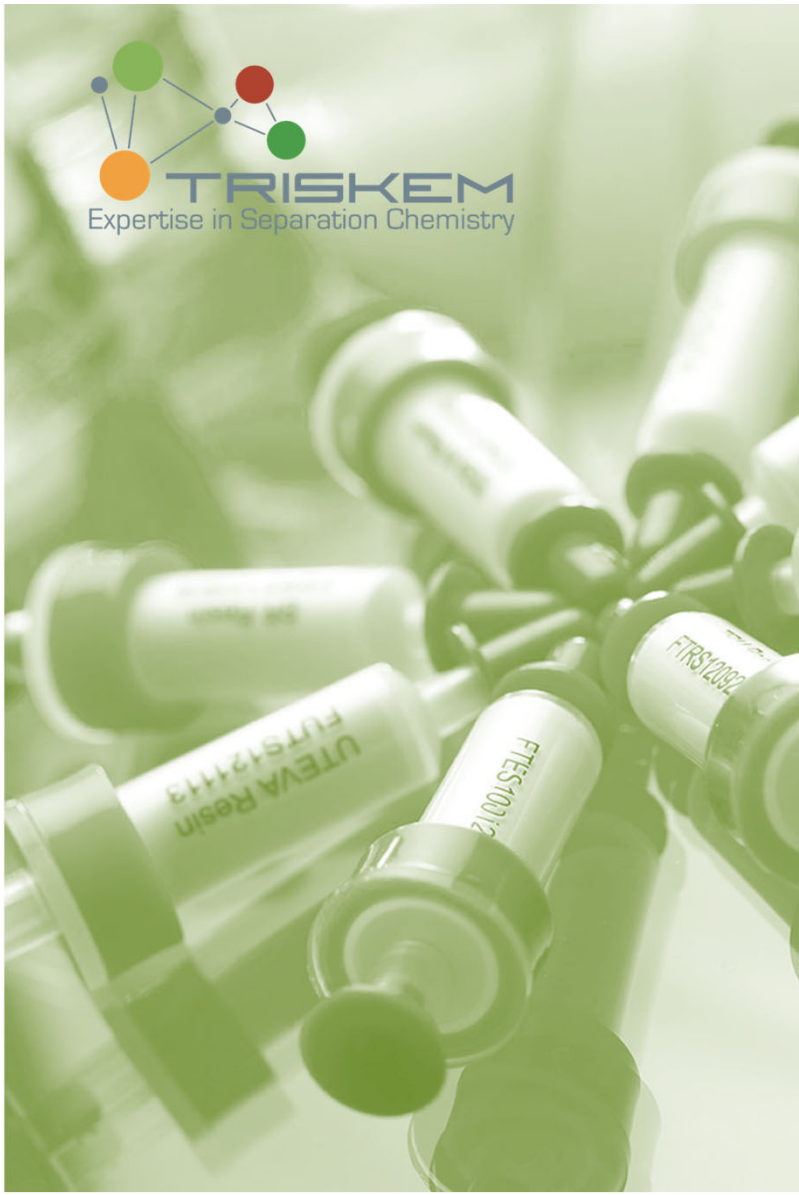
Advances in Radiochemical Separation: Optimized Procedures and Novel Extraction Materials

RRMC Workshop 2026

Inés Llopart, Steffen Happel, Alex Tarancón, Alex Blanco, Naji Abdallah, Matic Dokl

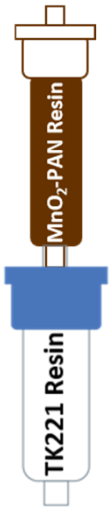
11-11-2026



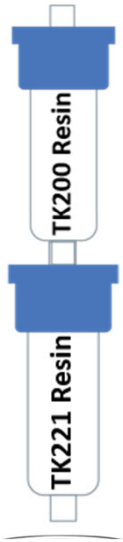
Optimized Procedures and Novel Extraction Materials

Commercially available

Ra determination



Actinides determination



Under development

TK227 discs



SE Resin



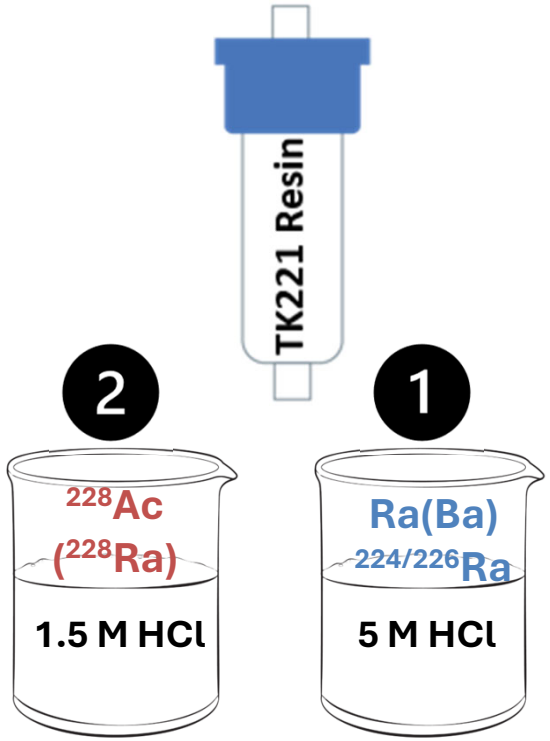
Ra determination

Ra

Preconcentration
(up to 1 L)

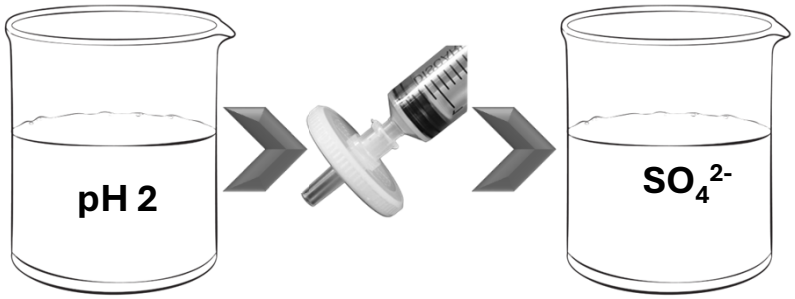


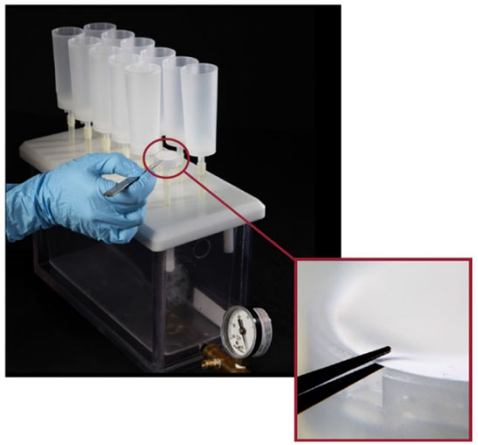
Interference removal
(actinides retention)



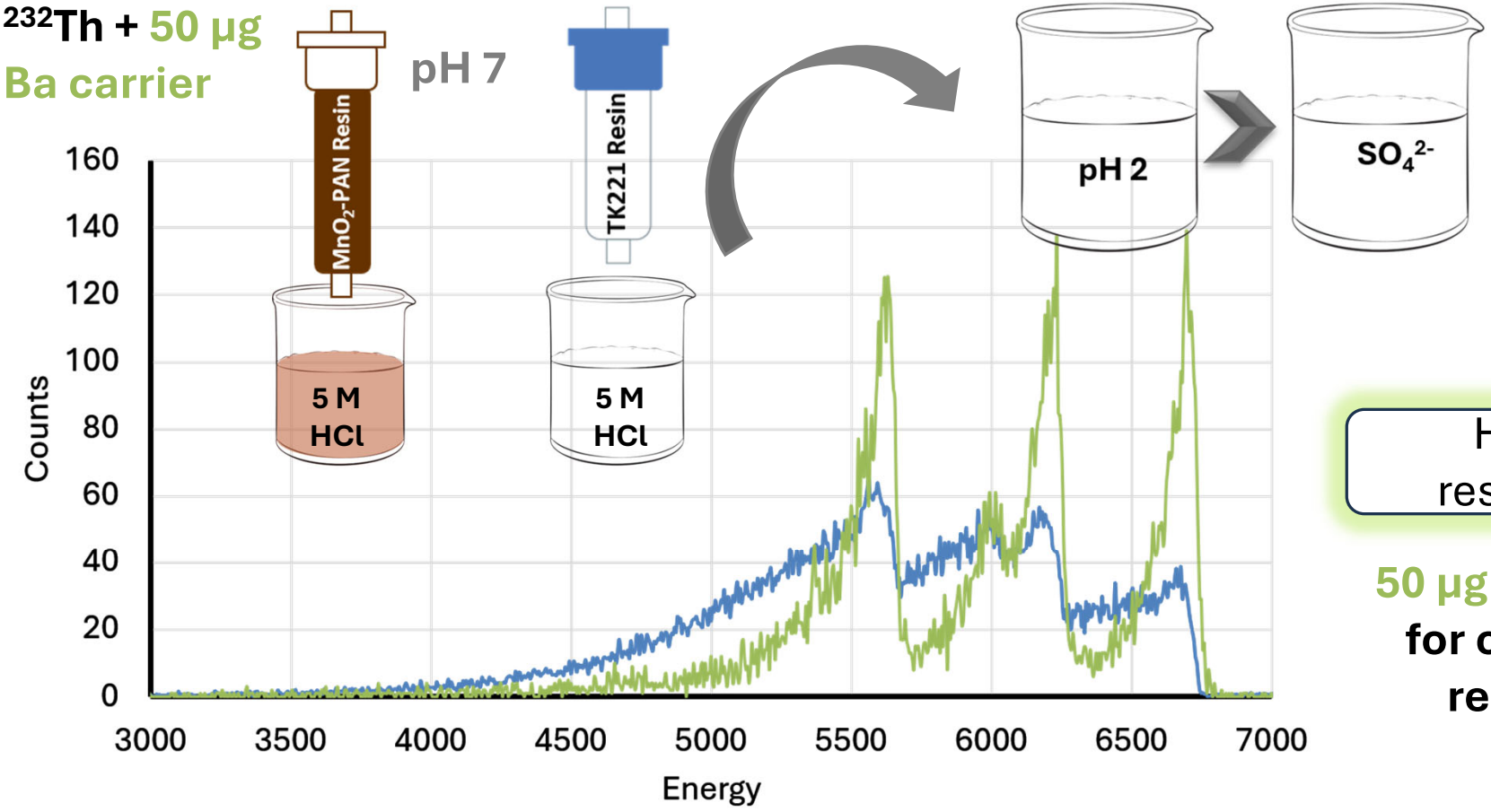
Based on Eichrom method RAW04 V1.0

α source preparation





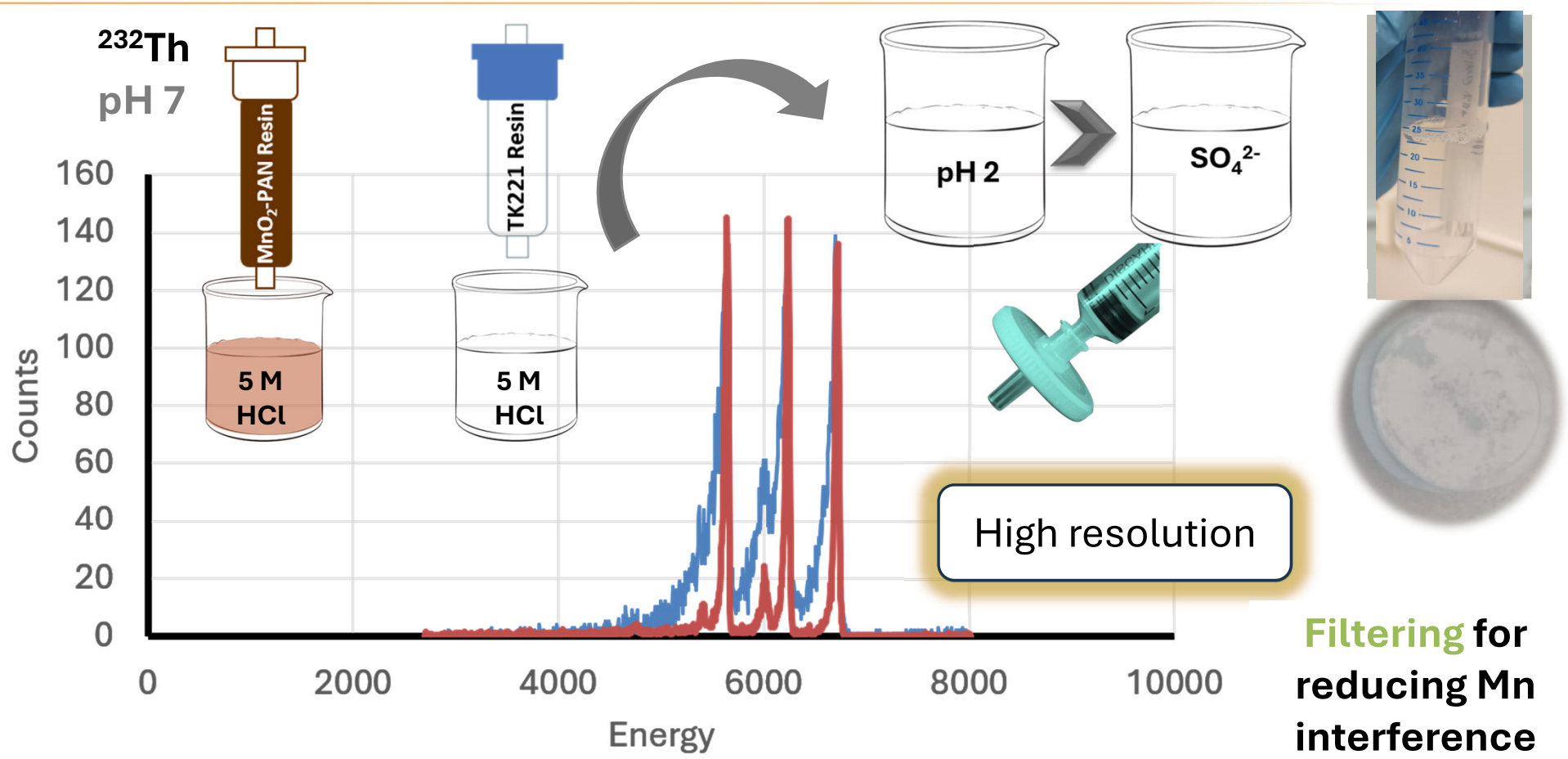
Ba carrier for chemical recovery



Higher resolution

50 µg Ba carrier for chemical recovery

Mn interference



Filtering for reducing Mn interference

Verification with spiked sample



Ba
Ce
Ra-226
Th-232

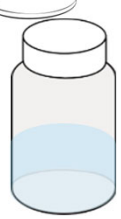


1. Load 5 M HCl
2. Rinse 5 M HCl



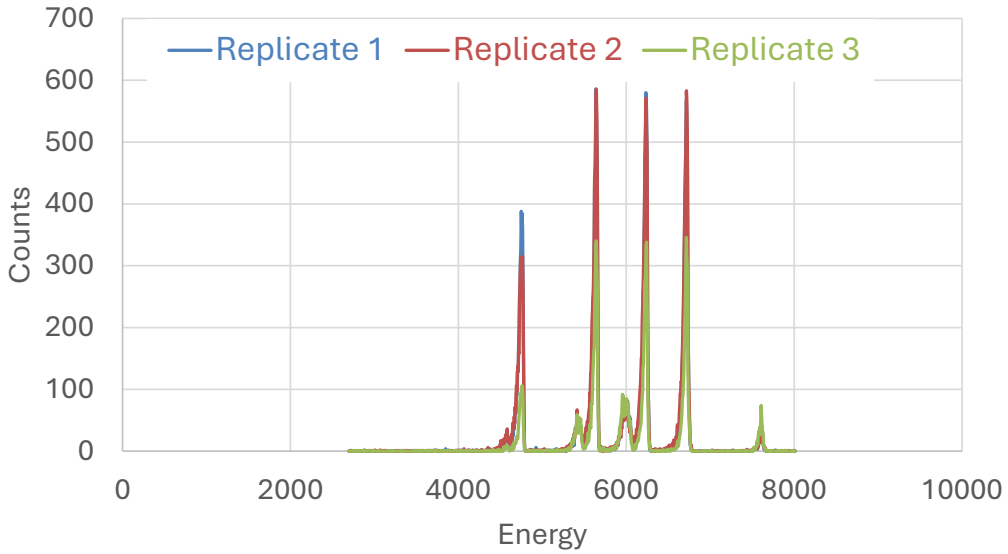
Ba
Ra-224
Ra-226
Ra-228

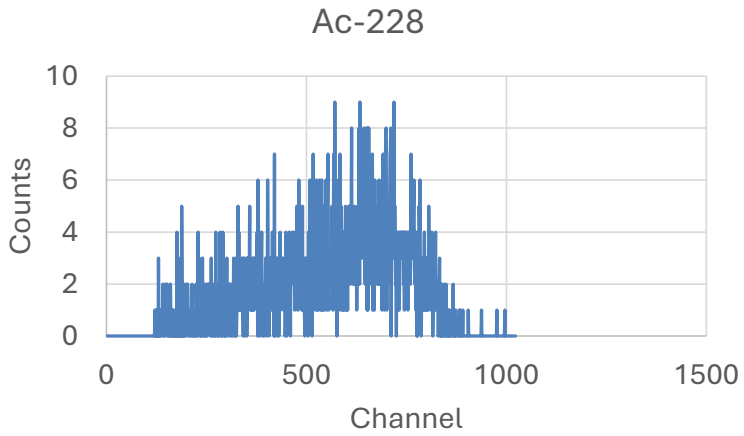
3. Elution 1.5 M HCl



Ce
Ac-228

0.1 Bq ^{226}Ra y 0.8 Bq $^{232/228}$Th





Verification with spiked sample



Ba
Ce
Ra-226
Th-232

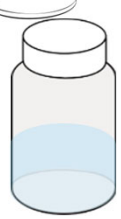


1. Load 5 M HCl
2. Rinse 5 M HCl



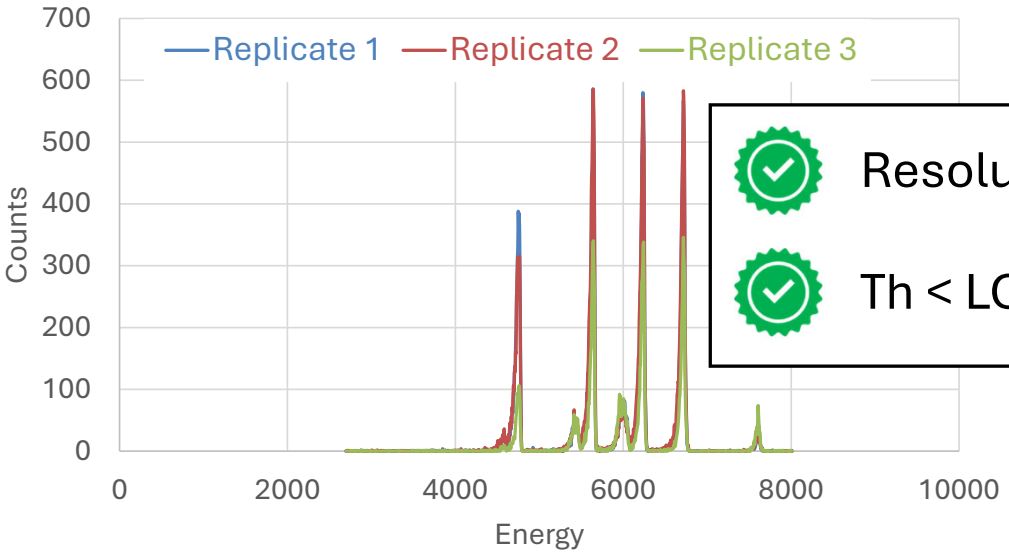
Ba
Ra-224
Ra-226
Ra-228

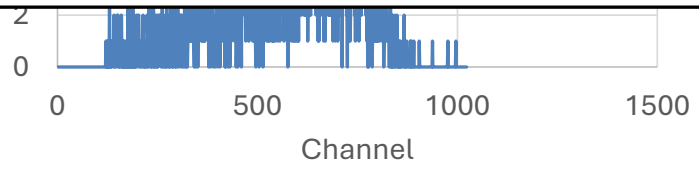
3. **Elution 1.5 M HCl**



Ce
Ac-228

0.1 Bq ^{226}Ra y 0.8 Bq $^{232/228}$Th





Resolution	MDA ^{226}Ra~ 4-15 mBq/L (1L, 24h)	MDA ^{228}Ra~ 47 mBq/L (1L, 1h)
Th < LOD		

Method validation: real samples

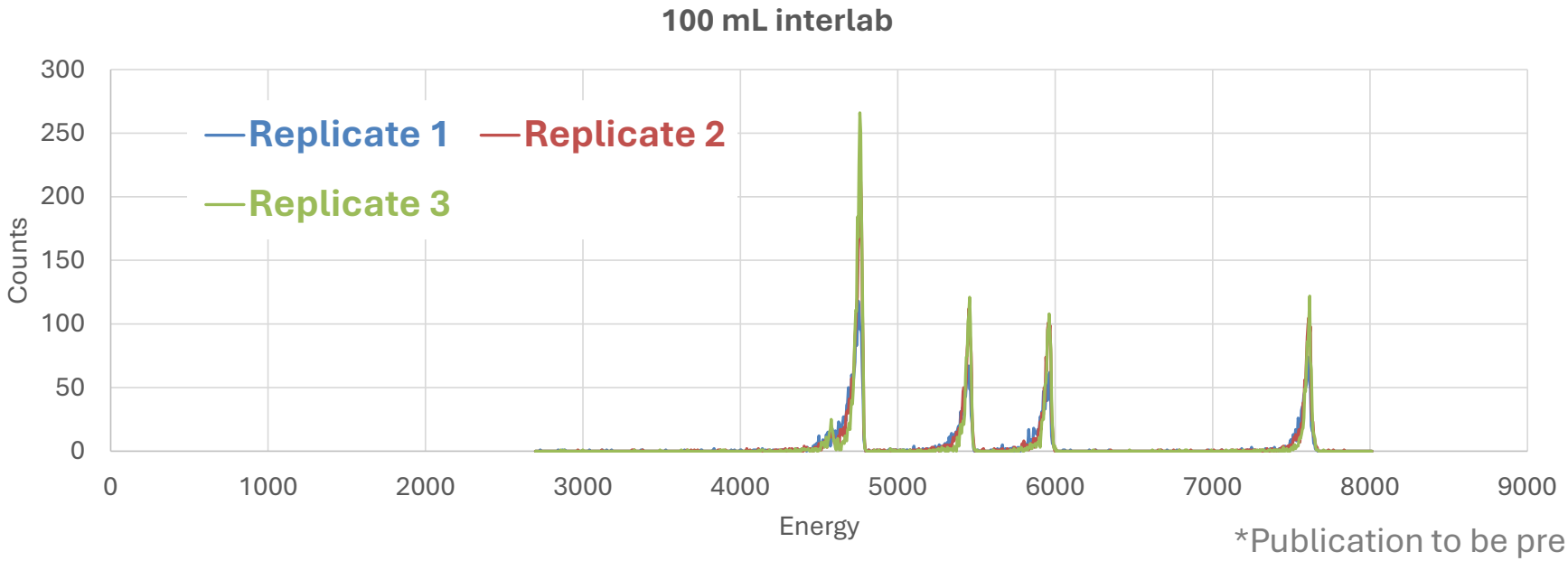
Interlab sample: ^{152}Eu, ^{238}U, ^{210}Po, ^{3}H, ^{90}Sr, ^{226}Ra

Diluted 10 times
100 mL



Ba
Ce

Sample	Ra-226 (Bq/L)
Measured	12.4 ± 0.3
Reference	13.0 ± 0.7



*Publication to be prepared

Method validation: real samples



Containing:

Degasify

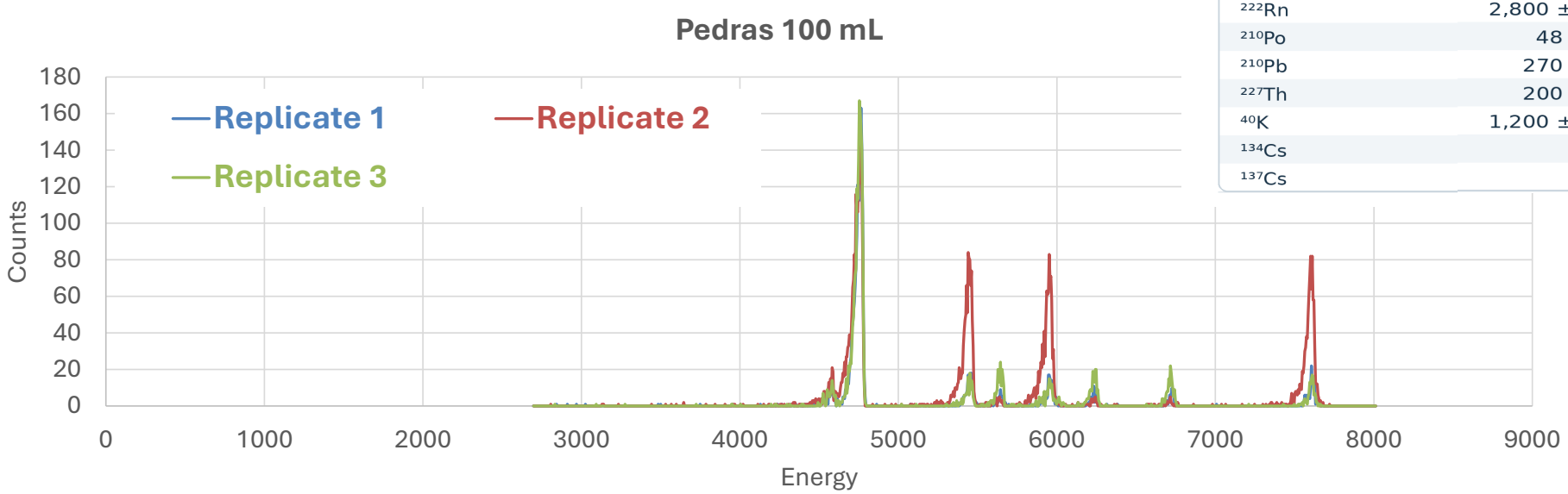
100 mL



Ba
Ce

mBq/L

Radionuclide	Activity ± SD
^{223}Ra	100 ± 80
^{224}Ra	110 ± 25
^{226}Ra	1,360 ± 350
^{226}Ra (via ^{214}Pb, ^{214}Bi)	1,200 ± 65
^{228}Ra (via ^{228}Ac)	1,600 ± 145
^{234}U	12 ± 4
^{238}U	23 ± 7
^{222}Rn	2,800 ± 700
^{210}Po	48 ± 10
^{210}Pb	270 ± 30
^{227}Th	200 ± 80
^{40}K	1,200 ± 500
^{134}Cs	<10
^{137}Cs	<10



Method validation: real samples



Containing:

Degasify

100 mL

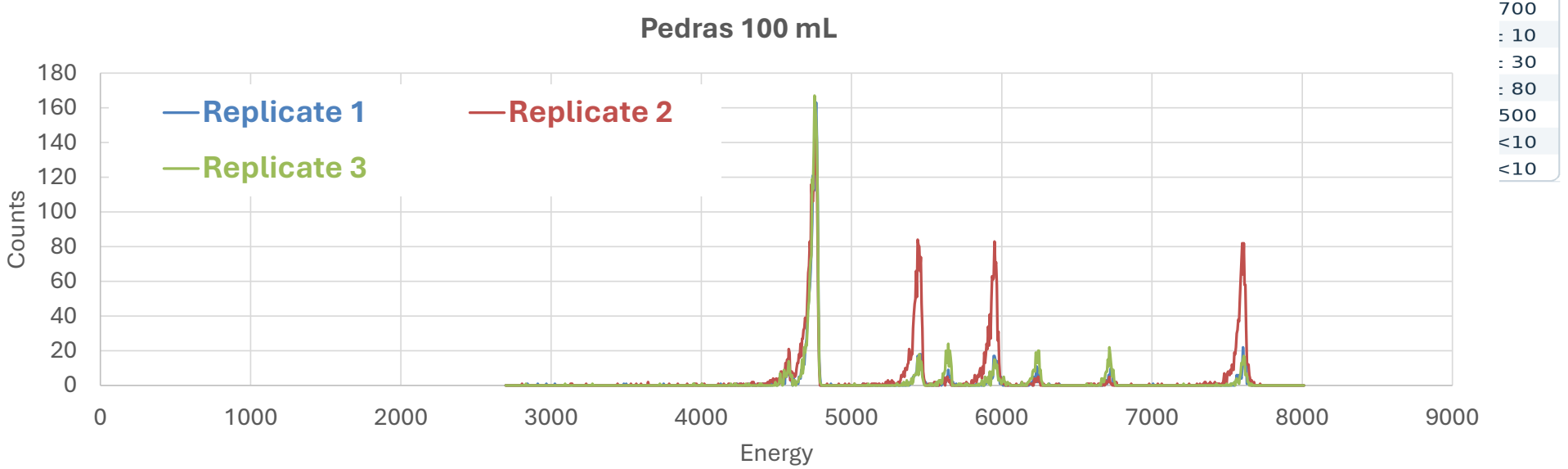


Ba
Ce

mBq/L

Sample	Ra-226 (Bq/L)	Ra-228 (Bq/L)
Measured	1,5 ± 0,2	1,8 ± 0,2
Reference	1,4 ± 0,4	1,6 ± 0,2

tivity ± SD
100 ± 80
110 ± 25
360 ± 350
1,200 ± 65
600 ± 145
^{234}U 12 ± 4
^{238}U 23 ± 7
700
: 10
: 30
: 80
500
<10
<10



Method application 1 L samples



1 L

pH 7

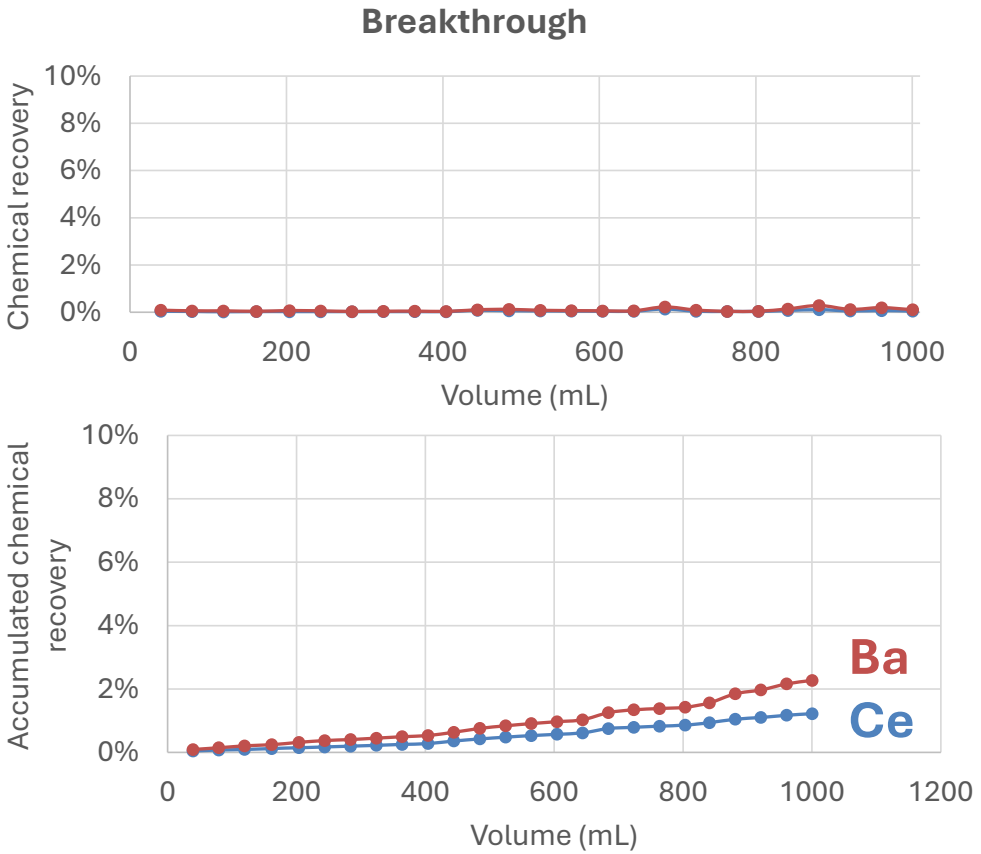
Ba
Ce



Collect 50 mL fractions

Ba(Ra) and **Ce(Ac)** well retained on MnO_2-PAN Resin

No Breakthrough of Ba(Ra) and Ce(Ac)



Method application 1 L samples



1 L

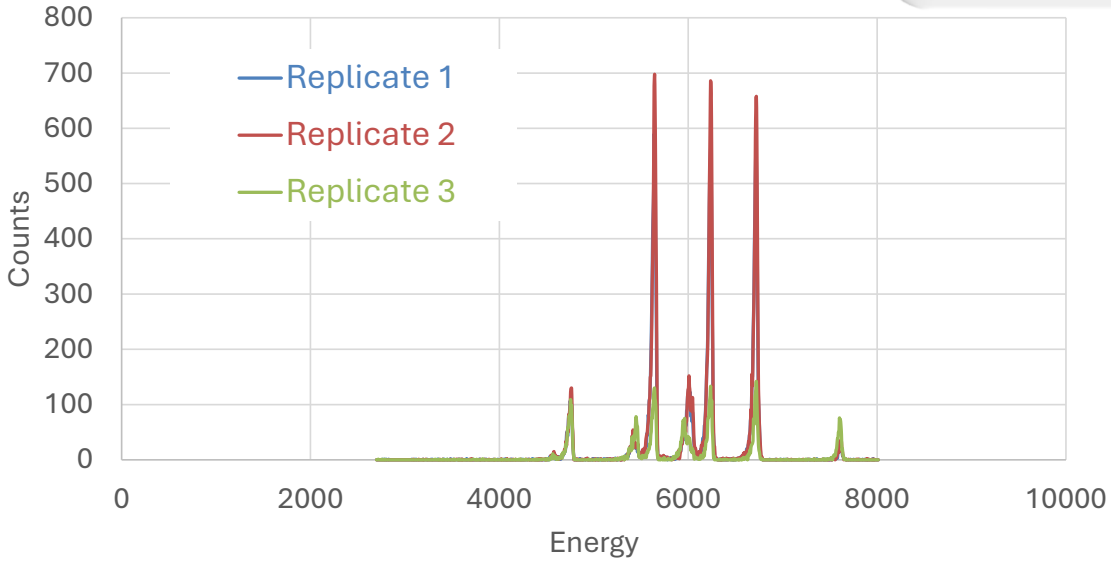
Ba
Ce
Ra-226
Th-232

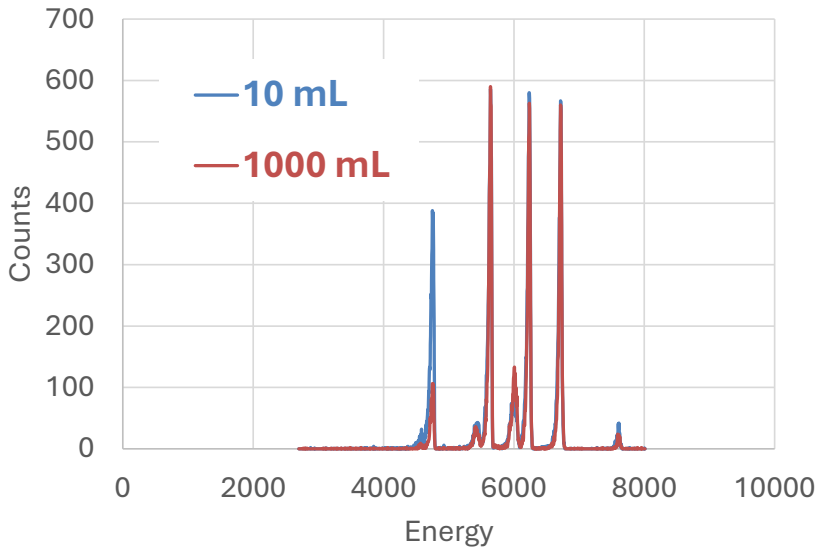
No significant differences:

- Alpha spectrum
- Chemical recovery (Ba/Ce)

2 hour for loading 1 L onto MnO_2-PAN Resin

0.1 Bq ^{226}Ra y 0.8 Bq $^{232/228}$Th

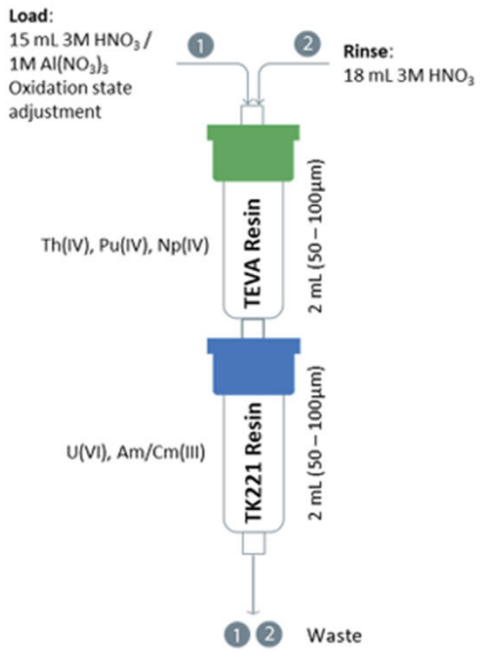


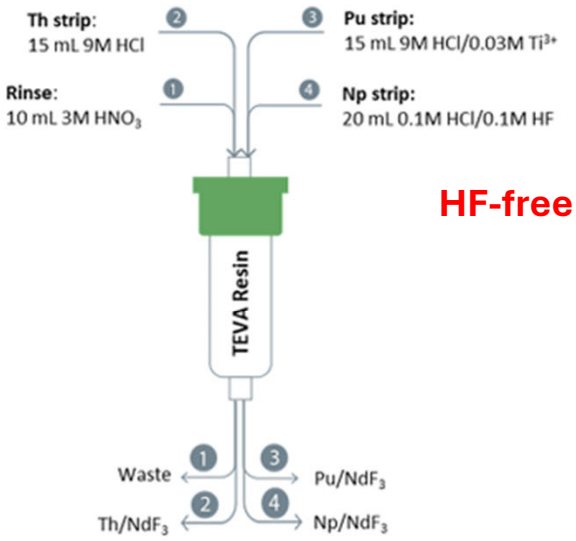


Actinides determination

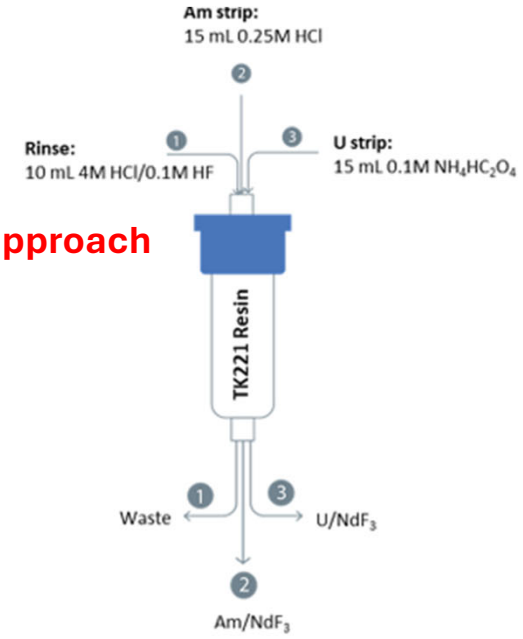
Actinides

Determination of **U, Th, Pu and Am** in water is essential for environmental monitoring, nuclear safeguards and radioanalytical quality assurance





HF-free approach



Taken from Papp, Vajda & Happel

Actinides determination

Actinides

Better actinide retention
Removal of HF for elution



Pu, Th, U

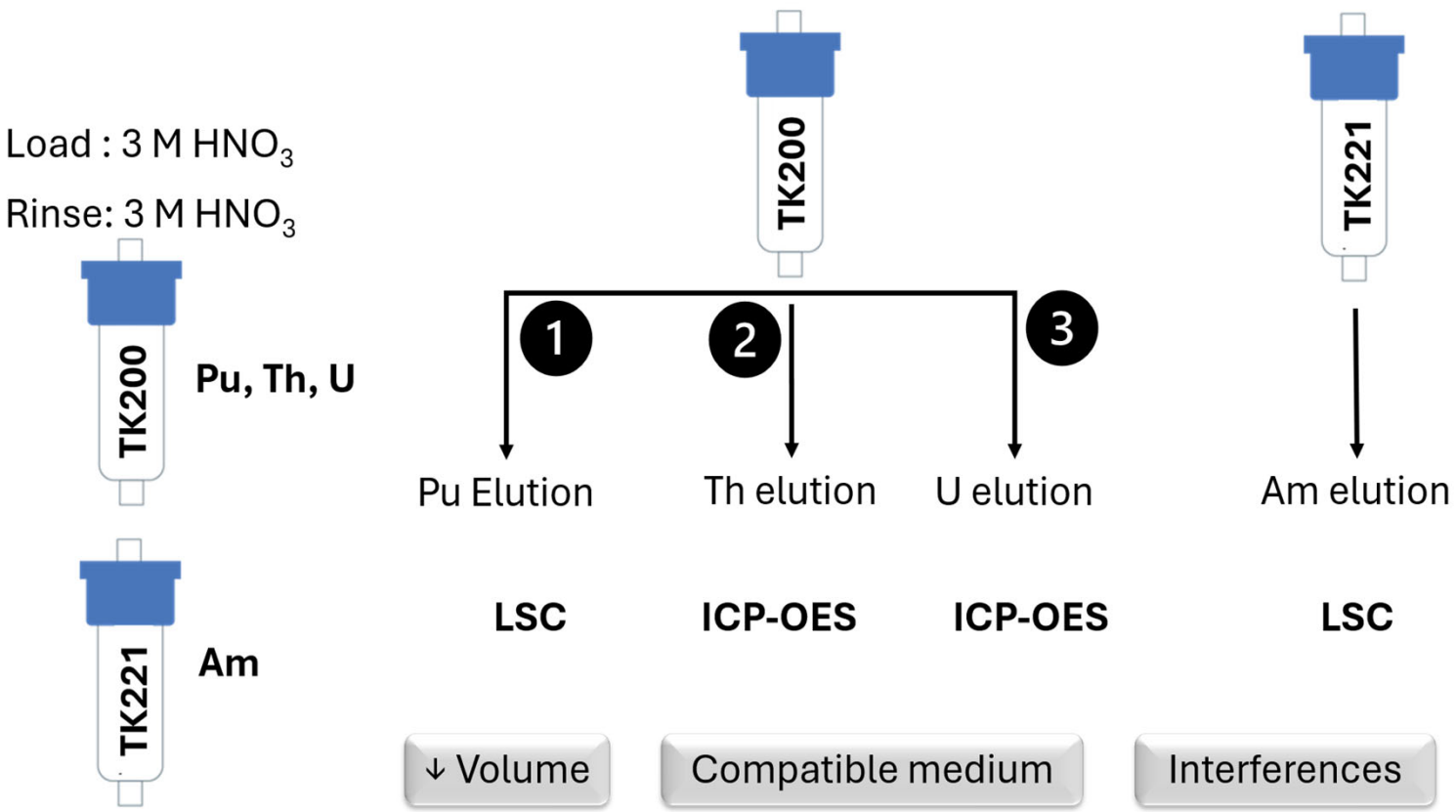
Retention of trivalent actinides



Am

Actinides determination

Actinides

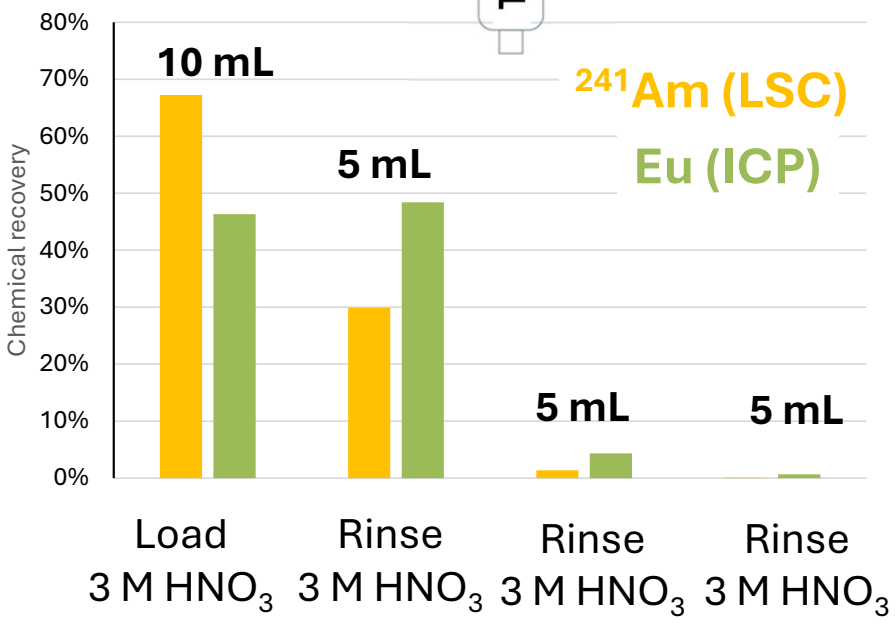


Actinides determination

Actinides

Am not retained

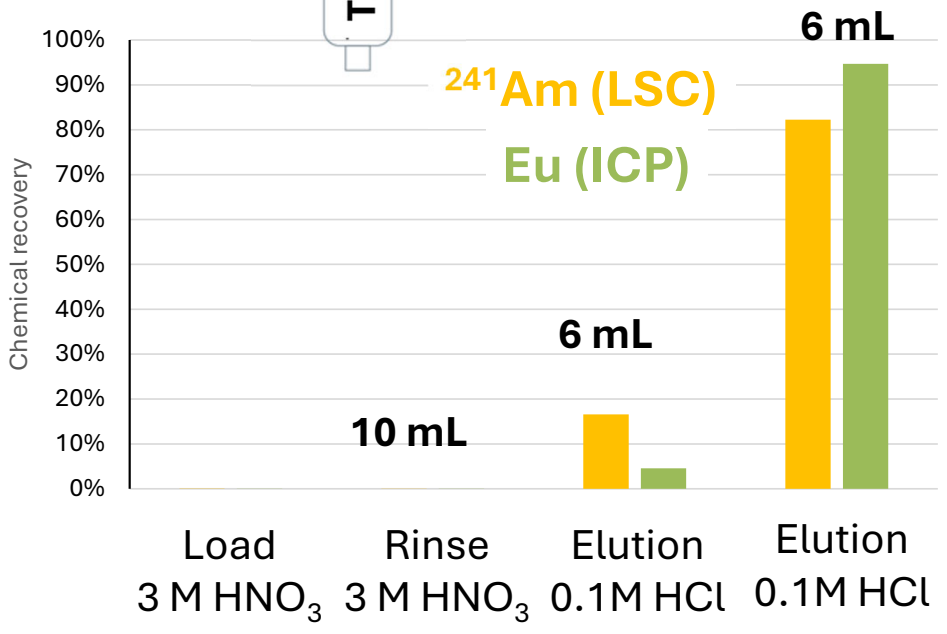




- Need to rinse with 10 mL 3M HNO_3



Am retained and eluted



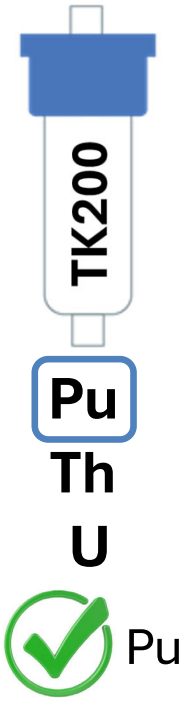
- With 12 mL 0.1 M HCl ^{241}Am can be eluted

Actinides determination

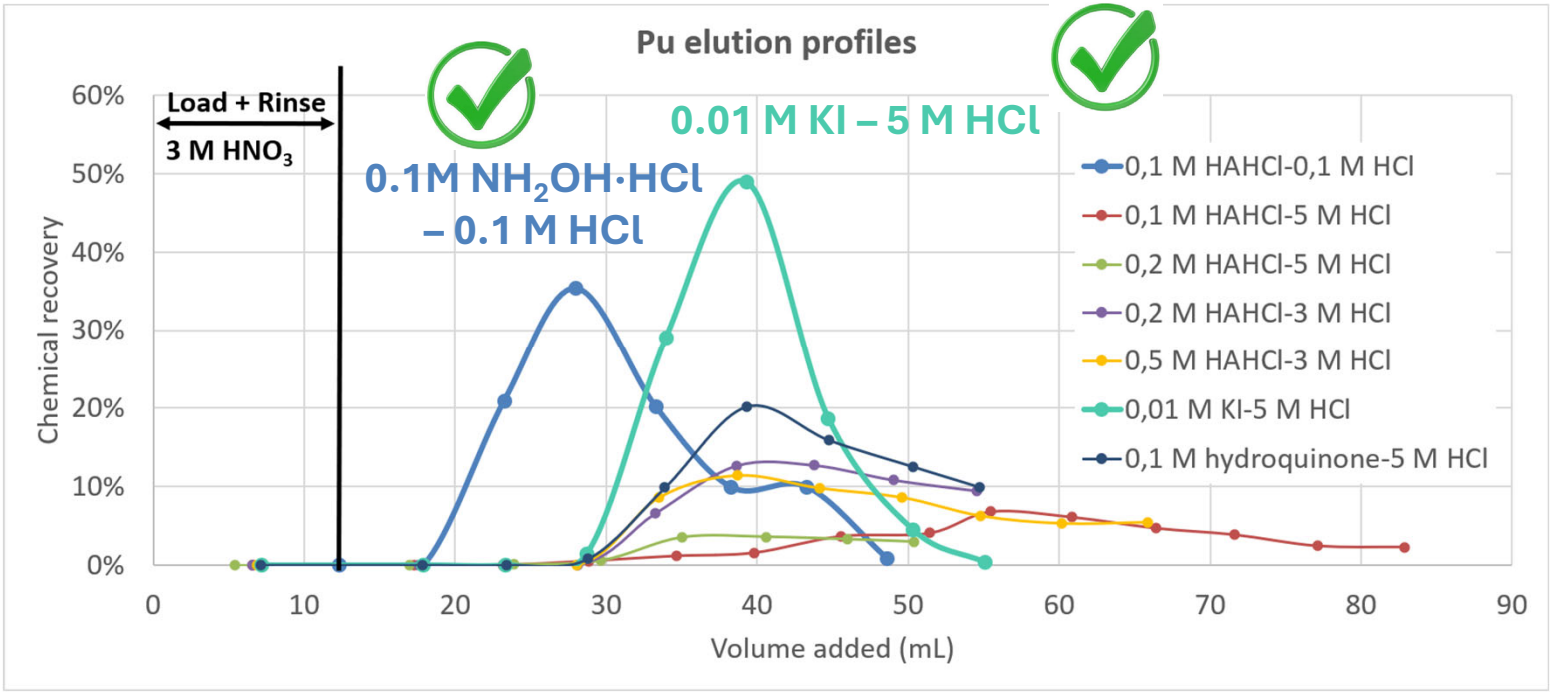
Actinides

Load: 3 M HNO_3
Rinse: 3 M HNO_3

1. Reduce to Pu (III) with Fe sulfamate/ascorbic ac
2. Oxidize to Pu (IV) with $NaNO_2$



Pu retained

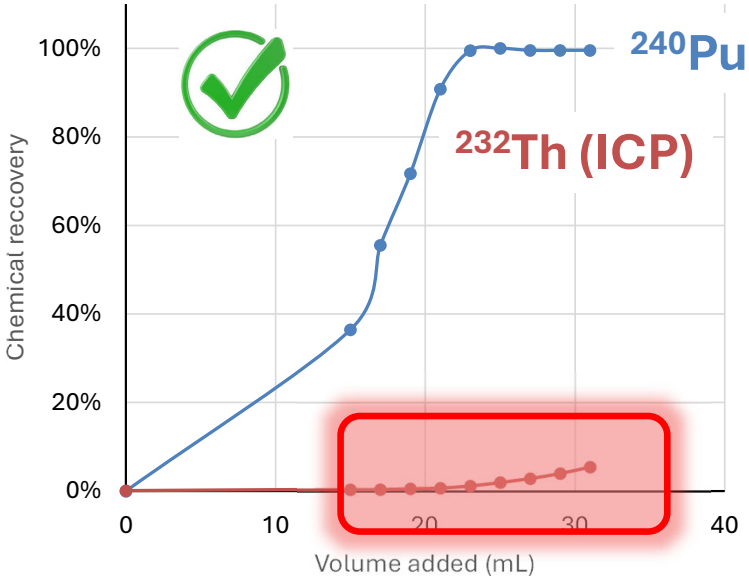


Actinides determination

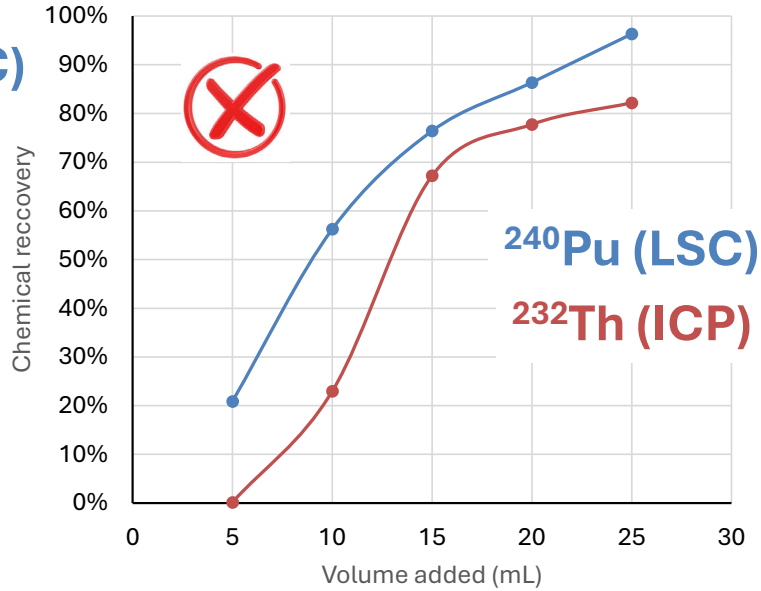
Actinides



Pu elution with 0.01 M KI -5 M HCl



Pu elution with 0.1M $NH_2OH \cdot HCl$ – 0.1 M HCl

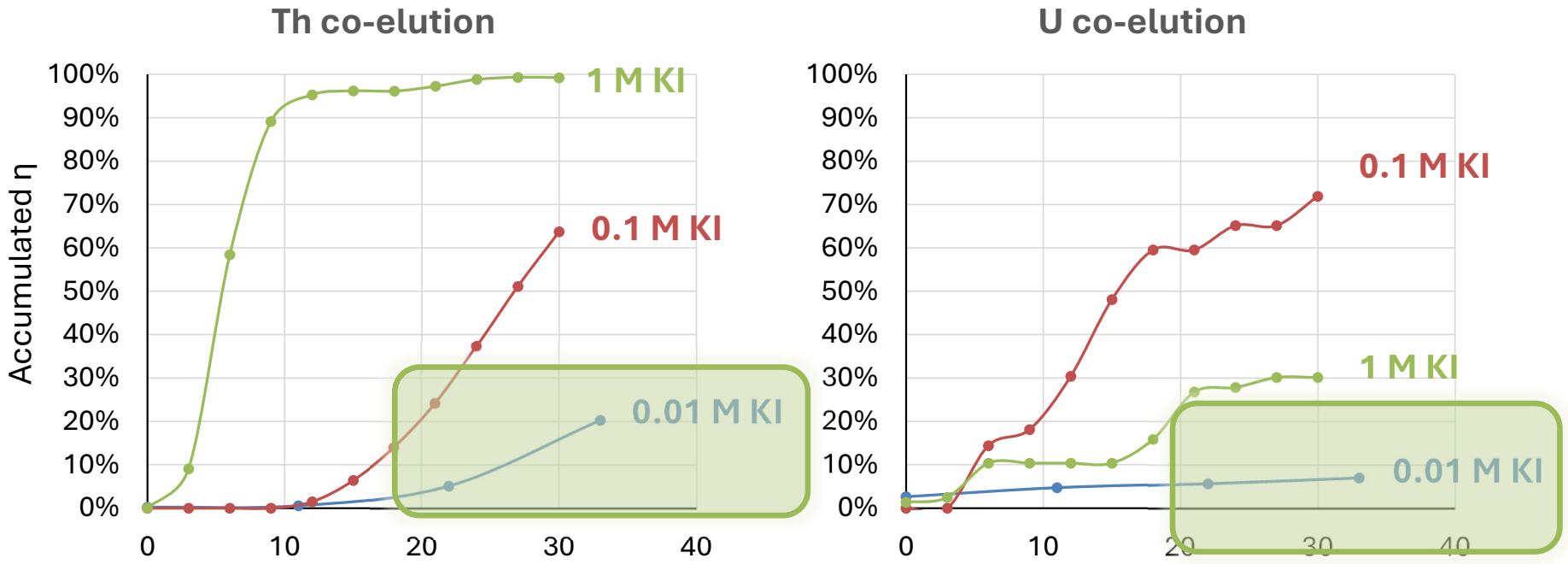


- With **22-25 mL of 0.01 M KI - 5 M HCl** it is possible to elute Pu without Th and U co-elution

Actinides determination

Actinides



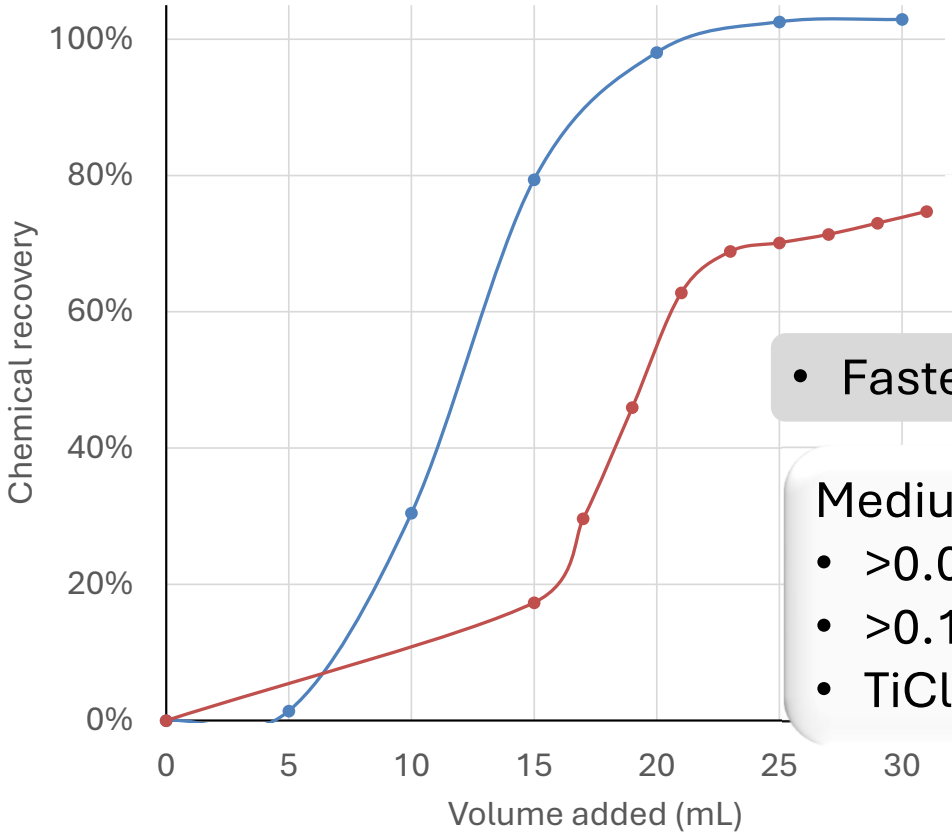


- **0.01 M KI - 5 M HCl** best-performing solution for Pu elution, minimizing Th/U co-elution

Actinides determination

Actinides





0.01 M KI-5 M HCl

0.01 M KI-6 M HCl

- Faster Pu elution using 5 M HCl

Mediums to be tested:

- >0.01 M Ascorbic acid (3 M HNO_3)
- >0.1 M Hydroquinone (3 M HNO_3)
- $TiCl_3$

Actinides determination

Actinides

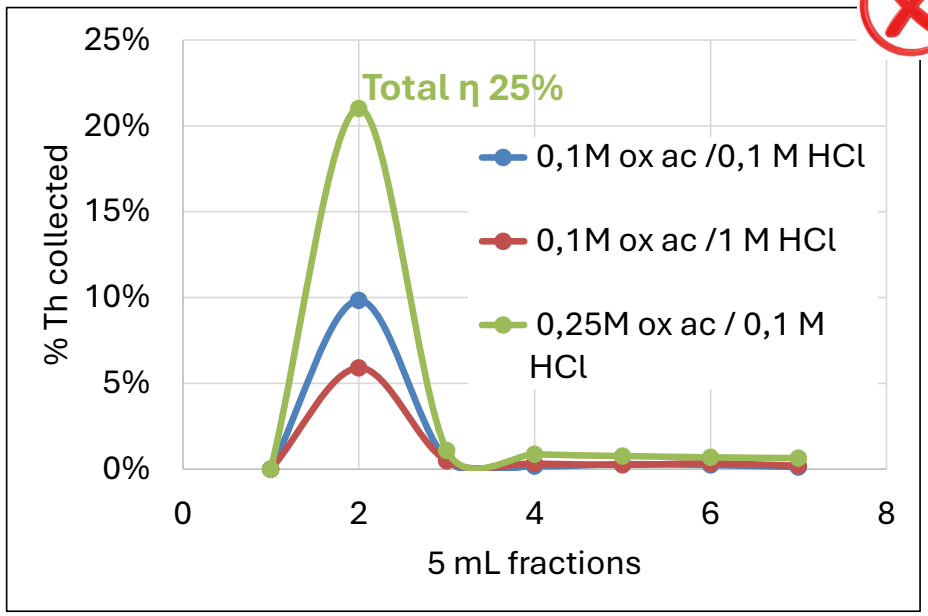
TK200

~~Pu~~

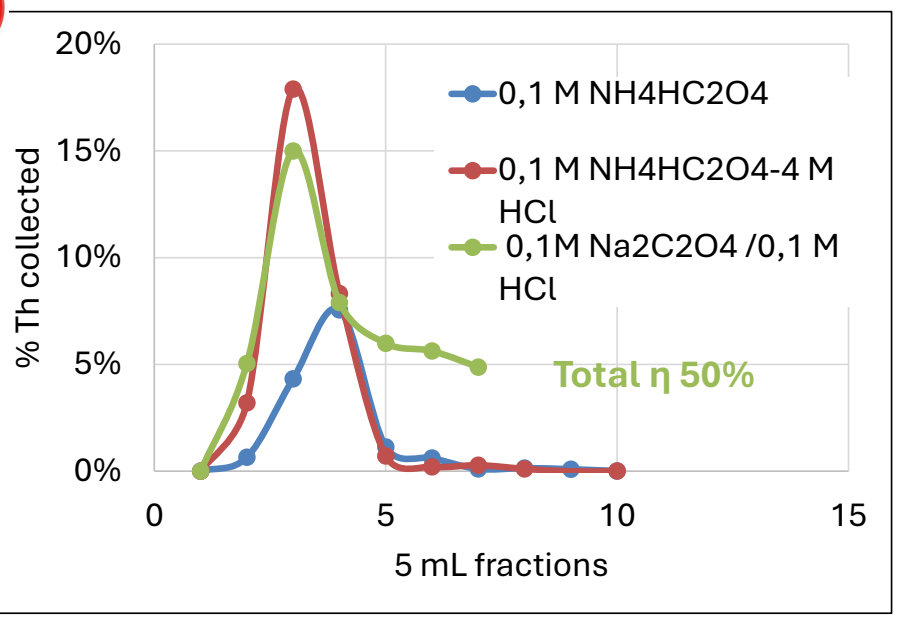
Th

U

Elution of Th with oxalic acid



Elution of Th with oxalates

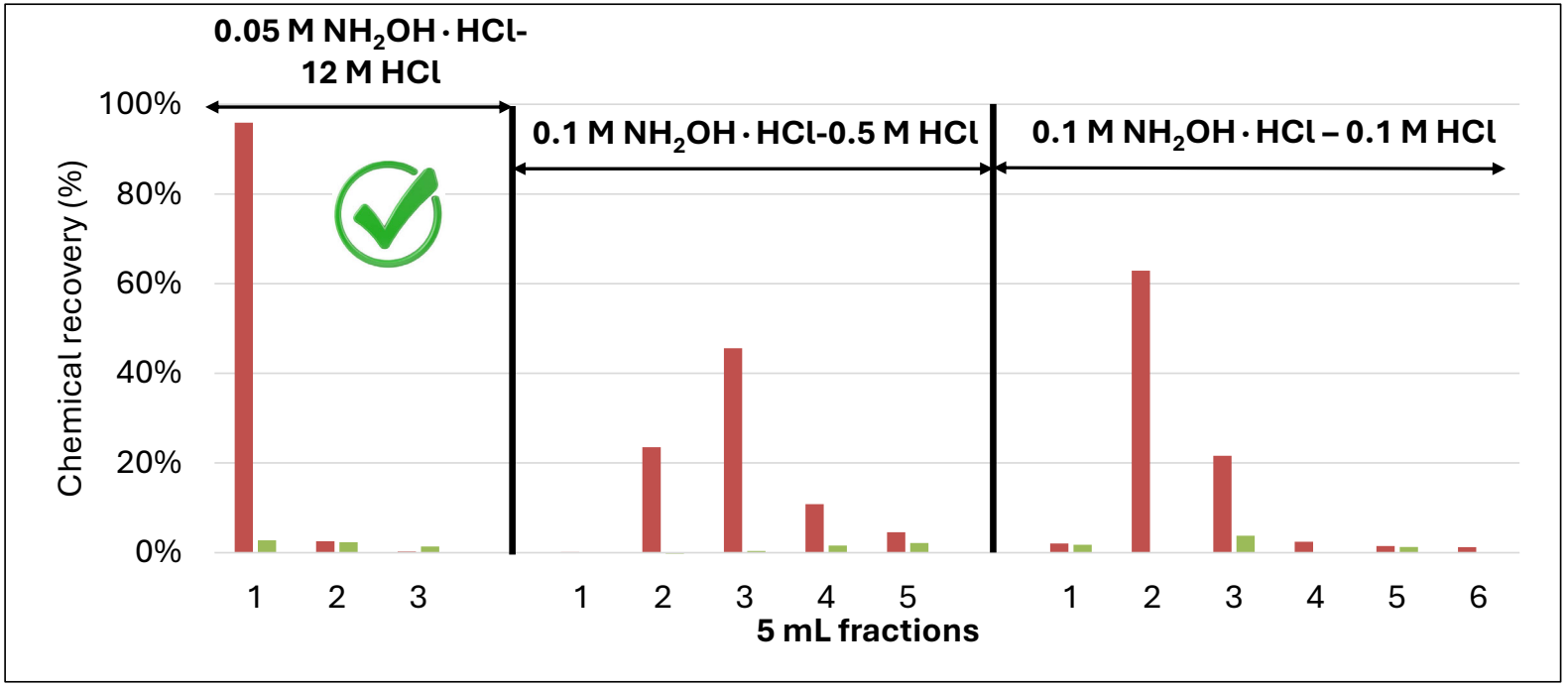


- Neither oxalic acid nor oxalates are able to completely elute large Th amounts (lower Th concentration showed proper Th elution)

Actinides determination

Actinides



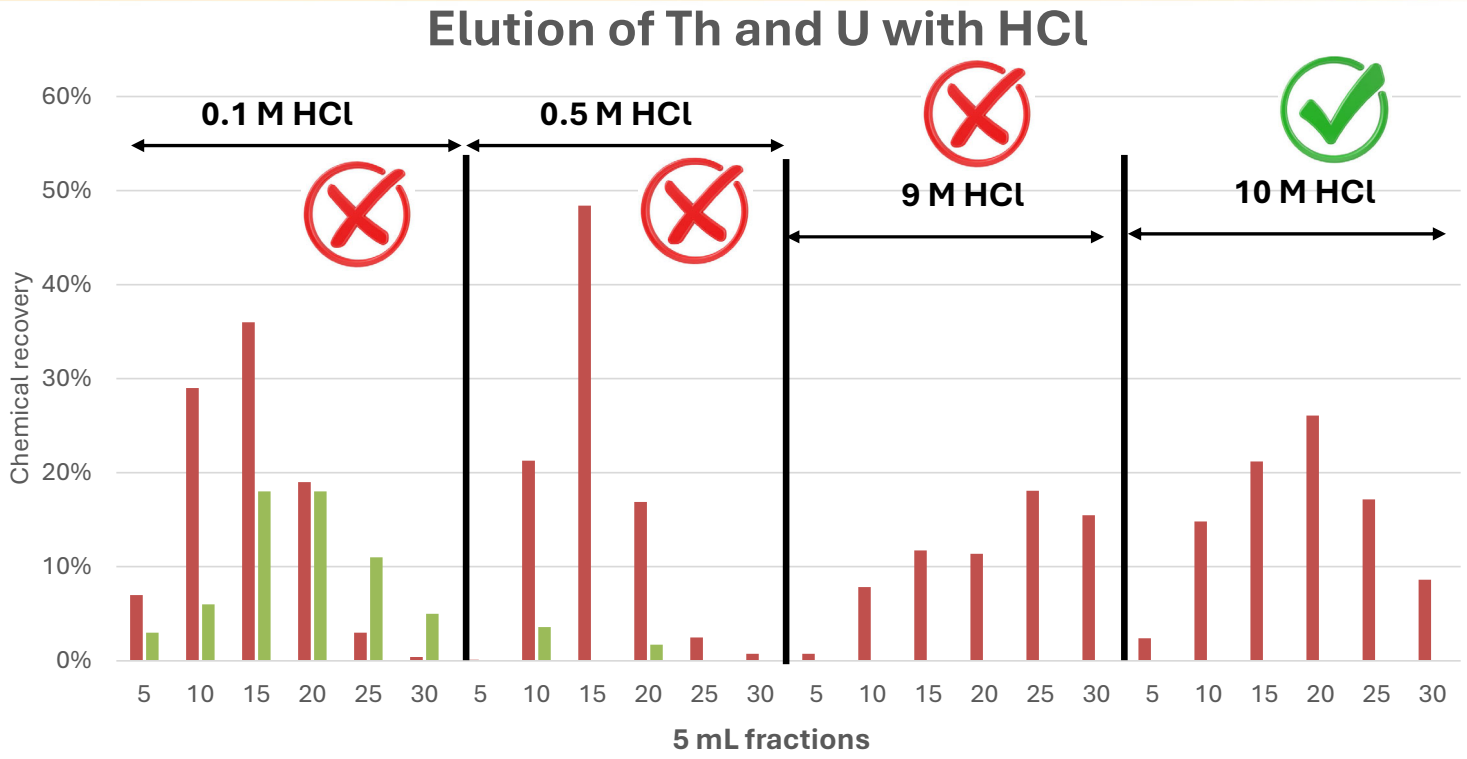


- **15 mL of 0.05 M $NH_2OH \cdot HCl$ - 12 M HCl** - possible to elute Th without U co-elution

Actinides determination

Actinides





- Increasing HCl concentration reduces co-elution of U, but larger volume is required compared to hydroxylamine-HCl

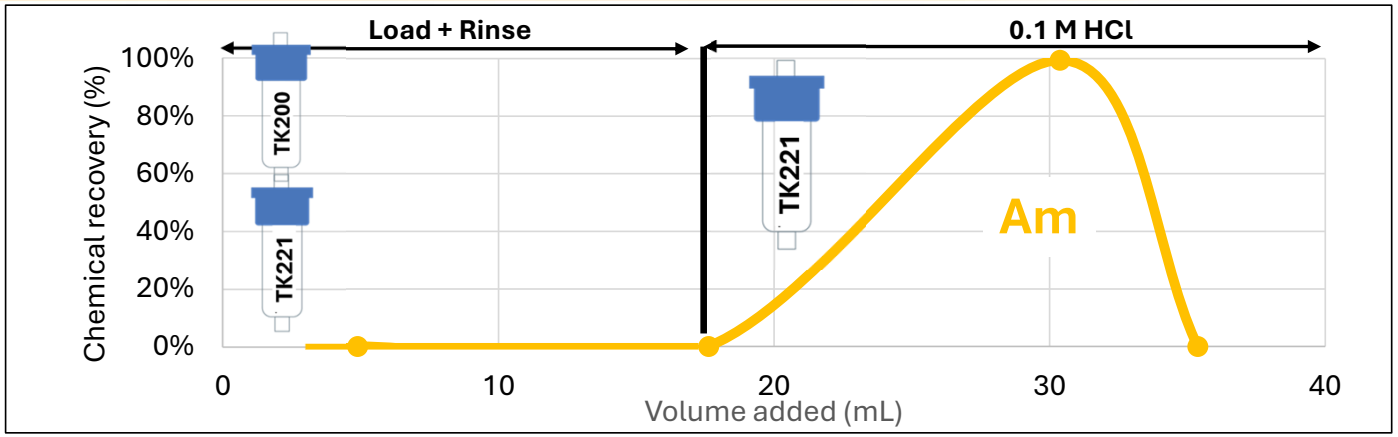
Actinides determination

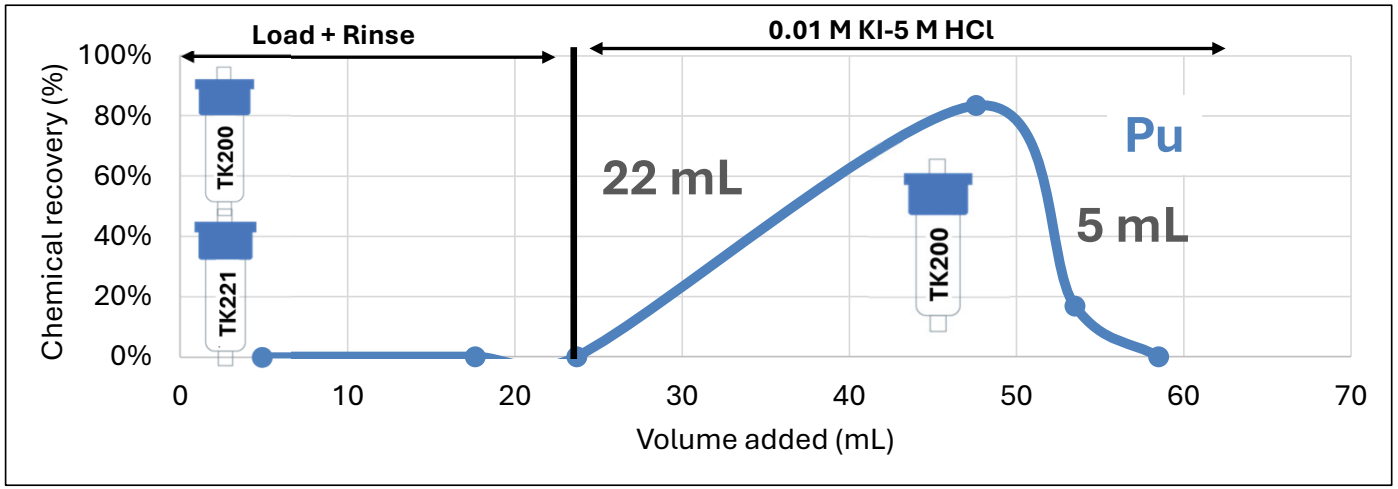
Actinides

Load: 3 M HNO_3

Rinse: 3 M HNO_3

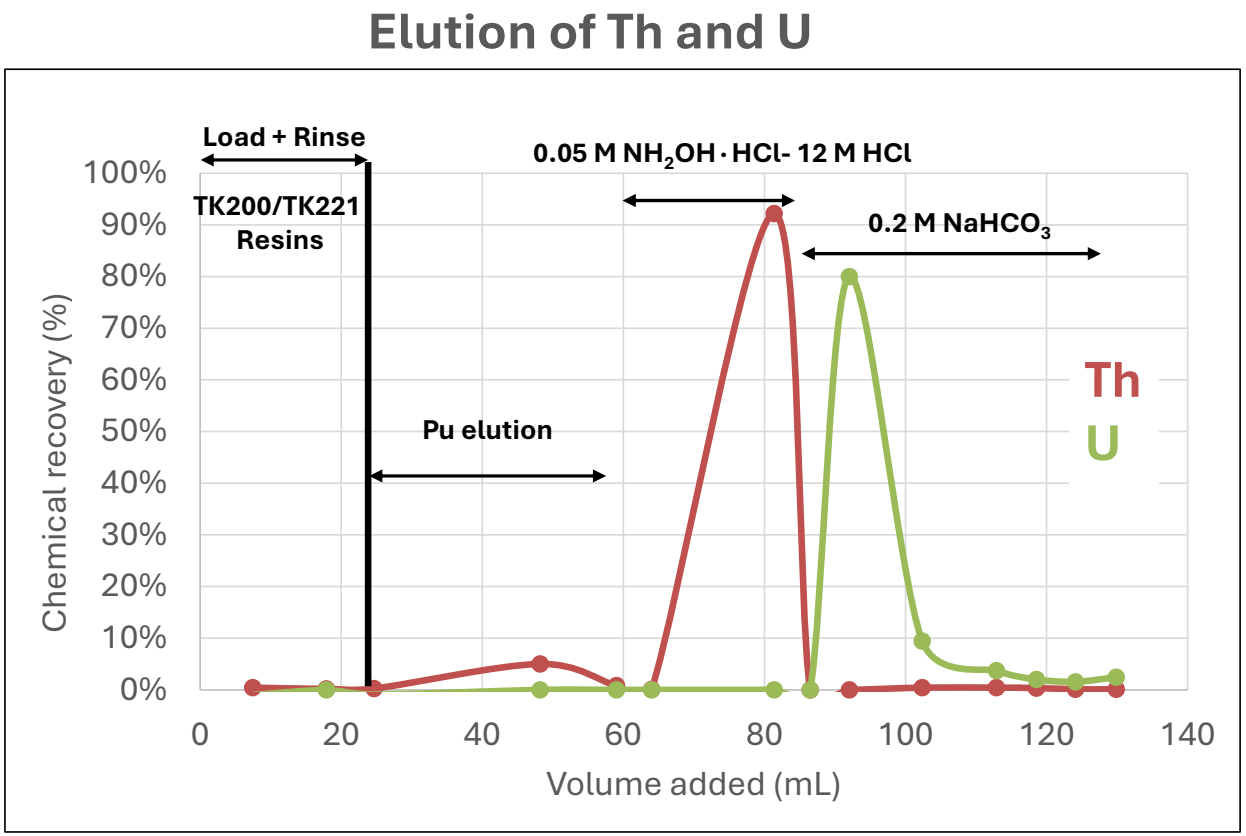






Actinides determination

Actinides

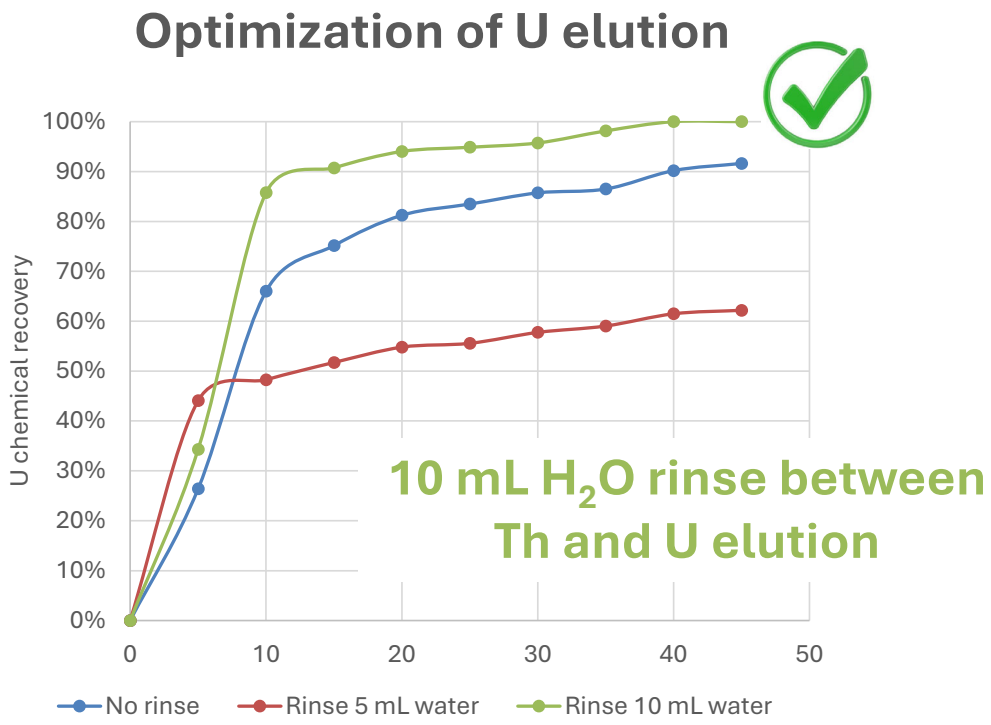


15 mL for the elution of Th 0.05 M $NH_2OH \cdot HCl$- 12 M HCl

45 mL for the elution of U 0.2 M $NaHCO_3$

Actinides determination

Actinides



- Complete procedure
  - Pu, Th and U elution
- Alpha spectrometry measurements
- Application in real samples

Y-90 determination TK227 disc

Sr/Y



20 % EtOH
0.5 M HNO_3

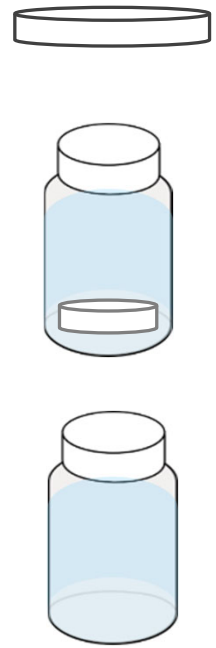
1 L tap water
0.5 M HNO_3

Rinse
0.5 M HNO_3
9 M HCl

No elution
Direct
measurement GPC

No elution
Cherenkov

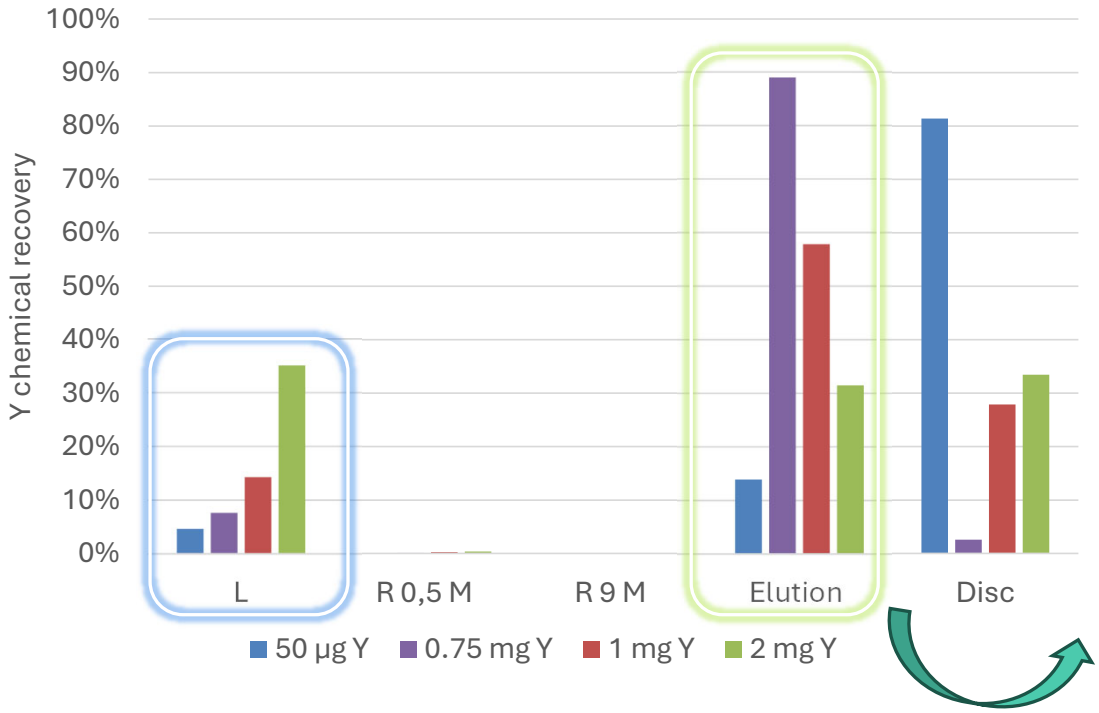
Y elution
20 mL 0.1 M HCl



Y-90 determination TK227 disc

Sr/Y

Capacity studies of TK227 Discs



Load: ↑ mg loaded ↑ Y collected

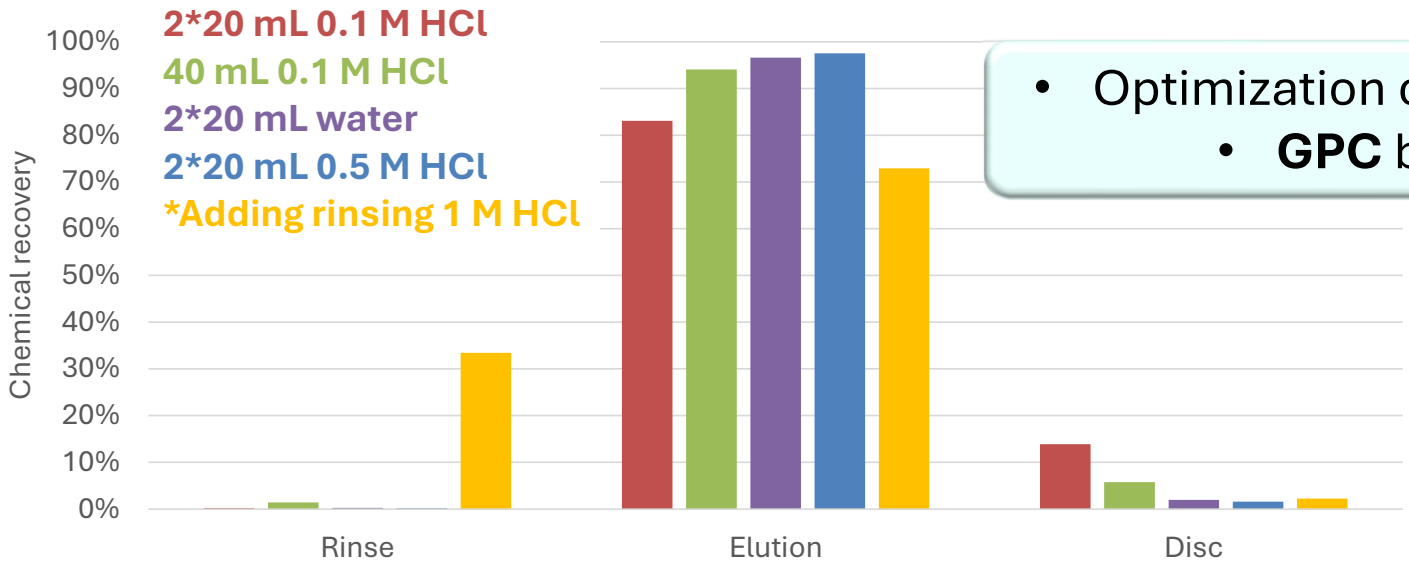
Elution: quantitative elution achieved when loading >0.75 mg Y

Elution: 20 mL 0.1 M HCl

Y-90 determination TK227 disc

Sr/Y

Defining suitable elution conditions



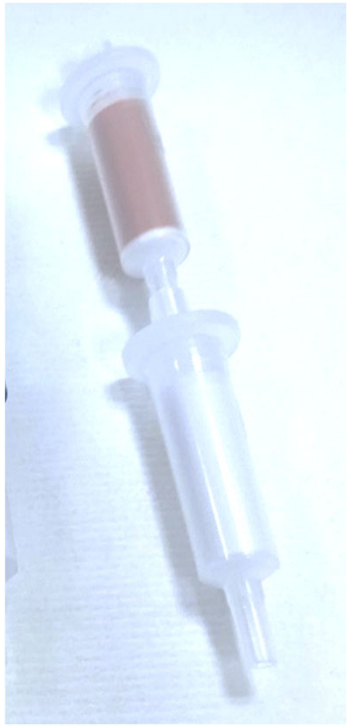
- Optimization of **disc preparation**
- **GPC** beta testing

Elution using 40 mL 0.1 M HCl/water → Close to 100% chemical recovery

On the determination of ^{79}Se

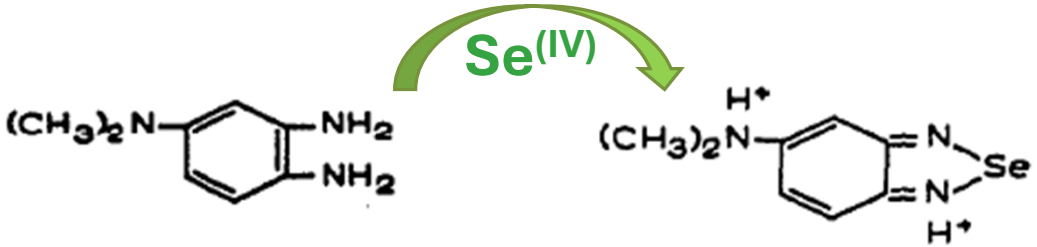
Se

SE Resin characterization



SE Resin

Se retention



OgRem Resin

Extractant bleeding

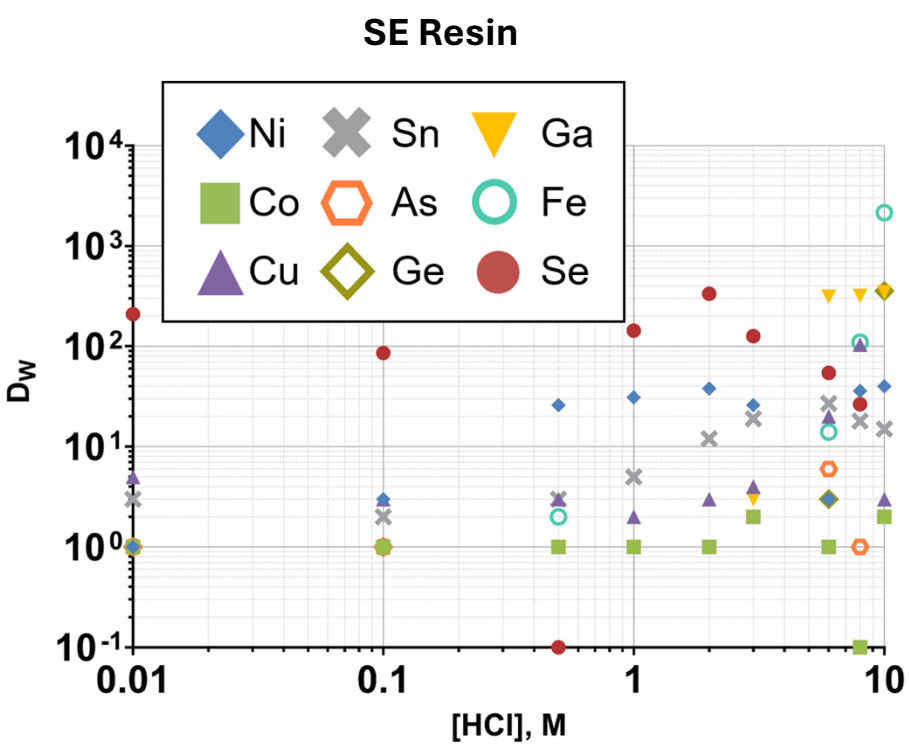
Acid media (H^+)

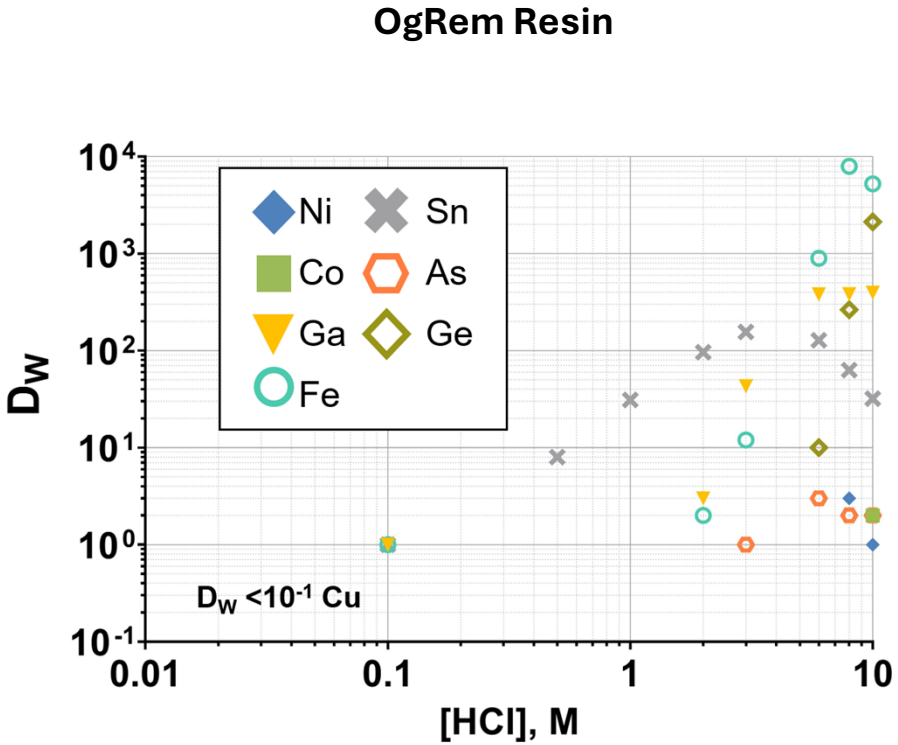
Influence Se oxidation state

On the determination of ^{79}Se

Se

SE Resin characterization





On the determination of ^{79}Se

Se

SE Resin method optimization

$Se^{(IV)}$ standard (2% HNO_3)

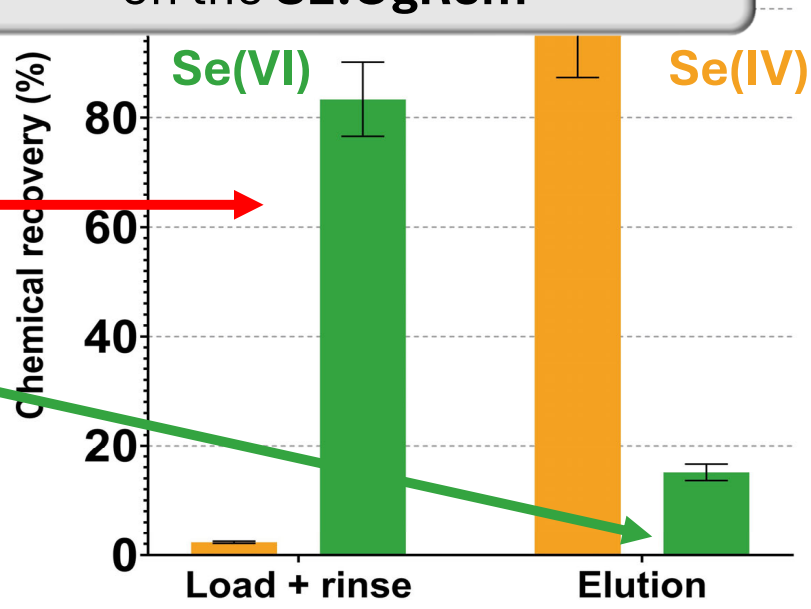
$Se^{(VI)}$ standard (in H_2O)

- 85% $Se^{(VI)}$
- 15% $Se^{(IV)}$



1. 7 mL 2.5 M HCl
2. 10 mL 2.5 M HCl
3. 2x10 mL 1 M NaOH

Only Se(IV) is completely retained on the **SE:OgRem**



On the determination of ^{79}Se

Se

SE Resin characterization

Ragnar Bye and Waiter Lund, 1988 ➔ relevance of HCl concentration, temperature and time on Se reduction

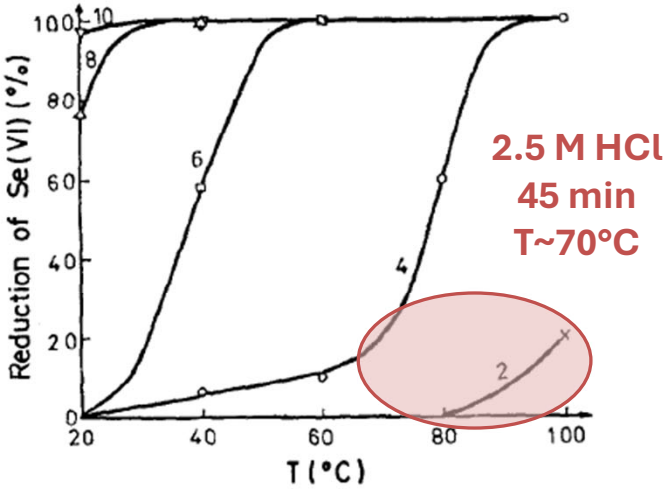


Fig. 2. Reduction of 1.6 µg Se(VI) with 10 ml HCl of various concentrations (mol/l) after 30 min in dependence on temperature

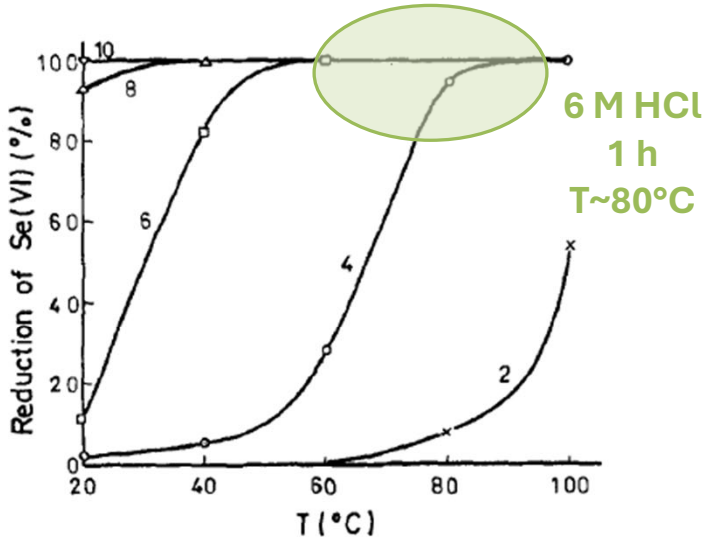
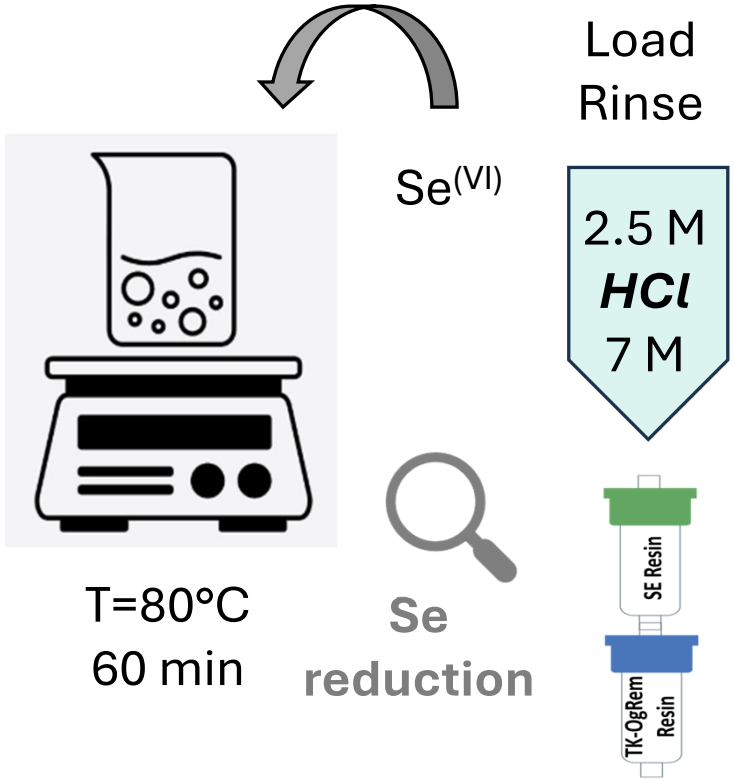


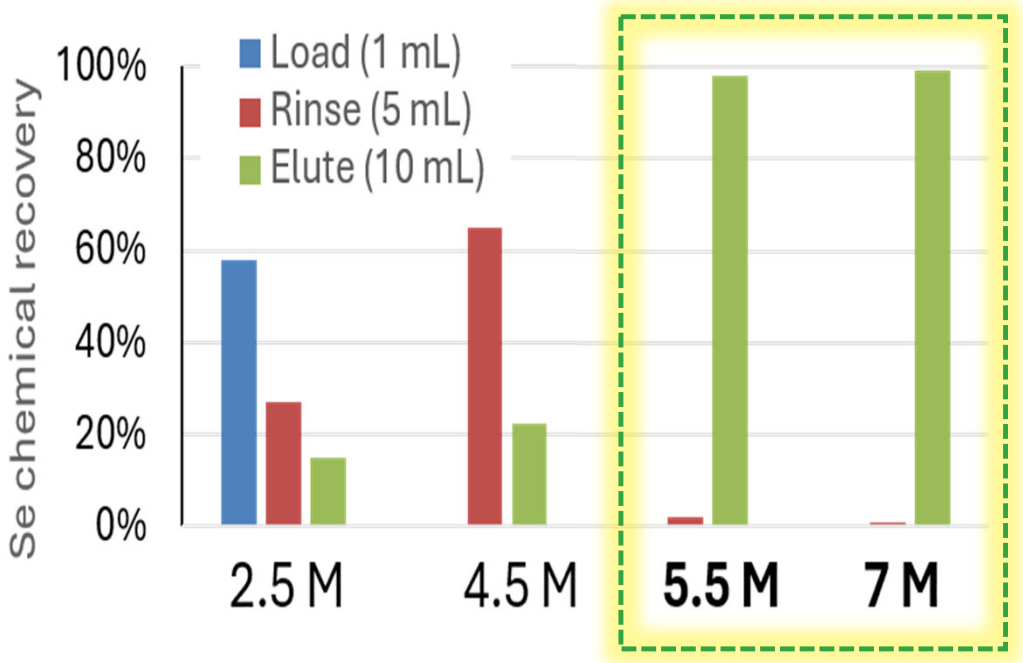
Fig. 4. Reduction of 1.6 µg Se(VI) with 10 ml HCl of various concentrations (mol/l) after 2 h in dependence on temperature

On the determination of ^{79}Se

Se

SE Resin characterization

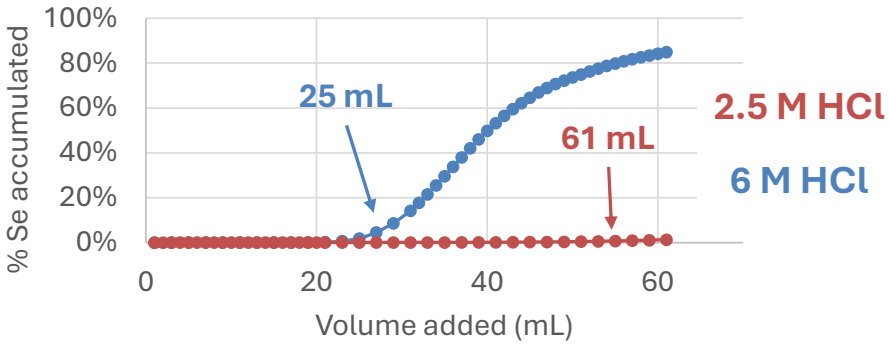




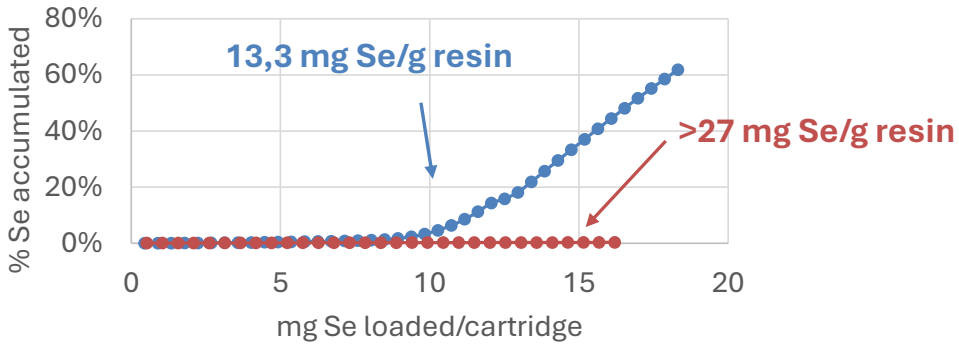
On the determination of ^{79}Se

Se

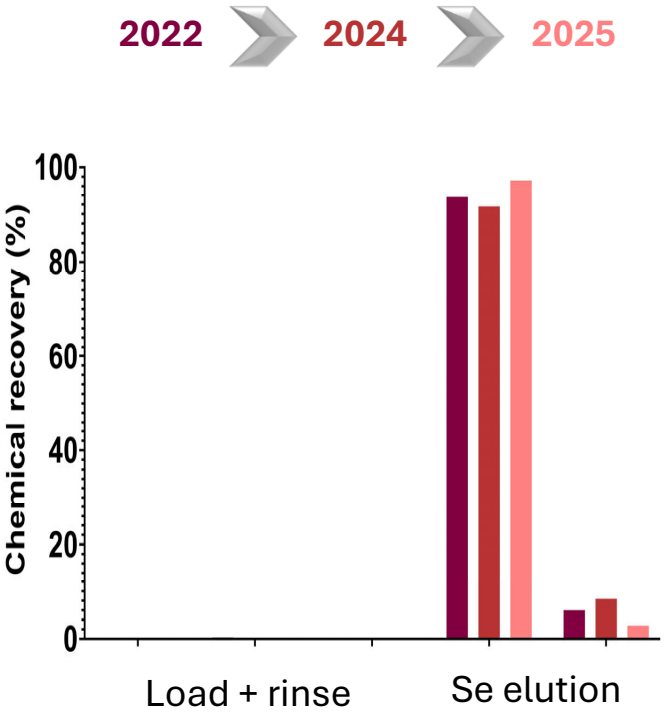
Breakthrough volume

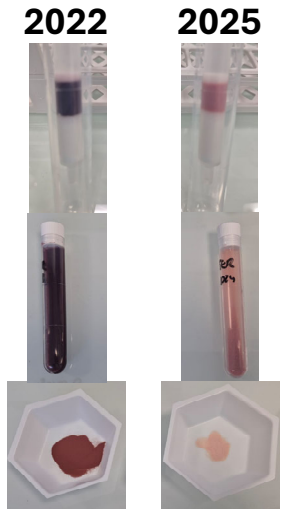


Capacity of SE Resin



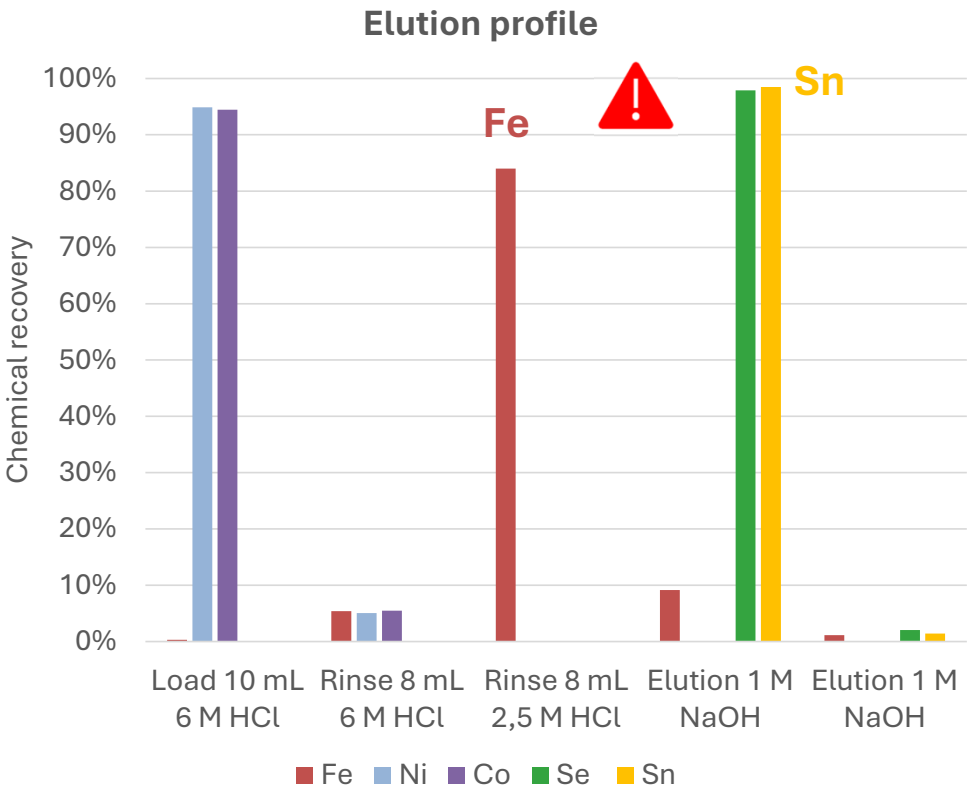
Ageing of the resin



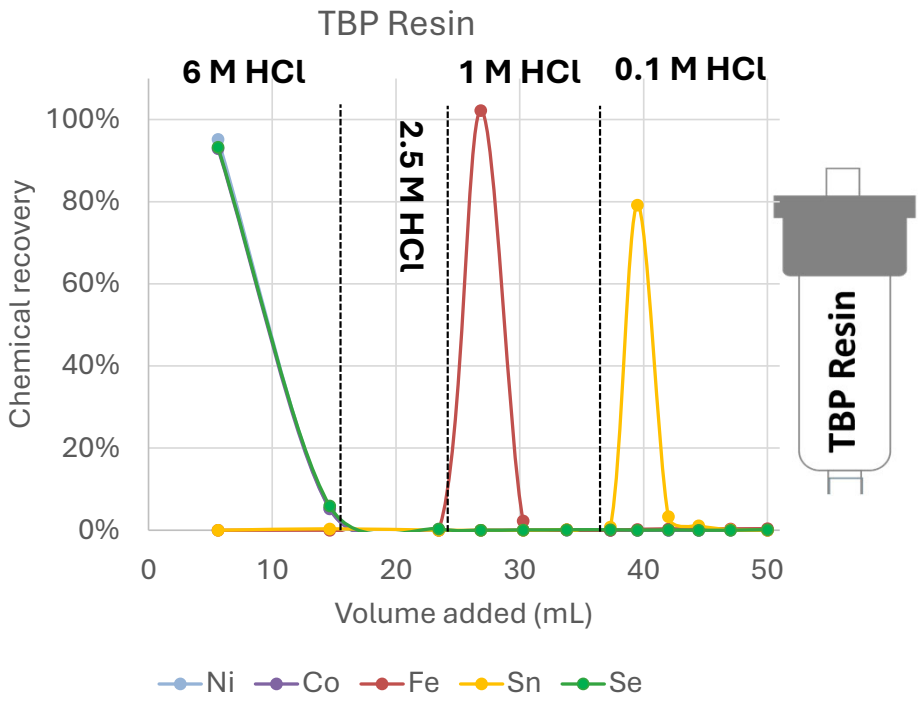


On the determination of ^{79}Se

Se

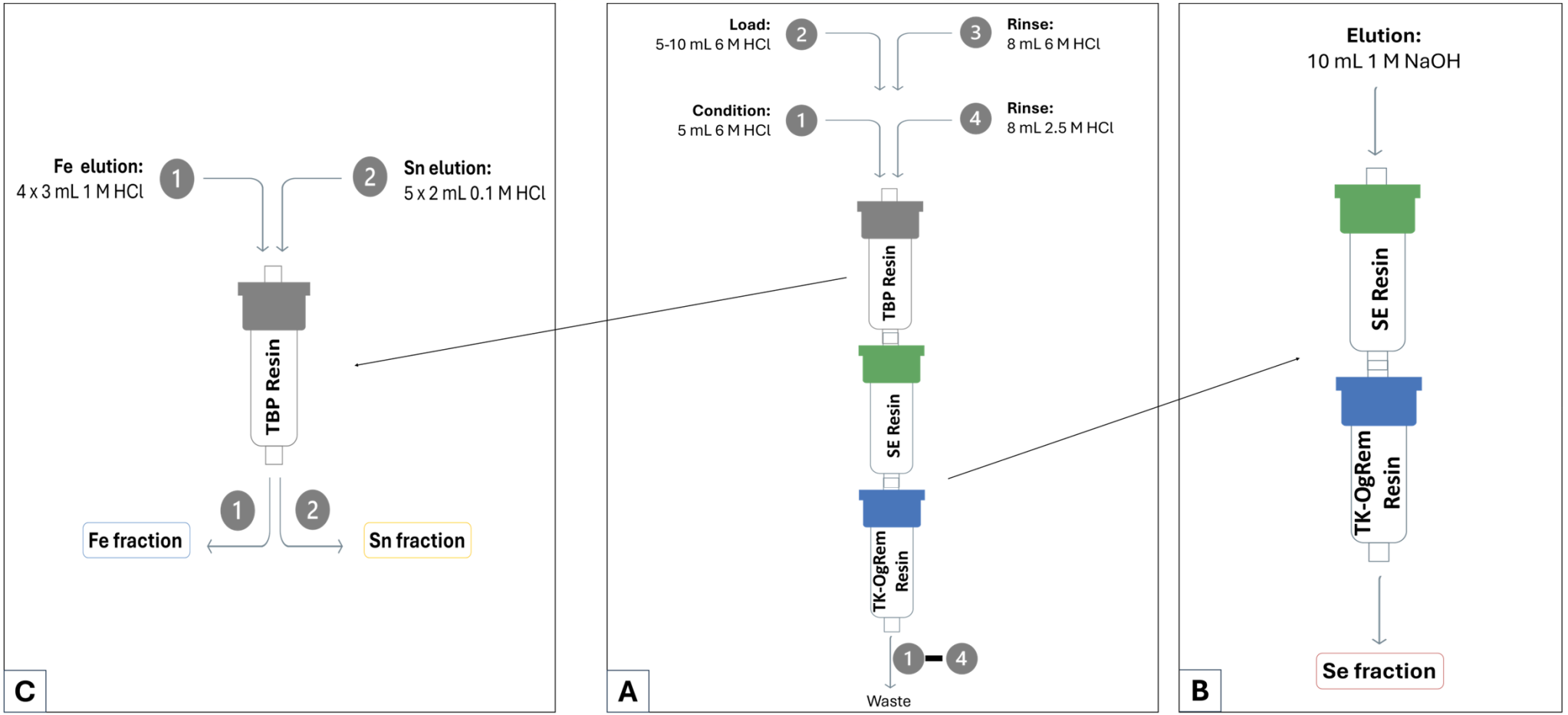


TBP for Sn, Fe removal



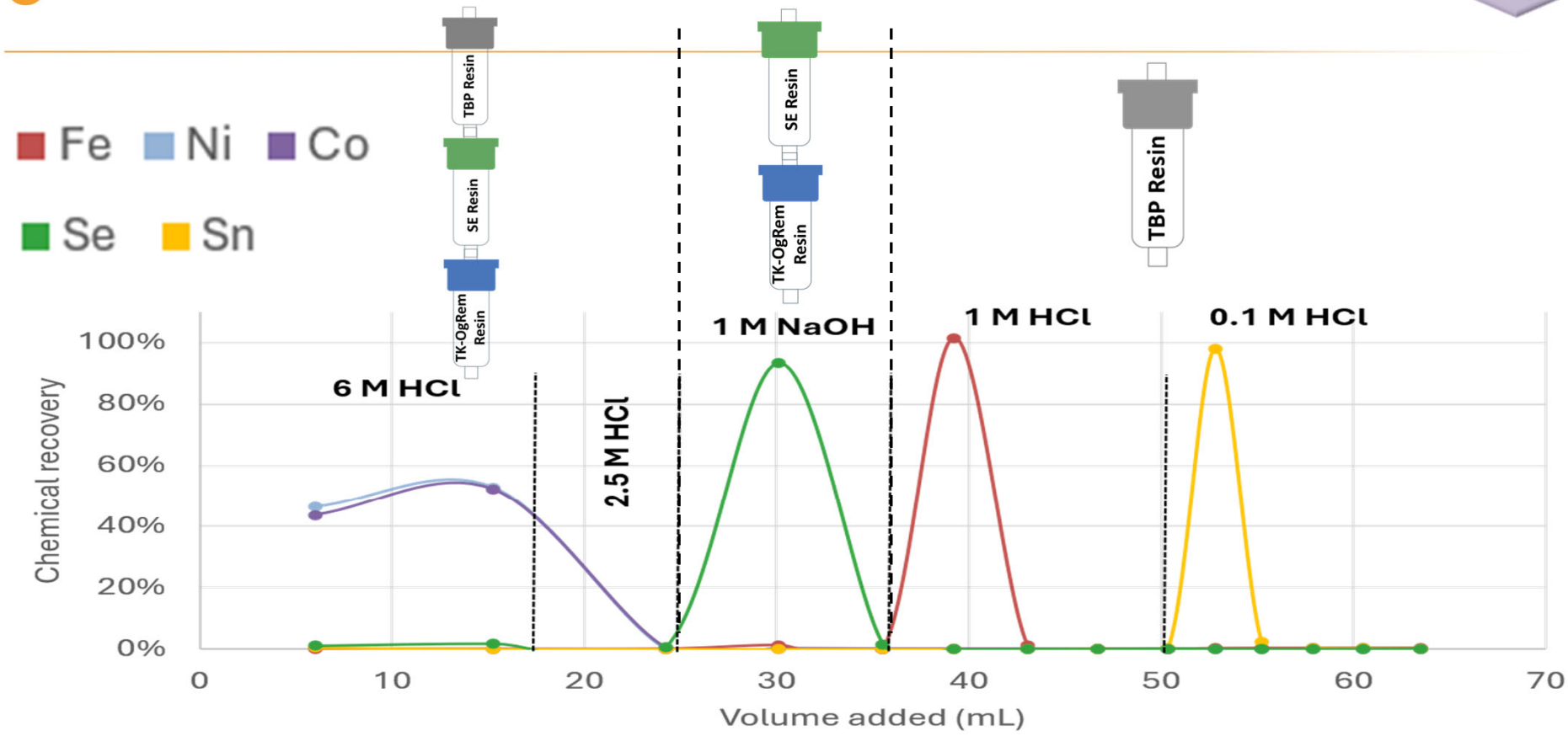
On the determination of ^{79}Se

Se



On the determination of ^{79}Se

Se



Publication submitted to *ACA "Towards Effective Determination of Se-79 using Novel Extraction Chromatography: Selectivity and Stability Investigations"* Dokl et al.

Thank you very much for your attention!

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11-11-2026

