Options for Separation and Measurement of $^{89}Sr/^{90}Sr$

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Yield tracers

analytes

Properties of Selected Nuclides								
		Decay		Detector Suitable for Measurement				
Nuclide	Half-Life	Mode	Energy	GFPC	LSC	Cerenkov	MS/AES	Gamma
^{82}Sr	25.35 days	ε						
^{82}Rb	1.25 min	β^+	β^+mean = 1479 keV γ = 511 keV (190.4%)					
^{85}Sr	64.849 days	ε/γ	γ = 514 keV (96%)	No	Yes	No	No	Yes
^{88}Sr	Stable			No	No	No	Yes	No
^{89}Sr	50.563 days	β^-	β_{max} = 1500 keV β_{mean} = 587 keV	Yes	Yes	Yes	No	No
^{90}Sr	28.79 years	β^-	β_{max} = 546 keV β_{mean} = 196 keV	Yes	Yes	No	Yes	No
^{90}Y	64 hours	β^-	β_{max} = 2280 keV β_{mean} = 934 keV	Yes	Yes	Yes	No	No

Methods and Application Notes

Sample Extraction / Dissolution

Matrix removal / Concentration (ppt, IX)

Sr Resin separation to isolate pure Sr fraction

Counting source preparation

Detailed instructions for $^{89}Sr/^{90}Sr$ discrimination

Factors

Quality Objectives

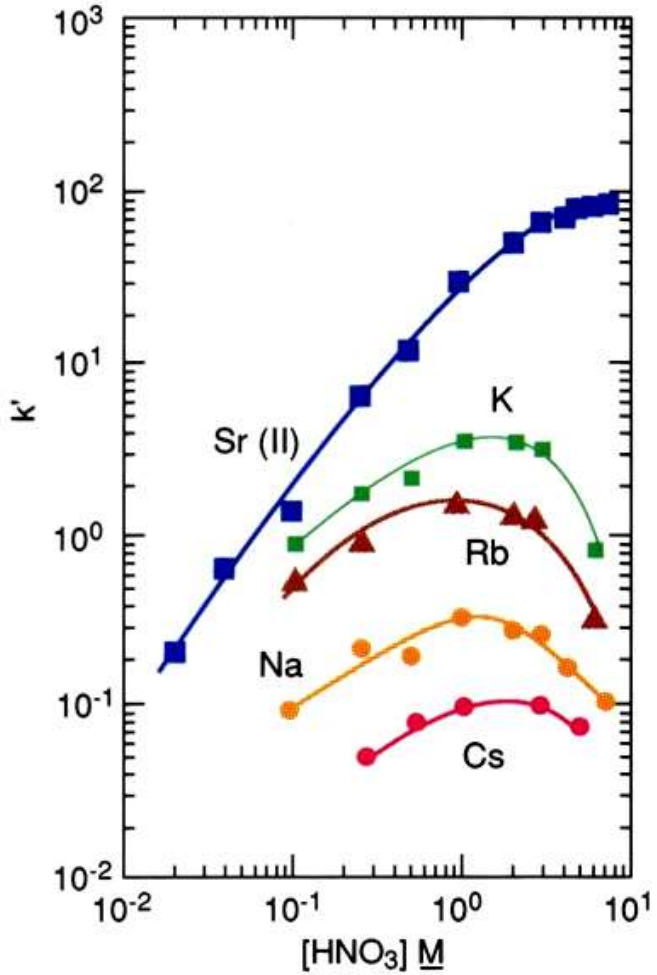
Ratio $^{89}Sr/^{90}Sr$

Urgency

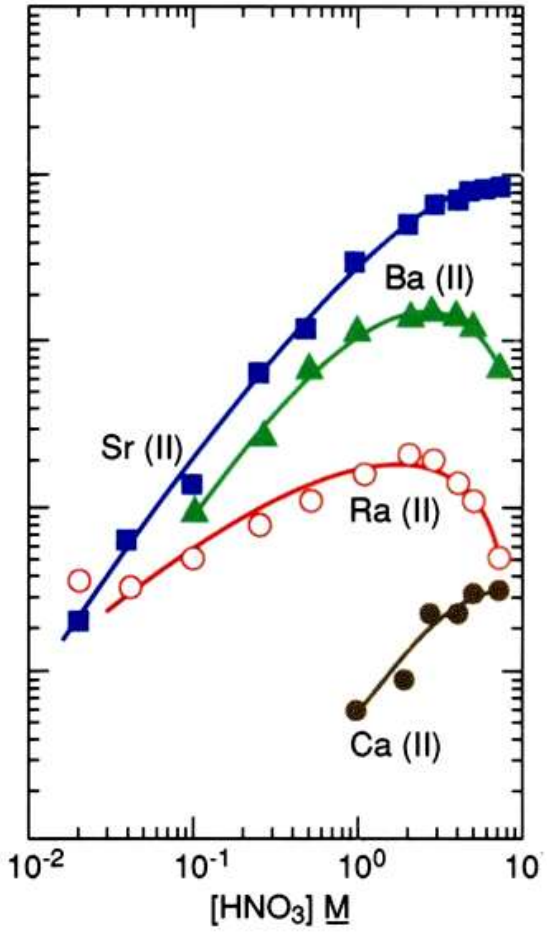
Budget

Available Equipment

Uptake on Sr Resin

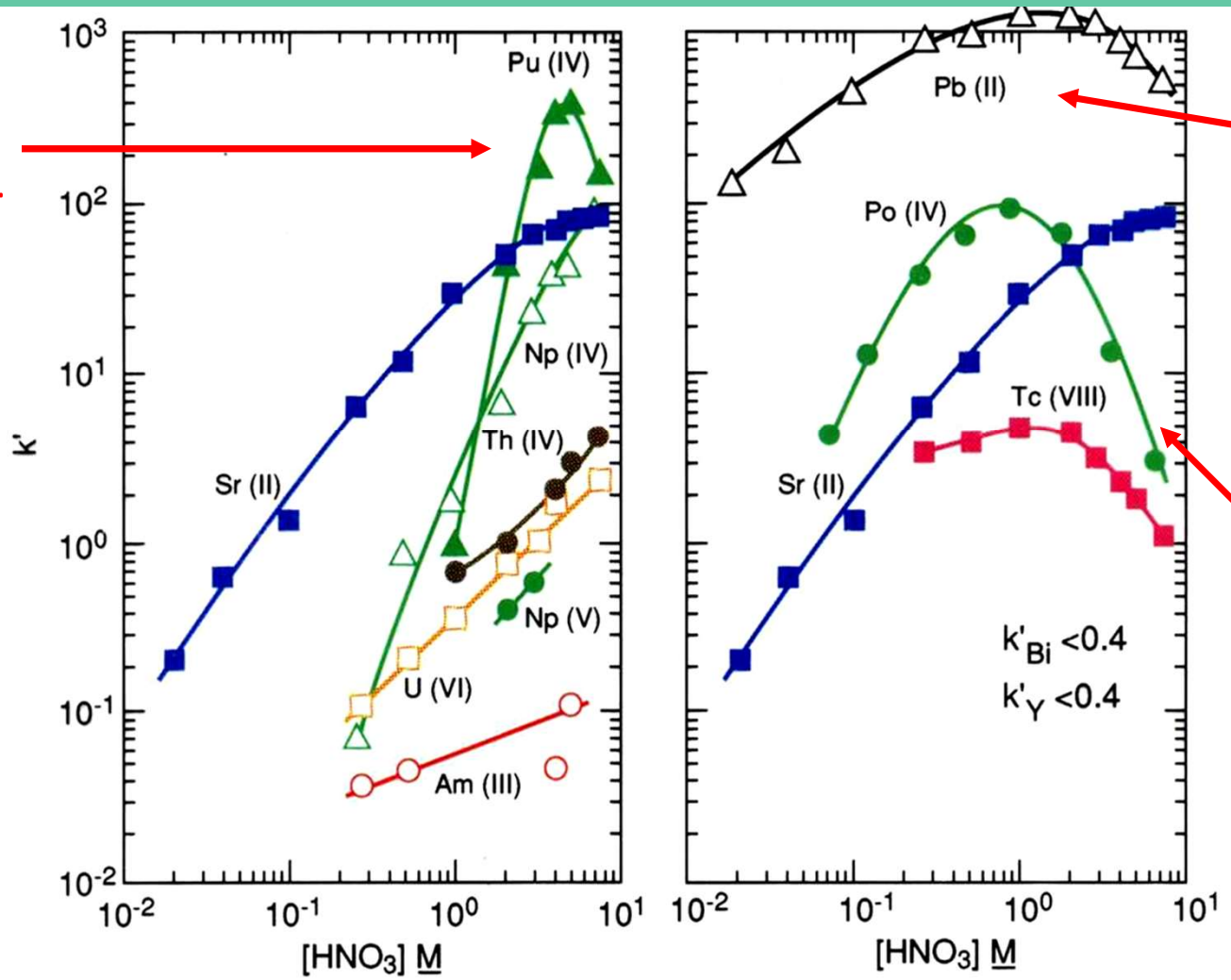


Load from 8M HNO_3 to reject Ba, Na, K.



Uptake on Sr Resin

Rinse with 3M HNO_3 – 0.05M Oxalic acid



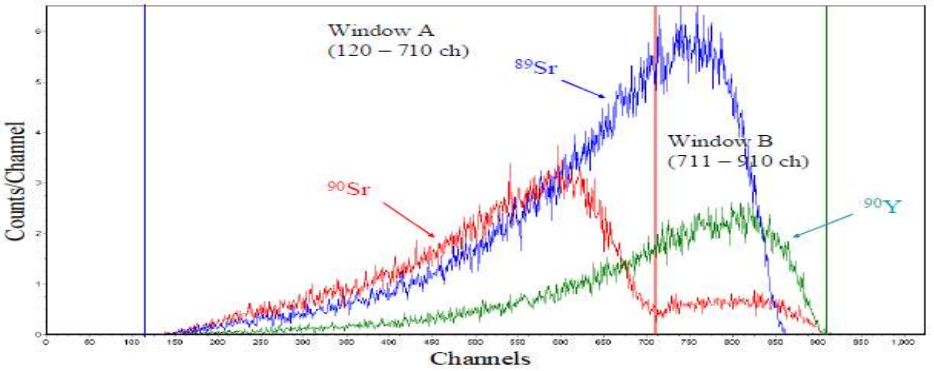
Pb remains on column when stripping Sr with dilute HNO_3.

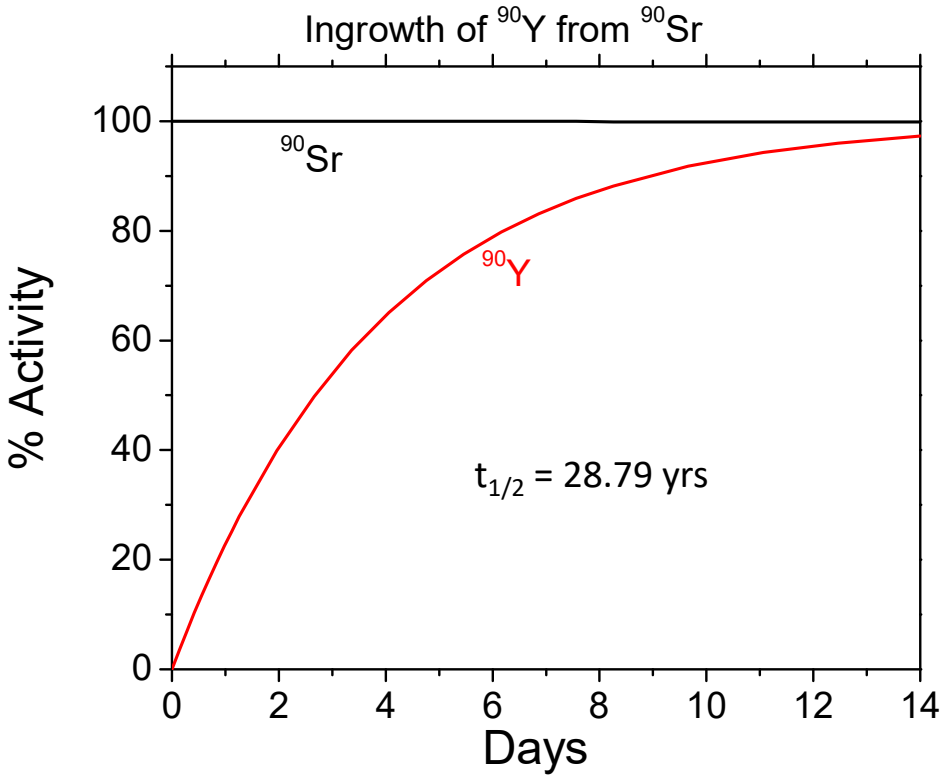
Po removed with 8M HNO_3.

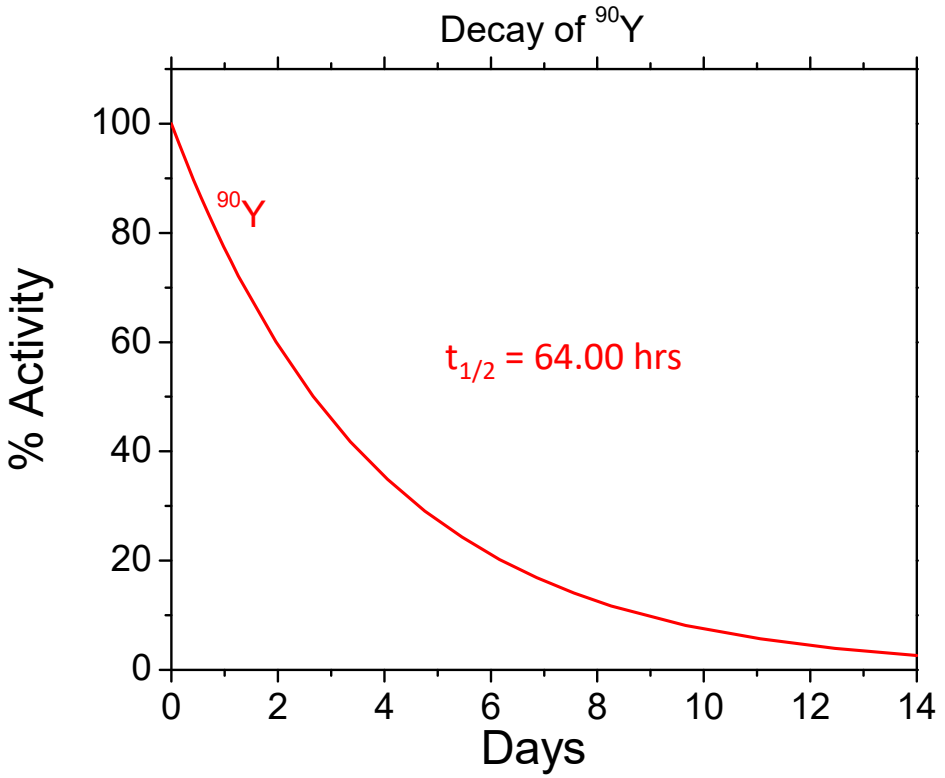
Why is $^{89}Sr/^{90}Sr$ Challenging?

Decay of $^{89}Sr/^{90}Sr$ + Ingrowth ^{90}Y

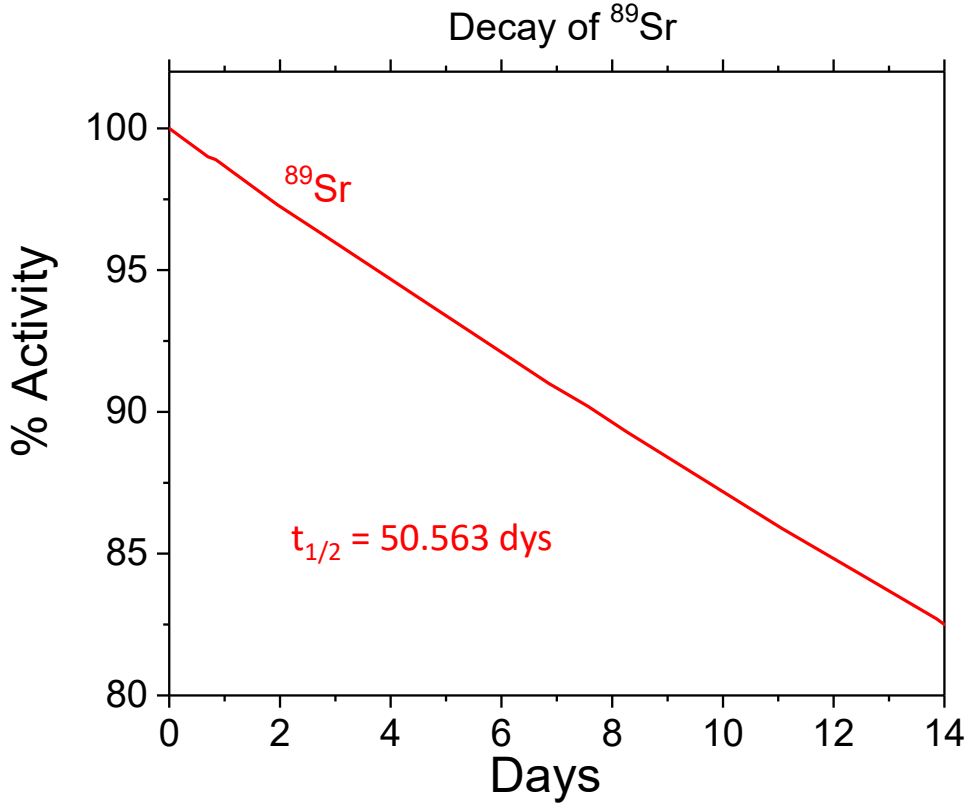
Pure Beta emitters





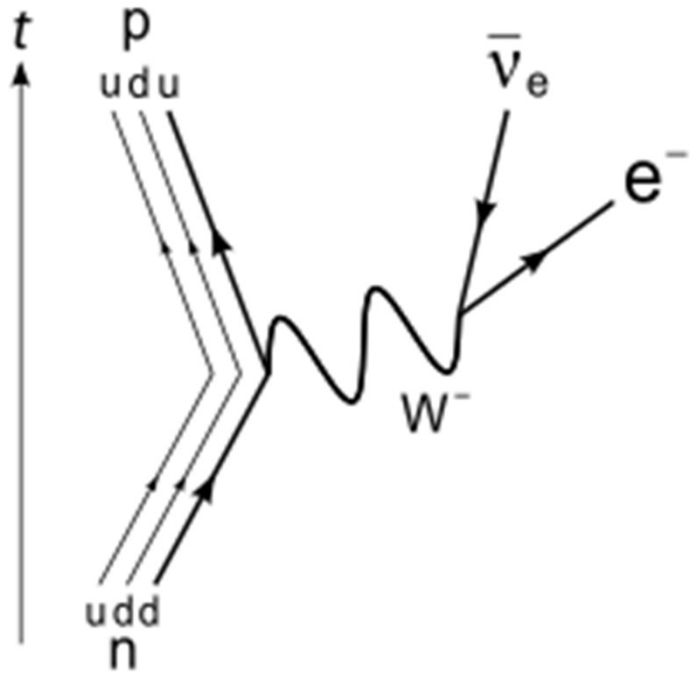


^{90}Y decays into stable ^{90}Zr



^{89}Sr decays into stable ^{89}Y

Beta/Positron Decay



https://en.wikipedia.org/wiki/Beta_decay

Beta emission accompanied by electron antineutrino.

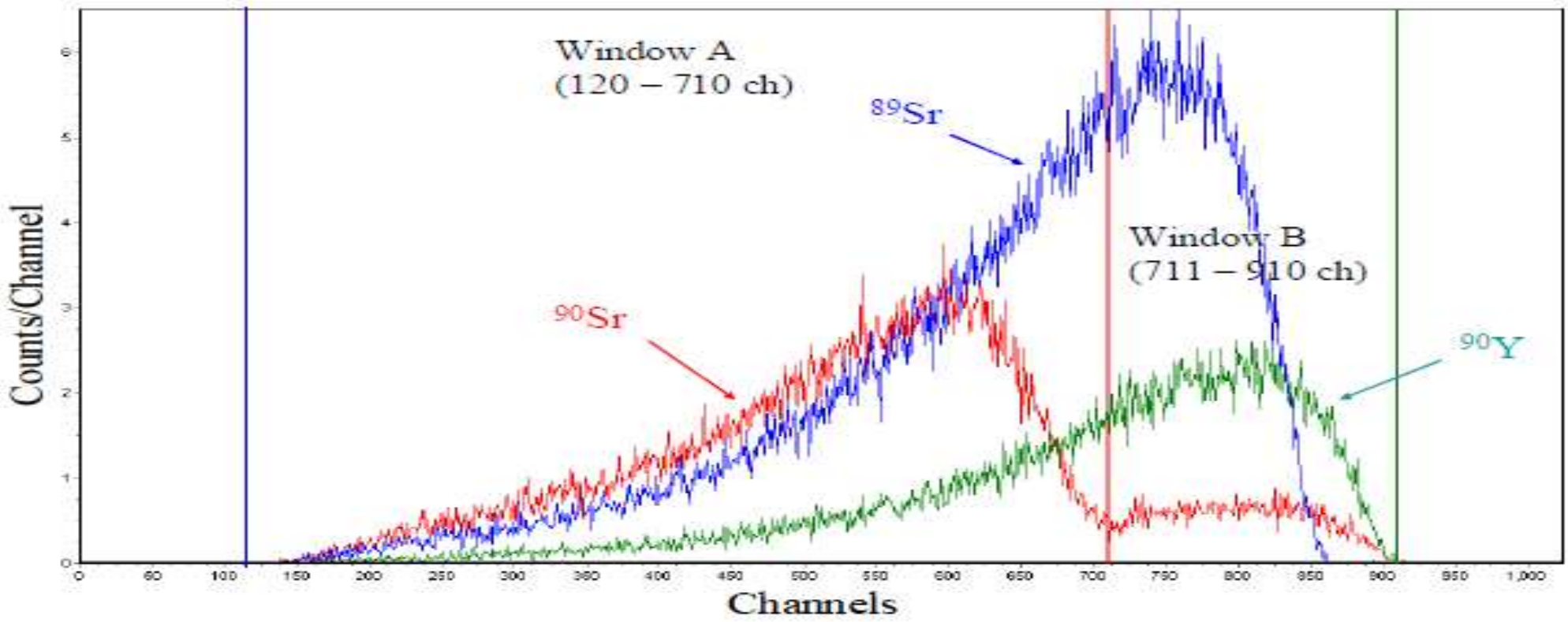
Energy distributed between electron and neutrino.

Neutrinos have very little interaction with matter (only weak force).

Measurement yields spectrum of electron energies with characteristic β^-_{max}.

Measurement Techniques

LSC Spectra



IAEA/AQ/27, “Rapid Simultaneous Determination of 89Sr and 90Sr in Milk: a Procedure Using Cherenkov and Scintillation Counting,” IAEA Analytical Quality in Nuclear Applications Series No. 27.

LSC Measurement

Pros:

4π geometry

High Efficiency

Cons:

Requires Cocktail

Quenching

Luminescence

Little Selectivity

Destructive

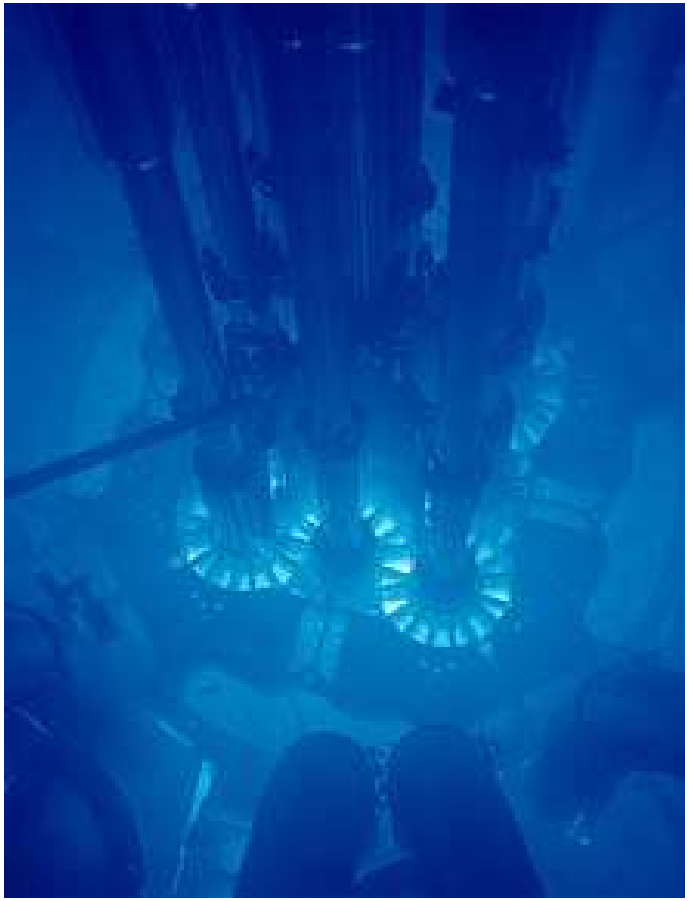
Cherenkov Radiation

The speed of light in a vacuum is a universal constant (c).

The speed at which light propagates in water is only ~0.75c. (function of refractive index)

Matter may be accelerated beyond this speed (>0.75c, <c) during nuclear reactions.

Cherenkov radiation results when a charged particle, most commonly an **electron**, travels through a dielectric medium with a speed greater than that at which light propagates in the same medium.



Cherenkov Spectra

Pros:

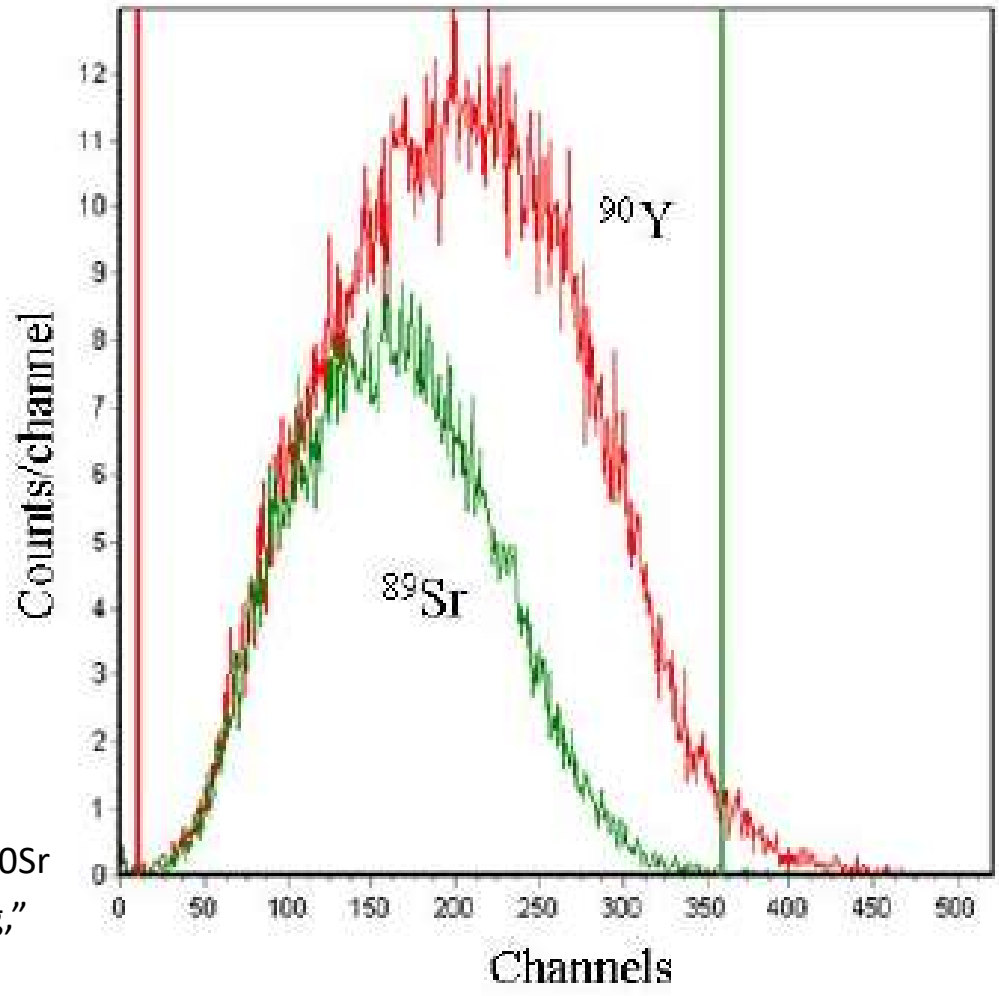
No cocktail = No Quench
No luminescence

Non-destructive

Selective for high energy β-/β+.
(Measure $^{89}Sr/^{90}Y$, reject ^{90}Sr)

Cons:

Lower Efficiency than LSC



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Gas Flow Proportional Counting

Pros:

Low background

Simultaneous counting

Non-destructive

Cons:

Efficiency (2π geometry)

Low selectivity (reject alpha)

http://www.canberra.com/products/radiochemistry_lab/alpha-beta-counters.asp

ICP-MS, ICP-AES, MP-AES , AA

- Screen samples for native Sr content.

- Yield tracer by stable Sr.

- ^{90}Sr (MS), relatively high levels.

Method Options

Following Matrix Removal/Sr Resin Isolation of Sr:

1) MS (^{90}Sr Only)

2) Two count methods
   - Different counting techniques
   - Same technique with period of ingrowth (^{90}Y)

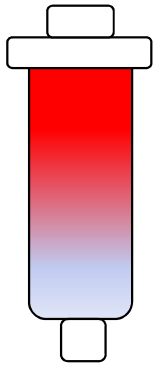
3) Count, ingrowth, Separate ^{90}Y

Mass Spectrometry

- ^{90}Sr Only, or ^{88}Sr yield monitor/native content.
- Separation: Concentrate, remove matrix + ^{90}Zr isobar.
- Limited to higher activity samples (half-life 28.79 yrs).
- Couple with radiometric detection for ^{89}Sr???

Feuerstein J, Boulyga S.F., Galler P., Stingeder G., Prohaska T., "Determination of ^{90}Sr in soil samples using inductively coupled plasma mass spectrometry equipped with dynamic reaction cell (ICP-DRC-MS)." *J. Environ. Radioact.* 11, 1764-9 (2008).

Cherenkov/LSC



Separate Sr

Count ^{89}Sr immediately by Cherenkov
(Limit impact of ^{90}Y ingrowth)

Add Cocktail.

Count $^{89/90}$Sr by LSC

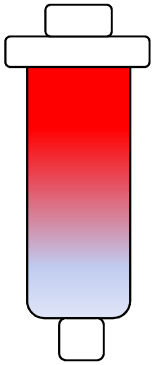
1 day, Bias: <20% ^{89}Sr and <40% ^{90}Sr

Ratios of ^{89}Sr/^{90}Sr activity of up to 35.

Fastest route to ^{89}Sr and ^{90}Sr.

IAEA/AQ/27, "Rapid Simultaneous Determination of 89Sr and 90Sr in Milk: a Procedure Using Cherenkov and Scintillation Counting," IAEA Analytical Quality in Nuclear Applications Series No. 27.

2-Count Methods



Separate Sr

Prepare Gas Flow Planchet or LSC source.

Count immediately for total $^{89/90}Sr$
(Limit impact of ^{90}Y ingrowth)

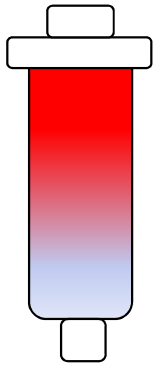
Wait 7-14 days for ^{90}Y Ingrowth
(Maximum ^{90}Y Ingrowth/Minimum ^{89}Sr decay)

Second Count. Solve equations to calculate ^{89}Sr and ^{90}Sr. (Appendix B)

Economical. Verify ^{90}Sr by ^{90}Y. Difficult to measure low ratios of ^{89}Sr.

EPA 402-R-10-001d, "Rapid Radiochemical Method for Total Radiostrontium (Sr-90) In Water for Environmental Remediation Following Homeland Security Events," October 2011.

Cherenkov/Cherenkov



Separate Sr

Count ^{89}Sr immediately by Cherenkov.
(Limit impact of ^{90}Y ingrowth)

Wait 7-14 days for ^{90}Y Ingrowth.

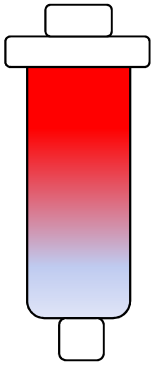
Acidify sample to 3-8 M HNO_3.

Separate ^{90}Y. Count by Cherenkov.

Rugged. Best $^{89}Sr/^{90}Sr$ discrimination.
Minimizes waste (no cocktail).

Banavali, A. D. et al. "Strontium-89, 90 Analysis by Eichrom Column Chemistry and Cherenkov Counting". 38th Annual Conference on Bioassay Analytical and Environmental Radiochemistry. Santa Fe, NM. November 1992.

GFPC/Ingrowth-Separation/GFPC



Separate Sr

Prepare Gas Flow Planchet.

Count immediately for total $^{89/90}Sr$.
(Limit impact of ^{90}Y ingrowth)

Wait 7-14 days for ^{90}Y Ingrowth

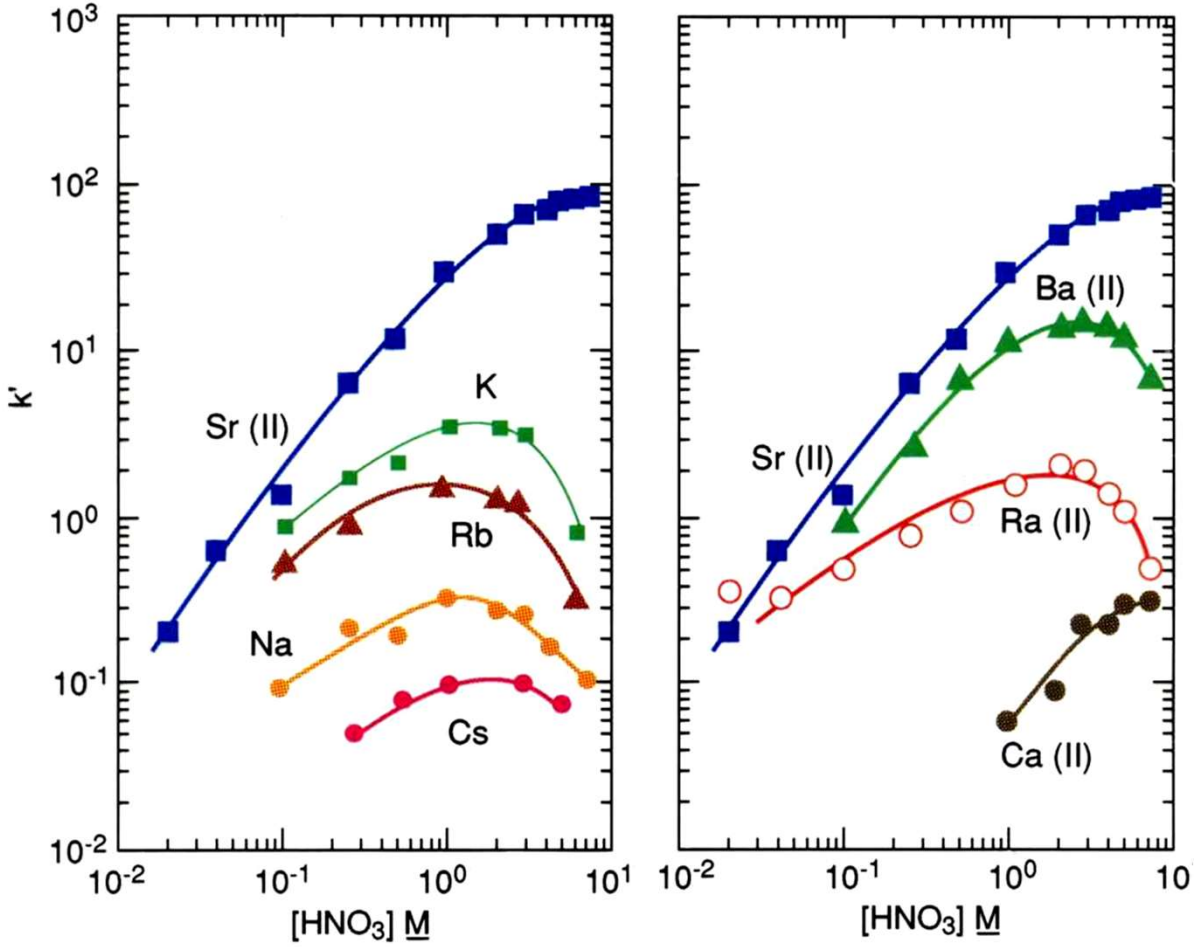
Dissolve sample with 3-8 M HNO_3.

Separate ^{90}Y. Prepare planchet and count ^{90}Y.

Rugged. Good $^{89}Sr/^{90}Sr$ discrimination.
Often lowest background method.

ASTM D5811-08, "Standard Test Method for Strontium-90 in Water."

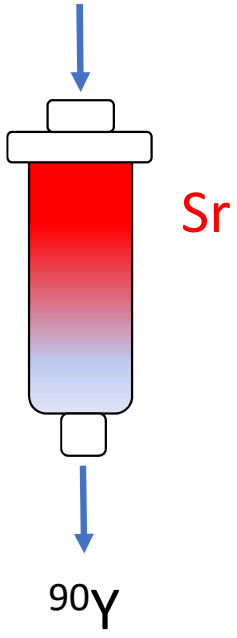
Uptake on Sr Resin



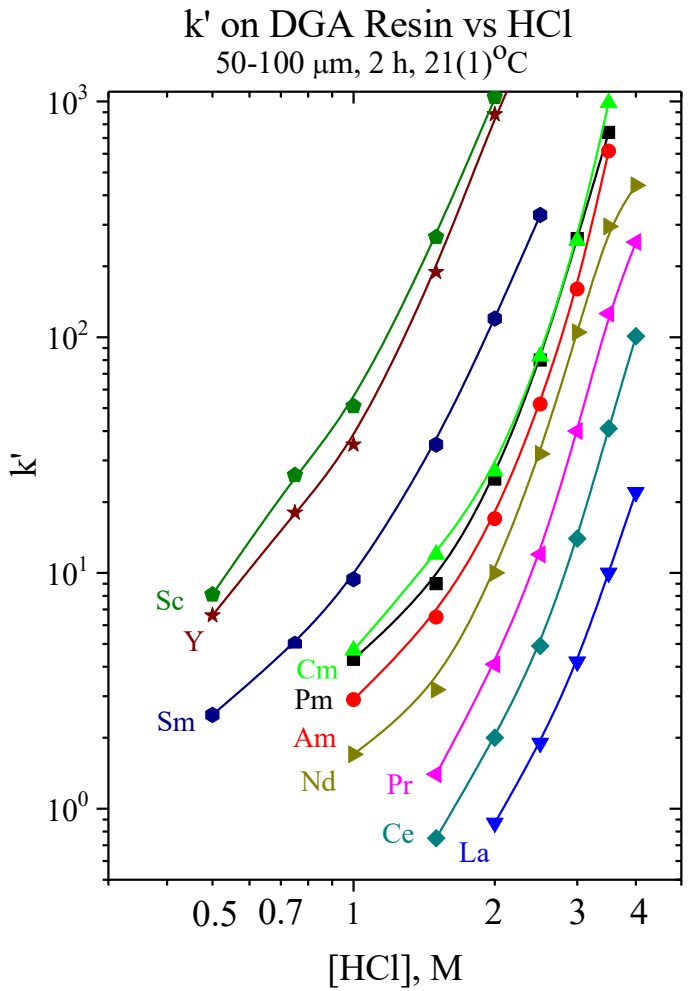
3-8M HNO_3

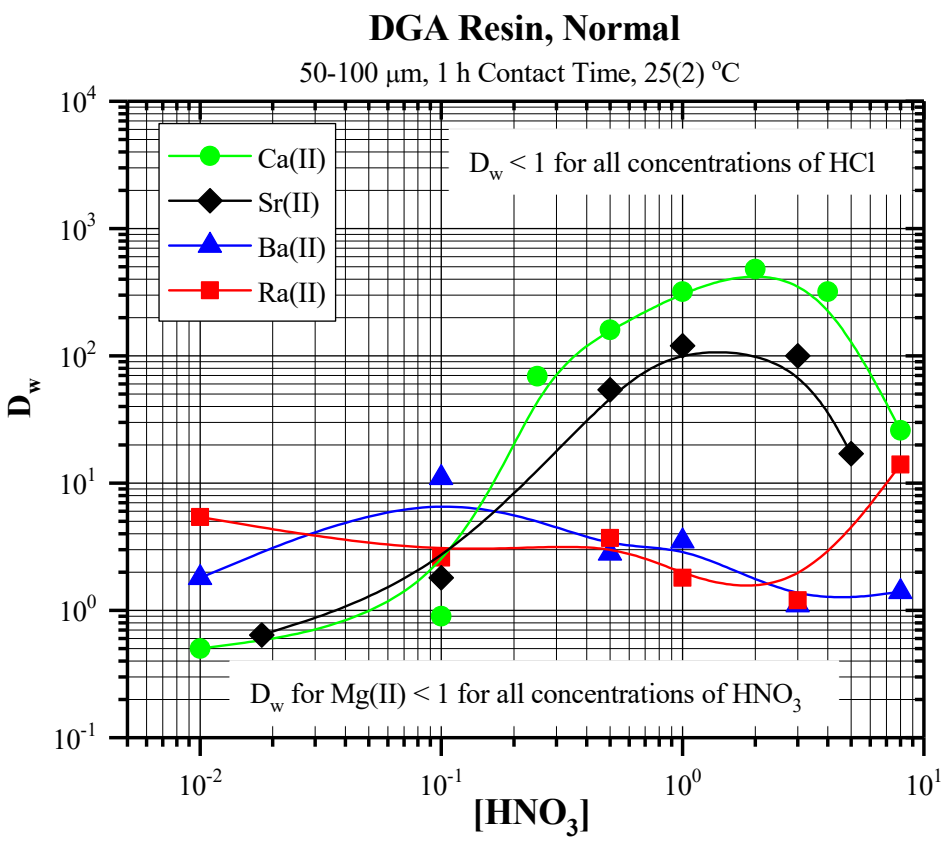
5 mg Stable Sr

$^{89/90}Sr + {}^{90}Y$



Uptake on DGA Resin, Normal

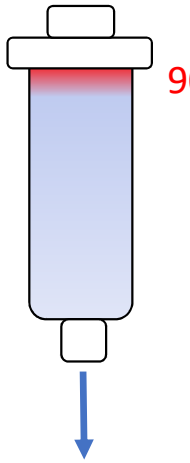




3-8M HNO_3

5 mg Stable Sr

$^{89/90}Sr + {}^{90}Y$



Sr

Rinse, Rinse, Rinse!

Conclusions

- The are many options for the discrimination of ^{89}Sr and ^{90}Sr

- $^{89}Sr/^{90}Sr$ discrimination may be achieved by selective measurement techniques, ingrowth of ^{90}Y, and/or separation of ingrown ^{90}Y.

- The method choice must take into account factors such as:

  - Quality Objectives
  - Ratio $^{89}Sr/^{90}Sr$
  - Urgency
  - Budget
  - Available Equipment

Questions???