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RADIOISOTOPE PROGRAM (8000)

PROGRESS REPORT FOR OCTOBER 1972

A. F. Rupp

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ISOTOPES DEVELOPMENT CENTER

RADIOISOTOPE PROGRAM (8000) PROGRESS REPORT FOR OCTOBER 1972

A. F. Rupp

Work Sponsored by
AEC Division of Applied Technology

NOVEMBER 1972

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RADIOISOTOPE PROGRAM (8000) PROGRESS REPORT FOR OCTOBER 1972

A. F. Rupp

RADIOISOTOPE PRODUCTION AND MATERIALS DEVELOPMENT

REACTOR-PRODUCED ISOTOPES — 08-01-01

A. Biomedical Radioisotopes

1. Phosphorus-33 *(T. A. Butler)*

The purpose of this project is to develop methods of preparing hundred-millicurie quantities of carrier-free phosphorus-33 containing ≤ 5% phosphorus-32. The two methods for producing phosphorus-33 being evaluated are based on the irradiation of highly enriched targets of sulfur-33 (>92 at. %) or chlorine-36 (approximately 63 at. %) in a fast neutron flux. Phosphorus-33 (25.2 days; 0.248-MeV β^-_{max}) has both a longer half-life and a lower energy beta than phosphorus-32 (14.3 days; 1.709-MeV β^-_{max}), which makes it advantageous for autoradiography, longer ecological and agricultural experiments than with phosphorus-32, synthesis of tagged complex organophosphorus compounds, and double labeling experiments.

The disagreement between product and in-process analyses referred to in the August report seems to be resolved with the addition of carrier phosphorus in the analytical technique. The process analyses use the technique developed by L. C. Brown[1] in which Cab-O-Sil is added to prevent geometry change due to adsorption of carrier-free phosphorus on the glass vials. The agreement between the process and product analyses is now within 5%, and the previous bias seems to have been eliminated.

A 1.06-g $K^{36}Cl$ target was processed after four irradiation cycles. The product yield two weeks after discharge was 800 mCi of phosphorus-33, but the phosphorus-32 activity was 13%. Another target had been processed earlier in which the phosphorus-32 activity was 20%, yet the chlorine isotopic ratios showed no degradation of enrichment. The problem appears to be caused by incomplete removal of sulfur in the $BaSO_4$ precipitation. Iron is added in the form of $Fe_2(SO_4)_3$, and the recovery of the $K^{36}Cl$ target entails addition of a stoichiometric amount of $Ba(OH)_2$ to remove $BaSO_4$. Even when spark source mass spectrographic analysis shows presence of excess barium in the $K^{36}Cl$, it is possible for sulfur

[1] L. C. Brown, "Determination of Phosphorus-32 and -33 in Aqueous Solution," *Anal. Chem.* 43(10), 1326-8 (August 1971).

to remain if the $BaSO_4$ precipitation did not result in a good filterable precipitate. We will test a modified procedure in which the iron, in the form of freshly precipitated $Fe(OH)_3$, is added to the target solution which has been converted to $H^{36}Cl$ by passage through a H^+-form cation column. Reprecipitation of $Fe(OH)_3$ will then be accomplished with cesium-free KOH.

A review of the literature on the phase diagram for mixtures of K^+, NH_4^+, Cl^-, and NO_3^- was made, and an experiment was performed on inactive materials to confirm the reason for the observed loss of chlorine-36 in a previous target contaminated with nitrate. The decomposition temperature of NH_4NO_3 is 210°C and the sublimation temperature for NH_4Cl is 337°C. Considerable weight loss occurs at lower temperatures, and the phase diagram for the mixtures of ammonium and potassium salts indicates that the presence of even small amounts of NH_4NO_3 will result in loss of $NH_4{}^{36}Cl$ on heating. An experiment was performed in which 1 ml of 1 *M* nitric acid was added to a weighed amount of KCl in solution and neutralized with NH_4OH. A positive test result for nitrate ion and a 10% weight gain in the recovered KCl implies that conversion of chloride to nitrate occurs during firing at 450°C. This result indicates the importance of excluding nitrates from the chemical procedure.

2. Potassium-43 *(T. A. Butler)*

The objectives of this project are to prepare potassium-43 by the $^{43}Ca(n,p)^{43}K$ reaction, using isotopically enriched ^{43}CaO targets and to establish cooperative programs with medical institutions to evaluate it. Potassium-43 is potentially useful for metabolic and clinical studies of blood flow, rejection of transplanted organs, and kidney function. The half-life of potassium-43 is 22.5 hr; gamma-rays are 0.373 and 0.617 MeV.

Three batches of potassium-43 were processed this month. There have been a few new inquiries regarding potassium-43 with indication that several new institutions will begin potassium-43 studies for myocardial applications and that one is interested in its renal imaging possibilities. We are now investigating the possibilities of achieving the production goal of hundred-millicurie batches.

3. Silicon-32 *(T. A. Butler)*

Silicon-32 (∿650 year) exhibits many desirable physical decay characteristics that make it an interesting and attractive radionuclide for a variety of uses: (1) the only long-lived radionuclide of silicon for use in agriculture, geology, solid-state physics, etc., (2) as a parent for a ^{32}Si-^{32}P generator system which would offer a constant supply of phosphorus-32 for medical and scientific application, and (3) as a long-lived Cerenkov counting

standard for phosphorus-32 determinations. Reactor production of silicon-32, which will be investigated initially, can occur via three completely different reaction paths: (1) $^{30}Si(n,\gamma)^{31}Si(n,\gamma)^{32}Si$, *(2)* $^{31}P(n,\gamma)^{32}P(n,p)^{32}Si$, *and (3)* $^{34}S(n,\gamma)^{35}S(n,\alpha)^{32}Si$. *Silicon-32 can also be prepared in large quantities via the spallation reaction using high-energy (>100 MeV) protons and will be investigated in collaborative efforts with other AEC laboratories as high currents of these high energy protons become available.*

The silicon-32 content of the three-cycle $AlPO_4$ target described earlier[2] will be determined by analyzing for the phosphorus-32 in secular equilibrium with the silicon-32. A high-purity phosphorus-32 standard with minimum phosphorus-33 contamination (phosphorus-33 content estimated to be $\leq 0.013\%$ of the phosphorus-32 as of end of bombardment) was prepared for final counting equipment calibration. An enriched $K_2{}^{32}SO_4$ target (99.86 at. % sulfur-32) was irradiated in the hydraulic tube of the HFIR, and the phosphorus-32 was purified via the chemical processing used for phosphorus-33 production. Gamma-ray pulse-height spectra of this preparation, obtained using both a high-resolution Ge(Li) detector and a high-efficiency NaI(Tl) detector, have shown no gamma-emitting radiocontaminants. Beta decay curves for this sample will also be obtained by both Cerenkov and liquid scintillation counting to ensure its freedom from undesired beta-emitting radiocontaminants. An aliquot of this preparation will be submitted to NBS for standardization during November. The counting equipment to be used for the silicon-32 yield determination will be standardized simultaneously.

4. Gadolinium-153 *(T. A. Butler, F. N. Case)*

Gadolinium-153 (242 days) offers potential as a useful and important radionuclide due to its favorable physical decay characteristics, e.g., it decays solely by electron capture to stable europium-153 with 97- and 103-keV gamma rays and europium x-rays as the predominant accompanying photon emissions. This energy range is useful for various types of gaging and transmission bone-scanning applications. The neutron burned-out europium control plates from HFIR offer a by-product source of highly enriched gadolinium-152 that would be prohibitively expensive to match by calutron separations.

a. Recovery of Gadolinium-152 from HFIR Control Plates

Development of in-cell apparatus for the HDEHP solvent extraction separation of Gd(III) from chemically reduced Eu(II) has continued since the

[2]A. F. Rupp, *Radioisotope Program (8000) Progress Report for September 1972*, ORNL-TM-4002, Oak Ridge National Laboratory.

last reporting of this item.[3] This equipment has been tested successfully at tracer levels and will be installed in the cell for full-scale production next month.

Three batches of gadolinium-152 were prepared as feed for use in scaling up a laboratory-demonstrated extraction process for the separation of gadolinium and europium. The gadolinium-152 was obtained by selection of segments from a spent HFIR control plate composed of natural europium.

b. Purification of Gadolinium-153

Previous experience with gadolinium separated from HFIR europium control plates for use as reactor target material indicates that there are sufficient high mass gadolinium isotopes present to produce appreciable terbium-160 (72.4 d) via the $^{158}Gd(n,\gamma)^{159}Gd(\beta^- \text{ decay})^{159}Tb(n,\gamma)^{160}Tb$ reaction path. Following irradiation, the gadolinium will be separated from the terbium-160 and all other 3+ rare earths by high-pressure, ion-exchange chromatography. Initial attempts to separate approximately 50-mg quantities of mixed Tb-Gd-Eu oxides by high-pressure ion exchange have been very successful. Greater than 98% of the gadolinium was recovered with <0.01% terbium or europium contamination. Additional development work will be pursued next month to characterize and optimize column performance and capacity, elution conditions, equipment design, and product purity.

B. Reactor Products Pilot Production
(Production and Inventory Accounts) *(R. W. Schaich)*

Processed Units		Service Irradiations	
Radioisotope	Amount (mCi)	Type	Number
Calcium-47	10	None	
Copper-67	1.4		

ACCELERATOR-PRODUCED ISOTOPES — 08-01-02

A. Gadolinium-148 Production Estimates *(E. Lamb)*

Because of the absence of any gamma, x-ray, or neutron emissions in the decay scheme of gadolinium-148, this isotope would be extremely useful in applications requiring very low radiation levels if it could be produced in sufficient quantity. Gadolinium-148 has a half-life of 93 years, a specific activity of 26 Ci/g, a power density of 0.504 W per gram of pure isotope, and emits a 3.27-MeV alpha particle. High-energy particle accelerators, such as BLIP or LAMPF, would probably afford the most likely means of producing gadolinium-148 by either a compound nucleus or a spallation reaction on target nuclei three or more mass units removed from gadolinium-148.

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[3]A. F. Rupp, *Radioisotope Program (8000) Progress Report for July 1972*, ORNL-TM-3942, Oak Ridge National Laboratory.

The production rate in BLIP by proton bombardment of a natural europium thick target is estimated to be 22 mCi of gadolinium-148 per day, or 0.426 mW/day.[4] The reaction assumed is a compound nucleus reaction of the type, $^{nat}Eu(p,xn)^{148}Gd$.

The gadolinium-148 production rate in LAMPF was estimated using the approximate thick target yield equation given in LA-DC-11982, p. 8 (1971), and a thin target cross section of ∿20 mb for 1-1/2-in.-thick holmium-165 targets and for protons of 700-MeV energy.[5] The estimated gadolinium-148 production rate is 4.2 mCi/day in each target, or ∿50 mCi/day for 12 targets utilizing the total beam of 500 μA. Since a spallation reaction is involved, the recovery of gadolinium-148 from the target would be complicated by other radionuclides produced during the bombardment.

The production rate in an accelerator was estimated for the $^{147}Sm(\alpha,3n)^{148}Gd$ reaction, assuming an alpha-particle energy of 55 MeV and a beam current of 15 μA and using an estimated excitation function.[6] The estimated production rate is 22 μCi/day, approximately a factor of 1000 lower than the BLIP or LAMPF production rate.

A 2.0-g target of light europium isotopes was bombarded with 42-MeV protons in the LRL 88-in. cyclotron at a beam current of ∿15 μA to a total irradiation of 1700 μA-hr. The yield of gadolinium-148 from this irradiation was 225 μCi, or ∿48 μCi/day.[7]

These calculations, although based principally on estimated values rather than experimental evidence, indicate that the maximum production rate of gadolinium-148 in BLIP or LAMPF would be in the range of 20 to 50 mCi/day (0.4 to 1.0 mW/day). The low predicted production rate would negate the use of gadolinium-148 in such applications as the cardiac pacemaker, which requires ∿150 mW_t in one unit. An extensive production development program for gadolinium-148 production is not indicated; however, we plan to discuss with BLIP personnel the possibility of an irradiation to obtain experimental production data for comparison with the theoretical predictions.

B. Cyclotron Products Pilot Production (Production and Inventory Accounts) *(L. O. Love)*

October 1972 ORNL 86-Inch Cyclotron runs for ORNL and non-ORNL programs are given in Table 1.

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[4]L. G. Stang *et al.*, *The Production of Radioisotopes by Spallation*, BNL-50195 (T-547), Brookhaven National Laboratory (August 1969).
[5]H. A. O'Brien, LASL, personal communication.
[6]Jürgen Lange and Helmut Münzel, *Estimation of Unknown Excitation Functions for (x,xn)-, (α,pxn)-, (d,xn)-, and (p,xn)-Reactions*, Karlsruhe Nuclear Research Center Report KFK-767, May 1968 (ORNL-tr-3020).
[7]Frank Asaro, LRL, Berkeley, personal communication.

Table 1. Cyclotron Irradiations and Runs for October 1972

Product	No. of Runs	Time (hr:min)	Total Charges
	ORNL Programs		
Gallium-67	3	18:30	$ 1,778
	Non-ORNL Programs		
Cobalt-57	1	51:15	$ 8,708
		69:45	$10,486

FISSION PRODUCTS — 08-01-03

A. Krypton-85 Enrichment *(R. A. Robinson)*

All six thermal diffusion units are now shut down. Unit D, on a low-level run, developed a water leak through the cooled tube and the light isotope end of the tube string was flooded. Since the cause of the leak was unknown and, if general corrosion caused the perforation, all the other tubes were probably in danger of failure also, all the units were shut down and the product material withdrawn.

A volume of 0.83 liter of 33.3% krypton-85 and 1.56 liters of 25.8% material along with several liters of krypton enriched to lower concentrations of mass 85 were recovered as salable material.

The low-level and depleted ends will be removed and stored, and the thermal diffusion tubes will be pulled out for inspection to determine the reason for the failure.

B. Cesium-137 Pilot Production (Production and Inventory Accounts) *(R. W. Schaich)*

1. Processing and Process Status

The cesium carbonate intermediate product prepared in September was converted to $^{137}CsCl$ in eight batches (which were later combined into five fractions) yielding a total of 81,000 Ci. Another oxalate/carbonate/chloride cycle was run with an estimated yield of 75,000 Ci.

Several fractions of relatively low concentration (1-5 Ci/gal) cesium-137 solution have been in various storage tanks for some time. Batches of this material have been brought into the feed crystallizers as the process situation permitted and processed to recover the cesium-137. All of the

solution has now been returned to the process system, leaving only the full-strength cesium-137 feed in solution storage. The storage tank system will be decontaminated during November. There are no plans for using this storage system, but the tanks could still be used if needed.

Reworking of cesium-137 glass residues by leaching and filtration was started. Batches of the crushed residues were alternately treated with NaOH solutions (concentration up to 0.3 *M*) and HNO_3 (concentration up to 1.0 *M*) under slow agitation at room temperature. The solutions were periodically filtered and fresh solution introduced; the NaOH solutions were acidified before filtration. Combined leach solutions were assayed and recycled to the feed crystallizers. All of the glass residue on hand was put through one cycle; then the solids were air-dried and stored for later treatment. A total of 35,000 Ci — about one-half of the estimated cesium-137 content — was recovered by this treatment. The current cesium-137 process status is shown below.

Item	Cesium-137 (Ci)
In-process material	574,000
$^{137}CsCl$ products	322,900
Sources in fabrication	25,100
Completed sources awaiting shipment	182,500

2. Operational Summary

Item	Oct 1972		CY 1972		FY 1973	
	No.	Ci	No.	Ci	No.	Ci
HAPO shipments received	0	0	0	0	0	0
Product batches prepared	15	156,000	31	304,300	30	297,300
Sources						
Fabricated	0	0	23	55,300	0	0
Shipped	0	0	23	55,300	0	0
Special form cans						
Fabricated	0	0	20	114,400	10	500
Shipped	0	0	8	1,900	3	1,000

3. Current Orders

Current orders for cesium-137 as sources or bulk powder are shown below:

Customer	Amount (Ci)	Estimated Shipping Date
Brookhaven National Laboratory	203,000	FY 1973
Lockheed Georgia Company	∿35,000	a
Atomic Energy of Canada Limited	25,200	December 1972
Gamma Industries	30	December 1972
Technical Operations, Inc.	8	November 1972
Technical Operations, Inc.	100	December 1972
Technical Operations, Inc.	150	December 1972
J. L. Shepherd Associates, Inc.	50,001	To be scheduled

[a]Sources are in storage awaiting receipt of customer's container.

An order is on hand from Atomic Energy of Canada Limited for 88,000 Ci of cesium-137 as CsCl powder. The powder has been canned and stored awaiting release by customer.

C. Strontium-90 Pilot Production (Production and Inventory Accounts) *(R. W. Schaich)*

1. Processing and Process Status

No strontium-90 processing was done. The current strontium-90 process status is shown below.

Item	Strontium-90 (Ci)
In-process material	805,900
Strontium-90 products	426,200
Sources in fabrication	0
Returned SNAP sources	446,600
Completed sources awaiting shipment	221,000

2. Operational Summary

Item	Oct 1972		CY 1972		FY 1973	
	No.	Ci	No.	Ci	No.	Ci
HAPO shipments received	0	0	0	0	0	0
Product batches prepared	0	0	13	510,000	0	0
Sources						
Fabricated	0	0	9	581,000	0	0
Shipped	0	0	5	360,000	0	0
Special form cans						
Fabricated	0	0	39	5,600	0	0
Shipped	0	0	13	900	0	0

3. Current Orders

Current orders for strontium-90 as sources or bulk powder are shown below.

Customer	Amount (Ci)	Estimated Shipping Date
U.S. Navy (ORNL)	221,000	FY 1973
U.S. Navy	278,675	a

[a]To be released by customer.

D. Short-Lived Fission Products Pilot Production (Production and Inventory Accounts) *(R. W. Schaich)*

Isotope	Number of Batches	Amount (Ci)
Xenon-133	2	700
Cerium-144	1	24

E. Promethium-147 Shipments and Current Orders *(R. W. Schaich)*

Donald W. Douglas Laboratories has a current order for 51,000 Ci to be shipped in November 1972. Radiochemical Centre was shipped 2011 Ci of promethium-147. A shipment of 5260 Ci of promethium-147 was made to Mitsubishi (Japan).

SOURCE DEVELOPMENT — 08-01-04

A. Americium-241 *(F. N. Case)*

Representatives from Tuskegee Institute spent a week at the Isotopes Development Center to make literature surveys and to study methods for measuring ^{241}Am/Be neutron sources and americium-241 photon sources. Since the time allocated by Tuskegee for the study was short and only two of the sources loaned to them by Monsanto arrived, most of the effort was devoted to the literature survey. Sources to be supplied by Amersham did not arrive. Measurements will be made by ORNL personnel on both the Monsanto and Amersham sources, and raw data will be sent to Tuskegee for analysis and reporting. Additional aid will be extended by the Isotopes Development Center group as needed.

B. Tests of BNL Cobalt-60 Irradiator Sources *(R. A. Robinson)*

Source integrity tests were performed on a BNL cobalt-60 source design, which may be used for U.S. Army food irradiation experiments. The source material (0.75-in.-diam cobalt metal disks) was doubly encapsulated in rectangular stainless steel tubing and sealed by TIG welding of the end caps. The overall dimensions of the source capsule were ∿13 in. long by 7/8 in. wide by 3/16 in. thick. The source design passed all of the test requirements for ORNL Class III-C (ref. 8) except for the puncture test, which limited the source to Class II-C. The corresponding ANSI classification of the source is E54313. The capsule passed all tests required for IAEA certification as "special form."

C. Aluminum Foil Krypton-85 Sources *(R. A. Robinson)*

Several aluminum foil disk sources, 0.005 in. thick and 7/8-in. diameter, were made by bombarding foils with 41% enriched krypton-85 at 3000 V for

[8]R. G. Niemeyer, *Source Application Guide Based on the ORNL Source Capsule Classification System*, ORNL-4427, Oak Ridge National Laboratory (July 1969).

3 min. The surface activity measured with a cutie pie averaged 2.5 R/hr, or 647 mR/hr.cm^2. This activity was in line with the activity of 64 mR/hr·cm^2 achieved with 4.5% krypton and 9 mR/hr.cm^2 made with 0.7% krypton-85. However, the retention of activity was not as good as has been observed with the earlier low-level sources. The activity dropped to 50% of the initial values in ten days.

One foil disk was coated with green phosphor held on with dried sodium silicate solution. The source put out a dim but visible light.

D. Radioisotope Characterization, Quality Control, and Standards
(S. A. Reynolds)

1. Radioisotope Characterization

The problems of obtaining readily usable decay-scheme data for common radionuclides were described in a letter to appropriate ANS officers, in which a request was also made for suggestions of methods of communicating ANS needs to nuclear-data compilers. A possible mechanism for both tabulation and communication was the proposed ANS information center, but the executive secretary indicated essentially no chance for setting up such a center. The general problem will be discussed further at the ANS-16 meeting next month.

An answer to an inquiry about fission yields of neptunium-237 was attempted, but values are very uncertain.

2. Radioisotope Special Analysis and Quality Control

Data were received from the College of American Pathologists (CAP) on an intercomparison of assays of iodine-131 involving 36 laboratories. A statistical analysis was done here, using all the results except three obvious outliers. The mean was only 2% different from the NBS value, and the standard deviation was 7.3%. Especially noteworthy was that six laboratories calibrated their instruments with commercial iodine-131 and that their average deviation was only 2%. The ORNL value was 0.7% different from NBS. This information was communicated to CAP, NBS, and the NRC standards subcommittee.

Analysis of hafnium-181 products was reviewed and found satisfactory. The relative amount of hafnium-175 by-product agreed with that estimated from the thermal cross sections. Since some products are now being made in HFIR for the first time, it was recommended that careful attention be given use of optimum irradiation times to minimize impurities. Discrepancies in the assay of phosphorus-33 by liquid scintillation counting have apparently been eliminated by addition of phosphate carrier to the phosphate-33 scintillator mixture and calcium carrier to the calcium-45 substitute standard, both in microgram amounts. Agreement between process control and analytical measurements has been quite adequate on the last two products. Analytical methods were recommended for flux monitors being prepared at ORNL. Isotope

dilution mass spectrometry was suggested for enriched uranium isotopes and plutonium, alpha counting for neptunium, and activation analysis for impurities in cladding.

RADIOISOTOPE SALES

(J. E. Ratledge)

ITEMS OF INTEREST

An order was received from Atomic Energy of Canada for 12,430 Ci of promethium-147 as oxide. An order was received from Mitsubishi International Corporation for 5,225 Ci of promethium-147 as oxide. Orders for 30,000 Ci of tritium were received from both Radium Chemie A. Zeller & Company, Switzerland, and U.S. Radium Corporation. An order for 100 Ci of enriched krypton-85 (∿41%) was received from Measurex Corporation.

Shipments of interest made during the month are listed below:

Customer	Isotope	Amount
Large Quantities		
New England Nuclear Corporation	Tritium	4,000 Ci
Canrad Precision Industries, Inc.	Tritium	3,000 Ci
Radium Chemie A. Zeller & Company	Tritium	10,000 Ci
Mitsubishi International Corporation	Promethium-147	5,225 Ci
Atomic Energy of Canada	Promethium-147	12,430 Ci
Radiochemical Centre	Promethium-147	2,001 Ci
Radiochemical Centre	Krypton-85	100 Ci
Measurex Corporation	Krypton-85 (enriched)	100 Ci
Withdrawn Items		
Mayo Clinic	Copper-67	2 lots
Cleveland Metropolitan General Hospital	Iodine-131	50 mCi
Puerto Rico Nuclear Center	Iodine-131	15 mCi
Unusual Items		
Bell Telephone Laboratories	Tellurium-123 source	1 Ci
Brookhaven National Laboratory	Carbon-14 (six targets)	
Panametrics[a]	Iron-55 source	60 mCi
Items Used in Cooperative Programs		
Oak Ridge Associated Universities	Gallium-67	
University of Southern California	Platinum-195m	
Vanderbilt University	Xenon-133	

[a]On loan for two months.

A summary of radioisotopes shipped during September and October 1972 is given in Tables 2 and 3, respectively.

Table 2. Summary of Radioisotopes Shipped During September 1972

Radioisotope	Number of Shipments	Quantity (mCi)
Argon-37	1	400
Barium-140	1	1
Calcium-47	5	4
Cesium-137	4	1,015,581
Copper-67	2	13
Europium-152	1	1
Gallium-67	9	418
Iodine-129	2	526[a]
Iodine-131	2	100
Krypton-85, normal	1	10,000
Lead-203	2	6
Niobium-95	2	2
Phosphorus-33	4	207
Potassium-43	4	11
Promethium-147	20	200,000
Ruthenium-103	1	2
Ruthenium-106	4	18
Strontium-89	3	16
Strontium-90	1	5
Tritium	18	10,730,000
Xenon-133	51	54,510
Yttrium-91	1	2
Zirconium-95	1	1
Fission products	2	20
Misc. compound preparations	3	30
Cyclotron service irradiations[b]		
Rhodium-102	1	<1
Yttrium-88	1	30
Aluminum-26	1	<0.1
	148	12,011,379
		526[a]

[a]Milligrams.
[b]For International Chemical and Nuclear Corporation.

Table 3. Summary of Radioisotopes Shipped During October 1972

Radioisotope	Number of Shipments	Quantity (mCi)
Calcium-47	9	5
Cerium-144	15	20,000
Cesium-137	6	2,075
Cobalt-60	1	25
Copper-67	2	8
Gallium-67	10	450
Hafnium-181	1	2
Iodine-129	2	402[a]
Iodine-131	5	640
Krypton-85, enriched	3	102,500
Krypton-85, normal	10	270,005
Niobium-95	2	10
Phosphorus-33	5	10
Potassium-43	7	30
Promethium-147	3	19,666,000
Ruthenium-106	2	12
Samarium-151	1	30[a]
Strontium-89	2	40
Strontium-90	2	10
Technetium-99	2	3,000[a]
Tritium	13	9,522,000
Xenon-133	60	62,520
Yttrium-91	4	28
Zirconium/Niobium-95	2	35
Misc. compound preparations	3	
Cyclotron service irradiations[b]		
Cobalt-57	1	2,000
Germanium-68	1	24
	174	29,648,429
		3,432[a]

[a]Milligrams.
[b]For New England Nuclear Corporation.

The radioisotope sales proceeds and shipments for the first three months of FY 1972 and FY 1973 are given in Table 4.

Table 4. Radioisotope Sales and Shipments

Item	7-1-71 thru 9-30-71	7-1-72 thru 9-30-72
Inventory items	$ 98,316	$ 85,561
Major products	14,860	13,955
Radioisotope services	55,569	30,053
Cyclotron irradiations	45,088	24,658
Miscellaneous processed materials	21,891	16,099
Packing and shipping	19,124	15,975
Total	$254,848	$186,301
Number of shipments	688	510

ADMINISTRATIVE

Travel of IDC members and visitors to the IDC are given in Tables 5 and 6, respectively.

Table 5. Travel by IDC Personnel

Traveler	Site Visited	Purpose
J. J. Pinajian	Vanderbilt University Nashville, Tennessee	Consultation on cooperative programs
S. A. Reynolds	Gatlinburg, Tennessee	Attend annual Analytical Chemistry Conference
J. J. Pinajian	Georgia Institute of Technology, Atlanta	Give lecture and conduct experiment
E. E. Beauchamp	New York, New York	Attend meeting of ANSI Committee N43

Table 6. IDC Visitors

Visitor	Affiliation	Purpose of Visit
Shaoshichi Montonag Meriyushi Nakanishi	Japan	Discuss production cyclotrons and targets
D. D. Woodbridge W. R. Garrett	Envirolab, Inc. Melbourne, Fl.	Radiation treatment of sewage

Table 6. continued

Visitor	Affiliation	Purpose of Visit
F. E. Levett, D. R. Jackson, and E. Helminski	Tuskegee Institute	^{241}Am/Be neutron sources and ^{241}Am photon sources

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REPORTS

G. D. Alton, W. R. Garrett, and J. E. Turner, *Electron Scattering from Simple Atomic and Molecular Systems: A Study of the Phenomenological and Microscopic Optimal Models*, ORNL-4826, Oak Ridge National Laboratory (November 1972).

R. E. Greene, R. S. Pressly, F. N. Case, *A Review of Alpha Radiation Source Preparation Methods and Applications*, ORNL-4819, Oak Ridge National Laboratory (October 1972).

E. Lamb, *IPF Monthly Status Report for September 1972*, ORNL-TM-4003, Oak Ridge National Laboratory.

A. F. Rupp, *Radioisotope Program (8000) Progress Report for September 1972*, ORNL-TM-4002, Oak Ridge National Laboratory.

JOURNALS

J. C. Manthuruthil, D. C. Camp, A. V. Ramayya, J. H. Hamilton, J. J. Pinajian, "Excited States in ^{206}Pb from the Decay of ^{206}Bi," *Phys. Rev. Abstracts* 3(20), 25 (1972).

J. H. Hamilton, V. Ananthakrishman, A. V. Ramayya, W. M. LaCasse, D. C. Camp, J. J. Pinajian, L. H. Kern, and J. C. Manthuruthil, "Levels in ^{205}Pb Populated by the Decay of ^{205}Bi," *Phys. Rev.* C6(4), 1265-80 (1972).

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