SOP-RC-102

Determination of Uranium by Alpha Spectrometry

Revision 0

Approval: ____________________________ Date: 8/16/16

Laboratory Manager/LQAO/RSO

Concurrence: ____________________________ Date: 8/16/16

Effective Date: 8/17/16

Renewal Date: ________________ Initials: ________________

Texas Institute for Applied Environmental Research
i. Identification of the method

ii. Applicable matrix or matrices
   a. Drinking water and nonpotable water
   b. Solids, liquids, biological materials, filters

iii. Limits of detection and quantitation
   a. For a 400 min count, 0.23 mBq for $^{238}U$, 0.53 mBq for $^{234}U$
   b. Detection limit may be extended with varying geometries and increased sample size
   c. Holding time is 6 months after collection.

i. Scope and application, including parameters to be analyzed
   a. This method is for sample preparation and determination of Uranium by alpha spectroscopy.
   a. Radionuclides: $^{238}U$, $^{234}U$. Americium, thorium, neptunium, curium and plutonium may also be separated by this method. Tracers are used to monitor chemical recoveries and to correct the results to improve precision and accuracy. $^{232}U$ is the tracer used for the uranium determination.
   b. Modifications: Any modification will be proven and documented under the DOP process. Zirconium crucibles may be used instead of stainless steel.

ii. Summary of the method
   a. Uranium from acid leached, dry-ashed and wet-ashed materials is equilibrated with $^{232}U$ tracer, and is isolated by anion exchange chromatography. The separated U isotopes are microprecipitated for alpha spectrometry.

iii. Definitions
   a. Becquerel (Bq)- unit of radiation measurement equal to 27 picoCuries ($2.7 \times 10^{-10}$ Curies) or 60 dpm (disintegrations per minute)
   b. Refer to QAM-R-100, “TIAER Laboratory Radiochemistry Program” for other definitions.

iv. Interferences
SOP-RC-102
Determination of Uranium by Alpha Spectroscopy

a. Deionized (DI) water may contain a sufficient quantity of solid material to adversely affect the resolution of the final filtered sample.
b. If not properly separated, $^{241}\text{Am}$, $^{238}\text{Pu}$, $^{237}\text{Np}$ and $^{234}\text{U}$ may interfere with unresolvable alpha energies.

v. Safety

a. Due to the use of HF in the preparation of the reagents and in the precipitation procedure, rubber gloves must be worn and plasticware must be used as noted above.
b. Titanium trichloride is an extremely powerful reducing agent, which should be used in a well-ventilated hood.
c. All radiochemistry precautions are in effect in accordance with QAM-S-101, “Laboratory Safety”. The RSO and Lab Manager will determine who can perform this procedure.

vi. Equipment and supplies

a. Porcelain or stainless steel crucibles
b. Ion exchange columns
c. Column rack
d. Ultrasonic bath
e. Millipore 47 mm diameter Pyrex glass filtration chimney (or equivalent), fitted glass support and metal clamp
f. Millipore 47 mm diameter filters (or equivalent), 0.45 µm pore size
g. Gelman 25 mm diameter polysulfone filtration chimney, stem support and stainless steel screen (or equivalent)
h. Gelman 25 mm Metricel filter (or equivalent), 0.1 µm pore size
i. Whatman 4 filters (or equivalent)
j. Eppendorf 100 µL pipette (or equivalent)
k. 100 µL disposable pipette tips
l. 10 mL plastic pipette
m. 10 mL plastic culture tubes
n. Pipetting bulb
o. 50 mL plastic graduated cylinder
p. 10 mL plastic graduated cylinder
q. 20 L plastic carboy with spigot
r. 2 L vacuum filtration flask
s. 250 mL vacuum filtration flask

vii. Reagents and standards
a. $^{232}$Uranium tracer solution - about 0.3 Bq/g of solution in a dispensing bottle.
b. Bio Rad AG 1-X4 (100-200 mesh), anion exchange resin.
c. TRU Resin- prepacked column preferable with 0.7g 100-150 micron particle size resin.
d. U/TEVA Resin- prepacked column preferable with 0.7g 100-150 micron particle size resin.
e. Hydrofluoric acid (48%), HF
   i. 0.58 N HF - Measure 20 mL of 48% HF in a plastic graduated cylinder and pour into a 1L plastic bottle. Add 980 mL DI. Recap the bottle tightly and shake to mix.
f. Hydrochloric-hydrofluoric acid solution- add 333 mL conc HCl and 3.6 mL HF to 500 mL DI and dilute to 1 L. Prepare fresh daily.
g. Concentrated Nitric Acid, HNO$_3$
   i. 0.5 M HNO$_3$= 32 mL conc HNO$_3$ up to 1 L with DI
   ii. 2 M HNO$_3$= 127 mL conc HNO$_3$ up to 1 L with DI
   iii. 3 M HNO$_3$= 191 mL conc HNO$_3$ up to 1 L with DI
h. Aluminum nitrate, anhydrous
   i. Nitric acid-aluminum nitrate solution- dissolve 212 g of anhydrous Al(NO$_3$)$_3$ in DI. Add 191 mL conc HNO$_3$ and dilute to 1L with DI.
j. Concentrated Hydrochloric acid, HCl
   i. 1 M HCl= 83 mL conc HCl up to 1 L with DI
   ii. 4 M HCl= 333 mL conc HCl up to 1 L with DI
   iii. 7 M HCl= 581 mL conc HCl up to 1 L with DI
   iv. 9 M HCl= 750 mL conc HCl up to 1 L with DI
k. Oxalic acid dihydrate (H$_2$C$_2$O$_4$*2H$_2$O)
l. HCl-oxalic acid solution- dissolve 6.3 g oxalic acid dihydrate in 400 mL DI. Add 417 mL conc. HCl. Cool to room temperature and dilute to 1 L with DI.
m. Sodium nitrite
n. Nitric acid-sodium nitrite solution- add 32 mL conc HNO$_3$ to 200 mL DI. Dissolve 1.72g sodium nitrite in the solution and dilute to 250 mL with DI. Prepare fresh daily.
o. Ammonium oxalate monohydrate ((NH₄)₂C₂O₄·H₂O)

p. Ammonium hydrogen oxalate (0.1M) - dissolve 6.31 g of oxalic acid dihydrate and 7.11 g of ammonium oxalate monohydrate in 900 mL of water, filter (Whatman No. 4 suggested) and dilute to 1 L with DI water.

q. Ammonium hydroxide (5% by wt) - dissolve 50 g ammonium hydroxide in 950 g of water.

r. Ascorbic acid.

s. Iron powder

t. Sulfamic acid (NH₂SO₃H)

u. Ferrous sulfamate solution (0.6M) - add 57 g of sulfamic acid to 150 mL DI, heat to 70°C, add 7 g of iron, in small increments until dissolved, filter (Whatman No. 4 suggested), transfer to flask and dilute to 200 mL with water. Prepare fresh weekly.

v. Filtered deionized water - filter 20 L of DI water through 0.45 µm pore size Millipore filters. Store the filtered water in a 20 L capacity plastic carboy with a spigot.

w. Neodymium carrier solution, 1000 mg/L (Spex Industries, Wayne, NJ), or equivalent.

x. Neodymium carrier solution, 500 mg/L. Dilute 10 mL of the 1000 mg/L Nd carrier solution to 20 mL with filtered deionized water.

y. Neodymium fluoride substrate solution - 10 µg/mL - pipette 5 mL of Nd carrier (1000 µg/mL) into a 500 mL plastic bottle. Add 460 mL of 1N HCl to the plastic bottle. Cap the bottle and shake to mix. Measure 40 mL of 48% HF in a plastic graduated cylinder. Uncap the bottle and add the HF. Recap the bottle and shake to mix thoroughly.

z. Ethanol, 100%.

i. Ethanol, 80% - mix 800 mL of 100% ethanol and 200 mL of filtered DI water. Store in a 1 L plastic bottle.

aa. Titanium trichloride, 20% solution.

viii. Sample collection, preservation, shipment and storage

a. Aqueous samples should be acidified with HNO₃ so that the pH is less than 2. Adding the acid precludes the formation of precipitates and thus analyte loss. In addition, lowering the pH will minimize the adsorption of radionuclides on container walls by creating relatively non-polar surfaces.
b. No preservation is necessary for soil, sludge, air filter, or organic samples before analysis.
c. Samples should be collected and shipped in plastic containers.

ix. Quality control
   a. Refer to QAM-Q-101, "Laboratory Quality Control"

x. Calibration and Standardization

xi. Procedure
   a. Sample preparation
      i. For solid samples, weigh about 10 g of well mixed, representative sample material. For liquid, measure a volume of representative, mixed sample. Record all weights and volumes before and after drying and ashing steps. Sample amount will depend on activity and may have to be increased if sensitivity is not sufficient.
      
      ii. Ashing of sample. Though ash and dry weights are not considered as basic data, they are used as in calculating the activity in the original sample. Thus, a completely carbon-free ash is not a necessity. Dry ashing is conducted as a two-stage process. The first stage is done at about 125°C to completely dry the sample. Subsequently, the temperature is raised at intervals over an 8 hr period to 500°C to produce an ash with a small amount of carbon. The length of time required for drying large samples is 16-24 hr. The temperature of the furnace should be raised slowly over a period of 8 hr (or more, if necessary) in this critical temperature range. When the upper limit has been reached without sample ignition, the furnace temperature can be raised more rapidly to 500°C and the samples ashed for 16 hr. If considerable amounts of carbon remain after 16 hr at 500°C, the sample should be crushed, transferred to a smaller metal tray and placed in a muffle furnace regulated at 550°C for 24 hr or until ashing is complete. There is always a danger that samples will fuse at this temperature and, therefore, some balance between this problem and the excessive carbon must be reached. After thorough ashing, the material
usually may be removed readily from the tray with a spatula, followed by brushing. A small paint brush is adequate. Except for very small original samples, the weight loss of residual ash in the trays is negligible. Before reuse, the trays are thoroughly scrubbed with detergent and water. After ashing, all samples should be weighed before further processing. This gives weight of ash per unit weight of original material. The sample must then be ground to pass a 40 mesh screen. Ash of a coarser size, though blended, may give anomalous analytical results. Since sieving will produce an inhomogenous sample, the ash should be blended thoroughly before analysis. If the entire ash sample is to be consumed in a single analysis, the grinding and sieving is not necessary.

iii. Acid extraction of Solid ashed sample
   1. Weigh out 10 g of ash and transfer to a 400-mL beaker.
   2. Add a weighed amount of $^{232}\text{U}$ tracer solution (~ 0.03 Bq) from the dispensing bottle.
   3. Add 200 mL of HNO$_3$ to the beaker and evaporate slowly to dryness.
   4. Add 25 mL of HNO$_3$ to the beaker. Repeat the acid addition and evaporation until a white residue is obtained. (Note: If silicious material is present, transfer the sample to a 100 mL platinum dish or a 100 mL Teflon beaker with HNO$_3$. Add 10 mL of HF to the vessel and evaporate to dryness. Repeat additions of 25 mL HNO$_3$ - 10 mL HF as necessary to volatilize the silica. Remove the HF by adding three successive 10 mL volumes of HNO$_3$ to the vessel and evaporate to dryness.)
   5. Add 25 mL of HCl and evaporate to dryness. Repeat the acid addition and evaporation twice more.
   6. Heat to dissolve the residue in 50-100 mL of 7N HCl.
   7. Continue with Determination.

b. Water or Liquid for Separation of Th, Cm, Am, Pu, and U.
i. If not already prefiltered, filter the sample through a 0.45 micron filter.
ii. If samples larger than 1 L are analyzed, evaporate the sample to ~1 L.
iii. Aliquot 500 to 1000 mL of the filtered sample (or enough to meet the required detection limit) into an appropriate size beaker.
iv. Add 5 mL of HCl per liter of sample (0.5 mL per 100 mL) to acidify each sample.
v. Add the appropriate tracers.
vi. Evaporate sample to <50 mL and transfer to a 100-mL beaker. (Note: For some water samples, calcium sulfate formation may occur during evaporation.) Gently evaporate the sample to dryness and redissolve in approximately 5 mL of HNO₃. Evaporate to dryness and redissolve in HNO₃ two more times, evaporate to dryness.

vii. Separation

a. Dissolve each precipitate from above in 10 mL of nitric acid-aluminum nitrate solution. (Note: An additional 5 mL may be necessary if the volume of precipitate is large.)

b. Add 2 mL of 0.6M ferrous sulfamate to each solution. Swirl to mix. (Note: If the additional 5 mL was used to dissolve the sample in Step 1, add a total of 3 mL of ferrous sulfamate solution.)

c. Add 200 mg of ascorbic acid to each solution, swirling to mix. Wait for 2-3 min. (Note: If particles are observed to be suspended in the solution, centrifuge the sample. The supernatant will be transferred to the column in the next step. The precipitates will be discarded.)

d. Uranium separation from plutonium, americium using U/TEVA resin:
   i. For each sample solution, place a U/TEVA Resin column in the column rack.
   ii. Place a beaker below each column, remove the bottom plug from each column and allow to drain.
   iii. Pipette 5 mL of 3M HNO₃ into each column to condition the resin and allow to drain.
iv. Place a clean, labeled 50-mL beaker below each column.

v. Transfer each solution into the appropriate U/TEVA Resin column by pouring or by using a plastic transfer pipette and collect the eluate.

vi. Add 5 mL of 3M HNO$_3$ to rinse to each beaker and transfer each solution into the appropriate U/TEVA Resin column and collect eluate.

vii. Add 5 mL of 3M HNO$_3$ into each column and collect eluate.

viii. Set aside the solutions collected for americium and plutonium separations.

ix. Pipette 4 mL of 9M HCl into each column and allow to drain. Discard this rinse. (Note: The rinse converts the resin to the chloride system. Some neptunium may be removed here.)

tax. Pipette 20 mL of 5M HCl - 0.05M oxalic acid into each column and allow it to drain.

xi. Discard eluate. (Note: This rinse removes neptunium and thorium from the column.

xii. The 9M HCl and 5M HCl-0.05M oxalic acid rinses also removes any residual ferrous ion that might interfere.)

xiii. Place a clean, labeled beaker below each column.

xiv. Pipette 15 mL of 0.01M HCl into each column to strip the uranium. Allow to drain.

xv. Evaporate to dryness. Treat with 5 mL of HNO$_3$ several times to remove traces of oxalic acid. Convert to HCl. Set the labeled beakers aside for Microprecipitation.

e. **Plutonium and americium separation using TRU resin**

i. Place a TRU Resin column in the column rack for each sample dissolved.

ii. Remove the bottom plug from each column and allow each column to drain.
iii. Pipette 5 mL of 2M HNO₃ into each column to condition resin and allow to drain (just prior to sample loading).

iv. Transfer each solution from the Uranium Separation step into the appropriate TRU Resin column by pouring and/or using a plastic transfer pipette.

v. Allow the load solution to drain through the column.

vi. Pipette 5 mL of 2M HNO₃ into the sample beaker and transfer this rinse to the appropriate column using the same plastic pipette.

vii. Allow the initial rinse solution to drain through each column.

viii. Pipette 5 mL of nitric acid-sodium nitrite solution directly into each column, rinsing each column reservoir while adding the nitric acid-sodium nitrite solution. (Note: Sodium nitrite is used to oxidize Pu⁺³ to Pu⁺⁴ and to enhance the plutonium/americium separation).

ix. Allow the rinse solution to drain through each column.

x. Add 5 mL of 0.5M HNO₃ to each column and allow to drain. (Note: 0.5M HNO₃ is used to lower the nitrate concentration prior to conversion to the chloride system.)

xi. Discard the load and rinse solutions.

xii. Ensure that clean, labeled beakers or vials are below each column.

xiii. Add 3 mL of 9M HCl to each column to convert to HCl. Collect the eluate.

xiv. Add 20 mL of 4M HCl to elute americium. Collect the eluate in the same beaker.

xv. Evaporate to dryness. Treat with 5 mL HNO₃ several times until wet-ashing of the residue is complete. Convert to HCl. Set beakers aside for Microprecipitation.
xvi. Rinse the columns with 25 mL of 4M HCl-0.1M HF. Discard eluate.

xvii. Ensure the clean, labeled beakers or vials are below each column. Add 10 mL of 0.1M NH₄HC₂O₄ to elute plutonium from each column.

xviii. Evaporate to dryness. Treat with 5 mL HNO₃ several times until wet-ashing of the residue is complete. Convert to HCl. Set beakers aside for **Microprecipitation**.

c. Water or Liquid for **Microprecipitation**
   i. Evaporate the separated sample to a small volume. If the liquid contains a significant amount of solid or organic material, proceed with treatment of the sample as a solid.
   ii. Add a weighed amount of $^{232}$U tracer solution (~ 0.017 Bq) from a dispensing bottle and evaporate slowly to dryness.
   iii. Add 50 mL of HNO₃ and evaporate to dryness. Add 25 mL of HNO₃ and evaporate twice more.
   iv. Dissolve the residue in 25 mL of HCl and evaporate to dryness. Repeat the HCl addition and evaporation.
   v. Heat to dissolve the residue in 50 mL of 7N HCl.
   vi. Continue with **Determination**.

d. Air filters.
   i. Cellulose filters:
      a. Add a weighed amount of $^{232}$U tracer solution (~ 0.017 Bq) from a dispensing bottle to the filter in a platinum dish and dry ash in an electric muffle at 550°C.
      b. Dissolve the residue in HNO₃ and transfer to a 250-mL beaker.
      c. Add 25 mL of HNO₃ and evaporate to dryness. Repeat the acid addition and evaporation twice more.
      d. Dissolve the residue in 25 mL of HCl and evaporate to dryness. Repeat the HCl addition and evaporation twice more.
      e. Heat and dissolve the residue in 50 mL of 7N HCl.
      f. Continue with **Determination**.
   ii. Glass fiber filters:
a. Place the filter and a magnetic stirring bar in a 400-mL Teflon beaker. Add a weighed amount of $^{232}$U tracer solution (~ 0.033 Bq) from a dispensing bottle.
b. Add 100 mL of HNO$_3$, mechanically stir while heating for 1 h. Reduce the solution volume to ~ 25 mL. Remove the stirring bar and rinse with H$_2$O.
c. Add 10 mL of HF and evaporate to dryness.
d. Repeat the 25 mL HNO$_3$ - 10 mL HF additions and evaporations as necessary to volatilize the silica.
e. Add 25 mL of HNO$_3$ to the beaker and evaporate to dryness. Repeat twice more.
f. Heat and dissolve the residue in 25 mL of HCl and evaporate to dryness. Repeat the HCl addition and evaporation twice more.
g. Dissolve the residue in 50 mL of 7N HCl.
h. Continue with Determination.

e. Preparation of Uranium samples without other radionuclides:
i. For water, evaporate the H$_2$O sample to a small volume.
ii. Add a weighed amount of $^{232}$U tracer solution (~ 0.017 Bq) from a dispensing bottle and evaporate slowly to dryness.
iii. Add 50 mL of HNO$_3$ and evaporate to dryness. Add 25 mL of HNO$_3$ and evaporate twice more.
iv. Dissolve the residue in 25 mL of HCl and evaporate to dryness. Repeat the HCl addition and evaporation.
v. Heat to dissolve the residue in ≤ 50 mL of 7N HCl.
f. Determination: For water or previously prepared solid, vegetation or filter samples now acid digested, pass the 7N HCl Uranium sample solution obtained during sample preparation through a prepared anion exchange column (20 mL of Bio-Rad AG1-X4 conditioned with 500 mL of 7N HCl).
i. Discard the column effluent.
ii. Wash the column with 400 mL of 7N HCl. Discard the washings.
iii. Elute the uranium with 200 mL of 1N HCl, collecting the eluent in a 250-mL beaker.
iv. Discard the resin.
v. Evaporate the eluate to near dryness.
vi. Destroy any residual organic material with dropwise additions of HNO₃.

vii. Evaporate the solution to dryness. Dissolve the residue in a few drops of HCl.

viii. Convert the solution to the chloride with three 5 mL additions of HCl.

ix. Add 1-2 mL of 1N HCl, prepared with filtered DI water. Cool to room temperature.

g. **Microprecipitation** of Uranium

i. The U bearing solution must be in HCl solution.

ii. Transfer 1-2 mL of the U bearing solution (1N HCl) to a 10-mL plastic culture tube.

iii. Wash the original sample vessel twice with 1-mL portions of 1N HCl. Transfer the washings to the culture tube. Mix by gently shaking the tube.

iv. Add 100 µL of the 0.5 mg/mL Nd carrier with an Eppendorf pipette. Gently shake the tube to mix the solution.

v. Add four drops of 20% Ti trichloride to the tube and gently shake the tube. A strong permanent violet color should appear. If the color fails to appear, add a few more drops of Ti trichloride.

vi. Add 10 drops (0.5 mL) of 48% HF to the tube and mix well by gentle shaking.

vii. Place the tube in a cold-water ice bath for at least 30 min.

viii. Insert the polysulfone filter stem in the 250 mL vacuum flask. Place the stainless steel screen on top of the fitted plastic filter stem.

ix. Place a 25 mm Metricel filter on the stainless steel screen. **Caution** - place the less glossy side of the Metricel filter face up. The filters are usually shipped in the box in this manner, but the analyst should check each filter visually.

x. Wet the filter with 100% ethanol. Center the filter on the stainless steel screen support and apply a vacuum.

xi. Lock the filter chimney firmly in place on the filter stem. Open the system to full vacuum.

xii. Wash the filter with 100% ethanol, followed by a filtered deionized water wash.
xiii. Draw 5 mL of Nd substrate solution into a plastic pipette.
xiv. Add 5 mL of the Nd substrate solution down the side of
the filter chimney. Apply a vacuum to the filter for at
least 15 sec.

xv. Repeat these 2 steps above with an additional 5 mL of
the substrate solution.

xvi. Place the sample to be filtered in a 150 mL beaker
containing 25 mL of H$_2$O. Set the beaker in an ultrasonic
unit containing about a 2.54 cm depth of H$_2$O.

xvii. Ultrasonicate the sample tube for about 1 min to
suspend the NdF$_3$ precipitate.

xviii. Pour the sample down the side of the filter chimney and
apply a vacuum.

xix. Add about 2 mL of 0.58N HF to the tube and
ultrasonicate briefly. Pour the wash down the side of the
filter chimney. Repeat this step.

xx. Add about 2 mL of filtered deionized water to the tube
and ultrasonicate briefly. Pour the wash down the side of
the filter chimney. Repeat.

xxi. Add about 2 mL of 80% ethanol to the tube and
ultrasonicate briefly. Pour the wash down the side of the
filter chimney. Repeat.

xxii. Wash any drops remaining on the sides of the chimney
down toward the filter with 80% ethanol. **Caution** -
Directing of a stream of liquid onto the filter will disturb
the distribution of the precipitate on the filter and render
the sample unsuitable for α-spectrometry resolution.

xxiii. Without turning off the vacuum, remove the filter
chimney.

xxiv. Reduce or turn off the vacuum to remove the filter.
Discard the filtrate. (**Caution** – If the filtrate is to be
retained, it should be placed in a plastic container to
avoid dissolution of the glass vessel by dilute HF.)

xxv. Place the filter directly on a suitable mounting disc.
Secure with a mounting ring.

xxvi. Place the mounted sample under a heat lamp (sample
to lamp distance should be about 10 cm) for 10 min prior
to α-spectrometry measurement.
h. **Analysis:** Proceed with analysis using QAM-RI-107, “Determination of Uranium by Alpha Spectroscopy”

xii. **Data analysis and calculations**
   a. Refer to QAM-RI-107 for data analysis and calculations.

xiii. **Method performance**
   a. Method performance, data assessment and acceptance, corrective action: refer to QAM-Q-101, "Laboratory Quality Control" for DOP and DOC requirements.
   b. It is necessary to analyze reagent blanks with each batch of samples to correct the U results.

xiv. **Pollution prevention**
   a. Waste management and pollution prevention: refer to QAM-W-101, "Disposal of Laboratory Waste".

xv. **Data assessment and acceptance criteria for quality control measures**
   a. Method performance, data assessment and acceptance, corrective action: refer to QAM-Q-101, "Laboratory Quality Control"

xvi. **Corrective actions for out-of-control data**
   a. All aspects of this procedure comply with QAM-Q-101, “Quality Control” and QAM-Q-105 “Corrective Action”.

xvii. **Contingencies for handling out-of-control or unacceptable data**
   a. All aspects of this procedure comply with QAM-Q-101, “Quality Control” and QAM-Q-105 “Corrective Action”.

xviii. **Waste management**
   a. Refer to QAM-W-101 “Disposal of Laboratory Waste”

xix. **References**
   a. USDOE Health and Safety Laboratory manual 300.

xx. **Any tables, diagrams, flowcharts and validation data**
   a. Lower Limit of Detection (LLD) (expected- will be determined by Demonstration of Performance)
### LOWER LIMIT OF DETECTION (LLD) (expected)
Uranium Isotopes

<table>
<thead>
<tr>
<th>Parameter</th>
<th>(%)</th>
<th>Count (mBq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Counter Efficiency</td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>Counter Background</td>
<td>(cps)</td>
<td>3.33x10^-6 for $^{238}$U</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.33x10^-6 for $^{234}$U</td>
</tr>
<tr>
<td>Yield</td>
<td>(%)</td>
<td>85</td>
</tr>
<tr>
<td>Blank</td>
<td>(cps)</td>
<td>3.33x10^-6 for $^{238}$U</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.33x10^-5 for $^{234}$U</td>
</tr>
<tr>
<td>LLD (400 min)</td>
<td>(mBq)</td>
<td>0.23 for $^{238}$U</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.53 for $^{234}$U</td>
</tr>
<tr>
<td>LLD (1000 min)</td>
<td>(mBq)</td>
<td>0.21 for $^{238}$U</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.48 for $^{234}$U</td>
</tr>
<tr>
<td>LLD (5000 min)</td>
<td>(mBq)</td>
<td>0.065 for $^{238}$U</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.15 for $^{234}$U</td>
</tr>
</tbody>
</table>