



Rapid Detection of Thorium, Radium, and Actinium Impurities in ^{224}Ra and ^{212}Pb by Alpha Spectrometry

Madeleine Eddy
12th ICI, Florence, Italy
17 February 2026

meddy@eichrom.com

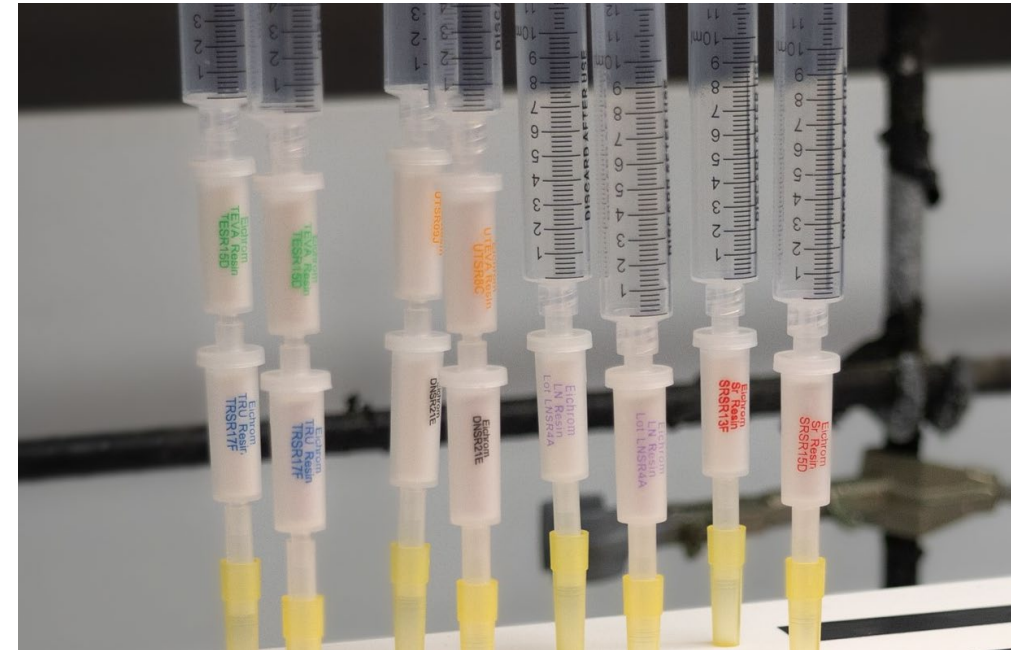
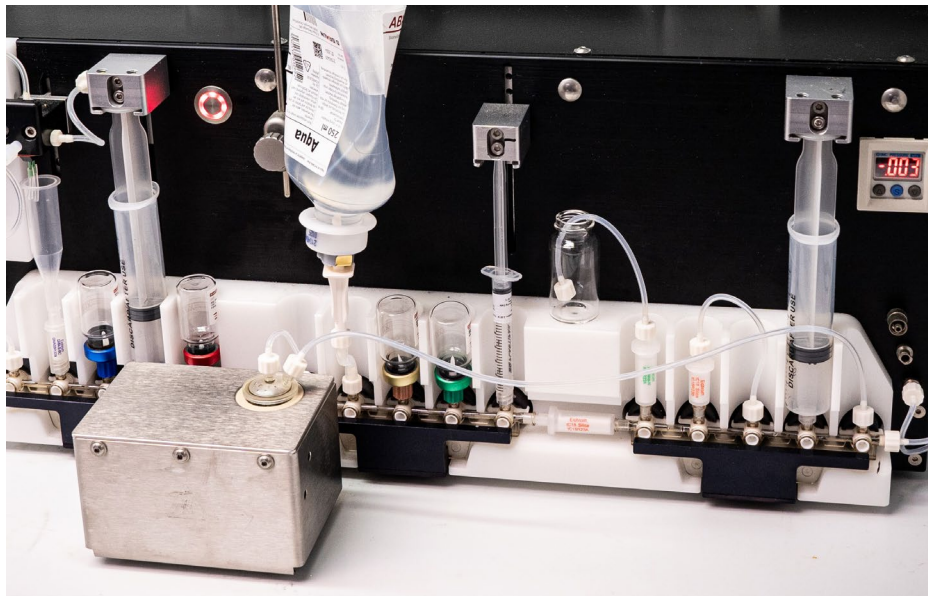
“Pioneers of radionuclide separation methods and resins since 1990”

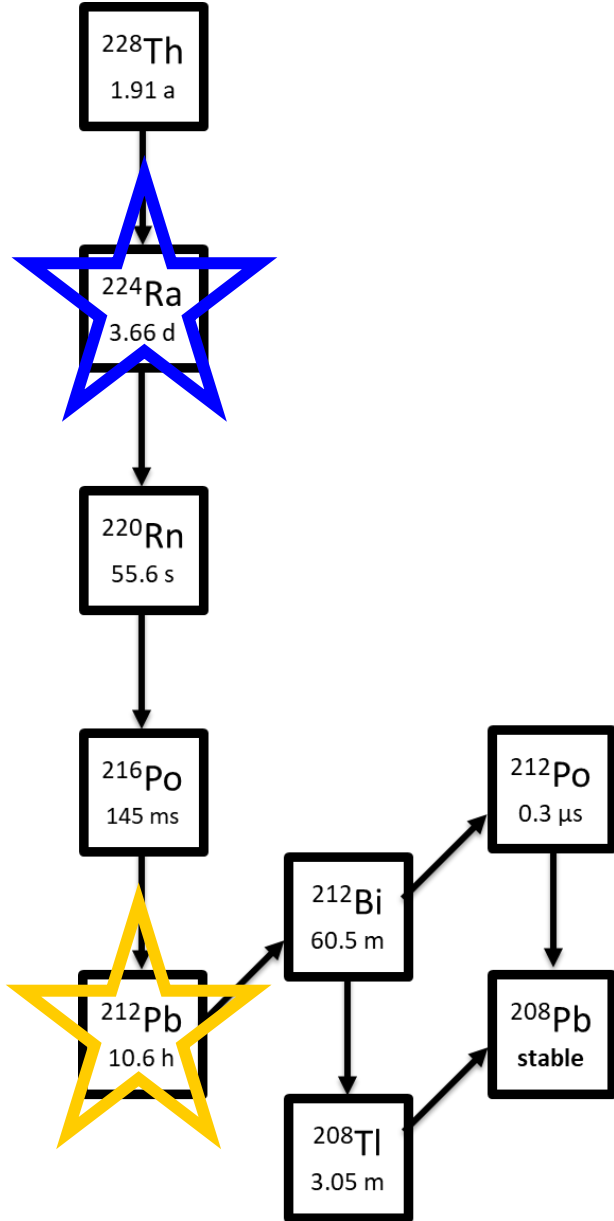
Our Products:

- Extraction Chromatography Resin (EXC)
- Analytical Ion Exchange Resin (IX)
- Functionalized Silica (SPE)
- Type A shipping systems

Our Resources:

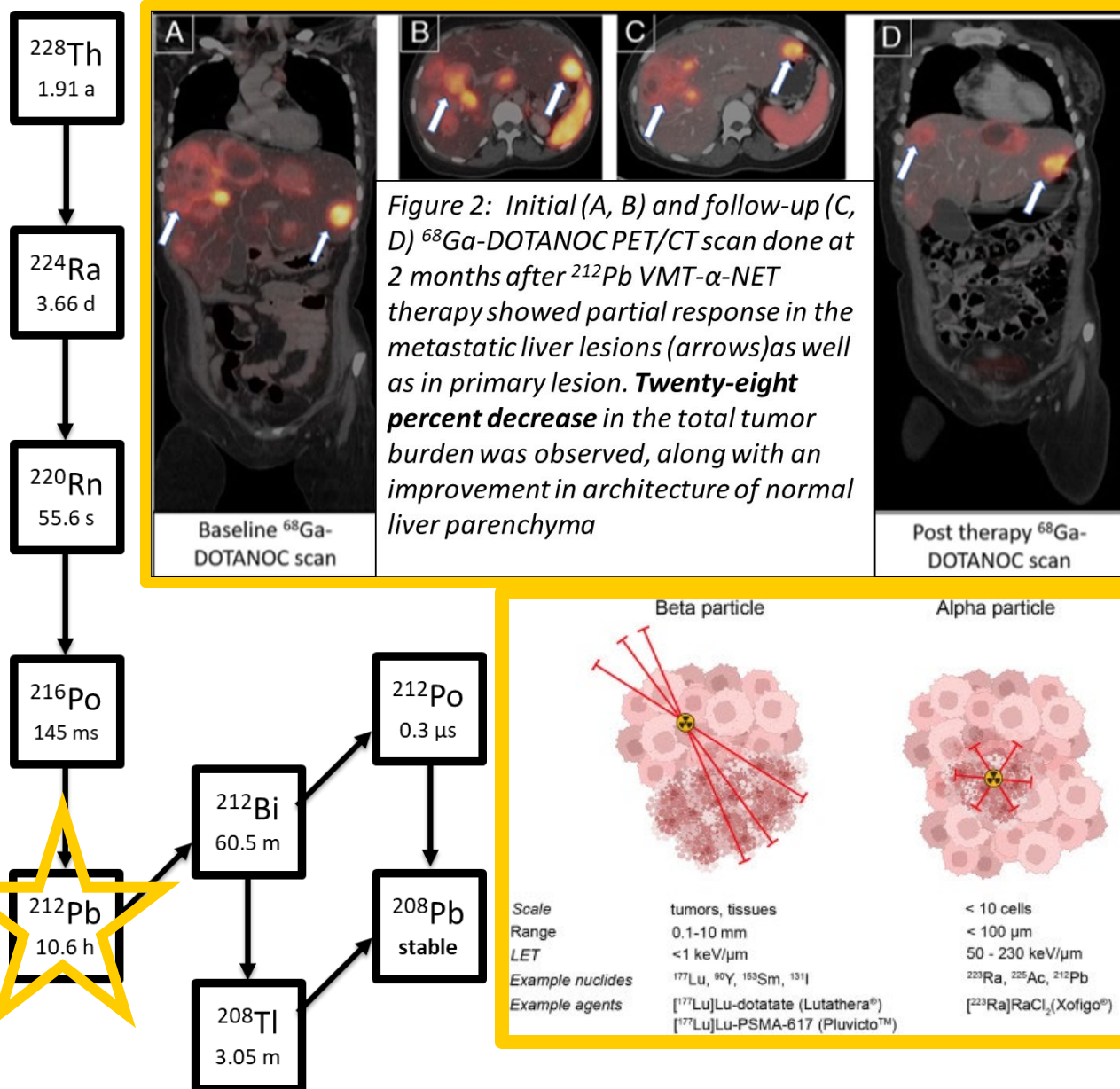
- Separation methods
- Presentation archive (including this one!)





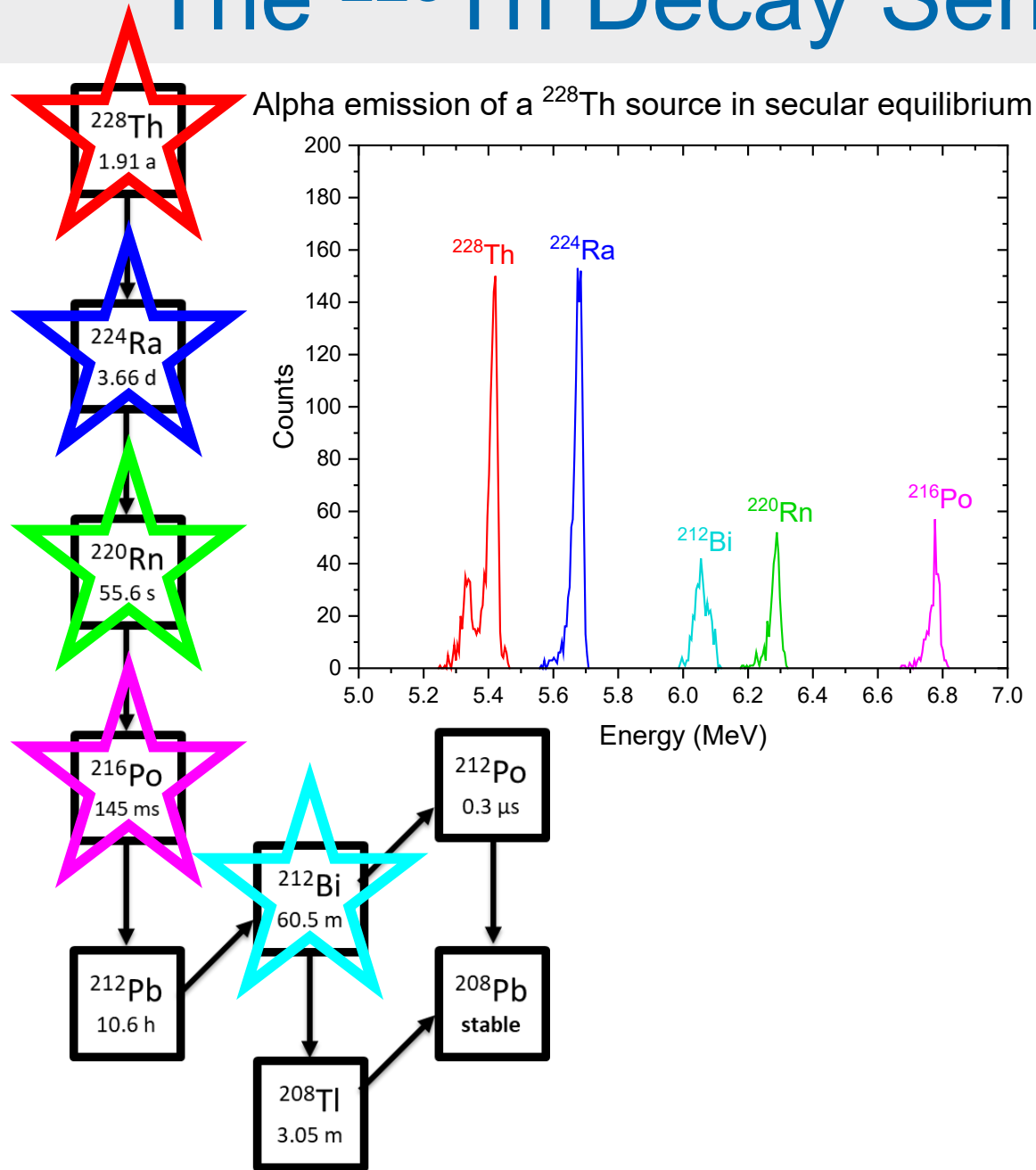
Protocols:

1. ^{228}Th in ^{224}Ra
2. ^{228}Th and ^{224}Ra in ^{212}Pb
3. ^{225}Ac (^{229}Th) in ^{224}Ra



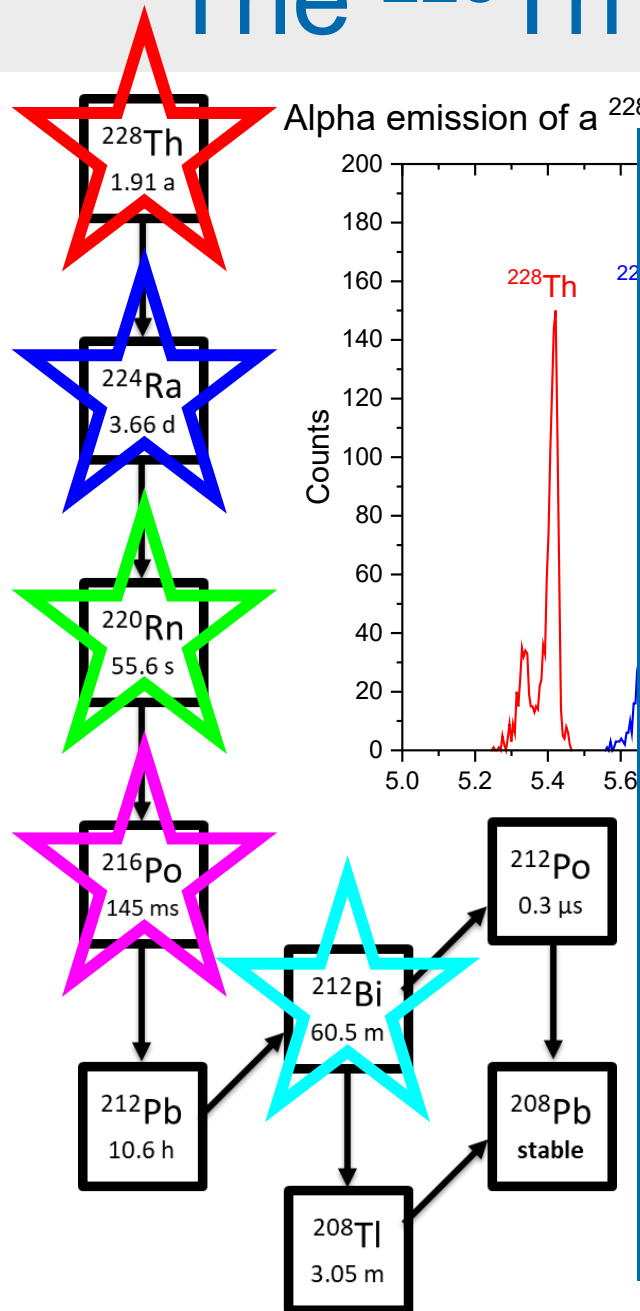
- ^{212}Pb is an emerging therapeutic radionuclide
- The decay chain works with routine production
 - ^{224}Ra separated from ^{228}Th biweekly
 - ^{212}Pb separated from ^{224}Ra daily

The ^{228}Th Decay Series

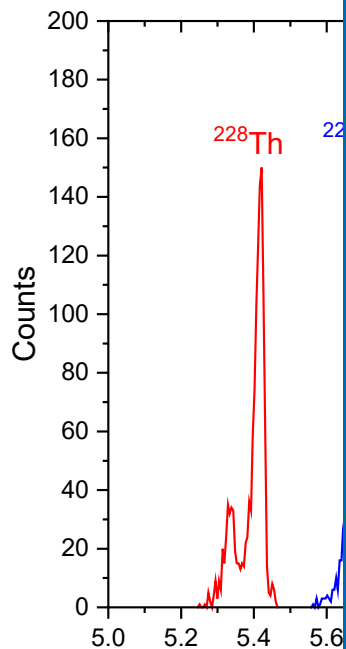


- ^{224}Ra or ^{212}Pb products are highly pure, **99.999+%**
- Still need to quantify long-lived radionuclide impurities
 - Parent isotopes ^{228}Th and ^{224}Ra
 - Other Th isotopes and daughters
- Difficult to find impurities of $<0.001\%$
 - Highly radioactive sample
 - Complex decay chain
 - Peak overlap / tailing
 - Worse for HPGe

The ^{228}Th Decay Series



Alpha emission of a ^{228}Th source in secular equilibrium



Some additional steps are required for proper QC

Chromatographic separation

- Isolate impurities from bulk of radioactivity

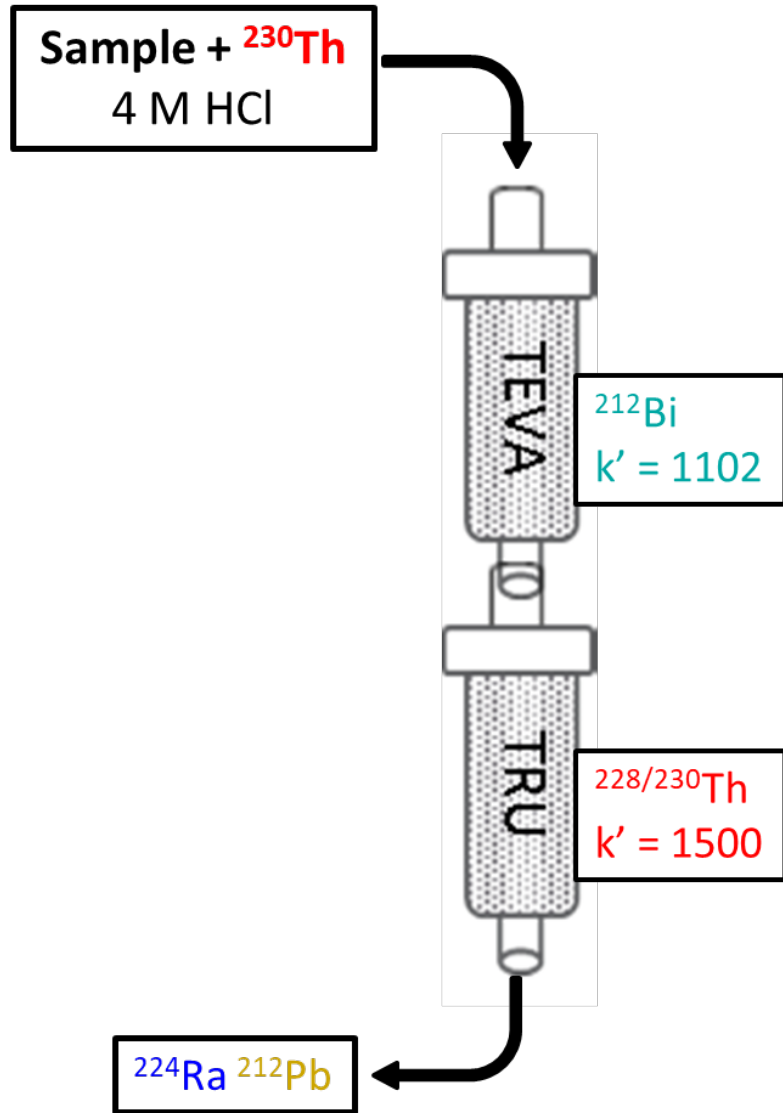
Microprecipitation for source prep

- Rapid, adequate resolution, user-friendly

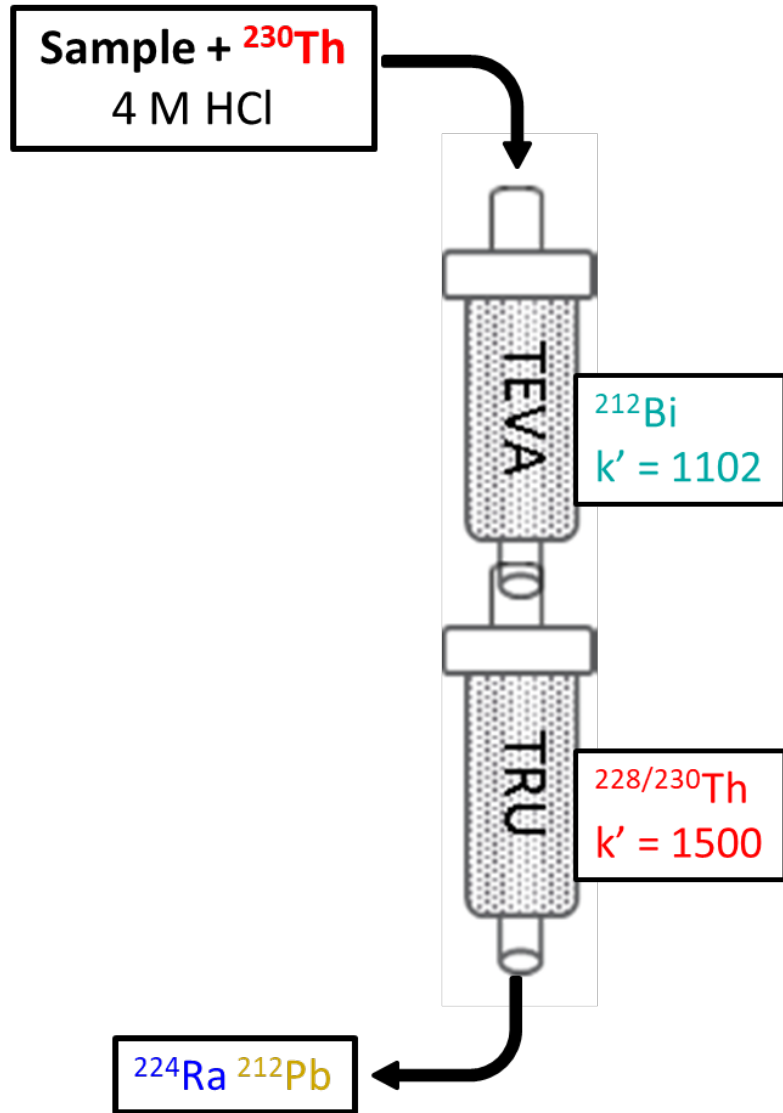
Alpha spectrometry analysis

- Low background, high efficiency, traceable*

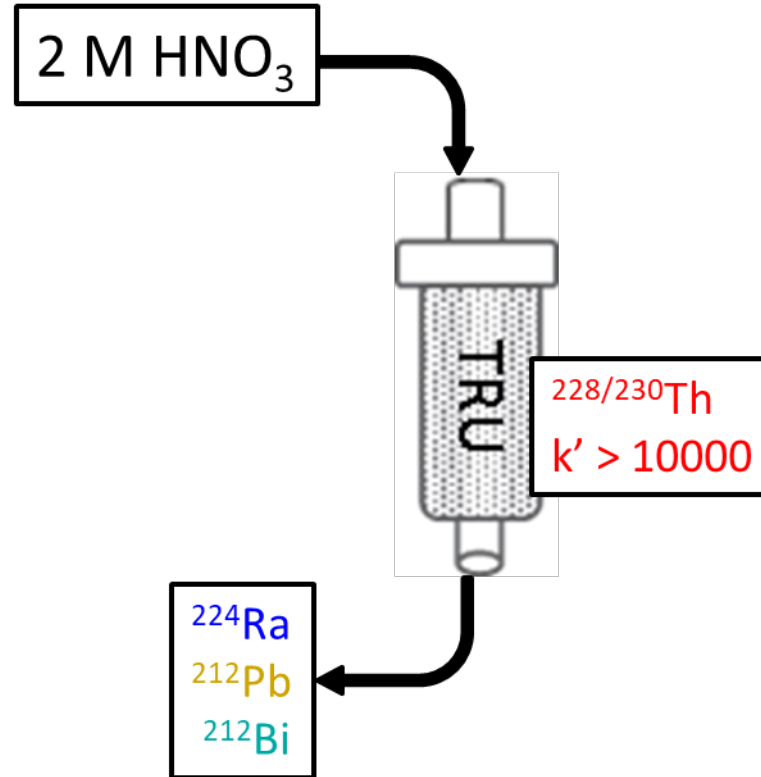
Load



Load

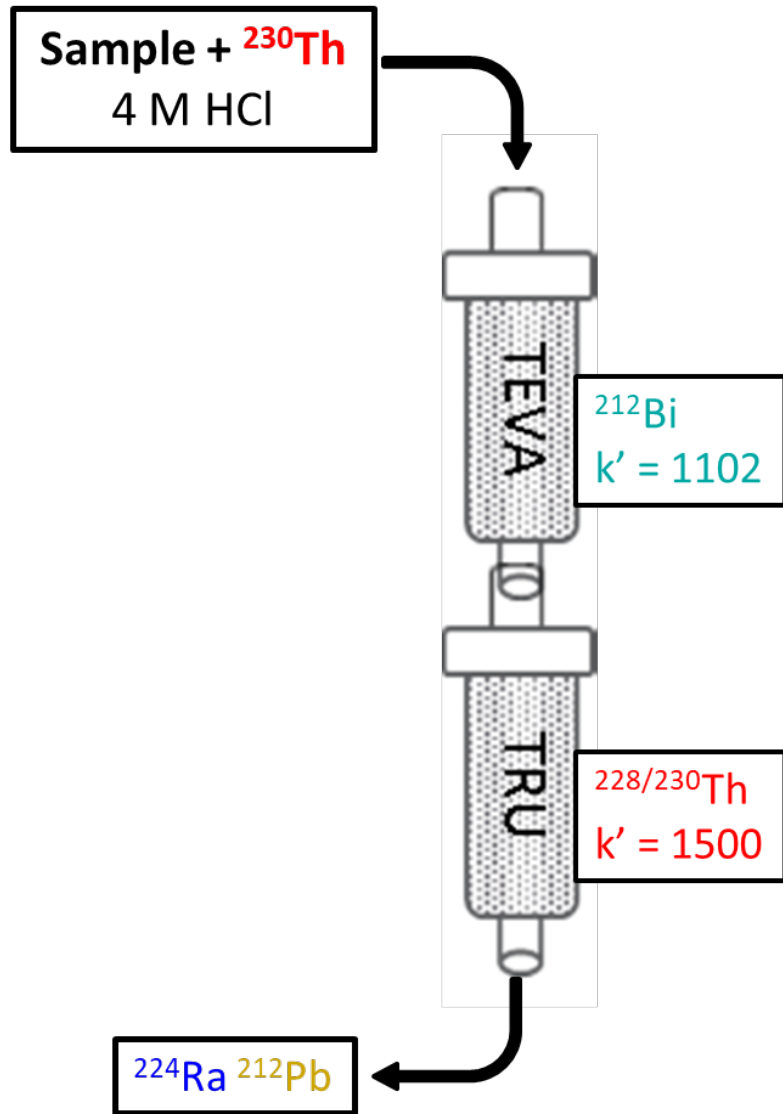


Rinse

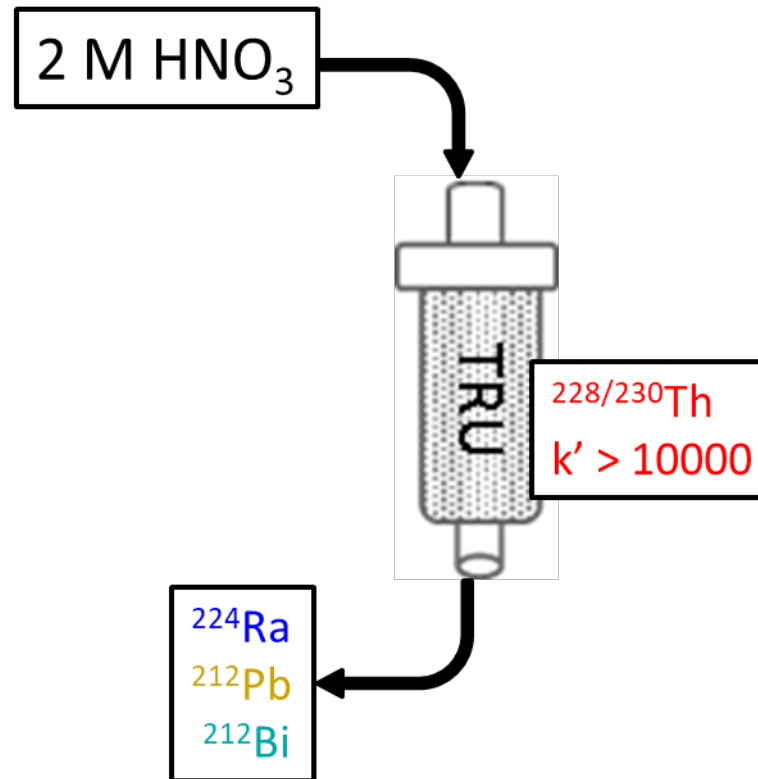


^{228}Th in ^{224}Ra

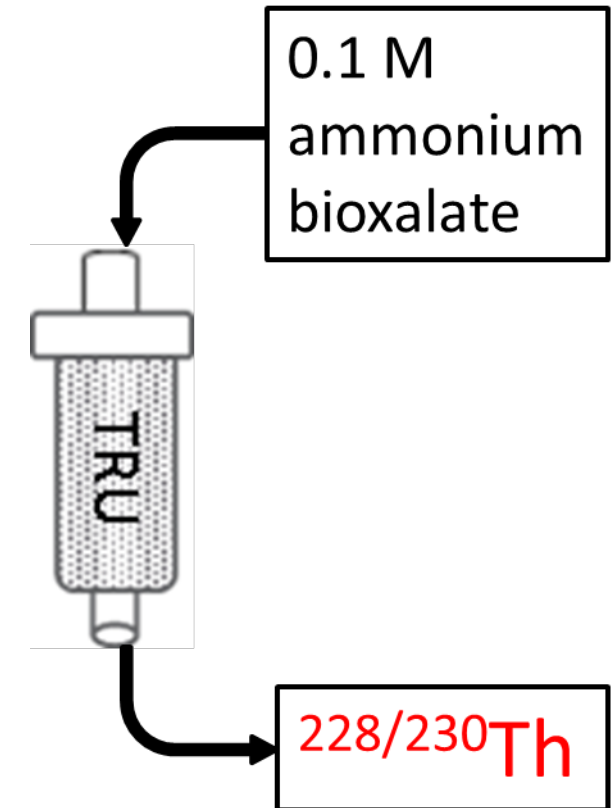
Load



Rinse

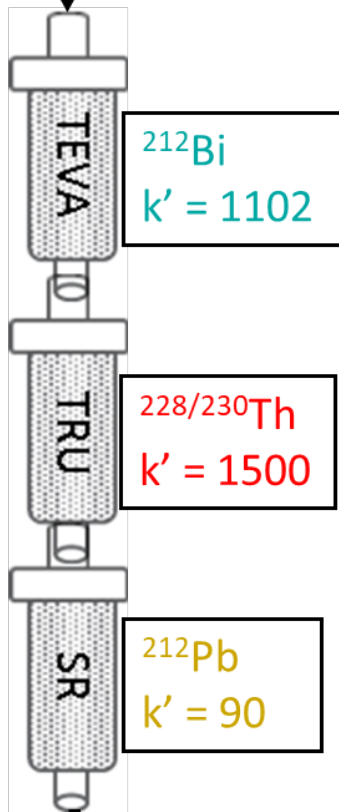


Strip (^{228}Th)



Load (^{224}Ra)

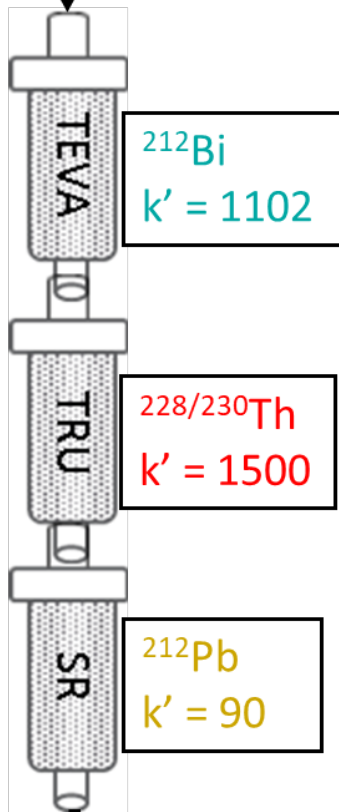
Sample +
 ^{133}Ba ^{230}Th
4 M HCl



$^{224}\text{Ra}/^{133}\text{Ba}$

Load (^{224}Ra)

Sample +
 ^{133}Ba ^{230}Th
4 M HCl



^{212}Bi
 $k' = 1102$

$^{228/230}\text{Th}$
 $k' = 1500$

^{212}Pb
 $k' = 90$

$^{224}\text{Ra}/^{133}\text{Ba}$

Rinse

2 M HNO_3

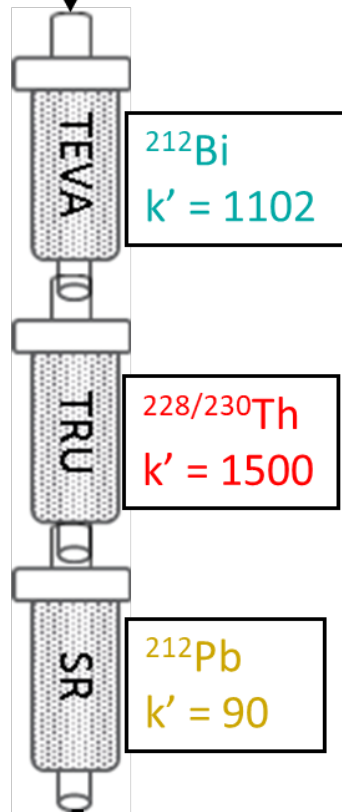
$^{228/230}\text{Th}$
 $k' > 10000$

$^{224}\text{Ra}/^{133}\text{Ba}$
 ^{212}Pb ^{212}Bi

^{228}Th and ^{224}Ra in ^{212}Pb

Load (^{224}Ra)

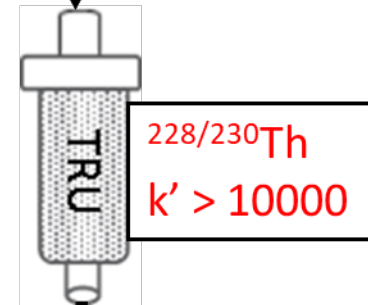
Sample +
 ^{133}Ba ^{230}Th
4 M HCl



$^{224}\text{Ra}/^{133}\text{Ba}$

Rinse

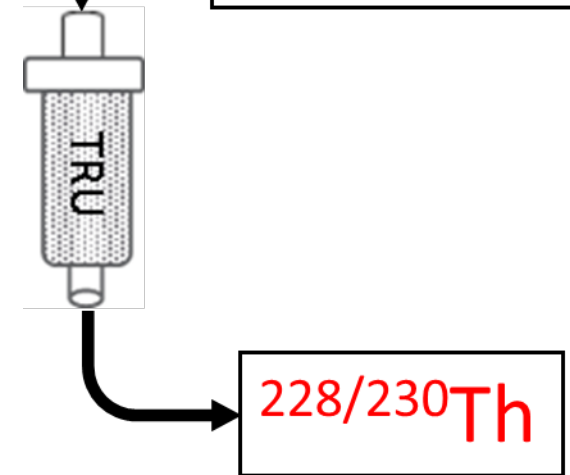
2 M HNO_3



$^{224}\text{Ra}/^{133}\text{Ba}$
 ^{212}Pb ^{212}Bi

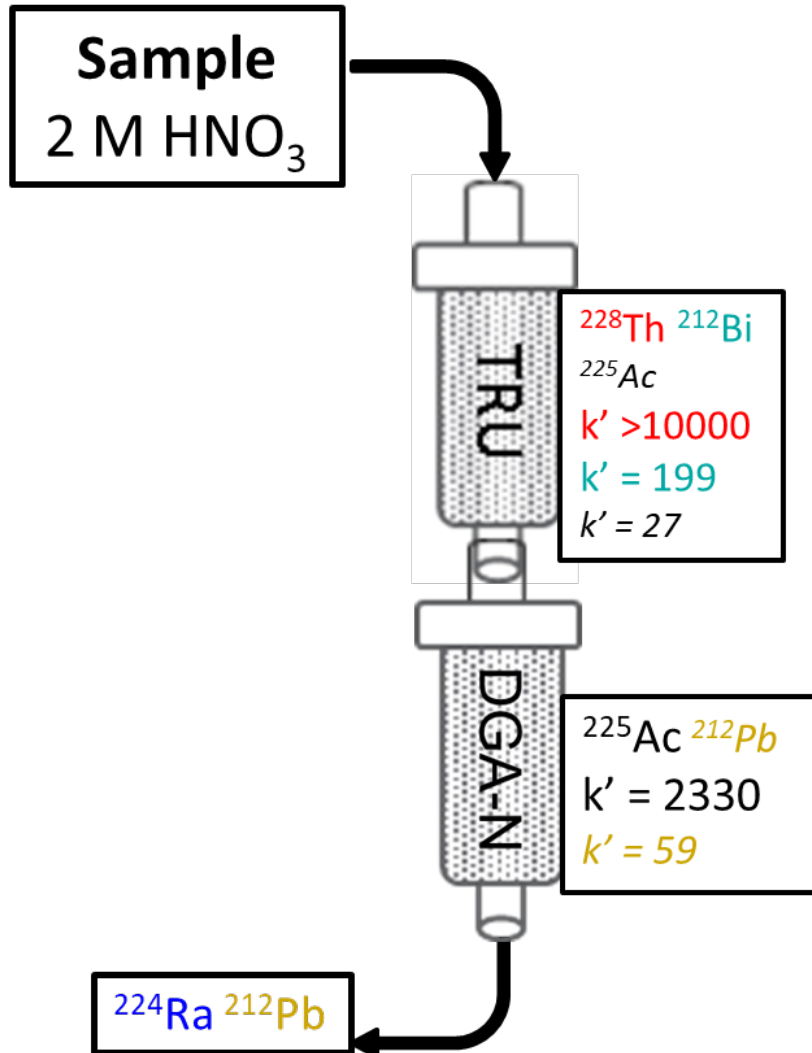
Strip (^{228}Th)

0.1 M
ammonium
bioxalate



^{225}Ac (^{229}Th) in ^{224}Ra

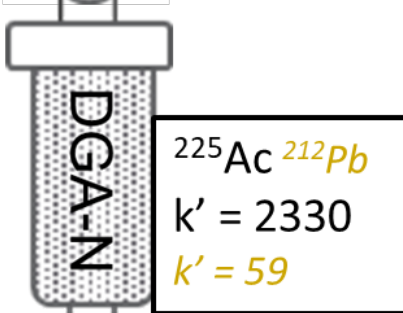
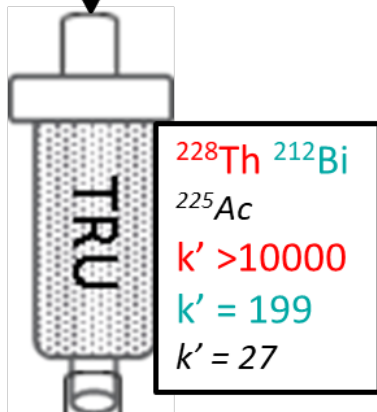
Load



^{225}Ac (^{229}Th) in ^{224}Ra

Load

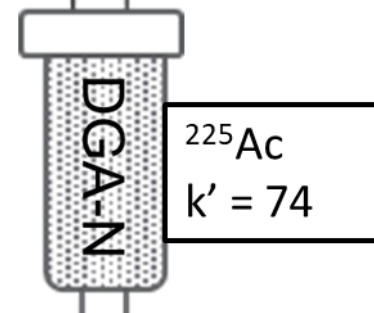
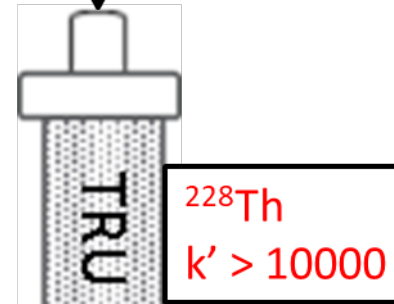
Sample
2 M HNO_3



^{224}Ra ^{212}Pb

Rinse

8 M HCl

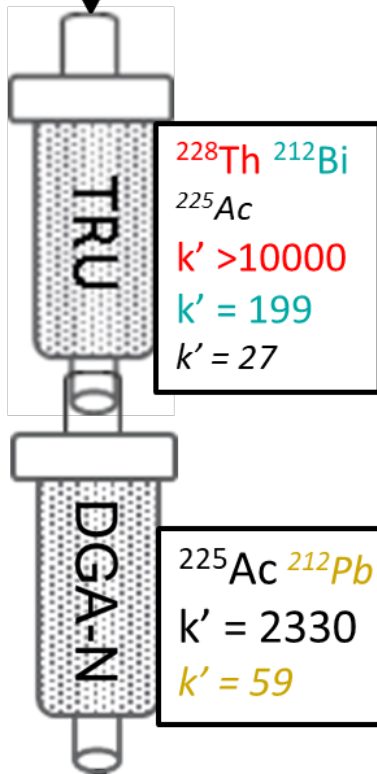


^{224}Ra ^{212}Pb
 ^{212}Bi

^{225}Ac (^{229}Th) in ^{224}Ra

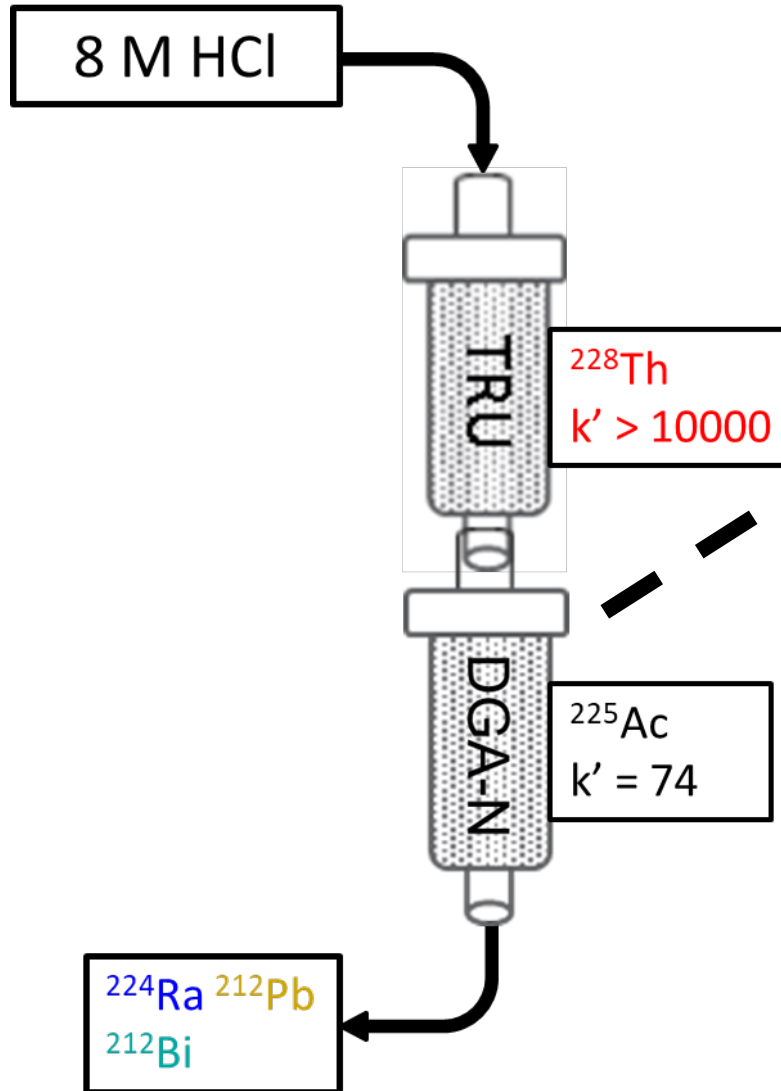
Load

Sample
2 M HNO_3



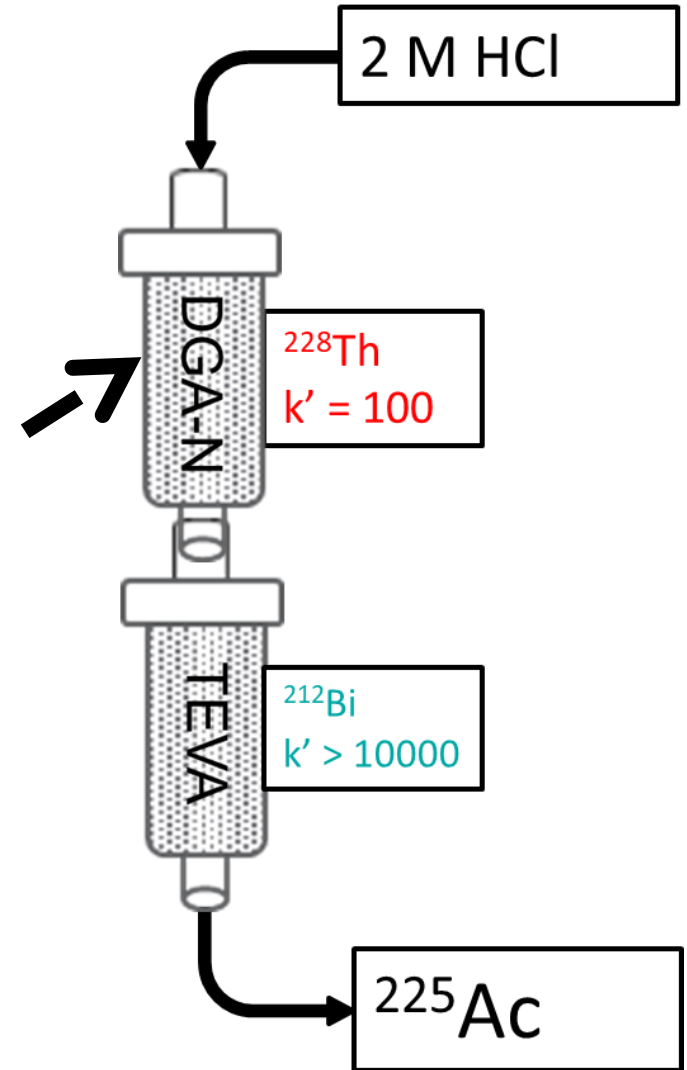
Rinse

8 M HCl



Strip (^{225}Ac)

2 M HCl



CeF₃ for ²²⁸Th and ²²⁵Ac

- 40-50 µg Ce carrier
- 1 mL conc. HF
 - Substitute 1.5 mL 8 M NH₄HF₂

BaSO₄ for ²²⁴Ra

- 50 µg Ba carrier
- 3 g (NH₄)₂SO₄
- 5 mL isopropanol
- Ice bath

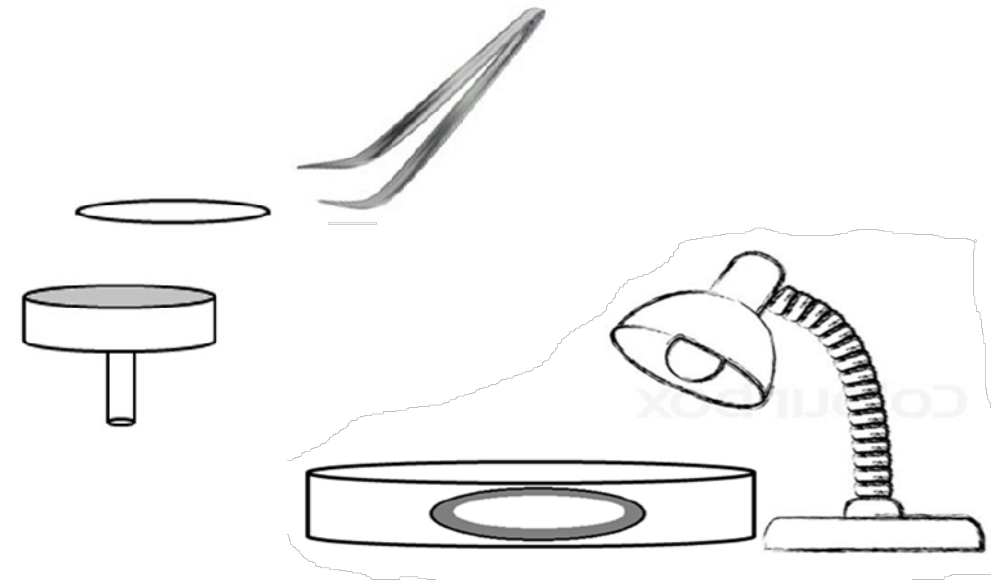
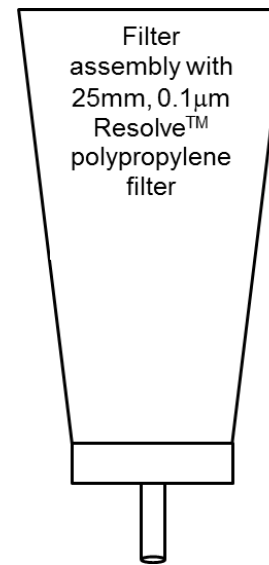
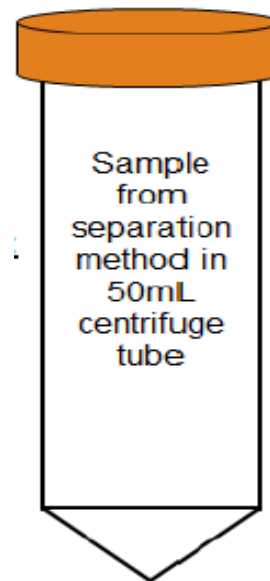
CeF₃ for ²²⁸Th and ²²⁵Ac

- 40-50 µg Ce carrier
- 1 mL conc. HF
 - Substitute 1.5 mL 8 M NH₄HF₂

- Wait 20-30 min
- Filter over Eichrom's Resolve® Filter
- Mount on adhesive planchet
- Dry under heat lamp
- Analyze using a calibrated alpha spectrometer

BaSO₄ for ²²⁴Ra

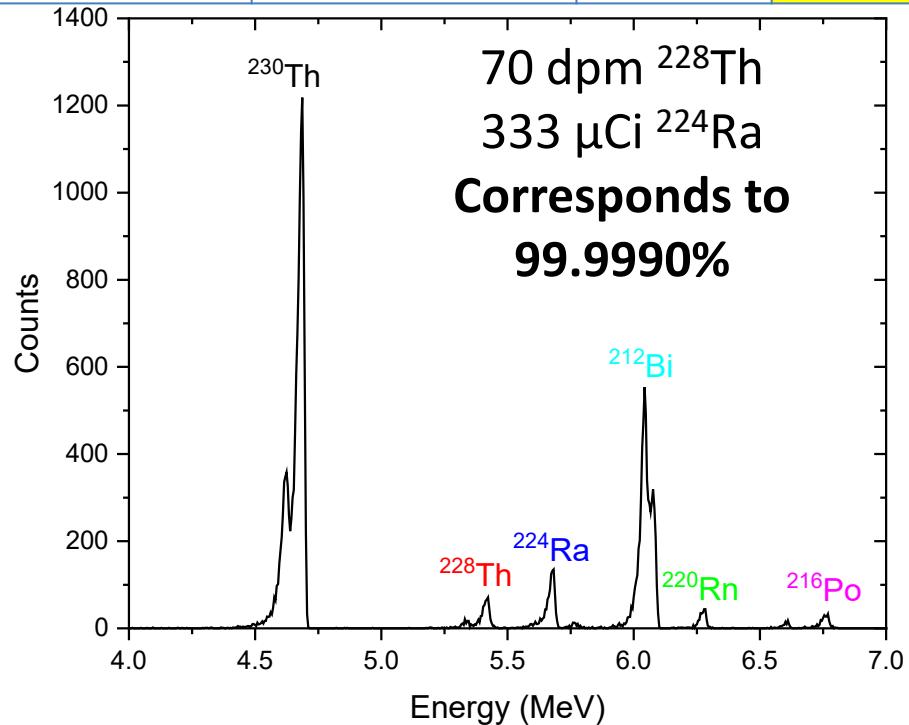
- 50 µg Ba carrier
- 3 g (NH₄)₂SO₄
- 5 mL isopropanol
- Ice bath



^{224}Ra product QC Results

^{228}Th in ^{224}Ra by Alpha Spec.

% yield ^{230}Th	dpm ^{228}Th (1%)	μCi ^{224}Ra	% Purity
93.2	69.79	333	99.9990
102.9	12.27	246	99.9998
91.2	22.64	233	99.9996
95.6	224.6	256	99.996
102.9	47.62	205	99.9990
91.2	45.9	226	99.9991
99.3	1110	2260	99.998



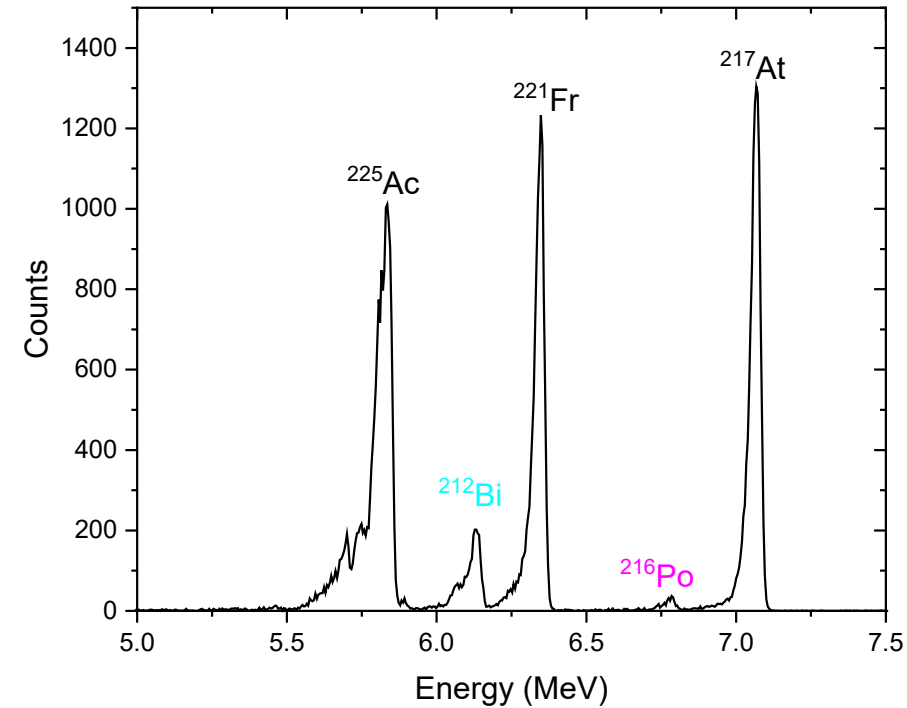
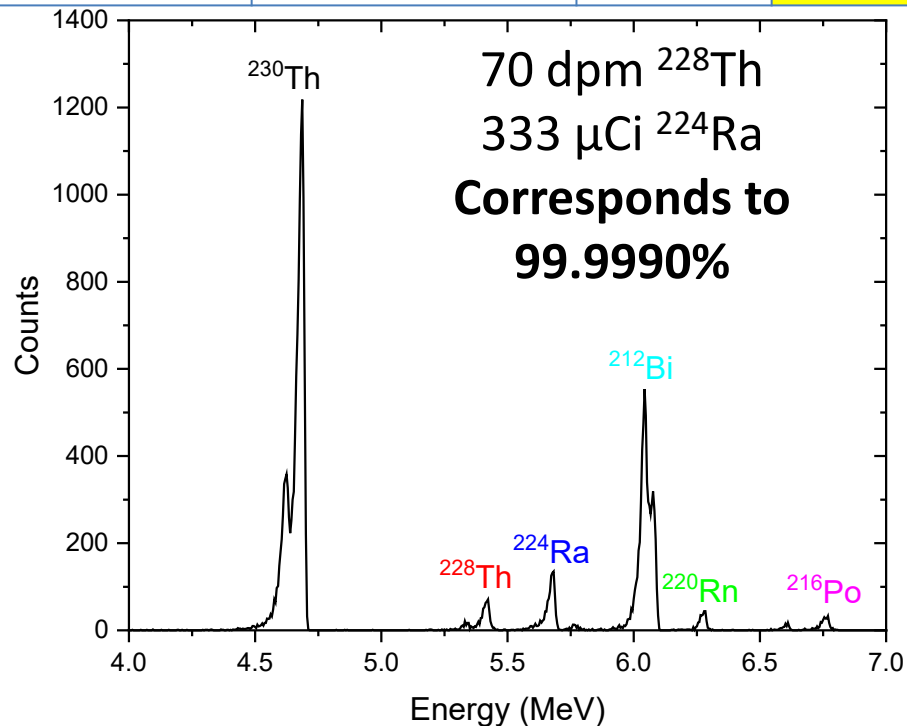
^{224}Ra product QC Results

^{228}Th in ^{224}Ra by Alpha Spec.

% yield ^{230}Th	dpm ^{228}Th (1%)	μCi ^{224}Ra	% Purity
93.2	69.79	333	99.9990
102.9	12.27	246	99.9998
91.2	22.64	233	99.9996
95.6	224.6	256	99.9996
102.9	47.62	205	99.9990
91.2	45.9	226	99.9991
99.3	1110	2260	99.9998

^{225}Ac in ^{224}Ra by alpha spec

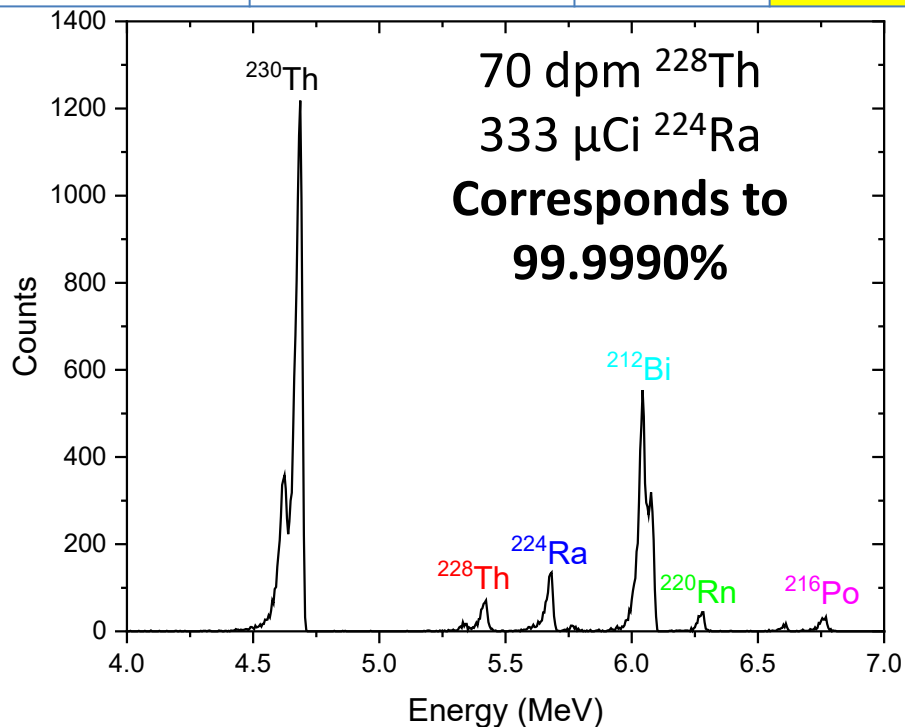
dpm ^{225}Ac (10%)	μCi ^{224}Ra	% Purity
8527	206	99.97
14130	226	99.96



^{224}Ra product QC Results

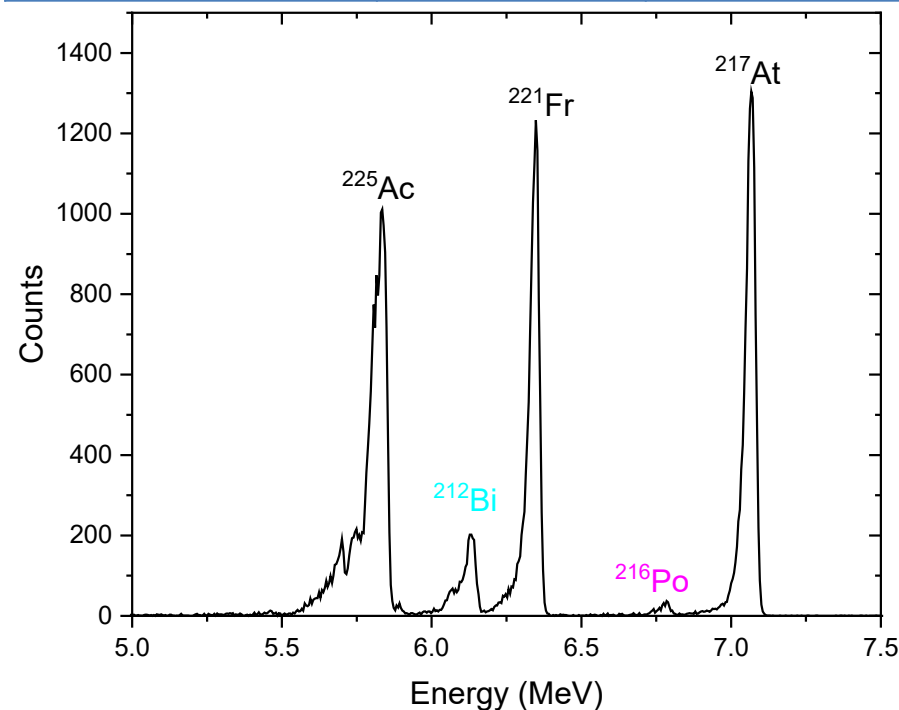
^{228}Th in ^{224}Ra by Alpha Spec.

% yield ^{230}Th	dpm ^{228}Th (1%)	$\mu\text{Ci } ^{224}\text{Ra}$	% Purity
93.2	69.79	333	99.9990
102.9	12.27	246	99.9998
91.2	22.64	233	99.9996
95.6	224.6	256	99.9996
102.9	47.62	205	99.9990
91.2	45.9	226	99.9991
99.3	1110	2260	99.9998



^{225}Ac in ^{224}Ra by alpha spec

dpm ^{225}Ac (10%)	$\mu\text{Ci } ^{224}\text{Ra}$	% Purity
8527	206	99.97
14130	226	99.96



^{225}Ac in ^{228}Th by alpha spec*

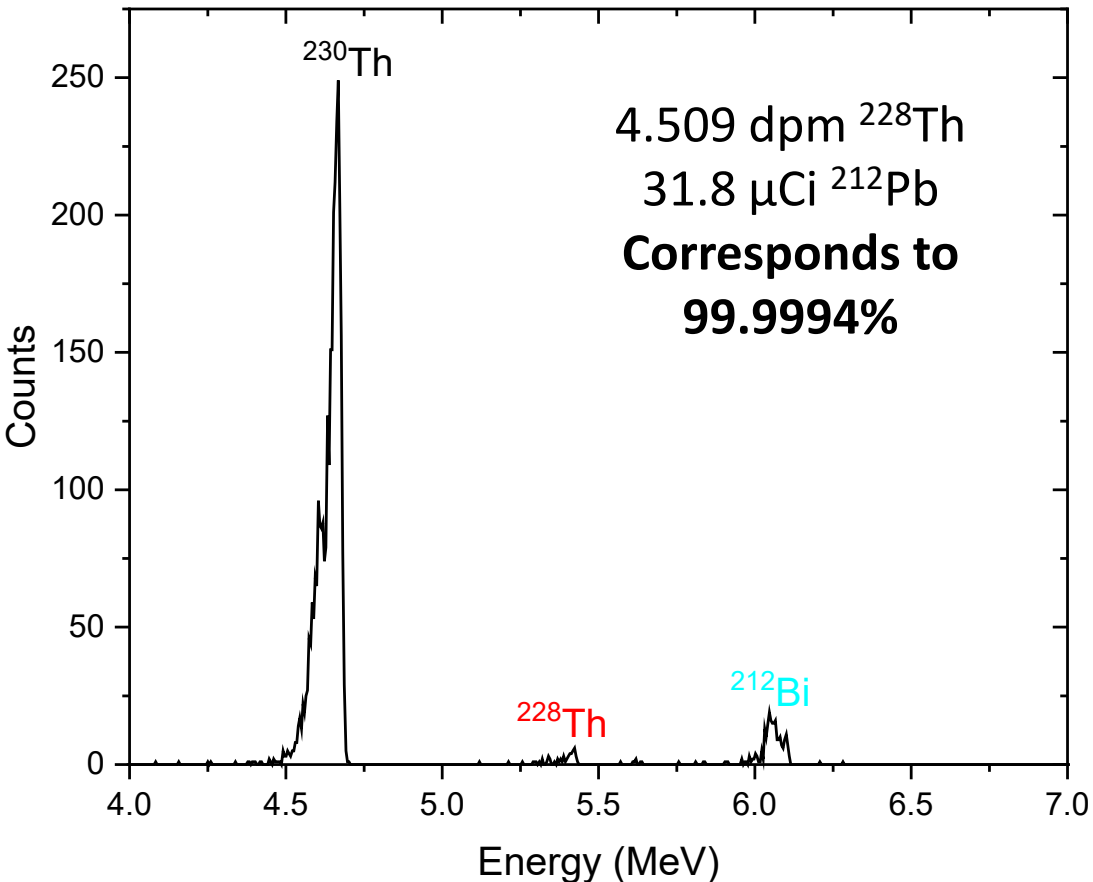
dpm ^{225}Ac (10%)	$\mu\text{Ci } ^{224}\text{Ra}$	% Purity today	% Purity Ref. date	%Purity CoA
8527	206	99.97	99.995 ₀	>99.9955
14130	226	99.96	99.97 ₃	99.97 ₃

*Assume 70.8% Yield of ^{225}Ac during ^{224}Ra separation

^{212}Pb Product QC Results

^{228}Th in ^{212}Pb by Alpha Spec.

% yield ^{230}Th	dpm ^{228}Th (1%)	μCi ^{212}Pb	% Purity
103.31.86	6.358	144	99.9998
96.3	2.369	96.5	99.9999
98.9	3.603	46.3	99.9997
97.9	4.509	31.8	99.9994



212Pb Product QC Results

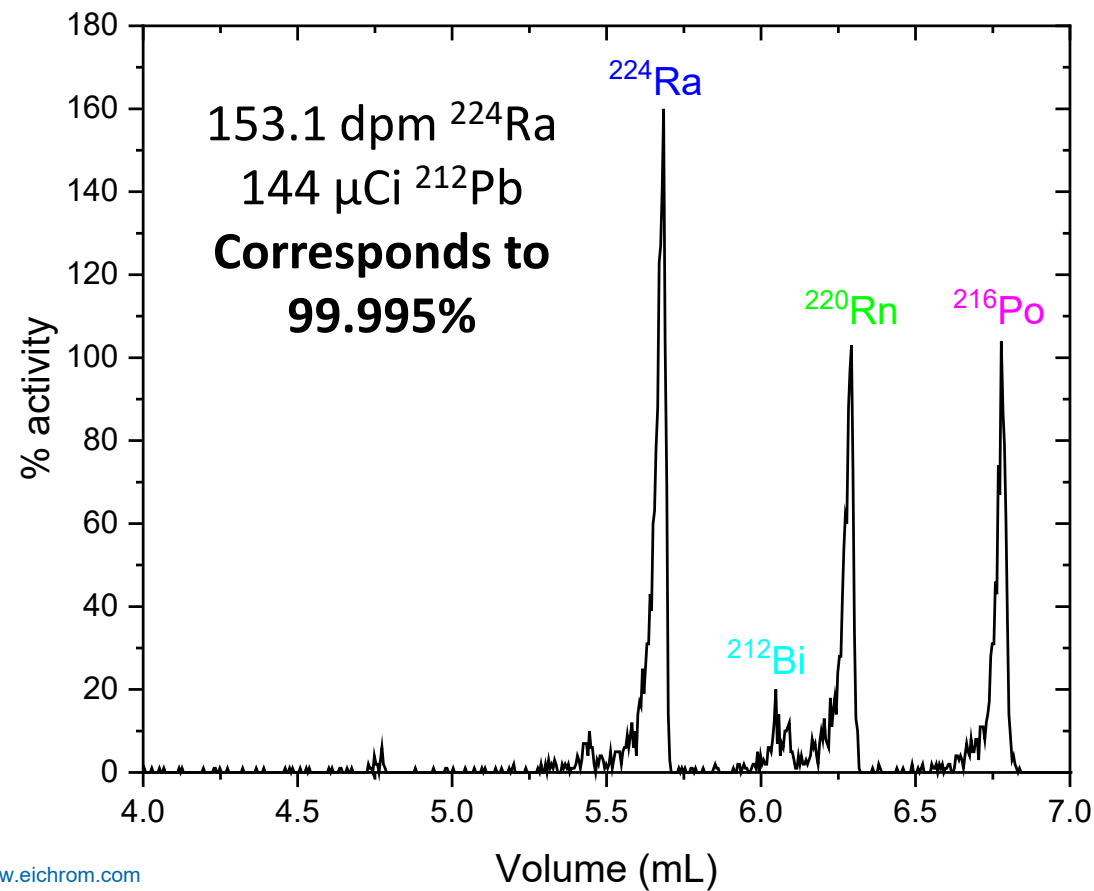
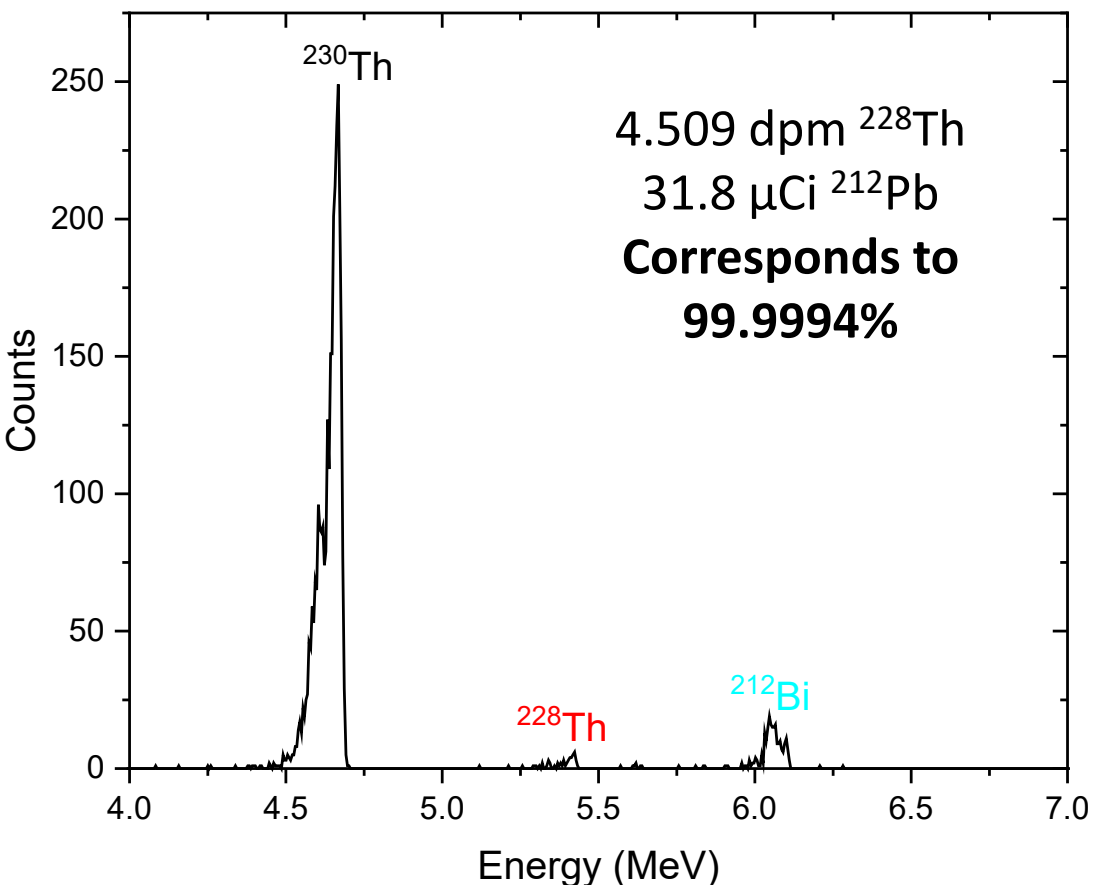
228Th in 212Pb by Alpha Spec.

% yield ²³⁰ Th	dpm ²²⁸ Th (1%)	μCi ²¹² Pb	% Purity
103.31.86	6.358	144	99.9998
96.3	2.369	96.5	99.9999
98.9	3.603	46.3	99.9997
97.9	4.509	31.8	99.9994

224Ra in 212Pb by Alpha Spec.

% yield ¹³³ Ba	dpm ²²⁴ Ra (1%)	μCi ²¹² Pb	% Purity
101.3	153.1	144	99.995
103.0	5.755	96.5	99.9997
89.5	4.624	46.3	99.9995
100.8	7.428	31.8	99.999

Combined % Purity
99.995
99.9996
99.9991
99.998



Conclusions:

- ^{228}Th in ^{224}Ra method works well
 - Routine use for 1 mCi samples
- The Th + Ra in Pb method builds off the success of Th in Ra
 - Th is pushing LOD
 - Ra is traced by ^{133}Ba via HPGe
- The $^{225}\text{Ac}(^{229}\text{Th})$ in ^{224}Ra shows promise
- The methods agree well with later measurements of decayed samples

Future Work:

- Optimize sample aliquot size for high-activity samples
- Modify ^{225}Ac method for ^{228}Th sources
- Lanthanum for ^{225}Ac yield tracer?
- ^{227}Ac by delayed ^{227}Th analysis of Ac alpha sources?
- Test methods on different types of ^{228}Th samples
- Adjust methods for applications to the $^{229}\text{Th} / ^{225}\text{Ac}$ decay chain

Thank you!

Madeleine Eddy, PhD
meddy@eichrom.com
+1 (630) 963-0320
www.eichrom.com