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Availability of Radioactive Isotopes

Announcement From Headquarters, Manhattan Project, Washington, D.C.

PRODUCTION OF TRACER AND THERAPEUTIC RADIOISOTOPES has been heralded as one of the great peacetime contributions of the uranium chain-reacting pile. This use of the pile will unquestionably be rich in scientific, medical, and technological applications.

Manhattan Project scientific, technical, and administrative personnel have, since the inception of the pile, been cognizant of its peacetime potentialities and have, since the end of the war, been active in attempting to realize these opportunities. Since, however, war-built piles and wartime researches had other objectives, a considerable transition in researches, developments, and operations connected with piles must be effected before the supply of radioisotopes can begin to meet the demand.

Comments on Availability of Radioisotopes

(1) A pile cannot make the extensive variety of radioisotopes producible with the cyclotron because the cyclotron makes use of a much greater diversity in energy and type of nuclear bombarding projectiles. Present piles are copious sources of low-energy neutrons, which can give rise to large yields only of isotopes produced by (n,f) and (n,γ) processes.

(2) Although large numbers of radioisotopes are produced in abundance by the fission of uranium in the piles, their availability is limited by the difficulties encountered in isolating them. It has not yet been found feasible to remove individual fission products from waste solutions of the plutonium extraction process. Most of the fission products being made available are not salvaged by-products of the plutonium process but are in each case items requiring special production from unprocessed irradiated uranium.

(3) Most of the radioisotopes in greatest demand, such as C 14, S 35, and P 32, must be produced by the irradiation of materials foreign to the pile. Existing piles were not designed for this purpose.

(4) Although a pile is a copious source of neutrons, it is not a limitless source. It is possible to load a pile for nonfission product radioisotope production only up to the limit at which so many neutrons are absorbed in the introduced material that the chain reaction ceases even though the control rods are withdrawn as far as feasible. With available pile facilities, this limit does not permit the production of a sufficient quantity and quality of many radioisotopes to meet anticipated national demands. To accomplish this it would very likely be necessary to build piles especially designed for the purpose.

(5) Technical problems involved in the irradiation of some materials have been, and will continue to be, responsible for delays in making certain isotopes available by routine irradiation. Examples of such problems are: (a) proper canning of the material to prevent rupture of the container by its internal action or by the external action of the coolant, with consequent loss of the material and damage to the pile; (b) careful purification to prevent loss of neutrons by absorption in impurities as well as undesirable radioactivity in the irradiated material; and (c) proper distribution of the material throughout the pile to prevent local overheating or undesirable regulation characteristics of the pile.

Organization for Allocation and Distribution

In accordance with the established custom of the Manhattan Project of seeking competent outside advice and aid on vital scientific matters, such as nonproject distribution of isotopes, Maj. Gen. L. R. Groves asked the president of the National Academy of Sciences to nominate a representative committee of outstanding scientists to recommend policies and aid in establishing arrangements for a desirable distribution of those tracer and therapeutic isotopes available from Manhattan Project facilities. An interim Advisory Committee on Isotope Distribution Policy was formed, two representatives being chosen from each of the major fields of isotope application: Physics—Lee A. DuBridge (chairman), head, Physics Department, University of Rochester, and president-elect of California Institute of Technology, Pasadena; and Merle A. Tuve, head, Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, D. C.; Chemistry—Linus Pauling, director, Gates and Crellin Chemistry Laboratories, California Institute

of Technology; and Vincent du Vigneaud, head of the Department of Biochemistry, Cornell University Medical College, New York City; Medicine—Cornelius P. Rhoads, director of Memorial Hospital, New York City, and chairman of the Committee on Growth of the National Research Council; and Cecil J. Watson, head of the Department of Medicine, University of Minnesota Medical School, Minneapolis; Biology—Raymond E. Zirkle, professor of botany and director of the Institute for Biophysics and Radiobiology, University of Chicago, Chicago, Illinois; and A. Baird Hastings, head of the Department of Biological Chemistry, Harvard University Medical School, Cambridge; Applied Science—Zay Jeffries, vice-president and manager of Chemicals Department, General Electric Company, Pittsfield, Massachusetts; and L. F. Curtiss, chief of the Radioactivity Section, National Bureau of Standards, Washington, D. C. Paul C. Aebersold, chief of the Isotopes Branch, Research Division, Manhattan District, was chosen acting secretary to coordinate the efforts of the Committee and to effect liaison with the Project.

The recommendations of this Committee on a suitable interim mechanism for allocation and distribution have been adopted without modification. This mechanism is as follows:

(1) All requests will be submitted to the Isotopes Branch, Research Division, Manhattan District, where each request will be reviewed with regard to all technical questions affecting the requester and the Project. This initial review will be made by a group of scientists in the Project who have had much experience in the production of radioisotopes and in technical matters concerned with their use.

(2) Nonproject requests will then be referred to an Advisory Subcommittee on Allocation and Distribution, which has been appointed by Gen. Groves on the nominations of the Distribution Policy Committee. This Subcommittee will have the responsibility of advising on the allocation and distribution of isotopes according to the scientific value of the intended application and the qualifications of the requester. It will operate under the supervision of the Distribution Policy Committee and in conformity with its approved policies. Its members are: K. T. Bainbridge (physics), Harvard University, chairman; J. W. Kennedy (chemistry), Washington University, St. Louis; J. G. Hamilton (biology and medicine), University of California; P. C. Aebersold (biophysics), Manhattan District, secretary.

(3) Each request for material for use in human beings will be referred by the Subcommittee on Allocation and Distribution to a Subcommittee on Human Application, which was similarly nominated and appointed. This Subcommittee will have final veto power on any distribution suggested for human application. Its members, chosen from among radiologists and clinicians experienced in radioisotope uses, are: Andrew H. Dowdy, University of Rochester, chairman; H. L. Friedell, Western Reserve University; G. Failla, Columbia University.

(4) Small Panels of Consultants, nominated by the Policy Committee from a number of specialized fields of possible isotope application and from various regions of the Nation, will be available as advisers on scientific matters connected with requests.

(5) Manhattan Project personnel have not been excluded from membership in any of the nonproject advisory groups. In many cases their membership has been strongly advocated by the Distribution Policy Committee.

(6) Effective liaison will be maintained between the Isotopes Branch of the Manhattan District Research Division, which initially receives and finally effects distribution on nonproject isotope requests, and the associated advisory groups whose functions are set forth above.

Principles of Allocation and Distribution

In establishing initial policies on the distribution of scarce materials, the criterion used has been the maximum benefit to the national welfare, due consideration being given to the limited amount of available material. The initial policies adopted are:

(1) Isotopes will be made available to individuals only through qualified institutions. The administration of the institution will make the necessary financial and legal arrangements, but the material will be allotted for the uses specified in the request.

(2) Secondary distribution of isotopes will not be sanctioned unless indicated and authorized under the original request or subsequently in writing through the accepted channels for requests.

(3) The initial order of priority adopted for the allocation of materials and of production effort is established according to intended use of the material, as follows: (a) publishable researches in the fundamental sciences, including human tracer applications, requiring relatively small samples; (b) therapeutic, diagnostic, and tracer applications in human beings and publishable researches in the fundamental sciences requiring larger samples; (c) training and education by accredited institutions in the techniques and applications of radioisotopes; and (d) publishable researches in the applied sciences. Allocation of material for researches which are not to be published or for routine commercial applications was considered by the Distribution Policy Committee not to fall within its responsibilities. Allocation for routine commercial

applications will be deferred until experience is gained with supplying the research needs previously mentioned. Special groups may then be established to advise on such allocation.

Production and Distribution Arrangements Within the Project

As indicated in the section on availability, none of the separate purified radioisotopes is in routine operational production. In some cases research groups have progressed only to the point of investigating how irradiations can best be performed to create a given isotope and how to isolate the isotope in small amounts. In other cases methods are under investigation in development groups for increasing the scale of irradiation and chemical processing. In a few cases it has now become possible to start placing irradiations and chemical processing into the hands of technical operations groups for routine "production."

Research into methods of small-scale creation of most of the isotopes took place widely before the establishment of the Project; since then, it has been carried on extensively by project laboratories engaged in nuclear research. Thus, credit for the results of research on radioisotopes is shared by many nonproject and project personnel. Most of the research within the Project in this regard has been done by nuclear physics and radiochemistry groups at Clinton Laboratories at Oak Ridge, at the Radiation Laboratory of the University of California, and at the Metallurgical and Argonne Laboratories of the University of Chicago.

The present "experimental-lot production" has been carried on largely by the Clinton Laboratories, which since July 1945 have been administered by the Monsanto Chemical Company. In the case of several isotopes in great demand, the Argonne Laboratory has cooperated in preparing materials in proper form for irradiation at Hanford and in testing the results. The Du Pont Company, operators of the Hanford Plant, has cooperated in making irradiations of materials possible at Hanford. The Monsanto Chemical Company has agreed to initiate the routine production of nationally demanded radioisotopes and to distribute them from the Clinton Laboratories under District Administration.

A Manhattan Project Technical Advisory Committee on Isotopes has been active in maintaining liaison between major laboratories of the Project on (1) production and distribution matters concerned with the national distribution program and (2) developments in radioisotope techniques and applications. This Committee is composed as follows: J. R. Coe, W. E. Cohn, R. McCullough, A. H. Snell, and K. Z. Morgan, of the Clinton Laboratories; W. H. Zinn, W. F. Libby, and R. E. Zirkle, of the Argonne and Metallurgical Laboratories; J. G. Hamilton, B. J. Moyer, and R. E. Connick, of the University of California Radiation Laboratory; J. H. Manley and R. Taschek, of the Los Alamos Scientific Laboratories; and, in regard to concentrated stable isotopes, H. L. Hull and C. E. Larson, of the Tennessee Eastman Corporation, Oak Ridge.

Details of Radioisotope Availability[1]

Pile-produced Radioisotopes

Radioactive isotopes are created in chain-reacting piles by two processes: (1) the fission of U 235 nuclei, which maintains the chain reaction, and (2) neutron absorption by nonfissionable nuclei placed in the pile for the purpose. The former—the so-called "fission products"—exist as a mixture of many radioactive species, each free of significant amounts of stable (carrier) isotopes, in a large amount of the parent substance, uranium. The desired radioisotope must subsequently be separated from uranium and from the other fission products, as well as from any neptunium and plutonium formed by neutron capture in U 238. In the chemical process actually used, the fission products are separated from the mixture either as individual radioactive species or as groups of species (Col. 1, Table 1).

The Fission Products

The methods now in operation for the preparation of fission-product radioisotopes were developed to meet certain definite specifications, which in turn were set by the biological work in which the radioactive materials were to be used. These specifications called for 0.1–1.0 curie[2] amounts of each of the major fission products in carrier-free, essentially solid-free (<10 mg./curie) form, and radiochemically pure (>90–98 per cent, depending on the species); smaller or less pure amounts of minor species were also required. The radiation intensities involved in working with mixtures of fission products at the curie level required the invention and use of chemical processes which were remotely controlled from behind specially constructed lead and concrete barriers and were economical of material. For these reasons the existing processes and equipment are not suited to isolate fission products in forms radically different from those listed. However, since these methods permit the isolation without carrier of nearly every fission product of half-life from 1 week to 30 years and occurring in significant amount, this inflexibility is not considered to be a handicap.

[1] Only those radioisotopes of half-life greater than 12 hours are considered.

[2] The curie is here defined as 3.7×10^{10} disintegrations/second. [See statement by Condon and Curtis, p. 712. Ed.]

Those fission-product radioisotopes which can now be isolated[3] from pile uranium in moderate quantity and good quality without added carrier are listed in Tables 1, 2, and 3. In Table 1 are given also the latest data on half-life and radiation energies for each radioelement involved and also the properties of daughter radioisotopes which will be present. The *temporarily or indefinitely delayed in fulfillment*. The activity stated in this column is related to the figures giving volume and other characteristics of the preparations.

The letters in the column headed "Class" are an attempt to indicate approximate availability and have the following meanings: A: usually on hand (long

TABLE 1*

FISSION PRODUCTS†

Group	Radioisotope	Half-life	Energies β Mev	Energies γ Mev	Radioactive daughters: Isotope	Half-life	Energies β Mev	Energies γ Mev	Probable contaminants	Approx. max. unit quantity which may be made available: Curies	Carrier added: Mg.	Solids present (nonvol.): Mg.	Solvent	Volume: Ml.	Class
I‡	Zr 95	65 d	1.0§ 0.39§	0.73	Cb 95	35 d	0.15	0.75	.....	1	0 ~ 0		½% – $H_2C_2O_4$	50	A
	Cb 95	35 d	0.15	0.75	None										
II	Y 91	57 d	1.8	.....	None				61	1	0 ~ 0		HCl	< 25	A
III‡	Ce 141	28 d	0.6	0.22	None				Pr	1	0 ~ 0		"	"	A
	Ce 144	275 d	0.35	.....	Pr 144	17 m	3.1	.....							
IV	Ba 140	12.8 d	1.05 0.4	0.5	La 140	40 h	1.4, 2.2	1.63‖	Sr	1	0 ~ 0		"	"	B
V‡	Sr 89	53 d	1.5	.....	None				Ba	1	0 ~ 0		"	"	A
	Sr 90	25 y	0.6	.....	Y 90	65 h	2.2	.....							
VI‡	Pr 143	13.8 d	1.0	.....	None				Ce, Y	0.1	0 ~ 0		"	"	B–C
	Nd 147	11 d	0.17 0.85	0.6	61 147	~ 4 y	0.2	.....							
	61 147	~ 4 y	0.2	.....	None										
	Eu 156	15.4 d	0.5 2.5	2	None										
	Eu 155	2–3 y	0.2	0.084	None										
VII	Cs 137	33 y	0.5 0.8	0.75	None				.....	0.01	0 ~ 0				A
VIII‡	Ru 103	42 d	0.2 0.8	0.56					.....	0.1 0.1	0 ~ 0		"	< 25	A–B
	Ru 106	1 y	< 0.005	.....	Rh 106	30 s	3.9	.....							
	Te 127	90 d	0.7	0.086											
	Te 129	32 d	1.8	0.1 0.3 0.8											

* Most data in this table are hitherto unpublished M.E.D. work.
† For I 131, see Tables 3 and 6.
‡ Specific composition depends on age.
§ Two per cent 1.0 Mev and 98 per cent 0.39 Mev.
‖ Complex spectrum.

values in the columns headed *"Approximate maximum unit quantity which may be made available" give essentially the amount which may be supplied at one time; requests for more than this amount may be* half-life permits stock-piling); B: often on hand (shorter half-life does not permit stock-piling); C: seldom on hand; produced on experimental basis only; D: not on hand; can be done but with difficulty.

Inasmuch as a routine production system, with attendant control and standards, does not exist, *no*

[3] It must be emphasized that no routine production system yet exists. The radioisotopes being made available at this time are the results of research and development proceedings.

guarantees of radiochemical or chemical purity or other such characteristic of any entry in any table may be made, although every effort will be made to turn out as high a quality of material as possible. Information relating to the known characteristics of any preparation will be furnished.

To obtain an isotope of this kind involves the insertion of the element, in a suitable form,[4] into the pile and its subsequent removal. Even though in some cases (n,p) radiocontaminants are produced along with the desired (n,γ)-induced radioisotope, no chemical separation process on the active material will be done prior to shipping (hence the term "service irradiation" to describe such an activation). In order to utilize the available facilities most efficiently, these materials will be exposed in the same containers in which they will be shipped, and only certain quantities will be irradiated. Therefore, *those radioelements supplied without processing will be available only in units which are 1, 0.1, 0.01, and (sometimes) 0.001 part of the quantities listed under "Approximate maximum unit quantity which may be made available."*

TABLE 2

FISSION PRODUCTS

(Derived from products in Table 1)

Source (Group in Table 1)	Radio-isotope	Probable radioactive contami-nants	Approx. max. unit quantity which may be made available	Carrier added	Solids present (nonvol.)	Solvent	Volume	Class
			Curies		Mg.			
I	Cb 95	Zr	0.05	0		½% $H_2C_2O_4$	< 25 ml.	C
VIII	Ru 103 / Ru 106		0.05	0	~0	HCl	"	C
VIII	Te 127 / Te 129		0.05	0	~0	"	"	C
VI	Pr 143*	Nd, 61	0.02	0	~0	"	"	C–D†
VI	Nd 147	Pr, 61	0.02	0	~0	"	"	C–D†
VI	61 147	Pr, Nd	10^{-4}	0	~0	"	"	C–D†

* See Table 6. † Depends on purity required and age.

Nonfission Radioisotopes

In Tables 4–6 are listed those neutron-induced radioisotopes of half-life greater than 12 hours which are known or believed to be producible in the pile.

(1) *Non-carrier-free radioisotopes; simple (n,γ) reactions* (Table 4). The most prominent reaction is simple neutron absorption, yielding a radioactive element isotopic with the parent element. This is the (n,γ) reaction (Table 4), which differs from transmutation and fission reactions in that carrier-free material is *not* produced (except in those few cases where a radioactive chain is begun).

TABLE 3

FISSION PRODUCTS

(By-products usually on hand in impure form)

Radio-isotope	Quantity usually available	Carrier added	Solids (nonvol.)	Solvent	Volume	Class
	Curies	Mg.	Mg.			
Sr 89 / Sr 90 *	1	0	~0	N/2 HCl	< 25 ml.	A
I 131†	0.1	0	~0	N/10 HNO_3	< 25 ml.	B
Ba 140*	1	>0	>0	N/2 HCl	< 25 ml.	B

* See Table 1 for radiation characteristics of isotopes and daughters.
† See Table 6.

(2) *Carrier-free radioisotopes* (Tables 5 and 6). Transmutation reactions yield radioisotopes which differ chemically from their parents and hence exist *without*[5] stable isotopic "carrier." Only a small number of elements are known to undergo (n,p), (n,α), etc. reactions to any appreciable degree in the pile; however, the few which do yield some of the most important radioelements (Table 5). In addition to these types, in which transmutations are effected, there is a group of (n,γ)-induced decay chains which can be utilized to yield carrier-free material (Table 6). In this case a radioisotope produced by a (n,γ) re-

[4] In many cases it is advisable to irradiate elements in the form of a compound. The particular compound selected must be such as to lend itself to irradiation under the expected pile conditions. Undesirable radioactive species and unsatisfactory containers must be avoided. For these and other reasons, the materials to be exposed in the pile for radioisotope production will usually be supplied and packaged by the Project.

[5] Except for impurities below detectable levels.

TABLE 4

LONG-LIVED RADIOACTIVE ISOTOPES PRODUCIBLE IN PILE BY (n,γ) REACTIONS
(Items in italics—Manhattan Project data)

Active isotope	Half-life	Radiation Mev β	Radiation Mev γ	Approx. specific activity (mc./gram element)*	Approx. max. unit quantity which may be made available*	Class
Na 24	14.8 h	1.4	1.4, 2.8	250	100 mc.	A
P 32	14.3 d	1.69		72	500 mc.‖	A
S 35†	87.1 d	*0.17*		1.0	1 mc.‖	D
Cl 36†	*10^6 y*	*0.66*		~ 0.002	10 μc.	D
K 42	12.4 h	3.5	?	20	1 c.	D
Ca 41	8.5 d	K	1.1	0.34	10 mc.	D
Ca 45	180 d	*0.3*		3.8	100 mc.‖	C
Sc 46†	85 d	0.26; 1.5	1.25	125	1 mc.	C
Ti 51	72 d	0.36	1.0	0.13	1 mc.	D
Cr 51	26.5 d	K	*0.32*	70	100 mc.	C
Fe 55	~ 4 y	K		0.07	100 μc.	C
Fe 59	*44 d*	0.26; 0.46	1.1, 1.3	0.15	1 mc.	C
Co 60	5.3 y	0.3	1.1, 1.3	48	100 mc.	B
Ni 59	*15 y*	*0.05* β^+			10 μc.	D
Cu 64	12.8 h	0.58 β^+; 0.66 β^-		440	10 mc.	C
Zn 65	250 d	0.4 β^+; K, e-	1.14	3.6	100 mc.	D
Zn 69	13.8 h	I.T.; 1.0	0.439	10	100 mc.	D
Ga 72	14.1 h	*3.4*; 0.8	0.84, *2.25*	230	100 mc.	C
Ge 71 ‡	11 d	*0.6*	0.5	14	100 mc.	D
Ge 77	12 h	1.9		0.9	10 mc.	D
As 76	26.8 h	1.1, 1.7; 2.7	0.57, *1.25*	770	100 mc.	C
Se 75	*125 d*	K, e-	*0.18, 0.35*	5.6	100 mc.	D
Br 82	34 h	0.465	0.547, 0.787; 1.35	170	100 mc.	C
Rb 86	19.5 d	1.60		52	100 mc.	D
Sr 89	53 d	1.5		0.2	10 mc.¶	D
Y 90	65 h	2.5		150	100 mc.¶	C
Zr 95‡	*65 d*	1.0, 0.39[z]	*0.73*	0.32	¶	D
Mo 99‡	67 h	1.3	0.24, *0.75*	12	100 mc.	D
Ru 103	*42 d*	0.2, *0.8*	0.56	6.4	10 mc.	D
Ag 108, 110	225 d	*1.3*	0.6, 0.9	10	100 mc.**	D
Cd 115 ‡	*2.8 d*	1.11	0.65	33.2	10 mc.	D
Cd 115	*43 d*	1.5		1.6	1 mc.	D
In 114	48 d	I.T., e-; 2.0	0.19	200	100 mc.	C
Sn 113	< 100 d	K, e-	0.085	0.26	1 mc.	D
Sb 122	2.8 d	0.81, 1.64	0.8	400	100 mc.	C
Sb 124	60 d	0.74, 2.45	1.72	33		C
Te 127 ‡	90 d	I.T., e-; *0.7*	0.086	0.3	10 mc.¶	C
Te 129	32 d	I.T., e-; 1.8	0.102; *0.3, 0.8*	0.3		C
Te 131	30 h	I.T. β^-	0.177	0.3		C
Cs 134	2 y	*0.75*	*0.8*	200	1 c.¶**	C
Ba 131‡	12 d	K, e-	*1.2* (?)	0.44	10 mc.¶	C
La 140	40 h	1.4, 2.2	1.63§	760	100 mc.¶	D

[z] Two per cent 1.0 Mev and 98 per cent 0.39 Mev particles.

TABLE 4—(*Continued*)

(Items in italics—Manhattan Project data)

Active isotope	Half-life	Radiation Mev β	Radiation Mev γ	Approx. specific activity (mc./gram element)*	Approx. max. unit quantity which may be made available*	Class
Ce 141 } †	28 d	0.6	0.22	90	100 mc.¶	C
Ce 143 }	33 h	*1.36*	*0.5*	22	100 mc.¶	C
Pr 142	19.3 h	2.14	1.9	750	100 mc.**	C
Eu 154	6.5 y	0.9	Present	250	100 mc.	D
Ta 182	97 d	*0.53*	1.22, *1.13*§	300	100 mc.	C
W 185	77 d	0.6	?	10	100 mc.	C
Os 191 }	32 h	1.5	Present	44	100 mc.	D
Os 193 }	17 d	0.35	Present	103	100 mc.	D
Ir 192, 194	19 h 70 d	2.2 Present	1.35 0.3, 0.4	~ 250	100 mc.	C
Au 198	2.7 d	0.8	0.12, 0.44	6,000	100 mc.**	C
Hg 197 }	64 h 25 h	K, e⁻ K, e⁻	0.075 0.13, 0.16	11	100 mc.	D
Hg 203, 205 }	51.5 d	*0.3*	0.28	16	100 mc.	D
Tl 206	3.5 y	0.87		2	10 mc.	D
Bi 210‡	5.0 d	1.17		9	10 mc.	C

* May be raised in special circumstances.
† Radioactive contaminant will be present from (n,p) reaction.
‡ Radioactive (nonisotopic) daughter will be present.
§ Complex.
‖ See Table 5.
¶ See Tables 1–3.
** See Table 6.

action decays to a radioactive daughter which is nonisotopic with its parent and with the source material.

A separation of the desired active species from the stable parent and from any (n,γ)-induced radioisotopes of this parent must usually be made before use. Since the parent exists in bulk and there is often formed a large amount of radioactive material which is isotopic with the parent, the processing is not always a simple matter. The same considerations hold in the case of daughters of neutron-induced decay chains.

Again, because of the desire to make available the greatest number of radioisotopes, *such carrier-free species will usually be supplied in the irradiated material, unseparated from the parent and radioisotopes of the parent.* In these cases, as in all others, any

TABLE 5

RADIOACTIVE ISOTOPES FROM TRANSMUTATION REACTIONS

(Items in italics—Manhattan Project data)

Method of formation	Active isotope	Half-life	Radiation Mev β	Target material	Yield mc./gram element irradiated	Conditions for shipment (C.F. = carrier-free)	Approx. max. unit quantity which may be made available	Class
(n,p)	C 14	~ 25,000 y	0.145	$Ca(NO_3)_2$		$BaCO_3$	1 mc.	A
	P 32	14.3 d	1.69	S	0.5*	In S C.F. in 0.1 *N* HCl	500 mc.†, ‡	B B
	S 35	87.1 d	*0.17*	KCl or other chloride	1.5*	In KCl C.F.	10 mc.†	B D
	Ca 45	180 d	*0.3*	Sc_2O_3	0.57*	In Sc C.F. in conc. HCl	100 μc.†, ‡	C C
(n,α)	H 3	~ 31 y	0.015	Li salt		Unavailable at present		

* Experimental data.
† See Table 4.
‡ May be raised in special circumstances.

pertinent experience in a particular separation will be made available. In a few cases, where the element is rare or where the separation is too hazardous to be accomplished without special facilities, only separated material will be supplied.

The symbols in the "Class" column of Tables 4, 5, and 6 have essentially the same meaning as those in Tables 1, 2, and 3 except for "D," which here indicates a reaction which has been reported but has not yet been checked by present personnel.

Pile Irradiation Services for Other Than Radioisotope Production

Materials to be exposed in the pile for radioisotope production will usually be supplied and packaged by the Project. The reasons for this are: (1) to insure that materials and containers introduced into the pile for the desired radioisotope production have minimal parasitic neutron absorption and minimal subsequent radioactivity, and (2) to avoid the possibility of loss of the irradiated material or of danger to the operation of the pile.

Requests for special irradiations, in which the requester desires to furnish the material, may arise because of: (1) other intended purposes than radioisotope production or (2) especially prepared or very rare materials. Such irradiations may require special handling which will be difficult to arrange during the inauguration period of the radioisotope distribution program. When sufficient experience has been gained in handling the normal irradiations and when a scale of charges is determined, special irradiation services may be announced.

Availability of Concentrated Stable Isotopes

In answer to numerous inquiries some brief comments are in order regarding the Project's ability to furnish concentrated stable isotopes. Arrangements have been completed thus far for the production, allocation, and sale of radioisotopes only. It may require considerable time to arrange these matters for such concentrated stable isotopes as may become available in excess of project needs.

The situation in regard to availability is now as follows:

(1) *Deuterium.* There is no heavy water or H 2 available.

(2) *Boron 10.* Small amounts of highly concentrated B 10 may be available for special neutron counter purposes. Prices and distribution mechanism are yet to be determined. These will be announced when arranged.

(3) *Carbon 13.* This isotope is mentioned separately only because of the wide interest in it for tracer purposes, particularly in organic chemistry and biology. There are no project facilities which can at present be converted to concentrate C 13 in production amounts without great expense both in the conversion of equipment and in operation. The cost of C 13 based on operational expenses alone would be considerably higher than costs quoted for C 13 concentrated by chemical exchange methods.

(4) *Isotopes of elements 3 to 82.* Small experimental lots of isotopes of nongaseous elements have been concentrated for project nuclear researches using electromagnetic pilot plant facilities of the Tennessee Eastman Corporation at Oak Ridge.

TABLE 6

Radioactive Isotopes From (n,γ)-produced Chains

(Items in italics—Manhattan Project data)

Active daughter isotope	Half-life	Radiation Mev β	Radiation Mev γ	Target material	Half-life of parent	Yield mc./gram element irradiated	Conditions for shipment	Approx. max. unit quantity which may be made available	Class
As 77	*40 h*	*0.8*		GeO_2	12.0 h	0.9	In GeO_2	1 mc.†	D
Rh 105	36 h	0.5		RuO_2	4.0 h	7.2	In RuO_2	10 mc.	D
Ag 111	7.5 d	0.8		Pd	26 m	9.7	In Pd	10 mc.	C
I 131	8.0 d	0.6	0.367 0.080	Te	30 h	2.5*	In Te C.F. in 0.5 *N* H_2SO_4	100 mc.	B C
Cs 131	*10.2 d*	*K*		*$BaCO_3$*	*12 d*	~ 0.4*	In $BaCO_3$ C.F. in 0.1 *N* HCl	100 μc.†	B C
Pr 143	13.8 d	1.0		CeO_2	33 h	9.1*	In Ce C.F. in 0.1 *N* HCl	10 mc.†	B C
Au 199	3.3 d	1.01	0.45	Pt	31 m	19.3	In Pt	†	D

* Experimental data. † See Table 4.

Studies have only recently begun on production costs and on the obtainable quality and quantity of concentrated materials. In general, production is quite expensive, and it is difficult to achieve the high isotopic purity desired for many nuclear studies. Arrangements may be formulated for nonproject distribution of experimental lots after more experience has been gained with concentration and assay methods and after project needs become more clear.

As the situation warrants, announcements will be made concerning the availability of concentrated stable isotopes.

Charges

Charges will be made for irradiated materials and processed isotopes, as is the case for many widely useful products resulting from other research efforts. Pending experience, a reasonable charge is considered to be one based on the "out-of-pocket" operational expenses necessitated by the nonproject production and service program. Charges will not include costs of rental, or construction of plant and major facilities or of research and development directed toward the supplying of isotopes in general. The Project will supply the major facilities and develop the production methods, but will assess a charge for the additional running expenses of man power and materials incurred by the filling of nonproject requests. Shipping expenses will be paid by the requester. Details of these arrangements and the prices to be charged may be obtained upon request from the Isotopes Branch of the Manhattan District Research Division.

Mechanism for Making Requests

As explained in the section on "Principles of Allocation and Distribution," radioactive materials will not initially be distributed directly to private individuals but only to accredited institutions or organizations. However, materials will be allocated to an individual or a department for the specific uses proposed in the request.

A request may be initiated by a responsible applicant in an accredited institution by a short letter to the Isotopes Branch, Research Division, Manhattan District, P. O. Box E, Oak Ridge, Tennessee. This letter should request application forms, price quotations, and any essential information not contained in this notice. It should indicate briefly the radioisotopes desired, the approximate quantities needed, and the use to be made of the materials. If the desired material can be produced or made available and the intended use is one for which the isotope is suited, application forms will be furnished the applicant. These forms will permit applicants to supply in a concise and uniform manner the necessary detailed information on the basis of which the reviewers and the nonproject Advisory Subcommittee on Allocation and Distribution will be able to recommend action.

Action on an initial formal application cannot be initiated unless it has been indicated on the application that, when material is allotted, an "Agreement for Order and Receipt of Radioactive Materials" will be negotiated by the business administration of the requesting institution. This agreement relates to business and legal responsibilities in connection with the ordering, receipt, application, and disposal of radioactive materials by the applicant. The honoring of subsequent applications from the same individual or department can be arranged on a continuing basis by the indication of authorization for this in the originally negotiated agreement. All correspondence concerning requests and all forms should be addressed to the Isotopes Branch, as indicated above.