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SURVEY OF SOURCES OF IONIUM (THORIUM-230)

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TABLE OF CONTENTS

INTRODUCTION

Ionium (thorium-230) occurs naturally in uranium ores and, at radioactive equilibrium, amounts to 17 grams per metric ton of uranium. The spectacular growth of the uranium milling industry over the last twenty years has focused considerable attention on ionium both as a natural resource and as a potential health hazard. With a half-life of 75,200 years, ionium has found some use as a thorium tracer and a two-stage irradiation of kilogram quantities of ionium to protactinium-231 and uranium-232 has been proposed [1,2].

Rohrman[3] and others[4,5] have adequately discussed the various aspects of ionium recovery and the general characteristics of the domestic uranium milling industry. However, there are three points which bear repeating. (1) The uranium recovery processes tend to reject thorium, and thus the ionium and natural thorium end up in the waste streams. (2) The general distribution of thorium-232 in the earth's crust and the general low uranium content of ores precludes the recovery of high isotopic purity ionium. However, in contrast to most uranium ores from other parts of the world, much of the domestic ore is very low in natural thorium, thus enhancing the possibility of recovering ionium at isotopic concentrations of one per cent or higher. (3) The mild acid leaching conditions employed in many uranium mills readily dissolves radiodecay thorium (i.e., ionium) incorporated in the crystal structure of the uranium ore, but is quite inefficient in dissolving natural thorium dioxide and most thorium ores, thus achieving an isotopic enrichment of the ionium.

Previous campaigns to recover ionium in the United States[6,7], Canada[3], and Great Britain[9] started with uranium mill waste materials. The source material for the United States campaigns was the St. Louis Airport Residues; waste materials accumulated from processing by Mallinckrodt Chemical Works of high uranium content, Belgian Congo ores. (For additional details of this material, see references 2 or 10.)

When the sale and removal of the Airport Residue was proposed in 1960[10] and future availability of ionium from this source was doubtful, Mound Laboratory, at the request of the Atomic Energy Commission, began a program to locate and evaluate alternate sources of ionium. The requirement for such an alternate source would be a potential of kilogram quantities of ionium with as low a thorium-232 content as possible. From the standpoint of processing economics, an ideal source would be a concentrated aqueous uranium mill waste solution from which the ionium could be recovered directly. Solid materials would be less desirable, due to the added cost of dissolution, and could be economically unfeasible sources if the ionium concentration were too low or the materials were difficult to dissolve.

An appeal for samples of process streams or stockpiled materials which might be rich in ionium was sent to a total of 25 sites. The majority of these were primary uranium mills, but other uranium processors were included. An attempt was made to contact every site processing unirradiated uranium within the continental United States. Replies were received from 21 sites and a total of 43 samples were received from 17 uranium mills and processing plants. In addition, samples of the St. Louis Airport Residues were included in this study. Appendix I lists the samples and any information on their source given by the supplier or obtained from the open literature.

The wide range of sample types posed a problem in the selection of an analytical procedure. A relatively mild leaching with hot nitric acid was selected for the initial analyses of the solid samples. Although this treatment would not completely dissolve the sample in many cases, it was felt that the major part of the ionium would be dissolved and a more vigorous dissolution method could not be economically justified for a large scale ionium recovery process. For separation of the thorium from the bulk of the inactive material, a fluoride precipitation on a cerium carrier was judged to be the least sensitive to interfering ions and, where required, this was preceded by a tri-butyl phosphate (TBP) extraction. Gross alpha counting of thin mounts of flouride precipitates was selected for the final ionium determination.

ANALYTICAL PROCEDURE

The samples were of three types: solids (usually dry), clear solutions, and slurries. The slurry samples were allowed to settle and a rough estimate was made of the relative volumes of solid and supernate. The supernates were then separated by filitration or centrifugation and the solids dried in an oven at 50°C. Wet solid samples were also dried at this temperature. Some of the liquid samples contained small amounts of precipitate, possibly due to hydrolysis. These precipitates were slurried before sampling and caused no apparent difficulty in analysis.

Dry solid samples were digested and prepared for analysis according to the following procedure:

1. Weigh 10 grams of the dry solid into a 250-ml beaker. Add 20 ml of concentrated HNO_3 and heat the slurry near boiling temperature for one hour.
2. Transfer the slurry to a 50-ml centrifuge tube, centrifuge and decant the supernate to a storage bottle. Slurry the insoluble residue with dilute HNO_3 in the centrifuge tube, centrifuge and transfer the supernates to the storage bottle. Repeat the wash a second time. Dilute the solution to 100 ml in the storage bottle and shake thoroughly to mix.

During the analyses, it was noted that the nitric acid leaching of a few of the samples failed to remove all of the 68 kev gamma photo peak of ionium. Various procedures to remove additional ionium were tested and the most effective consisted of leaching with hydrochloric acid, then sodium hydroxide followed by a perchloric acid digestion. The detailed procedure is as follows:

1. Weigh 2-5 grams of solid sample into a 50-ml centrifuge tube. Leach the solid with 20 ml 3 $\underline{N}$ HCL, stirring several minutes to insure adequate contact of the phases. Centrifuge and pour off the supernate to a storage bottle.
2. Repeat the HCl leach and retain the solution.
3. Add 5 ml 10 M NaOH to the residue and mix. Dilute the slurry to 20 ml with H_2O and warm on a water bath. Centrifuge and discard the supernate.
4. Repeat the NaOH leach. Centrifuge and discard the supernate.
5. Leach the residue with 20 ml of 3 $\underline{N}$ HCl. Stir, centrifuge, and transfer solution to the storage bottle.
6. Slurry the residue in 5 ml concentrated HNO_3, transfer to a beaker, and add 10 ml 70% $HClO_4$. Evaporate to perchloric acid fumes and continue heating for one hour.
7. After the slurry has cooled, transfer it to a 50-ml centrifuge tube with 10 ml of water. Centrifuge and transfer the supernate to the storage bottle.
8. Wash the insoluble residue with 20 ml of water and add the wash to the storage bottle.

9. Dilute the solution in the storage bottle to a convenient volume and shake thoroughly to mix.

Liquid samples and aliquots of the solutions from digestion of the solid samples were analyzed by one of the two following procedures:

Method A: Direct Cerium Fluoride Precipitation Procedure

1. Transfer 25 ml of the clear liquid solutions or 10 ml of the digest solutions from solid samples (diluted to 25 ml with water) to a 50-ml centrifuge tube. (If a yield determination is to be made, add a known amount of ionium at this point.)

2. Add NaOH solution to pH 10 or higher and stir the slurry 5 minutes. Centrifuge 5 minutes, decant and discard the supernate.

3. Add 2 ml of concentrated HCl to the precipitate and stir until the precipitate dissolves or is homogeneously dispersed. Add cerium carrier (1-2 mg as cerous nitrate) and, while stirring, add 10 ml of 1.5 N HF and continue the stirring 10 minutes. Centrifuge 10 minutes and decant the clear supernate to a second 50-ml centrifuge tube.

4. Wash the precipitate with 5 ml 0.1 N HF, stirring for 5 minutes and decant the supernate to the second centrifuge tube.

5. Slurry the CeF_3 precipitate in 0.5 ml H_2O and transfer to a 2-inch stainless steel disc previously prepared with a ¼-inch plastic retaining ring. Rinse the centrifuge tube twice with 0.5 ml portions of H_2O and add to the disc. Evaporate the slurry to dryness under a heat lamp and heat the disc to dull red heat to burn off the plastic ring and residual moisture.

6. Precipitate the combined HF solutions from Steps 3 and 4 by adding NaOH to pH 10 or higher. Stir the slurry 5 minutes, then centrifuge 5 minutes, decant and discard the clear supernate.

7. Repeat the addition of HCl, cerium carrier and HF as in Steps 3 and 4. Mount the precipitate as in Step 5.

8. Count the sample discs with a ZnS scintillation alpha counter previously calibrated with a standard ionium sample.

Method B: Tributyl Phosphate - CeF_3 Procedure

(Steps 1 and 2 are identical with those in Method A.)

3. Add concentrated HNO_3 in 1-ml portions, with stirring, until the hydroxide precipitate dissolves; then add one additional ml of concentrated HNO_3. Add 18.8 gm of solid $Al(NO_3)_3 \cdot 9H_2O$; stir and warm the solution until the salt dissolves completely. The total volume should be about 25 ml.

4. Add 5 ml of an equivolume mixture of tributyl phosphate and benzene, previously equilibrated with HNO_3 and stir 5 minutes. Centrifuge 5 minutes and transfer the organic phase to a second 50-ml centrifuge tube. Repeat the extraction with a second 5-ml portion of organic and add the phase to the second centrifuge tube. Discard the aqueous phase.

5. Add 1-2 mg cerium carrier to the combined organic solutions. While stirring add 10 ml of 1.5 N HF and continue stirring 10 minutes. Centrifuge 10 minutes and decant both the organic phase and aqueous supernate to a third 50-ml centrifuge tube.

6. Wash the CeF_3 precipitate as in Step 4 of Method A, and decant the wash solution to the third centrifuge tube.

7. Mount the CeF_3 precipitate as in Step 5 of Method A.

8. While stirring, add 1-2 mg cerium carrier to the organic phase and HF solution in the third centrifuge tube and continue stirring 10 minutes. Centrifuge 10 minutes; decant and discard both the organic phase and aqueous supernate.

9. Wash the CeF_3 precipitate as in Step 4 of Method A; decant and discard the wash solution.

10. Mount the CeF_3 precipitate as in Step 5 of Method A.

11. Count the samples in a ZnS scintillation alpha counter.

The direct cerium fluoride precipitation method was the shorter and simpler method, but could not be used for all samples. Certain samples formed large, gelatinous fluoride precipitates (probably rare earths) which produced thick or flakey alpha counting mounts. In general, the direct method was used for those samples which gave hydroxide precipitates not much larger than 5 ml after centrifugation for 5 minutes at 1500 RPM. For samples producing larger hydroxide precipitates, tributyl phosphate extraction eliminated the interfering material in every case. Yield determinations (recovery of added, known amounts of ionium) consistently ran above 90 per cent with the majority above 95 per cent. Final results were corrected for losses, as indicated by the yield determinations. The CeF_3 precipitates formed uniform, thin mounts with reasonable adherence. However, a ZnS scintillation alpha counter (Eberline Instrument Corporation Model Sac-1) was used for alpha counting in preference to a gas flow proportional counter in which the flow of gas might dislodge particles of the fluoride mount. Duplicate analyses and a yield determination were made on each of the samples and the results are given in Table 1. As noted earlier, the phases of the slurry samples were usually separated and analyzed separately. Supernates (-S) and residues (-R) are listed separately. When data was available from the supplier or the open literature, the ionium potential of the source was calculated and the values listed in the last column of Table 1.

Samples of five solutions and four solids with high concentrations of ionium were sent to Oak Ridge National Laboratory for the determination of thorium-232 by neutron activation analysis. The results are show in Table 2 along with the calculated thorium-232/ thorium-230 ratios.

Table I

IONIUM IN PROCESS SAMPLES

Sample Identification Number[a]	Sample Type	Ionium Concentration	Analytical Method[b]	Ionium[c] Potential of Source
1 A-S	Liquid	28.0 μg/gal	A	51 g/day
1 A-R	Solid	0.01 ppm	A	-
2 A	Liquid	120.0 μg/gal	B	45 g/mo
6 A	Solid	0.03 ppm	A	-
7 A	Solid	0.03 ppm	B	-
8 A	Solid	0.04 ppm	B	12.5 g/day
8 B	Solid	0.017 ppm	A	-
8 C	Liquid	44.0 μg/gal	B	>100 g/day
8 D	Liquid	74.0 μg/gal	B	180 g/day
10 A	Liquid	7.5 μg/gal	A	1.1 g/day
10 B	Liquid	28.0 μg/gal	A	-
10 C	Liquid	8.9 μg/gal	A	-
10 D-S	Liquid	11.0 μg/gal	B	-
10 D-R	Solid	0.01 ppm	A	-
10 E-S	Liquid	nil	B	-
10 E-R	Solid	0.009 ppm	A	-
10 F	Liquid	nil	A	-
10 G-S	Liquid	0.07 μg/gal	A	-
10 G-R	Solid	0.017 ppm	A	-
11 A	Solid	0.02 ppm	A	-
11 B	Liquid	0.01 μg/gal	A	-
12 A	Liquid	62.0 μg/gal	B	1.2 kg
13 A	Solid	0.02 ppm	A	-
14 A	Solid	0.01 ppm	A	-
14 B	Solid	0.03 ppm	A	-
14 C	Liquid	32.0 μg/gal	B	-
14 D	Liquid	2.0 μg/gal	A	-
15 A	Liquid	28.0 μg/gal	B	>10 g/day
15 B	Liquid	9.1 μg/gal	A	-
15 C	Liquid	33.0 μg/gal	A	-
18 A	Liquid	28.0 μg/gal	B	7 g/day

Table I (Continued)

Sample Identification Name[a]	Sample Type	Ionium Concentration	Analytical Method[b]	Ionium[c] Potential of source
18 B	Liquid	0.14 µg/gal	A	7 g/day
18 C	Liquid	0.4 µg/gal	B	0.14 g/day
18 D	Solid	0.39 ppm	A	390 g
18 E	Solid	2.8 ppm	B	8.2 kg
		(3.3*) ppm		–
20 A	Solid	0.03 ppm	A	–
20 B	Liquid	2.0 µg/gal	B	–
20 C	Liquid	30.0 µg/gal	B	5.4 g/day
22 A-S	Liquid	7.3 µg/gal	B	–
22 A-R	Solid	0.07 ppm	A	–
22 B	Solid	0.01 ppm	A	–
22 C	Liquid	26.0 µg/gal	A	–
23 A	Solid	0.003 ppm	A	–
23 D	Solid	0.013 ppm	B	–
24 A-S	Liquid	nil	B	–
24 A-R	Solid	1.1 ppm	A	10-20 g/day
		(1.1*) ppm		
24 B	Solid	0.07 ppm	A	79 g/mo
24 C	Solid	2.3 ppm	B	7.6 kg
		(7.0*) ppm		
26 A	Solid	0.12 ppm	A	–
28 A	Solid	3.7 ppm	B	250 kg
		(3.8*) ppm		

[a] The sources of these ionium samples are given in Appendix I.

[b] Analytical Method A = Direct CeF_3 Precipitation Method
Analytical Method B = TBP-CeF_3 Method

[c] Ionium potentials were calculated from the analytical results and information from the supplier or from the literature.

*$HClO_4$ leach

Table II

THORIUM CONCENTRATIONS OF IONIUM-BEARING SAMPLES

Sample	Thorium-232[a] (ppm[c])	Thorium-230[b] (ppm[c])	Thorium-230 (Iso. %)
2 A	2.80	0.031	1.1
8 D	1.14	0.020	1.7
12 A	0.91	0.016	1.7
14 C	2.24	0.0084	0.37
15 C	1.24	0.0087	0.70
18 E	101	3.3	3.2
24 A-R	1030	1.1	0.11
24 C	494	7.0	1.4
28 A	29	3.8	11.6

[a] Determined by neutron activation analysis

[b] Data from Table I, but units changed

[c] For solid samples, ppm = μg/gram of sample
For liquid samples, ppm = μg/ml of solution

DISCUSSION

Two possible sources of large error in the analytical procedure were recognized. The first arises from a possible incomplete leaching of ionium from the solid samples. Gamma pulse height analysis of one solid sample (24C), before and after the relatively mild nitric acid digestion, indicated that only about 15 per cent of the ionium remained in the soluble residue; but subsequent analysis, using the more vigorous dissolution method, resulted in a threefold increase in the amount of ionium. Three other solid samples, which had previously been analyzed at one part per million or higher ionium, were reanalyzed. Ionium content was increased 18 per cent in one sample and 3 per cent in another, but remained unchanged in the third. The two samples showing the greatest increase had both undergone a roasting process and it was felt that this accounted for their relative insolubilities.

A second possible source of error is coprecipitation of some of the decay products especially radium isotopes (Ra-226, Ra-224, and Ra-223 are expected to be present). This error should be markedly reduced, but may not be eliminated by a TBP extraction. Mounts of several of the richer samples were recounted after a period of at least one month and no significant change was observed. After one month, Ra-224 and Ra-223 decay to 0.3 per cent and 15 per cent, respectively, of their original values. In the same interval, Ra-226 activity increases nearly fourfold. Discounting the extremely unlikely case where the growth of the Ra-226 exactly balances the decay of Ra-224 and Ra-223, it was concluded that the coprecipitation of other activities was negligible. Considering all possible sources of error, it was estimated that the results were probably not accurate to more than ± 50 per cent for the low level samples and ± 10 per cent for the high level samples. In addition, it should be pointed out that the samples obtained were fairly small and there is no assurance that they are representative of the entire material or process stream.

The analytical results showed that twelve of the liquid samples had ionium concentrations of 25 micrograms per gallon or higher. However, two of the samples (10B, 18A) were intermediate process solutions (and would not be available for ionium recovery) and two other samples (15A and 8C) were essentially duplicates of more concentrated samples (15C and 8D). The remaining eight samples and, especially, the three most concentrated (2A, 8D, and 12A) were considered as potential sources of ionium. Of the solid samples, four had ionium concentrations above one part per million and were also considered as potential sources. It is interesting to note that the most promising liquid samples were solvent extraction raffinates and ion exchange effluents, or the tail solutions from mills using these processes. Futhermore, all of the solids with ionium concentrations over one ppm were derived from raffinate or effluent solutions. Tail residues, whether leached by acid or carbonate, had too low an ionium concentration to be considered as sources. While it is possible that more vigorous digestion of these residues would yield additional ionium, it is unlikely that the apparent ionium concentration would be increased by the two orders of magnitude necessary to make these samples comparable to those derived from raffinates.

The analytical results on the liquid samples seem to in agreement with the conclusion of Rohrman[3] that considerable quantities of ionium at isotopic concentrations of one per cent or higher pass through the uranium mills. Of course, the situation in the uranium milling industry has changed drastically from the time these liquid samples were taken in 1960 and the results cannot be applied to the current situation. However, there is a good chance that most of the solid materials are still in existence.

SUMMARY AND CONCLUSIONS

The data for the six sources with ionium isotopic concentrations of one per cent or higher are listed in Table III in order of descending isotopic concentration. On the basis of isotopic concentration and potential, the best source by far is the St. Louis residues. A second choice ionium source would depend upon a number of factors such as the quantity and isotopic concentration desired, size, type, and location of processing facilities, and the economics of recovery processes. Each alternate source may possess slight advantages over the St. Louis Residues in a particular situation, but it is the conclusion of this study that the best source of ionium was, and still is, the St. Louis Airport Residue.

Table III

SUMMARY OF DATA ON SOURCES OF IONIUM

Sample	Ionium Conc. (ppm[a])	Ionium (Iso. %)	Potential (kg)	Description
28 A	3.8	11.6	250	St. Louis Airport Residues
18 E	3.3	3.2	8.2	Stockpiled solid, Uravan, Colorado
8 D	0.020	1.7	0.18 per day	Solvent extraction raffinate, Grants, New Mexico
12 A	0.016	1.7	1.2	Recycled "Acid Sample," Edgemont, South Dakota
24 C	7.0	1.4	7.6	Q-11 Metal Oxide Fernald, Ohio
2 A	0.031	1.1	0.045 per mo.	Solvent extraction raffinate, Grand Junction, Colorado

[a] For solid samples, ppm = mg/gm of sample.
For liquid samples, ppm = mg/ml of solution.

REFERENCES

1. E. A. Coppinger, C. A. Rohrman, "Ionium (Thorium-230) for Radioisotope Preparation (Status Report)," U.S.A.E.C. Report HW-63239 (December 1959).

2. C. A. Rohrman, "Special Radioisotopes for Power: Availability and Applications of Thorium-230 (Ionium) from Uranium Ore Mills, "U.S.A.E.C. Report HW-71319 Rev. (October 1961).

3. C. A. Rohrman, "A Study of the Feasibility for the Large Scale Recovery of Ionium (Thorium-230) from Uranium Ore Milling Industry in the United States," U.S.A.E.C. Report HW-65518 (June 1960)

4. G. G. Marvin, E. F. Greenleaf, "Methods of Uranium Recovery from Ores," Progress in Nuclear Energy, Series III, Process Chemistry, Vol. 1, pp. 3-18 (1956).

5. K. B. Brown, C. F. Coleman, "Solvent Extraction in Ore Processing," Progress in Nuclear Energy, Series III, Process Chemistry, Vol. 2, pp. 3-34 (1958).

6. D. F. Peppard, et. al., J. Am. Chem. Soc. 75, 4576 (1953).

7. R. M. Edwards, R. H. Fariss, R. G. Werkema, "Ionium Recovery Plant Design Report," U.S.A.E.C. Report MCW-1427 (April 1957).

8. A. B. Van Cleave, A. P. Baerg, Canadian J. Tech. 34, 425 (1957).

9. D. J. Carswell, J. M. Fletcher, D. W. Clelland, J. Inorg. Nucl. Chem. 5, 147 (1957).

10. U. S. Atomic Energy Commission Request for Proposals for the Purchase and Removal of Uranium-Contaminated Residues, St. Louis Office Letter, June 10, 1960.

APPENDIX

IONIUM SAMPLE SOURCES

Identification Number	Description
1 A	Unfiltered waste effluent from the Anaconda Company, Grants, New Mexico. Approximately 30 per cent solids.
2 A	"TH^{230} Pregnant Solution" from Climax Uranium Company, Grand Junction, Colorado. Solution is probably a solvent extraction raffinate.
6 A	Dry tailings residue from Homestake-New Mexico Partners, Grants, New Mexico. Carbonate leach process.
7 A	Tailings composite from Homestake-Sapin Partners, Grants, New Mexico. Carbonate leach process.
8 A	"Mill Head" (dry) from Kermac Nuclear Fuels Corporation, Grants, New Mexico.
8 B	"Combined Tail" (dry) from Kermac.
8 C	"Combined Tail Solution" from Kermac.
8 D	Solvent Extraction raffinate from Kermac.
10 A	Solvent extraction raffinate from Lakeview Mining Company, Lakeview, Oregon.
10 B	"Loaded Carbonate" from Lakeview. This is the carbonate strip and is loaded with uranium.
10 C	"Clear Pregnant Liquor" from Lakeview. Solvent extraction feed solution.
10 D	"Number 8 Leach Discharge" from Lakeview. A slurry of insoluble residue and leach solution before clarification. Consists of approximately 50 per cent (volume) solids.
10 E	"N. Cyclone O'Flo" from Lakeview. Mill feed. Approximately 60 per cent (volume) solids.
10 F	"Yellow Cake Thickener O'Flo" from Lakeview. The clear supernate from the precipitation of uranium.
10 G	"Number 6 Thickener O'Flo" from Lakeview. Total tails. Approximately 60 per cent (volume) solids.

IONIUM SAMPLE SOURCES (CONTINUED)

Identification Number	Description
11 A	"C. C. D. Washed Tail" from Lucky Mac Uranium, Riverton, Wyoming. A product which is discharged to the tailings storage area, and represents the ore as finally leached.
11 B	Resin regeneration solution from Lucky Mac. A caustic solution.
12 A	"Acid Sample" from Mines Development, Incorporated, Edgemont, South Dakota. Solution is recycled to the mill.
13 A	"Dry Tailings" from Phillips Petroleum Company, Grants, New Mexico. Carbonate leach process.
14 A	Sand fraction of the insoluble residue from Rare Metals Corporation of America, Tuba City, Arizona.
14 B	Slime-fraction of the insoluble residue from Rare Metals.
14 C	Clear tailings water from Rare Metals.
14 D	Resin regeneration solution from Rare Metals. Caustic solution.
15 A	"Acid Raffinate" from Susquehanna-Western Incorporated, Riverton, Wyoming. Raffinate as pumped to tails after solvent extraction of the uranium.
15 B	"Carbonate Circuit Solution" from Susquehanna-Western. Solution that is circulated in a closed, carbonate circuit.
15 C	"Tailings Pond Effluent" from Susquehanna-Western.
18 A	"D-Liquor" from Union Carbide Nuclear Company. A sample of the"uranium barren" effluent from the ion exchange operation at Uravan. Routed to vanadium recovery.
18 B	"No. 1 Green Sludge Overflow" from UCNC, Uravan. The effluent from vanadium recovery.
18 C	Solvent extraction raffinate from UCNC, Rifle, Colorado.
18 D	This residue is essentially an aluminum phosphate precipitate which has been collected from both uranium and vanadium recovery operations at Uravan over a period of years. This residue is not currently being produced, but it is estimated that in excess of 1000 tons are stockpiled.

IONIUM SAMPLE SOURCES (CONTINUED)

Identification Number	Description
18 E	"Carbonate Roast Residue" from UCNC, Uravan, Colorado. An iron-aluminum-phosphate and vanadium bearing mixture from current vanadium recovery circuits. Probably in excess of 2500 tons of this material is stockpiled.
20 A	"Acid Leach Tails" from Vanadium Corporation of America, Durango, Colorado. Dry solid.
20 B	"Acid Leach Tails Liquor" from Vanadium Corporation. Liquid portion of the final tailings.
20 C	Solvent extraction raffinate from Vanadium Corporation.
22 A	"Total Tails, Mill" from Western Nuclear Incorporated, Split Rock Mill, Jeffery City, Wyoming.
22 B	"Tailings Sand, Pond" from Western Nuclear.
22 C	"Tailings Water, Pond" from Western Nuclear.
23 A	Mallinckrodt MgF_2 Slag obtained from Winchester Laboratory, Winchester, Mass.
23 D	Mallinckrodt Dolomite Slag obtained from Winchester Laboratory, Winchester, Mass.
24 A	Solvent extraction raffinate from current production. National Lead Company, Fernald, Ohio. Approximately 75 per cent (volume) solids.
24 B	"Trailer Cake" from Fernald. Magnesium fluoride residue from uranium reduction which has been mixed with graphite, leached with HCl (to recover uranium) and vacuum dried.
24 C	"Q-11 Metal Oxides" from Fernald. Calcined raffinate residue from Q-11 (pitchblende) processing. Some 800 to 1000 tons is stored in a silo, but has been covered by metal oxides from later processing of low grade ores. In addition, about 250 tons are stored in 1200 55-gallon drums.
26 A	Fluorinator ash from Goodyear Atomic, Portsmouth, Ohio.
28 A	A sample of "St. Louis Airport Residues" from Mallinckrodt Chemical Works retained from previous ionium processing.