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A.E.C. RESEARCH AND DEVELOPMENT REPORT

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**AMES
LABORATORY
IOWA STATE
COLLEGE**

ENGINEERING
SEMI-ANNUAL SUMMARY RESEARCH REPORT
JULY-DECEMBER, 1956

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U N I T E D S T A T E S A T O M I C E N E R G Y C O M M I S S I O N

SEMI-ANNUAL SUMMARY RESEARCH REPORT IN ENGINEERING

For July - December, 1956

by

Ames Laboratory Staff

March 15, 1957

Ames Laboratory
at
Iowa State College
F. H. Spedding, Director
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U N C L A S S I F I E D

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**This report is prepared from material
submitted by group leaders of
the Laboratory**

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ENGINEERING

Under the direction of F. H. Spedding, G. Burnet, R. W. Fahien, R. W. Fisher, G. Murphy, E. H. Olson, M. Smutz and D. R. Wilder.

Chemical Engineering1. Processing of Monazite Sand (M. Smutz)*

Welt and Smutz previously evaluated a process for recovering thorium, uranium and rare earths from monazite sand.¹ The process involved precipitating the thorium and rare earths as oxalates. Preliminary results of further investigation indicate that most of the oxalate ion can be recovered by only minor modifications in the process, which will result in a much more economical process.

2. Developing a Continuous Multistage Mixer-Settler Extractor
(M. Smutz)

A 14-stage box type mixer-settler has been built and tested. The box is made of polyethylene and one motor drives the stirrers in all of the stages. Each stage has individual interface control. The unit operated very successfully in a continuous run to separate niobium and tantalum. Three more units of similar design are now being constructed.

3. Separation of Rare Earths by Solvent Extraction (M. Smutz)

Precise equilibrium data for the system water-TBP-nitric acid-rare earth nitrates have been determined. The separation factors and order of extractability of the higher rare earths depend upon concentration. Yttrium, not being a rare earth, can be made less extractable than any of the rare earths by careful control of concentration.

A report (ISC-766) entitled "Solvent Extraction Equilibria for Rare Earth Nitrate-Tributyl Phosphate Systems" by L. Knapp, M. Smutz and F. H. Spedding is being distributed.

*Names indicate group leaders in charge of work.

¹ISC-662

ABSTRACT

Studies were made on the effect of process variables such as rare earth concentration, acid concentration, and salting-out agents on equilibrium data of the tributyl phosphate (TBP)-water-rare earth nitrate system. Distribution data were obtained for individual pure rare earths and yttrium in systems containing no nitric acid or salting-out agents. The extractability of the pure rare earths was shown to increase with increasing atomic number up to a maximum at dysprosium and then to diminish with further increases in atomic number. Ytterbium does not follow the pattern set by the other rare earths. At low concentrations ytterbium was found to be the least extractable of the rare earths studied but at high concentrations appeared to be the most extractable. Yttrium behaved similarly to ytterbium.

It was demonstrated that these distribution curves of pure rare earths could be used to predict the effect of rare earth concentration on separation factors in systems containing no acid or salting-out agents. If the distribution curves of two pure rare earths become more divergent with increasing concentration, the separation factors between these rare earths in a mixture become more favorable with increasing concentration. If the individual curves converge with increasing concentration the separation factors in a mixture become less favorable with increasing concentration.

The effect of nitric acid on the extraction of a mixture of monazite rare earths (La, Ce, Pr, Nd, and Sm) was determined. The distribution coefficient for the mixed rare earths decreased as the nitric acid concentration increased up to 5 normal aqueous concentration. At this point the distribution coefficient passed through a minimum and higher acid concentrations produced higher distribution coefficients. Increasing nitric acid concentration was found to have the same effect on separation factors as increasing the rare earth concentration.

Salting-out agents greatly increased the distribution coefficients of rare earth mixtures and had the same effect on separation factors as increasing the rare earth concentration of the system. Data indicated that salting-out agents with high ionic strength had the greatest effect on the rare earth distribution data.

Investigations of distribution data for other metal salts between water and TBP indicate that only transition metals with two or less electrons in their d orbitals may be extracted

as cations. This strongly indicates that a complex is formed in the organic phase. Extractability of these metal cations was found in general to increase with decreasing ionic size and increasing valence. However, exceptions to this rule were found in the case of the heavy rare earths.

The anions associated with the extractable metal cations were found to affect greatly the degree of extractability. Nitrate ions were found to produce the highest amount of extraction. Sulfate, phosphate, and chloride ions reduced the amount of extraction considerably.

Water and various acids have been found to extract into TBP. It has been postulated that these materials associate with the TBP by means of hydrogen bonding. TBP is also capable of extracting complex metal anions such as $\text{Cr}_2\text{O}_7^{2-}$ and TaF_7^- . These extractions occur only in the presence of excess hydrogen ions in the aqueous phase. The anions are, therefore, probably extracted as their acids, $\text{H}_2\text{Cr}_2\text{O}_7$ and H_2TaF_7 , and are associated with the organic solvent through hydrogen bonding.

4. Separation of Niobium and Tantalum (M. Smutz)

A report (ISC-802) entitled "Separation of Niobium and Tantalum by Liquid-Liquid Extraction" by E. L. Koerner, M. Smutz and H. A. Wilhelm is being distributed.

ABSTRACT

Niobium, also known as columbium, is one of the new industrial metals likely to play an important role in industrial processing in the near future. Its high melting point ($4376^\circ\text{F}.$) and low cross section for neutron absorption (1.1 barns) make it of special interest to the Atomic Energy Commission. Since tantalum, which invariably accompanies niobium in its ores, has a somewhat higher cross section for neutron absorption (21 barns) there is considerable interest in developing an industrial process for producing tantalum-free niobium. Tantalum itself is a valuable metal because of its high melting point ($5160^\circ\text{F}.$) and its resistance to most corrosive chemicals.

The purpose of this research was to find an economical method of producing a niobium oxide product containing as little tantalum and other impurities as possible, starting

with a typical niobium-rich ore or concentrate. The process selected as a result of the research consisted of the following processing steps:

1. Digestion of the ore or concentrate with hydrofluoric acid.
2. Extraction of niobium and tantalum from the digested mass with an organic solvent such as methyl isobutyl ketone.
3. Separation of tantalum and niobium by continuous countercurrent multistage extraction using an organic solvent and an aqueous scrubbing solvent.
4. Separation of niobium from other impurities by a second solvent extraction step using an organic solvent.
5. Stripping of the niobium and tantalum from their solvents and regeneration of solvents.

The process as outlined above was studied on a small scale and demonstrated on a somewhat larger scale so that a more accurate cost estimate could be made. Several pounds of niobium oxide containing less than 700 parts per million of tantalum oxide were produced. Several pounds of tantalum oxide containing less than 100 parts per million of niobium oxide were produced. Both purity values were the limit of detection for the spectrographic methods employed.

Preliminary cost estimates were made for production of purified niobium and tantalum oxides from an ore concentrate assaying 63 per cent niobium oxide and 7 per cent tantalum oxide. The basis chosen was a plant producing 300,000 pounds of total oxides per year or 270,000 pounds niobium oxide and 30,000 pounds tantalum oxide. Estimated chemical and total operating costs for one pound of either tantalum or niobium oxide were \$1.89 and \$2.80.

A report (ISC-793) entitled "Separation of Niobium and Tantalum-A Literature Survey" by E. L. Koerner and M. Smutz was distributed.

5. Production of Thorium Compounds (M. Smutz)

A paper by J. J. Barghusen and M. Smutz entitled "Production of Thorium Compounds" was submitted for publication in TRANSACTIONS OF THE AMERICAN SOCIETY FOR METALS.

ABSTRACT

Recently thorium has become an element of major significance, and therefore much interest has been focused on methods for recovering pure thorium compounds from monazite sands. This paper attempts to bring together all information concerning the various processes for preparing thorium compounds from monazite. Included are descriptions of several processes developed within the past ten years. A number of separation techniques are described, such as precipitation, liquid-liquid extraction, and ion exchange. The recently developed liquid-liquid extraction method for purifying thorium compounds is discussed in some detail.

6. Preparation of Pure Yttrium Fluoride (G. Burnet)

Modifications of both the wet and dry methods for converting yttrium oxide to the fluoride by hydrofluorination have been investigated. These are summarized below:

(a) Removal of water of hydration from wet process yttrium fluoride hemi-hydrate by steam distillation using various anhydrous solvents. It was possible to remove only surface moisture in this manner.

(b) Dry hydrofluorination at 600°C . starting with yttrium fluoride hemi-hydrate from the wet process. Spectrographic intensity ratios (oxygen line to argon line; a measure of residual oxygen content) were obtained which were approximately 15% lower than when yttrium oxide was used as the starting material. These samples were in the range corresponding to the lowest oxygen content obtained to date. Hydrofluorination times from 6 to 36 hours were investigated.

(c) Dry hydrofluorination of yttrium chloride, nitrate and sulfate obtained by dissolving the oxide in the corresponding acid and going to dryness. Incomplete results indicate intensity ratios approximately 25% lower than those obtained when the oxide is the starting material.

(d) Dry hydrofluorination of yttrium oxide of varying particle size. A sample of the oxide of which over 95% would pass through a 200 mesh screen was sized by elutriation into coarse, medium and fine fractions. These were treated individually with HF under similar conditions to determine the effect of particle size on conversion to the fluoride. It was shown that the smaller the particle size of the oxide, the higher the degree of conversion.

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(e) Dry hydrofluorination of the oxide and hemi-hydrate to determine the effect of time on conversion to the fluoride. In both cases the spectrographic intensity ratio was reduced significantly with time up to approximately 20 hours.

(f) Fluorination (using elemental fluorine) of dry and wet process fluorides, the oxide, and oxalate. The equipment required is 75% on hand and assembled. Special techniques required in handling elemental fluorine have been studied.

(g) Dry hydrofluorination of dry process yttrium fluoride to which a small amount of finely divided carbon had been added (6 hours at 600°C.). No improvement in the intensity ratio was obtained.

(h) Hydrofluorination of wet process yttrium fluoride hemi-hydrate, yttrium nitrate and yttrium sulfate using liquid HF at -60°C. No improvement over the oxide was obtained.

In addition to work on the preparation of yttrium fluoride, a study to determine the pick up of moisture by the dry process fluoride and the wet process fluoride hemi-hydrate has been completed. It was demonstrated that the dry process fluoride failed to pick up moisture when exposed to relative humidities from 30 to 100% while the hemi-hydrate gained increasing amounts up to 15% of its original sample weight at 100% relative humidity.

The above was substantiated by tests in which yttrium fluoride produced by dry hydrofluorination was allowed to cool under an atmosphere of nitrogen. The amount of oxygen in the product was the same for control samples cooled in the atmosphere.

Future work calls for continued efforts in several of the above areas and an attempt to hydrofluorinate molten yttrium oxide.

7. Mass Transfer in Packed Beds (R. W. Fahien)

Mass transfer in a system of spheres packed in a cylindrical tube through which air was flowing was studied as a function of flow velocity and radial position within the tube. The average effective diffusivity for the gas was correlated in terms of a Peclet number and a Reynolds number, both of which involve pellet diameter as a length parameter. The average diffusivity is obtained analytically by equations derived on the assumptions that velocity through the bed and diffusivity are not functions of radial position. Postulation of a series mechanism between molecular and eddy diffusion permitted interpretation of the Peclet number-Reynolds number plot. At low velocities, Peclet number approached linear dependence on Reynolds .

number; at high velocities Peclet number varied only slightly with Reynolds number. The variation of velocity with radial position was also measured. These data bore out previous studies that showed that the velocity reached a peak near the wall. A numerical solution was employed to calculate point values of diffusivity, which were found to vary appreciably with radial position.

8. Liquid-Liquid Extraction in Pulse Columns (R. W. Fahien)

A series of runs were made to determine experimentally the solute concentration gradient in a pulse liquid-liquid extraction column. Previous investigators had assumed that straight operating lines existed within the column. The present data indicate that this assumption is not completely correct and that in addition to curvature in the central section of the column, large end effects exist. An unusually large amount of mass transfer was found to occur in the bottom of the column.

9. Bastnasite Processing (E. H. Olson)

This project has been initiated to find an economical method for the recovery of rare earths from bastnasite ore.

The two large U. S. deposits of bastnasite are located in New Mexico and California. The approximate rare earth contents of these ores are as follows:

<u>Source</u>	<u>Rare Earth Content (% oxide)</u>
New Mexico ore	23.1
California ore	8.7
California ore concentrate (60%)	58.7
California ore concentrate (70%)	69.1

A satisfactory analytical method for determining the rare earth content has been obtained and some preliminary tests have shown that either nitric, hydrochloric, or sulfuric acid will open the ore. Chemical cost estimates indicate that nitric and sulfuric acid are more feasible than hydrochloric acid. Fusions with sodium chloride, sodium bisulfate, sodium hydroxide, and calcium chloride were carried out but in no instance were the rare earths rendered water soluble.

Efforts will be concentrated on determining the most economical process and optimum process conditions for separating the rare earths from calcium, barium, silicon, iron and other impurities in the ore.

10. Oxidation of Cerium(III) to Cerium(IV) (E. H. Olson)

This project is concerned with determining the amount of cerium(III) that can be converted to cerium(IV) in a nitric acid solution. If the cerium(IV) species can be obtained at large percentages the separation of lanthanum and cerium from higher molecular weight rare earths by liquid-liquid extraction could be accomplished using a much smaller extractor.

The conversion of cerium(III) to cerium(IV) has been studied using a glass reaction vessel and sparging at a constant rate with inert gas to remove gaseous decomposition products formed. The reaction vessel was placed in a thermostatically controlled temperature bath to enable the study of temperature effects on conversion.

It was found that approximately 25 to 35% of cerium(III) could be converted to cerium(IV) in a solution of 0.15 to 0.20 molar cerium nitrate in concentrated nitric acid in 12 hours at 100°C. In the one run made at 120°C the same amount of cerium(IV) was produced in 6 hours as was formed in 12 hours at 100°C. Lower concentrations of nitric acid reduced both the rate of formation and total yield of cerium(IV) from cerium(III).

Attempts to correlate the data with a rate law have been without success, probably for two main reasons. Stability studies revealed that as the nitric acid concentration decreases, the cerium(IV) concentration decreases. The concentration of nitric acid decreased during the runs, due to vapor losses in the inert gas stream. The second reason is an error in spectrophotometric analysis of cerium(IV). Just recently it has been discovered that the absorbency of cerium(IV) is dependent on the nitric acid concentration and temperature. This error will also affect the yields reported, but not greatly.

Another method being investigated to separate cerium from a mixture of rare earths is a controlled fusion using a weight ratio of 1:1 of rare earth nitrates to magnesium nitrate. The cerium nitrate is unstable at temperatures above 200°C and decomposes to the oxide. Tests run at 225°C and 250°C have shown that cerium decomposition is complete at 12 hours and 6 hours, respectively. A run at 275°C has been made and, although all samples have not been analyzed, the reaction is known to be complete in 3 hours. The cerium oxide is practically free of other rare earths, which indicates that the other rare earth nitrates are stable at these temperatures.

11. Liquid Metal Extraction (E. H. Olson)

The extraction studies on the removal of fission products from uranium using molten silver were continued. Specifically, the investigations during this period were centered on the extraction of neodymium from uranium.

The major problem encountered has been the difficulty in obtaining satisfactory methods of analysis for neodymium in silver and uranium phases at very low concentrations. The available spectrographic methods were satisfactory down to 500 ppm and 800 ppm in the silver and uranium phases, respectively. In order to evaluate an extraction process, however, concentrations of neodymium down to approximately 50 ppm are required.

During this period methods have been developed in cooperation with the spectrochemistry group, whereby neodymium concentrations down to 50 ppm and 100 ppm in the silver and uranium phases, respectively, can be obtained spectrographically. The expected errors are $\pm 5\%$ to $\pm 10\%$ and $\pm 5\%$ for the silver and uranium phases, respectively.

It is proposed to use 11.7-day half-life tracer neodymium in a series of extractor runs to determine the relative effects of temperature, silver drop size, and rate of silver addition on extraction of neodymium from uranium, using the present graphite extractor.

Engineering Development

1. Slurry Program (G. Murphy)

Slurry studies during this period resulted in the following information:

(a) Slurries of 0.0044-inch diameter particles of resin (Sp.gr.=1.35) in water in quantities up to 46% by weight show a progressive delay of the onset of turbulence with increasing velocity as the solid content is increased.

(b) Certain combinations of velocity and concentration of solid exist for which the pumping power requirements are markedly lower than for water alone. The range of these velocities is greater for vertical flow than for horizontal.

(c) The onset of turbulence in vertical flow is delayed by a coring effect of the solids for upward flow and coring of the fluid for downward flow.

(d) Analytical expressions were developed for radial forces and velocities pertaining to a spherical particle in a fluid which will explain coring as a result of velocity gradients in the slurry.

(e) A photographic method has been developed for obtaining the velocity distribution of the solids in vertical flow.

(f) In fully developed turbulent flow, downward flow results in greater friction loss than upward flow and horizontal flow results in less friction loss than upward flow for the same velocity and concentration of solids.

2. Mechanical Properties of Materials. (G. Murphy)

Study of mechanical properties of uranium and thorium gave the following results:

(a) Protection of uranium at elevated temperatures by plating have been improved through multiple-layer techniques.

(b) A protection technique using bellows has proved satisfactory in fatigue testing of uranium and its alloys at elevated temperatures.

(c) The endurance limit of normal uranium was determined as 15,000 psi in repeated bending (500,000,000 cycles) at 300°C.

(d) Alternate cycling of uranium in tension and compression at room temperatures results in a lowering of the yield strength in both tension and compression.

(e) Twinning appears to contribute to the plastic deformation of uranium at elevated temperatures.

(f) The creep rate of thorium at room temperature may be accelerated by prestrain greater than about 7%.

(g) Solutions have been developed for thermal gradients in cylindrical slugs containing heat sources.

(h) Solutions have been developed for thermal stresses in cylindrical slugs obeying Hooke's Law and having a variation in modulus of elasticity with temperature.

A report (ISC-839) entitled "Thermal Stress Analysis of a Cylinder of Semi-Plastic Material" by Donald Hunter and Glenn Murphy is being distributed.

ABSTRACT

A solution is derived for the thermal stresses in a finite cylindrical solid composed of a material for which the modulus of elasticity decreases linearly with an increase in temperature. The cylinder is assumed to contain a distributed heat source that is radially symmetrical. The solution is applied to evaluate the stresses in a cylindrical uranium fuel slug in which heat is produced by fission. The results are compared with those obtained from a plane strain solution.

Ceramic Engineering

1. Sintering Mechanism of Aluminum Oxide (D. R. Wilder)

The nitrogen adsorption unit has been used to determine the specific particle surface of previously prepared aluminum oxide particle size fractions. The effects of low temperature heating, 300-700°C, on such fractions will be observed and compared to the room temperature values to determine the characteristic sintering initiation temperature.

Other Engineering Research

1. Circulation of Molten Metals (R. W. Fisher)

A molten metal loop containing 94.7% bismuth, 0.3% manganese, and 5.0% uranium by weight was circulated at 1000°C for 4500 hours before failure occurred in the inconel sheath. This fuel material was circulated in a tantalum vessel of a 30-mil wall-thickness and pumped at a rate of 20 pounds per minute, the temperature differential being approximately 250°C.

We consider the 4500-hour period to be of satisfactory duration to prove that tantalum will successfully contain this particular alloy. A suitable liquid-metal coolant material must be found which does not react with the tantalum and which would remove the heat from the reactor core.

The 0.3% manganese was added to depress the melting point of the alloy, enabling the liquid fuel to operate at a lower temperature. It was determined, in the course of experiments, that the addition of this amount of manganese reduced the melting point of the original 95% bismuth-5.0% uranium alloy by 30°C.

A double loop is being constructed which will pump the uranium-bismuth-manganese ternary through a sodium-cooled heat exchanger with the sodium in turn being pumped through a second air-cooled heat exchanger. With data from this experiment it will be possible to determine the heat transfer coefficients of these materials through tantalum as well as to record the electrical characteristics of the ternary.

Because of the double wall construction of earlier loops, it has been difficult to determine these electrical and heat transfer data. New fabrication technique and new design will permit the proper location of thermocouples and sensing devices.

APPENDIX I: LIST OF REPORTS FROM THE AMES LABORATORY

1. Reports for Cooperating Laboratories

- ISC-673 G. A. Guter and G. S. Hammond. Steric Effects on the Formation Constants of Metal Chelates of β -Diketones.
- ISC-695 R. A. Foos and H. A. Wilhelm. Separation of Yttrium and Some Rare Earths by Liquid-Liquid Extraction.
- ISC-703 D. L. Horrocks and A. F. Voigt. The Formation of Thallium Chloride Complexes and Their Extraction into Ether.
- ISC-708 Ames Laboratory Staff. Metallurgy. Semi-Annual Summary Research Report. July-December, 1955.
- ISC-720 Charles Baroch and G. H. Beyer. Preparation of Zirconium from Zirconium Tetrafluoride.
- ISC-737 Charles V. Banks and Howard B. Nicholas. Annotated Bibliography of 1,2-Cycloheptanedionedioxime.
- ISC-738 Charles V. Banks, Howard B. Nicholas and James L. Pflasterer. Annotated Bibliography of 1,2-cyclohexanedionedioxime.
- ISC-743 O. N. Carlson, N. Ida, D. Peterson, F. Tate and H. A. Wilhelm. Preparation of Ingots of Uranium-Niobium Alloy.
- ISC-744 O. N. Carlson, F. A. Schmidt and F. H. Spedding. Preparation of Yttrium Metal by Reduction of Yttrium Trifluoride with Calcium.
- ISC-760 Ames Laboratory Staff. Engineering. Semi-Annual Summary Research Report. January-June, 1956.
- ISC-761 Compiled by P. Chiotti. Hanford Slug Program. Semi-Annual Summary Research Report. January-June, 1956.
- ISC-793 E. L. Koerner and M. Smutz. Separation of Niobium and Tantalum - A Literature Survey.
- ISC-794 Charles V. Banks and Richard Fullerton. Annotated Bibliography of Diaminoethanedionedioxime.
- ISC-795 S. G. Epstein, D. M. Bailey, R. L. Smythe, G. R. Kilp and J. F. Smith. Tabulation, Bibliography, and Structure of Binary Intermetallic Compounds. I. Compounds of Lithium, Sodium, Potassium, and Rubidium.

2. Publications

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The Preparation of 3,4-Bis(2-Furyl)-1,2,5-Oxadiazole.
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APPENDIX II: LIST OF SHIPMENTS

<u>Destination</u>	<u>Item</u>
Prof. K. Jargensen Copenhagen, Denmark	5 gm gadolinium oxide 2 gm dysprosium oxide 1 gm ytterbium oxide 1/2 gm holmium oxide 1 gm erbium oxide
Prof. Dr. H. Hopperman Heidelberg, Germany	10 gm yttrium metal
Nuclear Metals, Inc. Cambridge, Massachusetts	200 gm cerium metal
Atomics International Canoga Park, California	15 gm gadolinium metal 15 gm samarium metal
H. M. Wingard Westinghouse Electric Corp. Research Laboratories Pittsburgh, Pennsylvania	110 gm thorium
Colorado School of Mines Research Foundation, Inc. Golden, Colorado	1 gm lanthanum oxide 1 gm cerium oxide 1 gm praseodymium oxide 1 gm neodymium oxide 1 gm samarium oxide 1 gm gadolinium oxide 1 gm yttrium oxide 100 mg terbium oxide 100 mg dysprosium oxide 100 mg holmium oxide 100 mg erbium oxide 100 mg ytterbium oxide 100 mg thulium oxide 100 mg lutetium oxide
Colorado School of Mines Geology Department Golden, Colorado	1 gm lanthanum oxide 1 gm cerium oxide 1 gm praseodymium oxide 1 gm neodymium oxide 1 gm samarium oxide 1 gm gadolinium oxide 1 gm yttrium oxide 100 mg terbium oxide 100 mg dysprosium oxide 100 mg holmium oxide 100 mg erbium oxide 100 mg ytterbium oxide 100 mg thulium oxide 100 mg lutetium oxide

<u>Destination</u>	<u>Item</u>
University of Minnesota Minneapolis, Minnesota	1/4 gm terbium metal 1/4 gm thulium metal 1/4 gm lutetium metal 1/4 gm holmium metal 2/10 gm europium metal
State University of Iowa Chemistry Department Iowa City, Iowa	10 gm samarium metal 10 gm lanthanum metal 5 gm ytterbium metal 5 gm cerium metal 5 gm neodymium metal
Jet Propulsion Laboratory Pasadena, California	300 gm cerium metal
Knolls Atomic Power Laboratory Schenectady, New York	2 gm thulium metal
University of Southern California Los Angeles, California	10 gm ytterbium metal 200 gm cerium metal
Massachusetts Institute of Technology Cambridge, Massachusetts	1/2 gm samarium metal
University of California Los Alamos Scientific Laboratory Los Alamos, New Mexico	100 gm holmium oxide 20 gm holmium metal 100 gm yttrium metal
National Spectrographic Laboratory 6300 Euclid Avenue Cleveland, Ohio	1 gm lanthanum oxide 1 gm cerium oxide 1 gm praseodymium oxide 1 gm neodymium oxide 1 gm samarium oxide 1 gm gadolinium oxide 1 gm yttrium oxide 100 mg terbium oxide 100 mg dysprosium oxide 100 mg holmium oxide 100 mg erbium oxide 100 mg ytterbium oxide 100 mg thulium oxide 100 mg lutetium oxide
Argonne National Laboratory Lemont, Illinois	5 gm ytterbium metal
University of Illinois Urbana, Illinois	100 mg terbium oxide 100 mg terbium metal

<u>Destination</u>	<u>Item</u>
University of Wyoming Laramie, Wyoming	1 gm lanthanum oxide 1 gm cerium oxide 1 gm praseodymium oxide 1 gm neodymium oxide 1 gm samarium oxide 1 gm gadolinium oxide 1 gm yttrium oxide 100 mg terbium oxide 100 mg dysprosium oxide 100 mg holmium oxide 100 mg erbium oxide 100 mg ytterbium oxide 100 mg thulium oxide 100 mg lutetium oxide
Purdue University Lafayette, Indiana	10 gm cerium metal
Dr. Frank A. Kanda University of Syracuse Syracuse, New York	113 gm pure calcium
Dr. W. C. Koehler Oak Ridge National Laboratory Oak Ridge, Tennessee	1 bar polycrystalline neodymium
University of Kentucky Chemistry Department Lexington, Kentucky	15 gm cerium metal
Stephen M. Shelton Oregon Metallurgical Corp. Albany, Oregon	1 lb. yttrium fluoride
Dr. R. S. Milliken University of Chicago Chicago, Illinois	3 gm N ¹⁵
Dr. Joseph G. Graca Iowa State College Ames, Iowa	273 cc 5% NH ₄ Nd versinate 273 cc NH ₄ EDTA (ethylenediamine- tetraacetate) 200 cc each of 5.0% aqueous solutions of cerium, lanthanum praseodymium, and neodymium chloride. 200 cc each of cerium chloride versinate and lanthanum chloride versinate.
University of Wisconsin Madison, Wisconsin	66 gm neodymium metal 66 gm samarium metal 77 gm erbium metal

<u>Destination</u>	<u>Item</u>
Tufts University	3 gm lanthanum metal
Chemistry Department	3 gm gadolinium metal
Medford, Massachusetts	
Walter Reed Army Medical Center	10 gm cerium oxide
Washington, D. C.	