RESL TECHNICAL PROCEDURE

CHEM-TP-SR.06

SULFATE METHOD FOR ^{89}SR AND ^{90}SR IN LIQUID RADIOACTIVE WASTES OR WATERS

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TITLE: CHEM-TP-SR.06, SULFATE METHOD FOR ^{89}SR AND ^{90}SR IN LIQUID RADIOACTIVE WASTES OR WATERS

PURPOSE

The purpose of this procedure is to determine ^{89}Sr and ^{90}Sr in liquid radioactive wastes or waters.

APPLICABILITY

This procedure is applicable to samples that must be analyzed for ^{89,90}Sr and for samples that must be decontaminated from ^{140}Ba.

RESPONSIBILITIES

RESL staff responsible for implementing this procedure are:

AMT STAFF

DEFINITIONS

Cold water bath - A bath of cold, running tap water.

Hot water bath - A bath of boiling water.

H_2O - Distilled or demineralized water.

PROCEDURE

1.0 ABSTRACT

Strontium sulfate ($SrSO_4$) is precipitated and then dissolved in a EDTA solution. $SrSO_4$ is preferentially precipitated from EDTA at a lower pH. The sulfate precipitate is metathesized to a carbonate. After barium is separated as a chromate, the Sr is reprecipitated as a sulfate. Total radioactive Sr is determined by beta counting the $SrSO_4$. The strontium sample is then dissolved in EDTA and set aside for ^{90}Y ingrowth. After a suitable ingrowth period, ^{90}Y is separated and counted on $Y_2(C_2O_4)_3 \bullet 9H_2O$. The ^{90}Sr is determined by beta counting its ^{90}Y daughter. ^{89}Sr is determined as the difference between total radioactive Sr and ^{90}Sr.

2.0 SAFETY PRECAUTION

CAUTION: THIS PROCEDURE CALLS FOR THE USE OF 10 M NaOH, GLACIAL ACETIC ACID, 15 M NH_4OH, AND 1.5 M Na_2CrO_4. TAKE PROPER PRECAUTIONARY MEASURES. USE A FUME HOOD. WEAR GLOVES, SAFETY GLASSES/FACE SHIELD, AND PROTECTIVE CLOTHING

2.1 Refer to RESL-TP-IH.1for eye protection.

2.2 Refer to RESL-TP-IH.2 for general Laboratory safety.

2.3. Refer to RESL-TP-IH.4 for the handling of corrosive chemicals

2.4 Refer to CHEM-AP-11 for proper management of chemicals.

2.5 Refer to RESL-TP-IH.15 for acid and base neutralization.

2.6 Refer to RESL-AP-10 for waste management.

3.0 APPARATUS

3.1 Perchloric acid fume hood

3.2 Hotplate, 3600 W, 46 x 61 cm

3.3 Fiberglass mat, 1.6 mm thick, to cover hotplate

3.4 Centrifuge with a 12-place rotor, trunnions, and cups for 100-mL centrifuge tubes

3.5 Glass Centrifuge tubes: 100 mL

3.6 Glass fiber GF/A filters, 2.4 cm

3.7 Filtering apparatus: Custom-made, black Teflon filtering chimney, 2 cm inside diameter (i.d.); custom-made, white Teflon filter holder and frit, or a comparable commercial filtering apparatus, for example: Fisher Scientific(Vacuum Filter Holder #09-753E).

3.8 Heat lamp, 250 W

3.9 PVC filter holder: Custom-made, with locking ring for 2.4-cm GF/A glass fiber filters

3.10 DM-450 metricel membrane filter, 25 mm.

4.0 REAGENTS

4.1 Barium Carrier, 5 mg/mL: Dissolve 0.90 g of $BaCl_2 \cdot 2H_2O$ in H_2O and dilute to 100 mL.

4.2 Lithium Sulfate, 5%: dissolve 25 g of lithium sulfate in 500 mL of water in a 500 mL wash bottle.

4.3 Metacresol Purple Indicator (MCP), 0.1%: Dissolve 0.25 g of

m-cresolsulfonephthalein in H_2O and add 1 mL of 10 M NaOH. Dilute to 250 mL with H_2O and filter the solution through a DM-450 filter.

4.4 Oxalic Acid, 5%: Dissolve 50 g of $H_2C_2O_4 \cdot 2H_2O$ in 1 L of H_2O and filter through a DM-450 filter.

4.5 Phenolphthalein Indicator, 1%: Dissolve 2.5 g of phenolphthalein in 125 mL of 95% ethyl alcohol and dilute to 250 mL with H_2O.

4.6 Sodium Carbonate, 10%: Dissolve 100 g of Na_2CO_3 in 1 L of H_2O. Filter the solution through a DM-450 filter. Store in a plastic bottle.

4.7 Sodium Chromate, 1.5 Molar: Dissolve 87.8 g of $Na_2CrO_4 \cdot 4H_2O$ in H_2O and dilute to 250 mL.

4.8 Sodium Diethylenetriaminepentaacetate (DTPA), 0.2 Molar: Dissolve 39 g of diethylenetriaminepentaacetic acid and 25 g of NaOH pellets in 400 mL of H_2O. Filter through a glass fiber filter and dilute to 500 mL.

4.9 Sodium Ethylenediaminetetraacetate (EDTA), 0.6 Molar: Dissolve 233 g of disodium ethylenediaminetetraacetic acid dihydrate and 50 g of NaOH pellets in 800 mL of H_2O and dilute to 1 L. Filter the solution through a DM-450 filter.

4.10 EDTA, 0.2 Molar: Make a 1:3 dilution of 0.6 M EDTA.

4.11 EDTA, 0.06 Molar: Make a 1:10 dilution using 0.6 M EDTA.

4.12 Sodium Hydroxide, 10 Molar: Slowly add 400 g of NaOH pellets to 1 L of H_2O in a 2-L beaker while stirring the solution vigorously. This reaction is very exothermic; therefore use all necessary safety precautions and prepare this reagent on a heat-resistant surface. After the NaOH is dissolved in the water and the solution has cooled, filter the solution through a DM-450 filter. Store in a plastic bottle.

4.13 Sodium Sulfate, 1.2 Molar: Dissolve 170 g of Na_2SO_4 in 1 L of H_2O. Filter the solution through a DM-450 filter.

4.14 Sodium Sulfate, 0.12 Molar: Make a 1:10 dilution of 1.2 M sodium sulfate.

4.15 Strontium Carrier, 50 mg/mL: Add 42.5 g of reagent grade strontium carbonate to 450 mL of 1.5 M HNO_3. Transfer the solution to a 500-mL volumetric flask and dilute to 500 mL with H_2O. Filter the solution through a DM-450 filter. Determine the $SrSO_4$ gravimetric factor for the current Sr carrier solution as described in CHEM-TP-CA.09.

4.16 Yttrium Carrier, 10 mg/mL: Dissolve 6.35 g of 99.9% Y_2O_3 in 40 mL of 8 M HNO_3 by heating in a water bath and allow it to cool. Transfer the solution to a 500-mL volumetric flask and dilute to 500 mL with 0.5 M HNO_3. Filter the

solution through a DM-450 filter. Determine the $Y_2(C_2O_4)_3 \square 9H_2O$ gravimetric factor for the current yttrium carrier solution as described in Procedure CHEM-TP-CA.09.

5 PROCEDURE

5.1 Strontium Sulfate Precipitation

5.1.1 Add the sample to a beaker that is approximately double the volume of the sample. Add 1 mL of strontium carrier (50 mg) and two boiling chips.

5.1.2 Prepare a reagent blank in the same manner using water in place of the sample.

5.1.3 Boil the sample and reagent blank to approximately 1/10 of its original volume, transfer the sample and boiling chips to a container approximately double its volume, and add 4 drops of MCP.

5.1.4 If the solution is red, add NaOH to the yellow endpoint of the indicator. If the solution is purple, add concentrated nitric acid to the red endpoint of the indicator.

5.1.5 Add 5 mL of concentrated nitric acid for every 50 mL of solution. Make the sample 12% wt/vol. with Li_2SO_4 and boil the solution for 10 minutes.

5.1.6 Transfer the contents of the beaker to a 100-mL centrifuge tube using the 5% Li_2SO_4 wash solution from a wash bottle. Combine the rinse with the sample in the 100-mL centrifuge tube. Balance the tubes using 5% Li_2SO_4 wash solution and centrifuge the sample for 5 min at 2400 rpm. Decant and discard the supernate.

5.1.7 Wash the precipitate with about 20 mL of 5 % lithium sulfate and centrifuge for 5 minutes. Decant and discard the supernate.

(For example, boil a 1 L water sample in a 2 L beaker to 100 mL, transfer to a 250 Erlenmeyer flask, adjust the pH, and add 10 mL of 16N nitric acid.)

5.1.8 Slurry the sulfate precipitate with 5 mL of H_2O. Add 1 drop of MCP indicator and 10 M NaOH dropwise just to the purple endpoint of the indicator to neutralize excess acid. Add 10 mL of 0.2 M EDTA. Heat the solution in a hot water bath while swirling to dissolve the sulfate precipitate. Add another 5 mL of 0.2 M EDTA if it does not all dissolve. Continue heating and swirling. Repeat with another 5 mL of 0.2M EDTA, if necessary, to dissolve all the sulfate precipitate.

5.1.9 Separate any significant amount of $Fe(OH)_3$, if it precipitates at this point, by centrifugation. Balance the tubes and centrifuge the solution at 2400 rpm for 5 min. Decant the supernate into a clean 100-mL centrifuge tube

and slurry the $Fe(OH)_3$ precipitate with 2 mL of 0.06 M EDTA. Heat in a hot water bath and centrifuge again. Combine this supernate with the first supernate. Discard the $Fe(OH)_3$.

5.1.10 Add 5 mL of 1.2 M sodium sulfate to the combined supernates. Add 1 drop of MCP, if necessary, and glacial acetic acid, dropwise to the yellow endpoint of the indicator. Add 1 mL of 6 M acetic acid to precipitate the strontium sulfate. Heat 5 min in a hot water bath with occasional swirling, then cool for 10 min in a cold water bath. Centrifuge for 5 min at 2400 rpm. Decant and discard the supernate.

5.1.11 Continue at Step 5.2 with the barium chromate separation.

5.2 Barium Chromate Separation

5.2.1 Metastasize the strontium sulfate to strontium carbonate by swirling the precipitate with 20 mL of sodium carbonate. Heat for 10 min in a hot water bath and cool for 10 min in a cold water bath. Centrifuge for 5 min at 2400 rpm. Decant and discard the supernate.

5.2.2 Add 2 mL of 6 M HCl to the carbonate precipitate and, after the effervescence stops, add 5 mL of 0.2 M DTPA. Add 1 drop of phenolphthalein indicator and 10 M NaOH, dropwise with swirling to the red endpoint of the indicator.

5.2.3 Add 1 mL of barium carrier and 5 mL of sodium chromate, while swirling, to precipitate barium chromate. Heat in a hot water bath for 2 min. Add 1 drop of phenolphthalein indicator, glacial acetic acid dropwise with swirling to the yellow color of chromate ion (the colorless endpoint of phenolphthalein). Add 1 mL of 6 M acetic acid; the solution will turn orange due to the formation of dichromate. Heat the solution in a hot water bath and cool in a cold water bath for 2 min each.

5.2.4 Filter the barium chromate precipitate onto a 25-mm DM-450 metricel membrane filter. Rinse the 100-mL centrifuge tube with approximately 10 mL of H_2O from a wash bottle and use this solution to wash the barium chromate precipitate. Collect the filtrate and the wash in a clean 100-mL centrifuge tube. Discard the barium chromate precipitate and rinse the filter holder with H_2O.

5.2.5 Continue at Step 5.3 with the total strontium analysis.

5.3 Preparation of Strontium Sulfate for Total Strontium Analysis

5.3.1 Add 10 mL of 1.2 M sodium sulfate to the filtrate while swirling. Add 3 mL of glacial acetic acid while swirling to precipitate strontium sulfate. Heat the solution in a hot water bath for 5 min and cool in a cold water bath for 10 min.

5.3.2 Record the precipitation time in the sample logbook as the start of the ^{90}Y ingrowth period.

5.3.3 Centrifuge the solution for 5 min at 2400 rpm. Decant and discard the supernate.

5.3.4 Add 10 mL of 0.12 M sodium sulfate and slurry the solution to wash the strontium sulfate precipitate.

5.3.5 Weigh a 2.4-cm glass fiber filter. Record the filter weight in the sample logbook. Decant and filter the $SrSO_4$ supernate, with gentle suction, through the glass fiber filter mounted in the 2-cm i.d. filtering apparatus. Avoid letting the filter go totally dry until the acetone wash (Step 5.3.6) to reduce the possible collection of radon daughters from the air.

5.3.6 Wash the $SrSO_4$ in the 100-mL centrifuge tube by swirling it with approximately 20 mL of H_2O from a wash bottle and filter the precipitate. Remove the suction just as the filter goes dry. Rinse the 100-mL centrifuge tube with approximately 1 mL of acetone and use it to wash the $SrSO_4$ on the filter. Remove the filtering chimney, then the suction just as the filter goes dry. Discard the acetone wash.

5.3.7 Place the filter on a numbered watch glass and dry under a heat lamp at a distance of approximately 18 cm for 10 min. Allow it to cool for 10 min and weigh. Record the weight in the sample logbook. (This data will be used to determine the strontium yield by comparison with the strontium gravimetric factor.)

5.3.8 Place the filter in a PVC filter holder, then place the holder in a numbered Tennelec carrier for beta counting. Count the filtered strontium sulfate precipitate as soon as possible to decrease the uncertainty due to ^{90}Y ingrowth. Operate the Tennelec beta counter according to Procedure CHEM-TP-GB.1. Retain all the data generated by the Tennelec counter.

5.3.9 Place the filter with the $SrSO_4$ in a 90-mL polystyrene counting bottle after the $SrSO_4$ has been counted. Add 10 mL of 0.2 M EDTA to dissolve the precipitate. Add 1 mL of yttrium carrier, 1 drop of MCP indicator, and 10 M NaOH dropwise just to the purple endpoint of the indicator. Set aside for 7 to 14 days to allow for ^{90}Y ingrowth.

5.3.10 After 7 days, approximately 85% of the yttrium daughter product has grown into the strontium solution; after 14 days, ingrowth is 97% complete.

5.4 Preparation of Yttrium Oxalate After Ingrowth

5.4.1 Use filtration to remove the filter (from Step 5.3.9) after the ingrowth period. Use a 25-mm glass fiber filter and a clean 100-mL centrifuge tube

to catch the filtrate. Decant the solution and the filter into the filtering chimney. Use 5 to 10 mL of H_2O to rinse the counting bottle and use the rinse to wash the filter, combining the rinse with the sample solution.

5.4.2 Add 5 mL of 1.2 M sodium sulfate. Add, while swirling, 1 drop of MCP and glacial acetic acid dropwise to the yellow endpoint of the indicator. Add 1 mL of 6 M acetic acid and swirl to reprecipitate the strontium sulfate. Heat the solution in a hot water bath for 5 min and cool in a cold water bath for 10 min.

5.4.3 Record the precipitation time in the sample logbook as the end of the ^{90}Y ingrowth period.

5.4.4 Centrifuge the solution from Step 5.4.2 for 5 min at 2400 rpm. Decant the supernate into a clean 100-mL centrifuge tube for the yttrium hydroxide precipitation.

5.4.5 Redissolve the strontium sulfate precipitate in 10 mL of 0.2 M EDTA by heating in a hot water bath and with slurrying. Transfer the solution back to the original counting bottle. Use approximately 5 mL of H_2O from a wash bottle to complete the transfer of the sample and to rinse the centrifuge tube. Combine the rinse with the sample solution. Save this strontium solution in case it may be necessary to reanalyze the sample.

5.4.6 Add 10 M NaOH dropwise while swirling the supernate from Step 5.4.4, just to the purple endpoint of the indicator.

5.4.7 Add 1.5 mL of strontium carrier. (This addition will change the indicator back to yellow.) Use dropwise additions of 10 M NaOH to bring the indicator back to the purple endpoint. Add an additional 10 mL of 10 M NaOH and swirl the sample to precipitate $Y(OH)_3$. Heat in a hot water bath and cool in a cold water bath for 10 min each. Centrifuge for 5 min at 2400 rpm. Decant and discard the supernate.

5.4.8 Dissolve the $Y(OH)_3$ precipitate with 5 mL of 8 M HNO_3 and add one drop of MCP. Use dropwise additions of 10 M NaOH to bring the indicator back to the purple endpoint. Add an additional 3 mL of 10 M NaOH. Heat in a hot water bath and cool in a cold water bath for 10 min each. Centrifuge for 5 min at 2400 rpm. Decant and discard the supernate

5.4.9 Dissolve the $Y(OH)_3$ precipitate with 5 mL of 8 M HNO_3. Add 5 mL of oxalic acid and 2 to 3 drops of MCP indicator. Dilute the sample to approximately 25 mL with H_2O. Slowly add 15 M NH_4OH dropwise, with constant swirling, until the deep red of the indicator begins to become more pink in appearance. Complete the adjustment of pH to the salmon pink color of the indicator, ca. pH 1.5, by dropwise addition of dilute NH_4OH with constant swirling.

5.4.10 Digest the sample for 5 min in a hot water bath and then cool to room temperature in a cold water bath. Allow the $Y_2(C_2O_4)_3 \cdot 9H_2O$ precipitate to settle.

5.4.11 Weigh a 2.4-cm glass fiber GF/A filter. Record the filter weight in the sample logbook. Decant and filter the $Y_2(C_2O_4)_3 \cdot 9H_2O$ supernate with gentle suction through the glass fiber filter mounted in the 2-cm i.d. filtering apparatus. Avoid letting the filter go totally dry until the acetone wash (Step 5.4.12) to reduce the possible collection of radon daughters from the air.

5.4.12 Wash the $Y_2(C_2O_4)_3 \cdot 9H_2O$ in the 100-mL centrifuge tube by swirling it with approximately 20 mL of H_2O from a wash bottle and filter the precipitate. Rinse the centrifuge tube with approximately 1 mL of acetone and filter the rinse just as the last of the water passes through the $Y_2(C_2O_4)_3 \cdot 9H_2O$ on the filter. Remove the chimney and suction just as the filter goes completely dry.

5.4.13 Place the filter on a numbered watch glass and dry under a heat lamp at a distance of about 18 cm for 10 min. Then allow it to cool for 10 min and weigh. Record the weight in the sample logbook. (This data will be used to determine the yttrium yield by comparison with the yttrium gravimetric factor.)

5.4.14 Place the filter in a PVC filter holder, and place the holder in a numbered Tennelec carrier for beta counting. Begin counting as soon as possible. Operate the Tennelec Beta Counter according to procedure CHEM-TP-GB.1. The results for $^{89,90}Sr$ are calculated using a computer program.

6 CALCULATIONS

6.1 Variables and their Relative Uncertainties in the Calculation of ^{89}Sr and ^{90}Sr

Definition	Factor Symbol	Typical Value	Random Uncert. %	Systematic Uncert. %
Total Sr Gross Count	TSR	Variable	Variable	--
Total Sr Blank Count	BSR	2-3 cpm	Variable	--
Total Sr Count Time	CTSR	10-100 min	0.1	--
^{90}Y Gross Count	Y	Variable	Variable	--
^{90}Y Blank Count	BY	2-3 cpm	Variable	--
^{90}Count Time	CTY	10-100 min	0.1	0.3
Sr Yield	SY	0.85-0.95	3	0.2
Y Yield	YY	0.90-1.00	1	0.2
^{90}Sr Counting Efficiency ($SrSO_4$)	CE90	0.21	2	--
^{90}Y Counting Efficiency ($SrSO_4$)	CEY'	0.44	2	2
^{90}Y Counting Efficiency [$Y_2(OX)_3$]	CEY	0.450-0.455	1	--
^{89}Sr Counting Efficiency ($SrSO_4$)	CE89	0.39	2	2
^{90}Y Ingrowth Correction ($SrSO_4$)	YG'	0.01-0.16 (1-16 hrs)	--	$\leq 0.5^a$
^{90}Y Ingrowth	YG	0.84-0.97 (7-14 days)	0.2-0.3	$\leq 0.2^b$
^{90}Y Decay	YD	0.98-0.82 (1.5-18 hrs)	0.2	0.3^c
^{89}Sr Decay	SRD	Variable (7-100 days)	--	$\leq 0.3^d$
^{90}Sr Decay	D90	0.99	--	0.0005
dpm/µCi	MC	2.22×10^6	0	0
Sample Volume or Weight	V	10-400 mL	1	1

a) Applies to the term: [(CE90) + (CEY')(YG')] with ^{90}Y ingrowth time (t') ≥ 1 hr, and the deviation of the mean from the known value ($D'_{t'}$) = 0.25 hr, and the deviation of the halflife from the known value (D'_H) = 0.1 hr.

b) Applies for ^{90}Y ingrowth times (t) of 7 to 14 days with D'_t = 0.25 hr and D'_H = 0.1 hr.

c) Applies for ^{90}Y decay times (t) of $1.5 \leq t \leq 18$ hrs with D'_t = 0.25 hr and D'_H = 0.1 hr.

d) Applies for ^{89}Sr decay times (t) of 7 to 100 days, D'_t = 0.1 day and D'_H = 0.1 day.

6.2 Equations for ^{89}Sr

6.2.1 Calculation of ^{89}Sr Results

$$(^{89}Sr, qpm) = \frac{TSR - BSR}{CTSR} - (^{90}Sr) - (^{90}Y)$$

$$= \frac{TSR - BSR}{CTSR} - \left[(^{90}Sr, uCi/mL)(CE90)(MC)(V)(SY)\left(1 + \frac{(CEY')(YG')}{CE90}\right)\right]$$

$$= \frac{TSR - BSR}{CTSR} - \frac{(Y - BY)(CE90)(MC)(V)(SY)\left[1 + \frac{(CEY')(YG')}{CE90}\right]}{(CTY)(CEY)(MC)(V)(SY)(YY)(YG)(YD)}$$

$$(^{89}Sr, qpm) = \frac{TSR - BSR}{CTSR} - \frac{(Y - BY)[(CE90) + (CEY')(YG')]}{(CTY)(CEY)(YY)(YD)} = Q_1$$

$$^{89}Sr\left(\mu\text{Ci/mL}\right) = \frac{Q_1}{(CE89)(MC)(V)(SY)} = R_{89}$$

$$R_{89}^{0} = \frac{R_{89}}{SRD}$$

Where:

$CE90 = 0.3429 \times \exp(-0.00478 \times w)$

$CEY' = 0.4652 \times \exp(-0.000478 \times w)$

$CEY = 0.450$**

$CE89 = 0.4350 \times \exp(-0.00123 \times w)$

$YG = 1 - \exp(-0.2599 \times \Delta t_1)$ $\quad \Delta t_1$ = Days of yttrium ingrowth

$YD = \exp(-0.0108 \times \Delta t_2)$ $\quad \Delta t_2$ = Hrs of yttrium decay***

$SRD = \exp(-0.0137 \times \Delta t_3)$ $\quad \Delta t_3)$ = Days of Sr-89 decay****

$YG' = 1 - \exp(-0.0108 \times \Delta t_4)$ $\quad \Delta t_4$ = Hrs of time after separation of Sr until time counted

Q_1 = ^{89}Sr net count

R_{89} = Result for ^{89}Sr in μCi/appropriate units at the time of the total Sr count

R^0_{89} = Reported, decay-corrected result

w = Net weight of $SrSO_4$

** The value does not vary significantly over the range of $Y_2(C_2O_4) \bullet 9H_2O$ weights obtained.

*** Hours of yttrium decay from stop ingrowth time to the time counted.

**** Days from 1200 on the day of sample collection to the time counted.

6.2.2 Total Random Uncertainty in ^{89}Sr Results

$$S_{89} = \frac{1}{K_4}\left[\frac{TSR + BSR}{(CTSR)^2} + \frac{1}{K_3^2}\{K_2^2(Y + BY) + K_1^2[(4E-4)(CE90)^2 + (4E-4)(YG'*CEY')^2] + 2.0E-4(K_1K_2)^2\} + (1.4E-3)Q_1^2\right]^{\frac{1}{2}}$$

Where:

K_1 = (Y-BY)

K_2 = [(CE90) + (CEY')(YG')]

K_3 = (CTY)(CEY)(YY)(YG)(YD)

K_4 = (CE89)(MC)(V)(SY)(SRD)

6.2.3 Total Systematic Uncertainty in ^{89}Sr Results

$$E_{89} = [(4.4E-4)(RA^2)[(R_{90}^O)/(R_{89})]^2 + 4.2E-4]^{\frac{1}{2}}$$

Where:

RA = [(CE90) + (CEY')(YG')]/CE89

$R°_{90}$ = Decay-corrected result for ^{90}Sr in μCi/appropriate units

R_{89} = Result for ^{89}Sr in μCi/appropriate units at time of the total Sr count

6.2.4 Overall Uncertainty in ^{89}Sr Results

$$O = [S_{89}^2 + E_{89}^2(R_{89}^O)^2]^{\frac{1}{2}}$$

The coefficients in the equations for S_{89} and E_{89} apply only for the % uncertainties and the boundary conditions of specific cases. When components of uncertainty or boundary conditions change, the coefficients should be reevaluated.

6.3 Equations for ^{90}Sr

6.3.1 Calculation of for ^{90}Sr Results

$$(^{90}Sr, uCi/mL) = \frac{Y - BY}{(CTY)(CEY)(MC)(V)(SY)(YY)(YG)(YD)(D90)} = R_{90}^{O}$$

Where:

$R°_{90}$ =Reported decay-corrected result for ^{90}Sr in uCi/appropriate units

CEY = 0.450**

YG = $1 - \exp(-0.2599 \times \Delta t_1)$ Δt_1 = days of yttrium ingrowth

YD = $\exp(-0.0108 \times \Delta t_2)$ Δt_2 = hrs of yttrium decay***

D90 = $\exp(-6.659E\text{-}5 \times \Delta t_5$ Δt_5 = days of Sr-90 decay ****

** The value does not vary significantly over the range of $Y_2(C_2O_4)_3 \square 9H_2O$ weights obtained.

*** Hours of yttrium decay from stop ingrowth time to the time counted.

**** Days from 1200 on the day sample collection to the day of the end of the ^{90}Y ingrowth period.

6.3.2 Total Random Uncertainty in ^{90}Sr Results =

□ When the SY is determined gravimetrically,

$$S_{90} = \frac{1}{K}\left[(Y + BY) + (Y - BY)^2\left[\left[\frac{S_{CEY}}{CEY}\right]^2 + \left[\frac{S_V}{V}\right]^2 + \left[\frac{S_{SY}}{SY}\right]^2 + \left[\frac{S_{YY}}{YY}\right]^2\right]\right]^{\frac{1}{2}}$$

□ When the SY is determined radiometrically as in CHEM-TP-SR.2, -SR.3, -SR.7, and -SR.8

$$S_{90} = \frac{1}{K}\left[(Y + BY) + (Y - BY)^2\left[\left(\frac{S_{CEY}}{CEY}\right)^2 + \left(\frac{S_{TR}}{TR}\right)^2 + \left(\frac{S_v}{V}\right)^2 + \frac{GS}{(GS - BG)^2} + \frac{GSTD}{(GSTD - BG)^2} + \left(\frac{S_{yy}}{YY}\right)^2\right]\right]^{\frac{1}{2}}$$

Where:

K = (CTY)(CEY)(MC)(V)(SY)(YY)(YG)(YD)(D90)

GS = gross gamma counts of the sample

BG = background of the gamma well counter

GSTD = gross gamma counts of the standard

S_{CEY}/CEY = 0.02

S_V/V = 0.01

S_{SY}/SY = 0.03

S_{YY}/YY = 0.01

S_{TR}/TR = 0.003

6.3.3 Overall Uncertainty in ^{90}Sr Results

$$O_{90} = \left[S_{90}^2 + R_{90}^{o2}\left(E_{CTY}^2 + E_{CEY_1}^2 + E_{CEY_2}^2 + E_V^2 + E_{SY}^2 + E_{YY}^2 + E_{YG}^2 + E_{YD}^2 + E_{D90}^2\right)\right]^{\frac{1}{2}}$$

Where:

E_{CTY} = 0.003

E_{CEY1} = 0.011

E_{CEY2} = 0.003

E_V = 0.002

E_{SY} = 0.002

E_{YY} = 0.002

E_{YG} = 0.002

E_{YD} = 0.003

E_{D90} = 0.0005

The coefficients in the equations for S_{90} and O_{90} apply only for the % uncertainties and the boundary conditions shown in "Variables and Their Relative Uncertainties in the Calculation of ^{89}Sr and ^{90}Sr." When components of uncertainty or boundary conditions change, the coefficients should be reevaluated.

REFERENCES

Sr-2, "Determination of Strontium-89, -90 in Soil With Total Sample Decomposition."
RESL-TP-IH.4 Handling Corrosive Chemicals.
RESL-TP-IH.1 Eye Protection.
RESL-TP-IH2 General Laboratory Safety.
CHEM-AP-11 Management of Chemicals.
RESL-TP-IH.15 Acid and Base Neutralization.
RESL-AP-10 Waste Management.

QUALITY RECORDS

Results which are entered into the RESL database.
Laboratory sample logbook
Printout or electronic media generated by the Tennelec beta counter.