STRONTIUM-89/90 IN WATER

(WITH VACUUM BOX SYSTEM)

1. SCOPE

1.1. This is a method for the separation and measurement of strontium-89/90 in water.

1.2. This method does not address all aspects of safety, quality control, calibration or instrument set-up. However, enough detail is given for a trained radiochemist to achieve accurate and precise results for the analysis of the analyte(s) from the appropriate matrix, when incorporating the appropriate agency or laboratory safety, quality and laboratory control standards.

2. SUMMARY OF METHOD

2.1. Strontium is separated using Eichrom Sr Resin prior to gas flow proportional counting, liquid scintillation counting or Cerenkov counting. Cation exchange resin or calcium phosphate precipitation is used to concentrate strontium from water samples. Stable strontium and/or strontium-85 tracer are used to monitor method yields and correct results to improve precision and accuracy.

3. SIGNIFICANCE OF USE

3.1. This is a rapid, reliable method for the measurement of strontium in water samples.

4. INTERFERENCES

4.1. The presence of elemental strontium in the sample may bias the gravimetric yield determination. If it is suspected that natural strontium is present in the sample, its concentration should be determined by a suitable means and the yield calculation appropriately modified.

4.2. Strontium must be separated from interfering isotopes of other elements to enable measurement by beta counting.

4.3. Sr Resin with an 8M HNO_3 load solution is used to effectively remove barium-140 and potassium-40 isotopes as well as other matrix interference's. Tetravalent plutonium, neptunium, cerium and ruthenium, however, are not removed using nitric acid. If necessary, these isotopes can be effectively removed by including an additional rinse of 3M HNO_3-0.05M oxalic acid.

5. APPARATUS

- Beta detector –gas flow proportional, liquid scintillation or Cerenkov counter and appropriate counting planchet or vial.
- Fume hood
- Heat lamp
- Hot plate
- Plastic bottles or Glass Beakers, 1L
- Vacuum box, Eichrom Part: AR-BOX-12 or AR-BOX-24
- Vacuum box inner support tubes, Eichrom Part: AR-1000-TUBE-PE
- Vacuum box yellow outer tips, Eichrom Part AR-1000-OT
- Vacuum pump, Dry Pump, 115V, 60 Hz, Fisher Part: 01-092-25 or equivalent
- Volumetric flask or cylinder, 1L

For Ion Exchange Preconcentration Option:

- *Column reservoirs,* 250mL to 1L volume, Eichrom Part: AC-20X-20M
- *Ion exchange columns,* 1 to 1.5 cm diameter, 10 mL resin volume, Eichrom Part: AC-20E-20M

For Calcium Phosphate Precipitation Preconcentration Option:

- *Centrifuge, with rotor and carriers for 50mL and 250mL tubes*
- *Centrifuge Tubes,* 50mL and 250mL

For Sr-85 yield tracer option:

- *Gamma spectrometry system*

6. REAGENTS

Note: Analytical grade or ACS grade reagents are recommended. Evaluation of key reagents, such as aluminum nitrate and ammonium hydrogen phosphate, for contribution to method background levels from naturally occurring radioactive materials is recommended.

Deionized water, all reagents are prepared using deionized water
Nitric acid (70%), concentrated HNO_3
Oxalic acid dihydrate, $C_2H_2O_4 \cdot 2H_2O$

Strontium nitrate, $Sr(NO_3)_2$ **-or-** Sr-85 yield tracer
$Sr^{®}$ resin, 2mL prepacked cartridge, 50-100μm, Eichrom Part: SR-R50-S
If Counting Radiostrontium by Liquid Scintillation: *Liquid scintillation cocktail*
If Preconcentrating Sr by Cation Exchange: *Cation exchange resin* - hydrogen form, 100 to 200 mesh, Eichrom Part: C8-B500-M-H
If Preconcentrating Sr by Calcium Phosphate Precipitation: *Aluminum nitrate nonahydrate,* $Al(NO_3)_3 \cdot 9H_2O$ *Ammonium hydrogen phosphate,* $(NH_4)_2HPO_4$ *Sodium Hydroxide, NaOH* *Calcium nitrate,* $Ca(NO_3)_2$ *Isopropyl alcohol,* C_3H_7OH *Phenolphthalein pH indicator*

6.1. *Nitric acid (3M)* - Add 188mL of concentrated HNO_3 to 800mL of water. Dilute to 1L with water.

6.2. *Nitric acid (3M) - oxalic acid solution (0.05M)*- Add 188mL of concentrated HNO_3 and add 6.3g of oxalic acid dihydrate to 800 mL of water and dilute to 1 liter with water.

6.3. *Nitric acid solution (0.05M)* - Add 3.1mL of concentrated HNO_3 to 900mL of water. Dilute to 1 liter with water.

6.4. *Nitric acid solution (8M)* - Add 500mL of concentrated HNO_3 to 400mL of water. Dilute to 1L with water.

6.5. *Strontium (Sr) carrier (5 mg/mL), gravimetric* - Dissolve 12.1g $Sr(NO_3)_2$ 800mL of water. Dilute to 1L with water.

6.6. **Prepare Only if Using Cation Exchange Preconcentration:**

6.6.1. *Nitric acid solution (0.1M)* - Add 6.3mL of concentrated HNO_3 to 900mL of water. Dilute to 1L with water.

6.7. **Prepare Only if Using Calcium Phosphate Precipitation Preconcentration:**

6.7.1. *Ammonium hydrogen phosphate (3.2M)* - Dissolve 106g of $(NH_4)_2HPO_4$ in 200mL of water. Heat gently to dissolve. Dilute to 250mL with water.

6.7.2. *Calcium nitrate (1.25M)*- Dissolve 51g of $Ca(NO_3)_2$ in 100mL of water. Dilute to 250mL with water.

6.7.3. *Phenolphthalein solution*- Dissolve 1g phenolphthalein in 100mL 95% isopropyl alcohol. Dilute with 100mL of water.

6.7.4. *Sodium Hydroxide (12M)* – Carefully dissolve 240g NaOH in 350mL of water (Solution will become very warm). Dilute to 500mL with water.

6.7.5. *A*luminum Nitrate (1M) - Dissolve 375g of $Al(NO_3)_3 \cdot 9H_20$ in 600mL of water. Dilute to 1L with water.

7. PROCEDURE

7.1. Water Sample Precipitation

7.1.1. If samples larger than 1L are analyzed, evaporate the sample to approximately 1L.

7.1.2. Measure the sample volume using a standard graduated cylinder (or equivalent) and transfer volume to an appropriate size plastic bottle (cation exchange) or glass beaker (calcium phosphate).

7.1.3. Acidify the sample to pH 2 using concentrated nitric acid.

7.1.4. Add 1 mL of 5mg/mL strontium carrier (for gravimetric yield option) or strontium-85 tracer (for gamma yield determination option) into each sample aliquot.

7.2. Preconcentration of Sr:

7.2.1. Cation Exchange to Concentrate Strontium from Water Samples:

Note: Alternatively, evaporation to dryness (when insoluble residues such as calcium sulfate do not form) and calcium phosphate precipitation (7.2.2.) can be used to concentrate strontium.

7.2.1.1. Prepare a cation exchange column containing 10mL of C8-B500-M-H, 100-200 mesh in a 20mL plastic chromatography column for each sample analyzed. Slurry resin in ~20mL of deionized water. Pour slurry into empty column. Allow resin to settle and water to drain from each column.

7.2.1.2. Place columns on rack with large volume reservoirs (250mL to 1L).

7.2.1.3. Ensure that a suitable container is below each column.

7.2.1.4. Add 20mL of 0.1M HNO_3 to each column to precondition columns. Allow fluid to drain to the top of the column via gravity.

7.2.1.5. Load each sample onto the appropriate column and allow to drain. (Strontium will be retained by the column).

7.2.1.6. Rinse each column with 25mL of 0.1 M HNO_3.

7.2.1.7. Discard the feed and rinse the solution collected.

7.2.1.8. Ensure that a labeled 150mL beaker is below each column.

7.2.1.9. Add 50mL of 8M HNO_3 to each column to elute strontium.

7.2.1.10. Place each beaker on a hot plate in a fume hood and evaporate to dryness.

7.2.1.11. Dissolve residue in 10mL of 8M HNO_3.

7.2.2. Calcium Phosphate Precipitation Preconcentration Option:

7.2.2.1. Add 2mL of 1.25M $Ca(NO_3)_2$ to each sample.

7.2.2.2. If sample volume is greater than 200mL then place samples on a hotplate.

7.2.2.3. Heat to 60-80^oC.

7.2.2.4. Add 0.75mL of phenolphthalein indicator and 5 mL of 3.2M $(NH4)_2HPO_4$ solution per liter of sample.

7.2.2.5. While stirring, slowly add enough 12M NaOH to reach the phenolphthalein end point (pH 9-10) and form a calcium phosphate precipitate. Continue heating and mixing for 15-20 minutes.

7.2.2.6. Cool to room temperature. Allow precipitate to settle until solution can be decanted (30 minutes to 2 hours) or centrifuge in 250mL aliquots.

7.2.2.7. Decant supernate and discard to waste.

7.2.2.8. Dissolve precipitate in 7mL 70% HNO_3 and 8mL of 1M $Al(NO_3)_3$.

7.3. Sr Resin Column Preparation:

7.3.1. Place the inner tube rack (supplied with vacuum box system) into the vacuum box with centrifuge tubes in the rack. Fit the lid to the vacuum system box. Alternatively, a vacuum box inner liner may be used.

7.3.2. Place yellow outer tips into all 12 or 24 openings in the lid of the vacuum box. Fit a white inner support tube into each yellow tip.

7.3.3. For each sample solution, fit a Sr Resin cartridge on to the inner support tube.

7.3.4. Add syringe barrels (funnels/reservoirs) to the top end of each Sr Resin cartridge.

7.3.5. Connect the vacuum pump to the box. Turn the vacuum pump on and ensure proper fitting of the lid.

Note: The unused openings on the vacuum box should be sealed. Vacuum manifold plugs can be used to plug unused white tips to achieve good seal during the separation. Alternatively, unused vacuum box holes can be sealed with scotch tape.

7.3.6. Add 5mL of 8M HNO_3 into each Sr Resin cartridge reservoir. Adjust vacuum to achieve a flow rate of 1-2mL/min. Allow solution to completely drain through each cartridge.

7.4. Sr Resin Separation:

7.4.1. Transfer each dissolved sample into the appropriate Sr Resin cartridge reservoir. Allow solution to completely drain through each cartridge at 1-2mL/min.

7.4.2. Add 5mL of 8M HNO_3 to rinse to each sample beaker or centrifuge tube. Transfer the rinse solution into the appropriate Sr Resin cartridge reservoir. Allow solution to completely pass through each cartridge at 1-2mL/min. Place clean reservoirs about each Sr Resin cartridge.

7.4.3. Rinse each column with 5mL of 3M HNO_3 - 0.05M oxalic acid. Allow solution to drain.

Note: The 3M HNO_3 - 0.05M oxalic acid removes Pu(IV), Np(IV), Zr(IV), or Ce(IV), which are retained by Sr Resin. If these interference's are known to be absent, this step may be skipped.

7.4.4. Add 5mL of 8M HNO_3 to each Sr Resin cartridge reservoir. Allow the solution to completely drain through each cartridge at 1-2mL/min.

Note: This additional 8M HNO_3 rinse removes any residual oxalic acid and ensures full removal of K^+ and Ba^{2+} that may be present.

7.4.5. Record the time when the last rinse completely drains through each cartridge as the start of yttrium ingrowth. Discard eluate to this point as waste.

7.4.6. Disengage vacuum. Place clean, labeled centrifuge tubes are below each cartridge for Sr recovery. Replacing yellow outer tips and inner support tubes at this point can help ensure clean Sr fractions in the following steps.

7.4.7. Add 15mL of 0.05M HNO_3 to each Sr Resin cartridge reservoir to elute Sr. Engage vacuum. Allow solution to completely pass through each cartridge at 1mL/min.

7.4.8. Ensure that calibration standards are prepared per step 7.5 and GOTO 7.6 or 7.7 to count samples.

7.4.9. Place cartridges in sealed in plastic bags or centrifuge tubes for use in ^{90}Y separation following ingrowth period.

7.5. Preparation of Pure ^{90}Sr and Pure ^{90}Y for Counter Calibration Sources:

7.5.1. Add an appropriate volume of calibrated ^{90}Sr standard solution (in equilibrium with ^{90}Y) to a small beaker, add 1mL of Sr carrier and evaporate the solution to dryness.

7.5.2. Redissolve the residue in 5mL of 8M HNO_3.

7.5.3. Place a waste tube below a Sr Resin cartridge.

7.5.4. Add 5mL of 8M HNO_3 into a Sr cartridge reservoir to condition resin. Allow to solution to completely drain through the cartridge.

7.5.5. Place a clean centrifuge tube below the Sr Resin cartridge.

7.5.6. Transfer the redissolved residue into the appropriate Sr Resin cartridge reservoir. Allow solution to completely drain through Sr Resin cartridge.

7.5.7. Add 5mL of 8M HNO_3 to rinse to the beaker. Transfer the rinse solution into the Sr Resin cartridge reservoir. Allow solution to completely to drain through cartridge.

7.5.8. Add 5mL of 8M HNO_3 to the Sr Resin cartridge reservoir. Allow the solution to completely drain.

7.5.9. Set ^{90}Y fraction aside for source preparation. Place a clean, labeled centrifuge tube below each Sr Resin cartridge for ^{90}Sr recovery.

7.5.10. Add 10mL of 0.05M HNO_3 to the Sr Resin cartridge reservoir to strip the ^{90}Sr. Allow the solution to completely pass through the resin.

7.5.11. Prepare the ^{90}Sr from step 7.5.10. as appropriate for use as a calibration standard by evaporation on planchet or addition to liquid scintillation cocktail.

7.5.12. Prepare the ^{90}Y fraction as appropriate for use as a calibration standard by evaporation on a planchet, addition to liquid scintillation cocktail or rare earth fluoride micro precipitation (Eichrom Method SPA01).

7.6. Gas Proportional Counting Option for Sr Fractions:

Note: Gas proportional counting provides lower detection limits than liquid scintillation counting or Cerenkov counting.

7.6.1. For each sample analyzed, clean a cupped planchet with a paper towel moistened with ethanol. Let counting dishes dry.

Note: Planchets can also be annealed in an oven at 450°C for 1.5 hours. Properly annealed planchets will appear bronze/brown in color. Do not overheat planchets or they could become more susceptible to acid degradation.

7.6.2. Weigh the planchets on an analytical balance and record the weight.

7.6.3. Place each planchet on a hot plate in a hood. Arrange planchets so that each planchet is heated to approximately the same temperature (i.e. do not place some on outside edges of the hotplate with others in the middle).

7.6.4. Add 3-5mL of the column strip solution to the appropriate planchet, and evaporate onto each dish in successive 3-5mL volumes.

7.6.5. Allow each 3-5mL volume to evaporate to near dryness between additions.

Note: Adding more eluate before the planchet goes to complete dryness helps to prevent spattering.

7.6.6. Rinse the vial containing the column strip solution with 2mL of 0.05M HNO_3 and transfer to the counting dish.

7.6.7. After all the solution has evaporated to dryness, place planchets in an oven at 105-110°C for 30-60 minutes to ensure uniform drying. Cool each dish.

7.6.8. Reweigh each counting dish, and record the weight.

7.6.9. Count samples sufficient time to achieve the desired counting statistics and minimum detectable concentration.

7.6.10. After total strontium have been counted, set planchets aside in a safe place during the ^{90}Y in-growth period.

7.7. Cerenkov Counting Option for ^{89}Sr:

Note: This option gives somewhat poorer detection limits because of the relatively higher backgrounds of Cerenkov counting. However, it is fast and has virtually no interference between Sr-89 and Sr-90. It has been reported that high ratios of ^{89}Sr/^{90}Sr may cause a high bias with the gas proportional counting option. It is advisable to use the Cerenkov counting option in these cases.

7.7.1. Pour the column strip solution from step 7.4.7. into a liquid scintillation vial.

7.7.2. Count the samples in a liquid scintillation counter (without liquid scintillation cocktail) for a sufficient time to achieve the desired counting statistics and minimum detectable concentration.

7.7.3. Measure a blank vial before and after each sample group.

7.8. Gamma Counting of Strontium-85 Tracer Option:

7.8.1. Measure the ^{85}Sr on the counting dish or in the Sr strip solution using gamma spectrometry after counting the sample for beta activity.

7.8.2. Count the samples sufficient time to achieve the desired counting statistics (typically <5% rsd).

7.9. ^{90}Y Isolation after Ingrowth (approximately 1 week)

Note: If ^{89}Sr is known to be absent, ^{90}Sr can be measured with a single count. However, if ^{89}Sr is present, ^{90}Sr is measured by isolating ^{90}Y using this section and counting the ^{90}Y.

7.9.1. Add 5mL of 0.05M HNO_3 into each column from step 7.4.9. Allow the liquid to drain from the column. Add 5mL of 8M HNO_3 to precondition each column. Allow the liquid drain.

Note: The 0.05M HNO_3 removes bismuth-210 in-growth from any lead-210 that may be tightly bound to the resin.

7.9.2. Ensure that a clean, labeled centrifuge tube is below the column.

7.9.3. Add 5mL of concentrated HNO_3 to the Sr strip solution (Cerenkov counting option) or redissolve the evaporated Sr residue (gas proportional counting option) in up to 15mL of 8M HNO_3. Transfer the solution into the appropriate Sr Resin column and allow to drain.

Note: This dissolution may be performed as follows: Place the planchet in a clean, dry 150mL glass beaker. Add 5mL of 8M HNO_3 to redissolve the residue, warm gently, and swirl. Remove the planchet with a pair of tweezers and rinse any remaining residue into the beaker twice with additional 5mL volumes of 8M HNO_3. Warm the beaker gently if required to dissolve the residue.

7.9.4. Add 5mL of 8M HNO_3 to rinse the beaker and transfer each solution into the Sr Resin column and allow to drain.

7.9.5. Record the time of the completion of last rinse as the stop time for yttrium ingrowth.

7.9.6. Prepare the combined eluate from 7.9.3. and 7.9.4. for ^{90}Y counting as appropriate for the counting method used (evaporation on planchet, addition to liquid scintillation cocktail or rare earth fluoride micro precipitation via Eichom Method SPA01). Assume a 100% yield of yttrium.

8. CALCULATIONS

Calculate the strontium yield using stable Sr carrier added or Sr-85 tracer:

Calculate the *Sr-85 tracer yield:*

$$\text{Yield} = \frac{(C_s - B_s)}{E_s \times A_s}$$

where:

C_s = measured Sr-85 tracer, cpm
B_s = background, cpm
E_s = counting efficiency for Sr-85 tracer
A_s = Sr-85 tracer activity, dpm

Calculate the *Gravimetric Yield: Sr carrier*

$$\text{Yield} = \frac{R_w - T_w - B_w}{C_w}$$

where:

R_w = residue + dish, mg
T_w = tare weight of dish, mg
B_w = blank weight, mg (extractant loss from column)
C_w = $Sr(NO_3)_2$ added, mg

Percent yield = Yield x 100

Calculate ^{90}Sr activity based on ^{90}Y ingrowth:

Note: If ^{89}Sr is known to be absent, ^{90}Sr can be measured with a single count. However, if ^{89}Sr is present, ^{90}Sr is measured by counting the isolated ^{90}Y after ingrowth. This calculation applies to measurement by gas proportional counting, liquid scintillation counting or Cerenkov counting.

$$^{90}\text{Sr concentration (dpm/L)} = \frac{S_y - B_y}{E_y \times V \times Y_{Sr} \times Y_y \times I_y \times D_y}$$

where:

S_y = count rate for yttrium, cpm
B_y = background count rate for yttrium, cpm
E_y = Y-90 counting efficiency
V = sample volume, L
Y_{sr} = strontium yield
Y_y = yttrium yield = assumed to be 1.0 (100%)
I_y = yttrium in-growth factor = 1 - exp [(-ln2/2.6708) x (T_2-T_1)]
D_y = decay correction for Y-90 = exp [(-ln2/2.6708) x (T_4-T_2)]
T_0 = time of sample collection
T_1 = start time for yttrium ingrowth (last rinse-initial Sr separation)
T_2 = stop time for yttrium ingrowth (last rinse-Sr removal after ingrowth)
T_4 = midpoint of yttrium sample measurement

Note 10: Convert time differences from hours to days + fractions of days since decay factors are given in days.

Conversion of dpm/L to pCi/liter:

pCi/L = (dpm/L) /2.22
pCi/L = 37 mBq/L

Calculate Sr-89 by subtracting Sr-90 from Total Sr (89+90):

Note 11: This calculation is used for gas proportional or liquid scintillation counting. Alternately, ^{89}Sr and ^{90}Sr can also be measured simultaneously by setting windows judiciously using liquid scintillation counting, except when high levels of ^{89}Sr relative to ^{90}Sr are present.

$$\text{Sr-89 cpm} = \frac{S_t - B - S_{Sr90cpm} - \left(S_{Sr90dpm} \times E_y \times I'_y\right)}{Y_{Sr}}$$

$$\text{Sr-89 concentration (dpm/L)(corrected for Sr-89 decay)} = \frac{\text{Sr - 89 cpm}}{V \times E_{Sr89} \times D_{Sr89}}$$

where:

S_t = total Sr-89 + Sr-90 cpm
B = background strontium count rate, cpm
Y_{sr} = strontium yield
E_y = Y-90 counting efficiency
$E_{sr\text{-}89}$ = Sr-89 counting efficiency
$S_{Sr90cpm}$ = Y-90 dpm x Sr-90 counting efficiency
$S_{sr90dpm}$ = Y-90 dpm determined by measuring Y^{90} after ingrowth
I_y = yttrium in-growth factor = 1 - exp [(-ln2/2.6708) x (T_3-T_1)]
$D_{Sr\text{-}89}$ = decay correction for Sr-89= exp [(-ln2/50.5) x (T_3-T_0)]
T_0 = time of sample collection
T_1 = start time for yttrium ingrowth (last rinse-initial Sr separation)
T_2 = stop time for yttrium ingrowth (last rinse-Sr removal after ingrowth)
T_3 = midpoint of strontium sample measurement
V = volume, L

Calculate Sr-89 activity using Cerenkov counting and Sr-85 tracer:

Note 12: ^{89}Sr can be measured directly by Cerenkov counting with very little interference from ^{90}Sr. This calculation is used for ^{89}Sr by Cerenkov counting with a correction for beta emission from ^{85}Sr tracer illustrated.

$$\text{Sr-89 concentration (dpm/L)} = \frac{(S_{Sr89} - B_{Sr89}) - (E_{Sr85} \times A_{Sr85})}{V \times Y_{Sr} \times E_{Sr89} \times D_{Sr89}} - \frac{J_{Sr90} \times [E_{Sr90} + (E_{ys} \times I_y)]}{E_{Sr89} \times D_{Sr89}}$$

where:

S_{Sr89} = count rate for strontium, cpm
B_{Sr89} = background count rate for strontium, cpm
E_{Sr89} = Sr-89 counting efficiency
V = sample volume, L
Y_{Sr} = strontium yield
E_{ys} = Y-90 counting efficiency
I_y = yttrium in-growth factor = 1 - exp (-ln2/2.6708) x (T_3-T_1)
$D_{Sr\text{-}89}$ = decay correction for Sr-89 = exp (-ln2/50.5) x (T_3-T_0)

J_{Sr-90} = Sr-90 activity decayed T_0 to T_3 = CSr-90 x exp (-ln2/28.6) x (T_3-T_0)/365.25
T_0 = time of sample collection
T_1 = start time for yttrium ingrowth (last rinse-initial Sr separation)
T_3 = midpoint of strontium sample measurement
C_{Sr-89} = Sr-90 concentration (dpm/L) at time T_0.
A_{Sr-85} = Sr-85 concentration (dpm/L) at time of sample measurement, corrected for chemical recovery of strontium.
E_{Sr-85} = Sr-85 counting efficiency

Conversion of dpm/L to pCi/liter:

pCi/L = (dpm/L) /2.22

9. PRECISION AND BIAS

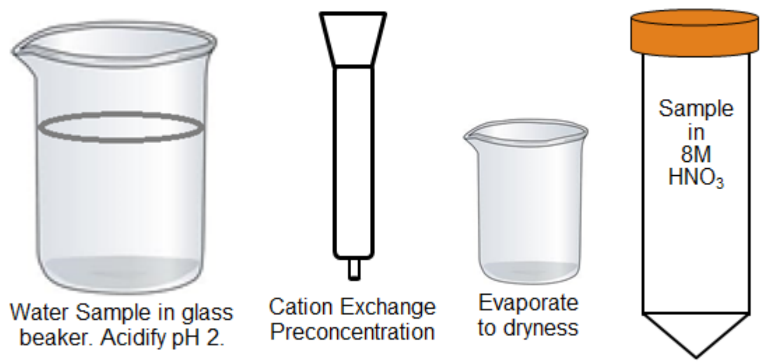
9.1. *Precision* - Relative standard deviations of 8% at the 500 dpm level (Sr-90) and 8% at the 2000 and 10,000 dpm levels (Sr-90) have been reported.

9.2. *Bias* - Mean tracer recoveries, corrected for chemical yield, of 104% ± 8% (Sr-90) and 95% ± 8% (Sr-89) have been reported.

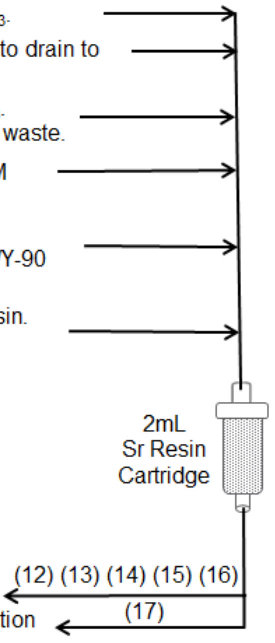
10. REFERENCES

1) Banavali, A.D., et al., “Strontium-89/90 Analysis by Eichrom Column Chemistry and Cerenkov Counting,” 38th Annual Conference on Bioassay, Analytical and Environmental Radiochemistry, Santa Fe, NM, November, 1992.
2) Horwitz, E.P., et al., “A Novel Strontium Selective Extraction Selective Chromatographic Resin,” Solvent Extraction and Ion Exchange, 10, 313-336, (1992).
3) Maxwell, S.L., et al., “High Speed Separations to Measure Impurities in Plutonium-238 Oxide and Trace Radionuclides in Waste,” 34th ORNL-DOE Conference on Analytical Chemistry in Energy Technology, Gatlinburg, TN, October, 1993.
4) Nelson, D.M, “Purification of Strontium in Water before Strontium-89/Strontium-90 Measurement,” DOE Methods Compendium, RP500.

1) Aliquot up to 1000mL of water into glass beaker.
2) Acidify to pH 2 with conc. HNO_3.
3) Add Sr yield tracer.
4) Slurry pack 10mL column of cation exchange resin.
5) Precondition cation exchange column with 20mL of 0.1M HNO_3.
6) Load sample on cation exchange column. Sr is retained. Discard eluate as waste.
7) Rinse column with 25mL of 0.1M HNO_3. Discard Eluate as waste.
8) Place 150mL glass beaker below cation exchange column.
9) Strip Sr from cation exchange with 50mL of 8M HNO_3.
10) Evaporate to dryness.
11) Dissolve residue in 8mL 8M HNO_3.



12) Precondition Sr Resin with 5mL 8M HNO_3.
13) Load sample on to Sr Resin. Allow liquid to drain to waste. Strontium is retained.
14) Rinse centrifuge tube with 5mL 8M HNO_3. Add rinse to Sr Resin. Allow liquid to drain to waste.
15) Rinse Sr Resin with 5mL 3M HNO_3-0.05M oxalic acid. Allow liquid to drain to waste.
16) Rinse Sr Resin with 5mL 8M HNO_3. Allow liquid to drain to waste. Reocord Sr-90/Y-90 separation time.
17) Place 50mL centrifuge tube below Sr Resin. Strip Sr with 15mL 0.05M HNO_3.



1) Aliquot up to 1000mL of water into glass beaker.

2) Acidify to pH 2 with conc. HNO_3.

3) Add Sr yield tracer and 2mL of $Ca(NO_3)_2$.

4) Heat samples to 60-80°C.

5) Turn down heat. Add 1mL of 3.2M $(NH_4)_2HPO_4$ and 0.75mL of phenolphthalein indicator.

6) While stirring sample, slowly add 12M NaOH until pH 9-10.

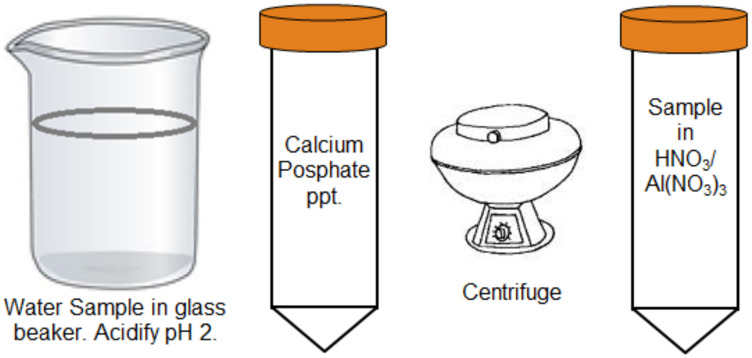
7) Heat and stir for 15-20 minutes. Cool. Allow precipitate to settle or centrifuge.

8) Decant supernate and discard as waste.

9) Transfer precipitate to centrifuge tube with DI water.

10) Centrifuge ~10minutes at 2000rpm. Decant supernate.

11) Dissolve precipitate in 7mL 70% HNO_3 and 8mL 1M $Al(NO_3)_3$.



12) Precondition Sr Resin with 5mL 8M HNO_3.

13) Load sample on to Sr Resin. Allow liquid to drain to waste. Strontium is retained.

14) Rinse centrifuge tube with 5mL 8M HNO_3. Add rinse to Sr Resin. Allow liquid to drain to waste.

15) Rinse Sr Resin with 5mL 3M HNO_3-0.05M oxalic acid. Allow liquid to drain to waste.

16) Rinse Sr Resin with 5mL 8M HNO_3. Allow liquid to drain to waste. Reocord Sr-90/Y-90 separation time.

17) Place 50mL centrifuge tube below Sr Resin. Strip Sr with 15mL 0.05M HNO_3.