Develoment of methods for the selective separation of Scandium for radiopharmaceutical applications

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Scope

- Why Scandium?
- Batch experiments
  - Selectivity
  - Kinetics
  - Interferences (Ti or Ca)
- Column experiments
  - Simulated Ti target
  - Simulated Ca target
- Summary
- Perspective

Scandium radioisotopes

Isotope	Half-life	Emission	Energy	Production
^{43}Sc	3.891h	β^+ (100%)	2.221 MeV	^{43}Ca (p,n) ^{43} Sc
^{44}Sc	3.927h	β^+(100%)	3.653 MeV	^{44}Ca (p,n) ^{44} Sc ^{44}Ti (n,p) ^{44} Sc
^{44m}Sc	5.,6 h	β^+(98,8%), EC (1,2%)	0.271 MeV 3.924 MeV	
^{46}Sc	83.79d	β^- (100%)	2.367 MeV	^{46}Ti (n,p) ^{46}Sc ^{44}Ca (α,n+p) ^{46}Sc
^{47}Sc	3.349d	β^- (100%)		^{44}Ca (α,p) ^{47}Sc ^{47}Ti (n,p) ^{47}Sc
^{48}Sc	43.67h	β^-(100%)	3.994 MeV	^{48}Ca (p,n) ^{48} Sc ^{48}Ti (n,p) ^{48}Sc
^{49}Sc	57.2 Min	β^-(100%)	2.006 MeV	^{49}Ti (n,p) ^{49}Sc ^{48}Ca (α,2n+p) ^{49} Sc

Radiopharmaceutical applications

- Appropriate half-lifes
- Various emissions
- Well known coordination chemistry

- **PET Imaging (e.g.** ^{44}Sc , β^+)
- **Therapy (e.g.** ^{47}Sc, β^-)

Production routes

Nuklearer Prozess	Optimaler Energie Bereich (MeV)	mb
^{43}Ca (p,n) ^{43}Sc	12 → 7	309
^{44}Ca (p,n) ^{44}Sc ^{44}Ti (n,p) ^{44}Sc	7-8 0,025 eV	328 200
^{46}Ti (n,p) ^{46}Sc ^{44}Ca (a,n+p) ^{46}Sc	8-10 21-34	234 404
^{44}Ca (a,p) ^{47}Sc ^{47}Ti (n,p) ^{47}Sc	12-16 9-10	121 144
^{48}Ca (p,n) ^{48}Sc ^{48}Ti (n,p) ^{48}Sc	4-5 13-14	255 67
^{49}Ti (n,p) ^{49}Sc ^{48}Ca (a,2n+p) ^{49}Sc	10 39	19,2 114

http://www-nds.iaea.org
C W Cheng and J D King 1979 *J. Phys. G: Nucl. Phys.* **5** 1261

General procedure - batch experiments

D_W (Weight distribution coefficient)

- Weigh 50 mg of the respective resin into a 2 mL Eppendorf cap
- Add 400 µL of the acid to be tested
- Close cap and shake for 30 min (preconditioning)
- Add 1mL of the sample solution
    - (e.g.. 1 mL multi-element solution)
- Close cap and shake for 30 min (analyte extraction)
- Centrifuge
- Withdraw 1 mL of the supernatant, Analysis (ICP-MS)

- **All D_W determined in triplicate**

D_W

$$D_W = \frac{N_{A_0} - N_A}{N_A} \times \frac{V}{m_R}$$

- **high D_w = Extraction**
- **low D_w = Elution**

N_{Ao} = Net count rate A_0 sample

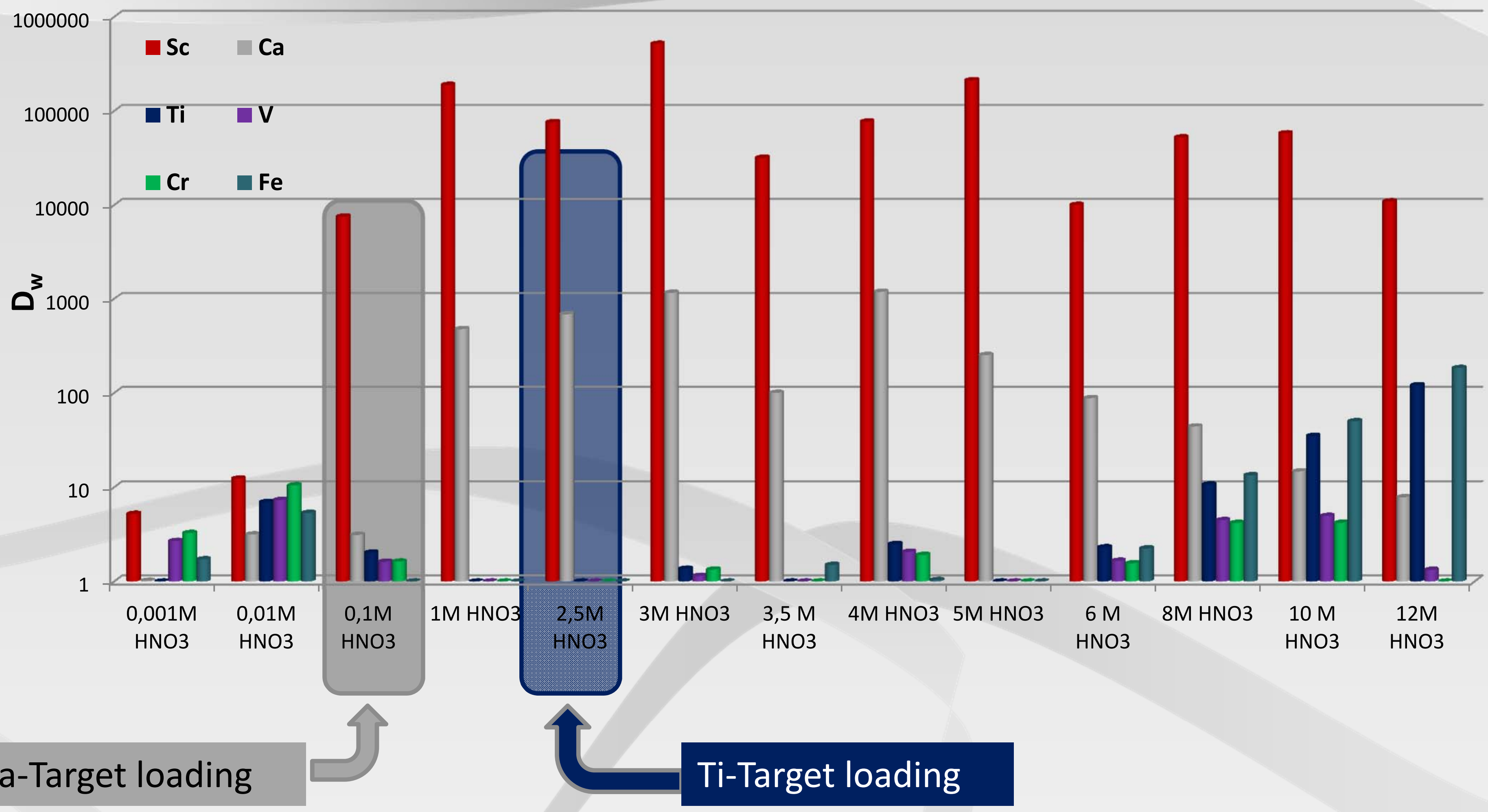
N_A = Net count rate sample

V = Volume aq. phase (1,4 mL)

m_R = amount of resin in g

DGA : D_w - in HNO_3

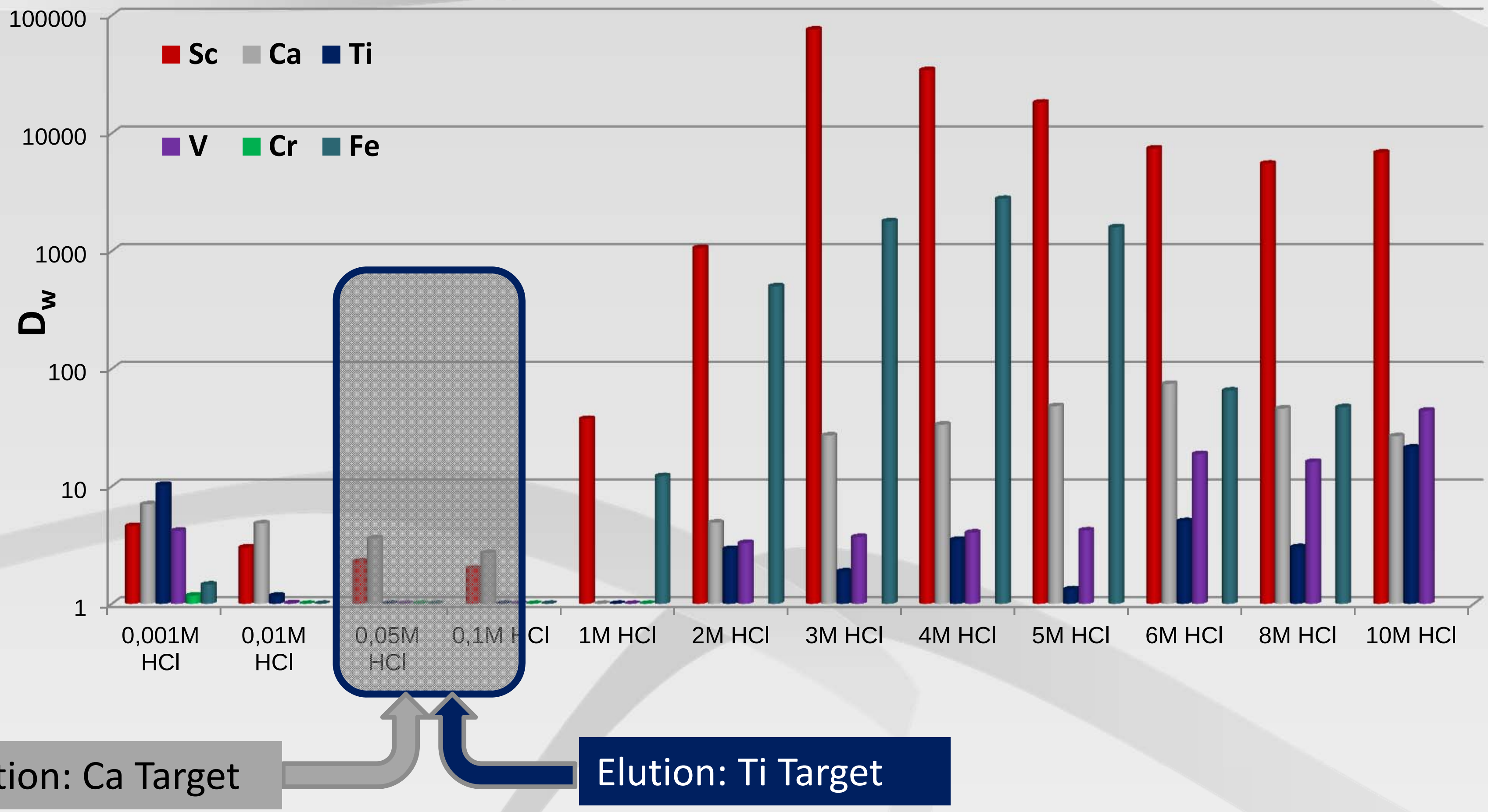
(each element 10µg/mL)



D_w of Sc and selected elements on DGA resin in HNO_3, varying concentrations

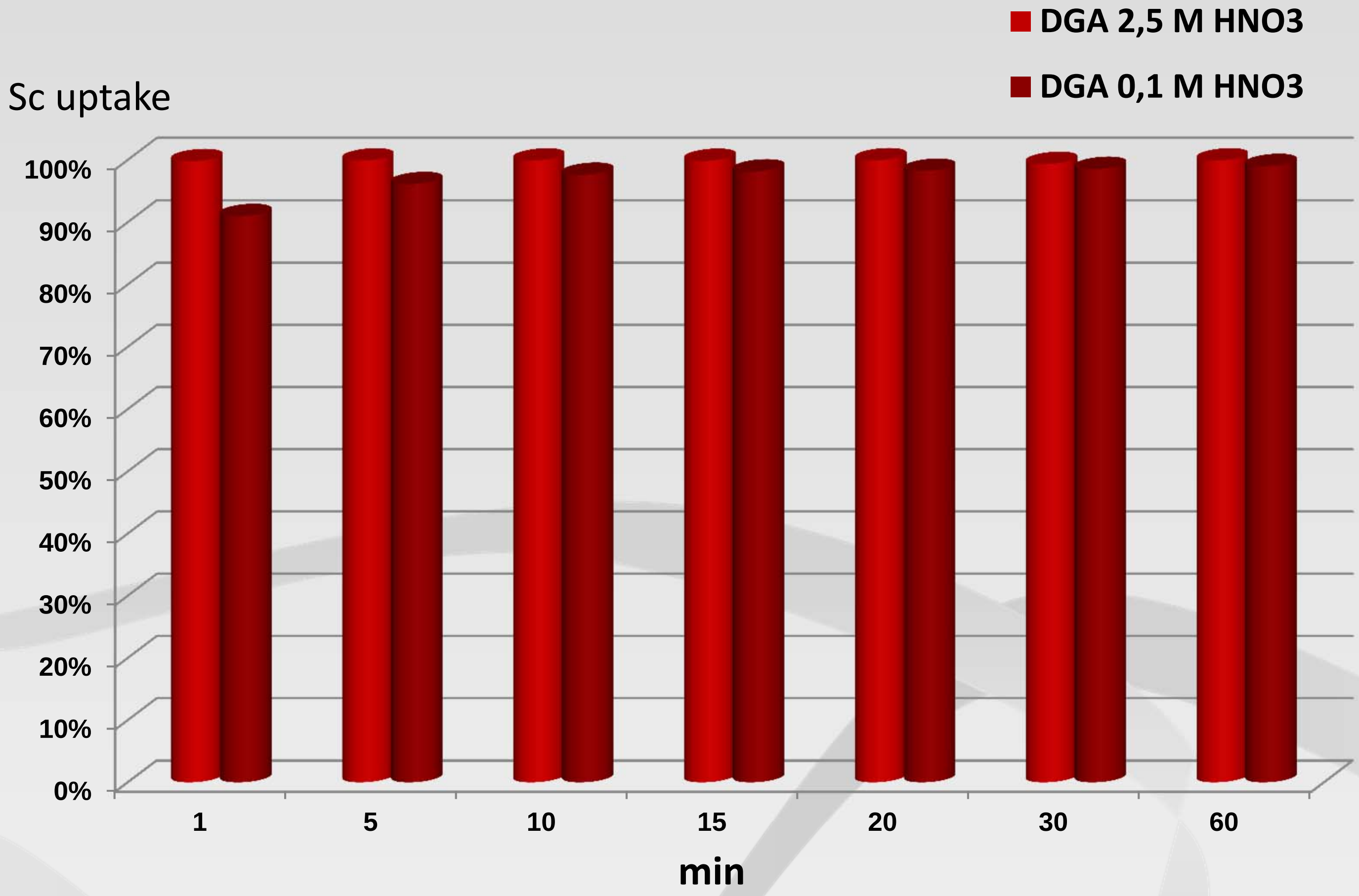
DGA : D_w in HCl

(each element 10µg/mL)



D_w of Sc and selected elements on DGA resin in HCl, varying concentrations

DGA Kinetics



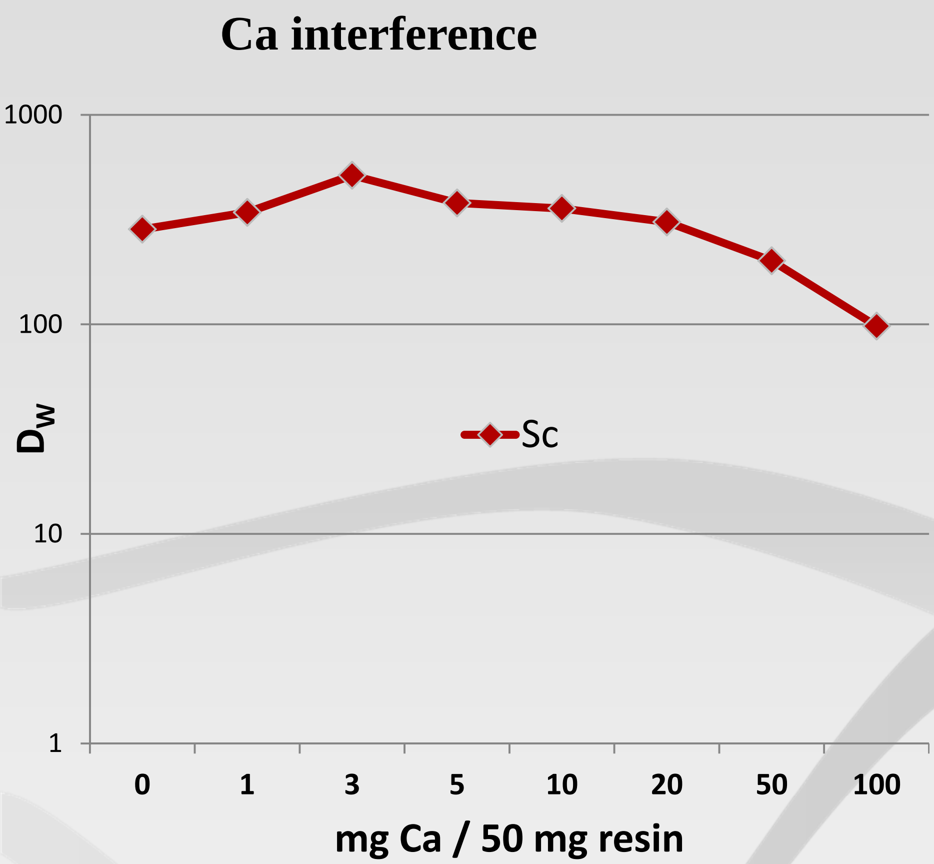
Kinetics: 2.5M HNO_3

- 1 min 99,7 %
- 5 min 99,8 %
- 10 min 99.9 %

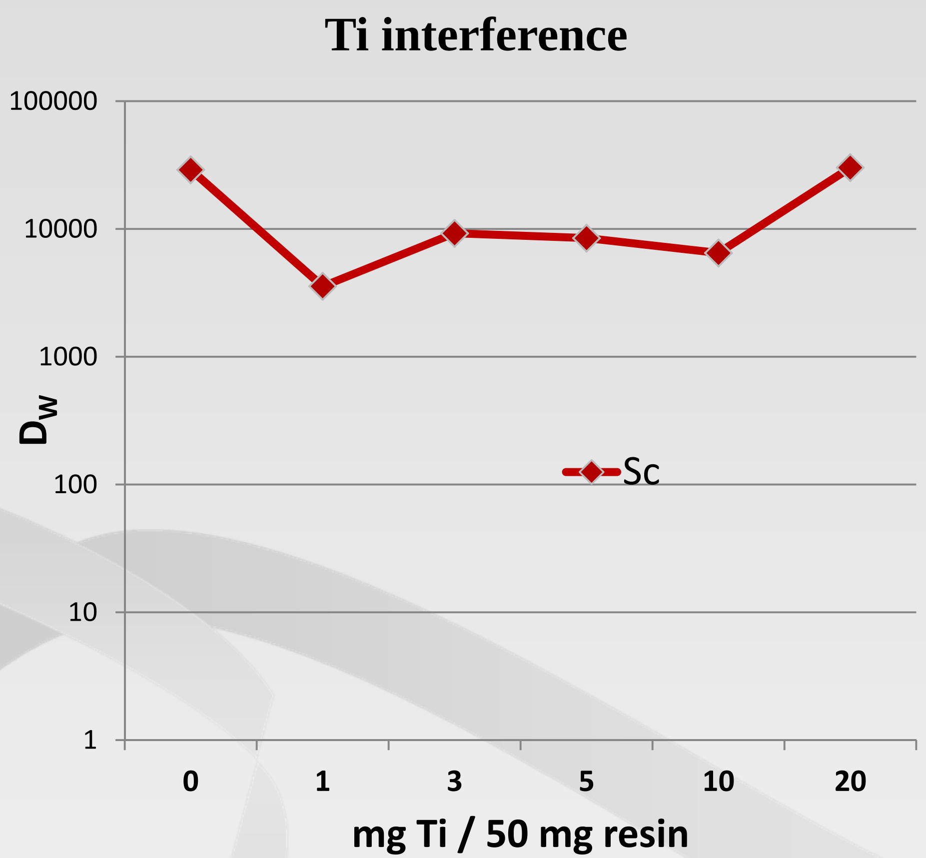
Kinetics: 0.1M HNO_3

- 1 min 90,9 %
- 5 min 96,1 %
- 10 min 97,6 %

D_w Sc – interferences – DGA



D_w of Sc on DGA resin in 0,1 M HNO_3 in presence of increasing amounts of Ca



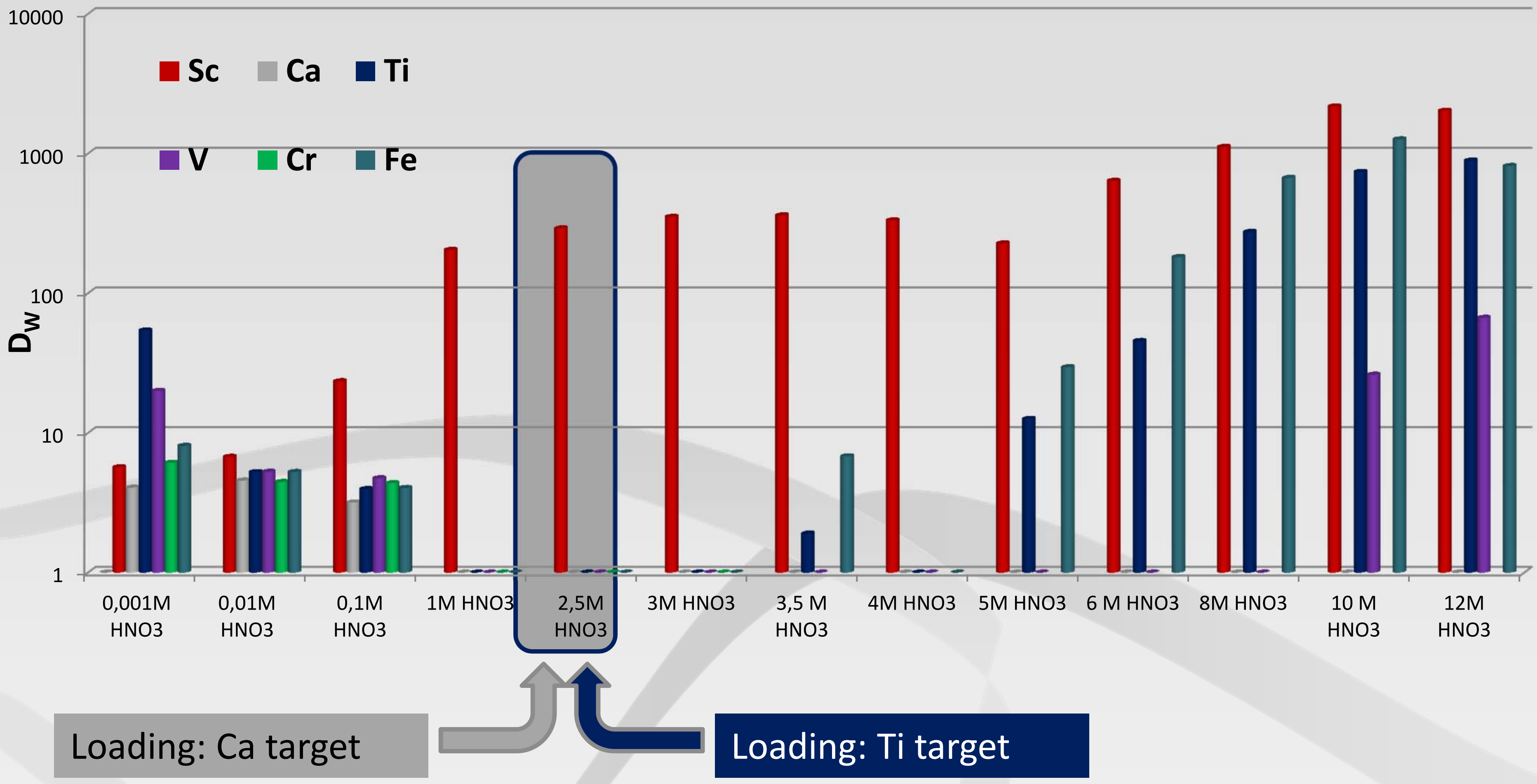
D_w of Sc on DGA resin in 2,5 M HNO_3 in presence of increasing amounts of Ti

Conclusions I - DGA resin

- Stable, high Sc D_w in HNO_3
- High Sc selectivity
- No selectivity for Ca or Ti
- Rapid extraction
  - Sample loading:
    - **Ti Target 2,5 M HNO_3**
    - **Ca Target 0,1 M HNO_3**
- Elution with 0,1 M HCl for Ti- and Ca- Target
  - **Negligible interferences**

TRU : D_w in HNO_3

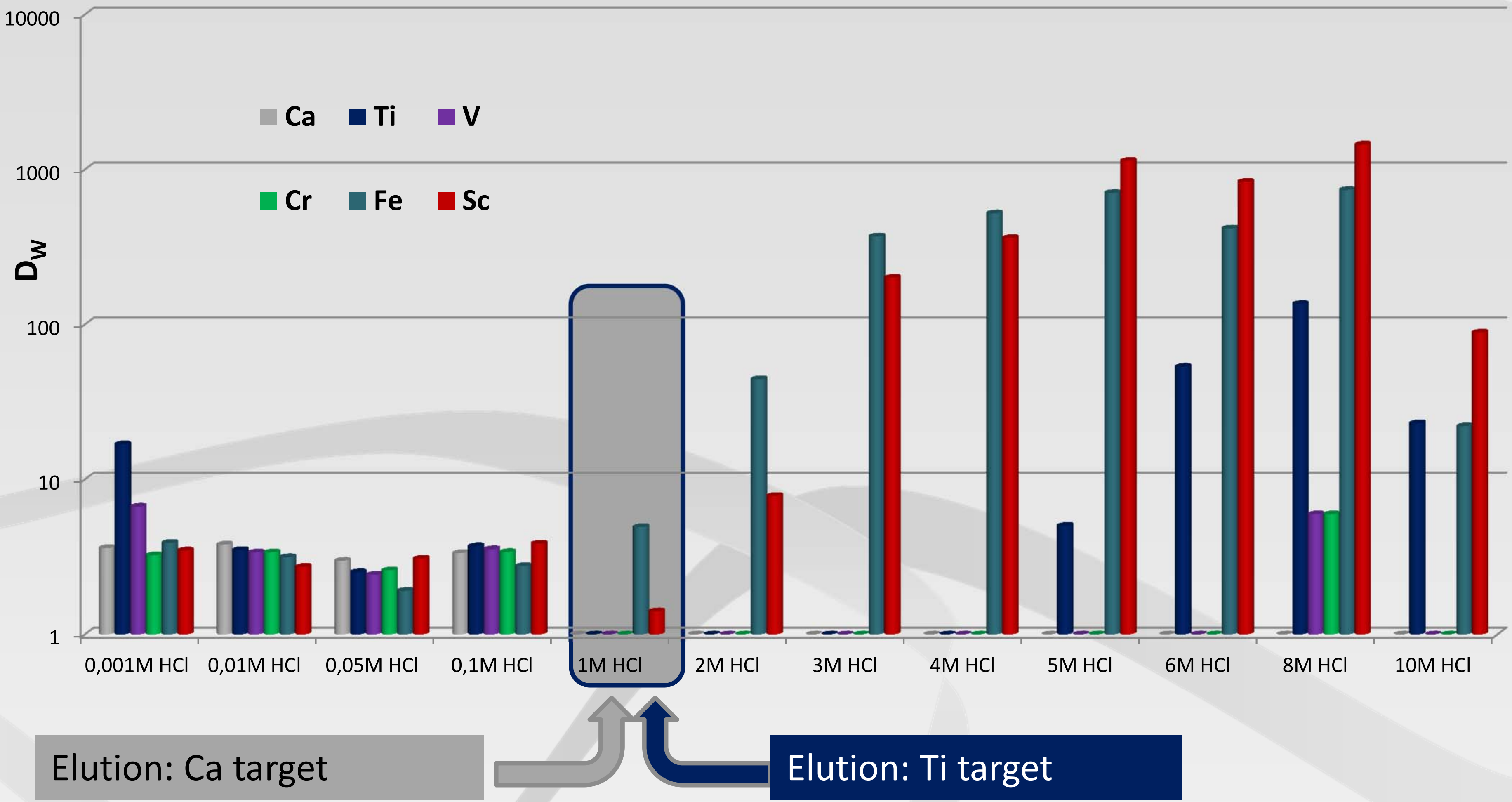
(each element 10µg/mL)



D_w of Sc and selected elements on TRU resin in HNO_3 ,varying concentrations

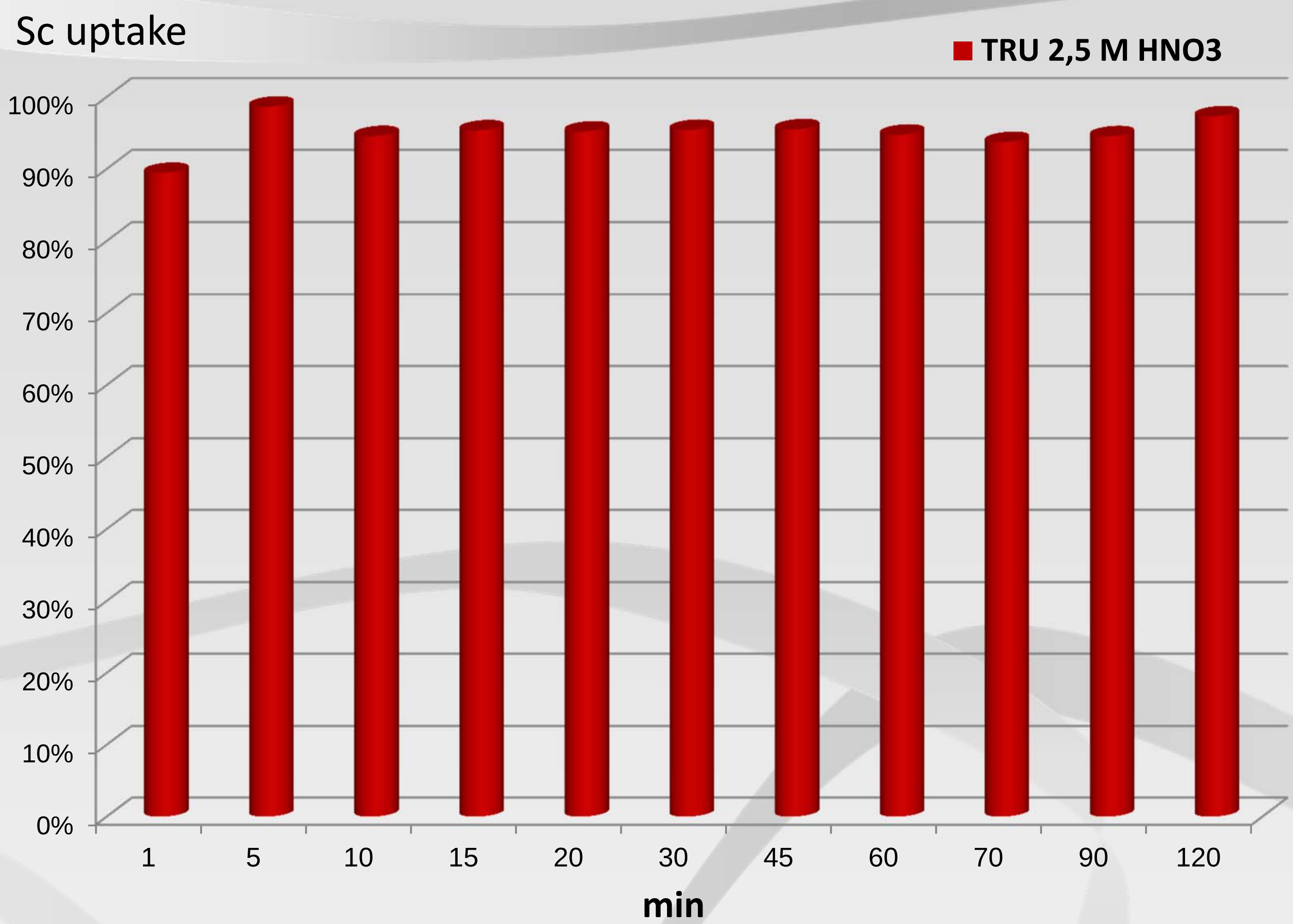
TRU : D_w - in HCl

(each element 10µg/mL)



D_w of Sc and selected elements on TRU resin in HNO_3 ,varying concentrations

TRU Kinetics

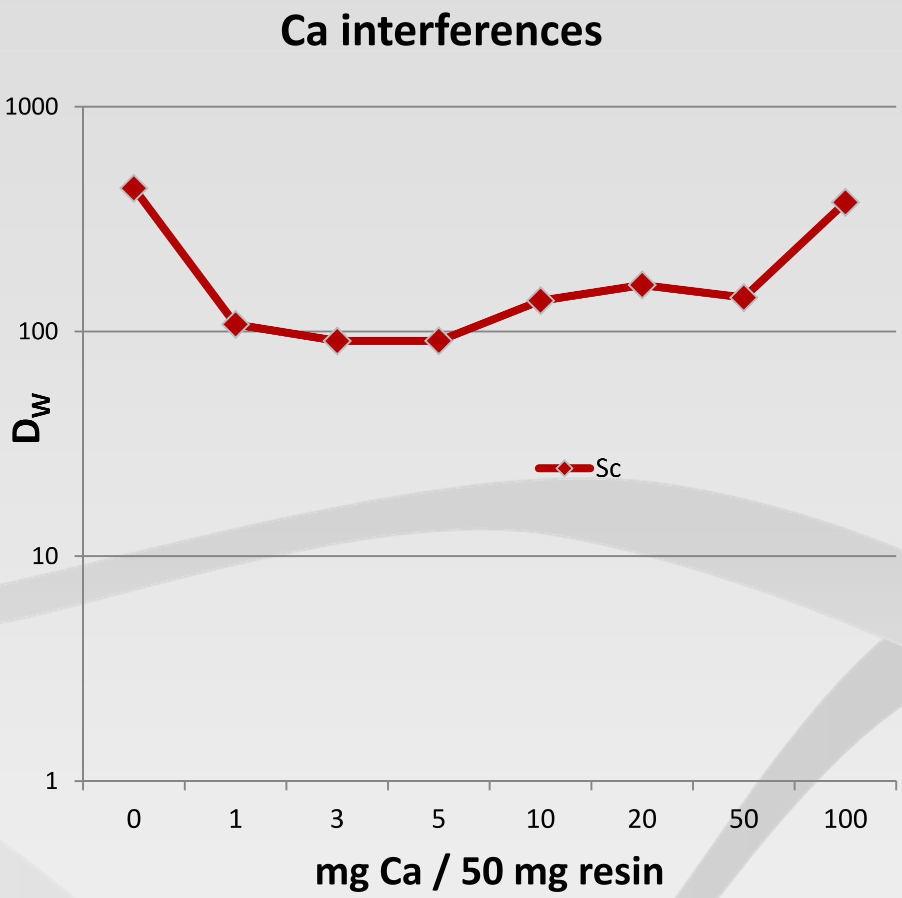


Sc uptake kinetics on TRU Resin in 2,5 M HNO_3

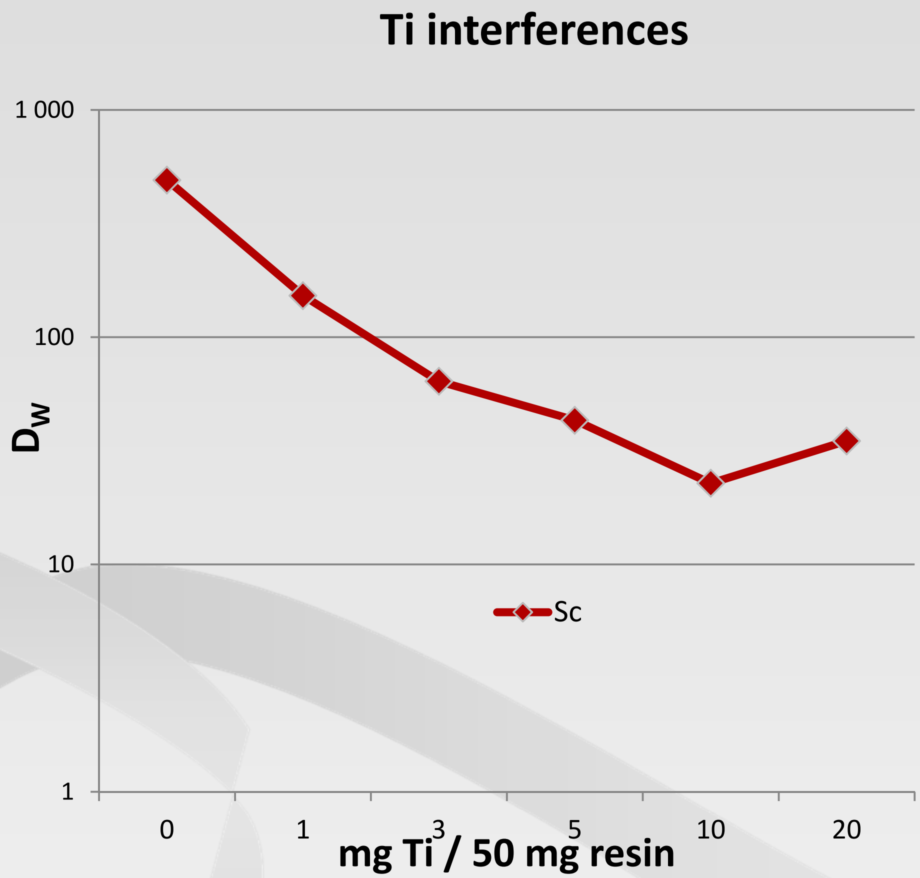
Kinetic: 2,5M HNO_3

- **1 min 89,4 %**
- **5 min 98,6 %**
- **10 min 95,4 %**

D_w Sc – interferences – TRU



D_w of Sc on TRU resin in 2,5 M HNO_3
In presence of increasing amounts of Ca

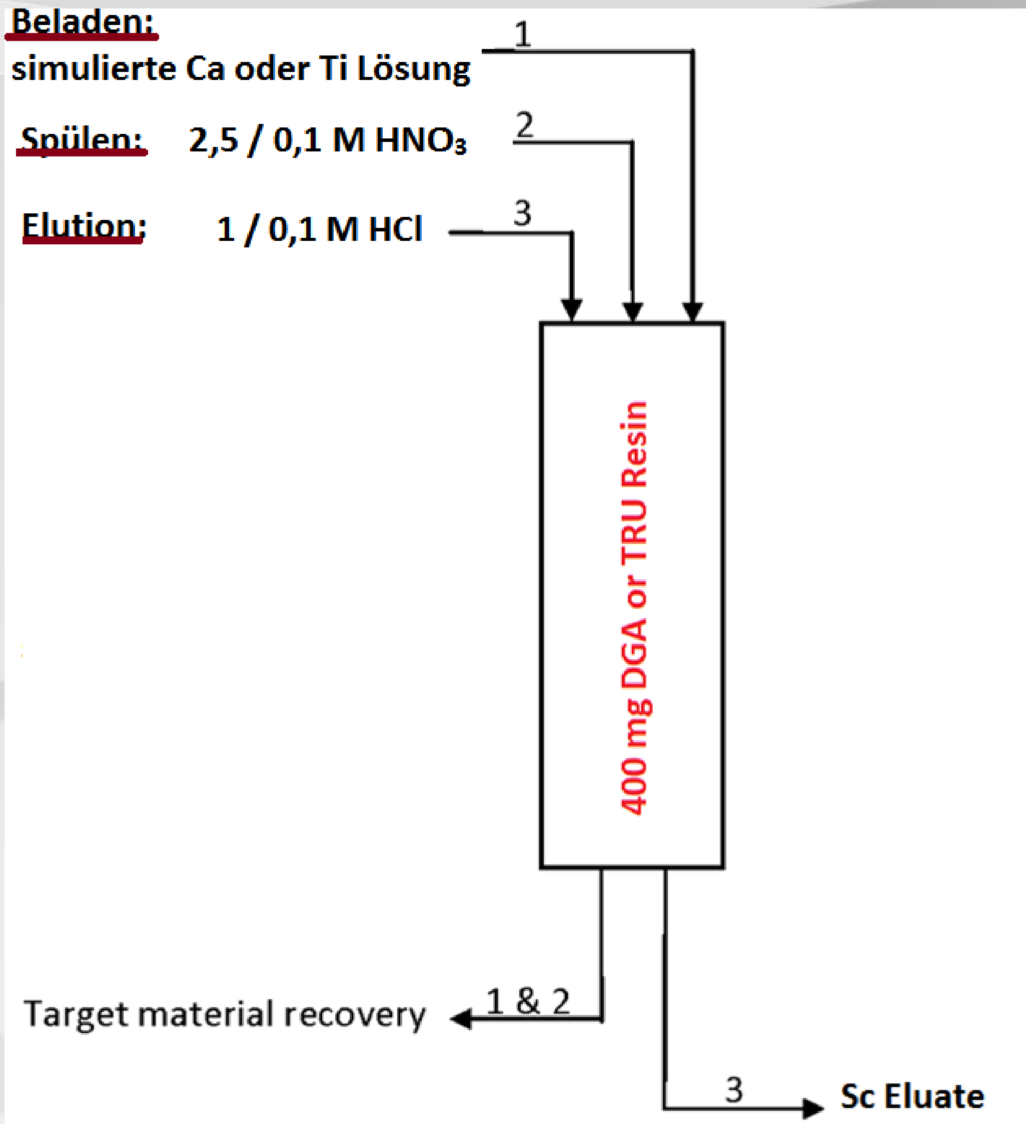


D_w of Sc on TRU Resin in 2,5 M HNO_3
In presence of increasing amounts of Ti

Conclusion II TRU resin

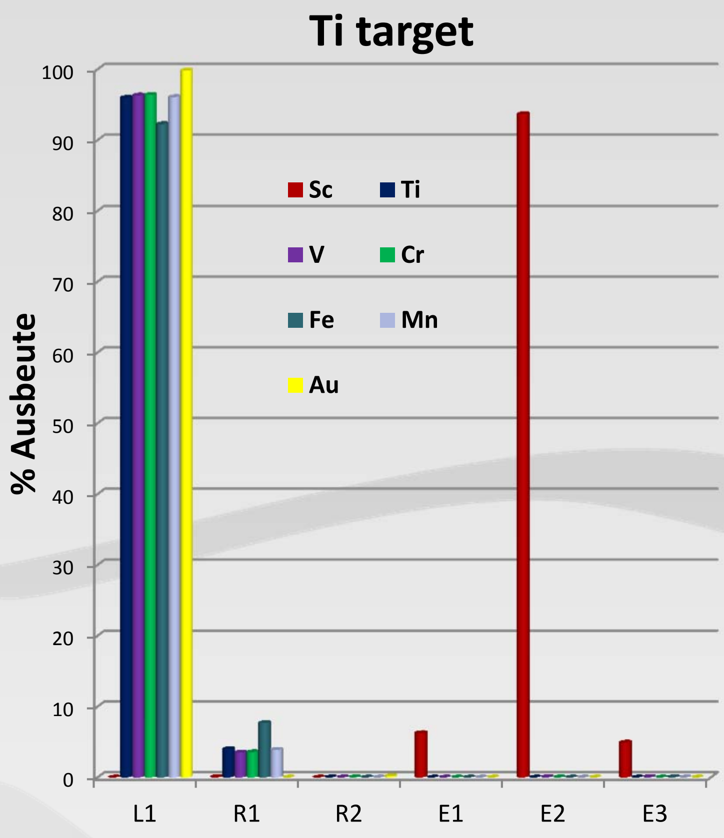
- ✓ Stable, high Sc D_w in 2,5 M HNO_3
- ✓ High Sc selectivity
- ✓ No selectivity for Ca or Ti
- ✓ Rapid extraction
- ✓ Loading from: **2,5 M HNO_3**
- ✓ Elution with: **1 M HCl for Ti- and Ca- Target**
  - **For Ca target: negligible interferences**
  - **For Ti target: at > 10 mg / 50 mg Resin : Ti interferences!**

General separation scheme

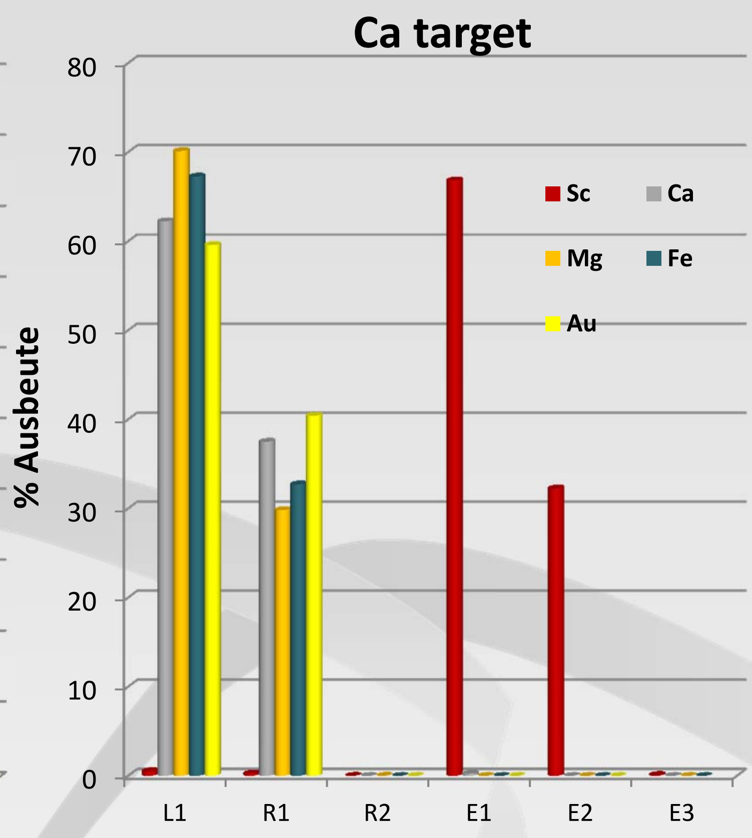


- **Load** : L1
- **Rinse** : R1 & R2
- **Elution** : E1 & E2

DGA: elutionstudy- simulated Ti- or Ca-target



Elution study simulated Ti-Target, 2 mL DGA Resin column



Elution study , simulated Ca-Target, 2 mL DGA Resin column

Load

L1 : 5 mL 2,5 M or 0,1 M HNO_3

Rinse:

R1 : 5 mL 2,5 M or 0,1 M HNO_3

R2 : 5 mL 2,5 M or 0,1 M HNO_3

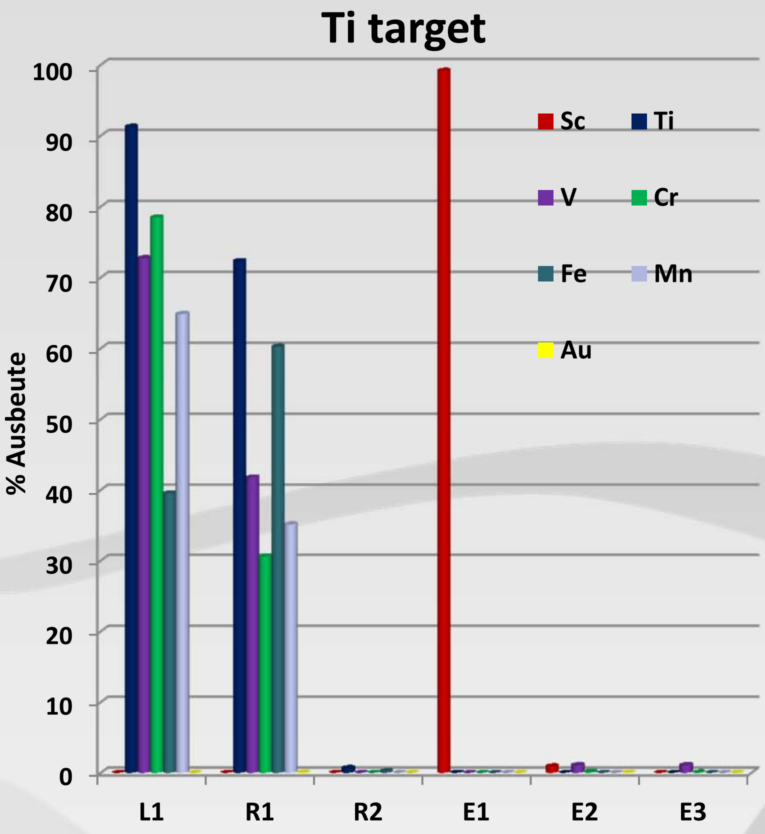
Elution:

E1 : 5 mL 0,1 M HCl

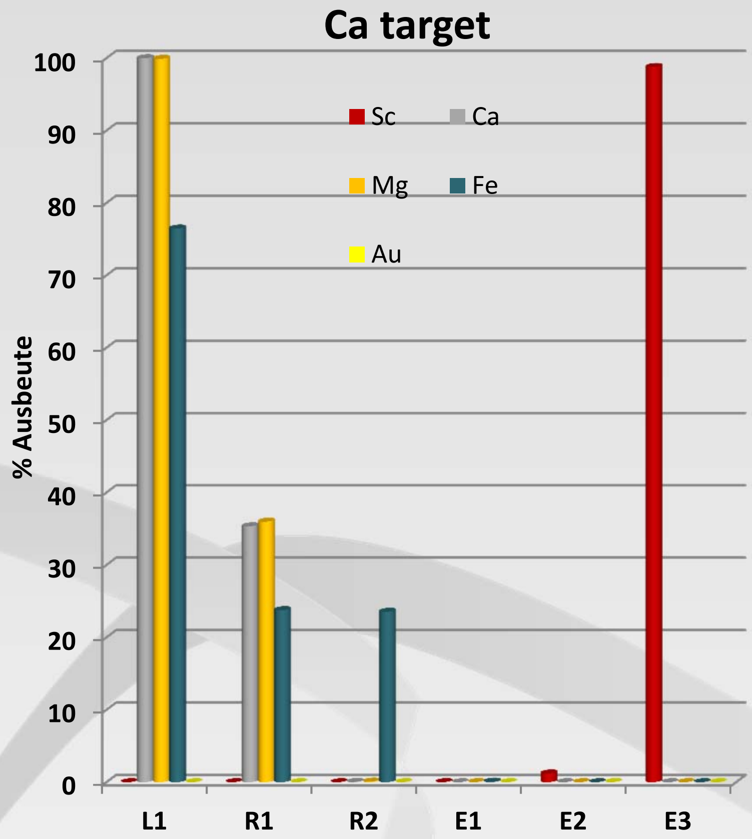
E2 : 5 mL 0,1 M HCl

E3 : 5 mL 0,1 M HCl

TRU: elution study-
simulated Ti- or Ca-target



Elution study simulated Ti-target, 2 mL TRU resin column



Elution study simulated Ca target, 2 mL TRU resin column

Load:

L1 : 5 mL 2,5 M HNO_3

Rinse:

R1 : 5 mL 2,5 M HNO_3

R2 : 5 mL 2,5 M HNO_3

Elution:

E1 : 5 mL 1 M HCl

E2 : 5 mL 1 M HCl

E3 : 5 mL 1 M HCl

Conclusion III

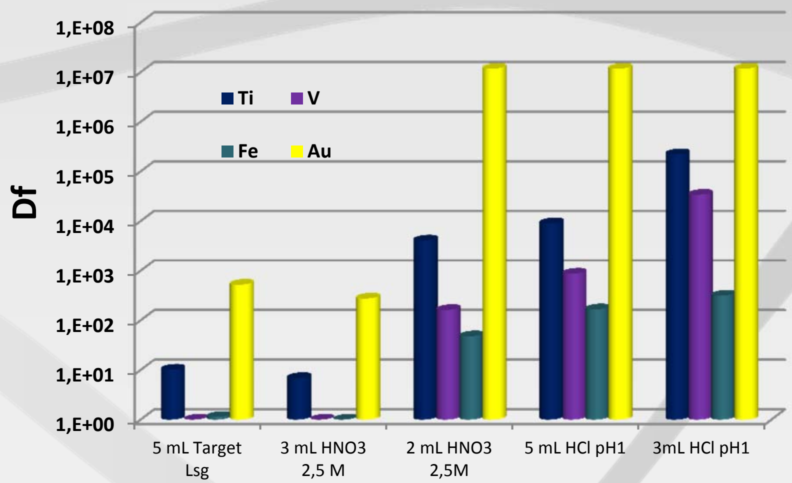
- ✓ High Sc selectivity on DGA and TRU resin
- ✓ Negligible Interferenzen from Ti and Ca
  (exception: TRU / Ti target)
- ✓ Rapid kinetics
- ✓ Quantitative Sc recovery in elution studies
- ✓ **Exzellente Sc separation (high purity)**
- ✓ Ti or Ca can be recovered in small volumes

DGA: Decontamination factors D_f

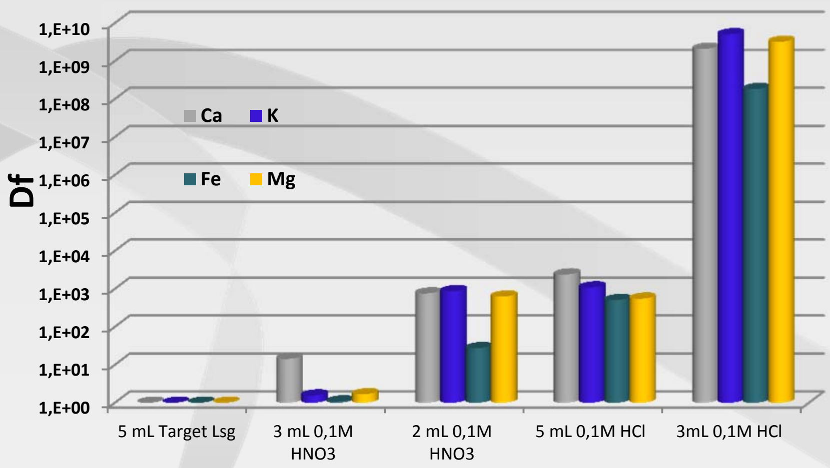
- Flow rate : 1-3 mL/min
- 0.4 g columns
- Loading solution: elevated amounts of Ca, Ti, Fe, V, Mg, K and Au
- Calculation of Decon faktors D_f for Sc fraktions

- Fraction E1 (5 mL 0.1 M HCl):
  - D_f: Au, Ti > 10 000; V, Fe > 500
- Fraction E2 (2 mL 0,1 M HCl):
  - D_f: Ti, Au > 200000, Fe > 300 V > 34000

- Fraction E1 (5 mL 0.1 M HCl):
  - D_f: Ca > 2500, K > 1000; Mg, Fe > 500
- Fraction E2 (2 mL 0,1 M HCl):
  - D_f: Ca, Mg, K, Fe > 100 000 000



Decon factors DGA resin (Ti target)



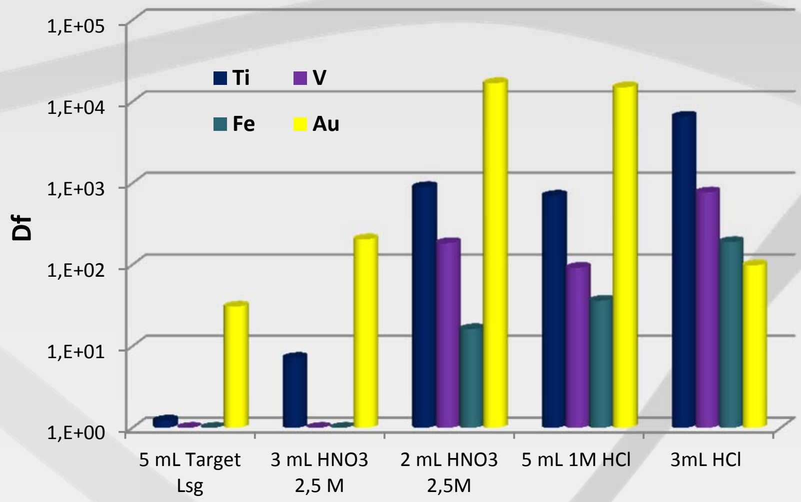
Decon factors DGA resin (Ca target)

TRU: Decontamination factors D_f

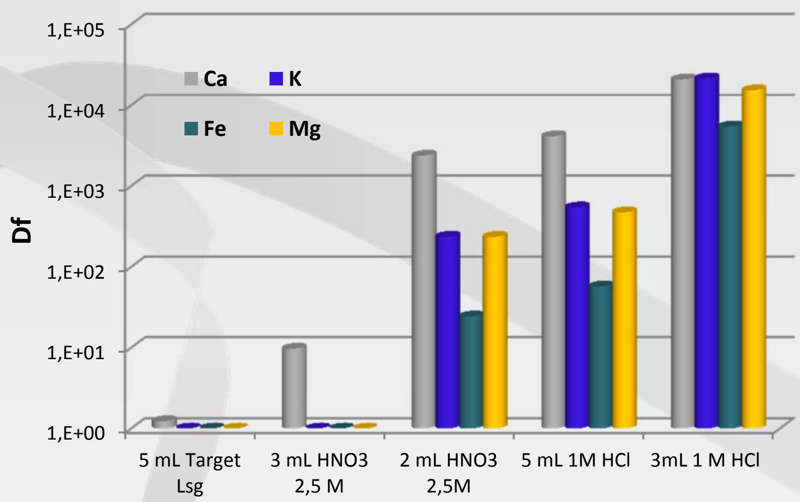
- Flow rate : 1-3 mL/min
- 0.4 g columns
- Loading solution: elevated amounts of Ca, Ti, Fe, V, Mg, K and Au
- Calculation of Decon faktors D_f for Sc fraktions

  - Fraction E1 (5 mL 1 M HCl):
    - D_f: Au, Ti > 10 000; V, Fe > 100
  - Fraction E2 (2 mL 1 M HCl):
    - D_f: Ti, Au > 6 500; Fe, V > 300

  - Fraction E1 (5 mL 1 M HCl):
    - D_f: Ca > 4000; Mg, K, Fe > 500
  - Fraction E2 (2 mL 1 M HCl):
    - D_f: Ca, Mg, K, Fe > 20 000



Decon factors TRU Resin (Ti Target)



Decon factors TRU Resin (Ca Target)

Optimized method

- Vacuum-supported flow (flow-rate: 1 – 3 mL/min)
  - **DGA resin** (400 mg)
    - Load from 5 mL 2.5 M HNO_3 (Ti) or 0.1 M HNO_3 (Ca)
    - Rinse with 4 mL and 2 / 3 mL 2.5 M HNO_3
    - Load and rinse contain~ 100% Ti or Ca
    - Sc elution in 5-7 mL 0.1 M HCl
  - **TRU resin** (400 mg)
    - Load from 5 mL 2.5 M HNO_3
    - Rinse with 4 mL and 2 mL 2.5 M HNO_3
    - Load and rinse contain~ 100% Ti or Ca
    - Sc elution in 5-8 mL 1 M HCl
  - Sc yield> 98%, high decon factors
- Separation time: 12 min

Perspectives

- Determination of TOC in Sc fraction
- Ca and Ti recovery for target preparation
- Optimisation of flow rates
- Irradiation of Ti and / or Ca targets
- Analytical applications (concentration and purification of Sc for ICP-MS)

Thank you very much!

- Prof. Jungclas, Kernchemie Marburg
- TrisKem International