716796

1. JNM 4/23/62
[redacted]
3. EEF
4. Berman
5. Eister

OAK RIDGE NATIONAL LABORATORY

OPERATED BY

UNION CARBIDE NUCLEAR COMPANY

UCC

POST OFFICE BOX X
OAK RIDGE, TENNESSEE

April 19, 1962

AIR MAIL

Dr. P. C. Aebersold
Director
Division of Isotopes Development
U. S. Atomic Energy Commission
Washington 25, D. C.

Dear Paul:

In connection with the request you made concerning "burn-out" + isotope production with high fluxes and related matters, I recalled the taped session we had here some years ago in connection with HFIR in which I held forth at some length on the subject. I have attached a copy to this letter. I think you will find it of interest and I believe you can get some of the extra information you want out of it. We have not been able to do much actual experimental work on the problem yet because of the enormous amount of high priority work we always seem to have on hand. As soon as we can, I want to get some people working on certain experiments I have in mind.

I haven't written the Vienna short-lived isotope abstract yet, but I hope to get it to you within the next week.

Best regards,

Sincerely yours,

A. F. Rupp
Director
Isotopes Development Center

AFR:jml

1104696

REPOSITORY Texas A+M Archives + Special Collections
COLLECTION Paul Aebersold Papers
BOX No. 4
FOLDER Gen. Correspondence - Jan - June 1962

From our discussions early in the HFIR planning conferences Jan 1958.

This is a tape recording - not for publication.

eventually edited

Stoll: Just one more comment on the heavy ion bombardment. This looks as if it would work nicely with the heavy ion cyclotron. The two perhaps should be put together.

Weinberg: I might say that Seaborg is trying to get a heavy ion cyclotron now.

Chetham-Strode: It is quite possible, and should also be realized, that by the time a heavy ion cyclotron comes to our Laboratory, there is not going to be a lot of very easy gravy left to pick up. Berkeley people, of course, have their linear heavy ion accelerator.

Weinberg: Yes, but the currents you can get would be much higher in the cyclotron.

Chetham-Strode: That's true. This in general is apt to mean that allowing for the delay in time and the normal increase of cyclotron currents in time, one does a lot of things much better.

Taylor: What is this argument about resolving time, limiting ultimately the last step? It seems to me that you have got to aim your accelerator down the snout of the reactor.

Chetham-Strode: I don't follow.

Taylor: You said that in deciding how far you could go toward short half-lives you would be limited by electronics perhaps along with kind of instruments, rather than by chemistry. You certainly don't want to do two chemical steps on short-lived things, so you will have to make all your transformations in one place then.

Chetham-Strode: Well, one normally thinks about this in terms of, for example, bombarding californium with first carbons, then oxygens, then neons, etc., so that you use heavier and heavier bombarding particles. So really this is sort of a two stage operation.

Boyd: Ultimately all new element discoveries will be based on physical rather than chemical evidence.

Lane: If there are no other questions, perhaps we can hear from Mr. Rupp on "Other Isotopes."

OTHER ISOTOPES - A. F. Rupp

One of the things I noted in discussing regular radioisotope production, contrasted with rather specialized types, is that we are dealing with a lot of target atoms in radioisotope production; and we have, of course, a wide range of cross sections we have to deal with and isotopic composition of the elements, of course, differing. All of these factors have to be taken into account in considering what is the best way to produce a certain radioisotope.

1104697

Since the reactor production of radioisotopes is primarily concerned with the reaction between neutrons and a great variety of target atoms, the concentration of the reactant common to all of the production reactions - the neutrons - is of the greatest importance in producing high specific activity radioisotopes. The isotopic activation cross-sections of the various target atoms are, of course, fixed values, and in only a comparatively few cases can one gain a factor of 10 by concentrating the target atoms by isotopic separation. Since in neutron-gamma reactions (which are by far the most common) the product atom is the same chemical species as the target atom and therefore cannot be separated chemically, the best way, and almost the only way, to increase the concentration of the product atoms is to increase the neutron flux. One other possible way to greatly increase the specific activity of nuclides produced only by (n,γ) reaction is to isotopically separate the radioactive product atoms from the target atoms in machines such as our electromagnetic separators. However, little is known in this field, and in any case, the method would not be applicable to fairly short-lived radioisotopes because of the time required to carry out such a complicated operation. plug

It therefore seems clear that if we are interested in producing all the possible radioisotopes in as nearly "carrier-free" form as possible, an ultra high flux reactor is required. But one would be justified in asking, "Why do we need pure, carrier-free radioisotopes?" Unfortunately, the best answer is the one that sounds the weakest: We intuitively know that radioisotopes will become more versatile and useful as their isotopic and chemical purity increases. There are many cases that could be cited to support this view, but I believe that the recitation of numerous specific cases is unnecessary. It is significant that in dealing with radioisotope customers, particularly those engaged in research work, we have seldom, if ever, encountered one who did not want higher specific activity material. In biological research, the ideal situation is one in which adequate tracer is added without disturbing the delicate chemical balance of living organisms. The same holds true in many studies of chemical equilibria. Physicists want radioactive sources of high intensity, but with as little substance as possible. Radiographers want high intensity point sources to improve definition. If we simply want to gain more knowledge about the radioactive nuclides themselves - their radiations, cross-sections, magnetic moments, spin, etc. - it is highly desirable to have the radioisotopes chemically and isotopically pure.

In general all radioisotope production would be benefited by having a higher flux, obviously because you could do things faster by having this higher flux. One of the things to mention would be gaining very high saturation values with short-lived material, where you essentially have to go to equilibrium where the atoms are decaying at the same rate they are being produced, and of course if you are producing the higher rates this value becomes higher in proportion to the flux. Some of these isotopes are listed in Table I. The first one is Cu 64, which has a half-life of 12.8 hours and a cross section of about 4.1 barns. It might be of interest to note at this point that the theoretical specific activity of isotopes like this are all pretty high, being around 10^8 curies per gram. Now with 10^{14} flux reactors we will get only about 73 curies per gram, and at 10^{15} we get about 263 curies per gram, based on

TABLE I

Examples of Short-Lived Isotopes

Nuclide	3 Cu^{64}	Ga^{72} omit	6 I^{130}
$T\frac{1}{2}$	12.82 hours	14.2 hours	12.6 hours
Target Atom Abundance	Cu^{63} (69.1%)	Ga^{71} (39.8%)	I^{129} **
Isotopic σ_a, Barns	4.1	4.9	11
Theoretical Specific Activity	3.83×10^6 c/g	3.04×10^6 c/g	1.87×10^6 c/g
* Act. at Saturation, 10^{14}, c/g	73	45	72
Activity at Max., 10^{15}, c/g	263	456	727
Time for Maximum, 10^{15}	6.33 days	6.76 days	5.48 days

Nuclide	2 K^{42}	1 Na^{24}	7 Au^{198}
$T\frac{1}{2}$	12.47 hours	15 hours	2.7 days
Target Atom Abundance	K^{41} (6.91%)	Na^{23} (100%)	Au^{197} (100%)
Isotopic σ_a, Barns	1.17	0.53	98
Theoretical Specific Activity	6.01×10^6 c/g	8.69×10^6 c/g	2.44×10^5 c/g
* Act. at Saturation, 10^{14}, c/g	3.4	37	810
Activity at Max., 10^{15}, c/g	34	374	815
Time for Maximum, 10^{15}	7.09 days	9 days	29.4 days

* Not true specific activity, but amount of radioisotope per gram of starting material.
** I^{129} is very long-lived radioactive nuclide obtained by U-F.

1104699

grams of material that you originally put into the reactor. This is not the true specific activity since it is based on the target that you put in. The time for maximum activity in this case is around 6.3 days.

Taylor: You could have gotten 263 curies per gram by irradiating for a little longer, couldn't you?

Rupp: No. Now let's select something with a different cross section. Take Na 24, which has a half-life of 15 hours and a cross section of only about 0.53 barns. In this case for 10^{14} flux you get about 37 curies per gram, and for 10^{15} flux essentially ten times as much or about 374 curies per gram. In comparison to these isotopes, with Au 198, with a 2.7 day half-life and a considerably larger cross section of 98 barns, we get about 810 curies per gram at 10^{14} flux and essentially the same quantity at 10^{15}. In other words you don't gain with such isotopes by going to higher fluxes. The thing I want to point out here is that this fact is not necessarily bad since the actual specific activity of a high cross section isotope is considerably higher than that calculated on the basis of original target material. Although these figures might be fairly good on sodium, for example, for the specific activity that we actually find when we take it out of the reactor, the value given for gold would be way off. In other words, the specific activity would be very much higher than this.

Question: You mean you don't put pure gold in the reactor?

Rupp: You put in pure gold, but you burn up the target material since it has a very high cross section.

Weinberg: Don't you burn it to a gold isotope that isn't radioactive? Isn't that the point?

Rupp: No. You burn it to radioactive gold, which decays to mercury.

Weinberg: But then the mercury captures and goes to gold.

Rupp: No, it goes to another mercury, so what you can do then is separate them chemically and have a very high specific activity

All I wanted to point out in this one case is that you can get a very much higher saturation value by burning out target atoms. To summarize the situation for short-lived isotopes since you can get very much higher saturation values it appears that an ultra high flux reactor for many of these things would be very good. You can actually get, in most cases, a factor of 10 or so higher specific activity, unless you run into materials with high cross sections.

The second item to be mentioned is the speeding up production of long-lived materials shown in Table II where irradiation times are too long in ordinary reactors. This would be somewhat the same argument that has been made for the transuranics. I might point out some of the differences in time that you get here for the maximum production on materials that are fairly long-

TABLE II

Examples of Long-Lived Isotopes

Nuclide	Ba^{133}	8 Tl^{204}	5 Ni^{63}	4 Co^{60}
$T_{\frac{1}{2}}$	7.2 years	4.1 years	80 years	5.3 years
Target	Ba^{132} (0.097%)	Tl^{203} (29.5%)	Ni^{62} (3.66%)	Co^{59} (100%)
Isotopic σ_a (Barns) Cross section of product	7	11	15	34
Time for Max., 10^{14}	19.8 years	9.6 years	44 years	7.8 years
Time for Max., 10^{15}	6.6 years	3.38 years	18.5 years	1.6 years

Theoretic spec act
Act at 10^{14}
Act at 10^{15}

$\frac{3.5}{4.1} \times 503$ C/g

1104701

lived, in order of a few years. Now in the case of Ba 133, which has a half-life of 7.2 years and a cross section of 7 barns, the time at 10^{14} flux for maximum production would be 19.8 years and at 10^{15} maximum would occur at 3.38 years. For Ni 63, which has a half-life of 80 years and a cross section of 15 barns, the maximum time would be about 44 years to get to a point where there's no use of keeping it in there any longer. This will occur in 18-1/2 years at 10^{15}. Co 60, about which I will speak a little more later, has a half-life of 5.3 years and a cross section of 34 barns. We have a maximum at 10^{14} of 7.8 years. This occurs in only 1.6 years at 10^{15} flux. Now, this again is tied up with the burn-out of the target which usually isn't of much interest to us in the low flux reactors that we have been using, but becomes a very important factor in a high flux reactor. I might note that for the production of some of the very long-lived things, such as C 14 which is produced by (n,p) reaction, and 10^5 year Cl 36, and things like very large quantities of Co 60, an ultra high flux reactor would not be required. It would be a great waste to even consider using a reactor for that kind of production.

Boyd: You're not saving any time, but you would be producing much more in a given time.

Rupp: Yes, but you can do it a lot cheaper. You can use neutrons that are tremendously cheaper in other reactors and get essentially the same results since it is a question of total neutrons, rather than neutron flux, so you would never consider doing that in a reactor of this kind.

Boyd: You're saying for a radioisotope that doesn't decay appreciably you should use a lower flux reactor?

Rupp: That's right. An ultra high flux reactor is not of any use for long-lived materials, and it is of limited use for even moderate-lived materials.

Boyd: What do you do now? Do you load that beryllium nitride in the outside of a reactor when you want to produce it?

Rupp: Yes. It can be produced in any large reactor.

The third item I would like to discuss is one that has been mentioned before, and that is the burning out of undesired atoms that are isotopic with radioisotope products. In some ways this is the most interesting thing about having a high flux reactor. An example of this would be Co 60, which achieves a maximum production per unit weight of starting target material in 1.6 years in the 10^{15} flux. The theoretical specific activity of Co 60 is 1140 curies per gram. The maximum activity per unit weight of starting target at 10^{15} flux is 692 curies per gram; and, since the target is partially burned out, the actual specific activity is higher than this. At 10^{15} flux, it would require about 5 years to burn 99% of the original target, so it can be seen that a fairly close approach to the theoretical specific activity can be made in 2-3 years' irradiation. You can keep burning out the remainder of the Co 59 as you continue the irradiation and approach, of course, the limiting values of specific activity. So, in a case of this kind you see it would be very

but not Eu 154 only ~ 1000 barns

practical in a 10^{15} flux reactor to get in 3 years a sample, that is a thin sample, that would have 90% or better of the theoretical specific activities of Co 60, and samples of this kind would be of very great interest in producing highly concentrated sources to be used for a lot of radiographic work or research work. So you actually can burn out the remaining atoms, and that I think is one of the more interesting things about the high flux reactor. To take a case in which this fact is very pronounced is 13 year Eu 152 which has a companion of 16 year Eu 154. Europiums are notable, all of them, that they have terrific cross sections, in the order of thousands of barns. It is interesting to note that in a 10^{15} flux reactor, the curve of the maximum production occurs in only 14 days. In other words, the burn-up of the radioactive atoms is so great there is just not much use of leaving it in longer than 14 days. This indicates that you can use this to burn Eu 152,154 out of fission product Eu 155, for example. We have a problem of fission product Eu 155, which has a soft gamma ray, the type that is very hard to obtain, but it is not contaminated with secondary produced Eu 152,154 which occurs because of neutron capture of inactive fission products produced in a fission chain. There are other instances when you could use the reactor to burn impurities or undesired nuclides out of preparations, and if you use fluxes much below 10^{15} this simply takes too long. But at 10^{15}, in general it seems that things like this are practical.

Wollan: Don't you have to pit the cost of this against the manufacture of radioactive materials at lower fluxes and then sending them through a calutron? good question!

would be higher specific activity

Rupp: That's right.

Cole: In regard to Co 60, you stated that this material might be better produced in lower flux reactors, but then you did point out where there were certain advantages for irradiating cobalt. Were you thinking of this letter aspect in terms of perhaps a small total flux?

Rupp: I should have made that clear. In the case of producing very large amounts, that is thousands and thousands of curies of Co 60 such as we produce now in Savannah River and Hanford, it would not be practical to do this in a reactor of ultra high flux, or the ORR or MTR for that matter. It is wasteful because the neutrons are so very expensive. But for producing specialized sources of all kinds you could certainly use a reactor of this kind to produce the very high specific activities which would be difficult to get any other way. In the case of cobalt, I think I could almost say this by inspection and from experience that it would be very much cheaper to make the ultra high specific activity cobalt this way than in the calutron because all we have to do is mix a thin film, put it in there, and just leave it for a year or so.

Wollan: Are you amortizing $100 million on that statement?

Rupp: No, it depends on what kind of ultra high flux reactor we build, of course.

Lane: Are you suggesting an ultra high flux of 10^{15} as distinct, I suppose, from the super high flux of 5×10^{15}?

* But we now think that Eu 155 has an unfavorably high σ_a and the burning out process would tend toward a residue of Eu 154

1104703

Rupp: No, I was just using the term ultra high flux reactor to distinguish it from any high flux reactor that we have at the present time.

Lane: Well, you made the statement that you weren't interested too much in fluxes over 10^{15}.

Rupp: That's right.

Weinberg: Why was that now?

Rupp: Well, if you take a number of cases and go through them, you find that at 10^{15} flux, it is possible to get reasonable burn-out or a high specific activity in times of the order of a year or so. You don't find many cases where you really need more flux than that to accomplish reasonable burn-out or to produce reasonable activities. Indeed, in some cases if you don't want to separate the material afterward, and you're interested in both production and high specific activity, you don't want too high a flux. As a matter of fact, there is a good case for irradiating these targets successively in two or three different fluxes.

Lane: Well, take the case of 99% burn-out in cobalt - 5 years. That's a little too long isn't it?

Rupp: That is a little bit too long, but if it were five times as much it wouldn't even be considered.

Winters: When you are talking there, you're talking about actual delivered flux though?

Rupp: Yes, delivered flux in the reactor, in the target

Lane: Well, but the point is that these samples aren't very big massive samples, they are not going to depress the flux tremendously are they?

Rupp: No, really the type that we are thinking about here are very thin films. You wouldn't want to use a reactor of this kind for just ...

Weinberg: Does this mean that Lane's idea of getting a very high localized flux would be very useful for you?

Rupp: Yes, it would.

Weinberg: The same type of reactor would also be useful for Chetham-Strode's work although he spoke of somewhat larger samples.

Winters: But he wouldn't put it into the reactor in the high flux region until after he got it boiled down to 6 grams.

Rupp: You have a heating problem there though.

1104704

Winters: For your first stage it doesn't pay to have a real high flux reactor.

Boyd: Would this nuclear incinerator burn some of the waste products?

Rupp: Yes, One thing I wanted to mention is that we don't really know very much about the cross section of some of these things, and we do want to put things like Sr 90 and the like into the ORR and try to find out a little bit more about their properties. I mentioned one case where it would be useful with fission products in burning out europium from Eu 155, and I am sure there are other cases like that.

probably not possible on basis of my present info... Too bad.

Boyd: Like operation bootstraps, you burn out the strontium, but you are producing fission products of course in order to get neutrons. Do you make anything this way or not?

B: 88 ght.

Rupp: Oh, you cannot burn up Sr 90 as far as we know and get anywhere on it as far as quantities are concerned. The only way you could do that is ~~if~~ in ~~you had~~ a thermonuclear react~~ion~~ or.

Now, another item to be mentioned deals with secondary reactions which go up with the square of the flux. Another item would be in conserving isotopically-enriched target material. Some of these target materials are really quite expensive. We like to have things like Ca 47, which is a gamma emitting calcium isotope, which would be useful if we had much of it. It is now made by a (pp,n) reaction on Ca 48 - a very expensive business. In fact, we just don't have any way of making any decent amounts of Ca 47. In a case like this, you could use the Ca 46 (n,γ) reaction, but the natural abundance of Ca 46 is 0.003%, so that we have a very, very small amount of target material, and it is extremely expensive and we want to conserve the material. There are other cases where we need, and do use, enriched material, such as Cr 51 by using enriched Cr 50, I 130 by using fission product I 129, Fe 55 and Fe 59 using enriched Fe 54 and Fe 58, and Sr 85 using enriched Sr 84. Again Sr 85 is a strontium isotope that has a gamma ray, so both of these are very important because the other isotopes, like calcium, are soft beta emitters, and are hard to follow through in biological systems and the same way with strontium. There is a lot of work waiting to be done with both calcium and strontium gamma emitters. If high fluxes were available, we could use a hundredth or maybe even a thousandth as much target material and get the same production as at lower fluxes, which would be very good of course. I am sure this would be economical unless the reactor were really terrifically expensive. Many radioisotopes are now made carrier-free by an expensive (n,p) reaction, plus chemical separation processes, and they could be produced by (n,γ) reaction with an acceptable specific activity. Now in this case I might cite Ca 45, which is made by (n,p) with Sc 45. We are not able to get a very high yield; the target material is expensive; and the chemical separation is pretty complicated. Right now, using an MTR flux and Ca 44 isotopically separated, we can get preparations that are within a factor of 10 in specific activity compared to the Ca 45 that is made from scandium. This is because that even if you make a very pure separation carrier-free, unless you baby it along every step of the way you are going to get casual contamination in it from calcium in the surroundings. So with another factor of 10 in flux we

it we loved it ughow

1104705

could prove even to the people who do research with teeth (they are the most particular on what kind of calcium they get) that it would just be nonsense to try to make it from scandium because using Ca 44 in an ultra high flux reactor you could make very, very good Ca 45. The same thing applies to P 32 which is made from sulfur. P 32 is used in large quantity, and is widely used in medicine. Right now we feel that with a 10^{15} reactor, we could make it directly by irradiating phosphorus to more than 100 curies per gram, and that is quite acceptable for most medical uses. That would bring down the cost of P 32 tremendously. Also, in the past, we have used 1 ft. long cans filled with sulfur for making one curie in the graphite reactor, and we are prepared to do it in the ORR with some small tubes with about 100 grams. So even with the (n,p) reaction you can go way down with the target material, and this cuts down the processing expense a whole lot. The same thing would apply to S 35 which is made from chlorine, and any other (n,p) product, that you could use the (n,γ) reaction and get the same thing. You could do it a lot cheaper and cut the cost of the material.

Well, that's about all the specific cases I wanted to bring up. However, I might mention one thing here. In talking about an ultra high flux reactor I feel that there are several kinds of reactors within that classification that should be studied. One is a reactor that is designed for radioisotope work exclusively, and I feel like a reactor of this kind would be very, very much cheaper than one that is designed to do all kinds of work. Anybody who has worked with reactors, built reactors, designed reactors, and knows where a lot of the cost goes, knows that it goes into the appurtenances of a reactor designed to do many different jobs. So I think that if it turns out that a reactor is not feasible for general research, that is from the standpoint of cost, I would like to say here and now that we shouldn't throw the idea of a high flux reactor out. It should then be considered for radioisotope work or for transuranic work or things of that type, and it might cost only one-tenth as much as the other type reactor in my opinion.

one of my old sermons. NB

I was right

Lane: Well, you can reverse that argument and say that if you are building the reactor for basic research, then you get it free for isotope production.

Rupp: Of course, this argument has always been used in the past, and this has never in dollars been true. I don't accept that argument at all.

Cole: I have come more and more to the conclusion that when you build reactors you should build them for a specific job.

He is agreeing with me.

Rupp: Absolutely, and that's the reason I feel that if it looks like you can't afford to build a general research reactor, I'd like to see us go ahead and study a radioisotope reactor for once.

Lane: It seems to me that it is going to be very difficult to put a dollar value on high flux neutrons for basic research. I think we are going to have to muster all of these arguments - the research, as well as the radioisotopes.

Rupp: Well, mind you, I'm not urging against that point, but I think the first time around that's alright. But if it turns out that having a general research

reactor of such high flux is out of the question. let's go back and look at it for a cheaper reactor for radioisotope work.

Lane: Well, would you be able to put a dollar value on how much more it would be worth for these high specific activity isotopes and high saturation isotopes? How much, based on your present business, would be the dollar sale of these isotopes per year on the material that you could make with high fluxes that you can't make now? Any idea?

Trying to pin me down.

Rupp: No, not right at the present time.

Lane: Could you derive that sort of number?

Rupp: I would have to put a lot of real crystal-balling in that, and if somebody pinned you down you would have a hard time bringing up enough supporting arguments.

Lane: We may have to stick our necks out on that sort of basis to get such a reactor.

Rupp: Well, let me put it this way. I think that we can come closer to putting a dollar value on it than anybody else can. I feel that there has not been one radioisotope reactor built in the entire world that I know of - there have been I don't know how many reactors built for power, for neutrons - there has never in the whole world been a reactor built for radioisotopes.

Comment: Now is no time to start! (Laughter) ← Typical of darts & arrows I has received in the last 15 years!

Rupp: No, on the contrary, I think it's time to build one for radioisotope work because this is one end of the nuclear energy business that has really proved itself, and there has never been a reactor designed and built for radioisotope work.

Lane: Yes there has, in Buffalo.

Rupp: Oh no, that's not a radioisotope reactor, that's a joke. You mean this cobalt reactor?

Lane: They are making as much from the cobalt as the steam!

Rupp: No, they may not build it until there is a guaranteed market for the cobalt.

Lane: Well, everybody that wants to build a pure radioisotope reactor can't justify the market, so it is never built. And we can for power & neutrons??

Turned out to be true also.

Cole: I think that your requirements are not essentially different from those for the transuranic elements.

Boyd: I do not think there is any merit in trying to put a dollar value on higher isotopes since you get yourself tied up ....

* And by golly, we still haven't. The Trans-U program has taken over the HFIR, except that I'm going to operate it! I'll let them pay the bills (~4-5 million/yr)

1104707

Rupp: Well, for example, on dollar value we can only talk about sales value. The actual value of something that we don't have now, that is something of very high specific activity, can't be ~~evaluated.~~ determined There is just no way of doing it.

Cole: You can evaluate it in terms of your own production, and how much of this money is tied up in the reactor end of it and how much is tied up in the products that come out of the reactor.

Rupp: Now if the reactor were designed with hydraulic tubes (HFIR is), and if it were designed specifically for radioisotope production where you could put loops in it and do continuous C 14 work, then you could prove it on a dollars and cents basis. I'm not saying the flux would be 10^{15}, however; it might still be a 10^{14} reactor.

Boyd: How many requests do you now get for high specific activity isotopes over and beyond what you can produce now?

Rupp: We get some requests for certain high specific activity isotopes, but I can't give a quantitative answer on this.

Boyd: What useful new radioisotopes can you get by multiple capture?

Rupp: We don't have enough information on this; there hasn't been enough work. I feel that there must be a lot of them, but I can't pinpoint them. I'm hedging

Lane: Haven't they ever irradiated material in the MTR to get multiple capture?

Rupp: There hasn't been any real production of these, at least not that I know of. still hasn't

Lane: Any other questions?

Snell: I would like to bring up another aspect of the matter that may be confusing to some people, I don't know. All of the isotopes produced in reactors comprise only one-half of the isotopic chart. What about using a cyclotron for producing isotopes in the lower half of the chart? Aren't there some attractive ones there that are useful?

Rupp: There are. We haven't done as much thinking along that line as we have the reactor-produced isotopes, but there definitely would be many of them that would be very useful. Your point is here whether it would be better to have a big cyclotron than have a big reactor?

Snell: No, not exactly. I didn't want to make it that sharp.

Lane: I don't understand what you mean by the lower half of the isotopic chart.

Rupp: The reference is to neutron deficient isotopes, specifically positron emitters, etc. These are isotopes we just don't have now at all. The field is wide open.

Snell: It is a really different point.

Fowler: Well, it's not completely different, however, since there is a matter of ultimate high flux that one can achieve with a machine. I think one can marshall arguments to the effect that the really ultimate in high flux is better achieved with a machine since the amount of heat which must be dissipated per neutron added is less at 900-Mev protons than it is for neutrons produced with fission. So if the limitation is the power you have to dissipate to get the high flux, the ultimate limit would be obtained with protons.

Lane: But so far that doesn't appear to be the limitation, at least from what we've heard today.

Fowler: Well, we haven't talked about ultimate high flux.

Rupp: I certainly haven't studied that too much, but I know that there are a lot of nuclides that would really be interesting if you could get them.

Snell: What I was really wondering - can one really develop a case for the 900-Mev cyclotron on the isotope production side. However, it would require horribly expensive running time, I believe.

Rupp: I know that most other cyclotron-produced radioisotopes have been very, very expensive. Well, usually there is a factor of 100 difference in unit cost.

Taylor: Do these procure any customers?

Rupp: Yes, most of these things are needed by research groups, groups that don't have a lot of money unless they have government contracts. I used to think that perhaps money didn't make any difference in buying such things as radioisotopes, and very often it makes up a very small amount of the total cost of the research project; but even so, for some reason or other which I don't understand, the price still seems to make a difference. A factor of 100 would make a real noticeable difference. Of course, there are some things that unless you get a reasonable amount of radioactivity you can't do good work anyway. That has been one of the limitations in cyclotron production - not being able to get enough to work with.

The seminar was adjourned by Mr. Lane.

And I'm think more all the time - I'm getting more & more interested in cyclotrons for certain purposes.

1104709