UPDATES ON TK300 ·TK103·TK250

ILLARION DOVHYI, STEFFEN HAPPEL

Joint Technical Workshop

Europeen Users Group Meeting

Portsmouth, 11 September 2026

TRISKEM
Expertise in Separation Chemistry

Cs-selective TK300 resin

OUR **GOALS**, PROBLEMS and SOLUTIONS

- To develop a resin for analysis of Cs isotopes (including DTM ^{135}Cs) in decommissioning/environmental samples
- Possibility an elution of Cs in water/diluted acid
- As a second step in the case of elevated volume of solutions, difficult matrices after AMP-PAN (by γ-spectrometry, low-level ICP-MS spectrometry)

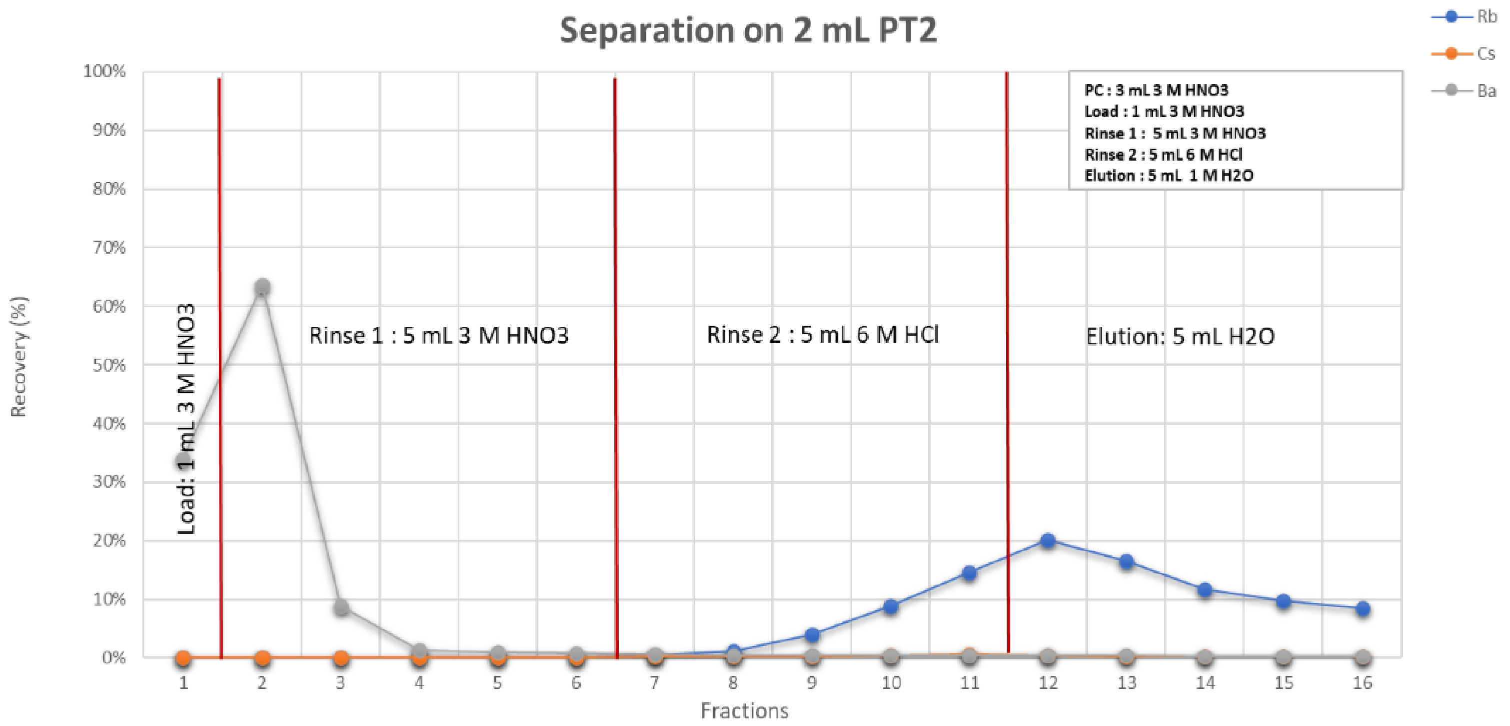
- 12 prototypes were already tested (2023)

- High-capacity prototypes are too expensive

Presented at TKI/Raddec Workshop (18.04.2024) => **scan QR-code** to download the presentation

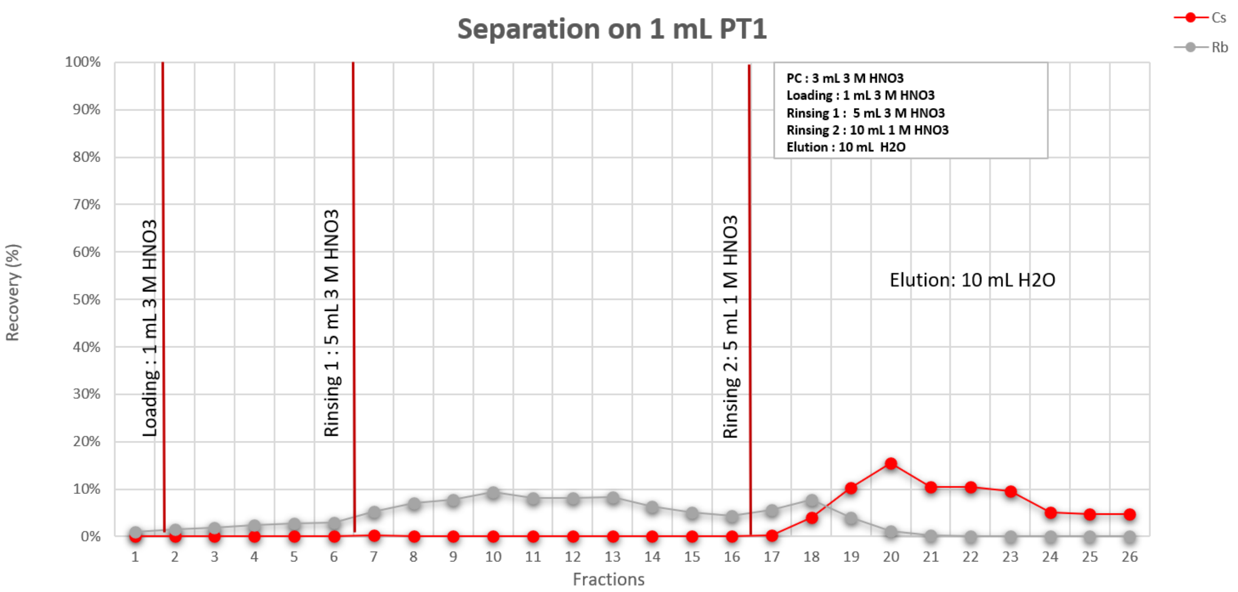
OUR GOALS, **PROBLEMS** and SOLUTIONS

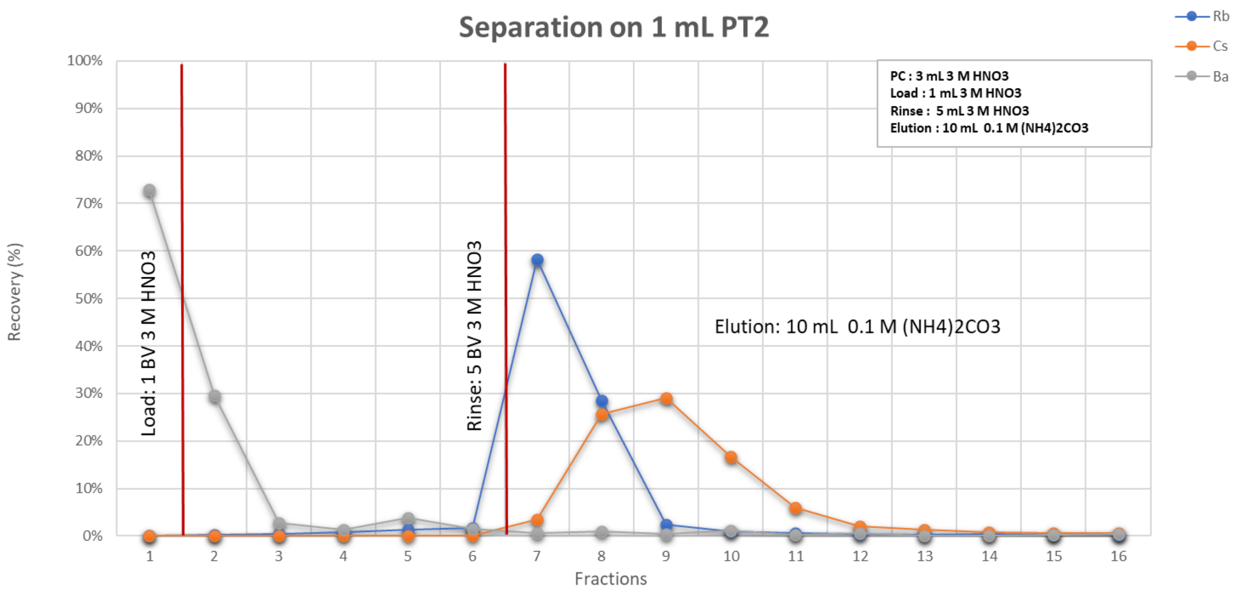
! - no elution of trace amounts of Cs in water/diluted acid because of trace of nitrates (couldn't be removed with an elevated HCl, only elution of Rb in / after 6 M HCl)



OUR GOALS, **PROBLEMS** and SOLUTIONS

! microamounts (0.1 µg) of Cs could be eluted with 0.1 M NH_4OAc, 0.1 M $(NH_4)_2C_2O_4$, 0.1 M $(NH_4)_2CO_3$ (22/08/2023), elevated amounts (100 µg) with water





OUR GOALS, PROBLEMS and **SOLUTIONS**

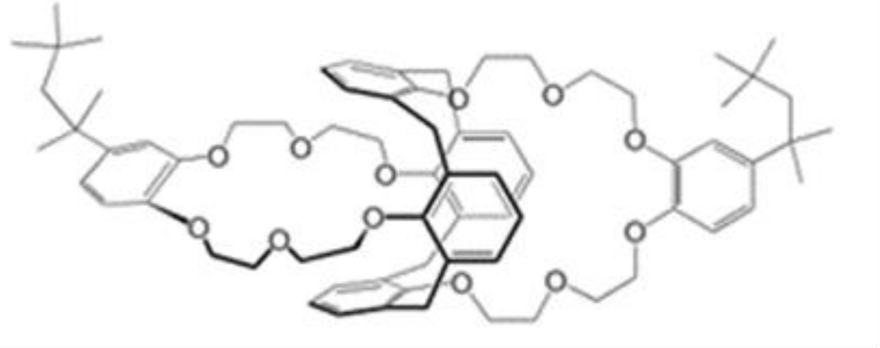
TK300

Calix-arene
► High selectivity

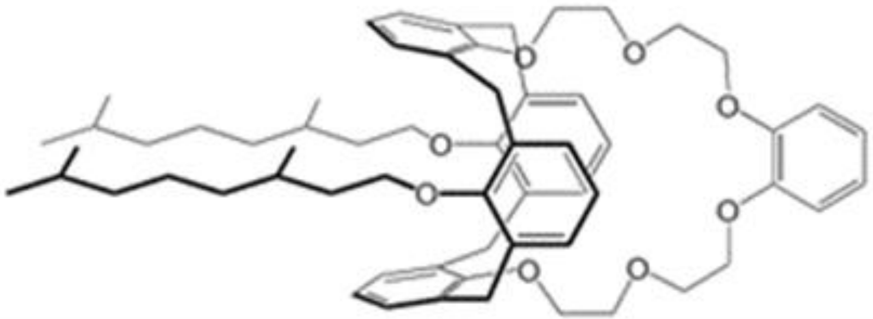
Fluorinated alcohol
►High Cs retention

Low-capacity
► not expensive

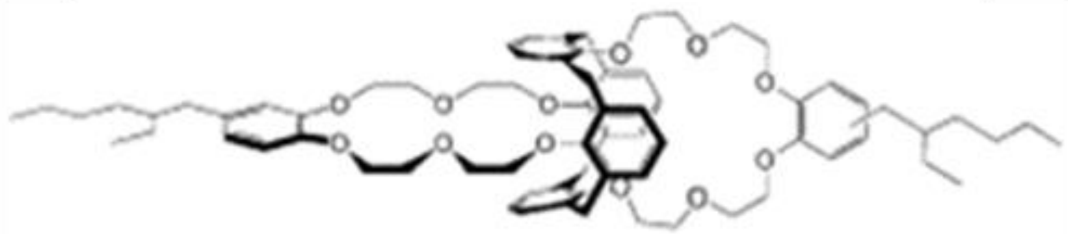
Designed for trace Cs analysis



Calix[4]arene-bis(tert-octylbenzocrown-6, $C_{72}H_{92}O_{12}$ (BOBCalix)

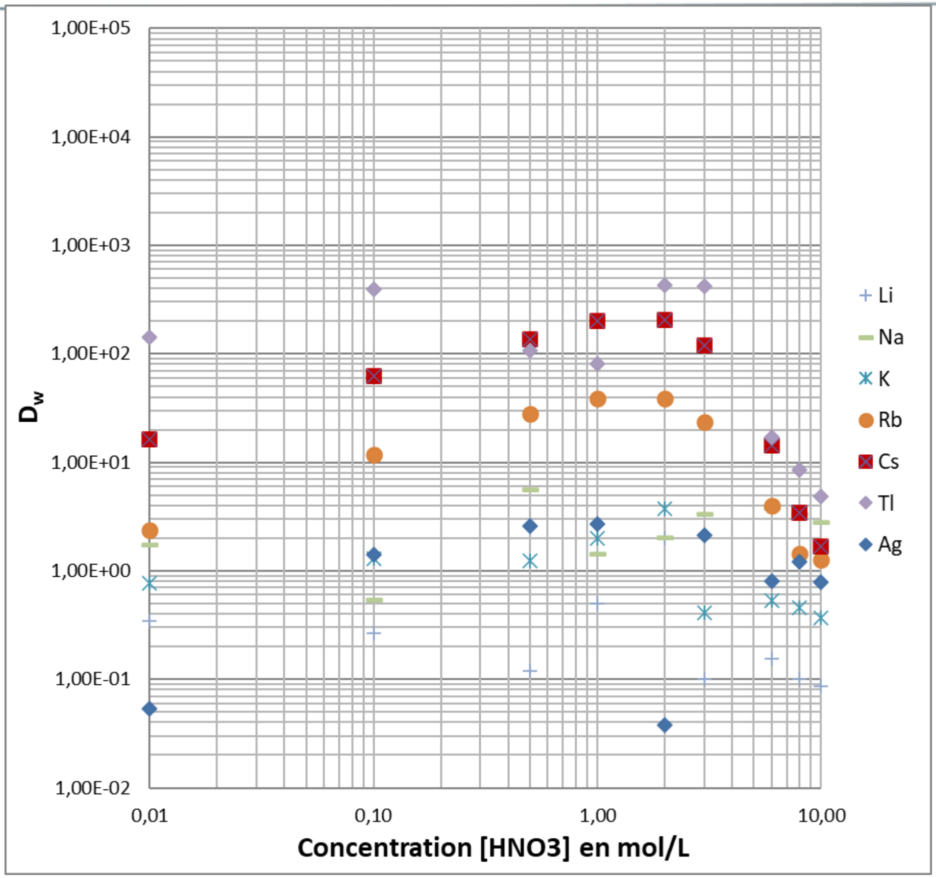


1,3-alt-25,27-Bis(3,7-dimethyloctyl-1-oxy)calix[4]arene-benzocrown-6, $C_{62}H_{82}O_8$ (MAXCalix)



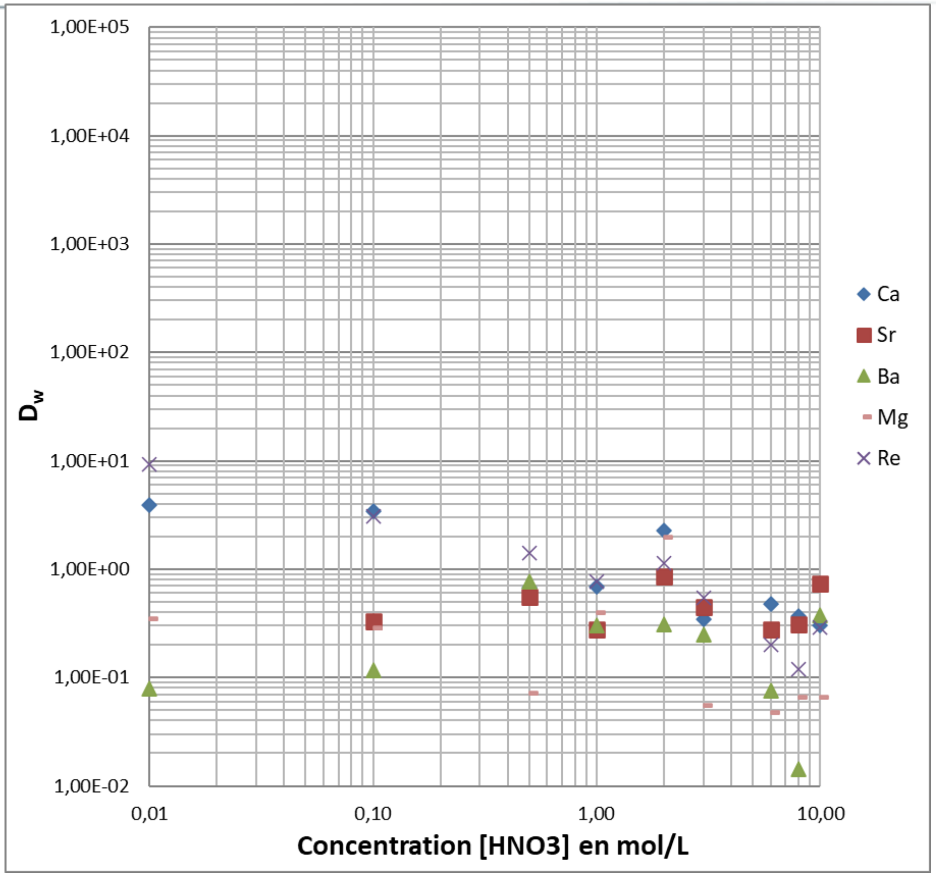
Calix[4]arene-bis[4-(2-ethylhexyl)benzo-crown-6], $C_{72}H_{92}O_{12}$ (BEBHCalix)

Dw STUDIES



Distribution coefficients of selected elements on TK300 Resin in HNO_3

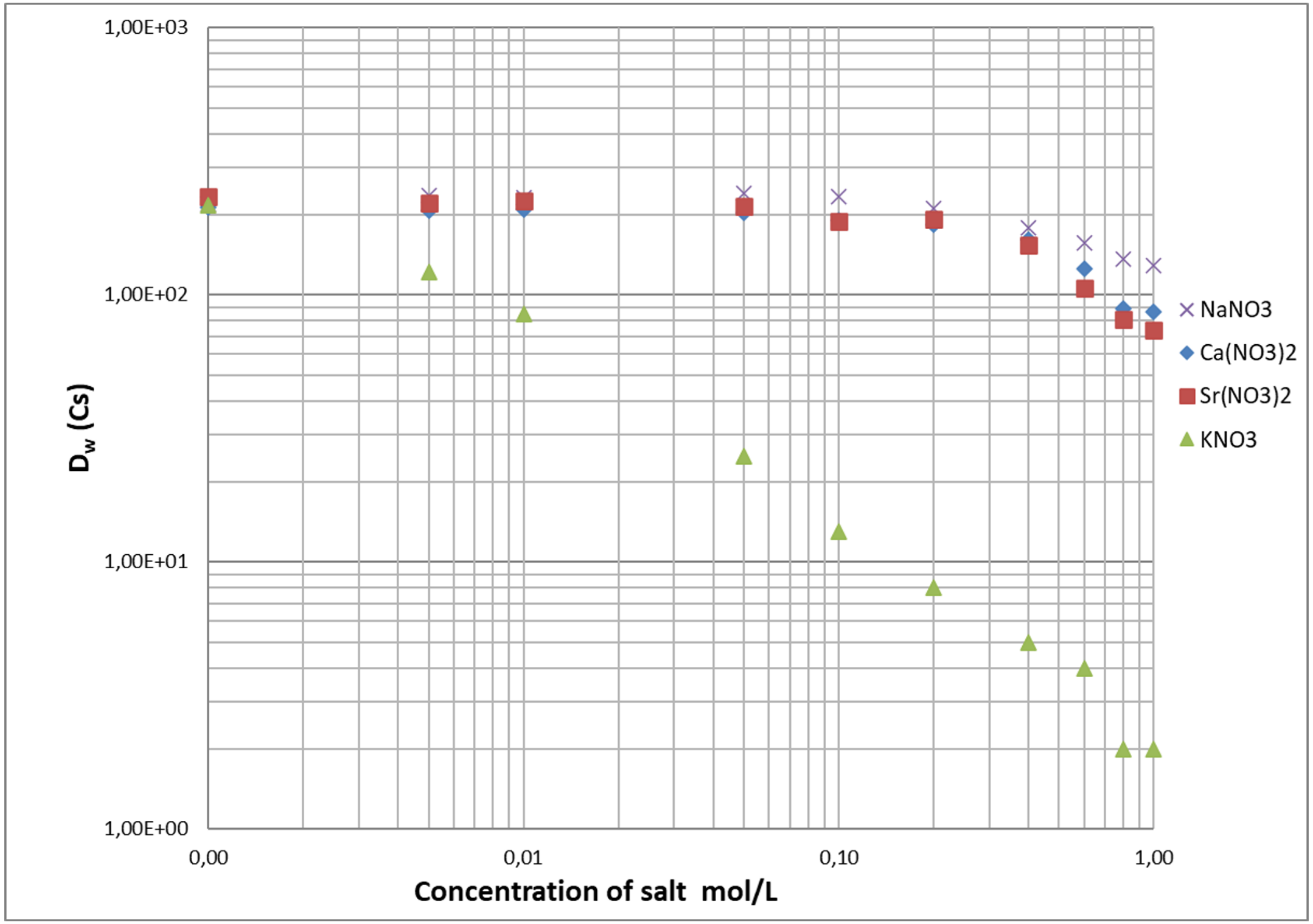
► Rb, Cs and Tl show retention in HNO_3



Distribution coefficients of selected elements on TK300 Resin in HNO_3

► low retention of alkaline earth elements

ELEVATED AMOUNTS OF NA, K, CA, SR

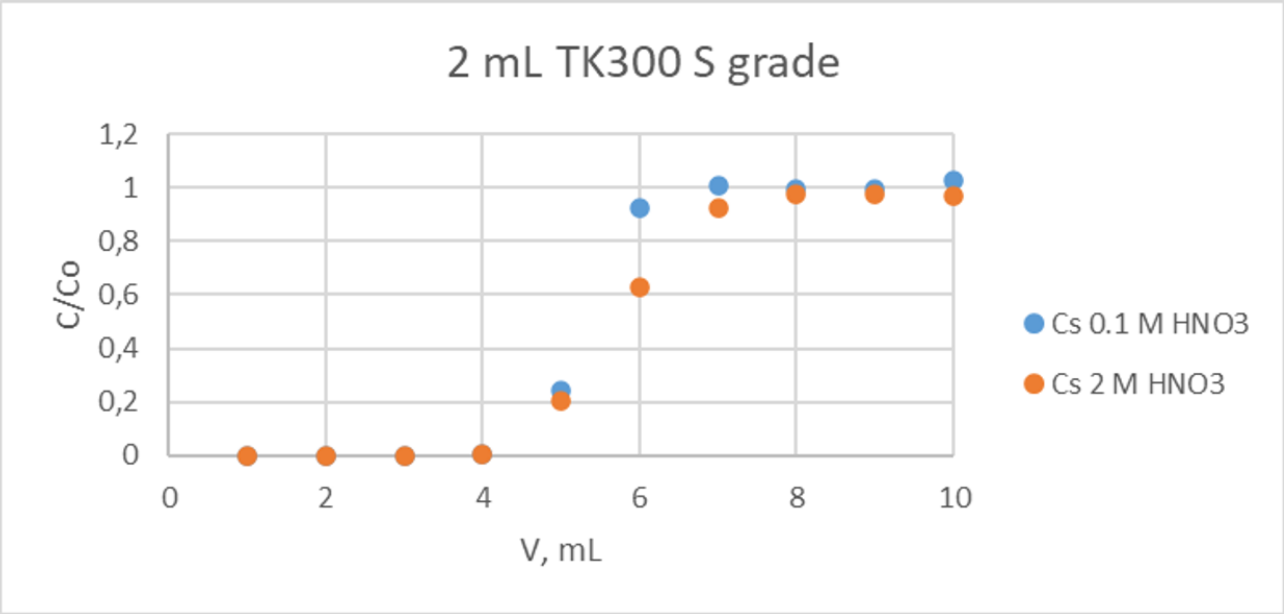


Distribution coefficients of Cs on TK300 Resin in 2 HNO_3 / salt

► high selectivity in the presence of elevated concentration of Na, Ca, Sr

►strong decrease of Dw in the presence of elevated concentration of K

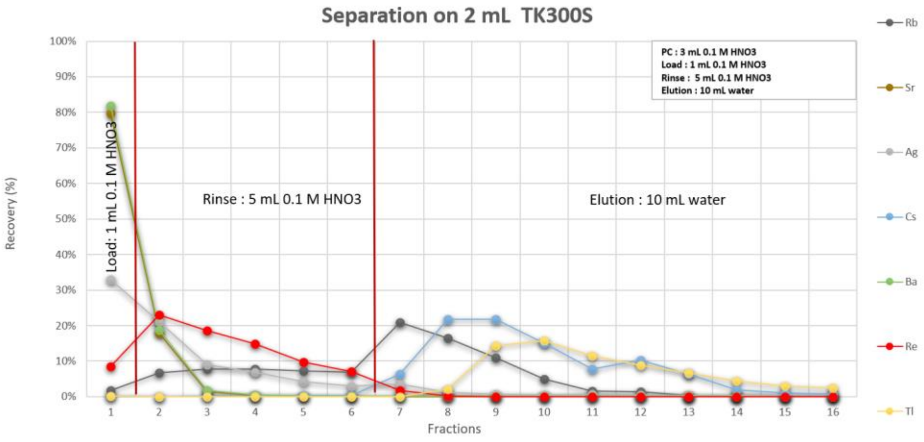
CAPACITY STUDIES

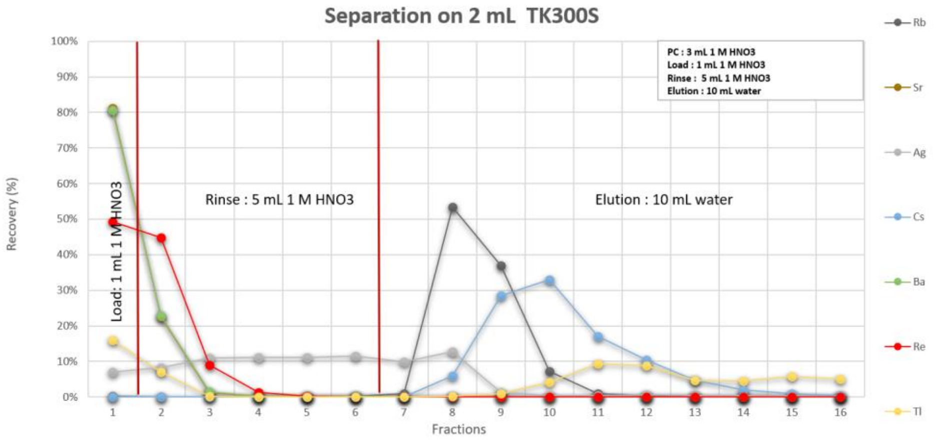


- ►200 ppm solution of Cs in 2 M HNO_3 was used
- ►Breakthrough capacity is close to theoretical for both in 0.1 M and 2 M HNO_3
- ►elevated volume of water is necessary for the elution of Cs from saturated resin

Experiment	Breakthrough capacity, mg Cs /g resin	Total capacity, mg Cs /g resin	Theoretical capacity, mg Cs /g resin	Elution in 15 mL of water, %
0.1 M HNO3	1.2	1.45	1.43	29
2 M HNO3	1.2	1.59	1.43	42

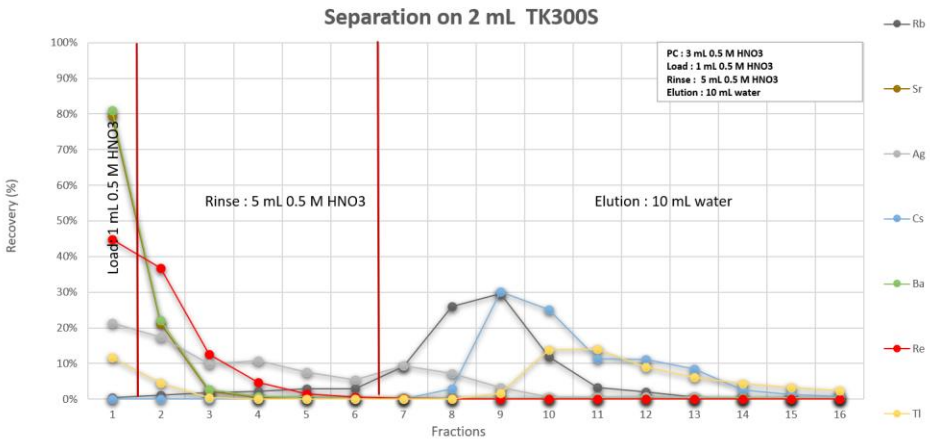
ELUTION STUDIES / TRACE LEVEL

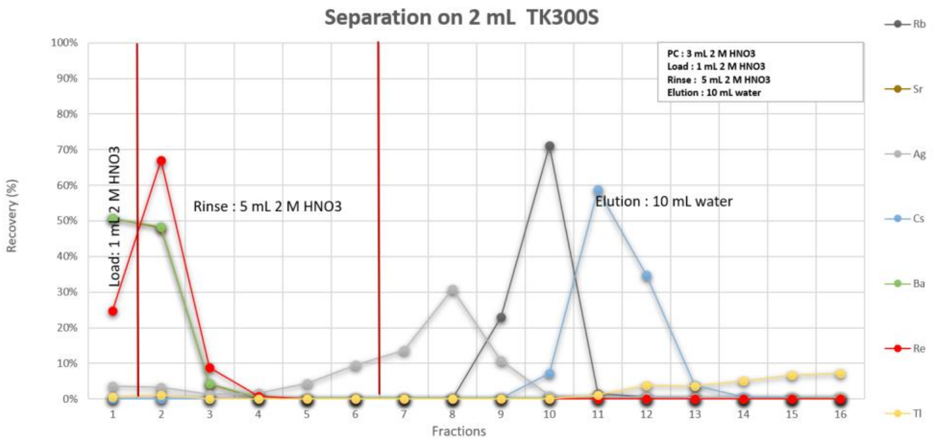




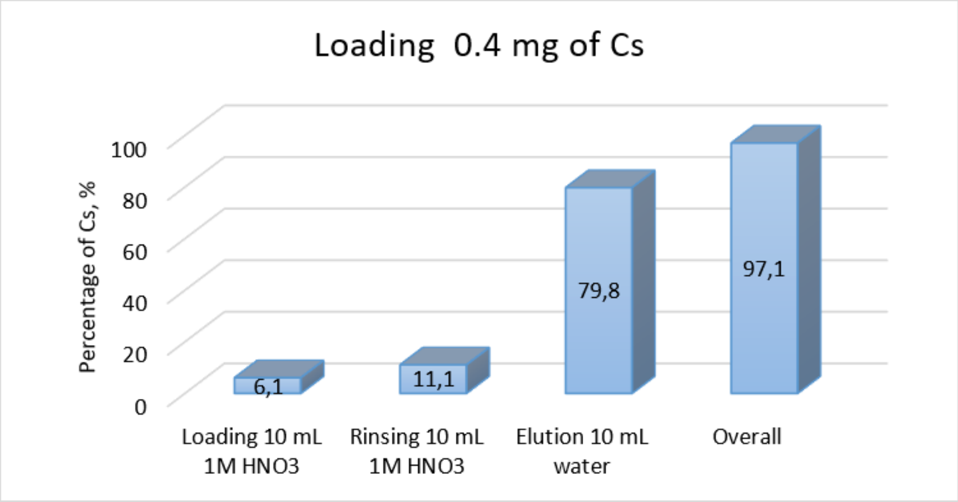
► retention of Cs (0.01-2 M HNO_3), Rb (0.5-2 M HNO_3), Tl, Ag (2 M HNO_3)

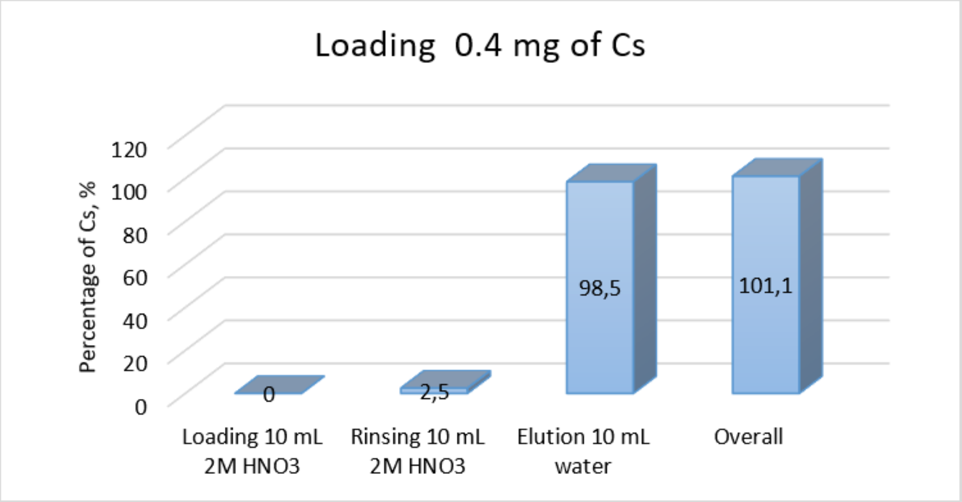
► low retention of Re (Tc) in pH 1-2, 0.5 M HNO_3 is better for loading to separate Tc

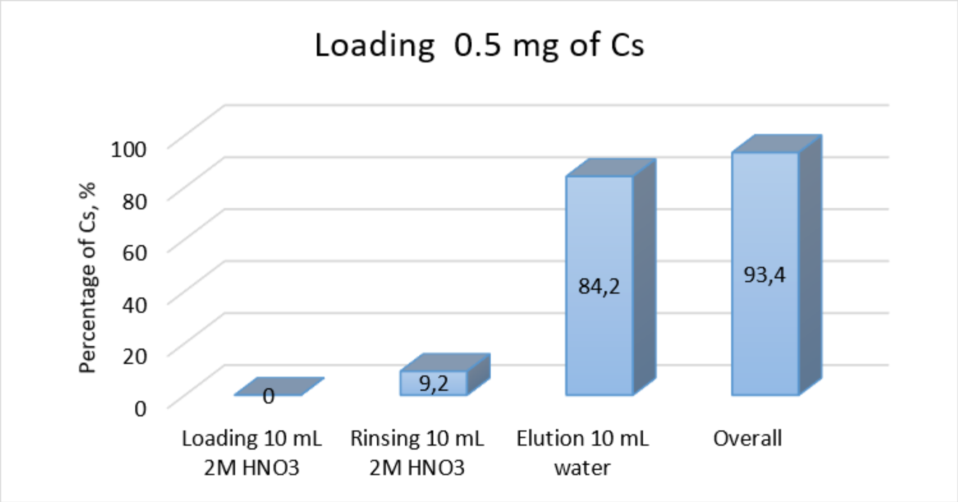




ELUTION STUDIES / ELEVETED AMOUNTS OF CS







- ►Resin is very hydrophobic
- ►A precondition with 20% EtOH can be used to increase wetting of grains and improving of mass transfer
- ►amounts of Cs below 0.5 mg are recommended

A POSSIBLE APPLICATION FOR SEAWATER SAMPLES

Talanta 226 (2021) 122121

Contents lists available at ScienceDirect

Talanta

journal homepage: www.elsevier.com/locate/talanta

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Determination of low-level ^{135}Cs and $^{135}Cs/^{137}Cs$ atomic ratios in large volume of seawater by chemical separation coupled with triple-quadrupole inductively coupled plasma mass spectrometry measurement for its oceanographic applications

Liuchao Zhu, Xiaolin Hou*, Jixin Qiao

Technical University of Denmark, Department of Environmental Engineering, Risø Campus, Roskilde, DK-4000, Denmark

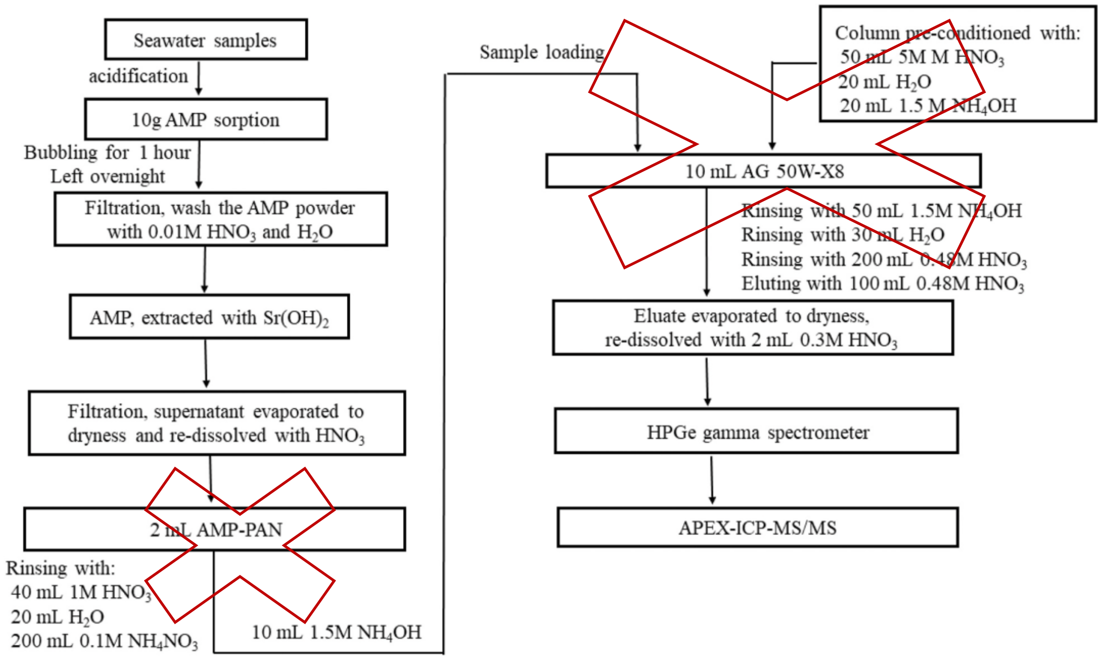

Fig. 3. Chemical procedure for separation of cesium form large volume seawater sample.

CONCLUSIONS

- A Cs-selective resin was developed
- High selectivity coefficient Cs/Sr, Cs/Ba,
- Can be used for separation of Cs in elevated HNO_3 solutions
- Retention of Cs is enough high in presence of elevated amounts of Na, Ca, Sr

TK103 resin

TRISKEM

Expertise in Separation Chemistry

WHY DO WE NEED TK103?

Journal of Chromatography A 1778 (2026) 467004

Contents lists available at ScienceDirect

Journal of Chromatography A

journal homepage: www.elsevier.com/locate/chroma

Check for updates

Evaluation of chromatographic resins for high efficacy separation of radium from chemical analogues

Maelle Coupannec [a,*], Kelly N. Kmak [b], John D. Despotopulos [b], Ralf Sudowe [a]

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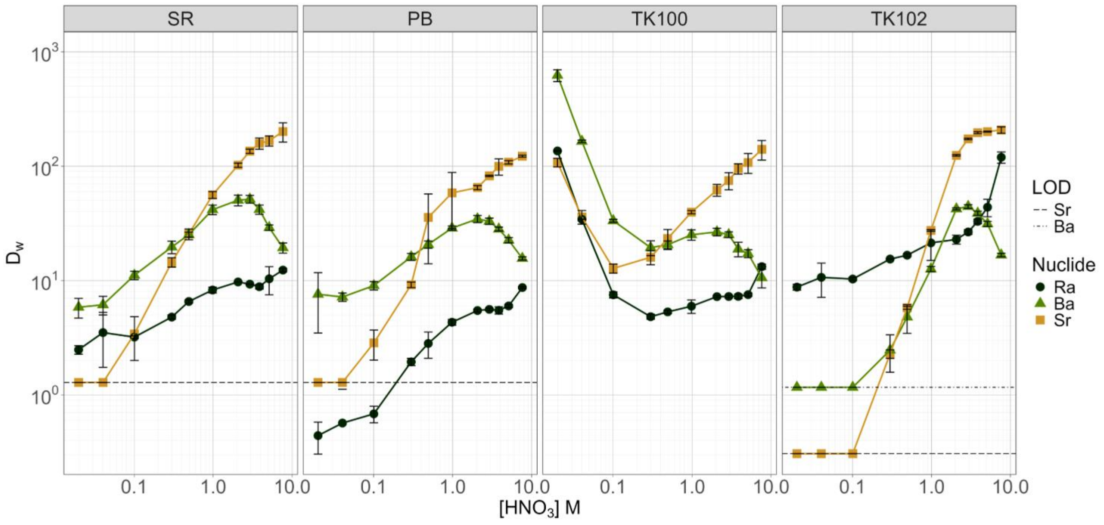

Fig. 2. Weight distribution ratio of Ra, Sr, and Ba on SR, BP, TK100, and TK102 extraction chromatographic resins. Error bars represent 2 standard deviations of the replicate samples.

- D_w of Ra are low in elevated (1-3 M) HNO_3

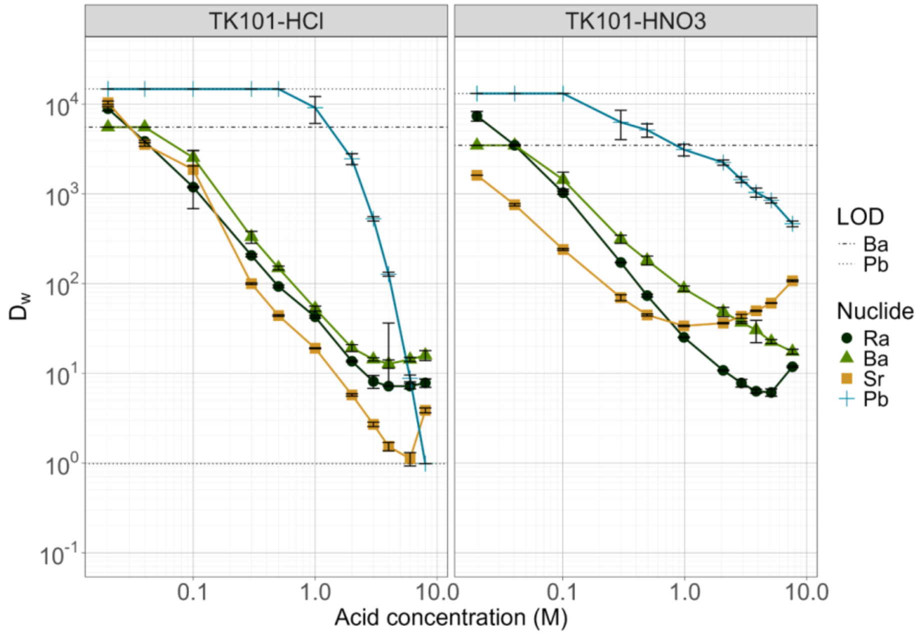

Fig. 3. Weight distribution ratio of Ra, Sr, Ba, and Pb on TK101 extraction chromatographic resin. Error bars represent 2 standard deviations of the replicate samples.

EXISTING PRODUCTS ANALIG RA-01

Journal of Environmental Radioactivity 202 (2019) 1–7

Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

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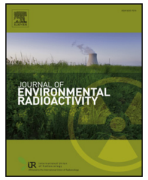

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A new rapid protocol for ^{226}Ra separation and preconcentration in natural water samples using molecular recognition technology for ICP-MS analysis

Check for updates

M. Verlinde[a], J. Gorny[a], G. Montavon[b], S. Khalfallah[b], B. Boulet[c], C. Augeray[d], D. Larivière[e], C. Dalencourt[e], A. Gourgiotis[a,*]

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[b] SUBATECH, UMR CNRS, 6457 IMT Atlantique/IN2P3/Université de Nantes, 4 rue Alfred Kastler, BP 20722, 44307, Nantes Cedex 3, France
[c] Institut de Radioprotection et de Sûreté Nucléaire (IRSN), PSE-ENV/SAME/LMRE, Bat 501 Bois des Rames, 91400, Orsay, France
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[e] Laboratoire de radioécologie, Département de chimie, Université de Laval, 1045 Avenue de la médecine, G1V 0A6, Québec, Canada

	Existing resin	TK103 concept
Extractant	Non described macrocycle	4,4′(5′)-di-tert-butylcyclohexano-18-crown-6
Production	Difficult / grafed	Impregnation
Breakthrough capacity	6-10 mg Ba / g resin	6-10 mg Ba / g resin
Industrial grade	Limitation	Possible
Cost	About 2000 Euro / 10 g	Target 300-400 Euro / 10 g

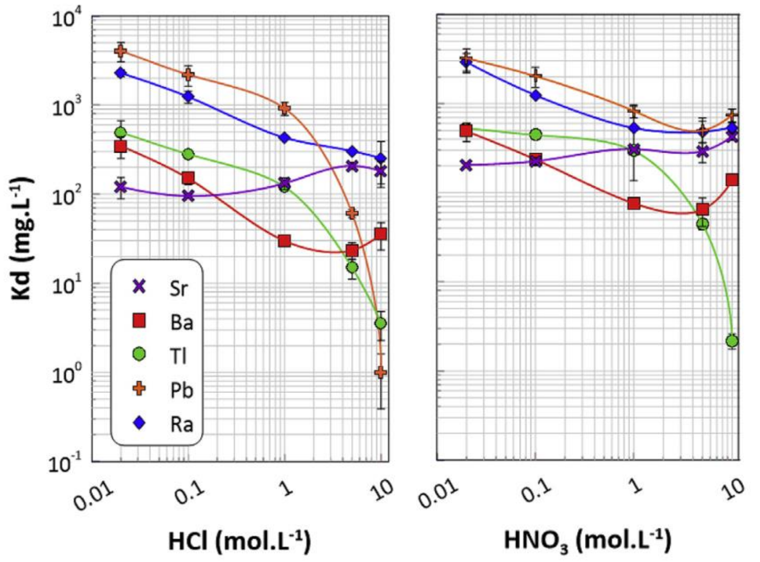


Fig. 4. Distribution coefficients K_d (mg.L^{-1}) of different elements in Analig® Ra-01 resin for HNO_3 and HCl medium (no retention for alkali metals, transition metals, lanthanides and actinides).

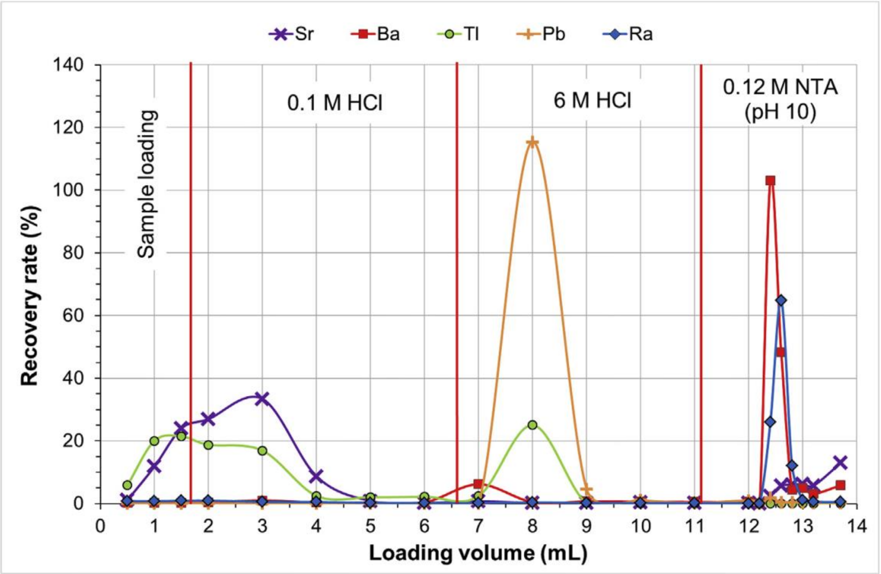
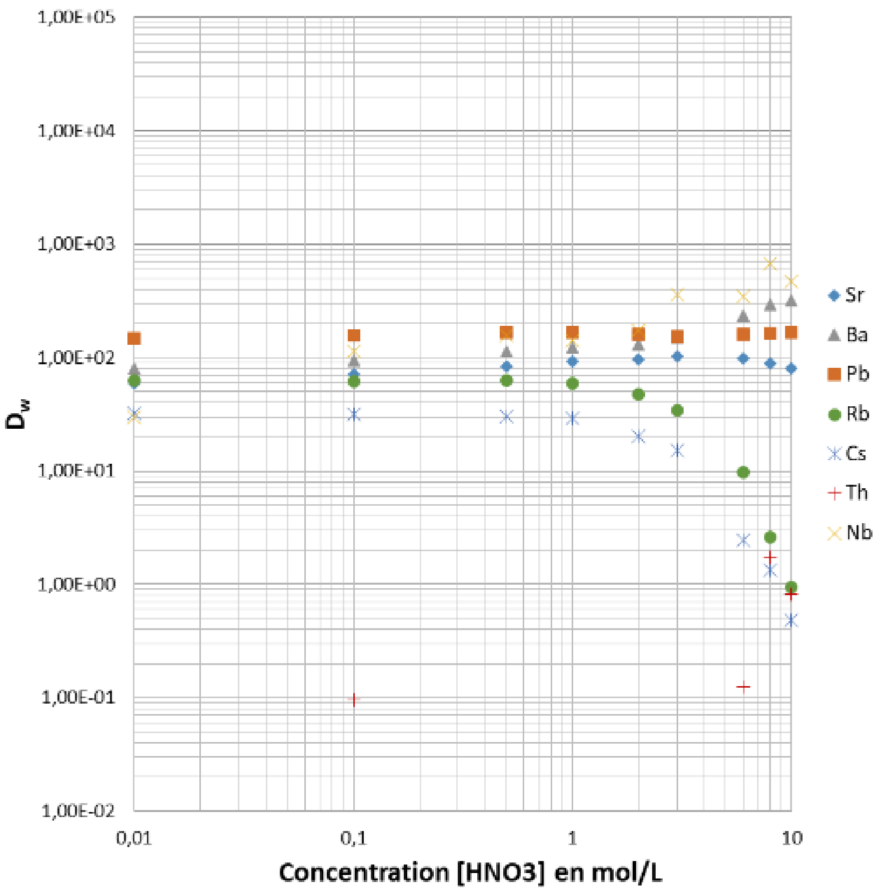
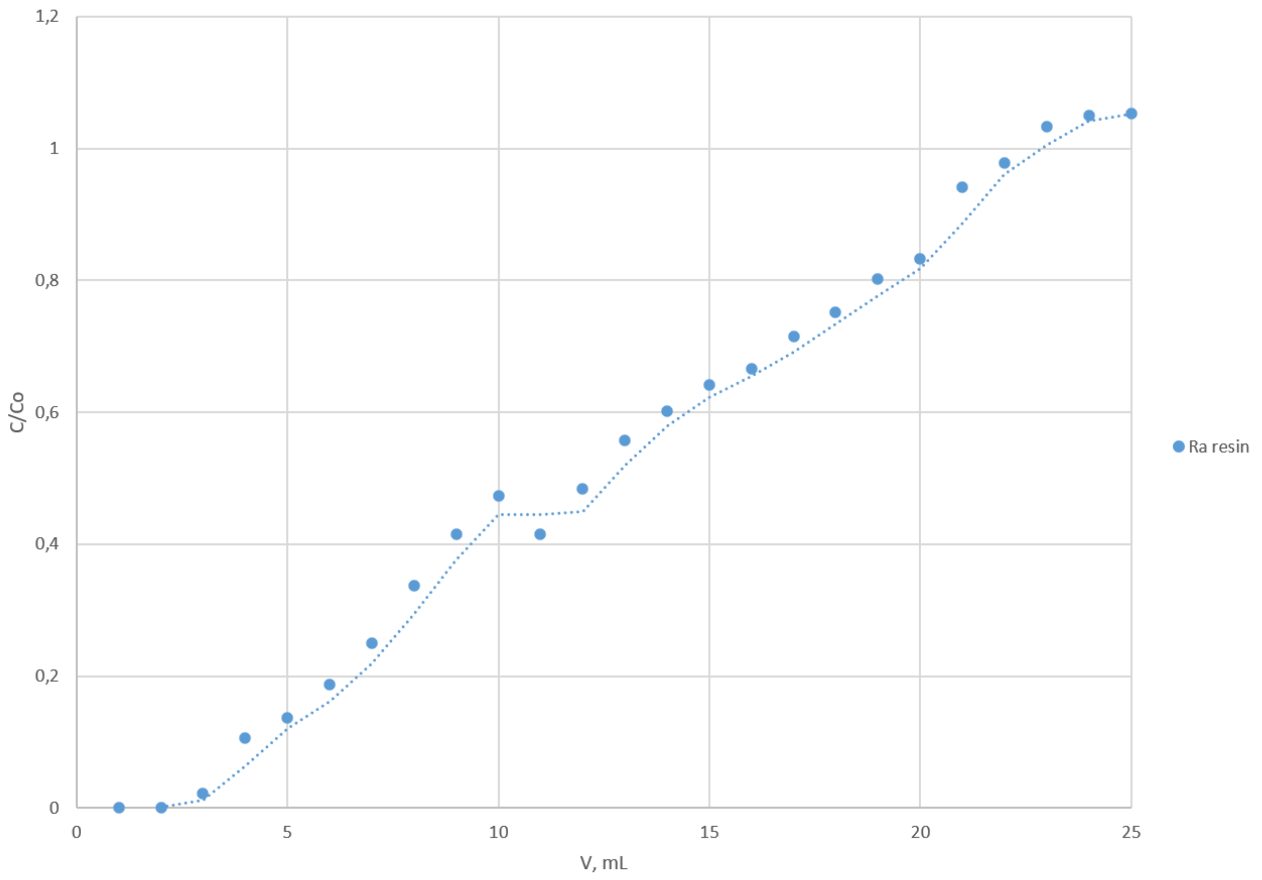


Fig. 5. Elution profiles for the elements (no retention for alkali metals, transition metals, lanthanides and actinides).

EXSISTING PRODUCTS RA RESIN (EMPORE)





Resin	Breakthrough capacity, mg Ba · g-1	Full capacity, mg Ba · g-1	Theoretical capacity, mg · g-1	Desorption wit M EDTA-Na, %
Ra resin	6.3	26.6	Unknown	28.4

OUR SOLUTIONS

TK103 prototypes - the high-capacity resins based on

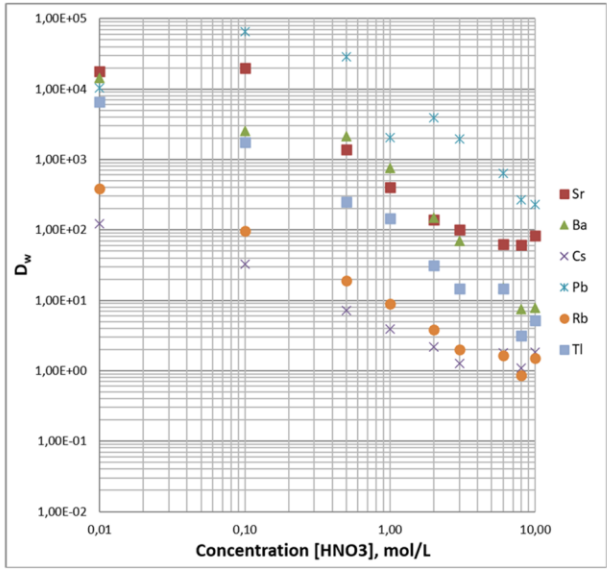
► common crown ether 4,4′(5′)-di-tert-butylcyclohexano-18-crown-6

► a fluorinated alcohol or another non-fluorine diluent

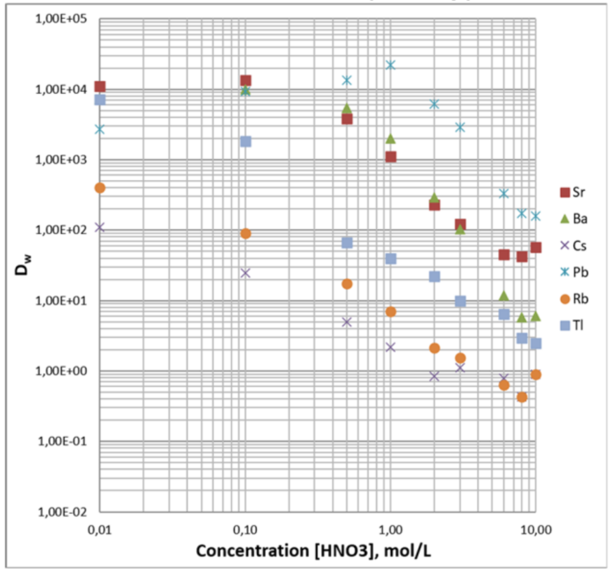
► a strong cation exchange extractant

D_W STUDIES HNO_3

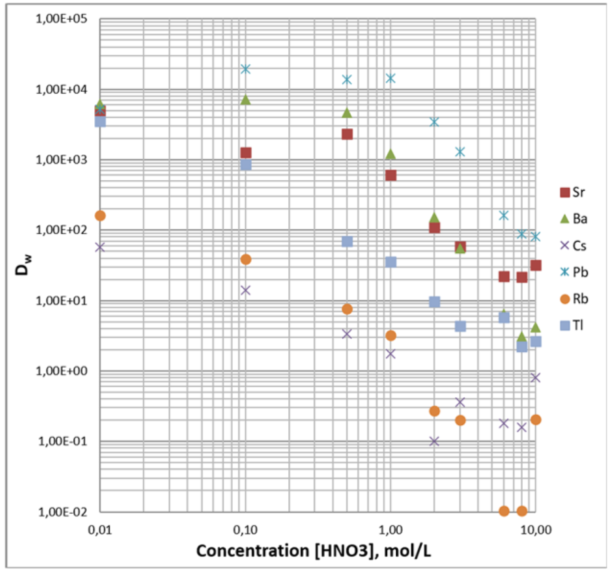
Fluorinated alcohol prototypes



PT52

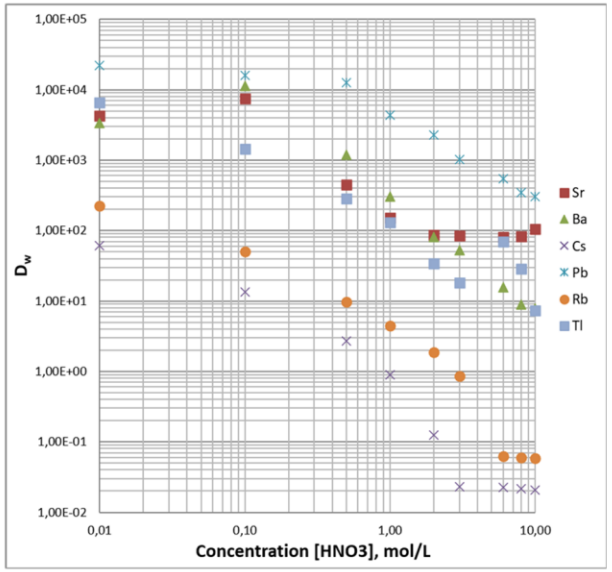


PT53



PT54

Fluorine-free prototypes



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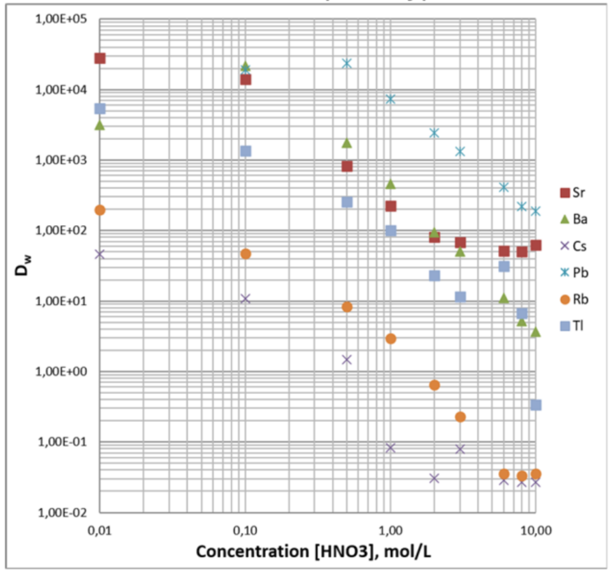

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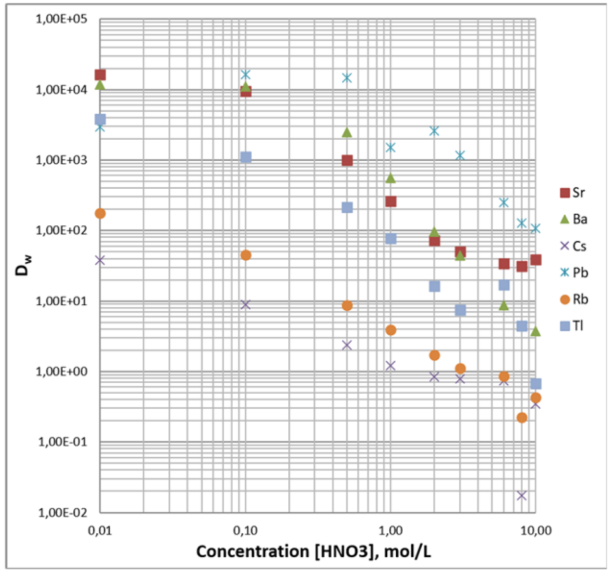
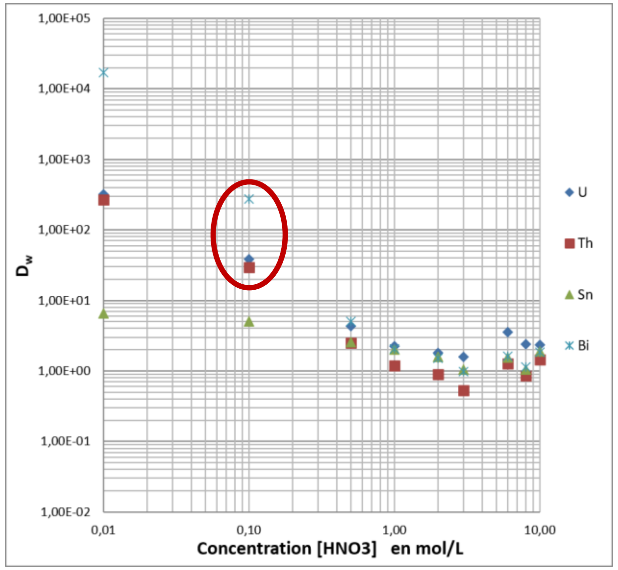


PT57

D_W STUDIES HNO_3

Fluorinated alcohol prototypes



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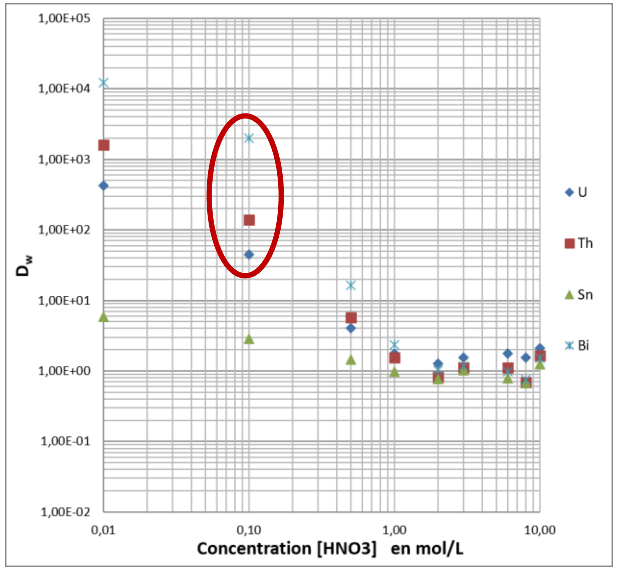

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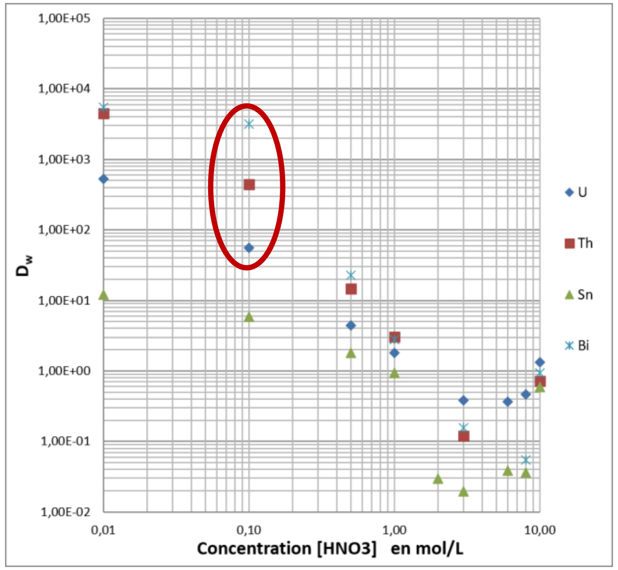
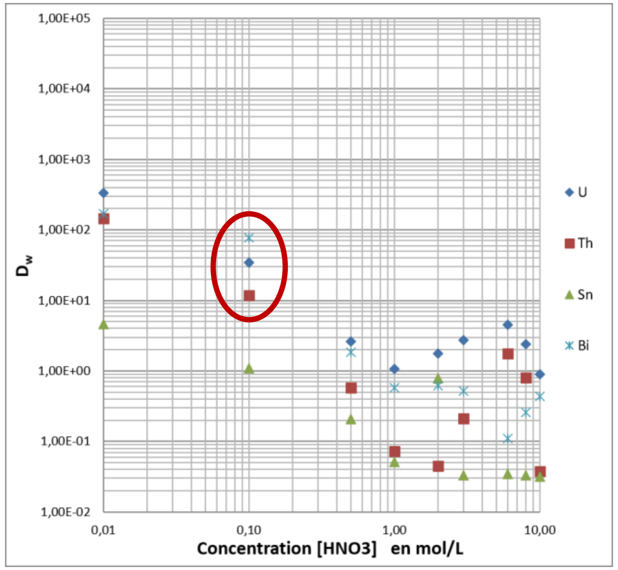


PT54

Fluorine-free prototypes



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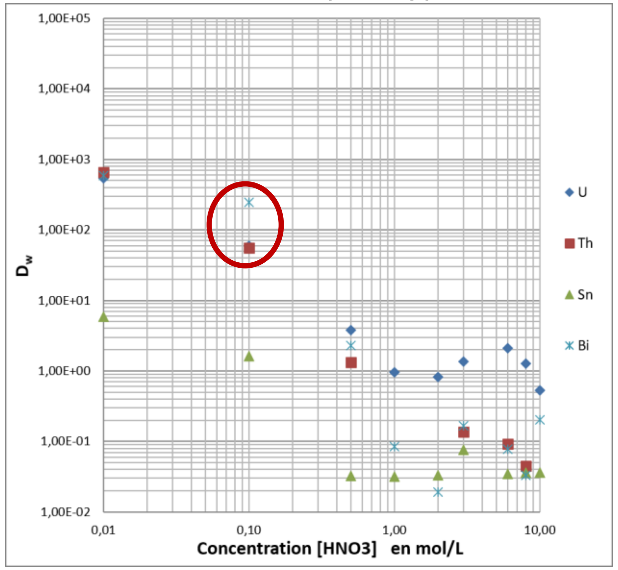

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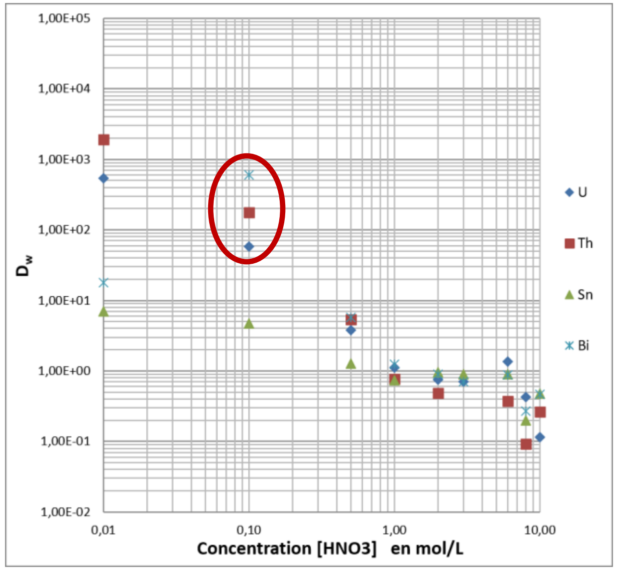
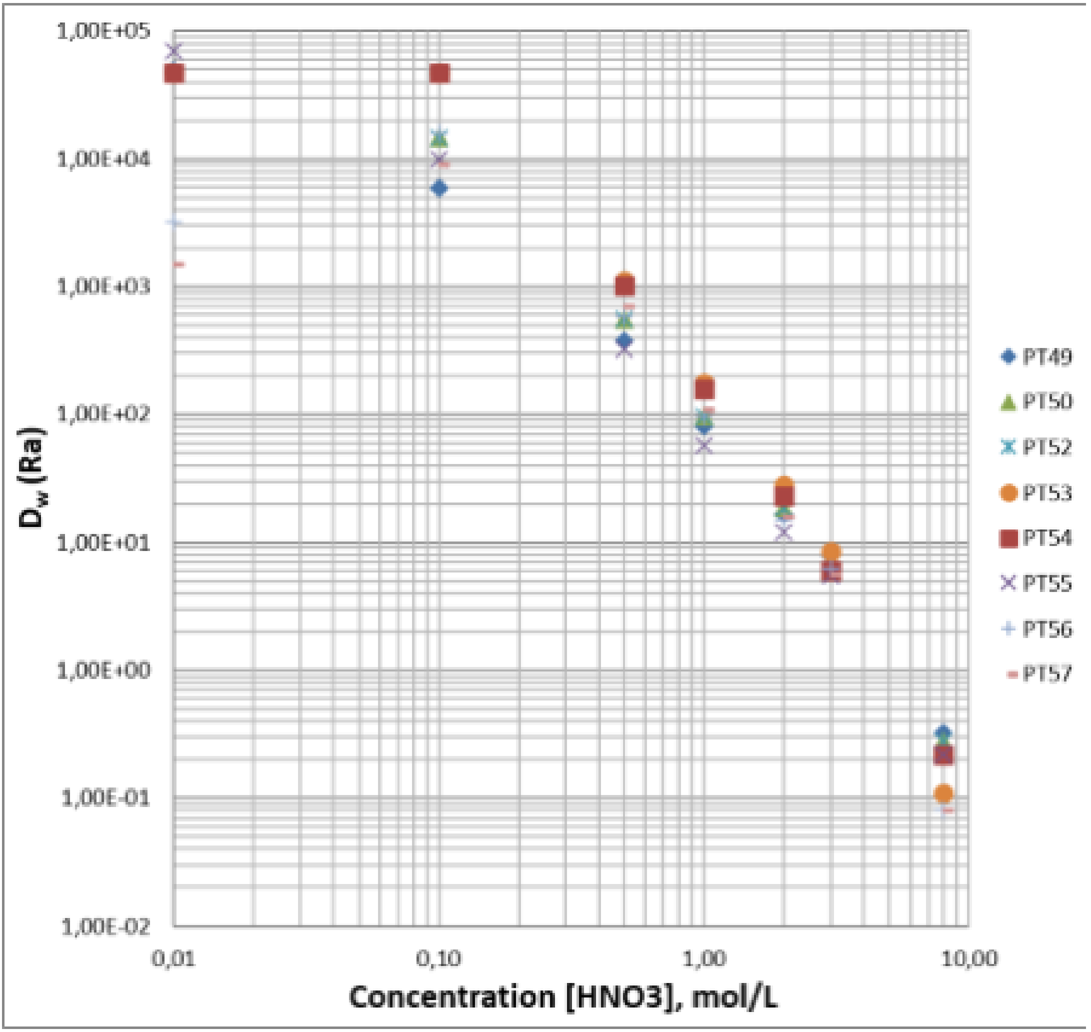


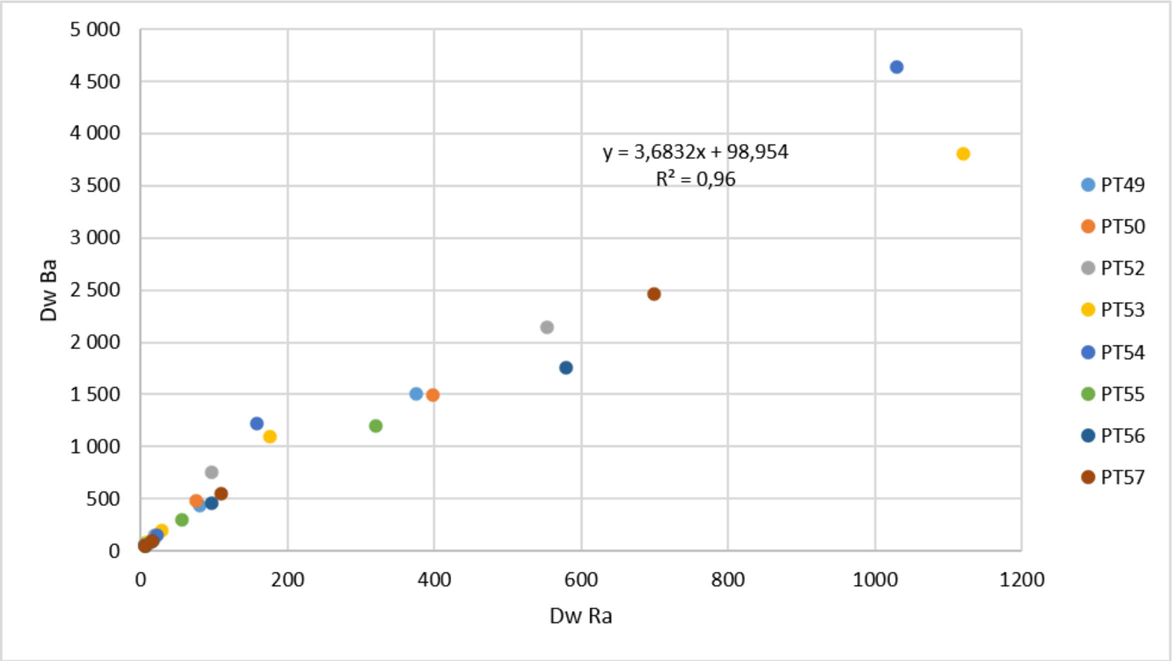
PT57

BETA-TESTING WITH RA by Nora Vajda group



- ► Significant retention ($D_w > 10^4$) of Ra was experienced in case of all resins in 0.01M HNO_3 solutions.
- ► A moderate retention of Ra on all resins (D_w about 100) was observed even in 1M HNO_3.
- ► At higher HNO_3 concentrations (> 1M) the retention of Ra is reduced and at 8M HNO_3 it becomes neglectable.
- ► The presence of stable Ba in concentrations below 10% of the expected resin capacity in 0.1M HNO_3 solution slightly reduces the retention of Ra on all three resins.

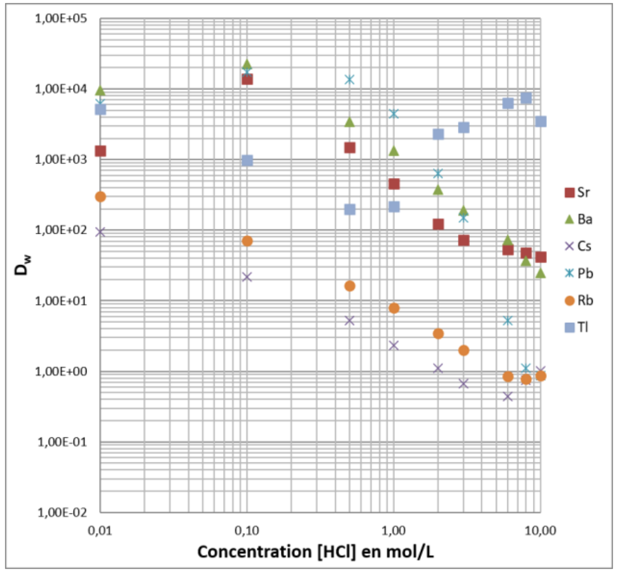
BETA-TESTING WITH RA by Nora Vajda group



► There is a good correlation between D_w (Ba) and D_w (Ra) for PT49-57 in 0.5-3 M HNO_3, without extremely high (0.01-0.1 M HNO_3) and low (8 M HNO_3) values

D_W STUDIES HCl

Fluorinated alcohol prototypes



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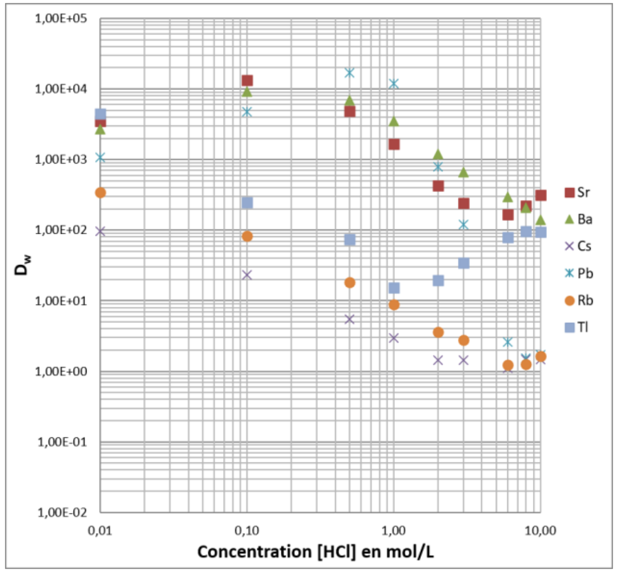
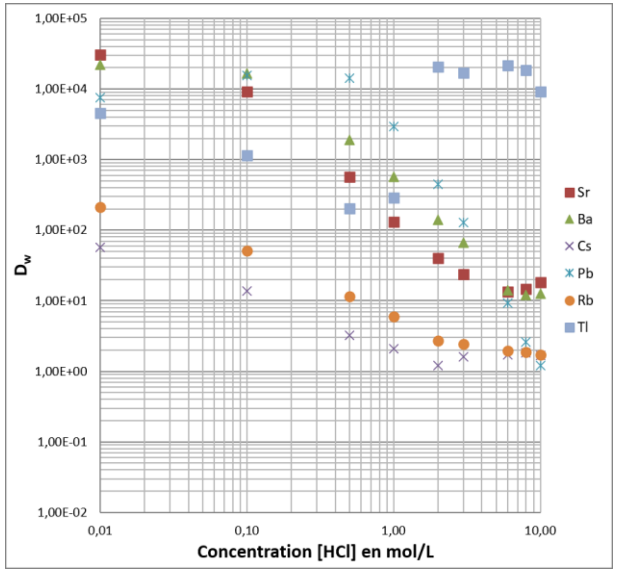


PT53

- ▶Retention of Ba is higher in 6-10 M HCl than in 6-10 M HNO_3
- ▶Retention of Pb is lower in 6-10 M HCl than in 6-10 M HNO_3

PT54

Fluorine-free prototypes



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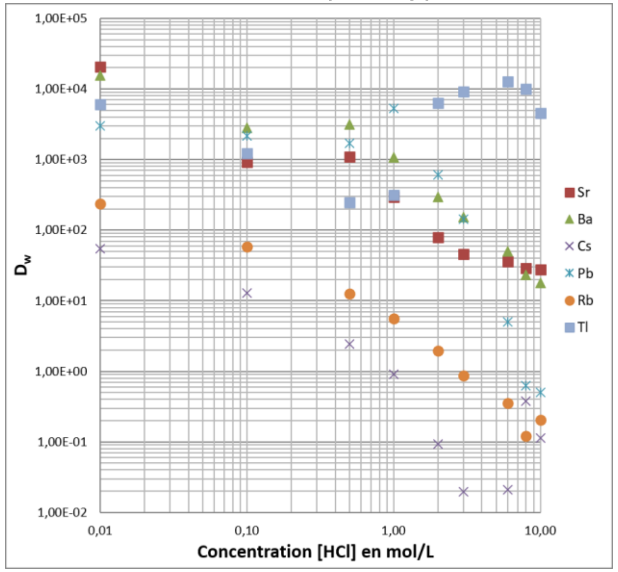

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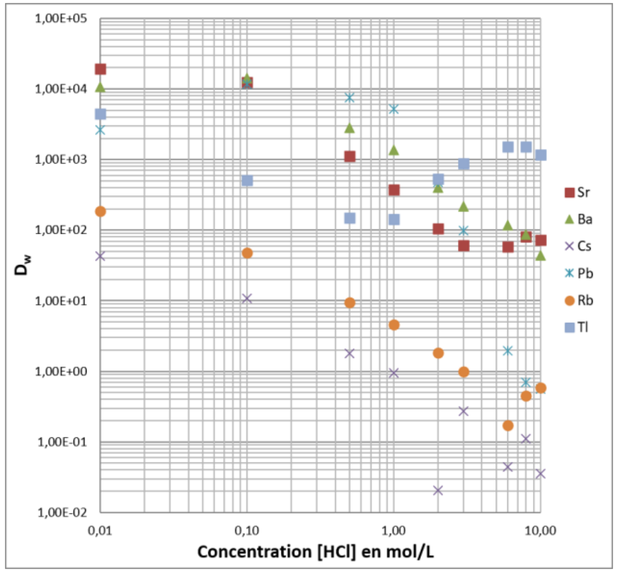
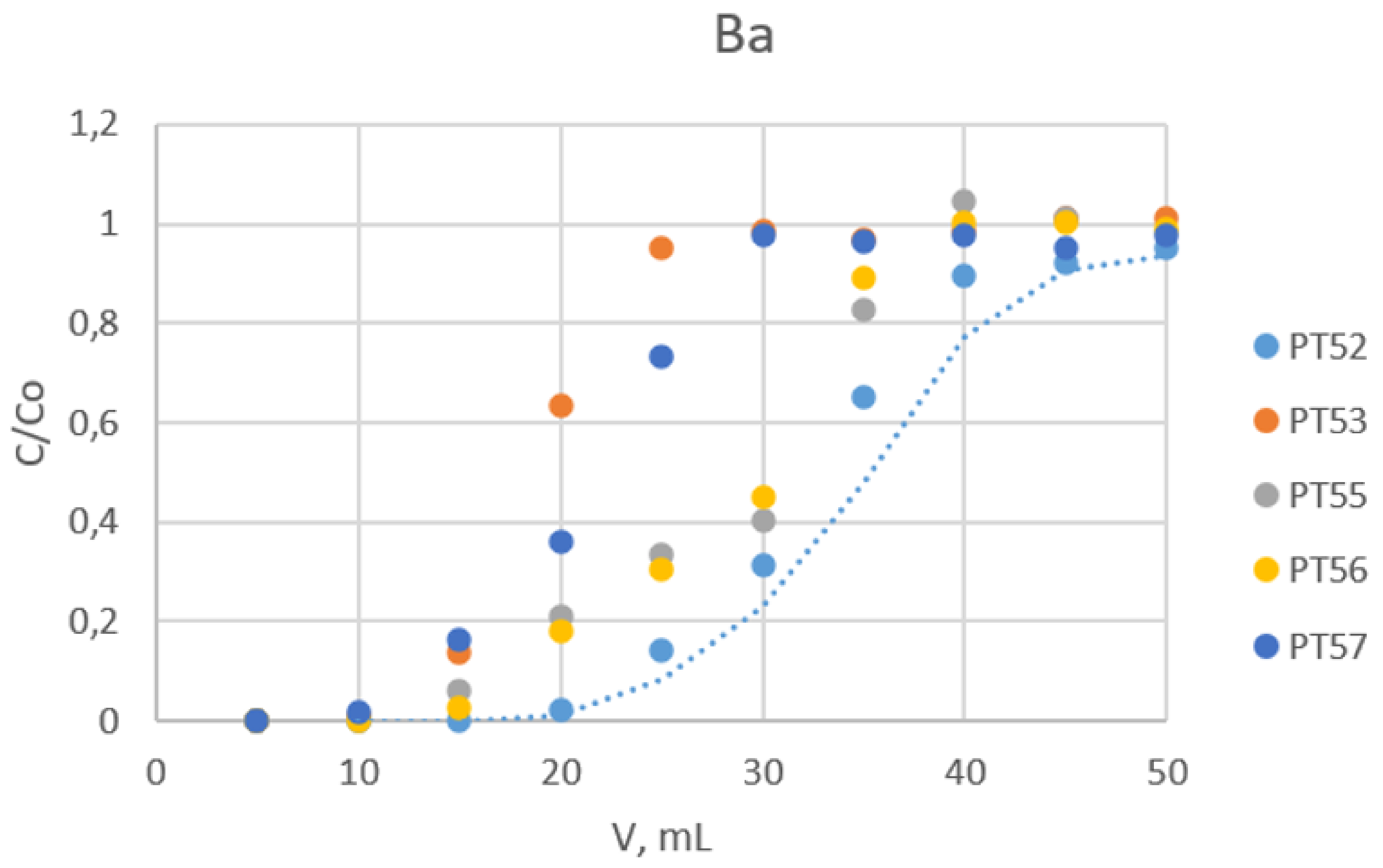


PT57

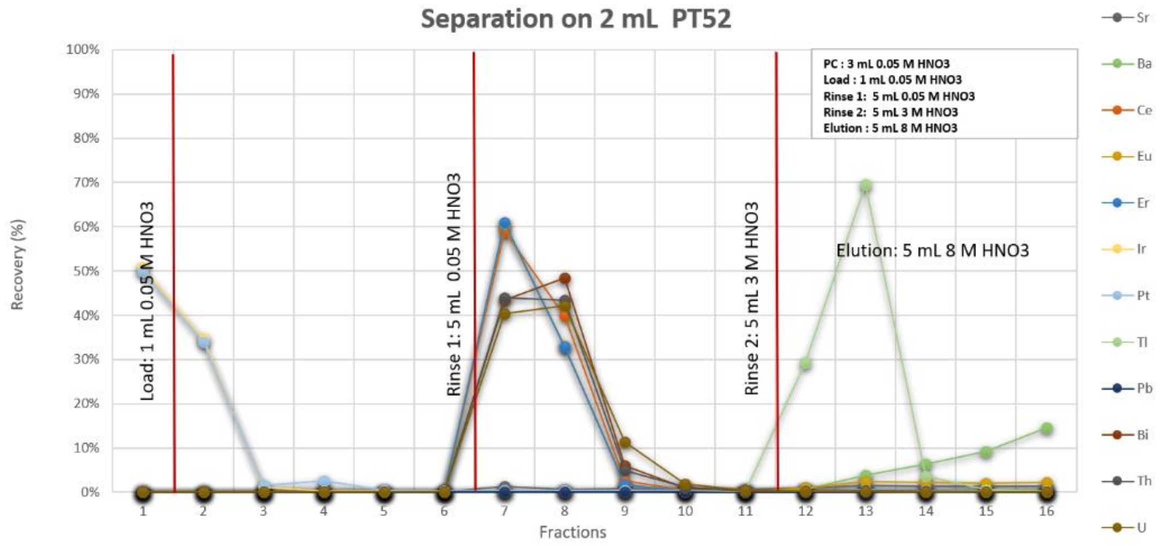
CAPACITY STUDIES IN 1 M HNO_3



CAPACITY STUDIES IN 1 M HNO_3

Prototype	DEC, mg · g^{-1}	FDEC, mg · g^{-1}	Theoretical capacity, mg Ba· g^{-1}	Desorption with 0.5 M Na_3NTA, %
PT52	8.8	18	48	93.4
PT53 T	9.4	15.6	28	82.1
PT55 T	9.9	17.2	48	92.1
PT56 T	10.0	17.3	28	91.1
PT57 T	6.7	13.1	14	101.6

ELUTION STUDIES



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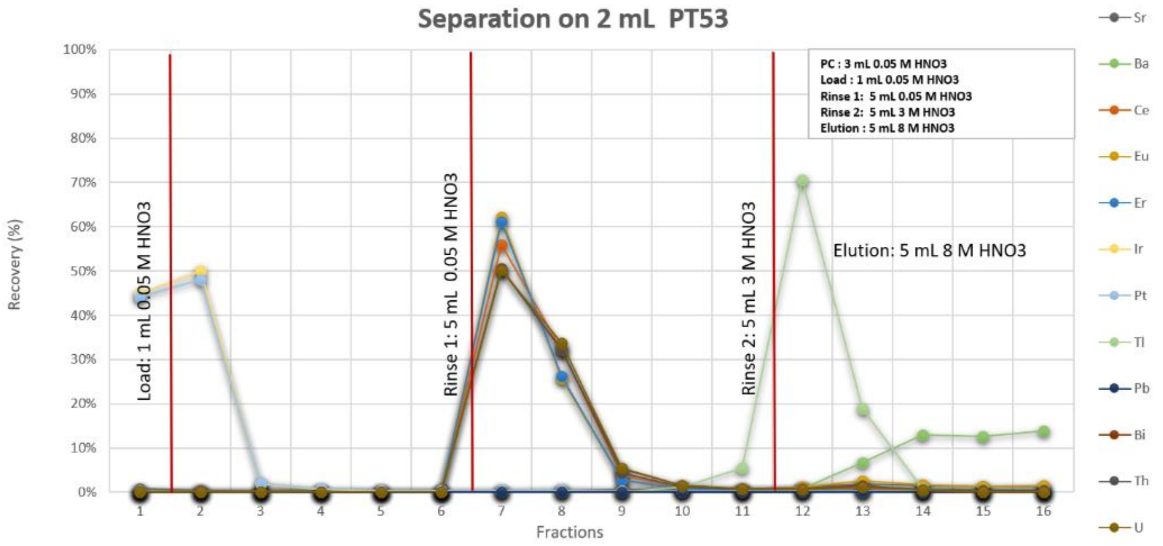
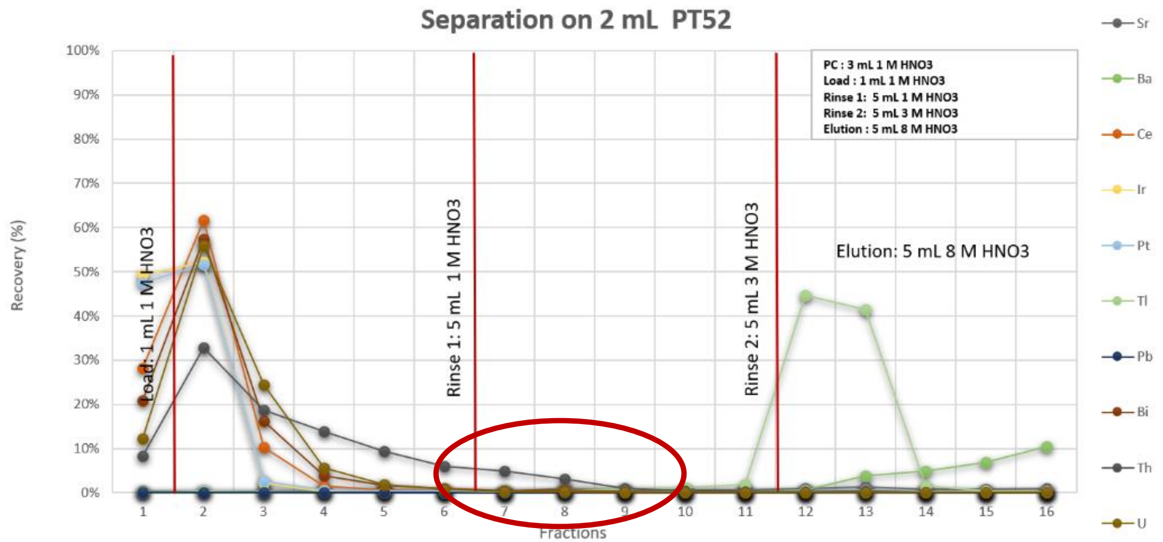
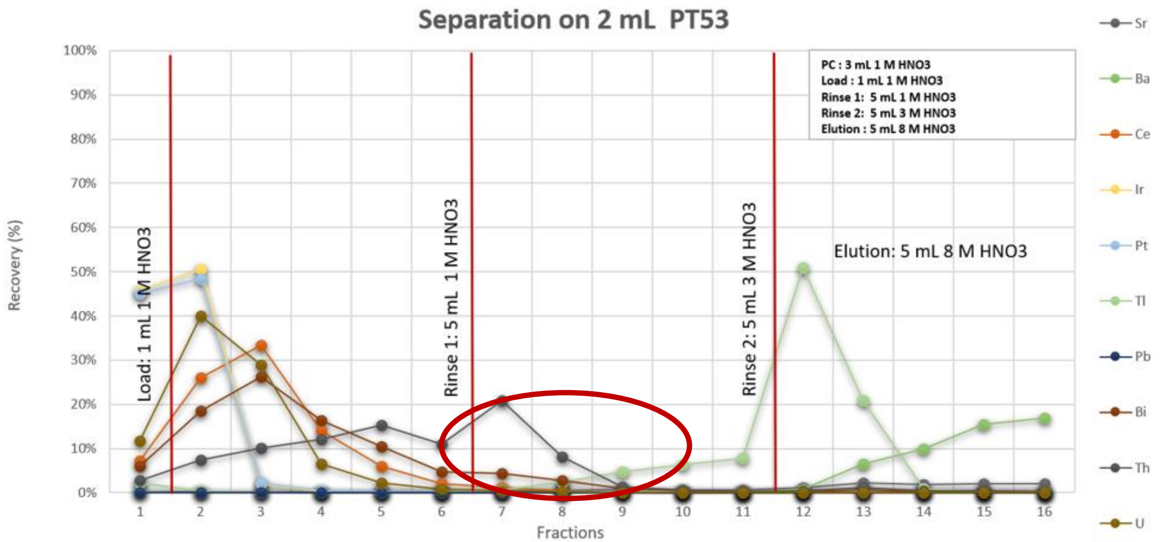


PT53 T grade

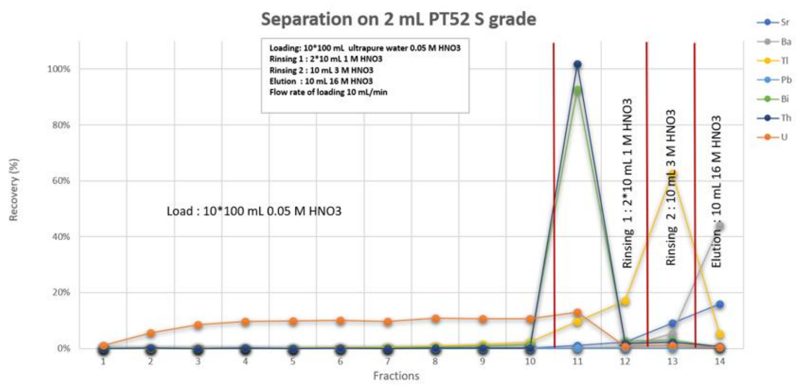


PT52

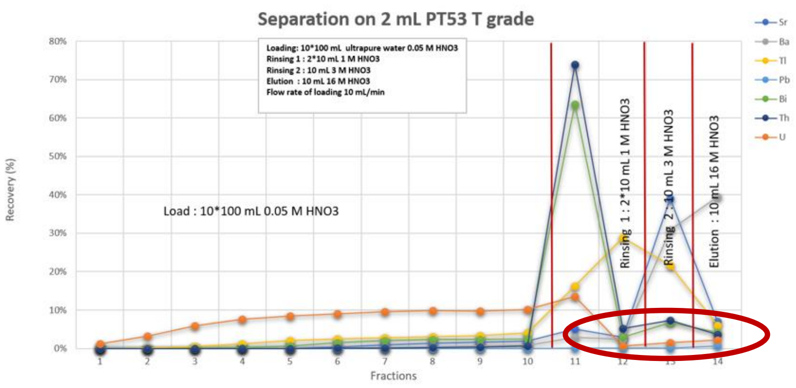


PT53 T grade

ELUTION STUDIES

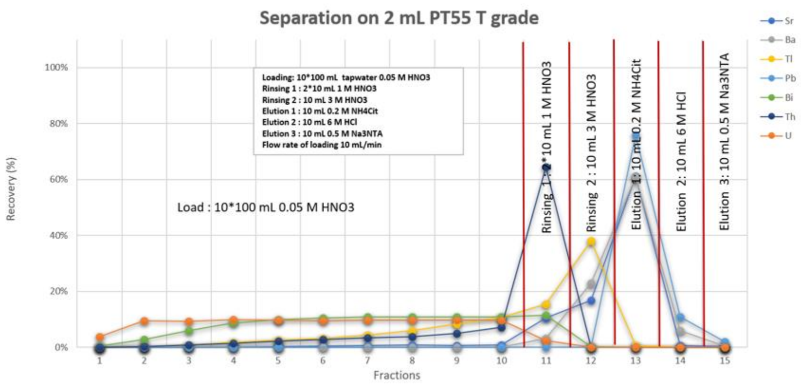


PT52

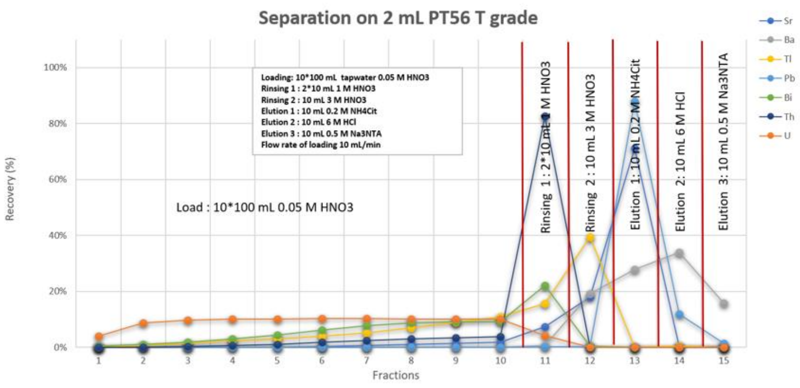


PT53

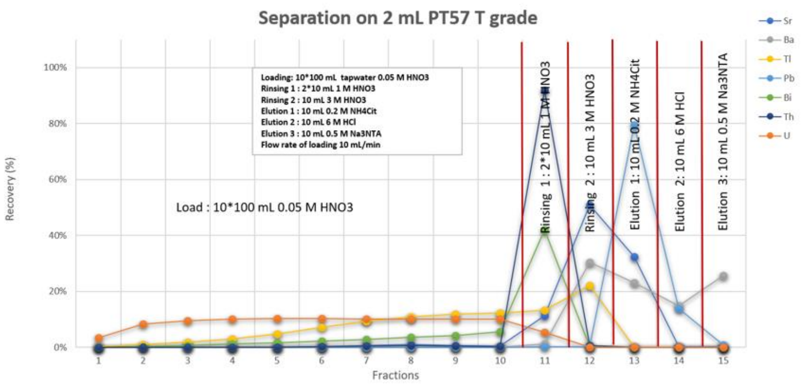
Fluorine-free prototypes



PT55



PT56



PT57

► retention of Sr, Ba, Pb from 1 L tapwater / 0,05 M HNO3

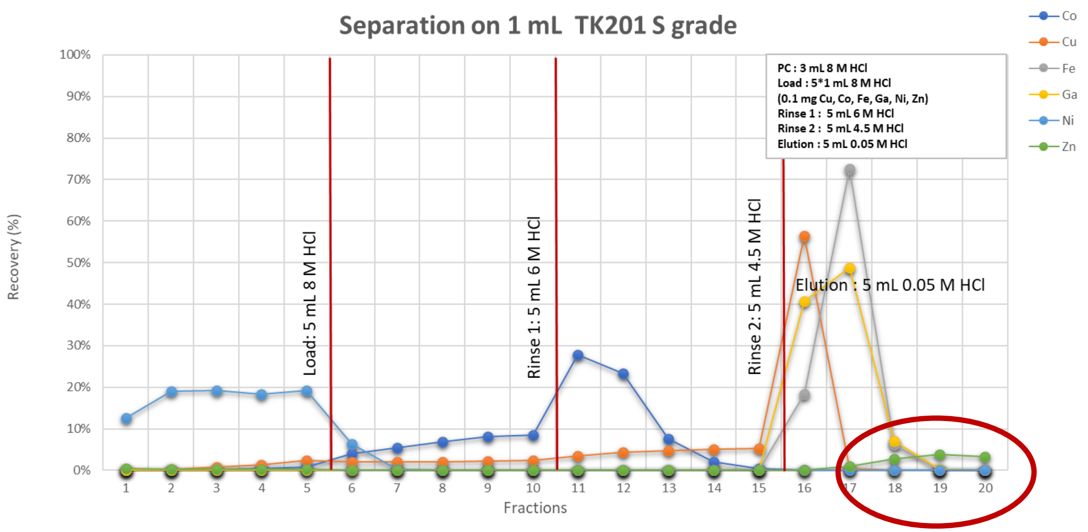
►elution of Bi, Th in 1 M HNO3

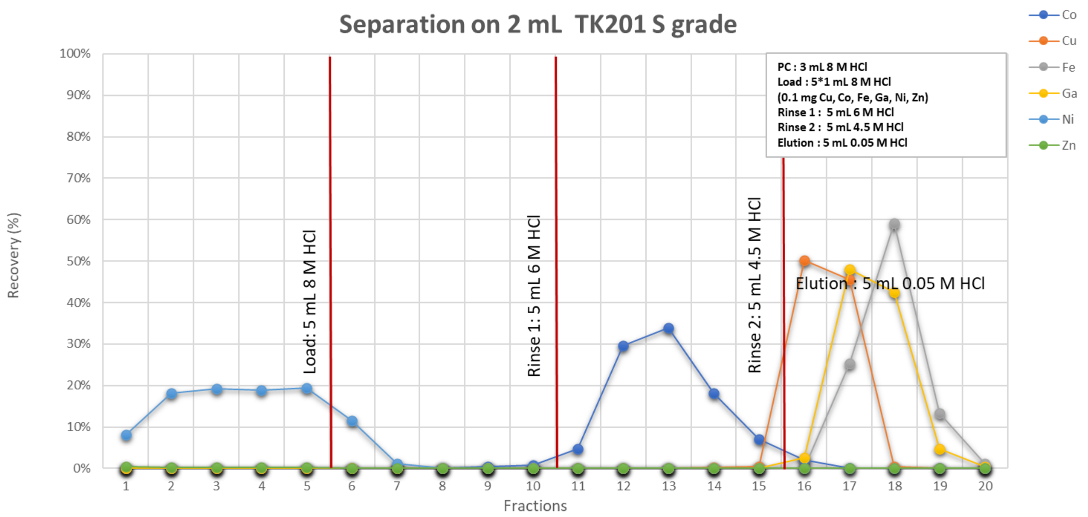
CONCLUSIONS

- ► One of these prototypes will ultimately be selected as a new Triskem product, TK103 Resin, following beta testing. It will be suitable for radioanalytical applications and low-level ICP-MS isotope analysis, as well as for the recovery and recycling of these elements, particularly Ra, from solutions with low to elevated acidity.
- ► They can be produces easily by impregnation with a common crown ether in different grades and quantity.

Cu-selective TK250 resin

Why do we need a new resin?





- Cu can be separated from Ni (target material) and Co, retention of Ni is low in elevated acid
- No separation with Fe, Ga
- Difficulties with purification in case of Zn target

Why do we need a new resin?

Svedjehed *et al. EJNMMI Radiopharmacy and Chemistry* (2020) 5:21
https://doi.org/10.1186/s41181-020-00108-7

EJNMMI Radiopharmacy and Chemistry

RESEARCH ARTICLE Open Access

Automated, cassette-based isolation and formulation of high-purity $[^{61}Cu]CuCl_2$ from solid Ni targets

Johan Svedjehed[1], Christopher J. Kutyreff[2], Jonathan W. Engle[2,3] and Katherine Gagnon[1*]

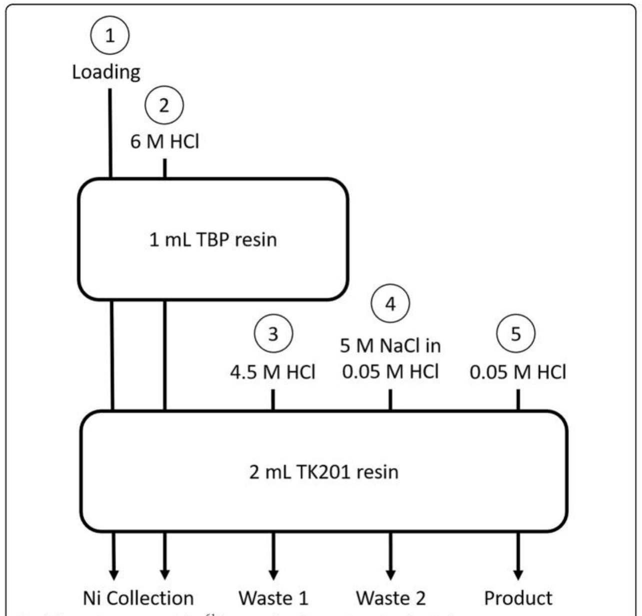
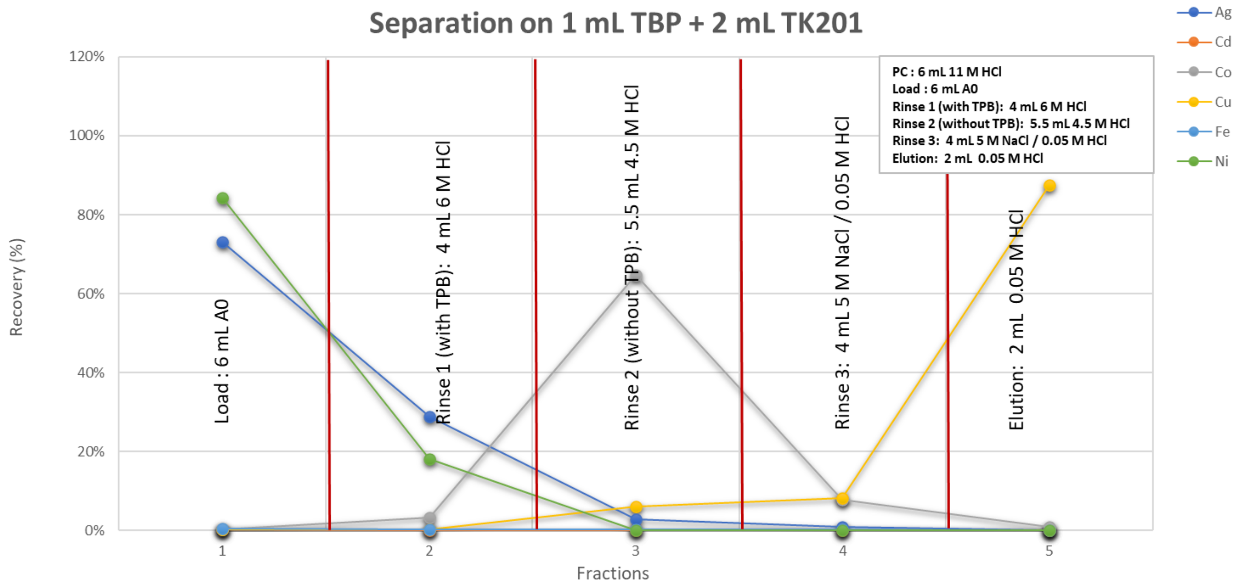
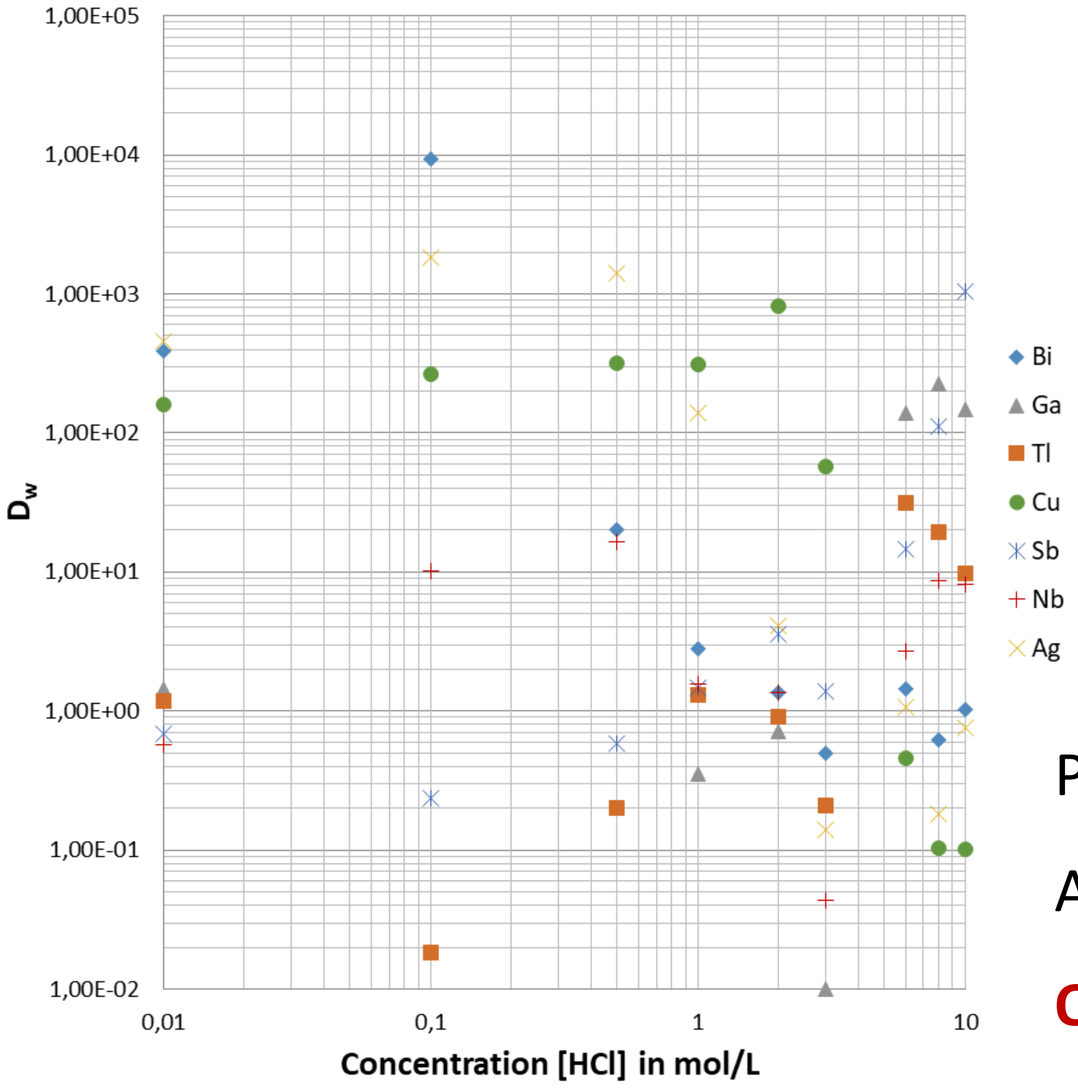


Fig. 1 Two-column approach for ^{61}Cu separation. Process steps described below



D_w studies HCl



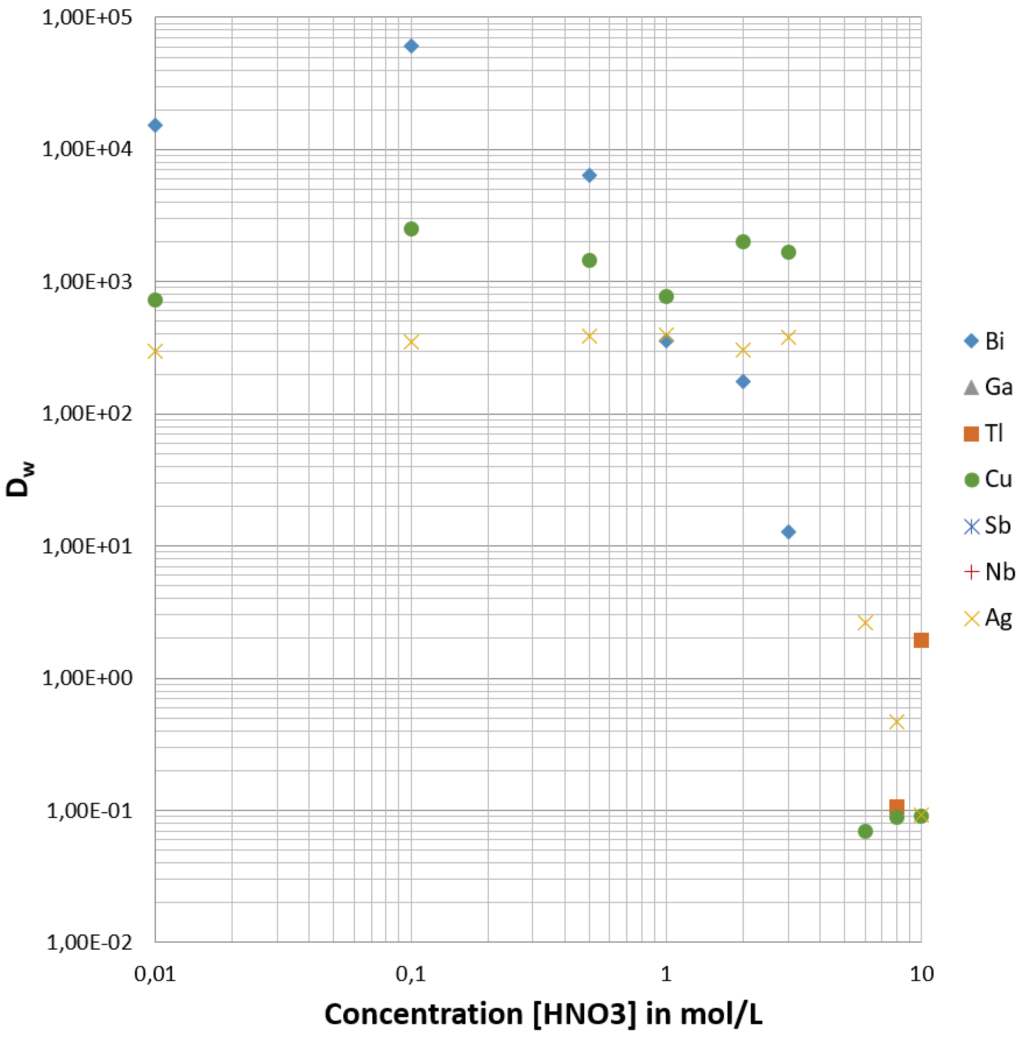
- High retention of Cu in 0.01-3 M HCl, low retention in 6-10 HCl
- Low retention of most elements

!

- High retention of Ag in 0.01-2 M HCl and Bi in diluted HCl 0.01-0.1 M HCl

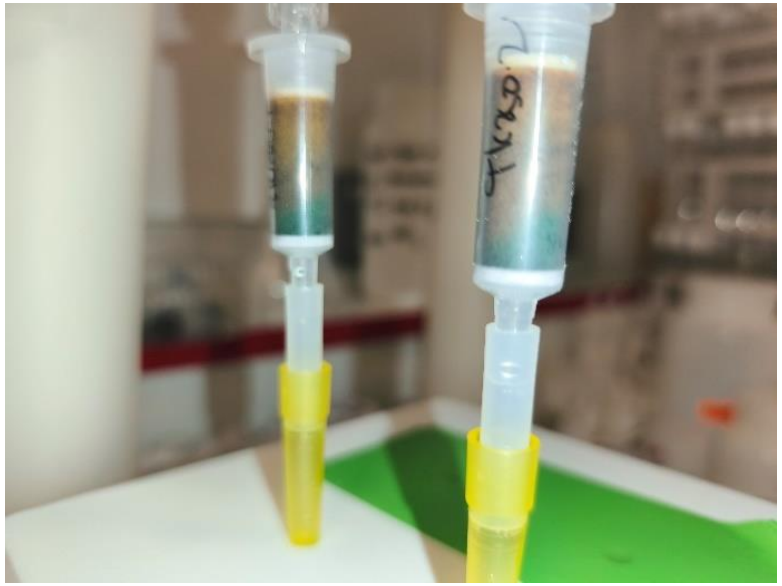
Presented at iSRS 2025 Gold Coast Australia (11-15.05.2025) => **scan QR-code** to download the poster

D_w studies HNO_3



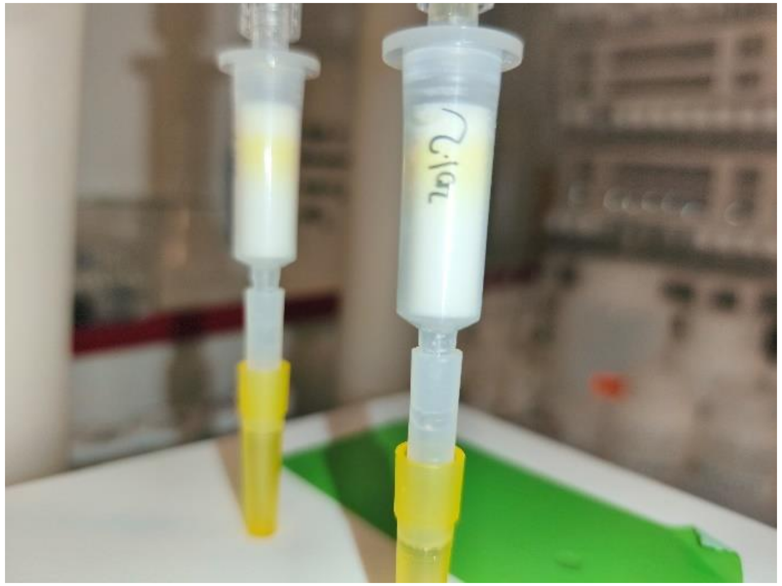
- High retention of Cu, Ag, Bi in 0.01-3 M HNO_3, even higher than in HCl
- Low retention of Cu in 6-10 HNO_3
- Low retention of most elements

Separation / conversion of Cu of TK250 / TK201



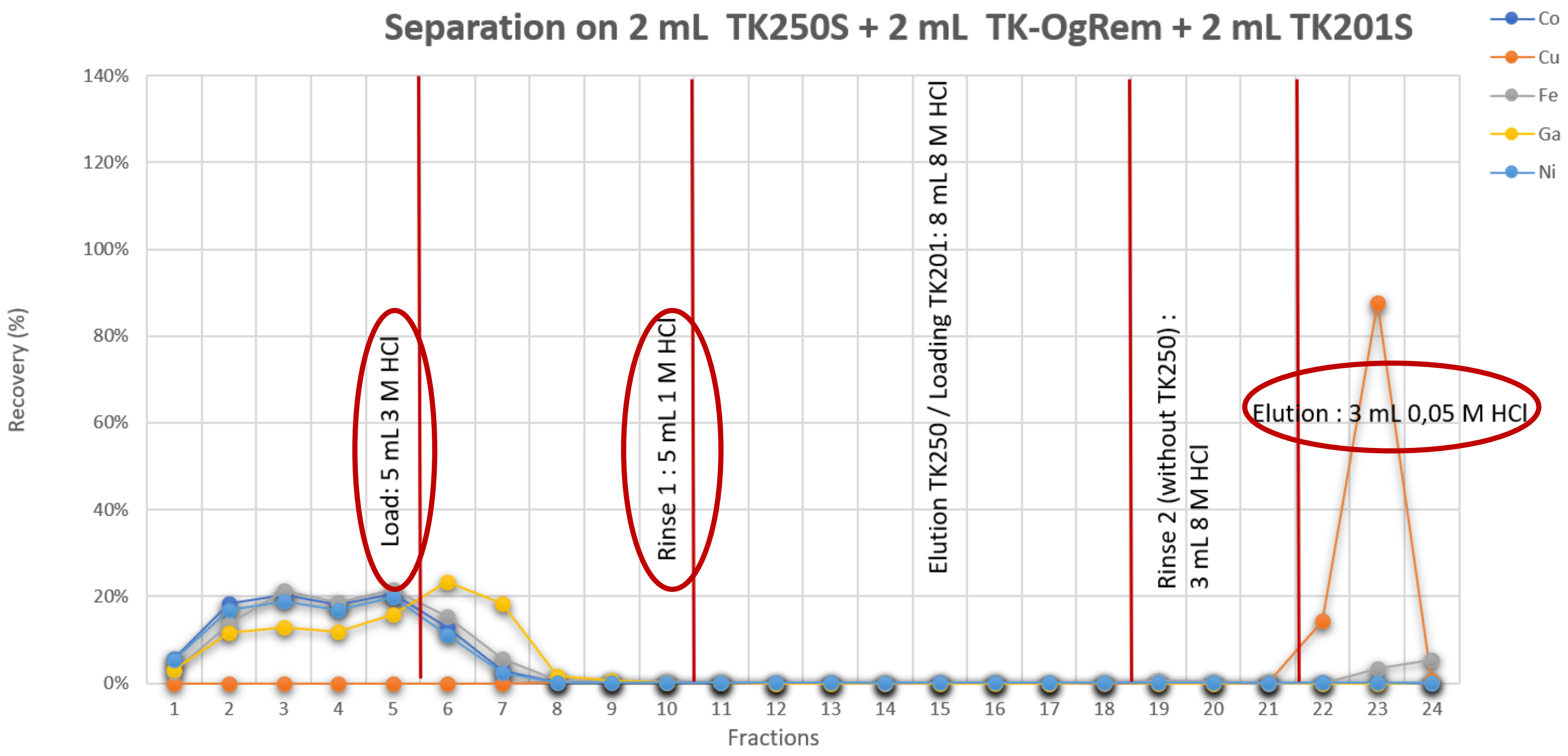
Brown zone – resin saturated with Cu in 3 M HCl, green zone – free resin

In 6 M HCl TK250 is purple, yellow zone of TK201 – loaded Cu



Blurring of Cu zone after rinsing in 6 M HCl

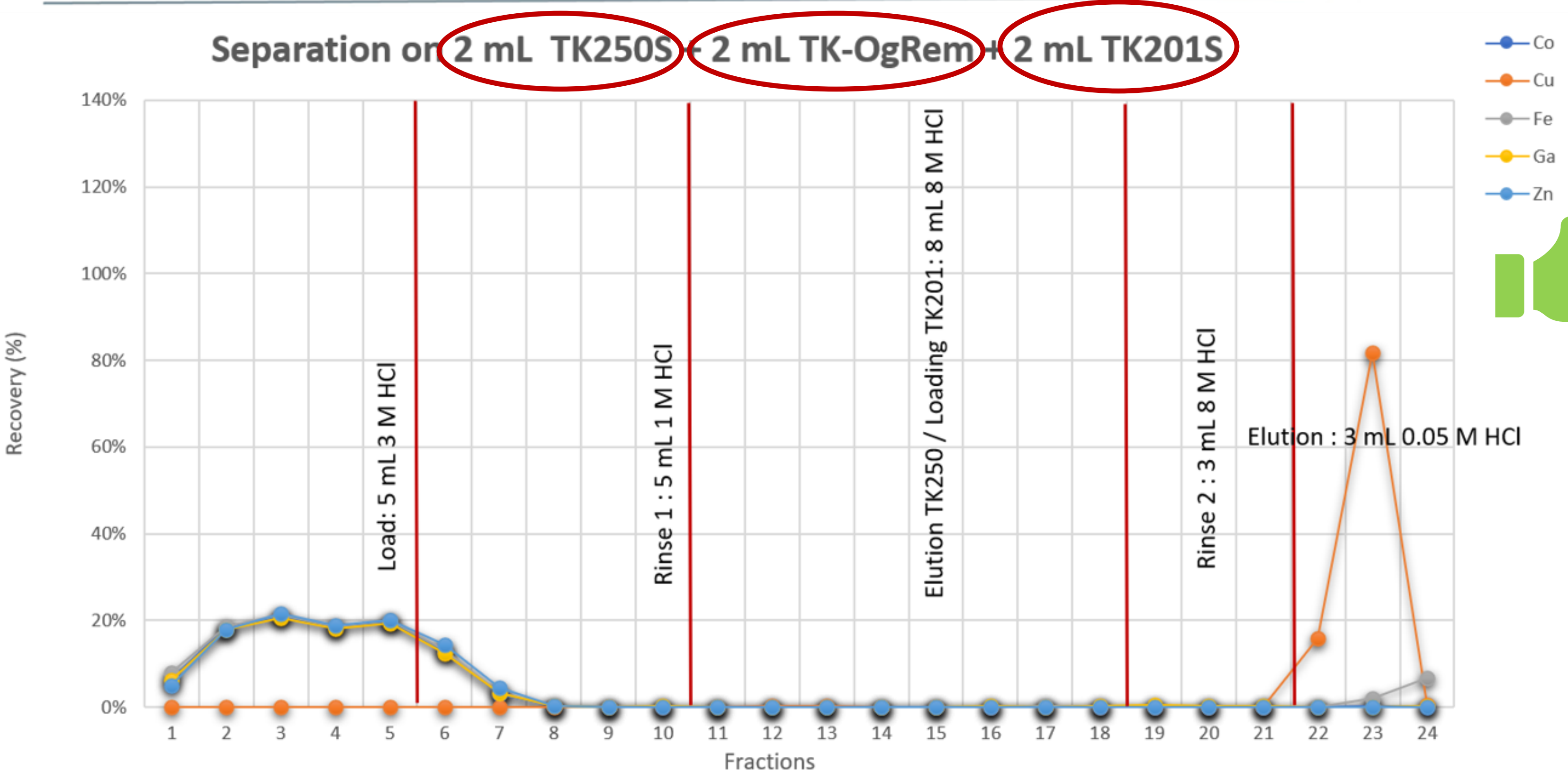
Separation / conversion of Cu of TK250 / TK201



- Separation of micrograms of Cu from 300 mg Ni/Zn targets
- Elevated 6-8 M HCl can be used for dissolution of Ni and Zn targets, 2-fold dilution is necessary to 3 M HCl
- 1 M HCl was used for precondition and rinsing of resin, to decrease losses of Cu and bleeding of extractant
- 0.05 M HCl allows to elute Cu

Experiment	Separation factor = $(C^0_{el}/C^0_{Cu})/(C^f_{el}/C^f_{Cu})$				
	Co/Cu	Fe/Cu	Ga/Cu	Ni/Cu	Zn/Cu
60 g/L Ni	1620	12	555	192 000	-
60 g/L Zn	431	11	274	-	44 000

Separation / conversion of Cu of TK250 / TK201



- 2 mL of TK250 + 2 mL of OgRem resin + 2 mL of TK201 is enough for separation of 5 µg of Cu without losses.
- Almost no retention of Ni, Zn, Co, Fe, Ga

Why 5 µg Cu?

Expected amount of Cu 0.6 µg

16.4 GBq / 27900 GBq/mg = 0,0006 mg = 0.6 µg

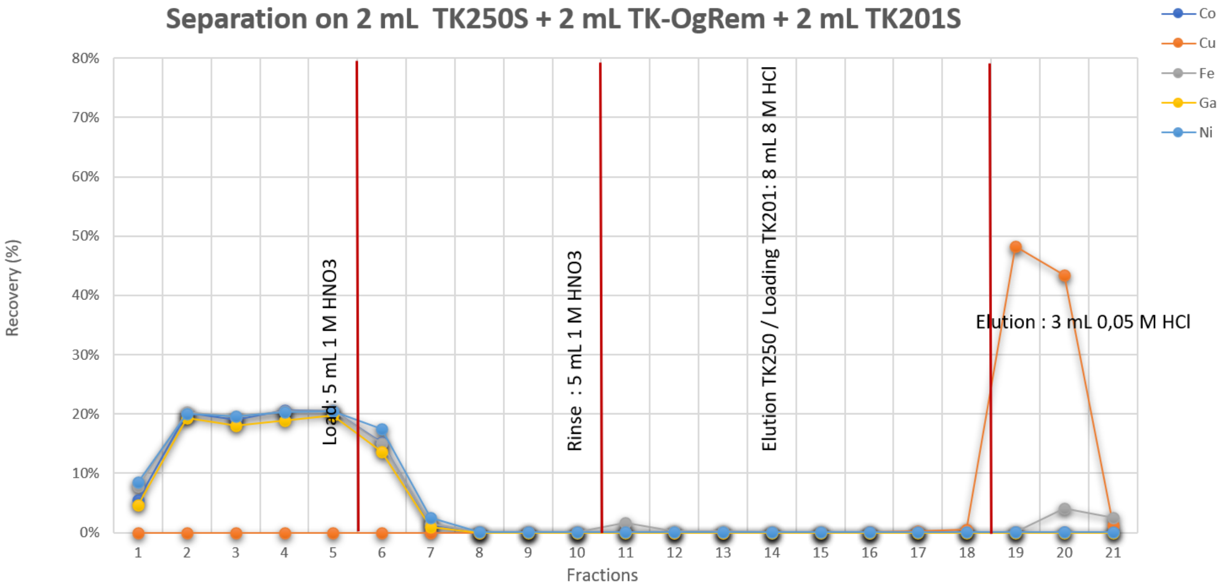
Experimental amount 5 µg Cu

So 5 µg is a 9-fold excess

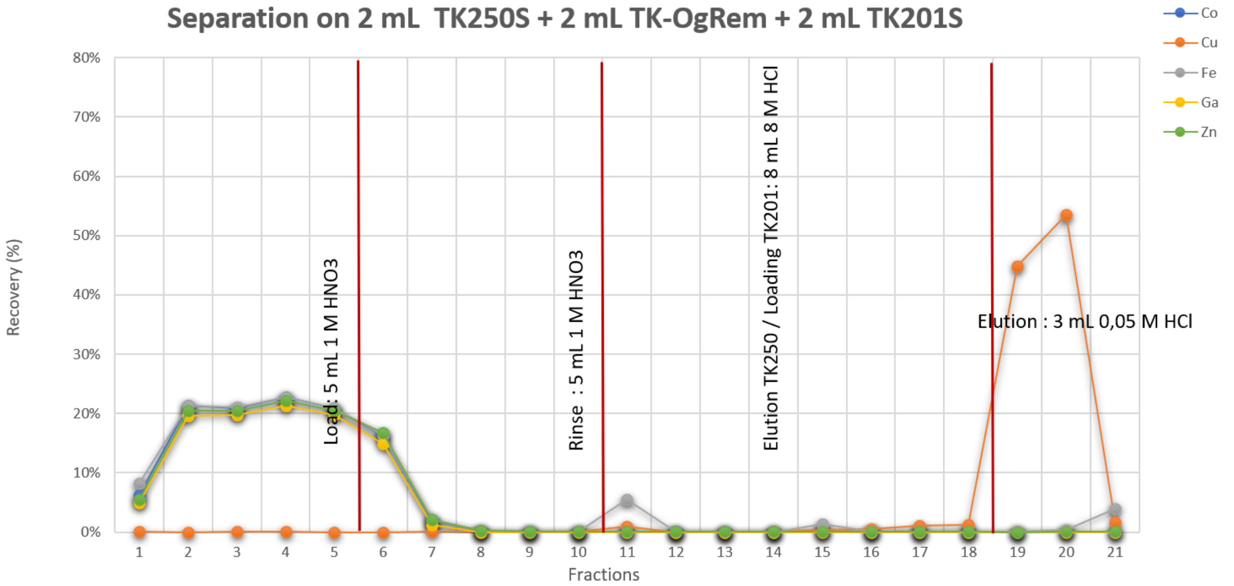
- The $^{70}Zn(d,x)^{67}Cu$ production yield is 6.4 MBq/µA/h . We can produce 16.4 GBq with a specific activity of 2.79 10^4 GBq/mg.
  →Suitable for **clinical studies**.

Beam: 26 MeV, 80 µA, 40 h
Target: 100% ^{70}Zn, 576 µm
Decay: 70 min

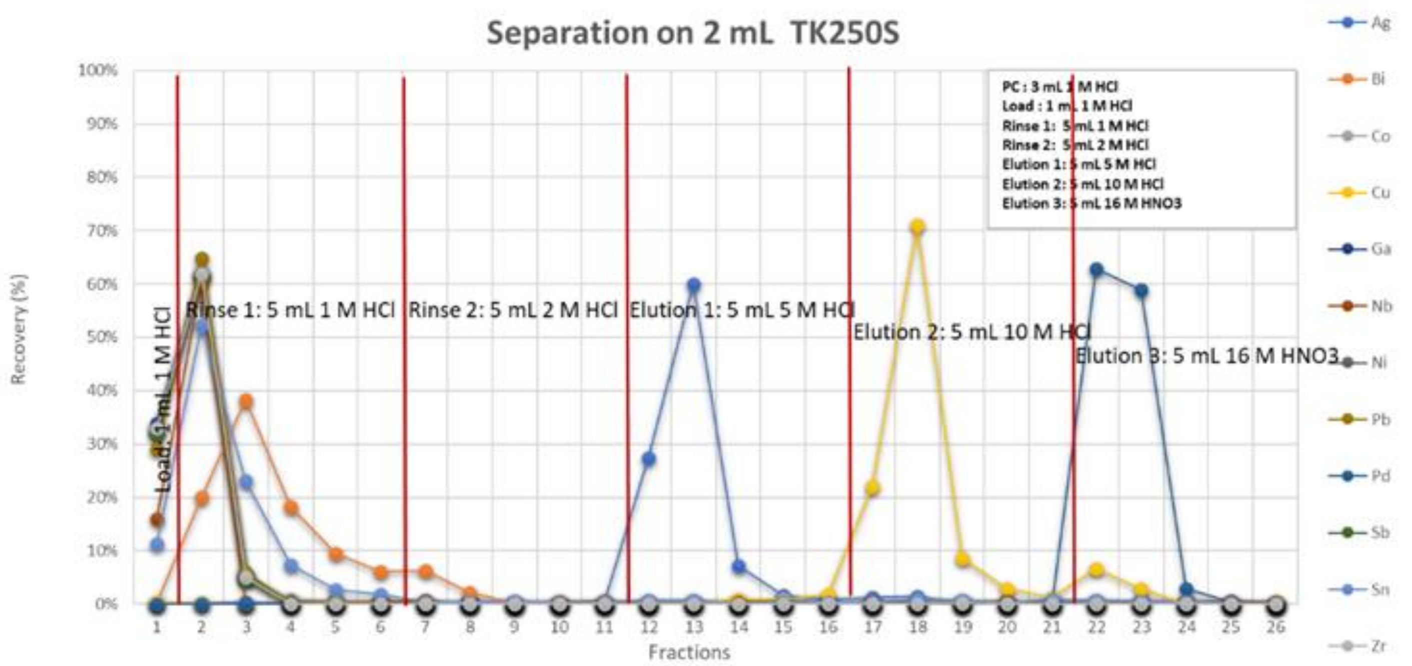
Separation / conversion of Cu of TK250 / TK201



HNO_3 solutions of Ni and Zn also can be used for loading, but in 1 M HNO_3, not 3 M HNO_3



Other applications



On going studies

- Separation of ^{111}Ag from irradiated Pd target
- No elution of Pd even in 10 M HCl
- Separation of ^{103}Pd from irradiated Rh
- Separation of ^{110m}Ag (decommissioning)
- Separation of ^{107}Pd (decommissioning)

Conclusions

- A highly Cu-selective resin was developed
- Can be used for both Ni and Zn targets
- It is possible to separate Cu in the presence of **60000-fold excess of Zn/Ni** and the main impurities Co, Ga, Fe
- Subsequent conversion of Cu on TK201 is possible
- We propose not only a product, but a technology of separation

!

- OgRem resin is necessary to eliminate bleeding of extractant in case of conversion on TK201

Scan QR-code to go to

Illarion Dovhyi, Steffen Happel Characterization of a new Cu selective resin for the separation of Cu from Ni and Zn targets, Nuclear Medicine and Biology, https://doi.org/10.1016/j.nucmedbio.2025.1

THANK YOU FOR YOUR ATTENTION