C-AD MIRP
EXPERIMENTAL WORK PERMIT
SEPARATION/PURIFICATION OF AC-225 FROM THORIUM

LOCATION: BUILDING MIRP, LAB 62 AND LAB 68
REVIEW PERIOD 7/16 THROUGH 7/17

Principal Investigator Signature:

Approval Signature, ESRC:

____________ _______7/14/16______
M. Sivertz Date

Approval Signature, RCD:

____

N. Contos Date

Approval Signature Radio Isotope Research Head:

____
L. Mausner Date

Approval Signature, MIRP Head:

____
C. Cutler Date

Approval Signature, C-AD A&R:

____
P. Cirnigliaro Date

Approval Signature, RSC:

____
D. Beavis Date

Define the Scope of the Work

Purpose of Experiments:

The DOE isotope program is interested in producing Ac-225 from proton irradiation of Th at high energies (>100MeV), the target undergoes fission and produces >300 isotopes. The Ac-225 chemistry working group has identified two separation issues for purification of production scale quantities of Ac-225: bulk separation of Thorium from Ac-225, and separations of Ac-225 from lanthanides (Ce and La). We will examine separations involving Thorium and Ac-225.

Hazards and Controls Associated with the Work

<u>Hazard:</u> Physical
Cuts from broken glass, Bursting or shattering of apparatus, Fire from runaway hot plate, or heating elements
Electrical shock from electrical (110 VAC) equipment

Default Controls:
- All glassware inspected for cracks or defects prior to use
- Handle glassware properly
- Distillation/reflux apparatus used under a fume hood with sash or in a glove box, process to be monitored at all times.
- Work alone after hours only if permitted by supervisor
- Use of hot plates or thermal heaters with temperature displays and feedback circuits to prevent overheating
- use of GFCI adapters where liquids are in close proximity to electrical devices

<u>Hazard:</u> Chemicals, (General):
Corrosives, Oxidizers (strong acids and bases)
Chemical burns, ingestion, inhalation, absorption through skin

Default Controls:
- All operations with < 250ml quantities of hazardous chemicals (pouring, mixing, evaporation, etc) in hood, or glove box
- Register Commercial Chemicals in CMS
- Work alone after hours only if permitted by supervisor
- Identify containers so contents are identifiable unless being actively used
- Food, beverage, smoking, and cosmetics are prohibited
- Handle glassware properly: no mouth suction, no drinking from lab ware.
- Unobstructed access to Emergency Eyewash and Shower

<u>Hazard:</u> Chemicals, Hydrofluoric Acid use
Chemical burns, ingestion, inhalation, absorption through skin
Default Controls:
Use hazardous chemicals controls plus:
- HF burn kit (training on use by SHSD rep)

- Location of HF to be entered on Fire Run Card and Hazard Information placard
- Designated area for HF use and storage must be Posted.
- Two people must be in speaking/hearing range at all times that HF is in use.
- Off-hours use generally prohibited. Must be approved by OMC Mgr. and Chem Hygiene officer
- HF storage in its own secondary containment
- PPE: as for corrosives plus:
- PPE: Face shield for >2% solutions (1 molar). or if high splash potential.
- HF resistant apron (typ. thick butyl rubber or neoprene)
- Spill cleanup: <10ml in fume hood can be neutralized with Calcium carbonate or hydroxide
- Spill cleanup: >10 ml or any amount outside hood: evacuate and call 2222.
- Any worker exposure immediately report to OMC.

<u>Hazard:</u> Dispersible Radioactive material
Alpha emitting materials (Th and Ac)

Default Controls:

Engineering Controls:
- Work conducted in designated RMA. Material may require additional controls (e.g. HEPA filtered glove box, HEPA filtered fume hood).
- Physical areas boundary.
- Shielding if required.
- Secondary containment for storage/transport for radioactive liquids

Administrative Controls:
- Radiological Work Permit, routine sampling for alpha contamination
- Specific procedures for handling and internal transport
- Rad Area Postings, and Rad Material labeling
- All radioactive materials brought on-site or taken off-site must go through I&SM.
  Training:

PPE:
- Latex, nitrile or other specified glove type, red-trimmed or rad work only designated Lab Coat

Dosimeter/Monitoring:
- TLD, Bioassay as specified by RCD
- RCT survey of all items and samples upon removal from RMA area
- RCT monitoring/job coverage as specified by RCD

Hazard: Environmental
Waste Generation, Spills

Hazard: Radioactive Waste Generation

Default Controls:

Engineering Controls:

- Segregate, quantify and package waste in appropriate containers.
- Segregate, quantify, and package Th and Ac waste in appropriate containers. No Th or Ac is to be disposed of into the D-waste stream.
- Have containers surveyed by a Radiological Controls Technician (RCT).
- Provide secondary containment for liquid waste that holds greater than 10% of total waste volume or 100% of the volume of the largest container.

Administrative Controls:

- Identify and record inventory on Radioactive Waste Inventory and Control Forms.
- Label containers with radioactive waste label.
- Tally the quantity of waste and characterize it.
- Submit the Rad Waste Control Form (RWCF) or the Accountable Nuclear Material Waste Control Form (ANMWCF) and supporting characterization documentation to the Radioactive Waste Accumulation Manager.
- Ensure waste is moved to Radioactive Waste Accumulation Area.
- Comply with the SBMS Subject Area "Radioactive Waste Management"

Hazard: Decay in Storage Radioactive Waste (half life < 90days)

Default Controls:

Only applies to isotopes with half-lives of <90 days, all others are Rad Waste
Engineering Controls

- See radioactive waste section above

Administrative Controls

- Segregate waste and mark containers with short-lived isotope(s)
- Have containers surveyed by a Facility Support Rep (FSR) before moving from controlled areas.
- Complete DIS Record for each disposal and include ultimate disposal (e.g. Haz, Mixed, RMW, Industrial).
- Retain records of DIS waste.

Notes:

1. Hazardous DIS Wastes must be accumulated at or near the “point of generation” and in accordance with RADCON requirements.
2. Comply with the SBMS Subject Area: “Radioactive Waste Management”.

Engineering Controls:

- Segregate, quantify and package waste in appropriate containers.
- Waste containers will be closed and placed in a tray (secondary containment) within storage accumulation area.
- Have containers surveyed by a Radiological Controls Technician (RCT) prior to removal.

Administrative Controls:

- All hazardous waste containers will have (red) “Hazardous Waste Labels” that has the generators name and chemical contents (formula not acceptable.
- All waste will be accumulated in closed containers and kept in established posted areas until ready for transfer to the 90 Day Haz Waste Area for pickup.

Hazard: Storage, Use of any chemicals or radioactive materials capable of resulting in a reportable release to the environment

Default Controls:

Engineering Controls:

- Use of secondary containment.
- Protect sinks, floor drains or other pathways to the environment.
- Segregate, quantify and package waste in appropriate containers.

Administrative Controls:

- Small low hazard spills on non-radioactive material may be cleaned up by the individual knowledgeable of the hazards and comfortable doing so.
- Spills of radioactive alpha emitters, in the lab environment, glove box or fume hood, will require the worker stop work and consultant the RCT or staff. Resumption of work will require the approval of the FS Representative and the Radio Isotope Research Head.
- Use of secondary containment.

Training:

JTAs

AD-030	C-AD Sealed Source User
AD-101	Occupational Safety & Health (OSH) Awareness
GE-03	Research Position
GE-100	Information Security Awareness Qualified
GE-53E	BNL Employee Requirements
GE-76	Source Custodian
GE-77I	C-AD Access Training

Additional R&A:

Hydrofluoric Acid: OPM 19.9.100 Working with Hydrofluoric Acid (HF)

Emergency Procedure:

Any release of alpha emitting material beyond the confines of the glove box or FS approved transport container will be considered a Stop Work. Approval of the ESSHQ Division Head and Department Chair is required for restart of work.

Worker feedback and Improvement:

Feedback via the post-job review provides supervisors, work planners and management, with an important and fresh source of information about task-specific performance. Such information can be used to improve the organization of work, increase productivity, and help identify opportunities to strengthen defenses against error and events, and to eliminate error precursors embedded in the task. Workers are encouraged to provide feedback verbally or written during any time that the work is performed or after completion of the work.

Project Termination:

All waste generated at BNL will be properly disposed of. All radiological contamination including equipment, laboratory, and supplies shall be decontaminated to the levels approved by the MIRP FS Representative.

Chemical Processes

Separations Ac from Th and/or Ac from lanthanides (Ce/La)

Phase One:

Bulk thorium (Th) is used with non-radioactive spikes of lanthanum and other metals. These experiments will involve dissolving Th foils, adding non-radioactive metals, then performing separations with cation exchange columns. The analysis will involve ICP-OES of the eluted solvents. Experiments will focus on using various ratios of complexing agent (either citric acid or tartaric acid) to Th at pH 1.5-2.5 in the separation. The goal of the experiment will be to determine what ratio of complexing agent is needed to elute the Th and allow retention of La from the column. The studies will track >21 other metals by ICP-OES to determine the impurity profiles.

Evaluate/develop a separation to purify Ac-225 from grams amounts of Thorium (up to 2 grams) utilizing chelating agents (citrate and tartaric acid) and cation exchange resin.

Notes:

1. Non-radioactive Lanthanum (La) has similar chemical properties to Actinium-225, so we will use La as a surrogate to track where Ac-225 should go in the separation.
2. The entire process of dissolution and concentration will take place within a HEPA filtered glove box, within a HEPA filtered fume hood, except the spectral analysis by ICP-OES.

Using a balance in the same lab as the glove box, on a lab bench, the bottle/container the thorium is in will be weighed. The Th container will be transferred to the glove box and remove the thorium. The container will then be removed from the glove box and the empty container will be weighed.

Note:

A specific procedure (Appendix 3) is used for transferring material in and out of the glove box is used to minimize the potential to spread alpha emitting radioactive material

Thorium will be dissolved in concentrated acid solutions and the final solution will be evaporated in an distillation apparatus and re-dissolved in weak acid and a complexing agent. Addition of other metals may occur before or after evaporation.

Dissolution of Th may involve concentrated acids and may use of hydrofluoric acid.

Bulk thorium (Th) is used with non-radioactive spikes of lanthanum and other metals. These experiments will involve dissolving Th, adding non-radioactive metals, then performing separations with cation exchange columns. The analysis will involve ICP- OES of the eluted solvents. Experiments will focus on using various ratios of complexing agent (either citric acid or tartaric acid) to Th at pH 1.5-2.5 in the separation. The goal of the experiment will be to determine what ratio of complexing agent is needed to elute the Th and allow retention of La from the column. The studies will track >21 other metals by ICP-OES to determine the impurity profiles.

Note:

See appendix 1, OPM 19.9.100 Working with Hydrofluoric Acid (HF).

Materials Used:

Materials Used	Disposal Method	Amount per Use	Amount per Year	Approximate Activity per sample	Approximate Activity per year	Comments
Strong Acid Cation Exchange Resin	Radioactive	10.00 g	1000.00 g			
acids: nitric acid, hydrochloric acid	Radioactive	10.00 ml	1000.00 ml			
Hydrofluoric Acid	Radioactive	1.00 ml	50.00 ml			HF will only be used during the dissolution of the Thorium matrials
tartaric acid and citric acid	Radioactive	2.00 g	1000.00 g			
base solutions: sodium hydroxide or ammonium hydroxide	Radioactive	10.00 ml	500.00 ml			a base rinse will be tested
metals representing an Ac-225 irradiated sample	Radioactive	1.00 ppm	100.00 ppm			A number of non radioactive metals will be used as spikes they will be in less than 0.1 ppm for each metal
Natural thorium (Th-231)	Radioactive	2.00 g	500.00 g			
Irradiated Thorium	Radioactive					
Actinium-225	Radioactive	0.00 other	0.00			0.05-0.1 mCi spikes will be used.
inorganic resins	Radioactive	10.00 g	100.00 g			
modified polymer solid supports	Radioactive	120.00 ea	100.00 ea			

APPENDIX

Completion of ESRC minutes of 6/16 ATS items (Appendix 9)

PI Signature Completion of all action Items: __________________________ Date:____________

WORK PERMIT SIGN OFF SHEET

Signature implies that the worker understands the scope and limitations of the Work Permit and training is kept current.

Print Name	Signature	Date	Process Review /Date

<u>Appendix 1</u>

If you are using a printed copy of this procedure, and not the on-screen version, then you <u>MUST</u> make sure the dates at the bottom of the printed copy and the on-screen version match.

The on-screen version of the Collider-Accelerator Department Procedure is the Official Version. Hard copies of all signed, official, C-A Operating Procedures are available by contacting the ESSHQ Procedures Coordinator, Bldg. 911A

C-A OPERATIONS PROCEDURES MANUAL

19.9.100 Working with Hydrofluoric Acid (HF)

Approved: __________***<u>Signature with Date on File</u>***___________________

Collider-Accelerator Department Chairman Date

J. Fitzsimmons

19.9.100 Working with Hydrofluoric Acid (HF)

1. **Purpose**

This document describes the requirements for working with HF in the Radionuclide Research and Production Laboratory. It applies to anyone in the R&RR Group working with HF in the facility.

HF is used in the R&RR Group to dissolve materials that cannot be dissolved in other acids. It can, therefore, be used for target material dissolution, column washing, etc. It is also used as a component of standards solution for the ICP (for which see C-A OPM 19.16.30, "ICP-OES Operation")

2. **Responsibilities**

2.1 Assure that the location of HF has been identified on the Fire Rescue Run Card System and Hazard Information Placard at doorways (See R&RR Grp ESH Coordinator).
2.2 HF must be used in an engineered controlled environment such as a fume hood or glove box.
2.3 Eye wash and shower stations shall be in the immediate area. If working in labs without showers the lab doors must be propped open.
2.4 Do not work alone with HF. Two people must be able to communicate verbally and within hearing range of each other while HF is being used at all times.
2.5 Do not work outside normal working hours unless approved by Occupational Medicine Clinic and the BNL Chemical Hygiene Officer.
2.6 Do not store with organic acids or sulfuric acid.
2.7 Do not transfer concentrated HF to glass or metal containers.
2.8 Segregate HF in plastic secondary containers with an appropriate label.

3. **Prerequisites**

3.1 General:

3.1.1 Personnel working with HF in laboratories or personnel who may be expected to give HF first aid take the Lab Standard Training before using HF. Those who require HF-related training are listed in C-A-OPM-ATT 19.9.100.a, Hydrofluoric Acid (HF) Staff".

3.1.2 Post areas where HF is used as a Designated Area (use this posting https://sbms.bnl.gov/sbmsearch/subjarea/120/12026e011.doc or equivalent). The Designated Area is recommended to be small as reasonably achievable to prevent contamination (typically, a fumehood).

3.1.3 Follow the decontamination plan in Chapter 8 of the Chemical Hygiene Plan (https://sbms.bnl.gov/sbmsearch/subjarea/120/12024e011.pdf) for the Designated Area and any equipment. The Designated Area must remain posted until decontaminated

4. **Precautions**

4.1 Hydrofluoric acid is classified as a highly acute toxin. Special precautions apply for its use. Hazards include:

- Severe burns to the skin.
- Deeply penetrates skin and may involve underlying bone.
- Inhalation can cause fluid in lungs and severe respiratory burns.
- Systemic fluoride ion poisoning from severe burns is associated with low calcium and magnesium and high potassium in the blood and can cause sudden death.

5. **Procedures**

5.1 PPE:
The following PPE is required;

- Chemical Splash Goggles when working with any amount of HF. A Face shield is required when handling solutions greater than 2% (1 molar), or if high splash potential exists.
- Long pants and a long sleeve shirt (or an ankle length skirt/dress with long sleeve shirt); Lab coat; HF resistant Apron (e.g., thick butyl rubber, neoprene, etc.) when handling solutions greater than 2% (1 molar), or if high splash potential exists.
- Socks and fully enclosing shoes are required
- Impervious gloves are required. (See Glove Guidance, below).

5.1.1 GLOVE GUIDANCE

- Chemical Splash gloves are not approved for spill cleanup. A combination of an inner composite glove with a heavy Neoprene outer glove is recommended.
- Gloves for spill cleanup will be Neoprene, Butyl rubber, or composite type gloves, or combinations of these gloves with a manufacturer approved degradation rate and breakthrough time greater than the anticipated length of operation are required. Glove choice and glove combinations for use with HF are a very important component of protection from HF. Contact the Working with Chemical Subject Matter Expert (Chemical Hygiene Officer) for specific advice regarding your application. Below are recommended glove choices.
    - <2% concentration (1 molar) and no splash potential; Neoprene disposable gloves (e.g., Ansell brand Neotouch). Nitrile disposable gloves are not

recommended for HF use. Gloves are to be immediately removed or changed out if there is any HF contact on gloves.
    - >2% concentration or if a splash potential exists; Neoprene, Butyl rubber, or Silver Shield or Barrier composite type gloves with a degradation rate and breakthrough time greater than the anticipated length of operation are required (e.g., Ansell Brand Dermashield) offer good dexterity and clean room quality for these type of operations)
    - >20% concentration; Neoprene, Butyl rubber, or Silver Shield type gloves with a manufacturer approved degradation rate and breakthrough time greater than the anticipated length of operation are required.
- A combination of double gloving that meets the degradation and breakthrough criteria is acceptable and often the preferred method of hand protection when working with concentrated HF (e.g., a impermeable glove underneath a close forming glove.
- The dexterity requirements of the operation should be taken into consideration when selecting gloves. Neoprene is the glove of choice for dexterity. Some vinyl gloves may be acceptable for breakthrough but are slippery when wet.
- Always check gloves for breakthrough (leaks) prior to use. Discard any damaged gloves.
- Decontaminate reusable gloves after use per the decontamination plan described in Chapter 8 of the Chemical Hygiene Plan (https://sbms.bnl.gov/sbmsearch/subjarea/120/12024e011.pdf.

5.2 Spill Response:

5.2.1 Large Quantity (>10 ml) or any quantity outside of fume hood:

- Evacuate area; Call x2222
- Do not attempt clean-up of HF
- Avoid inhalation of Vapors

5.2.2 Small Quantity (<10 ml) Inside Fume Hood:

- Apply powdered calcium carbonate or calcium hydroxide or use a commercial HF Spill kit
- Properly dispose of waste

5.3 First Aid:

Note:
The required burn kit shall be located in the corridor outside Labs 2-58 – 2-62 (PC2-11).

Because the worker may not feel an HF burn immediately, assume any liquid exposure detected is HF and respond as detailed below.

5.3.1 Skin Contact

For an HF Burn the primary focus should be victim decontamination with large amounts of water and initiation of first aid. Large burns the size of the palm of your hand can be lethal. You must have an HF Burn Kit available for continued treatment in route to a hospital. The first fifteen minutes of antidote application are critical.

> **Note:**
>
> Suffolk County procedures prohibit Fire Rescue from stocking HF Burn antidotes on their vehicles.

affected area thoroughly with large amounts of running water. Speed and thoroughness in washing off the acid is of primary importance.

- Begin Flushing even before removing clothing. Remove all contaminated clothing and jewelry while continuing to flush with water.
- If an HF Burn kit is available, flushing may be limited to 5 minutes, with the benzalkonium soaks (5A) or gluconate gel (5B) applied as soon as the rinsing is stopped. If an HF Burn Kit is not available continue flushing until medical treatment is rendered.
- Call x2222 immediately and specify there is an HF Burn.
- Immediately after a thorough flushing, use one of the following measures to neutralize the HF acid using the contents of the burn kit;
  - o Don surgical gloves (in HF Burn Kit) to avoid HF contamination during first aid and Begin soaking the affected areas in iced 0.13% benzalkonium chloride solution. Gauze sponges (compresses) should be soaked with a 0.13 % benzalkonium chloride solution and applied to the burned area with ice packs on top. Compresses should be liberally and continuously soaked (every 2-4 minutes) with the 0.13 % benzalkonium chloride solution to neutralize the HF acid. <u>DO NOT USE benzalkonium chloride solution for burns of the face or eyes as</u> it is an eye irritant. Benzalkonium chloride soaks or compresses should be continued until medical treatment is provided.

    OR

  - o Don surgical gloves (in HF Burn Kit) to avoid HF contamination during first aid and start massaging 2.5% calcium gluconate gel (in HF Burn Kit) into burn site. Apply gel evenly for 15 minutes and massage continuously until medical treatment is provided.
- After treatment of burned areas has begun, the victim should be examined to ensure that there are no other burn sites which have been overlooked.
- The burn victim MUST be seen by a physician. During transportation to a medical facility or while waiting for a physician to see the victim, it is extremely important to continue the benzalkonium chloride soaks or compresses or continue massaging with calcium gluconate gel.

5.3.2 <u>Eye Contact:</u>

5.3.2.1 Immediately flush the eyes for at least 15 minutes with large amounts of gently flowing water. Hold the eyelids open and away from the eye during irrigation to allow thorough flushing of the eyes.

5.3.2.2 <u>Do not use the benzalkonium chloride solutions or calcium gluconate gel prescribed for skin treatment</u>.

5.3.2.3 Irrigate the eye using the eye wash provided in the HF Burn kit for additional relief after flushing with eye wash.

5.3.2.4 Call x2222 immediately and specify there is an HF eye burn.

5.3.3 Inhalation of Vapors:

Vapor exposures can cause skin and mucous membrane burns as well as damage to pulmonary tissue. Vapor burns to the skin are treated the same as liquid HF burns.

5.3.3.1 Immediately move the victim to fresh air and call x2222 and specify an HF inhalation burn.

5.3.3.2 Keep the victim warm, quiet and comfortable.

5.3.3.3 If breathing has stopped, start artificial respiration only when and if you can be sure you will not be exposed to HF on the victim or in his/her mouth or nose. Make sure mouth and throat are free of foreign material and airway is open.

Note:

HF is so reactive; it would be unlikely that the victim would re-exhale HF vapors that had been inhaled

5.3.3.4 Secure the HF inhalation incident area, evacuate the area of building if necessary, and do not allow others to enter.

5.3.3.5 The victim should be examined by a physician and held under observation for at least a 24 hour period for delayed effects.

5.3.4 Ingestion:

Ingestion of even a small, dilute of HF is a life threatening emergency.

5.3.4.1 Have the victim drink large amounts of water as quickly as possible to dilute the acid.

5.3.4.2 Do not induce vomiting and unconscious person.

5.3.4.3 Call x2222 immediately and specify an HF ingestion burn.

6. Documentation

6.1 Records regarding training to this SOP will be maintained by the R&RR Grp ESH Coordinator.

7. References

7.1. Chemical Safety (https://sbms.bnl.gov/sbmsearch/subjarea/120/120_SA.cfm?parentID=120)
  7.1.1 *Chemical Hygiene Plan*, section 6.1.A, Hydrofluoric Acid (https://sbms.bnl.gov/sbmsearch/subjarea/120/12024e011.pdf)

7.2. Spill Response SA (https://sbms.bnl.gov/sbmsearch/subjarea/26/26_SA.cfm?parentID=26)

7.3. Personal Protective Equipment (https://sbms.bnl.gov/sbmsearch/subjarea/119/119_SA.cfm?parentID=119)

7.4. RRP Key Personnel (Consult this document for contact information regarding any reference to staff in this document)

8. Attachments

8.1 HF Burn Kit Location memo

8.2 C-A OPM-ATT 19.9.100.a, "HF Trained Staff"

Attachment 8.1

HF Burn Kit Location Memo

Building 801
P.O. Box 5000
Upton, NY 11973-5000
Phone 631 344-3617
Fax 631 344-5962
bullis@bnl.gov

BROOKHAVEN
NATIONAL LABORATORY

managed by Brookhaven Science Associates
for the U.S. Department of Energy

Memo

date: *February 3, 2010*

to: *R. Selvey, CHO*

from: *J. Bullis*

subject: *Location of HF Burn Kit*

An approved HF burn kit has been purchased, as required in the Chemical Safety subject area, and will be located in building 801, in the hallway across from lab 2-58.

cc: A. Emrick
N. Felock
L. Mausner

* * *

Appendix 2

Collider-Accelerator Department

BROOKHAVEN NATIONAL LABORATORY

Building 911A
P.O. Box 5000
Upton, NY 11973-5000
Phone 631 344- 5636
Fax 516 344-5676
cim@bnl.gov

managed by Brookhaven Science Associates
for the U.S. Department of Energy

date:	*December 8, 2014*
to:	*C-A Experimental Safety Review RRPL Sub-Committee*
from:	*Y. Makdisi / P. Cirnigliaro*
subject:	*Minutes of the Separation of Ac-225 from Th-232 Experiment Presented 12-3-14*

Present: P. Cirnigliaro, N. Contos, J. Fitzsimmons, R. Karol, Y. Makdisi, L. Mausner, D. Medvedev, D. Ryan, S. Smith

J. Fitzsimmons presented to the committee the scope of the experimental study, *Develop a separation methodology to purify Ac-225 from Th-232, utilizing chelating agents, and cation exchange resin, polymers with crown ethers or inorganic titanium materials.* The experiment was presented in 3 studies A-C. The committee concentrated on Study A Phase 1, *Evaluate/develop a separation methodology using non-radioactive Ac-225 surrogates (La and Ce) from Th-232. A fourth study was briefly discussed where an organic polymer would be evaluated for an Ac-225/Bi-213 generator system.*

Study A
The Th is dissolved in concentrated acids, possibly including small additions of HF. The Th solution is heated to evaporate the solvent in a distillation apparatus to contain the acid fumes. The entire process will be carried out in a glove box with a commercial HEPA filtered exhaust. The glove box will be placed within a certified HEPA filtered fume hood. The resulting solute will be re-dissolved in weak acids and complexing agents. Addition of the La,Ce and other non radioactive metals to the solution may be made before or after the evaporation.

Phase 1 will include performing separations on cation exchange columns. Experiments will focus on using various ratios of complexing agents to optimize the ratio to allow retention of the La,Ce and maximize elution of the Th. Analysis of the resulting eluted solutions will involve ICP-OES.

Phase 2 is similar to phase 1 with the inclusion of Ac-225 to the solution containing complexing agents. Analysis will include ICP-OES and gamma spectroscopy. Ac-225 samples may be evaporated prior to analysis.

Phase 3 will include high activity amounts of Ac-225 and proton irradiated Th targets. A separate safety submission will be submitted to ESRC for Phase 3.

Studies B-D will be reviewed in separate ESRC meetings, including smaller ESRC sub-committees and RSC review as appropriate.

The following are the pre-start action items for Study A, Phase 1:

- A review of the radiological requirements and implementation, if required, of a Bio-Assay baseline and monitoring of workers and radiological control staff associated in this study. (Contos, Kahanhauser)
- The glove box will be fitted with a commercial HEPA filter on the exhaust and intake. A fan will be fitted on the exhaust to maintain negative pressure in the glove box. A schedule for filter replacement will be established.
(Contos, Fitzsimmons)
- The glove box will be checked for integrity and periodically leak checked to ensure no leakage of radioactive (alpha) material during use.
(Contos, Fitzsimmons)
- The glove box will be placed within the certified HEPA filtered fume hood. A face velocity test of the fume hood shall be performed and results evaluated. (Cirnigliaro)
- The hot plate used in this study shall be of the type that visually indicates the hot plate temperature and maintains the set point temperature. Periodic testing of the operational controls of the hot plate should be performed.(Fitzsimmons)
- A radiological procedure shall be documented to minimize alpha contamination when samples are removed from the glove box for analysis by ICP-OES and gamma spectroscopy.(Contos, Fitzsimmons)
- A radiological procedure shall be documented to minimize alpha contamination of analytical instrumentation systems and associated duct work when samples are analyzed by ICP-OES and gamma spectroscopy.(Contos, Fitzsimmons)
- An Experimental Work Plan is to be developed and documented for this study. (Cirnigliaro, Fitzsimmons)
- A Radiation Work Permit shall be generated for this experimental study. (Contos, Fitzsimmons)
- Schedule a walkthrough of a ESRC sub-committee of the experimental set up prior to approval to start experiment.(Fitzsimmons)

The ESRC committee, after the completion of the pre-start conditions including a walkthrough, has approved the experimental study Part A, with the following restrictions:

1) The maximum amount of Th-232 used is 2 grams.
2) No use of Ac-225 is allowed at this time.

The ESRC has requested that the Radiation Safety Committee review this experimental proposal, specifically the use and controls of Ac-225.

cc: T. Roser, P. Pile, B. Mueller, D. Beavis, E. Lessard, S. Kurczak, L. Muench, J. Nalpea, A. Goldberg, L. Evers, L. Walker, H. Kahnhauser

File

Appendix 3

Procedure to transfer alpha materials from glove box
Reduction of contamination to transfer container

All column separation will be performed with a disposable absorbent pad under the column. This pad will be replaced weakly or if it is believed to be contaminated.

To reduce contamination of the transfer chamber the door from the glove box to the transfer chamber will be closed during all chemical work and during any liquid transfers to beakers, flasks, or waste containers.

The door to the transfer chamber may be opened when all radioactive samples are in closed systems, (such as: closed containers, glassware that is capped or closed to the environment, waste that is in a closed container.)

Prior to a transfer into or out of the glove box a disposable absorbent pad will be placed in the transfer chamber to absorb any radioactive spills or potential contamination. This pad will be replaced weakly or if it is believed to be contaminated.

Transfer of Samples for analysis

All samples for analysis will be in either a 5 ml vial (gamma spectroscopy samples) or in a 15 ml centrifuge tube (ICP-OES samples).

The samples will be placed in a small tray or container in the transfer chamber.

A radiation control technician will survey the outside of the vial/tube for contamination.

The worker will wear PPE according the RWP for the Ac-225 work.

If the outside of the vial/tube is free of contamination then the sample will be placed in a secondary container with a lid for transport to the instrument room for analysis.

If the outside of the vial/tube is contaminated then the work will be stopped and actions outline in the work permit will be followed.

Transfer of Waste

Liquid radioactive waste will be placed in containers that can fit inside the transfer chamber.

Solid radioactive waste: Columns with resins and disposable pads will be disposed of as solid radioactive waste and the material will be placed in separate container.

The radioactive waste containers will be placed on the disposable absorbent pad in the transfer chamber.

A radiation control technician will survey the outside of the container for contamination.

The worker will wear PPE according the RWP for the Ac-225 work.

If the outside of the container is free of contamination then the radioactive waste container will be placed in secondary containment and stored in the fume hood until the radioactive waste group picks up the material for disposal.

After transfer of the any radioactive waste the disposable absorbent pad will be placed in a low level radioactive waste.

If the outside of the container is contaminated then the work will be stopped and actions outline in the work permit will be followed.

Glove box and transfer chamber opening is 10.5X10.5 inches.

Appendix 4

Procedure to transfer alpha containing material from Lab 62 to Lab 68

From Appendix 3

Transfer of Samples for analysis

All samples for analysis will be in either a 5 ml vial (gamma spectroscopy samples) or in a 15 ml centrifuge tube (ICP-OES samples).

The samples will be placed in a small tray or container in the transfer chamber.

A radiation control technician will survey the outside of the vial/tube for contamination.

The worker will wear PPE according the RWP for the Ac-225 work.

If the outside of the vial/tube is free of contamination then the sample will be placed in a secondary container with a lid for transport to the instrument room for analysis.

Transfer of Alpha containing materials from Lab 62 to Lab 68

The samples for analysis will be transported inside a closed secondary container for transfer from Lab 62 to Lab 68.

Different secondary containers will be used for the gamma spectroscopy sample and for the ICP-OES sample.

If they are contaminated the secondary containers will be replaced.

The worker will wear PPE according the RWP for the Ac-225 work.

The samples inside secondary containment will be moved to Lab 68.

A vortex mixer is located at the ICP-OES.

The sample for ICP-OES analysis will be placed on a vortex mixer and mixed for ~10 seconds. The sample will be vortexed either inside the secondary container used to transfer the sample or the sample will be moved to a 50 ml centrifuge tube and vortexed.

The sample will be placed in a 50 ml centrifuge tube for secondary containment, and placed in the sample holder rack for the ICP-OES. This rack is in a large secondary container located on the L-Block in front of the ICP-OES.

Appendix 5

Procedure to minimize alpha contamination using ICP-OES and Gamma Spec instrumentation.

From Appendix 3 and 4

A radiation control technician will survey the outside of the Ac-225 and/or thorium vial/tube for contamination.

The worker will wear PPE according the RWP for the Ac-225 work.

If the outside of the vial/tube is free of contamination then the sample will be placed in a secondary container with a lid for transport to the instrument room for analysis.

Minimize Sr-82 impact

To minimize the impact of Ac-225 on the analysis of Sr-82 batches, samples of Ac-225 will not be analyzed on the same day as the analysis of Sr-82 batches. If a different detector not associated with the analysis of the Sr-82 batch is available then the analysis of Ac-225 can occur on the same day. If the analysis of the Sr-82 batch is complete then the analysis of Ac-225 can occur on either ICP-OES or a gamma detector.

Gamma Spec analysis

The sample will be counted in the counting vial used by the group.

After counting the sample the sample will be placed back in secondary containment and transported back to the glove box.

After all the samples have been counted a background count will be performed and gamma peaks for Ac-225 (99 keV, 3%), Fr-221 (217.6 keV, 12.5%), Tl-209 (117.00 keV, 77.0%, 465 keV, 96.6%, 1566 keV, 99.7%), Bi-213 (440 keV, 79.2%) may be monitored. If radioactivity associated with Ac-225 is observed in the gamma spectrometer then the instrument will undergo wipe tests by the radiation control group to determine the location of the radioactivity. The instrument will be decontaminated before the next user.

If the sample is spilled or contamination is observed/detected the worker will stop work, contact radiation control group immediately and follow the information in the C-AD MIRP experimental work permit: separation/purification of Ac-225 from thorium procedure on spills.

ICP-OES analysis

From Appendix 4

The Ac-225 or thorium samples inside secondary containment will be moved to Lab 68.

A vortex mixer is located at the ICP-OES.

The Ac-225 or thorium sample for ICP-OES analysis will be placed on a vortex mixer and mixed for ~10 seconds. The sample will be vortexed either inside the secondary container used to transfer the sample or the sample will be moved to a 50 ml centrifuge tube and vortexed. [Explanation: Thorium can form a concentration gradient in unmixed vials.]

The sample will be placed in a 50 ml centrifuge tube for secondary containment, and placed in the sample holder rack for the ICP-OES. This rack is in a large secondary container located on the L-Block in front of the ICP-OES.

The worker will wear PPE according to the RWP for the ICP-OES, and follow safety precautions associated with the RWP for the ICP-OES.

Ac-225 and thorium samples will have volumes up to 5 mL.

The sample for analysis will be kept capped until the sample is being analyzed.

The entire sample will be used in the analysis, the empty vial will be capped and disposed of in low level radioactive waste.

After analysis of the sample the ICP-OES tubing will be carefully removed from the sample vial by pulling the tube up in a chem wipe and the sample tubing will be transferred to a tube with 10 ml of a 2% nitric acid solution in a 15 ml centrifuge tube. The chem wipe will be disposed of as low level radioactive waste. The entire 10 ml sample of 2% nitric acid solution will be pumped into the instrument. The 2 % nitric acid should remove any radioactive contamination on the tubing, and glass wear in the instrument. The tubing will be pulled up in a chem wipe, or other wipe and transferred to a separate solution. The chem wipe or other wipe will be analyzed by radiation control for the presence of thorium, Ac-225 or daughters of Ac-225. If this approach is found to be adequate at removing radioactive contamination on the tubing then radiation control may omit the survey of the tubing.

A stock solution of 2% nitric acid solution will be labeled "for Ac-225 or Thorium analysis-not for production" and the solution will not be used during the Sr-82 batch analysis. [Explanation: A 2% nitric acid solution is used to rinse the ICP-OES before and after analysis of Sr-82 samples].

After all Ac-225 or Thorium analysis is conducted the radiation control group will conduct surveys of the ICP-OES area.

Spills

Drip pans are under the tubing associated with the ICP-OES. If tubing "pops" off the spill will be captured in the drip pans. The worker will stop the pump flow to the ICP-OES and follow the following section.

If the sample is spilled or a contamination is found the worker will stop work. Contact radiation control group immediately and follow the information in the C-AD MIRP experimental work permit: separation/purification of Ac-225 from thorium procedure on spills.

Appendix 6

Separation/Purification of Ac-225 from Thorium

Chemical Process to Separation Ac from bulk Th and lightly irradiated foils

Phase two: Purpose: Examine separations of Ac-225 and other isotopes from irradiated Th and bulk non irradiated Th.

Change of Hazards
New radioactive Hazards: Lightly irradiated Th (5-30 min) and fission products
New Chemical Hazard: Use of small amounts of HF
New Chemical Hazard: Th mass 1-100 grams

A procedure for the separation has been prepared (Appendix 7) and will be followed for the chemical processing. The procedure will undergo minor modifications when problems arise. General information: a Th foil will be irradiated at BLIP for 5-30 min. The irradiated foil and 10-100 grams of Th will be dissolved in Hydrochloric acid with trace amounts of HF. Actinium-225 and other radioactive and non-radioactive metals may be added. Various ion exchange columns or solid supports will be used during the purification. During the purification evaporation steps are needed in order to change the solvent conditions or to concentrate solvents.

Notes:

3. The entire process of dissolution, concentration and separations will take place within a HEPA filtered glove box, within a HEPA filtered fume hood, except the analysis by ICP-OES and/or gamma spectroscopy.

Comments about specific hazards

Radiation dose

The following table represents various radiation doses associated with a 30 min irradiation of a single Th foil (0.005" thick) at 115 μA without the raster.

Case	EOB	Glove Box Material	Dose rate (mR/hr) Contact with source	Dose rate (mR/hr) Contact with outside of Glove Box	Dose rate (mR/hr) 6 inches from source	Dose rate (mR/hr) 12 inches from source or outside of Glove Box	Dose rate (mR/hr) 24 inches from outside of Glove Box
1	1 day post	None	3288		67	19	
2	1 day post	Acrylic - 1/2 inch		20		5	2
3	1 day post	Acrylic - 1 inch		18		5	2
4	1 day post	Lead Glass- 1/2 inch		13		3	2
5	1 day post	Lead Glass- 1 inch		9		2	1
6	4 day post	None	1010		23	7	
7	4 day post	Acrylic – 1/2 inch		6		2	1

8	4 day post	Acrylic – 1 inch		6		2	< 1
9	4 day post	Lead Glass – 1/2 inch		4		1	< 1
10	4 day post	Lead Glass – 1 inch		3		1	< 1

Note:
Source is placed 12 inches from inside glove box inside wall.
Operator is placed 12 inches from outside of glove box.
Density of acrylic plastic (Plexiglas) is 1.18 g/cm^3.
Density of leaded glass is 4.36 g/cm^3.

ALARA: To minimize radiation dose to the worker the target will be stored for 4 days. After various manipulations and during various waiting periods such as evaporations and eluting columns the worker will minimize the amount of time spent within 12 inches of the glove box.

Weighing Th masses (currently in approved ESR document)
Using a balance in the same lab as the glove box, on a lab bench, the bottle/container the thorium will be weighed. The Th container will be transferred to the glove box and some thorium will be removed. The container will then be removed from the glove box and the Thorium container will be weighed. This Th container will be surveyed by facility support when it leaves the glove box.

Hydrofluoric acid (currently in approved ESR document)
Lightly irradiated Th foils (5-30 min) and Bulk thorium (Th) will be used and dissolved in 10 M HCl and trace HF. The approved experimental work plan covers use of HF, and will be followed. An HF burn kit will be present in the lab when HF is used, and workers will be trained under OPM 19.9.100 Working with Hydrofluoric Acid (HF).

Concentration of samples
Concentration of samples will occur by evaporating the solutions in a distillation apparatus and re-dissolved in weak acid and/or a complexing agent. Addition of other metals may occur before or after evaporation. Appendix 8 Figure 2 shows the distillation apparatus that will be used.

Analysis of samples: (currently in Approved ESR document)
Analysis of samples will involve ICP-OES and/or gamma spectroscopy. Approved procedures in Appendix 3-5 will be followed and cover the movement of samples from the glove box, to the instrument room and analysis.

Note:
See appendix 1, OPM 19.9.100 Working with Hydrofluoric Acid (HF).
Specific procedures have been approved to:
Transferring material in and out of the glove box (**Appendix 3**).
Transfer alpha containing material from lab 62 to Lab 68 (**Appendix 4**)
Perform gamma Spectroscopy and ICP-OES (**Appendix 5**)

Materials Used:

Materials Used	Disposal Method	Amount per Use	Amount per Year	Comments
Strong Acid Cation Exchange Resin	Radioactive	10.00 g	1000.00 g	
acids: nitric acid, hydrochloric acid	Radioactive	100.00 ml	1000.00 ml	
Hydrofluoric Acid	Radioactive	10.00 ml	50.00 ml	HF will only be used during the dissolution of the Thorium matrials
tartaric acid and citric acid	Radioactive	500.00 g	1000.00 g	
base solutions: sodium hydroxide or ammonium hydroxide	Radioactive	50.00 ml	500.00 ml	a base rinse will be tested with polymers
metals representing an Ac-225 irradiated sample	Radioactive	1.00 ppm	100.00 ppm	A number of non radioactive metals will be used as spikes they will be in less than 0.1 ppm for each metal
Natural thorium (Th-231)	Radioactive	2-100 g	500.00 g	
Actinium-225[1]	Radioactive	0.00 other	0.00	0.05-1 mCi spikes will be used.
Fission fragment isotopes	Radioactive			
inorganic resins	Radioactive	10.00 g	100.00 g	
MP1 resin	Radioactive	5 g	100 g	
B-DGA resin	Radioactive	1 g	20 g	
modified polymer solid supports	Radioactive	100.00 ea	1000.00 ea	

Appendix 7

Separation/Purification of Ac-225 from Thorium

General Procedure for purification of Ac-225 from irradiated/bulk Thorium

0.5 -100 Grams of Thorium metal (not irradiated) with 0.1-100 Grams of irradiated Thorium Targets

Dissolution

- Dissolve Th metal and irradiated Th in 10 M HCl and Trace HF
- Spike in Ac-225 and other isotopes

Column 1

- MP1 (Cl) column prep (5ml)
- Pass Th solution through column
- Rinse with 0.1 M HCl → Cd, Sb, Te elute
- Rinse with 8 M HNO_3 → U, Fe, Mo, Pa, Nb, Zr, Ru Elute

Evaporation of 10 M HCl Th solution eluted from column 1

- Evaporations will be done using a distillation apparatus

Dissolve Th sample in 0.1 M HCl

Mix Th sample with citric acid solution 10:1 ratio

- Check and adjust pH with ammonia hydroxide

Column 2

- AG50 x8 (NO_3) column prep (5 ml)
- Rinse 1 M Citrate pH2 (10 bed Volume) Th
- HCl/Nitric acid
- 6 M HNO_3 (12 bed Volumes)

Evaporate 6 M HNO_3 Ac-225 solution (optional)

- Evaporations will be done using a distillation apparatus

Dissolve Ac-225 sample in 6 M HNO_3

Column 3

B-DGA column prep (0.5 ml)

- Rinse 4M HNO_3 (3 bed Volume) Ra/Ba
- Rinse 10 M HNO_3 (50 bed Volumes) Ac
- Rinse 0.1 M HNO_3 Ln

Appendix 8

Separation/Purification of Ac-225 from Thorium : Distillation apparatus

Most Distillation apparatus require circulating water as shown in Figure 1. We will use the apparatus shown in Figure 2 for the concentration of samples in the glove box.

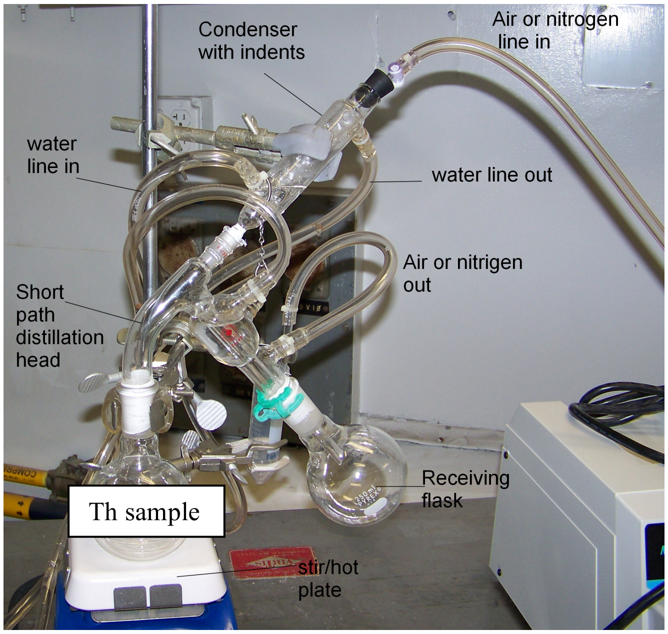


Figure 1. Short Path distillation apparatus requires circulating water. There is not enough space to have the water circulator in the glove box. An alternative would be to drill holes in the box for water lines, but this compromises the integrity of the glove box.

Distillation Apparatus: Does not require water (will be used)

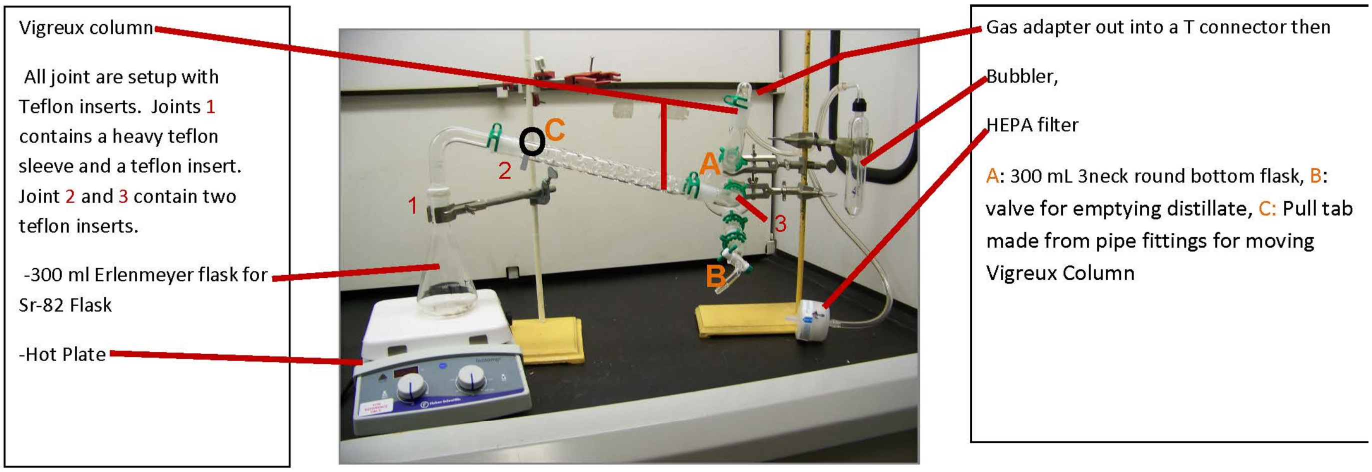


Figure 2. Waterless distillation apparatus: Condensation occurs in the Vigreux Column (C). The Vigreux Column can be purchased in different lengths, and a second Vigreux Column can be placed at the gas adapter out to increase condensation and shorten the footprint. So the apparatus can be shortened to fit in the glove box. The apparatus has been extensively tested in a chemical fume hood.

Appendix 9

ESRC Minutes 6-19-2016

Sivertz, Michael

Sent: Wed 7/6/2016 7:11 PM
To: Hoffman, Caitlin
Cc: Sivertz, Michael; Beavis, Dana; Bergh, Paul J; Christie, William; Cirnigliaro, Peter P; Craner, Francis; Drees, Angelika; Etkin, Asher; Folz, Charles; Gaffney, Michael; Karol, Raymond C; Kretschmann, Michael; Kusche, Karl; Lambiase, Robert; Lessard, Edward T; Lynch, Don; Needrith, William; Pearson, Charles E; Roser, Thomas; Sampson, Paul; Li, Junjie; Sullivan, Patrick T (DOE); Tuozzolo, Joseph E; VanEssendelft, Melvin J; Tao, Jing; Li, Jing; Fedurin, Mikhail

The action items for the Ac/Th separation experiment were not clear.
Here is a revised version of those action items:

Action Items:

1) The RWP shall specify that the HEPA and Charcoal filters on the glove box be replaced annually. After the Th/Ac dissolution/separation would be a good time. (Nick Contos)

2) The RWP shall be amended after the test irradiation to include dose data from the glove box use, including extremity dose. (Nick Contos)

3) Extremity dose administration levels shall be noted in radiological controls for the experimenter RWP. (Nick Contos)

4) A&R Division shall ensure the HF emergency kit is in compliance and not expired. (Peter Cirnigliaro).

5) Instructions on keeping the radiological waste in a shielded area to decay for 4 months shall be included in the RWP, and Experimenters shall be instructed in this practice. (Jonathan Fitzsimmons,)

6) Waste characterization of the Ac/Th waste products shall be investigated, and reported on to the ESRC. (Peter Cirnigliaro).

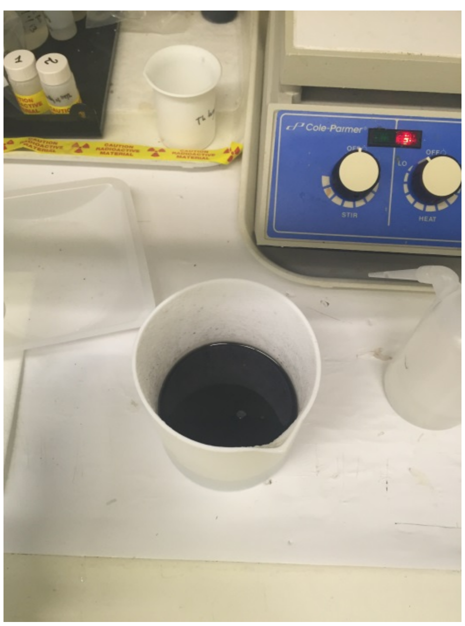
Mike Sivertz
sivertz@bnl.gov

Appendix 10 BLANK

Appendix 11: Thorium dissolution/conversion protocol

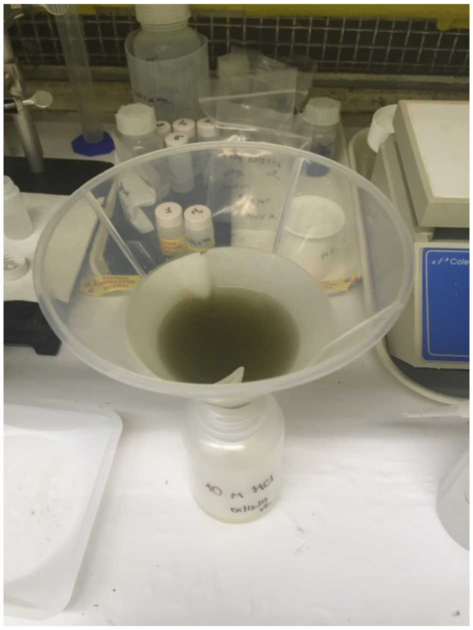
1. Thorium metal mass for dissolution: 11.19 g

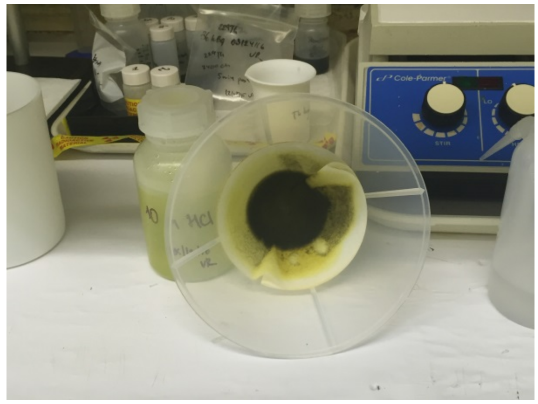
2. Th was placed in a Teflon beaker (0.5 L), and portions of 10 M HCl (5 mL each) were added. A vigorous reaction was observed; 400 µL of 2 M HF were added after the first 10 mL of HCl. After the addition of 40 mL of HCl solution, the reaction subsided. No further gas evolution. An additional amount of 160 mL of 10 M HCl was added. Total volume ~200 mL.



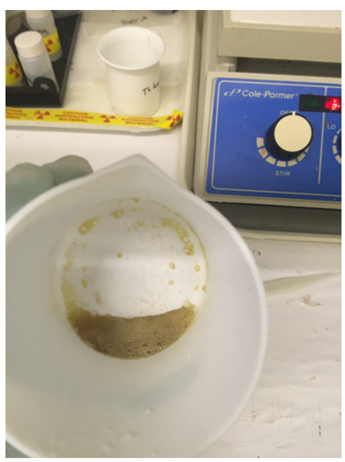
3. After dissolution, the solution was slightly heated at 60-70 °C for ~50 minutes. Even after ~30 minutes, the solution had not cleared up. Therefore, an additional portion of 200µL of 2 M HF was added. After further 50 minutes, a slight change in solution color was observed (slight yellow).

4. The solution was filtered through a paper filter. A gamma count of the natural ^{232}Th decay product ^{228}Th (via 238 KeV ^{224}Ra peak) revealed that the solid residue on the filter contain approx. 20% of the total thorium mass.

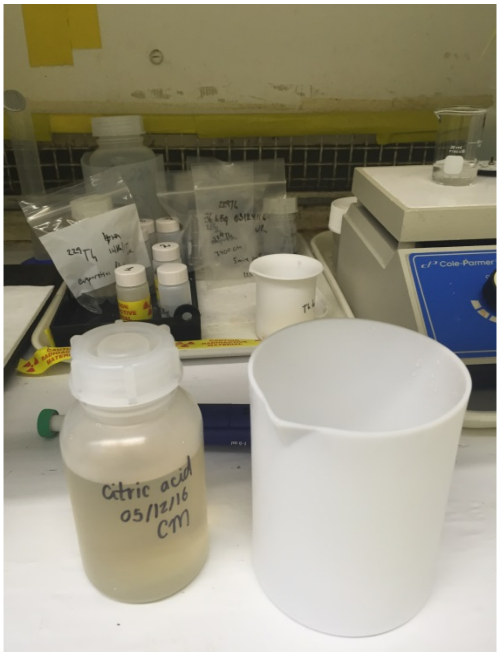




5. After filtration, the filtrate (~200 mL) was transferred to the Teflon beaker (0.5 L) and evaporated to near dryness.



6. Evaporation residue was re-dissolved in 200 mL of 1 M citrate at pH2.



Appendix 12

Radioactive waste from processing Th foils and bulk Th

Appendix 12: Radioactive waste from processing Th foils and bulk Th

Radioactive waste generated from processing the irradiated Th foils falls into two categories: low level solid radioactive waste and liquid radioactive waste.

Solid low level radioactive waste

Low level solid radioactive waste such as vials, pipette tips will be placed in a suitable container, double bagged, with a J-hook closure and disposed of as low level radioactive. Packaged low level radioactive waste containing column material (MP1, AG50, B-DGA) will be monitored for radiation levels and may be held for 4 months prior to disposal. This material will be kept in secondary contaminant in the chemical fume hood in lab 2-62. Lead shielding will be used to minimize the radiation dose.

Liquid radioactive waste

Liquid radioactive waste will be collected based on the column used MP1, Cation and B-DGA columns. The activity will be segregated based on the elution from a specific column. The excel file indicates where certain radionuclides will elute in the separation.

MP1 (smaller volume higher radioactivity)

The eluted solutions from the MP1 column will be collected, and stored in a glass container for 4 months. The pH of the solutions will be adjusted to between 2-8, and the solvents will be moved out of the glove box and stored in a glass container for 4 months in a secondary containment in the chemical fume hood in Lab 2-62. Lead shielding will be used to minimize the radiation dose.

Cation Column 1) citric acid load and citric acid rinse (large volume, low radioactivity, Th mass)

The citric acid load and citric acid rinse steps on the sation column will be collected, and stored in a glass container for 4 months. The solution should contain almost all the Thorium mass, with some other radioactive nuclides. The pH of the solutions will be adjusted to between 2-8, and the solvents will be moved out of the glove box and stored in a glass container for 4 months in a secondary containment in the chemical fume hood in Lab 2-62. Lead shielding will be used to minimize the radiation dose.

Cation Column 2) Rinse steps with HCl and nitric acid.

The rinse steps will be analyzed and process further for the recovery of Ag-111 from the HCl rinses, and the 2.5 M HNO_3 will be processed for the recovery of Ba/Ra. When the purification study is complete, the pH of the solutions will be adjusted to between 2-8, and the solvents will be moved out of the glove box and stored in a glass container for 4 months in a secondary containment in the chemical fume hood in Lab 2-62. Lead shielding will be used to minimize the radiation dose.

B-DGA column (smaller volume higher radioactivity mostly radioactive lanthanides and Ba/Ra)

The rinse steps will result in radioactive lanthanides and Ba/Ra in different elations then Ac-225. When the purification study is complete, the pH of the solutions will be adjusted to between 2-8, and the solvents will be moved out of the glove box and stored in a glass container for 4 months in a secondary containment in the chemical fume hood in Lab 2-62. Lead shielding will be used to minimize the radiation dose.

Solidification of liquid waste:

Liquid waste will be solidified according to BNL radioactive waste guidelines. The process will occur in the chemical fume hood in lab 2-62. Lead shielding will be used to minimize the radiation dose.