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Experimental Results of NWCF Run H-4 Calcine Dissolution Studies Performed in FY-98 and FY-99

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ABSTRACT

Dissolution experiments were performed on actual samples of NWCF Run H-4 radioactive calcine in fiscal years 1998 and 1999. Run H-4 is an aluminum/sodium blend calcine. Typical dissolution data indicates that between 90-95 wt% of H-4 calcine can be dissolved using 1gram of calcine per 10 mLs of 5-8M nitric acid at boiling temperature. Two liquid raffinate solutions composed of a WM-188/aluminum nitrate blend and a WM-185/aluminum nitrate blend were converted into calcine at the NWCF. Calcine made from each blend was collected and transferred to RAL for dissolution studies. The WM-188/aluminum nitrate blend calcine was dissolved with resultant solutions used as feed material for separation treatment experimentation. The WM-185/aluminum nitrate blend calcine dissolution testing was performed to determine compositional analyses of the dissolved solution and generate UDS for solid/liquid separation experiments. Analytical fusion techniques were then used to determine compositions of the solid calcine and UDS from dissolution. The results from each of these analyses were used to calculate elemental material balances around the dissolution process, validating the experimental data. This report contains all experimental data from dissolution experiments performed using both calcine blends.

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CONTENTS

FIGURES

TABLES

Experimental Results of NWCF Run H-4 Calcine Dissolution Studies Performed in FY-98 and -99

BACKGROUND AND INTRODUCTION

In 1995, a settlement agreement was reached between the State of Idaho and the U.S. Department of Energy. Sections of the agreement mandated treatment of high level radioactive calcine waste currently stored at the Idaho Nuclear Technology and Engineering Center (INTEC) at the Idaho National Engineering and Environmental Laboratory (INEEL). Treatment includes processing the calcine for transport to a national repository by the year 2035.

Radioactive calcine is the product of calcination of radioactive raffinates originating from nuclear fuel reprocessing activities previously conducted at INTEC. The calcination process converted liquid raffinates into granular solid material reducing storage volume and leakage potential. Due to the numerous types of fuels reprocessed at INTEC, there is a variety of calcine compositions in storage. The calcine is stored in stainless steel bins encased in cylindrical concrete vaults known as Calcined Solids Storage Facilities (CSSFs). The CSSF structures are commonly referred to as binsets. There are seven binsets constructed at INTEC with six presently storing calcine. The volume of calcine stored is currently estimated at roughly 4200 m^3.

Calcine dissolution is the key front-end unit operation of several separations' treatment options under consideration as documented in the Draft Environmental Impact Statement [8]. To support the investigation of various treatment options, dissolved calcine solutions were used as feedstock for solid/liquid separations, ion exchange, and solvent extraction experiments performed in the Remote Analytical Laboratory (RAL) in 1998-99.

NWCF Run H-4 Calcine included two feed blends, WM-188/aluminum nitrate and WM-185/aluminum nitrate. Samples pulled from the WM-188/aluminum nitrate blend calcine were dissolved to determine percent dissolution and provide feedstock solutions for AMP-PAN and FS-2 ion exchange experiments, solid/liquid separations using the cells unit cross-flow filter (CUF), and the universal extraction (UNEX) solvent extraction experiment. Samples pulled from the WM-185/aluminum nitrate blend calcine were used for dissolution testing, characterization determinations, and to calculate elemental material balance for calcine dissolution. This report documents the compositional data and calculated results for numerous radioactive H-4 calcine dissolution experiments performed in FY-98 and -99.

EXPERIMENTAL

All Run H-4 radioactive calcine dissolution experiments were conducted in the RAL hot cell. The cell provides radiation shielding necessary to handle radioactive material remotely with manipulators. Using manipulators, RAL analysts assembled the dissolution setup using standard equipment. A typical dissolution experimental setup is shown in Figure 1. The standard equipment setup consisted of a 1-liter glass dissolver, stirrer/hotplate, and reflux condenser. The dissolver was placed on a stirrer/hotplate with a reflux condenser inserted in the top of the dissolver allowing cooling water to reflux the acid vapors exiting the system.

Dissolution parameters were varied slightly as needed to provide appropriate quantities and compositions of the dissolved calcine product to separations'experimenters. For example the CUF required ample solids to evaluate solid/liquid separation effectiveness, while the ion exchange and solvent extraction experiments required specifically requested dissolved solution acid concentrations for desired separation effectiveness.

Figure 1. Dissolution equipment setup.

The generic dissolution procedure consisted of adding a measured volume of nitric acid to the dissolver, heating to desired temperature, adding the measured mass of calcine, and observe dissolution for a set amount of time. (The specific dissolution procedure is found in Appendix A.) When the time had been reached, the solution was allowed to cool and any undissolved solids (UDS) were given time to settle prior to filtering solution through a tared 0.45 micron Cole Parmer filter unit. The filtered solution was transferred into an appropriately labeled bottle for use in separation experiments. The filter containing the UDS was then allowed to dry then weighed. The UDS weight was then calculated and percent dissolution was determined by:

$$wt\%dissolution = [1 - \frac{UDS\ wt}{Initial\,Calcine\,wt}] * 100\%$$

WM-188/Aluminum Nitrate Blend Calcine Dissolution Testing

There were four sets of dissolution testing. Details for each set of testing follows.

RAL prep batch 01-R

An initial dissolution of WM-188/aluminum nitrate blend calcine was performed to determine fission product concentration, weight percent dissolution, and acid consumption (moles of acid used to dissolve 1 gram of calcine). The filtered solution was submitted for cesium, strontium, and gamma scan analyses. Table 1 provides the experimental parameters associated with batch 01-R.

Table 1. Dissolution parameters for batch 01-R.

Batch	Calcine added (grams)	HNO_3 acid (molarity)	Volume added (liters)	Dissolution time (minutes)	Temperature
01-R	28.956	8.0	0.290	30	boiling

Dissolution test #1

A dissolution test #1 was performed. This test was performed in a series of four batch experiments. The parameters for the four batch experiments were 1g calcine/10mL acid ratio, 4.5 or 9.0M nitric acid, 1.5 hour dissolution time, and boiling temperature of solution. (Batch 3 was dissolved in 9.0M nitric acid). The dissolved solutions were combined and used as feedstock for AMP-PAN cesium ion exchange testing. The target final acid concentration of the dissolved solution was 2.0M H^+ (this is the reason there were two different nitric acid concentrations used). A final volume of 2.1 liters was collected for ion exchange testing. Table 2 provides the individual batch experimental parameters for dissolution test #1.

Table 2. Dissolution parameters for individual batches for dissolution test #1.

Batch	Calcine added (grams)	HNO_3 acid (molarity)	Volume added (liters)	Dissolution time (minutes)	Temperature
#1	54.054	4.5	0.541	75	boiling
#2	51.593	4.5	0.516	95	boiling
#3	59.883	9.0	0.600	90	boiling
#4	25.303	4.5	0.255	90	boiling

Dissolution test #2

Dissolution test #2 also incorporated a series of four batch experiments. The final filtered solutions were combined to provide a feedstock solution for ion exchange testing. Approximately 1.5 liters was collected for use with the ion exchange testing. Final acid concentration was measured after the solutions were combined. Weight percent dissolution was not calculated because of solids losses occurring during routine remote activities in the hot cell. Table 3 provides the individual batch parameters for dissolution test #2.

Table 3. Dissolution parameters for individual batches for dissolution test #2.

Batch	Calcine added (grams)	HNO_3 acid (molarity)	Volume added (liters)	Dissolution time (minutes)	Temperature
#1	26.085	5.1	0.261	90	boiling
#2	41.936	5.1	0.420	90	boiling
#3	48.912	5.13	0.490	90	boiling
#4	49.09	5.13	0.491	90	boiling

Dissolution test #3

Dissolution test #3 was performed to provide feedstock solution for UNEX solvent extraction batch contacts. Solvent extraction batch contacts need small volumes of solution; consequently, only one batch dissolution was performed. Approximately 0.4 liters of filtered solution was collected from the single batch test. Final acid concentration was measured and the weight percent dissolution was calculated for test #3. Table 4 provides test parameters for dissolution test #3.

Table 4. Dissolution parameters for dissolution test #3.

Batch	Calcine added (grams)	HNO_3 acid (molarity)	Volume added (liters)	Dissolution time (minutes)	Temperature
#1	39.151	5.1	0.392	90	boiling

WM-185/Aluminum Nitrate Blend Calcine Dissolution Testing

Two sets of dissolution testing were performed using the WM-185/aluminum nitrate blend calcine. Details for these tests follow.

Batch chloride

The batch chloride dissolution experiment was performed to determine chloride concentration, final dissolved solution acid concentration, and weight percent dissolved for the WM-185/aluminum nitrate blend calcine. The experiment utilized the identical equipment as was used with the WM-188/aluminum nitrate blend calcine experiments. Table 5 provides test parameters used for batch chloride test.

Table 5. Dissolution parameters for batch chloride.

Batch	Calcine added (grams)	HNO_3 acid (molarity)	Volume added (liters)	Dissolution time (minutes)	Temperature
Batch Cl^-	20.181	5.1	0.201	60	Boiling

Calcine characterization and dissolution with elemental material balance

Prior to initiating calcine dissolution, the calcine was fully characterized using fusion methods for solids elemental characterization. The analytical department uses three fusion methods for determining solid elemental compositions. These methods use lithium tetraborate, sodium hydroxide, or sodium carbonate dependent on which analyte is desired. Lithium tetraborate fusion is used for most metals and radioactive elements. Sodium hydroxide fusion is used for lithium, boron, and anions. Sodium carbonate fusion is used for the remaining anions that form difficult to dissolve complexes such as phosphate. Fusion methodology begins by mixing a measured mass of sample with one of the three compounds at a-1:10 ratio, heating at high temperature in a furnace to form a melt, redissolving the melt in a chosen solvent, and submitting the solvent matrix for elemental analysis. Two independent characterizations were performed to provide elemental analyses of the calcine prior to performing dissolutions. The elemental analyses provided initial starting elemental compositions for use in material balance determinations.

Two dissolutions were performed to determine the material balance around H-4 calcine dissolution. The experimental setup was modified to allow for off-gas to be routed through two scrubber vessels set in series flow. The first scrubber was filled with 100mL of 1M sodium hydroxide and the second scrubber filled with 100mL of 1M nitric acid. The purpose of the scrubber additions was to determine if any volatile elements were escaping through the off-gas. The other difference from previous dissolutions was the addition of Tc-99 and I-129 to dissolution #1. Spiking with Tc-99 and I-129 increases the concentration of Tc-99 and I-129 to levels above analytical detection limits in an attempt to determine the fate of the two volatile species during dissolution.

At the completion of the dissolutions, the UDS were weighed to determine percent dissolved. The UDS were then recovered and characterized in the same manner as the initial calcine mass using analytical fusion methods. The elemental material balance surrounding dissolution was then calculated by adding elemental results from the dissolved solution with the UDS and off-gas results and dividing the sum by the initial elemental mass results in the calcine. Table 6 provides dissolution parameters used for dissolution #1 and dissolution #2.

Table 6. Dissolution parameters for dissolution #1 and dissolution #2.

Batch	Calcine added (grams)	HNO_3 acid (molarity)	Volume added (liters)	Dissolution time (minutes)	Temperature
Dissolution #1	10.001	8.0	0.100	120	Boiling
Dissolution #2	10.005	8.0	0.001	120	Boiling

RESULTS AND DISCUSSION

WM-188/Aluminum Nitrate Blend Dissolution Testing Results

RAL prep batch 01-R

The dissolution of this batch was the initial dissolution performed using the WM-188/aluminum nitrate blend calcine. Requested analytes from the dissolved solution included cesium, strontium, and gamma emitting isotopes. Weight percent dissolved, final acid concentration, and acid consumption was determined for batch 01-R dissolved solution. Table 7 presents the experimental results for batch 01-R.

Table 7. Experimental results for batch 01-R dissolution.

Dissolution Results	Wt % Dissolved	93.5%	Final acid Conc.	5.015M	Acid consumed	0.03 mol/gram		
Analytes	Cesium (ug/mL)	Strontium (ug/mL)	Eu-154 (dps/mL)	Eu-155 (dps/mL)	Cs-134 (dps/mL)	Cs-137 (dps/mL)	Zr-95 (dps/mL)	Co-60 (dps/mL)
Analytical data	4.19	9.1025	1.74E+04	5.08E+03	1.48E+04	3.89E+06	1.35E+03	4.11E+03

Dissolution test #1

Final dissolved solutions from four batches were combined to provide a feedstock solution for AMP-PAN ion exchange testing. The final solution was analyzed for those elements impacting ion exchange performance. A weight percent dissolved was calculated using UDS weights from the four batches and the total weight of calcine added to all four batches. The final dissolved acid concentration was measured and the acid consumed was calculated. Table 8 presents the analytical data and dissolution results from the final dissolved solution combined from the four batch dissolution solutions.

Dissolution test #2

Final dissolved solutions from four batches were combined to provide a feedstock solution for other ion exchange testing. The final solution was analyzed for chosen elements impacting ion exchange efforts. The final dissolved acid concentration was measured and the acid consumed was calculated. Weight percent dissolved was not calculated due to a loss of solids during batch #1and batch #4 testing in the hot cell. Table 8 presents the analytical data and dissolution results from the final dissolved solution combined from the four batch dissolution solutions.

Dissolution test #3

Final dissolved solution provided a feedstock solution for UNEX solvent extraction batch contacts. The final solution was analyzed for chosen elements impacting solvent extraction efforts. A weight percent dissolved was calculated using UDS weight and the initial calcine weight added to the dissolver. The final dissolved acid concentration was measured and the acid consumed was calculated. Table 8 presents the analytical data and dissolution results from the final dissolved solution.

Table 8. Experimental results from WM-188 blend dissolution tests #1, #2, and #3.

METAL and ANION RESULTS (ug/mL)			
	Test #1	Test #2	Test #3
Aluminum	2.92E+04	2.93E+04	2.79E+04
Barium	NR	NR	<3.10E+00
Boron	NR	NR	4.93E+02
Cadmium	NR	4.20E+01	NR
Calcium	6.93E+03	NR	3.00E+03
Cesium	9.13E+00	<5.57E+00	NR
Chloride	< 4.86E+01	2.83E+02	<2.44E+01
Chromium	2.11E+02	NR	NR
Fluoride	9.48E-01	2.64E-02	4.37E+02
Iron	9.86E+02	2.94E+02	2.51E+02
Lead	6.75E+01	8.36E+01	3.55E+01
Mercury	5.72E+00	<1.76E+00	4.34E+00
Nickel	1.10E+02	1.82E+01	NR
Potassium	1.28E+03	1.32E+03	1.50E+03
Sodium	4.02E+03	6.62E+03	5.51E+03
Strontium	9.00E+00	<11.30E+00	NR
Zinc	NR	NR	2.20E+01
Zirconium	3.26E+02	1.40E+02	NR
RADIOACTIVE RESULTS (dps/mL)			
Am-241	NR	NR	6.01E+02
Co-60	NR	4.16E+02	1.73E+03
Cs-134	NR	NR	3.73E+03
Cs-137	8.37E+06	1.12E+06	5.35E+06
Eu-154	NR	3.11E+03	1.51E+04
Pu-238	NR	NR	4.27E+03
Pu-239	NR	NR	5.15E+02
Tc-99	NR	NR	2.88E+02
Total Sr	NR	NR	8.07E+05 (dpm/mL)
Total Alpha	NR	NR	3.33E+05 (dpm/mL)
Total Beta	NR	NR	1.49E+08 (dpm/mL)
DISSOLUTION RESULTS			
Wt% dissolved	98.2%	ND	93.3%
Solution acid conc.	2.033M	1.041M	0.98M
Acid consumption	0.039 mol/gram	0.041 mol/gram	0.041 mol/gram

NR= Analyte not requested
ND= not determined, Less than indicate result is at or below analytical detection limit.

A specific list of desired analytes was requested for each dissolver solution resulting from the three dissolution tests. Analytes for each dissolver solution were requested based on their impacts on the performance of separations testing that the solution was going to be used for.

To summarize the three main WM-188/Alumnum Nitrate blend calcine dissolution testing results: 1) between 93 and 98 wt% of the calcine is expected to be dissolved using testing parameters documented in the preceding tables; 2) acid concentration of final dissolved product used for feedstock solutions to separations experiments can be adjusted by using between 4.5 and 8M nitric acid dissolvent; and 3) acid consumption values of 0.03-0.04 mol/gram calcine can be used to predict final dissolved product acid concentrations if the initial acid concentration of the dissolvent is known.

WM-185/Aluminum Nitrate Blend Dissolution Testing Results

Batch Cl^- dissolution results

Table 9 presents the experimental data compiled for batch Cl^- dissolution including the acid consumed per gram of calcine dissolved.

Table 9. Experimental results for Batch Cl^- dissolution.

	Chloride concentration	Acid concentration	Acid consumption	wt.% dissolved
Batch Cl^-	5.1E+01 ug/mL	1.28M	0.038 mol/gram	88.9%

The batch Cl^- dissolution revealed that there was 5.1E+01ug/mL chloride in WM-185/aluminum nitrate blend dissolved solution versus 2.83E+02 ug/mL in the WM-188 blend dissolved solution (see table 8 test #2). For corrosion considerations, chloride concentration in dissolver solution is important for high level waste equipment design. Further discussion of chloride is outside the scope of this effort.

Calcine characterization results with elemental compositions

Characterization of the H-4 calcine was the first stage of the material balance testing. Using the previously described fusion method, a full compositional analysis for H-4 calcine was completed. Table 10 presents the elemental fusion results and associated averaged values for H-4 calcine material used for both elemental material balance dissolutions compared with a previously estimated elemental composition of the WM-185/aluminum blend calcine. The previously estimated data represents an estimated composition calculated by O'Brien [8] using actual NWCF calciner feed tank compositions. It should be noted that there is excellent agreement between the averaged values and the previously estimated data.

The elemental composition of the "as received" calcine was determined from fusion data. Elemental compositions were used to estimate compound compositions. Using the summation of weight percentages for each compound, a component material balance around the fusion data was determined. Table 11 contains the calculated compound concentrations and the total sum of compound weight percentages.

Table 10. Elemental composition of WM-185/aluminum nitrate calcine.

		H-4 Calcine WM-185/ANN				Previously Estimated	
Component	Units	Test 1	Test 2	AVG.1 &2		Wm-185/ANN	
Eu-154	mCi/gm	7.30E-04	8.60E-04	7.95E-04		9.56E-04	Lithium Tetraborate Fusion Method for H-4 Results
Cs-137	mCi/gm	0.266	0.27	0.268		0.287	
Co-60	mCi/gm	8.60E-05	1.19E-04	1.03E-04		1.44E-04	
Aluminum	Wt.%	35	32.5	33.75		34.97	
Zirconium	Wt%	2.29E-03	2.42E-03	2.36E-03		0.24	
Calcium	Wt%	3.8	3.85	3.825		2.48	
Sodium	Wt%	9.45	9.58	9.515		7.36	
Molybdenum	Wt%	<0.0150	0.021	0.018		ND	
Potassium	Wt%	1.39	1.4	1.395		1.69	
Iron	Wt%	0.306	0.317	0.3115		0.33	
Chromium	Wt%	0.063	0.068	0.0655		0.057	
Magnesium	Wt%	0.105	0.116	0.1105		ND	
Rhodium	Wt%	<0.0100	<0.0097	<0.0099		ND	
Niobium	Wt%	0.0087	<0.0081	0.0084		ND	
Oxygen	Wt%	<35.48	<35.48	<35.48		ND	
Manganese	Wt%	0.244	0.241	0.2425		0.252	
Nickel	Wt%	0.0309	0.0302	0.03055		0.02	
Palladium	Wt%	<0.1416	<0.1369	<0.1393		ND	
Tin	Wt%	<0.0327	<0.0316	<0.0322		ND	
Copper	Wt%	0.0128	0.0333	0.02305		ND	
Cadmium	Wt%	0.0422	0.0446	0.0434		0.03	
Silver	Wt%	0.0127	0.0112	0.01195		ND	
Cerium	Wt%	<0.0161	<0.0155	<0.0158		ND	
Lead	Wt%	0.1058	0.1172	0.1115		0.095	
Barium	Wt%	<0.0020	<0.0019	<0.0020		ND	
Uranium	Wt%	<0.1062	<0.1026	<0.1044		0.018	
Gadolinium	Wt%	0.0169	0.0152	0.01605		ND	
Strontium	Wt%	0.0209	0.0903	0.0556		ND	
Neodymium	Wt%	<0.0184	<0.0178	<0.0181		ND	
Technetium	Wt%	ND	ND	ND		ND	Sodium Hydroxide Fusion Method for H-4 Results
Iodine	Wt%	ND	ND	ND		ND	
Ruthenium	Wt%	<0.0277	<0.0276	<0.0277		ND	
Selenium	Wt%	<0.1044	<0.1041	<0.1043		ND	
Boron	Wt%	0.599	0.541	0.57		0.52	
Mercury	Wt%	<0.0031	<0.0031	<0.0031		0.0002	
Sulfate	Wt%	1.394	1.393	1.3935		0.84	
Phosphate	Wt%	ND	ND	ND		0.06	
Nitrate	Wt%	11.29	11.41	11.35		14.88	
Chloride	Wt%	0.068	0.124	0.096		0.26	
Fluoride	Wt%	0.77	0.65	0.71		0.74	
	Total %	100.6894	98.49432	99.86075			

Oxygen wt% was calculated using major known oxide compounds.

ND= No data

Less than indicates result is at or below analytical detection limits.

Table 11. Calculated compound concentrations for H-4 calcine.

Compound	wt.% in H-4 Calcine
Al_2O_3	63.75
B_2O_3	1.84
CaO	3.4
CaF_2	1.48
$CaSO_4$	2.04
CdO	0.05
Ce_2O_3	<0.02
Cr_2O_3	0.1
HgO	<0.01
Fe_2O_3	0.45
K_2O	1.68
MnO_2	0.38
Na_2O	7.2
$NaNO_3$	15.7
NiO	0.04
Gd_2O_3	0.02
PbO or Pb_3O_4	0.12
SrO	0.07
Cs_2O	<0.01
Mo_2O_3	<0.02
MgO	0.18
PdO	0.16
SnO	<0.04
Cu_2O	0.03
Ag_2O	0.01
BaO	<0.01
UO_2	<0.12
Nd_2O_3	<0.02
RuO_2	<0.04
SeO_2	<0.15
ZrO_2	0.32
Total wt.%	**99.46**

Assumptions: NO_3^- was assumed to be used up as $NaNO_3$; SO_4^{2-} and F^- was assumed to be used up as either $CaSO_4$ or CaF_2.

Less than indicates calculated results use concentrations at or below analytical detection limits.

WM-185/aluminum nitrate blend calcine dissolutions

Two dissolution experiments were performed using the WM-185 /aluminum nitrate blend. The dissolution parameters were identical for both experiments. The first dissolution was different in that radioactive technetium and iodine were spiked in the initial calcine solids and the UDS solids prior to being fused for compositional analysis. The purpose of the radioactive spikes was to increase concentrations to measure recovery or determine the fate of the species during performance of the fusion methods. This spike procedure provided inconclusive evidence as to the fate of the elements because the spike isotopes chosen were the same isotopes as were found to be in the calcine.

Table 12 includes the experimental data received from the two dissolutions. The data includes the masses used to calculate weight percent dissolved.

Table 12. WM-185/ aluminum nitrate experimental dissolution data.

Experiment	Initial calcine weight (g)	UDSweight (g)	Weight % dissolution
Dissolution #1	10.001	0.541	94.6%
Dissolution #2	10.005	0.554	95.5%

The elemental composition results for the dissolved solution were reported in units elemental concentrations of dissolved constituents per gram of calcine added to the nitric acid dissolvent. The elemental compositions of the UDS were also required to determine what percentage of each element was not dissolved in nitric acid. Analyses of the two scrub solutions were requested to determine if volatile species were scrubbed from the dissolver off-gas. Table 13A provides the elemental compositions of the final dissolved solutions and Table 13B provides elemental compositions of the UDS and Off-gas solutions.

Table 13A. Elemental composition of WM-185 blend dissolved solutions.

		Dissolved Solutions	
Component	Units	Diss. #1	Diss. #2
Eu-154	dps dissolved/g calcine	2.23E+04	2.49E+04
Cs-137	dps dissolved/g calcine	1.04E+07	1.01E+07
Co-60	dps dissolved/g calcine	2.410E+03	3.009E+03
Technetium	dps dissolved/g calcine	240424	ND
Iodine	dps dissolved/g calcine	ND	ND
Aluminum	mg dissolved/kg calcine	3.55E+05	3.25E+05
Zirconium	mg dissolved/kg calcine	1.869E+03	1.837E+03
Calcium	mg dissolved/kg calcine	3.67E+04	3.65E+04
Sodium	mg dissolved/kg calcine	1.068E+05	1.022E+05
Molybdenum	mg dissolved/kg calcine	7.324E+01	7.348E+01
Potassium	mg dissolved/kg calcine	1.410E+04	1.460E+04
Iron	mg dissolved/kg calcine	2.612E+03	2.601E+03
Chromium	mg dissolved/kg calcine	5.270E+02	5.178E+02
Magnesium	mg dissolved/kg calcine	9.394E+02	9.604E+02
Rhodium	mg dissolved/kg calcine	<2.02	<2.02
Niobium	mg dissolved/kg calcine	2.460E+00	1.950E+00
Manganese	mg dissolved/kg calcine	2.233E+03	2.277E+03
Nickel	mg dissolved/kg calcine	2.201E+02	2.149E+02
Palladium	mg dissolved/kg calcine	<28.33	<28.31
Tin	mg dissolved/kg calcine	7.850E+00	1.746E+01
Copper	mg dissolved/kg calcine	1.054E+02	1.070E+02
Cadmium	mg dissolved/kg calcine	3.488E+02	3.522E+02
Silver	mg dissolved/kg calcine	<0.44	<0.44
Cerium	mg dissolved/kg calcine	1.350E+01	1.419E+01
Lead	mg dissolved/kg calcine	9.140E+02	9.082E+02
Barium	mg dissolved/kg calcine	1.247E+01	1.350E+01
Uranium	mg dissolved/kg calcine	2.606E+02	2.401E+02
Gadolinium	mg dissolved/kg calcine	1.713E+02	1.668E+02
Strontium	mg dissolved/kg calcine	1.449E+02	1.440E+02
Neodymium	mg dissolved/kg calcine	2.908E+01	2.953E+01
Ruthenium	mg dissolved/kg calcine	5.567E+01	5.224E+01
Selenium	mg dissolved/kg calcine	<6.09	10.79
Boron	mg dissolved/kg calcine	6.38E+03	5.72E+03
Mercury	mg dissolved/kg calcine	19	15
Sulfate	mg dissolved/kg calcine	9.500E+03	9.900E+03
Nitrate	mg dissolved/kg calcine	ND	ND
Chloride	mg dissolved/kg calcine	<1200	1.010E+03
Fluoride	mg dissolved/kg calcine	1.600E+04	3.900E+03

Less than indicates result is at or below analytical detection limit.

Table 13B. Elemental composition of WM-185 blend UDS and Off-Gas solutions.

Undissolved Solids			
Component	**Units**	**UDS #1**	**UDS #2**
Eu-154	dps/g UDS	4.115E+04	3.995E+04
Cs-137	dps/g UDS	2.880E+05	2.950E+05
Co-60	dps/g UDS	4.769E+03	5.792E+03
Technetium	dps/g UDS	2826.2	1639.2
Iodine	dps/g UDS	ND	100.5
Aluminum	mg/kg UDS	5.18E+05	2.84E+05
Zirconium	mg/kg UDS	9.557E+03	1.595E+04
Calcium	mg/kg UDS	6.15E+03	6.40E+03
Sodium	mg/kg UDS	4.350E+04	3.160E+04
Molybdenum	mg/kg UDS	<147.40	<151.78
Potassium	mg/kg UDS	3.750E+04	3.850E+04
Iron	mg/kg UDS	4.560E+03	6.821E+03
Chromium	mg/kg UDS	5.331E+02	5.853E+02
Magnesium	mg/kg UDS	1.902E+03	1.828E+03
Rhodium	mg/kg UDS	<96.92	<99.80
Niobium	mg/kg UDS	9.591E+01	9.481E+02
Manganese	mg/kg UDS	3.752E+03	4.329E+03
Nickel	mg/kg UDS	4.331E+02	1.495E+03
Palladium	mg/kg UDS	<1361.97	<1402.43
Tin	mg/kg UDS	<313.99	2.414E+03
Copper	mg/kg UDS	1.969E+02	5.697E+02
Cadmium	mg/kg UDS	2.151E+02	2.661E+02
Silver	mg/kg UDS	1.121E+02	1.185E+02
Cerium	mg/kg UDS	<154.47	<159.06
Lead	mg/kg UDS	5.008E+02	6.331E+02
Barium	mg/kg UDS	1.121E+02	1.258E+02
Uranium	mg/kg UDS	<1020.72	<1051.04
Gadolinium	mg/kg UDS	2.403E+02	2.703E+02
Strontium	mg/kg UDS	1.999E+02	2.755E+02
Neodymium	mg/kg UDS	<176.68	<181.93
Ruthenium	mg/kg UDS	<268.49	<271.13
Selenium	mg/kg UDS	<1013.51	<1023.45
Boron	mg/kg UDS	<472.43	<477.06
Mercury	mg/kg UDS	1.390E-01	6.200E-02
Sulfate	mg/kg UDS	1.957E-01	1.245E-01
Nitrate	mg/kg UDS	1.710E+00	1.520E+00
Chloride	mg/kg UDS	1.300E-02	3.000E-02
Fluoride	mg/kg UDS	< 1.57	1.800E+00

Off-Gas					
Component	**Units**	**CS #1**	**AS #1**	**CS #2**	**AS #2**
Eu-154	dps/g calcine	BDL	BDL	BDL	BDL
Cs-137	dps/g calcine	59	61.2	33.1	55.5
Co-60	dps/g calcine	BDL	BDL	BDL	BDL
Technetium	dps/g calcine	1.41	ND	1.8	ND
Ruthenium	N/A	<5.50	ND	<5.50	ND
Mercury	mg/kg calcine	<0.31	<0.31	<0.31	<0.31
Nitrate	mg/kg calcine	<0.50	ND	<0.50	ND
Chloride	mg/kg calcine	< 0.12	< 0.12	< 0.12	< 0.12

BDL= Below detection limit
ND= No data or not determined
CS= Caustic scrub solution
AS= Acidic scrub solution

Elemental material balance around dissolution of WM-185/aluminum nitrate blend

Material balance calculations were completed for each stable element and radioactive specie that had been analyzed for in Table 13A. Each elemental material balance calculation was found by taking the sum of concentrations of each element in the effluent section of the dissolution system and dividing this sum by the concentration of the analyzed element in the initial calcine fusion. The following equation was used to determine elemental material balance for each element.

$$\%MB = \frac{CONC._{diss.sol} + CONC._{UDS.} + CONC._{OFF-Gas}}{CONC._{calcine}} \times 100\%$$

Unit conversions were needed to ensure agreement of terms throughout the calculation. The effluent sections of the dissolution system consisted of the dissolved solution, UDS, and off-gas in the case of volatile species. Table 14 includes the material balance results calculated for the H-4 dissolution experiment. Table 14 does not include material balance calculations for all stable elements because analytical results received were at or below detection limits. (Refer to Tables 10 and 11). Appendix B provides all of the material balance dissolution testing raw data as received from the analytical department.

Table 14. Elemental material balance for WM-185 blend calcine dissolution.

Elemental Material Balance			
Element	**Dissolution #1**		**Dissolution #2**
Eu-154	94.45		85.36
Cs-137	109.97		101.70
Co-60	87.22		73.85
Technetium	157.81		100.04
Iodine	ND		101.23
Aluminum	107.88		104.81
Zirconium	103.98		112.16
Calcium	97.45		95.72
Sodium	115.50		108.49
Potassium	116.01		119.41
Iron	93.30		93.88
Chromium	87.67		80.64
Magnesium	99.63		91.30
Manganese	99.97		104.34
Lead	88.95		80.46
Gadolinium	109.04		119.50
Boron	107.01		106.22
Sulfate	68.13		71.09

The material balance results for the major calcine constituents are well within analytical error ranges incurred during analyses. The results validate analytical procedures used in determining compositional analysis for both liquid and solid fractions of the dissolution experiment.

CONCLUSIONS

The weight percent dissolved for both WM-188/aluminum nitrate blend calcine and the WM-185/aluminum nitrate blend calcine is expected to reach 90-95 wt% using 5-8 M nitric acid at a 1 gram calcine to 10 mLs acid ratio, at boiling temperature for 1-1.5 hours.

Spiking radioactive technetium and iodine to improve measurement of recovery of volatile species did not provide desired additional useful information.

Acid consumption for each blend dissolution testing ranged between 0.03-0.04 mols of acid consumed per gram of calcine dissolved. The final acid concentration of the dissolved solution can be adjusted to meet separations experimental testing requests.

The material balance results for the H-4 dissolution experiments validate analytical procedures used to determine compositions of both liquid and solid fractions of the dissolution experiment.

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Appendix A

Dissolution Procedure

APPENDIX A

Dissolution Procedure

Procedure For Dissolution Of Radioactive Calcine Solids

Equipment:

1. Ensure the following equipment is assembled and operational.

   -Reflux condenser connected to DI water supply
   -Dissolution Vessel with appropriate stirbar and glass stoppers
   -Magnetic Stirplate/Hotplate
   -Balance
   -500 mL Filter Unit with 0.45 µm filter
   -Vacuum Pump with tubing and hookup
   -Weighing Boats/Cups and necessary accessories
   -Ringstand to support reflux condenser

2. Retrieve calcine from storage location.

Procedure:

1. Insert stirbar in dissolver vessel and place dissolver on hotplate then insert condenser (supported by ringstand) in top of dissolver.

   a. Researcher will provide technician/analyst with dissolution parameters to be used for dissolution.
   b. Parameters: Nitric acid concentration________M, % product to % fines ratio________, calcine weight to acid volume_________gms/mL, dissolution time________hrs.

      Note: % product to % fines ratio is needed for pilot plant calcine dissolution only.

2. Tare weigh boat/cup on balance and record weight._________gms

3. Re-zero balance then carefully pour calcine into weighing boat/cup until balance indicates weight as directed by researcher. Record actual weight of calcine. _________gms.

4. Slowly add calcine to dissolver.

   (Note: Some experiments may require calcine to be added to an already heated acid, in this case this step will be performed after step 7.)

5. Add appropriate volume of nitric acid to dissolver. (Calcine weight x mL acid volume = mLs of nitric acid required.) Volume added________mLs. Place stopper in calcine addition port and ensure vessel is sealed.

6. Start water flow through condenser and record time.__________

7. Turn heat on to hotplate. Begin stirring, stir at a rate that just moves solution in a circular motion but doesn't slosh solution up on walls of dissolution vessel.

8. Observe solution during heatup. When solution reaches temperature record time _______. Maintain solution temperature for dissolution time recorded above. If directed by experimenter, pull a sample of the heated solution for kinetic study purposes.

9. At the end of dissolution time, shut off heat to hotplate. Record time________. Continue stirring for 1 hour to assist cooling of solution. Continue water flow through condenser to prevent evaporation of solution during cool down.

10. Allow to cool for 1 hour, shut down stirring and water flow to condenser. Record time to calculate volume of water added to PEW through condenser.

11. Carefully remove condenser from dissolver vessel. Insert glass stopper to top of dissolver and transport vessel to window with vacuum pump capabilities. Allow settling for a minimum of 12 hours before filtering solution.

12. Prepare to filter solution. Place filtration unit on balance and record tare weight._________gms

13. Assemble filtration unit and attach to vacuum pump. Energize vacuum pump.

14. Carefully decant solution from dissolver vessel into filtration unit leaving very small volume of solution with undissolved solids (UDS) in dissolver vessel. When solution has passed through filter and captured in bottom of filtration unit, transfer solution into an appropriately labeled sample bottle for analysis.

15. Reassemble filtration unit and pour remainder of UDS with solution into filtration unit by carefully swishing solution in a circular motion before pouring rapidly into filtration unit. Rinse dissolver vessel as necessary to remove all solids from dissolver vessel to filtration unit.

16. After all rinse solution has passed through filter, pour a small volume of Isopropanol (15 mLs) onto solids to assist with drying of solids. Allow solids to completely dry under vacuum. De-energize vacuum pump.

17. Disassemble filtration unit and reweigh top portion of unit on balance. If balance reading does not stabilize, solids need more time to dry. When reading stabilizes, record weight._________gms

18. Calculate percent dissolution: Subtract tare weight of filter (step 13) from final weight of filter with solids (step 18), this will be weight of UDS. Subtract UDS weight from initial mass of calcine added to dissolution vessel (step 3) then divide this number by initial mass of calcine added (step 3) and multiply by 100% to determine percent dissolution. Record percent dissolution.________%

(Step 13)________gms - (Step 18)________gms =____________UDS wt.

(Step 3)________gms - (UDS wt.) = ________grams dissolved

$$\% \text{ Dissolution} = \frac{gramsdissolved}{(Step3)} \text{ X } 100\%$$

19. Thoroughly rinse dissolver vessel as necessary for future use. Disassemble experimental setup as directed by researcher. Clean work areas as needed.

Appendix B

H-4 Calcine Material Balance Dissolution Raw Analytical Data

APPENDIX B

H-4 Calcine Material Balance Dissolution Raw Analytical Data

Initial Calcine Data

units	Component	CalcLTF-1	CalcLTF-2	CalcNH-1A	CalcNH-1B	CalcNH-2A	CalcNH-2B	Calc (AVG)
dps/mL	Eu-154	54	66	48.7	42.9	38.4	44.4	49.07
dps/mL	Cs-137	1.97E+04	2.068E+04	2.07E+04	2.05E+04	2.11E+04	1.84E+04	2.018E+04
dps/mL	Co-60	6.36	9.1	5.54	7.15	2.31	5.53	6.00
mg/kg	Aluminum	3.50E+05	3.25E+05	N/A	N/A	N/A	N/A	3.375E+05
mg/kg	Zirconium	2.294E+03	2.420E+03	N/A	N/A	N/A	N/A	2.357E+03
mg/kg	Calcium	3.80E+04	3.85E+04	N/A	N/A	N/A	N/A	3.825E+04
Wt%	Sodium	9.45	9.58	N/A	N/A	N/A	N/A	9.52
mg/kg	Molybdenum	<153.30	208.99	N/A	N/A	N/A	N/A	181.15
Wt%	Potassium	1.39	1.4	N/A	N/A	N/A	N/A	1.40
mg/kg	Iron	3.06E+03	3.17E+03	N/A	N/A	N/A	N/A	3.118E+03
mg/kg	Chromium	634.2	681.74	N/A	N/A	N/A	N/A	657.97
mg/kg	Magnesium	1.046E+03	1.162E+03	N/A	N/A	N/A	N/A	1.104E+03
mg/kg	Rhodium	<100.80	<97.39	N/A	N/A	N/A	N/A	99.10
mg/kg	Niobium	87.15	<81.16	N/A	N/A	N/A	N/A	84.16
mg/kg	Manganese	2.44E+03	2.41E+03	N/A	N/A	N/A	N/A	2.423E+03
mg/kg	Nickel	308.7	302.32	N/A	N/A	N/A	N/A	305.51
mg/kg	Palladium	1.416E+03	1.369E+03	N/A	N/A	N/A	N/A	1.393E+03
mg/kg	Tin	<326.55	<315.51	N/A	N/A	N/A	N/A	321.03
mg/kg	Copper	128.1	332.75	N/A	N/A	N/A	N/A	230.43
mg/kg	Cadmium	422.1	446.4	N/A	N/A	N/A	N/A	434.25
mg/kg	Silver	127.05	111.59	N/A	N/A	N/A	N/A	119.32
mg/kg	Cerium	<160.65	<155.22	N/A	N/A	N/A	N/A	157.94
mg/kg	Lead	1.058E+03	1.172E+03	N/A	N/A	N/A	N/A	1.115E+03
mg/kg	Barium	<19.95	<19.28	N/A	N/A	N/A	N/A	19.62
mg/kg	Uranium	1.062E+03	1.026E+03	N/A	N/A	N/A	N/A	1.044E+03
mg/kg	Gadolinium	169.05	152.17	N/A	N/A	N/A	N/A	160.61
mg/kg	Strontium	208.95	902.9	N/A	N/A	N/A	N/A	555.93
mg/kg	Neodimium	<183.75	<177.54	N/A	N/A	N/A	N/A	180.65
dps/mL	Technetium	N/A	N/A	0.528	482.05	N/A	N/A	ND
dps/mL	Iodine	N/A	N/A	ND	0.947	N/A	N/A	0.947
mg/kg	Ruthenium	N/A	N/A	<276.55	<275.86	N/A	N/A	276.205
mg/kg	Selenium	N/A	N/A	<1043.92	<1041.32	N/A	N/A	1042.62
mg/kg	Boron	N/A	N/A	5.99E+03	5.41E+03	N/A	N/A	5700
WT%	Mercury	N/A	N/A	<0.0031	<0.0031	N/A	N/A	0.0031
WT%	Sulfate	N/A	N/A	1.39429	1.39264	N/A	N/A	1.393465
WT%	Nitrate	N/A	N/A	11.29	11.41	N/A	N/A	11.35
WT%	Chloride	N/A	N/A	0.068	0.124	N/A	N/A	0.096
WT%	Flouride	N/A	N/A	N/A	N/A	0.77	0.65	0.71

Less than indicates results are at or below analytical detection limits.

UDS data

units	Component	UDSLTF-1	UDSLTF-2	UDSNH-1A	UDSNH-1B	UDSNH-2A	UDSNH-2B
dps/mL	Eu-154	85.6	80.7	BDL	11.1	33.4	18.4
dps/mL	Cs-137	599	596	407	725	613	780
dps/mL	Co-60	9.92	11.7	BDL	2.05	9.91	11.9
mg/kg	Aluminum	5.18E+05	2.84E+05	N/A	N/A	N/A	N/A
mg/kg	Zirconium	9557.02	15947.5	N/A	N/A	N/A	N/A
mg/kg	Calcium	6.15E+03	6.40E+03	N/A	N/A	N/A	N/A
Wt%	Sodium	4.35	3.16	N/A	N/A	N/A	N/A
mg/kg	Molybdenum	<147.40	<151.78	N/A	N/A	N/A	N/A
Wt%	Potassium	3.75	3.85	N/A	N/A	N/A	N/A
mg/kg	Iron	4560.43	6820.84	N/A	N/A	N/A	N/A
mg/kg	Chromium	533.08	585.3	N/A	N/A	N/A	N/A
mg/kg	Magnesium	1902.12	1827.62	N/A	N/A	N/A	N/A
mg/kg	Rhodium	<96.92	<99.80	N/A	N/A	N/A	N/A
mg/kg	Niobium	95.91	948.12	N/A	N/A	N/A	N/A
mg/kg	Manganese	3751.73	4328.91	N/A	N/A	N/A	N/A
mg/kg	Nickel	433.13	1494.95	N/A	N/A	N/A	N/A
mg/kg	Palladium	<1361.97	<1402.43	N/A	N/A	N/A	N/A
mg/kg	Tin	<313.99	2413.96	N/A	N/A	N/A	N/A
mg/kg	Copper	196.88	569.7	N/A	N/A	N/A	N/A
mg/kg	Cadmium	215.1	266.1	N/A	N/A	N/A	N/A
mg/kg	Silver	112.07	118.52	N/A	N/A	N/A	N/A
mg/kg	Cerium	<154.47	<159.06	N/A	N/A	N/A	N/A
mg/kg	Lead	500.77	633.12	N/A	N/A	N/A	N/A
mg/kg	Barium	112.07	125.8	N/A	N/A	N/A	N/A
mg/kg	Uranium	<1020.72	<1051.04	N/A	N/A	N/A	N/A
mg/kg	Gadolinium	240.29	270.3	N/A	N/A	N/A	N/A
mg/kg	Strontium	199.9	275.5	N/A	N/A	N/A	N/A
mg/kg	Neodimium	<176.68	<181.93	N/A	N/A	N/A	N/A
dps/mL	Technetium	N/A	N/A	5.822	3.344	N/A	N/A
dps/mL	Iodine	N/A	N/A	ND	0.205	N/A	N/A
mg/kg	Ruthenium	N/A	N/A	<268.49	<271.13	N/A	N/A
mg/kg	Selenium	N/A	N/A	<1013.51	<1023.45	N/A	N/A
mg/kg	Boron	N/A	N/A	<472.43	<477.06	N/A	N/A
WT%	Mercury	N/A	N/A	N/A	N/A	0.139	0.062
WT%	Sulfate	N/A	N/A	0.1957	0.1245	N/A	N/A
WT%	Nitrate	N/A	N/A	1.71	1.52	N/A	N/A
WT%	Chloride	N/A	N/A	0.013	0.03	N/A	N/A
WT%	Flouride	N/A	N/A	N/A	N/A	< 1.57	1.8

Less than indicates result is at or below analytical detection limit.

Dissolved solution and off-gas data

units	Component	Diss-1	Diss-2	CS-1	CS-2	AS-1	AS-2
dps/mL	Eu-154	2.23E+03	2.49E+03	BDL	BDL	BDL	BDL
dps/mL	Cs-137	1.04E+06	1.01E+06	5.9	3.31	6.12	5.55
dps/mL	Co-60	241	301	BDL	BDL	BDL	BDL
mg/kg	Aluminum	3.55E+05	3.25E+05	N/A	N/A	N/A	N/A
mg/kg	Zirconium	1869.32	1837.28	N/A	N/A	N/A	N/A
mg/kg	Calcium	3.67E+04	3.65E+04	N/A	N/A	N/A	N/A
Wt%	Sodium	10.68	10.22	N/A	N/A	N/A	N/A
mg/kg	Molybdenum	73.24	73.48	N/A	N/A	N/A	N/A
Wt%	Potassium	1.41	1.46	N/A	N/A	N/A	N/A
mg/kg	Iron	2612.32	2600.76	N/A	N/A	N/A	N/A
mg/kg	Chromium	527.04	517.75	N/A	N/A	N/A	N/A
mg/kg	Magnesium	939.44	960.42	N/A	N/A	N/A	N/A
mg/kg	Rhodium	<2.02	<2.02	N/A	N/A	N/A	N/A
mg/kg	Niobium	2.46	1.95	N/A	N/A	N/A	N/A
mg/kg	Manganese	2232.58	2276.51	N/A	N/A	N/A	N/A
mg/kg	Nickel	220.06	214.93	N/A	N/A	N/A	N/A
mg/kg	Paladium	<28.33	<28.31	N/A	N/A	N/A	N/A
mg/kg	Tin	7.85	17.46	N/A	N/A	N/A	N/A
mg/kg	Copper	105.39	107.03	N/A	N/A	N/A	N/A
mg/kg	Cadmium	348.8	352.2	N/A	N/A	N/A	N/A
mg/kg	Silver	<0.44	<0.44	N/A	N/A	N/A	N/A
mg/kg	Cerium	13.5	14.19	N/A	N/A	N/A	N/A
mg/kg	Lead	914.04	908.22	N/A	N/A	N/A	N/A
mg/kg	Barium	12.47	13.5	N/A	N/A	N/A	N/A
mg/kg	Uranium	260.58	240.12	N/A	N/A	N/A	N/A
mg/kg	Gadolinium	171.3	166.78	N/A	N/A	N/A	N/A
mg/kg	Strontium	144.91	143.99	N/A	N/A	N/A	N/A
mg/kg	Neodimium	29.08	29.53	N/A	N/A	N/A	N/A
dps/mL	Technetium	812.63	11602	0.141	0.18	N/A	N/A
dps/mL	Iodine	<0.25	ND	ND	< 8.07E-02	N/A	N/A
mg/kg	Ruthenium	55.67	52.24	<0.55	<0.55	N/A	N/A
mg/kg	Selenium	<6.09	10.79	N/A	N/A	N/A	N/A
mg/kg	Boron	6.38E+03	5.72E+03	N/A	N/A	N/A	N/A
WT%	Mercury	0.0019	0.0015	<0.0031	<0.0031	<0.0031	<0.0031
WT%	Sulfate	0.95	0.99	N/A	N/A	N/A	N/A
WT%	Nitrate	ND	ND	<0.050	<0.050	N/A	N/A
WT%	Chloride	<0.1200	0.101	< 0.012	< 0.012	< 0.012	< 0.012
WT%	Flouride	1.6	0.39	N/A	N/A	N/A	N/A

Less than indicates result is at or below analytical detection limit.

WM-185 aluminum nitrate blend elemental material balance sample cross reference guide

CalcLTF-1	=	Initial calcine using lithium tetraborate fusion dissolution #1
CalcLTF-2	=	Initial calcine using lithium tetraborate fusion dissolution #2
CalcNH-1A	=	Initial calcine using sodium hydroxide fusion dissolution #1
CalcNH-1B	=	Initial calcine using sodium hydroxide fusion dissolution #1 (Tc and I spike)
CalcNH-2A	=	Initial calcine using sodium hydroxide fusion dissolution #2
CalcNH-2B	=	Initial calcine using sodium hydroxide fusion dissolution #2 (Tc and I spike)
UDSLTF-1	=	UDS lithium tetraborate fusion dissolution #1
UDSLTF-2	=	UDS lithium tetraborate fusion dissolution #2
UDSNH-1A	=	UDS sodium hydroxide fusion dissolution #1
UDSNH-1B	=	UDS sodium hydroxide fusion dissolution #1 (Tc and I spike)
UDSNH-2A	=	UDS sodium hydroxide fusion dissolution #2
UDSNH-2B	=	UDS sodium hydroxide fusion dissolution #2 (Tc and I spike)
Diss-1	=	Dissolved solution from dissolution #1
Diss-2	=	Dissolved solution from dissolution #2
As-1	=	Acid scrub solution dissolution #1
Cs-1	=	Caustic scrub solution dissolution #1
As-2	=	Acid scrub solution dissolution #2
Cs-2	=	Caustic scrub solution dissolution #2

Elemental material balance unit conversions

Diss-1	9.997	mls/gm calcine		
Diss-2	9.995	mls/gm calcine		
CalcLTF-1	500	mls/gm calcine		
CalcLTF-2	483.09	mls/gm calcine		
CalcNH-1A	500	mls/gm calcine		
CalcNH-1B	498.75	mls/gm calcine		
CalcNH-2A	490.20	mls/gm calcine		
CalcNH-2B	493.83	mls/gm calcine		
UDSLTF-1	480.77	mls/gm uds	0.054	gm uds/gm calcine
UDSLTF-2	495.05	mls/gm uds	0.055	gm uds/gm calcine
UDSNH-1A	485.44	mls/gm uds	0.054	gm uds/gm calcine
UDSNH-1B	490.20	mls/gm uds	0.054	gm uds/gm calcine
UDSNH-2A	505.05	mls/gm uds	0.055	gm uds/gm calcine
UDSNH-2B	495.05	mls/gm uds	0.055	gm uds/gm calcine
Cs-1	9.999	mls/gm calcine		
As-1	9.995	mls/gm calcine		