auger electrons (9.2 per decay [3]), it is also being discussed as a potential therapeutic nuclide when labeled to DNA-affine carriers.

The Swiss authorities responsible for the permission of clinical trials[2] request a radionuclide purity grade of 95 % (at the time of application, the sum of activities of all contaminating iodine radioisotopes must not exceed 5 % of the ^{124}I activity). The problem had therefore to be discussed to establish under which realistic production conditions this quality level is achievable. For this purpose, the yields of radionuclides formed in the nuclear reactions $^{124}Te(d,2n)^{124}I$ (E_d = 14 MeV) and $^{124}Te(p,n)^{124}I$ (E_p = 12.2 MeV) were measured, using as target material tellurium of 89.6 %[3] and 99.8 %[4] isotopic enrichment, respectively. Earlier publications [4-6] discussed higher incident energies but 14 MeV is the maximum deuteron energy of the cyclotron used for irradiations in this work and 12.2 MeV is a proton energy which can easily be obtained in a low-energy "baby"-cyclotron which is generally used exclusively for the production of short-lived positron emitters.
Experimental

The irradiations were carried out at the Compact Cyclotron CV 28 of the University Hospital of Essen, Germany, typically for 10 min at a beam current of 25 µA . The deuteron energy of 14 MeV was the maximum available; the proton energy of 12.2 MeV was set by interpolation of high frequency data and was additionally confirmed by energy-dependent activation of copper foils and subsequent evaluation using well-known excitation functions [7]. The know-how elaborated in Essen in the course of frequent routine productions of ^{123}I by irradiation of enriched [^{124}Te]TeO_2 followed by dry distillation [8] was adopted.

[2]Bundesamt für Gesundheitswesen, Bollwerk 27, 3001 Berne, Switzerland
[3]The supplier, Rohstoff-Einfuhr, Düsseldorf, stated an enrichment of 90.8 %. Re-measurement at PSI, however, yielded 89.6 % enrichment.
[4]Teknowledge, Stockholm AB. The enrichment was confirmed by re-measurement at PSI.

The target material consisted of isotopically enriched [^{124}Te]TeO_2. It was molten onto a 90 % Pt / 10 % Ir plate[5] which was cooled from the back by a water circuit. To prevent exfoliation of the brittle glassy target material, parallel furrows of 0.2 mm width and 0.2 mm depth with a distance of 0.1 mm each along the beam direction were cut into the surface of the platinum backing. This target arrangement withstands beam currents of up to 35 µA without measurable evaporation of iodine during irradiation. The target is arranged at a 15° angle from the beam direction. Thus, with a target thickness of 0.2 mm or 0.118 g/cm^2 of [^{124}Te]TeO_2, the energies of both target beams (14 MeV for deuterons and 12.2 MeV for protons) are degraded to values too low to activate the target material [5,6].

The iodine radioisotopes were distilled from the dismantled target plate in a quartz tube for 6 min at 740 °C, transported into a small stainless steel trap by a stream of air (20 mL/min) and eluted in about 100 µL of 0.02 M NaOH solution. Under these conditions, 80 - 95 % of the total activity of iodine radioisotopes was trapped in solution and more than 90 % of the activity was concentrated in the first drop of 20 µL. Details are described elsewhere [9,10].

The activity of the targets was measured before irradiation and a second time shortly after irradiation. After distillation of the iodine radioisotopes into the NaOH solution, the latter was measured and the target plate was re-measured. If possible, the measurement of the distilled fraction was repeated during several days. The measurement was carried out under adequate geometrical conditions with a calibrated (^{152}Eu) Ge(Li) detector with multichannel analyzer and an automatic peak integration program. Influence of radionuclides other than iodine isotopes was excluded. After the decay of most radioisotopes (typically 2 - 3 months after EOB), ^{125}I was measured separately with a calibrated (^{125}I) planar ultrapure germanium detector (0.3 mm Be cap, suitable for energies between 3 and 200 keV).

The distillation yields and the amounts of the long-lived iodine radioisotopes were determined by measurement of ^{124}I in the target before and after irradiation and before and after distillation.

The results of the (d,2n) process were obtained by averaging more than 30 production runs for a clinical trial using [^{124}I]Iododeoxyuridine ([^{124}I]IUdR) [1]; the results of the (p,n) processes were obtained by two independent production runs.

Results

The yields of the three production reactions are presented in Table 1. Generally, the yields of the (p,n) reactions are about 25 % less than those of the (d,2n) reaction. Although the data were corrected for the distillation yield, comparisons between the three reactions are difficult: the yield of the (d,2n) process is a more than two-year average of routine production runs for a clinical trial [1], the yields of the (p,n) reactions were obtained by specially designed experiments using freshly prepared targets.

Table 1: Yields of ^{124}I produced by different nuclear processes

Nuclear Reaction	Energy Range [MeV]	Enrichment of ^{124}Te [%]	Yield[a] in [MBq/µAh] ([mCi/µAh])
^{124}Te(d,2n)^{124}I	14 → 0	89.6	15[b] (0.41)
^{124}Te(p,n)^{124}I	12.2 → 0	89.6	11.3 (0.31)
^{124}Te(p,n)^{124}I	12.2 → 0	99.8	13.0 (0.35)

[a] corrected for distillation yield
[b] on average, taken from more than 30 production runs

[5]Degussa AG, Hanau, Germany

The comparison of the results given in the literature with those of our experiments is difficult due to different experimental conditions. Considering our furrowed target with the corresponding yield loss (correction: x 3/2), the stoichiometric yield loss caused by the use of TeO_2 instead of metallic tellurium (x 160/124), the different incident energy of the particles and the different isotopic enrichment, the yield of the (d,2n) reaction presented here seems to be substantially higher than those given in the literature [4,5]. The yields of the (p,n) reactions are comparable with published low-current data [6] and are higher than those reported for the clinical application described in [11].

Table 2: Relative activities of contaminants in ^{124}I produced via the nuclear reaction ^{124}Te(d,2n)^{124}I by using 14 MeV deuterons and 89.6 % enriched ^{124}Te

Nuclide	Amount of Activity at EOB	Amount of Activity 45 hrs after EOB
I-124 (4.15 d)	100.00	100.00
I-123 (13.2 h)	1.16	0.15
I-125 (60.2 d)	1.41	1.89
I-126 (13.0 d)	1.16	1.43
I-130 (12.4 h)	7.87	0.87
I-131 (8.02 d)	0.31	0.36
Sum of Contaminants	11.91	4.70

Table 3: Relative activities of contaminants in ^{124}I produced via the nuclear reaction ^{124}Te(p,n)^{124}I by using 12.2 MeV protons and 89.6 % enriched ^{124}Te

Nuclide	Amount of Activity at EOB	Amount of Activity 45 hrs after EOB
I-124 (4.15 d)	100.00	100.00
I-123 (13.2 h)	10.03	1.29
I-125 (60.2 d)	0.15	0.28
I-126 (13.0 d)	0.75	1.26
I-130 (12.4 h)	3.48	0.53
Sum of Contaminants	14.41	3.36

Table 4: Relative activities of contaminants in ^{124}I produced via the nuclear reaction ^{124}Te(p,n)^{124}I by using 12.2 MeV protons and 99.8 % enriched ^{124}Te

Nuclide	Amount of Activity at EOB	Amount of Activity 45 hrs after EOB
I-124 (4.15 d)	100.000	100.000
I-123 (13.2 h)	10.039	1.293
I-125 (60.2 d)	0.018	0.024
I-126 (13.0 d)	0.041	0.051
I-130 (12.4 h)	0.379	0.042
Sum of Activities	10.476	1.410

The purity data of ^{124}I are presented in Tables 2 - 4 and Figures 1 - 3. The data given for 45 hrs after EOB are of importance for the routine application of [^{124}I]IUdR in the clinical trial mentioned in [1,10]. Although produced with high yields, 25-min ^{128}I was not taken into account since it decays quickly and does not interfere with the purity data of the other iodine radioisotopes.

As can be seen from Figs. 1 - 3, in all three production reactions a time window can be defined within which the sum of the contaminants does not exceed 5 % of the ^{124}I activity. These windows are presented in Table 5. The 5 % limit for the sum of contaminating activities was requested by the Swiss Regulatory Authorities granting permission for the clinical trial using [^{124}I]IUdR [1,10]. Since the amount of ^{124}I also decreases by decay, it is advisable to administer ^{124}I immediately after the contaminants reach the limit of 5 % of ^{124}I activity. It is noteworthy, however, that also for the production of ^{124}I by the (p,n) reaction using highly enriched ^{124}Te a waiting time must be taken into account until this limit is reached.

Table 5: Characteristic data of the decay and formation curves for contaminants in ^{124}I produced by different nuclear processes

Nuclear Reaction	Incident Energy of Particles (MeV)	Isotopic Enrichment of ^{124}Te (%)	Time Window after EOB for Observing 5 % Impurities	Minimum of Impurities (%) at Time after EOB
^{124}Te(d,2n)	14	89.6	1.6 d → 4.1 d	4.5 % at 2.6 d
^{124}Te(p,n)	12.2	89.6	1.1 d → 14.0 d	1.6 % at 4.0 d
^{124}Te(p,n)	12.2	99.8	0.7 d → 33.3 d	0.14 % at 6.0 d

Discussion

As expected, the ^{124}Te(d,2n) reaction gives the highest yields of ^{124}I. On the other hand, this yield advantage over the (p,n) reaction is not so important as to exclude the (p,n) reaction for the production of ^{124}I. When the two production processes are compared, the difference in the yields between the 89.6 % and the 99.8 % enriched target material may be explained mainly by different isotopic enrichment of ^{124}Te itself. The reasonably high yield of the (p,n) reaction may introduce the use of low-energy "baby"-cyclotrons for the production of 4.15-d ^{124}I. To date, these cyclotrons are used almost exclusively for the production of short-lived positron emitters such as 20-m ^{11}C, 10-m ^{13}N, etc. Thus, better use could be made of such cyclotrons by producing ^{124}I overnight when no patients are being treated.

Parallel to the (d,2n) reaction, the (d,n) channel produces additional yields and explains the existence of ^{131}I (from ^{130}Te(d,n)) and the relatively high amounts of ^{126}I (from ^{125}Te(d,n)) and ^{125}I (from ^{124}Te(d,n)). In general, the corresponding (p,γ) channels in the (p,n) reaction have a low yield which may be disregarded. The yields of (d,2n) reactions are higher than those of the corresponding (p,n) processes which may not only explain the higher yield of ^{124}I but also the high amount of ^{130}I (from ^{130}Te(d,2n)) and again of ^{125}I (from ^{125}Te(d,2n)) and ^{126}I (from ^{126}Te(d,2n)).

For practical consequences, the most important factor is that the higher yield of ^{124}I in the (d,2n) process is accompanied by high amounts of the long-lived contaminants ^{125}I and ^{126}I. In our clinical trial using [^{124}I]IUdR, however [1], this fact seems not to play an important role since 95 % of IUdR are metabolized in the first hour after administration followed by rapid excretion (with blocked thyroid). In other potential applications, the remaining ^{125}I with its high amount of more than 23 emitted Auger electrons per decay [3] bound to DNA could produce

radiobiological effects in the cells. This effect was proposed for radiotherapeutic applications [12] but convincing evidence has not yet been found.

In the (p,n) reaction, the yield of ^{124}I is somewhat smaller than that in the (d,2n) reaction, the amount of ^{125}I drops markedly below that of ^{126}I, and ^{131}I could not be detected at all. This can be explained by the lack of the (d,n)-corresponding (p,γ) channels. On the other hand, at 12.2 MeV the (p,2n) channel leading to a higher amount of short-lived ^{123}I is already visible. Thus in the (p,n) reaction the radionuclide purity problems proved to be smaller than in the (d,2n) process although at EOB the sum of the activities of the contaminants is higher than in the (d,2n) process.

As expected, the product of the highest radionuclide purity was obtained by the use of the highly enriched target material and the (p,n) process. The yields here of ^{124}I and ^{123}I are comparable to those obtained from the 89.6 % enriched target since the ^{124}Te(p,n) and ^{124}Te(p,2n) channels are hardly influenced by the enrichment grade only. On the other hand, the amounts of ^{126}I and ^{130}I decreased dramatically due to the extremely low amount of their origin isotopes ^{126}Te and ^{130}Te in the highly enriched target material.

For practical purposes, the amount of ^{123}I must also be considered in the (p,n) reaction with the highest enrichment grade of the target material. From excitation function measurements [6,13], this effect can be expected to be dramatically enhanced with increasing energy. Thus the production of ^{124}I by the ^{124}Te(p,n) process should be carried out advantageously at low energies which may qualify this process as a domain of low-energy accelerators.

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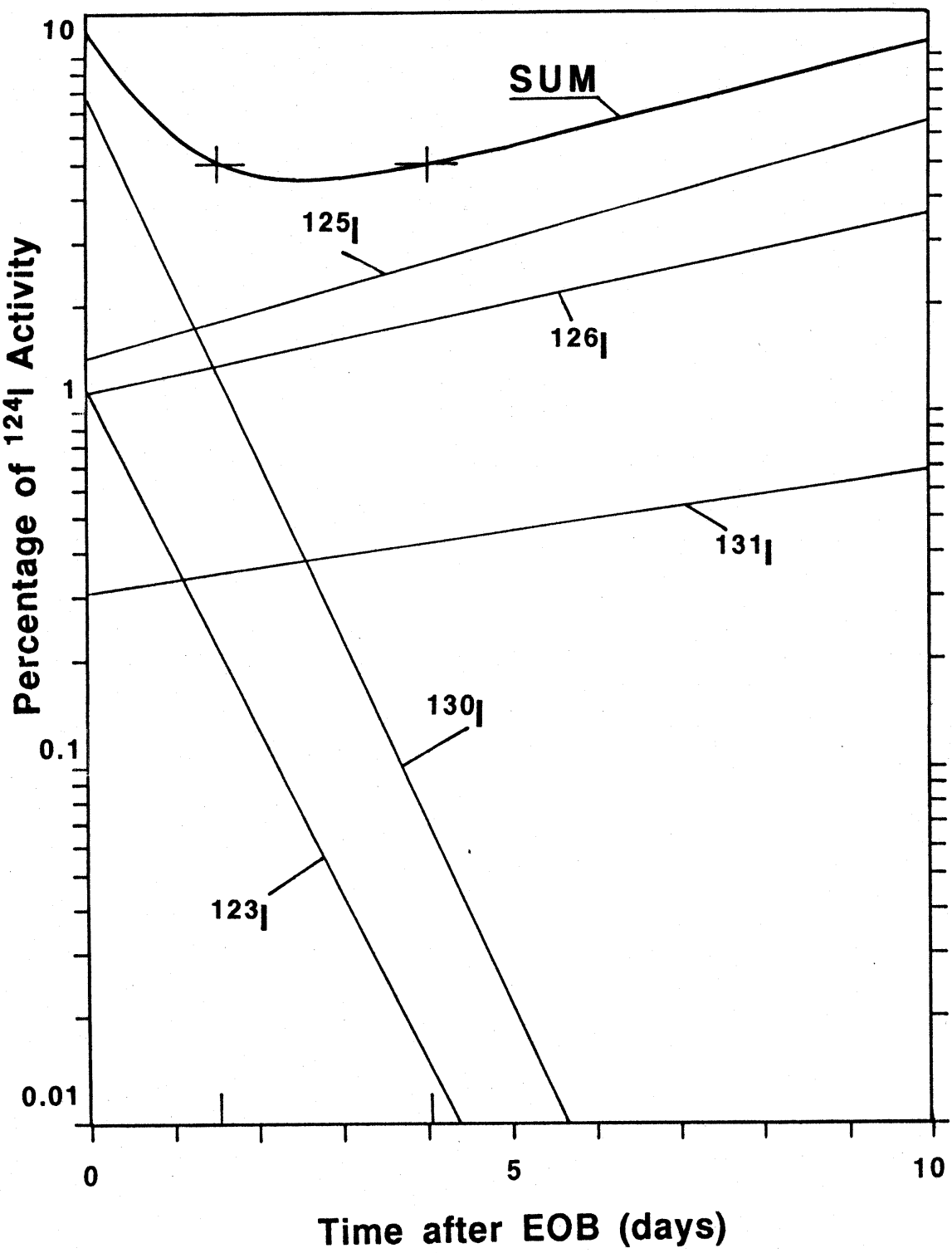

Fig. 1: Impurities in ^{124}I produced via the nuclear reaction $^{124}Te(d,2n)^{124}I$ using 89.6 % enriched $^{124}TeO_2$

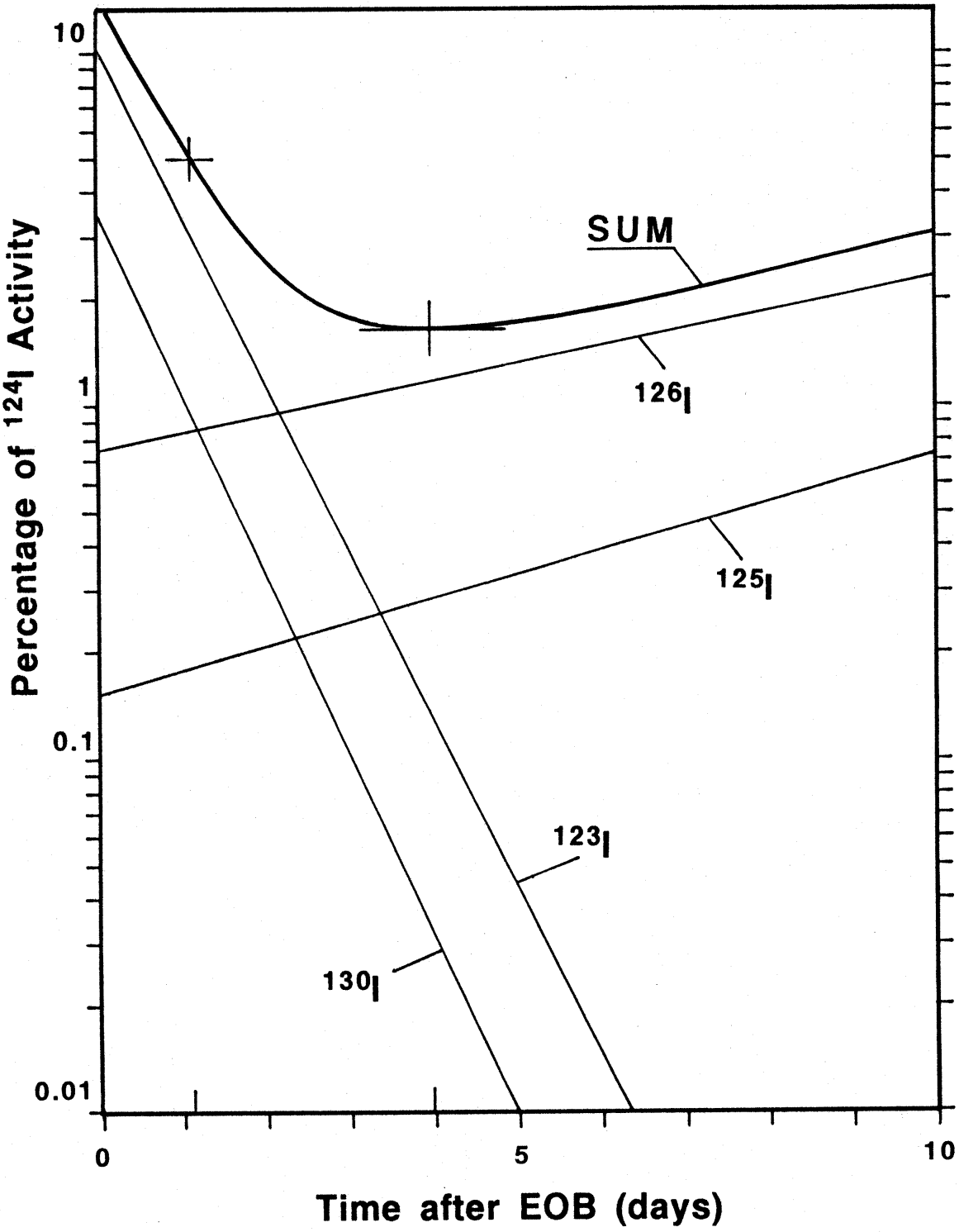

Fig. 2: Impurities in ^{124}I produced via the nuclear reaction $^{124}Te(p,n)^{124}I$ using 89.6 % enriched $^{124}TeO_2$

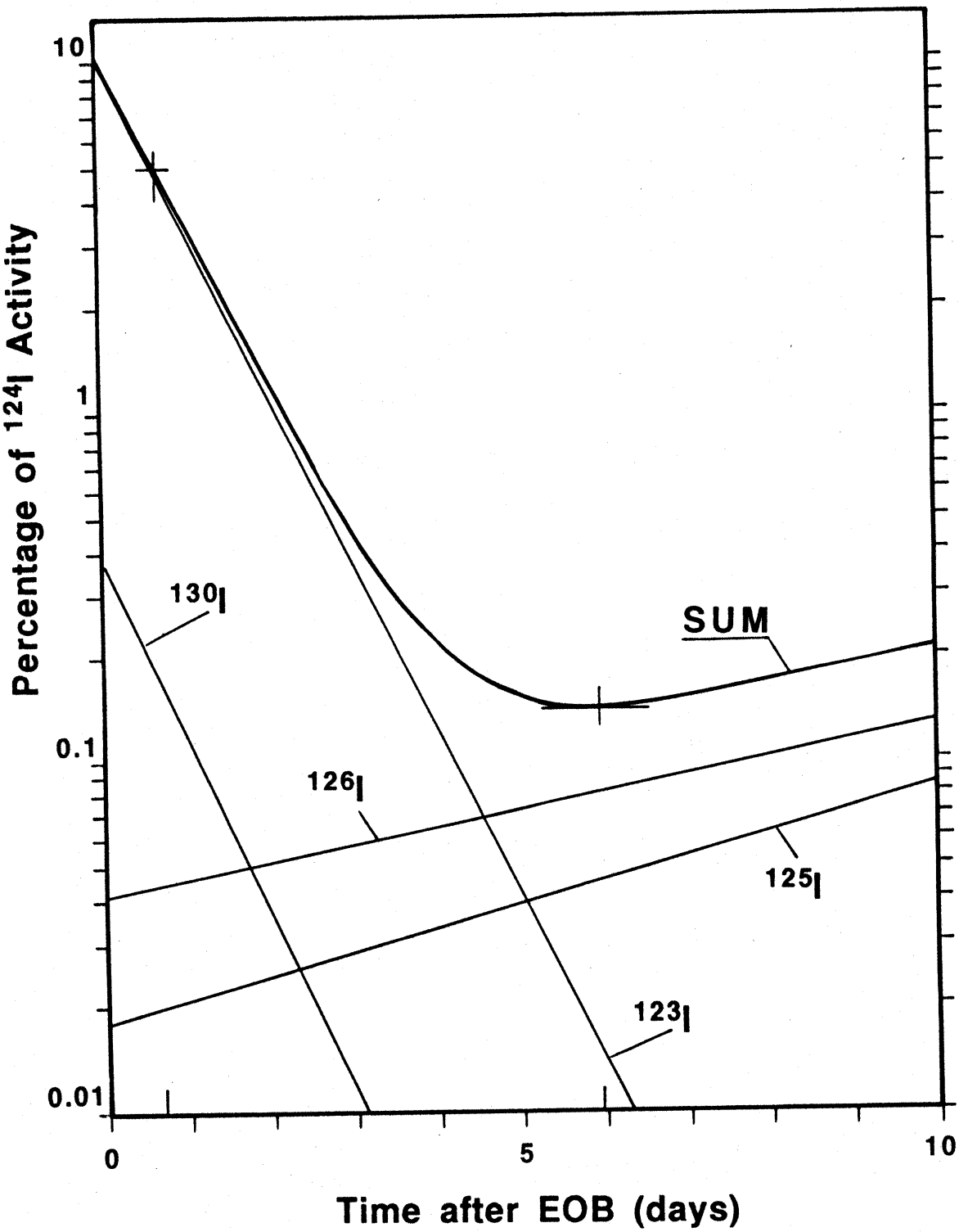

Fig. 3: Impurities in ^{124}I produced via the nuclear reaction $^{124}Te(p,n)^{124}I$ using 99.8 % enriched $^{124}TeO_2$

Q: F. Helus: What kind of material was it ? Was it metal ?

A: It was TeO_2. The same that N. Stevenson talked about in the morning and we have also a very similar target with grooves, but the backing is made of Pt and Ir.

Q: Straightforward question. What was the source ? You said Russian, but who ?

A: The left one is from a very old stock from University of Essen, it comes from ”Rohstoffeinfuhr”. And the right one is ‘Techno’, there is a distributor in Sweden. But the enrichment is ok, we checked this.

C: R. Lambrecht: In Riyhoud in Saudi-Arabia they produced ^{124}I using that (d,2n) reaction on ^{124}Te. And the levels of impurity using 95 % enriched ^{124}Te gave results of impurity levels that are comparable as seen here under the requirement at the higher enrichment for the (p,n) reaction. So if a facility has the option of high energy deuterons, it’s equivalent.

Q: R. Weinreich: And this nuclide can also be produced with a low energy cyclotrons ?

A: Yes, that’s the advantage of the proton reaction.

C: R. Weinreich: Might be a future field.

Bruce Mock, Indiana: ^{18}F Fluoride Production

I just want to make a real brief comment, and most people who might need to hear this are probably out there, sucking out the Cokes and enjoying the break. But all the concerns about rebuilding a fluoride target, this is the traditional CTI low pressure solid silver body target with a Havar foil. The conventional is what most of us have, operating at low pressure. And we went back to look at our rebuild history, so see how many times we had to rebuild it. And of these one or three rebuilds were unnecessary, because we were having problems with FDG and we wanted to do what anybody else does, blame it on the target. So we rebuilt the target, and that wasn’t the problem. And another time we rebuilt because we blasted the target that was empty at one point and thought that might be a wise idea. Our last rebuild was virtually two years ago and we’ve had well over 400 runs since. This is 371 runs of FDG and we’ve had a number of other straight fluoride runs for the purposes since that time. No change in the recovered yield for those 200 runs. We get between 90-98 mCi/µA depending on whether we talk about a 30 min run vs a 60 min run. The reason I think this has been very reliable in our hands is as follows. The target is cleaned every day before and after a run with about 2 mL of ^{16}O water. In the CTI configuration the target is here with two lines at the top, one line at the bottom. It’s normally the vent line, we just backflush conventional 16 MΩ water, 2 mL, force that to the target to our collection vial or to a dump. It’s no problem to do that, just by inserting a little 3-way valve in the vent line. It’s already there in the TSU, running that water to the target as often as we want, as frequent as we want. We’ve minimized the downtime on the target. And as I said, it’s been July ‘95 since we’ve last touched the target and there is no sign of yields changing. So simple ^{16}O water rinse, followed by nitrogen has kept the silver particles down or keeps them flushed free. It’s a very simple fix, it works in our lab and no extra charge to do. That’s the contribution, short and sweet.

Q: R. Dahl: You wash the target with 2 mL of water and do you just let it sit empty, do you blow it dry or do you do anything subsequent to that rinse?

A: After it’s been rinsed with the water, the nitrogen push gas is used to push the water through there, stays on for about 45-60 seconds, or longer, if you want to let it go on there.

We don't make a considerable effort to ensure that it's totally dry, but we do force the liquid through until we are sure that it's all out and we probably bubble the nitrogen for about good 45-90 seconds afterwards and then seal it all off, ready to use for the next run whether it's today or tomorrow.

Jean-Luc Morelle, Liège: Recent Advances in Approaches to solve the Problem of Impurities in the Production of Fluoride for FDG

The idea when I decided to design a new FDG-box was ... actually, I left IBA, I wanted to do that kind of work within the company, but there was not as much interest as I expected. So basically what I decided to do was to try to get back to that idea of a disposable system, that had been initiated by GE, but trying to avoid some drawbacks, trying to increase yields and trying to reduce time. Basically the system you see here is a system which is kit-based, but using only commercially available, sterile medical components.

So what I first spent much time on was trying to spot out in the usual method what would be the problems we would meet, by looking for a sterile operation system. And the first part that was obiously a problem was the ion retardation resin that you usually put at the end of the system, just before the final vial. That was the first thing I wanted to get rid of. The way of doing that of course was to try to reduce the amounts of acids or NaOH. So I thought it would be worthwhile trying that NaOH solution, since it has been described by the Füchtner group and I had heard very little about it.

So going back to literature I had to read what had been done and I read again the Hamacher paper and there I noticed that after the labeling step he was purifying on a low polarity cartridge. And it came to my mind that what he was doing was eluting his low polarity cartridge in which the labeled precursor was trapped. He was eluting it with ethanol, was drying the ethanol away and then going on with his hydrolysis. I thought why should you remove that out of the cartridge ? Just leave it in the cartridge and do the hydrolysis right there. Then when we tried to do that in our lab it was really only a ten minute experiment. We dropped a few µL of NaOH on the ... it was a C18 Sep-Pak....let it there for a few seconds, about one or 1.5 minutes and after that eluted the Sep-Pak with water and what we got was FDG. So that could reduce considerably the amount of hardware that we had to involve in a kit system. Otherwise in the previous version we had five manifolds of stopcock valves which was quite a problem, it really became a huge box, you really noticed that it's quite big and the dimensions are fixed by the dimensions of the elements we use. Maybe we could have used other stopcock manifolds, but they were very practical because of the spacing between the valves was just slightly larger than the diameter of very common vials, syringes etc.

And the other thing was that we had a lot of trouble finding medically sterile components, that were accepting the contact with acetonitrile. And so we found only one brand, which is PVB, it's a German company that makes them out of polysulfone which turned out to be resisting properly to acetonitrile. So what you see on the picture is the module without anything and then the kit's right in the front. And the kit will be split in two parts. First what I call the hardware part, where you have the valves, the tubes and the vessels and then the reagent part, which could be supplied separately or be prepared by the user. And then that just fits onto it. Actually if you look now at the advantages of this lets say hydrolysis on the solid support on the low polarity cartridge, it's mainly reducing time and reducing the amount of hardware, which makes that kit approach cost effective at reasonable dimensions. The time you need for the labeling is about three minutes, the time you need for the hydrolysis is about 1.5 minutes. And the two essential steps are less than five minutes and all the rest is only transferring reagents across the pressure drop of the cartridges, rinsing the Sep-Pak after we put the activity onto it to purify the product etc.

Maybe I can show this and describe step by step what's been done. The activity arrives through this little cap, arrives here on this little cartridge I showed this morning. From there on the target water is recovered, coming out this way. It's recovered in this little vial which is normally located here. It has a scale that weighs the amount of water. So that once you've recovered all your target water, the system knows it and you can start a synthesis automatically right away. Then after that you have your activity here, you elute the activity from the aluminum mixture, we haven't really figured out, what would be the optimum mixture composition, we've tried everything from pure aqueous eluant to a mixture up to 90 % acetonitrile and 10 % water. We went down to 5 % water, we had slightly dropping yields. We think however that we might work with probably mainly an aqueous eluant mixture. So from there we transfer liquid from there to here and then back to the reactor, which is here. So we go back and forth. This is still a little problem for this component, which was not designed to have pressure from below. So there's a little bit of work to be done as far as the packaging of that part is concerned.

Now you're in the reactor, the reactor is supposedly located in this hole. This hole contains an infrared heater and it's regulated using an infrared thermocouple but they're chosen such that the wavelengths are different. So that the thermocouple that looks at the glass of the reactor vessel is not influenced by the fact that the infrared bulb goes on or off. And I say infrared bulb, it's a big word, it's a special halogen bulb that's available standard on the market with golden plating. It has a strong focus, it's designed to unsolder electronic parts on the prints. We just put it at lower voltage, so it's mainly heat that comes out. This allows us to evaporate quite quickly the solvent of the eluate mixture to dryness. Then we have here an acetonitrile supply that allows us to do a second evaporation as a usual method. All the gases are directed through this tube in here to this end and they go into here, where there is a slight negative pressure. And everything is collected into this vial, all the liquids condense in the tubes and they are recovered in here.

The next step is to bring very usually the triflate, which has been connected here. Maybe one little word about that, the triflate is packaged dry in the vial and just a minute before the activity is brought into the module, a slight amount of solvent is transferred from here to there, just in the right amount, using this little level detector, that allows us to transfer the 1.5mLof acetonitrile to dissolve the triflate. The triflate again is sent into the reactor. The reactor is kept at the usual mild temperature around 70, 80 °C, and labeling occurs. During that labeling step you will be conditioning automatically the Sep-Pak, your low polarity cartridge. Here it's a C-18, but it turned out to work with many other low-polarity cartridges. For that we have an ethanol supply in this vial that is send through the cartridge to the waste and after that we use part of the water which is in this syringe to rinse the relay, the Sep-Pak. And that's happening during the last two minutes of the labeling, which continues going on in the reactor. Then here you have the acetonitrile mixture with the labeled triflate. It's sucked into this syringe, which still contains about 20 mL of water and mixes up with water, so that we're practically in an aqueous solution and not in the acetonitrile solvent, which is only 5 %. This mixture is then sent over the low polarity cartridge to the waste and all the activity is trapped in here. After that we use the content of that syringe to thoroughly rinse the Sep-Pak, to get rid of any trace of solvents. Actually we do that in 5 or 6 steps, each time sending back a little bit of nitrogen through the system to dry this and send a bit water again, dry it, that a few times. The result is we detect no solvents in the final product.

Afterwards we have this syringe, that contains 400 µL of 1.5 M NaOH, which is then sent onto the Sep-Pak, the quantity is such that you just moisten the Sep-Pak up to here. You wait 90 seconds and then elute this with 2 or 3 mL of water coming from this syringe, which is pushed into this one. This one contains ahead of time the equivalent amount of HCl to neutralize the NaOH that was pulled out of the C-18 cartridge and contains a light citrate buffer in order to compensate for small differences between the quantities in HCl and NaOH.

Then this syringe pushes the whole mixture into the final vial. And here the product is available. So this is the present status of the system.

C: R. Ferrieri: Two years ago I reported on decreased FDG synthesis with increased yields, using the near infrared lamp and just so that you are aware, I have a patent on file for that.

A: I didn't know at all that you had a patent for that. We have to discuss this issue.

C: R. Ferrieri: I should say the associate of the University is the Brookhaven Lab, which have been fired, but they held the patent on it...

C: R. Lambrecht: I don't think that's a novel feature this module though, the feature of the way of doing the synthesis. To eliminate some of the problems from impurities in the water is the key factor that your patent probably doesn't cover.

A: J.-L. Morelle: Yes, I don't consider this as being for me the novelty in the system. Basically what I consider as the two original features in the module is the fact that you have the hydrolysis within the standard cartridge, and the second point is that you are only using commercially available components to make your kit, which I think allows many people to use the system. Either they have money and prefer buying fully packed kits, or they're on the short side and they can buy those components available on the market and put them together as they wish. So that was a bit orientation we wanted to take.

Q: C. Dence: I just wanted to ask you, have you seen any difference in the origin of the water, the quality of the water that you use vs the yield as we observed in the standard GE box that we have?

A: I'm not able to actually answer this question yet. I can say is that all the first steps up to the labeling step is really the usual way that most of the modules perform. I had some experience of course with the IBA module which with some skilled customers were able to perform correctly and up to rather high yields. And up to rather high levels of activities, the CTI module operates along the same principles, so I'm not upset a bit about the fact of going to the labeling step. So what we tested separately, to this time it has only been tested separately, was to put the highest possible amount of activity on the Sep-Pak for the hydrolysis step. We did what we could with the cyclotron we have available in Liège, we put 1.5 Ci on the on the C-18 Sep-Pak for hydrolysis and we saw no difference between 5 mCi and 1.5 Ci. But of course we were not able to put 3 or 4 Ci yet.

Q: C. Dence: But your yield is proportional? When you get 65 % with 5 mCi then you also get 65 % when you are using 2 Ci?

A: Yes, the hydrolysis performed exactly the same way.

Q: C. Dence: What's the overall yield?

A: The overall yield should be the same. If I say that, I couldn't give the answer, because we tested the hydrolysis step separately. To this date we have operated the module as such only up to 300, 400 mCi, where it performed very ordinarily with a maximum yield that has peaked up to 67 %, general decay corrected yield, with fluctuations between 50 and 60 %. So there's some optimization we would like on the new system.

C: C. Dence: And my last comment. Are you aware of anybody else using basic hydrolysis? And doing it in 90 seconds to your final conversion?

A: What I know is the Füchtner paper, besides that I don't know of other people using it. If there is anybody here that has experience with that, I'm interested to hear about it.

C: C. Dence: This is just a general comment. When you are dealing with sugars, the basic hydrolysis is always is the one that is going to give the most problems as far as byproducts and ...We're doing it with more mass on it, you have to be away from basic hydrolysis in order to preserve the quality of your sugar.

A: OK, but as for that concern there will be a talk or at least a poster in Uppsala. About the testing that has been done on the basic hydrolysis to be sure, that it was glucose and not mannose.

C: We've tried the basic hydrolysis quite a few times and it seems like it works. We haven't had any problems with it, I tested with HPLC. Seems fine.

C: J. Clark: Maybe could you just have a show of hands who has done base hydrolysis on a regular basis. Lot's of people are doing it, but the man who has done it first, maybe is over there.

C: F. Füchtner: We have used this basic hydrolysis for over a year an we haven't had problems with the chemical and radiochemical purity. The yields are comparable to the acetic hydrolysis.

C: C. Dence: Yes, your important element may be your room temperature. If you are doing anything above 90 or 100 °F, then we will see the difference.

A: Let's say what raised our attention on the subject was that little paper that was published by the Australian group about epimerization. The first thing that surprised us, that they were using actually the column that Dionex system and the element for the Dionex system itself is a strong base. So it was a bit strange, and their results were anyway at a high temperature.

C: C. Dence: Just be aware that the combination of temperature and a strong base always could be a problem.

A: But if you see the poster in Uppsala, there is a poster and an abstract on this subject.

C: F. Füchtner: We can carry out this hydrolysis at a temperature of 60 °C for one minute and we can't detect any impurities.

Edward Carroll, Riyadh: A New Radiation Detector

The general point was, there was a comment made earlier that if you have a higher energy machine - we are not talking 'high' energy - if you got 26 MeV and you only need 18 or something like that, it certainly makes life easy. So we have essentially a two part target, a back and a front. The front was a ¼ inch thick piece of aluminum....it went down to what we thought was the right thickness, because I didn't even have any range tables in those days. It worked much better than the commercial target we bought, because of a simple mistake that was made in the degrader, which since has been fixed. This was the RDS-112, because the head of the department, to get us off the ground quickly on the PET had bought all commercial targets.

The second item is that Lewis Carrol, Fred Ramsey (Lewis was here two years ago) and he had presented a detector, which was basically a pin diode detector, that he was just

measuring the DC out of it. As a simple detector, this was without a scintillator crystal, just the pin diode itself. He since made a version of it that is AC coupled. It clips at 60 keV, so it just sees what's above that. But for such a simple detector I can use it as a room detector, because I can get one pulse out of it for every five µR, which means they're minutes apart. And you don't care if you're just monitoring the room at low levels. It goes up to 200 R without any problems, the linearity goes off about 5% of the high end, that's in the electronics and it's predictable. I take it out at my end using our micro-controller. If there is anyone who's interested in that or, by the way, sources for various cyclotrons parts and things like that, Lewis Carrol has a page: www.carrol-ramsey.com and that's how you get to George Henry for instance whose name has been mentioned about four times.

This is a 30 cm long thing. There's nothing to it, the body has got four holes drilled from the back. Two across and one diagonally and that's your water cooling. There are no O-rings in the body, that front plate, it's another one that I've used, as you can tell from the darkened center. That's about it, you put it together, you put it on the line, you run it for years. The point is, you don't have to worry about foils or anything because the ratio of the thickness of the front plate to the conduction path is only like 3:1, and that's through the aluminum. If you go to the next slide you can see the front side, which is also unimpressing. All you see, there's a couple of screws to mouth the plate, that's it. You can see an O-ring groove on the face of it, because it just has a couple of screws that go through the coils in a plastic plate, which is behind that aluminum plate, and that actually seals against the aluminum.

(End of talk not recorded)

A New High Current Spherical Target Design for $^{18}O(p,n)^{18}F$ with 18 MeV Protons

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The new idea is a totally water cooled titan sphere target body with two cooling circuits:

(1) Sphere cooling circuit: The sphere is cooled from the backside and the water outlet is in the bottom and in the top of the target holder.

(2) Beam window cooling circuit: the water cools the vacuum and the beam window. This setup is also used to degrade the proton energy from 30 MeV to 18 MeV.

These two circuits are separated by a waterguidance which is designed for high speed waterflow with heat transfer coefficient α = 12000 W/(m^{2}K).

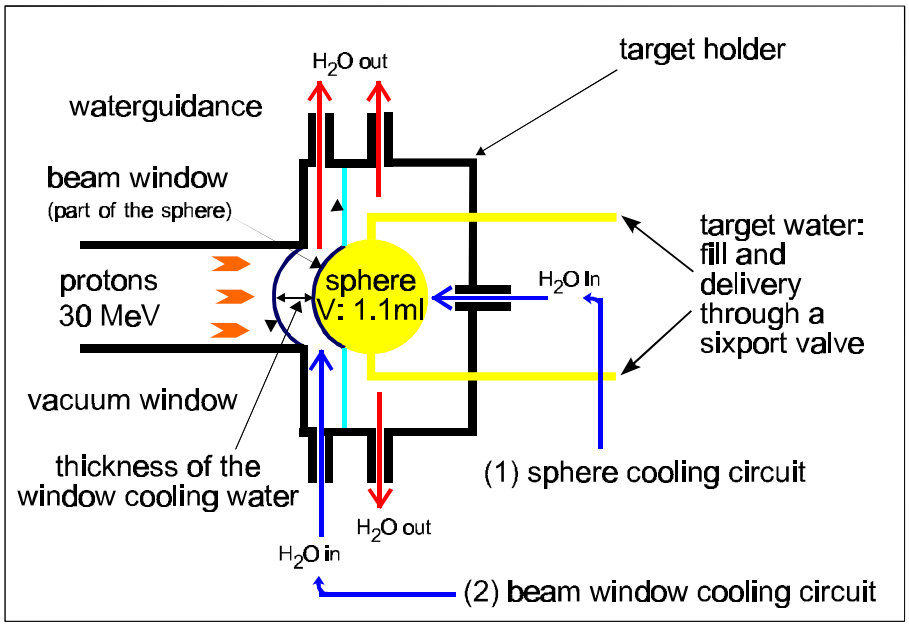


Fig. 1: Spheric target body with $H_2{}^{18}O$ loading and unloading lines (i.d: 0.9 mm). The Sphere is mechanically fixed in the target holder by these two lines. The total length is 8.94 cm and the sphere o.d. is 13.4 mm.

Yields

An average production rate is Y = (2093 ± 175) MBq/(µAh). This corresponds to (94 ± 8) % of the theoretical production rate Y = 2238 MBq/(µAh) for 18 MeV protons calculated by M. Guillaume [Int. J. Appl. Rad. Isot. **42**: 749 (1991)] based on the measured cross section by T.J. Ruth and A.P. Wolf [Radiochim. Acta **26**: 21 (1979)]. Typical yield by 50 µA, 18 MeV, 1 h irradiation → 85000 MBq.

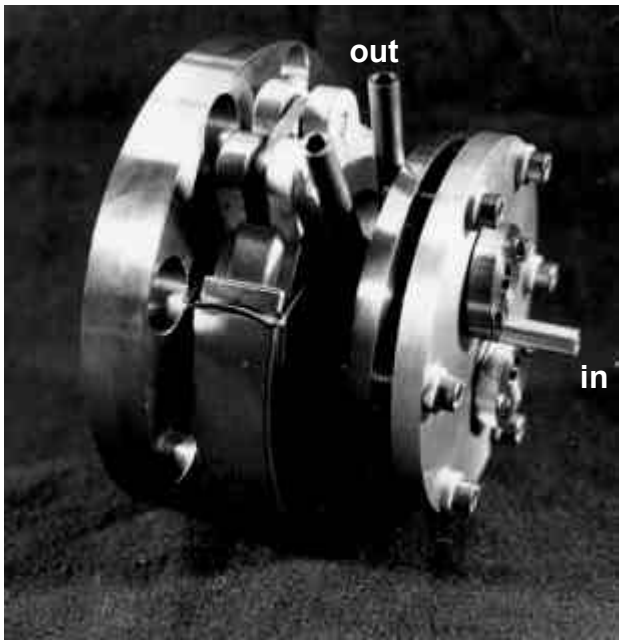
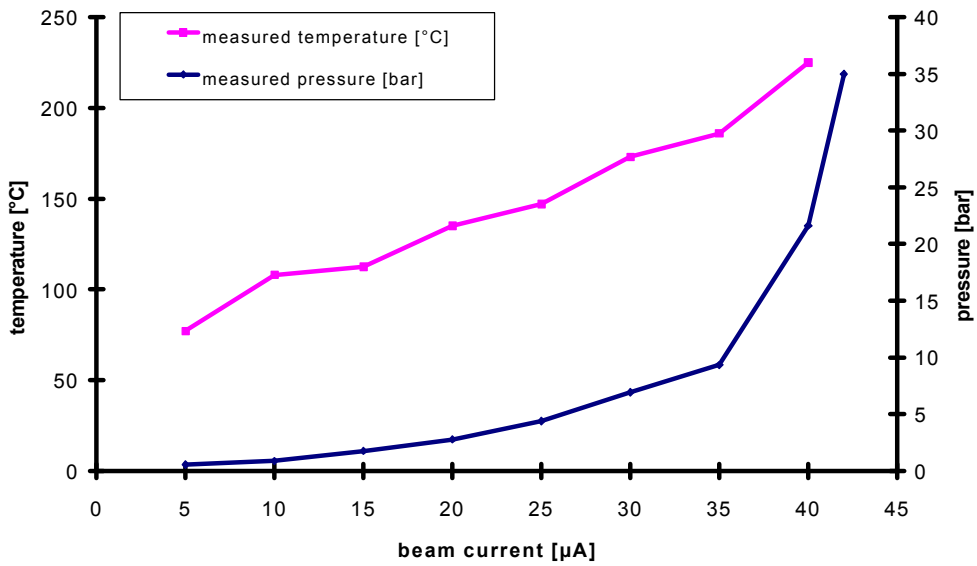


Fig. 2: Target head assembly:
the short tube on the right hand side is the cooling water inlet for the sphere and the two tubes in the middle are the cooling outlets for the sphere and the window cooling circuit. The target head is attached to the beamline with a KN-40 clamp.

Technical Data of the Sphere

• diameter:	inside	13.0 mm
	outside	13.4 mm
• wall thickness:		2 mm
• max pressure (calculated):		100 bar
• working pressure:		60 bar
• surface:	inside	5.31 cm²
	outside	5.64 cm²
• volume:		1.15 mL
• beam window area:		1.56 cm²
• beam area:		0.79 cm²

Performance:



A New Target Changer for the DKFZ MC-32 Cyclotron

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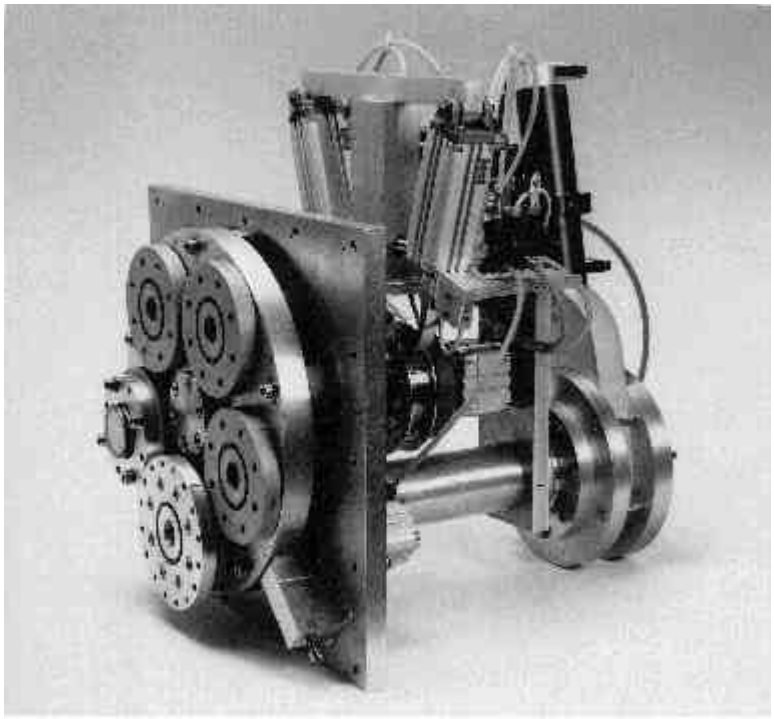
A new type of target changer for the DKFZ Scanditronix MC-32 cyclotron has been constructed. It holds up to five targets which are mounted on a rotating steel disk with a special epicyclic gear system which permits a 360 degree rotation of the target changer while the targets remain in their original position relative to the base plate. The twisting of cables and tubes connected to the targets can thus be avoided.