



facility 755652

facility 755653

project 10243

Radium-228

Case Narrative

COGCC

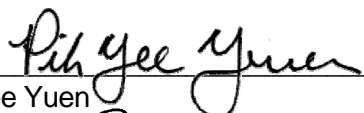
PW NORM 2017 – 10048

Work Order Number: 1706286

1. This report consists of the analytical results and supporting documentation for two water samples received by ALS on 06/13/2017.
2. These samples were prepared according to the current revision of SOP 749.
3. The samples were analyzed for the presence of ^{228}Ra by low background gas flow proportional counting of ^{228}Ac , which is the ingrown progeny of ^{228}Ra , according to the current revision of SOP 724. The analyses were completed on 06/27/2017.
4. The analysis results for these samples are reported in units of pCi/L. Sample 1706286-3 was filtered prior to analysis. Sample 1706286-1 was not filtered prior to analysis.
5. Sample volume was insufficient to allow preparation of a duplicate. A laboratory control sample duplicate (LCSD) was prepared in lieu of a client sample duplicate.
6. ICP-AES measurement of barium concentrations prior to chemical separation for the batch QC samples showed concentrations less than zero. To avoid a low bias in the final analytical results, the initial barium concentration was taken to be zero. These samples are identified with a "Z" flag on the Radiochemistry ICP Worksheet, which can be found in Section 5, "Raw Data" of this report.
7. The requested MDC was not met for samples 1706286-1 and -3 due to reduced aliquots of the samples taken for analysis. These samples are identified with an "M" or an "M3" flag on the final reports. The reported activity for samples identified with an "M3" flag exceeds the achieved MDC. Reports are submitted without further qualification.
8. No further anomalous situations were noted during the preparation and analysis of these samples. All remaining quality control criteria were met.

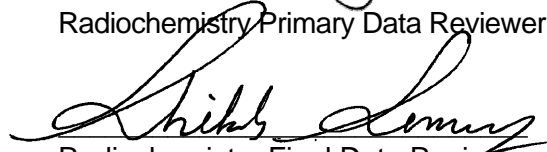


The data contained in the following report have been reviewed and approved by the personnel listed below. In addition, ALS certifies that the analyses reported herein are true, complete and correct within the limits of the methods employed.



Pik Yee Yuen
Radiochemistry Primary Data Reviewer

7/24/17
Date



Radiochemistry Final Data Reviewer

7/26/17
Date

Section 1

CHAIN OF CUSTODY

ALS -- Fort Collins

Sample Number(s) Cross-Reference Table

OrderNum: 1706286

Client Name: COGCC

Client Project Name: PW NORM 2017

Client Project Number: 10048

Client PO Number: CT 2017-3066

Client Sample Number	Lab Sample Number	COC Number	Matrix	Date Collected	Time Collected
755652 Coalview	1706286-1		WATER	13-Jun-17	10:16
755652 Coalview	1706286-2		WATER	13-Jun-17	10:16
755653 Oscar Y	1706286-3		WATER	13-Jun-17	11:36
755653 Oscar Y	1706286-4		WATER	13-Jun-17	11:36



Turnaround time for samples received after 2 p.m. will be calculated beginning from the next business day.

Chain-of-Custody

ALS WORKORDER #

Turnaround time for samples received after 2 p.m. will be calculated beginning from the next business day.

[illegible]

REPORT LEVEL / QC REQUIRED		NOTES
Summary (Standard QC)		
LEVEL II (Standard QC)		6010 total = B, Be, Ca, Cr, Fe, K, Li, Mg, Na, Ni, P, S, Si, V 6020 total = Al, Ag, As, Ba, Cd, Co, Cu, Mo, Mn, Na, Pb, Se, Sr, Th, Tl, Zn dissolved = filter and preserve upon receipt at lab
LEVEL III (Std QC + forms)		
LEVEL IV (Std QC + forms + raw data)	X	

SIGNATURE	PRINTED NAME	DATE	TIME
<i>[Signature]</i>	Peter Gintautas	6/13/2017	14:20
<i>[Signature]</i>	C Trimb	6-13-17	1420



Chain-of-Custody

Turnaround time for samples received after 2 p.m. will be calculated beginning from the next business day.

ALSO WORK ORDER #

17829071

[illegible]



ALS Environmental - Fort Collins
CONDITION OF SAMPLE UPON RECEIPT FORM

Client: COGCC

Workorder No: 1706286

Project Manager: SS

Initials: JNS

Date: 6/13/17

1. Does this project require any special handling in addition to standard ALS procedures?		YES	<u>NO</u>
2. Are custody seals on shipping containers intact?	<u>NONE</u>	YES	NO
3. Are Custody seals on sample containers intact?	<u>NONE</u>	YES	NO
4. Is there a COC (Chain-of-Custody) present or other representative documents?		<u>YES</u>	NO
5. Are the COC and bottle labels complete and legible?		<u>YES</u>	NO
6. Is the COC in agreement with samples received? (IDs, dates, times, no. of samples, no. of containers, matrix, requested analyses, etc.)		<u>YES</u>	NO
7. Were airbills / shipping documents present and/or removable?	<u>DROP OFF</u>	YES	NO
8. Are all aqueous samples requiring preservation preserved correctly? (excluding volatiles)	N/A	<u>YES</u>	NO
9. Are all aqueous non-preserved samples pH 4-9?	N/A	<u>YES</u>	NO
10. Is there sufficient sample for the requested analyses?		<u>YES</u>	NO
11. Were all samples placed in the proper containers for the requested analyses?		<u>YES</u>	NO
12. Are all samples within holding times for the requested analyses?		<u>YES</u>	NO
13. Were all sample containers received intact? (not broken or leaking, etc.)		<u>YES</u>	NO
14. Are all samples requiring no headspace (VOC, GRO, RSK/MEE, Rx CN/S, radon) headspace free? Size of bubble: <u> </u> < green pea <u> </u> > green pea	N/A	<u>YES</u>	NO
15. Do any water samples contain sediment? Amount of sediment: <u> </u> dusting <u>X</u> moderate <u> </u> heavy	N/A	<u>YES</u>	NO
16. Were the samples shipped on ice?		<u>YES</u>	NO
17. Were cooler temperatures measured at 0.1-6.0°C? IR gun used*: #2 <u>#4</u>	RAD ONLY	<u>YES</u>	NO
Cooler #:	<u>1</u>	<u>2</u>	<u>3</u>
Temperature (°C):	<u>amb</u>	<u>amb</u>	<u>4</u>
No. of custody seals on cooler:	<u>0</u>	<u>0</u>	<u>0</u>
External µR/hr reading:	<u>1.2</u>		
Background µR/hr reading:	<u>10</u>		
Were external µR/hr readings ≤ two times background and within DOT acceptance criteria? YES / NO <u>NA</u> (If no, see Form 008.)			

Additional Information: PROVIDE DETAILS BELOW FOR A NO RESPONSE TO ANY QUESTION ABOVE, EXCEPT #1 AND #16.

If applicable, was the client contacted? YES / NO NA Contact: Philab Date/Time:

Project Manager Signature / Date: Philab

Section 2



SAMPLE RESULTS SUMMARY

Radium-228 Analysis by GFPC Sample Results Summary

Client Name: COGCC
Client Project Name: PW NORM 2017
Client Project Number: 10048
Laboratory Name: ALS -- Fort Collins
PAI Work Order: 1706286

Page: 1 of 1
Reported on: Monday, July 17, 2017
10:22:11 AM

Lab Sample ID	Client Sample ID	Sample Type	Nuclide	Result +/- 2 s TPU	MDC	DL	Units	Matrix	Prep Batch	Date Analyze	Flags
1706286-1	755652 Coalview	Sample	Ra-228	7.6E+00 +/- 2E+00	1.3E+00	NA	pCi/l	WATER	RA170621-1	6/27/2017	M3
1706286-3	755653 Oscar Y	Sample	Ra-228	6.3E-01 +/- 5.7E-01	1.19E+00	NA	pCi/l	WATER	RA170621-1	6/27/2017	U,M

Comments:

Data Package ID: RA1706286-1

Qualifiers/Flags:
U - Result is less than the sample specific MDC.
LT - Result is less than Requested MDC, greater than sample specific MDC.
Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.
Y2 - Chemical Yield outside default limits.
M - The requested MDC was not met.
M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

Abbreviations:
TPU - Total Propagated Uncertainty
MDC - Sample specific Minimum Detectable Concentration
BDL - Below Detection Limit

Section 3

QC RESULTS SUMMARY

3

Radium-228 Analysis by GFPC

PAI 724 Rev 12

Method Blank Results

Lab Name: ALS -- Fort Collins

Work Order Number: 1706286

Client Name: COGCC

ClientProject ID: PW NORM 2017 10048

Lab ID: RA170621-1MB

Sample Matrix: WATER

Prep SOP: SOP749 Rev 4

Date Collected: 21-Jun-17

Date Prepared: 21-Jun-17

Date Analyzed: 27-Jun-17

Prep Batch: RA170621-1

QCBatchID: RA170621-1-1

Run ID: RA170621-1A

Count Time: 90 minutes

Final Aliquot: 1500 ml

Result Units: pCi/l

File Name: rac0627

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	DL	Lab Qualifier
15262-20-1	Ra-228	2.8E-01 +/- 2.9E-01	6E-01	1E+00	NA	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.310E+04	3.240E+04	ug	98.0	40 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

M - Requested MDC not met.

B - Analyte concentration greater than MDC.

B3 - Analyte concentration greater than MDC but less than Requested MDC.

DL - Decision Level

Data Package ID: RA1706286-1

Date Printed: Monday, July 17, 2017

ALS -- Fort Collins

LIMS Version: 6.843

Page 1 of 1

Radium-228 Analysis by GFPC

PAI 724 Rev 12

Laboratory Control Sample(s)

Lab Name: ALS -- Fort Collins

Work Order Number: 1706286

Client Name: COGCC

ClientProject ID: PW NORM 2017 10048

Lab ID: RA170621-1LCS

Sample Matrix: WATER

Prep SOP: SOP749 Rev 4

Date Collected: 21-Jun-17

Date Prepared: 21-Jun-17

Date Analyzed: 27-Jun-17

Prep Batch: RA170621-1

QCBatchID: RA170621-1-1

Run ID: RA170621-1A

Count Time: 90 minutes

Final Aliquot: 1500 ml

Result Units: pCi/l

File Name: rac0627

CASNO	Target Nuclide	Results +/- 2s TPU	MDC	Spike Added	% Rec	Control Limits	Lab Qualifier
15262-20-1	Ra-228	5.8E+00 +/- 1.5E+00	7E-01	6.820E+00	85.7	70 - 130	P

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.310E+04	3.300E+04	ug	99.8	40 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

LT - Result is less than Requested MDC, greater than sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

L - LCS Recovery below lower control limit.

H - LCS Recovery above upper control limit.

P - LCS Recovery within control limits.

M - The requested MDC was not met.

M3 - The requested MDC was not met, but thereported activity is greater than the reported MDC.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

Data Package ID: RA1706286-1

Radium-228 Analysis by GFPC

PAI 724 Rev 12

Laboratory Control Sample(s)

Lab Name: ALS -- Fort Collins

Work Order Number: 1706286

Client Name: COGCC

ClientProject ID: PW NORM 2017 10048

Lab ID: RA170621-1LCSD

Sample Matrix: WATER

Prep SOP: SOP749 Rev 4

Date Collected: 21-Jun-17

Date Prepared: 21-Jun-17

Date Analyzed: 27-Jun-17

Prep Batch: RA170621-1

QCBatchID: RA170621-1-1

Run ID: RA170621-1A

Count Time: 90 minutes

Final Aliquot: 1500 ml

Result Units: pCi/l

File Name: rac0627

CASNO	Target Nuclide	Results +/- 2s TPU	MDC	Spike Added	% Rec	Control Limits	Lab Qualifier
15262-20-1	Ra-228	6E+00 +/- 1.5E+00	6E-01	6.820E+00	87.9	70 - 130	P

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.310E+04	3.300E+04	ug	99.8	40 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

LT - Result is less than Requested MDC, greater than sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

L - LCS Recovery below lower control limit.

H - LCS Recovery above upper control limit.

P - LCS Recovery within control limits.

M - The requested MDC was not met.

M3 - The requested MDC was not met, but thereported activity is greater than the reported MDC.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

Data Package ID: RA1706286-1

Radium-228 Analysis by GFPC

PAI 724 Rev 12

Duplicate Sample Results (DER)

Lab Name: ALS -- Fort Collins

Work Order Number: 1706286

Client Name: COGCC

ClientProject ID: PW NORM 2017 10048

Field ID:
Lab ID: RA170621-1LCSD

Sample Matrix: WATER
Prep SOP: SOP749 Rev 4
Date Collected: 21-Jun-17
Date Prepared: 21-Jun-17
Date Analyzed: 27-Jun-17

Prep Batch: RA170621-1
QCBatchID: RA170621-1-1
Run ID: RA170621-1A
Count Time: 90 minutes

Final Aliquot: 1500 ml
Prep Basis: Unfiltered
Moisture(%): NA
Result Units: pCi/l
File Name: rac0627

CASNO	Analyte	Sample				Duplicate				DER	DER Lim
		Result +/-	2 s TPU	MDC	Flags	Result +/-	2 s TPU	MDC	Flags		
15262-20-1	Ra-228	5.8E+00 +/- 1.5E+00		7E-01	P	6E+00 +/- 1.5E+00		6E-01	P	0.0713	2.13

Comments:

Duplicate Qualifiers/Flags:

U - Result is less than the sample specific MDC.
Y1 - Chemical Yield is in control at 100-110%. Quantitative yield is assumed.
Y2 - Chemical Yield outside default limits.
W - DER is greater than Warning Limit of 1.42
D - DER is greater than Control Limit of 2.13
LT - Result is less than Request MDC, greater than sample specific MDC
M - Requested MDC not met.
M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.
L - LCS Recovery below lower control limit.
H - LCS Recovery above upper control limit.
P - LCS, Matrix Spike Recovery within control limits.
N - Matrix Spike Recovery outside control limits

Abbreviations:

TPU - Total Propagated Uncertainty
DER - Duplicate Error Ratio
BDL - Below Detection Limit
NR - Not Reported

Data Package ID: RA1706286-1

Section 4

INDIVIDUAL SAMPLE RESULTS



Radium-228 Analysis by GFPC

PAI 724 Rev 12

Sample Results

Lab Name: ALS -- Fort Collins

Work Order Number: 1706286

Client Name: COGCC

ClientProject ID: PW NORM 2017 10048

Field ID: 755652 Coalview

Lab ID: 1706286-1

Sample Matrix: WATER

Prep SOP: SOP749 Rev 4

Date Collected: 13-Jun-17

Date Prepared: 21-Jun-17

Date Analyzed: 27-Jun-17

Prep Batch: RA170621-1

QCBatchID: RA170621-1-1

Run ID: RA170621-1A

Count Time: 90 minutes

Report Basis: Unfiltered

Final Aliquot: 748 ml

Prep Basis: Unfiltered

Moisture(%): NA

Result Units: pCi/l

File Name: rac0627

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	DL	Lab Qualifier
15262-20-1	Ra-228	7.6E+00 +/- 2E+00	1.3E+00	1E+00	NA	M3

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.000E+04	2.450E+04	ug	81.7	40 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

DL - Decision Level

Data Package ID: RA1706286-1

Radium-228 Analysis by GFPC

PAI 724 Rev 12

Sample Results

Lab Name: ALS -- Fort Collins

Work Order Number: 1706286

Client Name: COGCC

ClientProject ID: PW NORM 2017 10048

Field ID: 755653 Oscar Y

Lab ID: 1706286-3

Sample Matrix: WATER

Prep SOP: SOP749 Rev 4

Date Collected: 13-Jun-17

Date Prepared: 21-Jun-17

Date Analyzed: 27-Jun-17

Prep Batch: RA170621-1

QCBatchID: RA170621-1-1

Run ID: RA170621-1A

Count Time: 90 minutes

Report Basis: Filtered

Final Aliquot: 748 ml

Prep Basis: Filtered

Moisture(%): NA

Result Units: pCi/l

File Name: rac0627

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	DL	Lab Qualifier
15262-20-1	Ra-228	6.3E-01 +/- 5.7E-01	1.19E+00	1E+00	NA	U,M

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.400E+04	3.140E+04	ug	92.3	40 - 110 %	

Comments: This sample was filtered prior to analysis.

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Sample specific Minimum Detectable Concentration

BDL - Below Detection Limit

DL - Decision Level

Data Package ID: RA1706286-1

Section 5

RAW DATA

5

Radium-228 Analysis by GFPC Raw Data Report

Laboratory Name: ALS -- Fort Collins
PAI Work Order: 1706286

Prep SOP: SOP749
Analytical SOP: PAI 724

Reported on: Monday, July 03, 2017
1:56:06 PM

Sample ID QC Type	Nuclide Type	Sample Date/Time	Prep Batch QC Batch ID	Ingrowth Date /Time	Decay Date/Time	Matrix %Moist.	Samp Aliq Analy Aliq	Inst ID Det ID	AntRunID File Name	Count Date/Time	GrossCPM BkgCPM	BaseEff ProgEff	CndDur(min) Yield	Activity +/- 2 s TPU	MDC DeclEv	ReportUnits ReportBasis	DER RPD	%Spk. Recov Flags
1706286-1	Ra-228 Trg. Analyte	6/13/2017 10:16:00 AM	RA170621-1 RA170621-1-1	6/25/2017 4:55:00 PM	6/27/2017 7:10:00 AM	WATER NA	750 ml 748 ml	LB4100-c A3	RA170621-1A rac0627	6/27/2017 9:05 AM	5,200 1,548	48.51% NA	90 81.7%	7.6E+00 2E+00	1.3E+00	pCi/l Unfiltered	NA NA	M3
1706286-3	Ra-228 Trg. Analyte	6/13/2017 11:36:00 AM	RA170621-1 RA170621-1-1	6/25/2017 4:55:00 PM	6/27/2017 7:10:00 AM	WATER NA	750 ml 748 ml	LB4100-c A4	RA170621-1A rac0627	6/27/2017 9:05 AM	1,889 1,548	48.35% NA	90 92.3%	6.3E-01 5.7E-01	1.19E+00	pCi/l Unfiltered	NA NA	U,M
RA170621-1	Ra-228 Trg. Analyte	6/21/2017 11:02:49 AM	RA170621-1 RA170621-1-1	6/25/2017 4:55:00 PM	6/27/2017 7:10:00 AM	WATER NA	1500 ml 1500 ml	LB4100-c D2	RA170621-1A rac0627	6/27/2017 9:05 AM	1,822 1,523	44.54% NA	90 98.0%	2.8E-01 2.9E-01	6E-01	pCi/l Unfiltered	NA NA	U
RA170621-1	Ra-228 Trg. Analyte	6/21/2017 11:02:49 AM	RA170621-1 RA170621-1-1	6/25/2017 4:55:00 PM	6/27/2017 7:10:00 AM	WATER NA	1500 ml 1500 ml	LB4100-c C4	RA170621-1A rac0627	6/27/2017 9:05 AM	9,433 2,536	48.66% NA	90 99.8%	5.8E+00 1.5E+00	7E-01	pCi/l Unfiltered	NA NA	85.7 P
RA170621-1	Ra-228 Trg. Analyte	6/21/2017 11:02:49 AM	RA170621-1 RA170621-1-1	6/25/2017 4:55:00 PM	6/27/2017 7:10:00 AM	WATER NA	1500 ml 1500 ml	LB4100-c D3	RA170621-1A rac0627	6/27/2017 9:05 AM	8,444 1,615	47.02% NA	90 99.8%	6E+00 1.5E+00	6E-01	pCi/l Unfiltered	0.07 NA	87.9 P

Comments:

Data Package ID: RA1706286-1

Qualifiers/Flags:

U - Result is less than the sample specific MDC.
Y1 - Chemical Yield is in control at 100-110%. Quantitative yield is assumed.
Y2 - Chemical Yield outside default limits.
W - DER is greater than Warning Limit of 1.42
D - DER is greater than Control Limit of 2.13
+ - Duplicate RPD not within limits.
LT - Result is less than Request MDC, greater than sample specific MDC
* - Aliquot Basis is 'As Received' while the Report Basis is 'Dry Weight'
- Aliquot Basis is 'Dry Weight' while the Report Basis is 'As Received'

M - Requested MDC not met.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

L - LCS Recovery below lower control limit.

H - LCS Recovery above upper control limit.

P - LCS, Matrix Spike Recovery within control limits.

N - Matrix Spike Recovery outside control limits

NC - Not Calculated for duplicate results less than 5 times MDC

B - Analyte concentration greater than MDC.

B3 - Analyte concentration greater than MDC but less than Requested MDC.

Notes:

1) The Tracer results are not yield corrected (i.e. activity measured not activity added).
2) Where sample time is not available, 12:00 PM (Mountain) is used for decay correction.

Abbreviations:

TR- Tracer TA - Target Analyte

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

DER - Duplicate Error Ratio

BDL - Below Detection Limit

Date Printed: Monday, July 17, 2017

ALS -- Fort Collins

LIMS Version: 6.843

Page 1 of 1

PAI - Gas Flow Proportional Sample Analysis LB4100-C

Unit Type: LB4100-C
 Counting Unit ID: Magenta
 High Voltage Mode: Simultaneous
 Application Revision: Rev.12/01/08 JCP

Data file name: RAC0627
 Batch ID: RA170621-1
 Count Preset (m): 90
 Batch Ended: 6/27/2017 10:26

2

Background log file: BKGABW
 Date of Bkg. Cal: 6/22/2017
 Alpha efficiency log file: Am. WIPE-06/17
 Alpha prog. log file: n/a
 Alpha attenuation calibration: AAM0606, 06/06/17
 Beta efficiency log file: RA228-06/17
 Beta prog. log file: n/a
 Beta attenuation calibration: ASR0607
 Beta prog. attenuation: n/a

Alpha Attenuation Calibration		Beta Attenuation Calibration	
$y = b \cdot m^a \cdot (e^{(mass-x)})$		$y = b \cdot m^a \cdot (e^{(mass-x)})$	
Alpha b=	0.9000	Beta b=	0.9641
m=	0.69110	m=	0.9996
a=	0.8270	a=	0.9174
x0=	21.4875	x0=	0.0000
Alpha to Beta X-talk		Beta to Alpha X-talk	
$y = b \cdot m^a \cdot mass$		$y = b \cdot m^a \cdot mass$	
a->b xtalk b=	0.2511	b->a xtalk b=	-1.65E-05
a->b xtalk m=	0.5984	b->a xtalk m=	0.0038

Del ID	Sample ID	Count End Date & Time	Count Dur. (min)	Resid. Mass (mg)	Alpha Activity				Beta Activity			
					Gross CPM	Bkg. CPM	b-a xtlk CPM	Base Cor.Fact.	Progeny Eff	Progeny Cor.Fact.	Gross CPM	Bkg. CPM
A1	1706271-1	6/27/2017 10:26	90.00	0.0	1.444	0.090	0.308	0.2716	1.058	n/a	87.200	1.595
A2	1706272-2	6/27/2017 10:26	90.00	0.0	0.322	0.090	0.028	0.2663	1.058	n/a	9.322	1.490
A3	1706281-1	6/27/2017 10:26	90.00	0.0	0.167	0.103	0.013	0.2667	1.058	n/a	5.200	1.548
A4	1706283-3	6/27/2017 10:26	90.00	0.0	0.267	0.089	0.001	0.2682	1.058	n/a	1.889	1.548
C1	1706341-1	6/27/2017 10:26	90.00	0.0	0.311	0.114	0.013	0.2660	1.058	n/a	5.378	1.714
C2	1706341-3	6/27/2017 10:26	90.00	0.0	0.400	0.126	0.038	0.2618	1.058	n/a	12.300	1.717
C3	1706395-1	6/27/2017 10:26	90.00	0.0	0.267	0.095	0.014	0.2629	1.058	n/a	5.711	1.700
C4	RA170621-1LCS	6/27/2017 10:26	90.00	0.0	0.222	0.127	0.025	0.2561	1.058	n/a	9.433	2.536
B1	1706299-1	6/27/2017 10:26	90.00	0.0	0.244	0.091	0.003	0.2653	1.058	n/a	2.556	1.630
B2	1706299-2	6/27/2017 10:26	90.00	0.0	0.233	0.120	0.002	0.2570	1.058	n/a	2.400	1.726
B3	1706329-1	6/27/2017 10:26	90.00	0.0	0.400	0.096	0.034	0.2589	1.058	n/a	11.144	1.645
B4	1706423-1	6/27/2017 10:26	90.00	0.0	0.300	0.122	0.012	0.2603	1.058	n/a	4.944	1.699
D1	RA170621-1MB	6/27/2017 10:26	90.00	0.0	0.378	0.104	0.043	0.2582	1.058	n/a	13.567	1.670
D2		6/27/2017 10:26	90.00	0.0	0.211	0.118	0.001	0.2556	1.058	n/a	1.822	1.523
D3	RA170621-1LCS	6/27/2017 10:26	90.00	0.0	0.467	0.132	0.025	0.2627	1.058	n/a	8.444	1.615

JP 7/5/17
 7/13/17
 JCB

Date 6/27/17SOP 724r 12

ALS
Low Background Gas Flow Proportional Counter Log
Instrument: LB4100C

Instrument Daily Response and Background Checks

Det.	Daily Response Check				Background Check				Det. Status
	Start 1	Status	Start 2	Status	Start 1	Status	Start 2	Status	
1	JP	P			JP	P			P
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16	✓	✓			✓	✓			OLB

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

Weekly Background Calibration

	Current Calib. File ID	Weekly Calib. Started	Status	File ID
Dr A	BK0621W			
Dr B				
Dr C				
Dr D	BK0622W			

Dr = Drawer

Gas Supply

P-10 Supply		P-10 Flow	
Tank 1	1650	Dr A	10
		Dr B	
Tank 2	850	Dr C	
		Dr D	✓

Comments:

Date

6/27/17

SOP 724r12

ALS

Low Background Gas Flow Proportional Counter Log

Instrument: LB4100C

Det.	Sample ID	Batch	Test	Count Dur. (min)	Start Time	Analyst Initials	File ID	Output Initials
1-16	Daily EFP	—	—	30	5:46	JP	EFC0627	JP
1-16	Daily Bkg	—	—	60	85:53	JP	BKC0627	JP
1	1706271-1	RA170621-1	RA228	90	856	JKB	RAC0627	JP
2	↓ 2							
3	1706286-1							
4	↓ -3							
5	1706291-288-1							
6	1706292-288-1							
7	1706329-1							
8	1706329-2							
9	1706341-1							
10	↓ 3							
11	1706395-1							
13	1706423-1							
14	RA170621-1MB							
12	↓ LGS							
15	↓ LGS							
1	AB170621-5US	AB170621-5	JP	30	1034		ABC0627	
2	1706259-1	AB170620-1						
3	↓ 2							
4	↓ 3							
5	↓ 4							
6	↓ 5							
7	1706260-1							
8	↓ 2							
9	↓ 3							
10	↓ 4							
11	↓ 5							
13	AB170620-1MB							
12	↓ LGS							
14	↓ LGS							
1	1706472-2	AB170622-1		75	1121		ABC0627A	
2	↓ -5							
3	↓ -50							
4	1706480-1							
5	↓ -2							
6	↓ -20							
7	1706310-1	AB170620-4		90	1124		ABC0627B	
8	1706317-3							
9	↓ -30							
10	1706383-1							
11	↓ 2							
12	↓ 5							
13	↓ 7							
14	↓ 12							
1	17063102 MS			30	1240		ABC0627C	
2	AB170620-4US							

Comments:

Page No.: 473515

B

(cont. from page NA)

B)

Form 780r8.doc (6/23/06)

Reviewed By / Date

JP 6/28/17

22 of 117

Radiochemistry ICP Worksheet

ALS -- Fort Collins

Prep Batch: RA170621-1

Prep Procedure: Ra228

Reviewed By: lad LAD Review Date: 6/27/2017

BARIUM Recovery Results

Reference Carrier

LabID	QC Type	Car Vol	Ref Carr Dil Vol	Ref Carr ICP Alq	Ref Carr ICP Run	Ref Carr ICP Conc
RA170621-1	CAR	2	27	0.05	10.05	IR170626-2A1 6.098217

Samples

Prep Num	LabID	QC Type	Init Alq (ml)	Samp Dil Vol (ml)	Car Vol (ml)	Init ICP Alq (ml)	Pre-Con Vol (ml)	Post-Con Vol (ml)	Pre-Sep Vol (ml)	Post-Sep Vol (ml)	Fin ICP Alq (ml)	Fin ICP Dil Vol (ml)	Initial ICP Run	Final ICP Run	Init ICP Conc (ug/ml)	Fin ICP Conc (ug/ml)	Init Samp Mass (ug)	Ref Mass (ug)	Flag	Fin Samp Mass (ug)	% Yield	Final Sample Alq
1	1706233-1	SMP	1500	2	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	0.00255	6.160895	38.29624	33095.03		30958.5	93.44%	1496
1	1706233-2	SMP	1500	2	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	0.00187	6.146247	28.08391	33095.03		30854.89	93.24%	1496
1	1706267-1	SMP	1500	2	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	-0.0015	6.333087	0	33095.03	Z	31823.76	96.16%	1496
1	1706268-1	SMP	1500	2	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	-0.0014	6.313728	0	33095.03	Z	31726.48	95.86%	1496
1	1706269-1	SMP	1500	2	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	0.00812	6.354945	121.6969	33095.03		31933.6	96.14%	1496
1	1706271-1	SMP	750	2	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	0.04315	4.415749	646.781	33095.03		22169.14	65.76%	748.0
1	1706271-2	SMP	750	2	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	0.06183	6.347848	926.769	33095.03		31897.94	93.76%	748.0
1	1706286-1	SMP	750	2	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	0.89622	4.872545	134.34.32	16547.51		24484.54	81.66%	748.0
1	1706286-3	SMP	750	2	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	0.06137	6.251221	919.9608	33095.03		31412.38	92.35%	748.0
1	1706288-1	SMP	750	2	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	-0.002	6.57091	0	33095.03	Z	33018.82	99.77%	1496
1	1706299-1	SMP	750	2	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	0.02032	6.254627	304.6679	33095.03		31429.5	94.10%	748.0
1	1706299-2	SMP	750	2	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	0.05291	6.178948	793.1577	33095.03		31049.21	91.62%	748.0
1	1706328-1	SMP	750	2	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	0.00494	6.500681	74.0394	33095.03		32665.92	98.48%	748.0
1	1706329-2	SMP	750	2	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	0.00749	6.455433	112.3356	33095.03		32438.55	97.68%	748.0
1	1706340-1	SMP	1500	2	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	0.00187	6.507267	28.08391	33095.03		32659.02	98.72%	1496
1	1706340-3	SMP	1500	2	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	0.00273	6.403486	40.84932	33095.03		32177.52	97.11%	1496
1	1706341-1	SMP	750	2	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	0.00216	6.481549	32.33005	33095.03		32569.78	98.32%	748.0
1	1706341-3	SMP	750	2	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	0.00630	6.324742	94.46407	33095.03		31781.83	95.76%	748.0
1	1706395-1	SMP	750	0	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	1.88441	5.26496	28247.31	0		26456.42	93.66%	748.0
1	1706423-1	SMP	750	0	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	1.88481	5.380095	28253.27	0		27034.98	95.69%	748.0
1	RA170621-1	MB	1500	2	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	-0.0007	6.451232	0	33095.03	Z	32417.44	97.95%	1496
1	RA170621-1	LCS	1500	2	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	-0.0018	6.575622	0	33095.03	Z	33042.5	99.84%	1496
1	RA170621-1	LCSD	1500	2	1500	1	10	1499	1499	25	0.05	10.05	IR170626-2A1	IR170626-2A1	-0.0018	6.571988	0	33095.03	Z	33024.24	99.79%	1496

Sample Idl	Ca	Fe	K	Mg	Na	Sr	Mn	S	Al	Ba	Pb	Ni
CCV	49.5477	19.8980	49.2578	50.0280	45.8265	0.4885	1.0010	4.9030	50.2585	0.9924	0.9944	0.9612
CCB	-0.1320	-0.0241	-0.1019	-0.0628	-0.4404	-0.0022	-0.0015	-0.0404	-0.1078	-0.0019	-0.0023	0.0000
I 1706233-1	10.0645	-0.0134	0.1651	2.4564	1.3494	0.0204	-0.0018	1.0146	-0.1174	0.0026	0.0360	-0.0016
I 1706233-2	8.9220	0.0015	0.1595	2.2675	1.9605	0.0196	-0.0019	1.4147	-0.1114	0.0019	0.0386	-0.0008
I 1706267-1	0.5822	0.0125	-0.0667	0.3078	-0.0054	0.0017	0.0094	0.0283	-0.1301	-0.0015	0.0373	-0.0007
I 1706268-1	0.8580	0.0082	-0.0036	0.4894	-0.0306	0.0027	0.0019	0.0728	-0.1138	-0.0014	0.0362	-0.0008
I 1706269-1	1.1462	0.0364	-0.0596	0.8698	-0.0331	0.0043	-0.0019	0.0970	-0.1319	0.0081	0.0404	0.0003
I 1706271-1	28.1017	0.6174	230.5700	46.2814	237.6468	0.9825	0.1481	49.7979	-0.1373	0.0431	0.0667	0.0130
I 1706271-2	6.3892	0.1246	2.3118	0.6965	136.0251	0.6821	0.0108	1.9644	-0.1198	0.0618	0.0361	-0.0015
I 1706286-1	13.3109	2.6025	1.6603	1.4703	146.5177	2.1296	0.0312	0.0849	-0.1030	0.8962	0.0361	-0.0005
I 1706286-3	16.6699	7.2268	3.6959	1.9286	188.7980	2.3197	0.1312	9.5958	-0.1222	0.0614	0.0404	0.0091
I 1706288-1	1.5041	0.0853	-0.1251	0.1386	0.1988	-0.0013	-0.0010	0.1051	-0.1235	-0.0020	0.0378	0.0004
I 1706289-1	0.0487	0.0416	0.0943	-0.0732	47.7455	0.0162	-0.0009	0.5861	-0.1265	0.0203	0.0388	-0.0008
I 1706289-2	0.0200	0.0351	0.0747	-0.0742	35.5285	0.0088	0.0004	0.0202	-0.1205	0.0529	0.0400	-0.0004
I 1706329-1	45.4231	0.0512	72.4876	4.9648	196.3098	1.2413	-0.0004	23.4479	-0.1181	0.0049	0.0353	-0.0008
I 1706329-2	35.8968	0.0929	78.3786	4.2231	195.2443	0.8274	0.0008	34.2684	-0.1102	0.0075	0.0379	-0.0004
I 1706340-1	4.3986	-0.0056	1.4924	4.3638	4.6053	0.1262	-0.0019	3.0275	-0.1199	0.0019	0.0391	-0.0014
I 1706340-3	4.3914	-0.0119	1.4736	4.3861	4.5007	0.1258	-0.0018	2.9871	-0.1289	0.0027	0.0361	-0.0003
I 1706341-1	31.0625	0.0246	75.2730	3.9922	193.7318	0.7659	-0.0001	32.6152	-0.1253	0.0022	0.0404	-0.0009
I 1706341-3	42.8273	0.1113	70.8712	4.8495	191.2936	1.1956	-0.0005	22.7850	-0.1162	0.0063	0.0366	-0.0014
I 1706395-1	16.1640	0.0268	29.1967	4.0171	253.3319	4.8274	0.0012	1.4107	-0.0903	1.8844	0.0356	-0.0008
I 1706423-1	15.0947	0.6347	3.8298	1.2705	190.1501	3.2368	0.0090	0.1011	-0.1181	1.8848	0.0364	-0.0022
I RA170621-1MB	-0.0957	0.3073	-0.0867	-0.0934	-0.0670	-0.0003	-0.0008	0.0081	-0.1307	-0.0007	0.0401	-0.0005
I RA170621-1LCS	-0.1202	0.0103	-0.1175	-0.1059	-0.4213	-0.0019	-0.0020	-0.0243	-0.1337	-0.0018	0.0359	-0.0006
I RA170621-1LCSD	-0.1205	-0.0135	-0.1251	-0.1007	-0.4736	-0.0021	-0.0020	-0.0404	-0.1265	-0.0018	0.0393	0.0001
CCV	50.2525	20.0736	49.2866	50.4469	47.4319	0.4895	1.0085	4.9717	50.4018	0.9919	1.0113	0.9764
CCB	-0.1290	-0.0222	-0.1191	-0.0649	-0.4829	-0.0022	-0.0016	-0.0323	-0.1012	-0.0022	-0.0020	-0.0010
F 1706233-1	-0.0905	-0.0101	-0.0987	-0.1002	89.8617	0.0186	-0.0020	1.6694	-0.1054	6.1609	0.2594	-0.0014
F 1706233-2	-0.1017	-0.0041	-0.1203	-0.1038	88.8665	0.0177	-0.0020	1.6613	-0.1162	6.1462	0.2394	0.0001
F 1706267-1	-0.1023	-0.0124	-0.1039	-0.1074	89.1215	0.0022	-0.0022	1.7138	-0.1192	6.3331	0.2783	-0.0011
F 1706268-1	-0.0981	0.0001	-0.1083	-0.1012	88.7914	0.0022	-0.0014	1.6532	-0.1132	6.3137	0.2061	-0.0010
F 1706269-1	-0.0990	-0.0135	-0.0935	-0.1054	87.6684	0.0029	-0.0020	1.6411	-0.1205	6.3549	0.1432	-0.0017
F 1706271-1	-0.0754	-0.0035	-0.0987	-0.1007	85.2691	0.1449	-0.0021	1.3622	-0.1241	4.4157	0.8158	-0.0003
F 1706271-2	-0.1090	-0.0027	-0.1191	-0.1074	89.5255	0.3970	-0.0016	1.8795	-0.1204	6.3478	0.3624	0.0002
F 1706286-1	-0.1147	-0.0100	-0.1079	-0.1012	88.4419	0.6876	-0.0020	1.5926	-0.1247	4.8725	0.2191	-0.0007
F 1706286-3	-0.0972	-0.0089	-0.0943	-0.0991	86.7374	0.9787	-0.0017	2.0372	-0.1163	6.2512	0.2330	0.0001
F 1706288-1	-0.1126	-0.0070	-0.1187	-0.1054	89.4057	0.0003	-0.0022	1.7017	-0.1180	6.5709	0.1742	-0.0017
F 1706289-1	-0.1072	0.0096	-0.1159	-0.1033	89.0581	0.0171	-0.0020	1.6977	-0.0735	6.2546	0.3214	-0.0006
F 1706289-2	-0.1117	0.0060	-0.1123	-0.1017	88.4677	0.0092	0.0035	1.6815	-0.1193	6.1789	0.2858	-0.0004
F 1706329-1	-0.0926	-0.0125	-0.0975	-0.0996	88.7058	0.5827	-0.0021	1.8876	-0.1205	6.5007	0.1421	-0.0003
F 1706329-2	-0.1138	-0.0067	-0.1151	-0.1038	88.6990	0.4318	-0.0021	1.8674	-0.1229	6.4554	0.2374	-0.0005
F 1706340-1	-0.1129	-0.0118	-0.1071	-0.1002	88.7603	0.0839	-0.0020	1.7623	-0.1078	6.5073	0.2262	-0.0006
F 1706340-3	-0.1220	-0.0105	-0.1115	-0.1074	88.6035	0.0733	-0.0022	1.7300	-0.1211	6.4035	0.2460	-0.0016
F 1706341-1	-0.1120	-0.0069	-0.1287	-0.1043	89.9109	0.5009	-0.0018	1.9159	-0.1126	6.4815	0.2023	-0.0016
F 1706341-3	-0.1138	-0.0144	-0.1083	-0.1054	89.0148	0.6902	-0.0018	1.9321	-0.1247	6.3247	0.2218	-0.0019
F 1706395-1	-0.1090	-0.0134	-0.1171	-0.1007	89.4126	0.6498	-0.0021	1.6855	-0.1168	5.2650	0.1858	-0.0003
F 1706423-1	-0.1096	-0.0131	-0.1067	-0.1043	88.9874	1.3537	-0.0020	1.9563	-0.1198	5.3801	0.2691	-0.0007
F RA170621-1MB	-0.1187	-0.0138	-0.1091	-0.1043	88.0422	-0.0014	-0.0021	1.6532	-0.1217	6.4512	0.1557	0.0001
F RA170621-1LCS	-0.1205	-0.0128	-0.1175	-0.1043	88.8656	-0.0015	-0.0021	1.6694	-0.1066	6.5756	0.1273	-0.0001
F RA170621-1LCSD	-0.1169	-0.0105	-0.1151	-0.1033	89.4514	-0.0016	-0.0018	1.6855	-0.1162	6.5720	0.1809	-0.0011

Sample Id1	Ca	Fe	K	Mg	Na	Sr	Mn	S	Al	Ba	Pb	Ni
RA170621-1RC	-0.1184	-0.0069	-0.1179	-0.1017	82.5896	-0.0011	-0.0015	-0.0202	-0.1156	6.0982	0.0496	-0.0009
CCV	49.8904	19.9762	49.7102	50.3467	47.6541	0.4918	1.0021	4.9070	50.6458	1.0034	0.9908	0.9788
CCB	-0.1181	-0.0189	-0.1055	-0.0540	-0.4652	-0.0021	-0.0015	-0.0445	-0.0813	-0.0013	-0.0038	-0.0019

Section 6

QUALITY ASSURANCE SUMMARY REPORTS

6

No *NON-CONFORMANCE REPORTS* or *QUALITY ASSURANCE SUMMARY SHEETS* are included in this data package.

Section 7

LABORATORY BENCH SHEETS



Radiochemistry Instrument Worksheet

ALS -- Fort Collins

Prep Batch: RA170621-1

Prep Procedure: Ra228

Analytical QASS / NCR? Y 10 M

Prep Num	LabID	QC Type	Init Aliq	Fin Aliq	Units	Report Units	Residual Mass (mg)	Cnt 1 File	Cnt 1 Inst/Det	Cnt 1 Pos Chk By	Cnt 2 File	Cnt 2 Inst/Det	Cnt 2 Pos Chk By	Cnt 3 File	Cnt 3 Inst/Det	Cnt 3 Pos Chk By	Notes
1	1706233-1	SMP	1500	1496.0	ml	pCi/l		RA170627 1		7/2							
1	1706233-2	SMP	1500	1496.0	ml	pCi/l		2									
1	1706267-1	SMP	1500	1496.0	ml	pCi/l		3									
1	1706268-1	SMP	1500	1496.0	ml	pCi/l		4									
1	1706269-1	SMP	1500	1496.0	ml	pCi/l		5									
1	1706271-1	SMP	750	748.00	ml	pCi/l		RA170627 1									
1	1706271-2	SMP	750	748.00	ml	pCi/l		2									
1	1706286-1	SMP	750	748.00	ml	pCi/l		3									
1	1706286-3	SMP	750	748.00	ml	pCi/l		4									
1	1706288-1	SMP	1500	1496.0	ml	pCi/l		7									
1	1706299-1	SMP	750	748.00	ml	pCi/l		RA170627 5									
1	1706299-2	SMP	750	748.00	ml	pCi/l		6									
1	1706329-1	SMP	750	748.00	ml	pCi/l		7									
1	1706329-2	SMP	750	748.00	ml	pCi/l		8									
1	1706340-1	SMP	1500	1496.0	ml	pCi/l		RA170627 9									
1	1706340-3	SMP	1500	1496.0	ml	pCi/l		10									
1	1706341-1	SMP	750	748.00	ml	pCi/l		11									
1	1706341-3	SMP	750	748.00	ml	pCi/l		12									
1	1706395-1	SMP	750	748.00	ml	BQ/L		13									
1	1706423-1	SMP	750	748.00	ml	pCi/l		14									
1	RA170621-1	MB	1500	1496.0	ml	BQ/L		15									
1	RA170621-1	MB	1500	1496.0	ml	pCi/l		16									
1	RA170621-1	LCS	1500	1496.0	ml	BQ/L		17									
1	RA170621-1	LCS	1500	1496.0	ml	pCi/l		18									
1	RA170621-1	LCSD	1500	1496.0	ml	pCi/l		19									
1	RA170621-1	LCSD	1500	1496.0	ml	BQ/L		20									

Radiochemistry Instrument Worksheet

ALS -- Fort Collins

Prep Batch: RA170621-1

Prep Procedure: Ra228

Analytical QASS / NCR? Y / N

Prep Num	LabID	QC Type	Init Aliq	Fin Aliq	Units	Report Units	Residual Mass (mg)	Cnt 1 File	Cnt 1 Ins/Det	Cnt 1 Pos Chk By	Cnt 2 File	Cnt 2 Ins/Det	Cnt 2 Pos Chk By	Cnt 3 File	Cnt 3 Ins/Det	Cnt 3 Pos Chk By	Notes
----------	-------	---------	-----------	----------	-------	--------------	--------------------	------------	---------------	------------------	------------	---------------	------------------	------------	---------------	------------------	-------

Tracer/Carrier Solution Information

Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
T1	BARIUM	418236	1/18/18	16,022.768	pCi/ml	NA	2	ml	RS031
T2	BARIUM	418236		16,022.768	pCi/ml	NA	1	ml	RS033

Spike Solution Information

Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
S1	Ra-228	1014.4095.79	3/23/18	91.033	DPM/ml	06/21/17	0.25	ml	RS019

Sample Barcodes

1706233-1 RA170621-1PS1		1706233-2 RA170621-1PS2		1706267-1 RA170621-1PS3	
1706268-1 RA170621-1PS4		1706269-1 RA170621-1PS5		1706271-1 RA170621-1PS6	
1706271-2 RA170621-1PS7		1706286-1 RA170621-1PS8		1706286-3 RA170621-1PS9	
1706288-1 RA170621-1PS10		1706299-1 RA170621-1PS11		1706299-2 RA170621-1PS12	
1706329-1 RA170621-1PS13		1706329-2 RA170621-1PS14		1706340-1 RA170621-1PS15	
1706340-3 RA170621-1PS16		1706341-1 RA170621-1PS17		1706341-3 RA170621-1PS18	
1706395-1 RA170621-1PS19		1706423-1 RA170621-1PS20		RA170621-1MB RA170621-1PS21	
RA170621-1LCS RA170621-1PS22		RA170621-1LCS RA170621-1PS23		RA170621-1CAR RA170621-1PS24	

Radiochemistry Instrument Worksheet

ALS -- Fort Collins

Prep Batch: RA170621-1

Reporting Units

LabID	IsiGrpName	RptUnits
1706299-1	Ra228_2012	pCi/l
1706267-1	Ra228_2012	pCi/l
1706268-1	Ra228_2012	pCi/l
1706269-1	Ra228_2012	pCi/l
1706271-1	Ra228_2012	pCi/l
1706286-1	Ra228_2012	pCi/l
1706233-1	Ra228_2012	pCi/l
1706288-1	Ra228_2012	pCi/l
1706423-1	Ra228_2012	pCi/l
1706329-1	Ra228_2012	pCi/l
1706340-1	Ra228_2012	pCi/l
1706341-1	Ra228_2012	pCi/l
1706395-1	Ra228_2012	Bq/L
1706299-2	Ra228_2012	pCi/l
1706329-2	Ra228_2012	pCi/l
1706271-2	Ra228_2012	pCi/l
1706233-2	Ra228_2012	pCi/l
1706340-3	Ra228_2012	pCi/l
1706341-3	Ra228_2012	pCi/l
1706286-3	Ra228_2012	pCi/l

NA

Radiochemistry Prep Worksheet

ALS -- Fort Collins

Prep Batch: RA170621-1

Prep Procedure: Ra228

Reviewed By: lad LAD Review Date: 7/18/2017

Non-Routine Pre-Treatment? ☒ Y ☐ N Batch: NA Re-Prep? ☒ Y ☐ N Batch: NA Balance: N/A
 Prep SOP: SOP749 Rev: 4 Prep Analyst: Lucas A. Daut LAD Balance: N/A
 Prep SOP: NONE Prep Date: 6/21/2017 Matrix Class: liquid Prep Dept: RS

Sample Prep Num	LabID	QC Type	Dish No.	Init Aliq ml	Fin Aliq ml	Prep Basis	Ingrowth Date/Time	Decay Date/Time	Standards	Prep Notes
1	1706233-1	SMP	NA	1500	1496.002	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
2	1706233-2	SMP		1500	1496.002	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
3	1706267-1	SMP		1500	1496.002	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
4	1706268-1	SMP		1500	1496.002	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
5	1706269-1	SMP		1500	1496.002	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
6	1706271-1	SMP		750	748.001	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
7	1706271-2	SMP		750	748.001	Filtered	06/25/17 16:55	06/27/17 07:10	T1	
8	1706286-1	SMP		750	748.001	Unfiltered	06/25/17 16:55	06/27/17 07:10	T2	
9	1706286-3	SMP		750	748.001	Filtered	06/25/17 16:55	06/27/17 07:10	T1	
10	1706288-1	SMP		1500	1496.002	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
11	1706289-1	SMP		750	748.001	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
12	1706289-2	SMP		750	748.001	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
13	1706329-1	SMP		750	748.001	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
14	1706329-2	SMP		750	748.001	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
15	1706340-1	SMP		1500	1496.002	Filtered	06/25/17 16:55	06/27/17 07:10	T1	
16	1706340-3	SMP		1500	1496.002	Filtered	06/25/17 16:55	06/27/17 07:10	T1	
17	1706341-1	SMP		750	748.001	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
18	1706341-3	SMP		750	748.001	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
19	1706395-1	SMP		750	748.001	Unfiltered	06/25/17 16:55	06/27/17 07:10	NA	
20	1706423-1	SMP		750	748.001	Unfiltered	06/25/17 16:55	06/27/17 07:10	↓	
21	RA170621-1	MB		1500	1496.002	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
22	RA170621-1	LCS		1500	1496.002	Unfiltered	06/25/17 16:55	06/27/17 07:10	S1,T1	
23	RA170621-1	LCSD		1500	1496.002	Unfiltered	06/25/17 16:55	06/27/17 07:10	S1,T1	

LAD 7/18/17

Radiochemistry Prep Worksheet

ALS -- Fort Collins

Prep Batch: RA170621-1

Prep Procedure: Ra228

Reviewed By: lad **LAD** Review Date: 6/27/2017

Non-Routine Pre-Treatment? Y / ☒ Batch: **NA** Re-Prep? Y / ☒ Batch: **NA** Prep QASS / NCR? Y / ☒ **NA**

Prep SOP: SOP749 Rev: 4

Prep SOP: NONE

Matrix Class: liquid

Prep Analyst: Lucas A. Daut **LAD**

Prep Date: 6/21/2017

Prep Dept: RS

Balance: N/A

Balance: N/A

Samp Num	Prep Num	LabID	QC Type	Dish No.	Init Aliq ml	Fin Aliq ml	Prep Basis	Ingrrowth Date/Time	Decay Date/Time	Standards	Prep Notes
1	1	1706233-1	SMP	NA	1500	1496.002	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
2	1	1706233-2	SMP		1500	1496.002	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
3	1	1706267-1	SMP		1500	1496.002	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
4	1	1706268-1	SMP		1500	1496.002	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
5	1	1706269-1	SMP		1500	1496.002	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
6	1	1706271-1	SMP		750	748.001	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
7	1	1706271-2	SMP		750	748.001	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
8	1	1706286-1	SMP		750	748.001	Unfiltered	06/25/17 16:55	06/27/17 07:10	T2	
9	1	1706286-3	SMP		750	748.001	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
10	1	1706288-1	SMP		1500	1496.002	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
11	1	1706299-1	SMP		750	748.001	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
12	1	1706299-2	SMP		750	748.001	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
13	1	1706329-1	SMP		750	748.001	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
14	1	1706329-2	SMP		750	748.001	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
15	1	1706340-1	SMP		1500	1496.002	Filtered	06/25/17 16:55	06/27/17 07:10	T1	
16	1	1706340-3	SMP		1500	1496.002	Filtered	06/25/17 16:55	06/27/17 07:10	T1	
17	1	1706341-1	SMP		750	748.001	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
18	1	1706341-3	SMP		750	748.001	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
19	1	1706395-1	SMP		750	748.001	Unfiltered	06/25/17 16:55	06/27/17 07:10	NA	
20	1	1706423-1	SMP		750	748.001	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
21	1	RA170621-1	MB		1500	1496.002	Unfiltered	06/25/17 16:55	06/27/17 07:10	T1	
22	1	RA170621-1	LCS		1500	1496.002	Unfiltered	06/25/17 16:55	06/27/17 07:10	S1,T1	
23	1	RA170621-1	LCSD		1500	1496.002	Unfiltered	06/25/17 16:55	06/27/17 07:10	S1,T1	

Radiochemistry Prep Worksheet

ALS -- Fort Collins

Prep Batch: RA170621-1

Prep Procedure: Ra228

Reviewed By: lad Review Date: 6/27/2017

Non-Routine Pre-Treatment? Y / (N) Batch: NA

Re-Prep? Y / (N) Batch: NA Prep QASS / NCR? Y / (N)

Prep SOP: SOP749 Rev: 4

Prep Analyst: Lucas A. Daut

Balance: N/A

Prep Date: 6/21/2017

Balance: N/A

Matrix Class: liquid

Prep Dept: RS

Samp Num	Prep Num	LabID	QC Type	Dish No.	Init Aliq ml	Fin Aliq ml	Prep Basis	Ingrowth Date/Time	Decay Date/Time	Standards	Prep Notes

Comments

Reduced aliquots were taken due to potential matrix interference and high prescreen activity. A LCSD was performed to conserve volume.

Spiked By: Lucas A. Daut Date: 6/24/2017

Date:

Witnessed By: Hunter C. Jordan Date: 6/24/2017

Date:

Yttrium Added By:

Witnessed By:

Tracer/Carrier Solution Information

Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
T1	BARIUM	418236	<u>1/19/18</u>	16,022.768	pCi/ml	NA	2	ml	RS031
T2	BARIUM	418236		16,022.768	pCi/ml	NA	1	ml	RS033

Spike Solution Information

Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
S1	Ra-228	1014.4095.79	<u>3/23/18</u>	91.033	DPM/ml	06/21/17	0.25	ml	RS019

Radiochemistry Prep Worksheet

ALS -- Fort Collins

Prep Batch: RA170621-1

Prep Procedure: Ra228

Prep Batch Not Validated!!!

Reviewed By: LAD

Review Date:

Non-Routine Pre-Treatment? Y / N Batch: Re-Prep? Y / N Batch: Prep QASS / NCR? Y / N

Prep SOP: SOP749 Rev: 4

Prep SOP: NONE

Matrix Class: liquid

Prep Analyst: Lucas A. Daut

Prep Date: 6/21/2017

Prep Dept: RS

Balance: N/A

Balance: N/A

Sample Num	LabID	QC Type	Dish No.	Init Aliq ml	Fin Aliq ml	Prep Basis	Ingrowth Date/Time	Decay Date/Time	Standards	Prep Notes
1	1706233-1	SMP		1500	1500	Unfilt	16:55	7:10	T1	
2	1706233-2	SMP		1500	1500		6/25	6/27	T1	
3	1706267-1	SMP		1500	1500				T1	Acidified
4	1706268-1	SMP		1500	1500				T1	
5	1706269-1	SMP		1500	1500				T1	
6	1706271-1	SMP	750	1500	1500				T1	
7	1706271-2	SMP	750	1500	1500				T1	
8	1706286-1	SMP	750	1500	1500				T1	
9	1706286-3	SMP	750	1500	1500				T1	
10	1706288-1	SMP		1500	1500				T1	
11	1706299-1	SMP	750	1500	1500				T1	
12	1706299-2	SMP	750	1500	1500				T1	
13	1706329-1	SMP	750	1500	1500				T1	
14	1706329-2	SMP	750	1500	1500				T1	
15	1706340-1	SMP		1500	1500	Filt			T1	0.45µM
16	1706340-3	SMP		1500	1500				T1	
17	1706341-1	SMP	750	1500	1500	Unfilt			T1	
18	1706341-3	SMP	750	1500	1500				T1	
19	1706395-1	SMP	750	1500	1500				T1	
20	1706423-1	SMP	750	1500	1500				T1	
21	RA170621-1	MB		1500	1500				T1	
22	RA170621-1	LCS		1500	1500				S1,T1	
23	RA170621-1	LCS		1500	1500				S1,T1	

Supersedes: NA

ALS -- Fort Collins

LIMS Version: 6.843

Radiochemistry Prep Worksheet

ALS -- Fort Collins

Prep Batch: RA170621-1

Prep Procedure: Ra228

Prep Batch Not Validated!!!

Reviewed By: LAD

Review Date:

Non-Routine Pre-Treatment? Y / N Batch: Re-Prep? Y / N Batch: Prep QASS / NCR? Y / N

Prep SOP: SOP749 Rev: 4

Prep SOP: NONE

Matrix Class: liquid

Prep Analyst: Lucas A. Daut

Prep Date: 6/21/2017

Prep Dept: RS

Balance: N/A

Balance: N/A

Samp Num Prep Num LabID QC Type Dish No. Init Alq ml Fin Alq ml Prep Basis Ingrowth Date/Time Decay Date/Time Standards Prep Notes

Comments

Spiked By: Lucas A. Daut

Date: 6/22/2017

Yttrium Added By:

Date:

Witnessed By:

Date: 6/22/17

Witnessed By:

Date:

Tracer/Carrier Solution Information

Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
T1	BARIUM	418236	1-19-18	16,022.768	pCi/ml	NA	2	ml	RS031

Spike Solution Information

Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
S1	Ra-228	1014.4095.79	3/23/18	91.033	DPM/ml	06/21/17	0.25	ml	RS019

Sample Condition Form (Liquid)				
Analyst: Lucas Dant				
Analysis Date: 6/21/17			Method: Prep	
		Sample Condition (Visual Appearance of Analysis Aliquot at Time of Prep)		
Work Order	Sample ID	pH	Color	Remarks
1706233	1	~2	Clear	None
↓	2			
1706267	1			
1706268	1			
1706269	1			
1706271	1		Yellow	Cloudy; oily
↓	2			dusting of brown Sed.; f. lter
1706286	1		Cloudy	Oily
↓	3		Orange	Oily; Orange Sediment; f. ltered
1706288	1		Clear	None
1706299	1 2 ^{LAD}		Cloudy	
↓	2		Clear	
1706329	1		Slightly Cloudy	Floating organ, zs
↓	2		yellow tinge	Cloudy
1706340	1		Clear	None ^{LAD 6/23} 0.45 µm Filt. Per wo Note
↓	3			
1706341	1		Yellow tinge	Cloudy; dusting of Tan Sediment
↓	3			
1706395	1		Yellow tinge	Cloudy; Smelly;
1706423	1			

Section 8

STANDARDS TRACEABILITY DOCUMENTS



Radiochemistry Solution Report

Solution Id: 418236	Name: Ba carrier	Lot:	Vendor Name:	Type: IS
---------------------	------------------	------	--------------	----------

Final Vol: 4000	Dept: RD	Prep By SDW	on	1/19/2017	Reviewed By tde	on	1/26/2017
Units: mL	Location: RS	Opened By	on		Verified By SDW	on	1/19/2017
Matrix: LIQUID	ExpireDate: 1/19/2018	Received By	on		Deactivated By	on	

Comment:

Component Name	Component ID	Volume Added	Units
Barium Stable Carrier Source<1>	3756 B07592	114.0018	g

Calibrated Primary Calibration Reference

CompName	Act/Conc	Date	1/2 Life (Yrs)	Final Act/Conc	Summed Conc	Units
BARIUM	562193.5	3/9/2017		16022.77		pCi/ml

Associated Parent IDs

3756 B07592

Abbreviations: NC = Not Calculated for reagents when the volume added is not entered. (Pmt) = Secular equilibrium; parent half life used to calculate concentration.
NE = Not Entered

Date Printed: Thursday, March 09, 2017

ALS Environmental -- FC

Standards DB Version: 1.111

Page 1 of 1

Prepare a working dilution of RSO# 1014

18/11/15

1. Density of 8% HNO₃, lot # 0000084176
Mass of 100mL vol. flask: 68.3149g
Mass of flask & 100mL acid: 172.2758g
Net Mass: 103.9609g
Density: 1.0396 g/mL

Balance # 12
Balance # 12

2. Mass of RSO# 1014 transferred:

Mass of open empty nalgene: 48.3028g
Mass of nalgene & standard: 53.2851g
Net mass of standard transferred: 4.9823g

Balance # 12
Balance # 12
Balance # NA

3. Dilute to final volume:

Mass of nalgene, standard, & diluent: 344.91g
Mass of empty nalgene (from above): 48.3028g
Net mass of new dilution: 296.6072g

Balance # 26
Balance # 12
Balance # NA

4. Final activity calculation:

$$195 \text{ Bq/g} \left(\frac{60 \text{ dpm}}{1 \text{ Bq}} \right) \left(\frac{4.9823 \text{ g}}{296.6072 \text{ g}} \right) (1.0396 \text{ g/mL}) = 204.32 \text{ dpm/mL}$$

18/11/15

JP 4/15/15

Std ID: 1014.4095.79

Description: Ra-228
Expiration: 4/9/2016
Activity: 204.32 dpm/mL

2s Uncertainty: 14.71 dpm/mL

Ref. Date: 10/7/2010
Ref Time: N/A
Prep Date: 1/16/2015 Prep by: TE
Matrix/Comp: 8% HNO₃
Half Life (y): 5.75E+00

Reverification Log		
Analysis Date	Initials	Expiration Date
4/2/2016	JP	4/02/2017
3/23/2017	JP	3/23/2018

JP 4/15/15

Continued on Page

1 Ellet
Signed

1/16/15
Date

[Signature]
Reviewed and Understood By
Signed

4/15/15
Date



1507
1014
National Institute of Standards & Technology

Certificate

Standard Reference Material® 4339b

Radium-228 Radioactivity Standard

This Standard Reference Material (SRM) consists of a solution of a standardized and certified quantity of radioactive radium-228 in a suitably stable and homogeneous matrix. It is intended primarily for the calibration of instruments that are used to measure radioactivity and for the monitoring of radiochemical procedures. A unit of SRM 4339b consists of approximately 5 mL of a solution, whose composition is specified in Tables 1 and 2, contained in a flame-sealed borosilicate-glass ampoule [1].

The certified radium-228 massic activity value, at a Reference Time of 1200 EST, 07 October 2010, is:

$$(195 \pm 14) \text{ Bq}\cdot\text{g}^{-1}$$

A NIST certified value, as used within the context of this certificate, is a value for which NIST has the highest confidence in its uncertainty assessment. It is a "measurement result" [2] obtained directly or indirectly from a "primary reference measurement procedure" [3]. The certified value is traceable to the derived SI unit, Becquerel (Bq).

Additional physical, chemical, and radiological properties for this SRM, as well as details on the standardization method, are given in Tables 1 and 2. Uncertainties for the certified quantities are expanded ($k=2$). The uncertainties are calculated according to the ISO and NIST Guides [4,5]. Table 3 contains a specification of the components that comprise the uncertainty analyses.

Expiration of Certification: The certification of SRM 4339b is valid indefinitely, within the measurement uncertainty specified, provided that the SRM is handled and stored properly and that no evaporation or change in composition has occurred. The solution matrix, in an unopened ampoule, is homogeneous and stable within its half-life-dependent useful lifetime provided the SRM is handled in accordance with instructions given in this certificate (see "Instructions for Handling and Storage"). Periodic recertification of this SRM is not required. The certification is nullified if the SRM is damaged, contaminated, or otherwise modified.

Maintenance of SRM Certification: NIST will monitor this SRM over the period of its certification. If substantive technical changes occur that affect the certification, NIST will notify the purchaser. Registration (see attached sheet) will facilitate notification.

Radiological and Chemical Hazard: Consult the Safety Data Sheet (SDS), enclosed with the SRM shipment, for radiological and chemical hazard information.

This SRM was prepared in the Physical Measurement Laboratory, Radiation and Biomolecular Physics Division, Radioactivity Group, M.P. Unterwiesing, Group Leader. The overall technical direction and physical measurement leading to certification and photon-emitting impurity analyses were provided by L. Pibida of the NIST Radioactivity Group, with production assistance by J. LaRosa, R. Collé, and L. Laureano-Pérez. Alpha-emitting impurity analyses were provided by J. LaRosa.

Support aspects involved in the issuance of this SRM were coordinated through the NIST Office of Reference Materials.

Lisa R. Karam, Chief
Radiation and Biomolecular Physics Division

Gaithersburg, Maryland 20899
Certificate Issue Date: 14 November 2012
SRM 4339b

Robert L. Watters, Jr., Director
Office of Reference Materials

Page 1 of 4

Table 1. Certified Massic Activity of SRM 4339b

Radionuclide	Radium-228 ^(a)
Reference time	1200 EST, 07 October 2010
Massic activity of the solution	195 Bq·g ⁻¹
Relative expanded uncertainty ($k = 2$)	7.2 % ^(b)

^(a) The final ²²⁸Ra purification from the ²³²Th mother solution was performed on 02 September 2010 0920 EST.

^(b) The uncertainties on certified values are expanded uncertainties, $U = ku_c$. The quantity u_c is the combined standard uncertainty calculated according to the ISO and NIST Guides [4.5]. The combined standard uncertainty is multiplied by a coverage factor of $k = 2$ and was chosen to obtain what is assumed to be an approximate 95 % level of confidence.

Table 2. Uncertified Information of SRM 4339b

Source description	Liquid in a flame-sealed 5 mL borosilicate-glass ampoule [1]
Solution composition	1.3 mol·L ⁻¹ HNO ₃ with 19.8 µg·g ⁻¹ Ba ²⁺
Solution density	(1.034 ± 0.002) g·mL ⁻¹ at 20.8 °C ^(a)
Solution mass	(5.180 ± 0.003) g ^(a)
Photon-emitting impurities	²²⁶ Ra: < 0.5 Bq·g ⁻¹ ^(b)
Alpha-emitting impurities	²³² Th: < 0.08 Bq·g ⁻¹ ^(c)
Half-lives used	²²⁸ Ra: (5.75 ± 0.04) a ^(d) [6] ²²⁸ Ac: (6.15 ± 0.02) h [7] ²²⁶ Ra: (1600 ± 7) a [8] ²³² Th: (14.02 ± 0.06) × 10 ⁹ a [9]
Calibration methods (and instruments)	The certified massic activity for ²²⁸ Ra was obtained by high-resolution gamma-ray spectrometry of three master solution ampoules (eleven separate determinations), as measured on three to five different spectrometers and geometries on each ampoule, and used assumed nuclear data for probabilities per decay for 16 gamma-ray transitions. Confirmatory measurements were performed by 2πα spectrometry of ingrown ²²⁸ Th with a planar, ion-implanted Si detector.

^(a) The stated uncertainty is two times the standard uncertainty. See reference 5.

^(b) Based on gamma-ray spectrometry of forced-fitted peak at 186.2 keV and assuming a probability per decay of 0.0355 [6].

^(c) The maximum ²³²Th activity concentration in ²²⁸Ra.

^(d) The stated uncertainty is the standard uncertainty. See reference 5.

Table-3. Uncertainty Evaluation for the Massic Activity of SRM 4339b

Uncertainty component		Assessment Type ^(a)	Relative standard uncertainty contribution on massic activity of ²²⁸ Ra (%)
1	Gamma-ray spectrometry precision; relative standard deviation of the grand mean on the average massic gamma-ray emission rates for 16 measured ²²⁸ Ac gamma-ray transitions. Each mean in the grand mean is based on 11 determinations with three sources in three to five different detectors. The uncertainty in the determination of the massic gamma-ray emission rate for any one transition in a given determination ranged from typically 0.5 % to 1.5 %. The relative standard deviation of the mean for the average of the 16 lines, for any one determination, was typically 1 %; whereas the relative standard deviation of the grand mean for the average of the 16 lines across all 11 determinations is 0.34 % ^(b) . Data passes normality test.	A	0.84
2	Uncertainty due to assumed gamma-ray probabilities per decay for the measured ²²⁸ Ac transitions [7]. The uncertainty on each transition has a shared (correlated) component of 2.5 % (see comments in [7]).	B	3.5
3	Detection efficiencies not embodied within component 1	B	0.4
4	Mass determinations for dilution factors and counting source preparations	B	0.1
5	Decay corrections for ²²⁸ Ra half-life uncertainty of 0.7 % [6]	B	0.003
6	Effect of ²²⁸ Ra and ²²⁸ Ac half-life uncertainties on secular equilibrium ratio	B	0.02
Relative combined standard uncertainty			3.6
Relative expanded uncertainty ($k = 2$)			7.2

^(a) Letter A denotes evaluation by statistical methods; B denotes evaluation by other methods.

^(b) Average massic gamma-ray emission rates of 11 geometries (R_V) for 16 measured ²²⁸Ac gamma-ray transitions with their respective energy (E_V); assumed gamma-ray probabilities per decay (I_V) and standard deviation of the mean (S_m).

E_V (keV)	Assumed I_V (%) [1]	Mean R_V (s ⁻¹ g ⁻¹) ⁽ⁱ⁾	S_m (%) ⁽ⁱⁱ⁾
129.065	2.50	1347	0.38
153.967	0.754	421.6	0.40
209.249	3.97	2264	0.55
270.245	3.55	2014	0.33
328.004	3.04	1822	0.43
338.32	11.4	6712	0.43
409.46	2.02	1185	0.29
463.002	4.45	2645	0.33
755.313	1.03	593.3	0.46
772.291	1.52	899.2	0.53
794.942	4.31	2588	0.35
835.704	1.7	995.3	0.42
911.196	26.2	15609	0.29
964.786	4.99	3007	0.35
968.96	15.9	9582	0.30
1588.2	3.06	1889	0.28

(i) Grand mean for $n = 11$ determinations with three sources in three to five different detectors.

(ii) Relative standard deviation of the grand mean on R_V for $n = 11$.

INSTRUCTIONS FOR HANDLING AND STORAGE

Handling: If the ampoule is transported, it should be packed, marked, labeled, and shipped in accordance with the applicable national, international, and carrier regulations. The solution in the ampoule is a dangerous good (hazardous material) because of both the radioactivity and the strong acid. The ampoule should be opened only by persons qualified to handle both radioactive material and alkaline and/or acidic solutions. Appropriate shielding and/or distance should be used to minimize personnel exposure. Refer to SDS for further information.

Storage: SRM 4339b should be stored and used at a temperature between 5 °C and 65 °C. The ampoule (or any subsequent container) should always be clearly marked as containing radioactive material.

REFERENCES

- [1] NIST Physical Measurement Laboratory; *Storage and Handling of Radioactive Standard Reference Materials, Ampoule Specifications and Opening Procedure*, available at <http://www.nist.gov/pml/div682/grp04/srm.cfm> (accessed Nov 2012). Note: This SRM is contained in a generic borosilicate-glass ampoule and not in the standard NIST ampoule.
- [2] JCGM 200:2012; *International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM)* (2008 version with Minor Corrections), 3rd edition; Joint Committee for Guides in Metrology: BIPM, Sevres Cedex, France; p. 19 (2012); available at http://www.bipm.org/utls/common/documents/jcgm/JCGM_200_2012.pdf (accessed Nov 2012).
- [3] JCGM 200:2012; *International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM)* (2008 version with Minor Corrections), 3rd edition; Joint Committee for Guides in Metrology: BIPM, Sevres Cedex, France; p. 18 (2012); available at http://www.bipm.org/utls/common/documents/jcgm/JCGM_200_2012.pdf (accessed Nov 2012).
- [4] JCGM 100:2008; *Guide to the Expression of Uncertainty in Measurement*; (ISO GUM 1995 with Minor Corrections), Joint Committee for Guides in Metrology: BIPM, Sevres Cedex, France (2008); available at http://www.bipm.org/utls/common/documents/jcgm/JCGM_100_2008_E.pdf (accessed Nov 2012).
- [5] Taylor, B.N.; Kuyatt, C.E.; *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*; NIST Technical Note 1297, U.S. Government Printing Office: Washington, DC (1994); available at <http://physics.nist.gov/Pubs/> (accessed Nov 2012).
- [6] Luca, A.; June 2009, ²²⁸Ra. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Ra-228_tables.pdf (accessed Nov 2012).
- [7] Pearce, A.; January 2010, ²²⁸Ac. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Ac-228_tables.pdf (accessed Nov 2012).
- [8] Christé, V. and M.M. Bé; December 2006, ²²⁶Ra. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Ra-226_tables.pdf (accessed Nov 2012).
- [9] Arinc, A.; September 2008, ²³²Th. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Th-232_tables.pdf (accessed Nov 2012).

Users of this SRM should ensure that the Certificate in their possession is current. This can be accomplished by contacting the SRM Program: telephone (301) 975-2200; fax (301) 948-3730; e-mail srminfo@nist.gov; or via the Internet at <http://www.nist.gov/srm>.

Section 9

ADDITIONAL SUPPORTING DOCUMENTATION

Gas Proportional Counter

Instrument Calibration

Background Calibration

LB4100-C
Long Instrument Background Calibration
Background Determination

Detector ID	Alpha				Beta				Detector ID
	CPM	LCL	UCL	Flag	CPM	LCL	UCL	Flag	
A1 (01)	0.090	0.0008	0.1552	PASS	1.595	1.077	2.154	PASS	A1 (01)
A2 (02)	0.090	0.0009	0.1871	PASS	1.490	1.002	2.004	PASS	A2 (02)
A3 (03)	0.103	0.0010	0.1910	PASS	1.548	1.133	2.265	PASS	A3 (03)
A4 (04)	0.089	0.0008	0.1652	PASS	1.548	1.149	2.298	PASS	A4 (04)
B1 (05)	0.091	0.0009	0.1811	PASS	1.630	1.210	2.420	PASS	B1 (05)
B2 (06)	0.120	0.0012	0.2328	PASS	1.726	1.238	2.475	PASS	B2 (06)
B3 (07)	0.096	0.0008	0.1672	PASS	1.645	1.159	2.318	PASS	B3 (07)
B4 (08)	0.122	0.0010	0.1990	PASS	1.699	1.193	2.387	PASS	B4 (08)
C1 (09)	0.114	0.0011	0.2189	PASS	1.714	1.155	2.310	PASS	C1 (09)
C2 (10)	0.126	0.0011	0.2229	PASS	1.717	1.244	2.489	PASS	C2 (10)
C3 (11)	0.095	0.0010	0.1910	PASS	1.700	1.230	2.460	PASS	C3 (11)
C4 (12)	0.127	0.0014	0.2806	PASS	2.536	1.449	4.346	PASS	C4 (12)
D1 (13)	0.000	0.0010	0.1891	FLAG-LOW	0.000	1.211	2.421	FLAG-LOW	D1 (13)
D2 (14)	0.000	0.0009	0.1731	FLAG-LOW	0.000	1.205	2.411	FLAG-LOW	D2 (14)
D3 (15)	0.000	0.0017	0.3403	FLAG-LOW	0.000	1.249	2.498	FLAG-LOW	D3 (15)
D4 (16)	0.000	0.0010	0.2010	FLAG-LOW	0.000	1.205	2.411	FLAG-LOW	D4 (16)

A ↓

Drawer Error. Voltage Error. Recount in File
JP
 Date: 6/22/17 BKC0622W

Reviewed by: _____

Interim limits for alpha set to be +/- 99%, beta +/-25%
 mh 06/07/2017

LB4100-C
Long Instrument Background Calibration
Background Determination

Detector ID		Alpha				Beta				Detector ID	
	CPM	LCL	UCL	Flag		CPM	LCL	UCL	Flag		
A1 (01)	#REF!	0.0008	0.1552	#REF!		#REF!	1.077	2.154	#REF!	A1 (01)	
A2 (02)	#REF!	0.0009	0.1871	#REF!		#REF!	1.002	2.004	#REF!	A2 (02)	
A3 (03)	#REF!	0.0010	0.1910	#REF!		#REF!	1.133	2.265	#REF!	A3 (03)	
A4 (04)	#REF!	0.0008	0.1652	#REF!		#REF!	1.149	2.298	#REF!	A4 (04)	
B1 (05)	#REF!	0.0009	0.1811	#REF!		#REF!	1.210	2.420	#REF!	B1 (05)	
B2 (06)	#REF!	0.0012	0.2328	#REF!		#REF!	1.238	2.475	#REF!	B2 (06)	
B3 (07)	#REF!	0.0008	0.1672	#REF!		#REF!	1.159	2.318	#REF!	B3 (07)	
B4 (08)	#REF!	0.0010	0.1990	#REF!		#REF!	1.193	2.387	#REF!	B4 (08)	
C1 (09)	#REF!	0.0011	0.2189	#REF!		#REF!	1.155	2.310	#REF!	C1 (09)	
C2 (10)	#REF!	0.0011	0.2229	#REF!		#REF!	1.244	2.489	#REF!	C2 (10)	
C3 (11)	#REF!	0.0010	0.1910	#REF!		#REF!	1.230	2.460	#REF!	C3 (11)	
C4 (12)	#REF!	0.0014	0.2806	#REF!		#REF!	1.449	4.346	#REF!	C4 (12)	
D1 (13)	0.104	0.0010	0.1891	PASS		1.670	1.211	2.421	PASS	D1 (13)	
D2 (14)	0.118	0.0009	0.1731	PASS		1.523	1.205	2.411	PASS	D2 (14)	
D3 (15)	0.132	0.0017	0.3403	PASS		1.615	1.249	2.498	PASS	D3 (15)	
D4 (16)	0.127	0.0010	0.2010	PASS		2.551	1.205	2.411	FLAG-HIGH	D4 (16)	

Δ

A Detech 6/23/17

Date: 6/23/17

JR

Reviewed by: _____

Interim limits for alpha set to be +/- 99%, beta +/-25%
 mh 06/07/2017

Gas Proportional Counter

Quality Control Data

Daily Instrument Performance Checks

LB4100-C
Daily Instrument Performance Check-Efficiency Determination

Detector ID	Alpha				Beta				Detector ID
	Eff.	LCL	UCL	Flag	Eff.	LCL	UCL	Flag	
A1 (01)	0.1989	0.1783	0.2179	PASS	0.3900	0.3497	0.4274	PASS	A1 (01)
A2 (02)	0.2048	0.1854	0.2266	PASS	0.3897	0.3493	0.4270	PASS	A2 (02)
A3 (03)	0.2147	0.1917	0.2343	PASS	0.3859	0.3545	0.4333	PASS	A3 (03)
A4 (04)	0.2052	0.1856	0.2269	PASS	0.3921	0.3481	0.4254	PASS	A4 (04)
B1 (05)	0.2363	0.2075	0.2536	PASS	0.4031	0.3709	0.4533	PASS	B1 (05)
B2 (06)	0.1963	0.1734	0.2120	PASS	0.3764	0.3321	0.4060	PASS	B2 (06)
B3 (07)	0.2192	0.1961	0.2396	PASS	0.3970	0.3616	0.4419	PASS	B3 (07)
B4 (08)	0.2186	0.1928	0.2357	PASS	0.3911	0.3566	0.4359	PASS	B4 (08)
C1 (09)	0.2085	0.1913	0.2338	PASS	0.3971	0.3617	0.4421	PASS	C1 (09)
C2 (10)	0.2254	0.1966	0.2403	PASS	0.4120	0.3688	0.4507	PASS	C2 (10)
C3 (11)	0.2089	0.1886	0.2305	PASS	0.3941	0.3594	0.4392	PASS	C3 (11)
C4 (12)	0.2303	0.1972	0.2410	PASS	0.4044	0.3660	0.4473	PASS	C4 (12)
D1 (13)	0.2151	0.1909	0.2333	PASS	0.3963	0.3517	0.4298	PASS	D1 (13)
D2 (14)	0.2148	0.1914	0.2340	PASS	0.3968	0.3534	0.4319	PASS	D2 (14)
D3 (15)	0.2262	0.1933	0.2362	PASS	0.3751	0.3543	0.4330	PASS	D3 (15)
D4 (16)	0.2257	0.1980	0.2420	PASS	0.3926	0.3581	0.4377	PASS	D4 (16)

Reviewed by: JP Date: 6/27/17

Interim Control Limits -- +/-10% of average from last 5 data points
Established: 06/08/17 mh

LB4100-C
Daily Instrument Performance Checks
Background Checks

Detector ID	Alpha				Beta				Detector ID
	CPM	LCL	UCL	Flag	CPM	LCL	UCL	Flag	
A1 (01)	0.117	-0.026	0.206	PASS	1.633	1.106	2.084	PASS	A1 (01)
A2 (02)	0.083	-0.026	0.206	PASS	1.683	1.017	1.963	PASS	A2 (02)
A3 (03)	0.133	-0.021	0.227	PASS	1.617	1.066	2.030	PASS	A3 (03)
A4 (04)	0.100	-0.027	0.205	PASS	1.750	1.066	2.030	PASS	A4 (04)
B1 (05)	0.083	-0.026	0.208	PASS	1.567	1.136	2.124	PASS	B1 (05)
B2 (06)	0.233	-0.014	0.254	PASS	1.833	1.217	2.235	PASS	B2 (06)
B3 (07)	0.133	-0.024	0.216	PASS	1.600	1.148	2.142	PASS	B3 (07)
B4 (08)	0.217	-0.013	0.257	PASS	1.667	1.194	2.204	PASS	B4 (08)
C1 (09)	0.133	-0.017	0.245	PASS	1.650	1.207	2.221	PASS	C1 (09)
C2 (10)	0.117	-0.011	0.263	PASS	1.800	1.210	2.224	PASS	C2 (10)
C3 (11)	0.150	-0.024	0.214	PASS	1.683	1.195	2.205	PASS	C3 (11)
C4 (12)	0.217	-0.011	0.265	PASS	2.583	1.919	3.153	PASS	C4 (12)
D1 (13)	0.183	-0.021	0.229	PASS	1.633	1.170	2.170	PASS	D1 (13)
D2 (14)	0.083	-0.015	0.251	PASS	1.600	1.045	2.001	PASS	D2 (14)
D3 (15)	0.183	-0.009	0.273	PASS	1.633	1.123	2.107	PASS	D3 (15)
D4 (16)	0.217	-0.011	0.265	PASS	2.483	1.932	3.170	PASS	D4 (16)

Reviewed by: JP Date: 6/22/17

Control Limits established from previous weekly background determinations.
 Weekly Background File: BKC0621W Date: 6/21/2017 Analyst: JP
 BKC0622W 6/22/2017 JP
 0 1/0/1900 0

LB4100-C
Daily Instrument Performance Check-Efficiency Determination

Detector ID	Alpha				Beta				Detector ID
	Eff.	LCL	UCL	Flag	Eff.	LCL	UCL	Flag	
A1 (01)	0.1989	0.1783	0.2179	PASS	0.3832	0.3497	0.4274	PASS	A1 (01)
A2 (02)	0.2086	0.1854	0.2266	PASS	0.3882	0.3493	0.4270	PASS	A2 (02)
A3 (03)	0.2109	0.1917	0.2343	PASS	0.3969	0.3545	0.4333	PASS	A3 (03)
A4 (04)	0.2096	0.1856	0.2269	PASS	0.3872	0.3481	0.4254	PASS	A4 (04)
B1 (05)	0.2335	0.2075	0.2536	PASS	0.4044	0.3709	0.4533	PASS	B1 (05)
B2 (06)	0.1984	0.1734	0.2120	PASS	0.3781	0.3321	0.4060	PASS	B2 (06)
B3 (07)	0.2190	0.1961	0.2396	PASS	0.3944	0.3616	0.4419	PASS	B3 (07)
B4 (08)	0.2135	0.1928	0.2357	PASS	0.3938	0.3566	0.4359	PASS	B4 (08)
C1 (09)	0.2107	0.1913	0.2338	PASS	0.4040	0.3617	0.4421	PASS	C1 (09)
C2 (10)	0.2192	0.1966	0.2403	PASS	0.3992	0.3688	0.4507	PASS	C2 (10)
C3 (11)	0.2124	0.1886	0.2305	PASS	0.3957	0.3594	0.4392	PASS	C3 (11)
C4 (12)	0.2225	0.1972	0.2410	PASS	0.4080	0.3660	0.4473	PASS	C4 (12)
D1 (13)	0.2205	0.1909	0.2333	PASS	0.3980	0.3517	0.4298	PASS	D1 (13)
D2 (14)	0.2231	0.1914	0.2340	PASS	0.3942	0.3534	0.4319	PASS	D2 (14)
D3 (15)	0.2249	0.1933	0.2362	PASS	0.3744	0.3543	0.4330	PASS	D3 (15)
D4 (16)	0.2236	0.1980	0.2420	PASS	0.3911	0.3581	0.4377	PASS	D4 (16)

Reviewed by: _____

JP

Dated 6/28/17

Interim Control Limits -- +/-10% of average from last 5 data points
Established: 06/08/17 mh

LB4100-C

Daily Instrument Performance Checks
Background Checks

Detector ID	Alpha				Beta				Detector ID
	CPM	LCL	UCL	Flag	CPM	LCL	UCL	Flag	
A1 (01)	0.183	-0.026	0.206	PASS	1.517	1.106	2.084	PASS	A1 (01)
A2 (02)	0.133	-0.026	0.206	PASS	1.733	1.017	1.963	PASS	A2 (02)
A3 (03)	0.183	-0.021	0.227	PASS	1.517	1.066	2.030	PASS	A3 (03)
A4 (04)	0.233	-0.027	0.205	FLAG-HIGH	1.650	1.066	2.030	PASS	A4 (04)
B1 (05)	0.200	-0.026	0.208	PASS	1.617	1.136	2.124	PASS	B1 (05)
B2 (06)	0.150	-0.014	0.254	PASS	1.917	1.217	2.235	PASS	B2 (06)
B3 (07)	0.067	-0.024	0.216	PASS	1.933	1.148	2.142	PASS	B3 (07)
B4 (08)	0.133	-0.013	0.257	PASS	2.033	1.194	2.204	PASS	B4 (08)
C1 (09)	0.150	-0.017	0.245	PASS	1.833	1.207	2.221	PASS	C1 (09)
C2 (10)	0.100	-0.011	0.263	PASS	1.717	1.210	2.224	PASS	C2 (10)
C3 (11)	0.117	-0.024	0.214	PASS	1.550	1.195	2.205	PASS	C3 (11)
C4 (12)	0.100	-0.011	0.265	PASS	2.750	1.919	3.153	PASS	C4 (12)
D1 (13)	0.100	-0.021	0.229	PASS	1.917	1.170	2.170	PASS	D1 (13)
D2 (14)	0.117	-0.015	0.251	PASS	1.550	1.045	2.001	PASS	D2 (14)
D3 (15)	0.100	-0.009	0.273	PASS	1.600	1.123	2.107	PASS	D3 (15)
D4 (16)	0.150	-0.011	0.265	PASS	2.350	1.932	3.170	PASS	D4 (16)

→ Recounted in
BKC06281X

Reviewed by: JKBDate: 6/28/17

Control Limits established from previous weekly background determinations.

Weekly Background File: BKC0621W

Date: 6/21/2017

Analyst: JP

BKC0622W

6/22/2017

JP

0

1/0/1900

0

BKC0628.XLD

Printed 6/28/2017 8:20 AM

LB4100-C
Daily Instrument Performance Checks
Background Checks

Detector ID	Alpha				Beta				Detector ID
	CPM	LCL	UCL	Flag	CPM	LCL	UCL	Flag	
A1 (01)	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	A1 (01)
A2 (02)	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	A2 (02)
A3 (03)	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	A3 (03)
A4 (04)	0.117	-0.027	0.205	PASS	1.383	1.066	2.030	PASS	A4 (04)
B1 (05)	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	B1 (05)
B2 (06)	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	B2 (06)
B3 (07)	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	B3 (07)
B4 (08)	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	B4 (08)
C1 (09)	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	C1 (09)
C2 (10)	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	C2 (10)
C3 (11)	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	C3 (11)
C4 (12)	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	C4 (12)
D1 (13)	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	D1 (13)
D2 (14)	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	D2 (14)
D3 (15)	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	D3 (15)
D4 (16)	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	#REF!	D4 (16)

Reviewed by: NCB

Date: 6/28/17

Control Limits established from previous weekly background determinations.
Weekly Background File: BKC0621W Date: 6/21/2017 Analyst: JP
BKC0622W 6/22/2017 JP
0 1/0/1900 0

Gas Proportional Counter

Instrument Calibration

**Initial Efficiency Calibration
Standards Traceability**

Instrument: LB4100-C

Calibration: Ra-228

Date of Calibration: 06/19/2017

Efficiency Log Files: **RA228-06/17**

Efficiency Instrument Files: ERA0619A-D

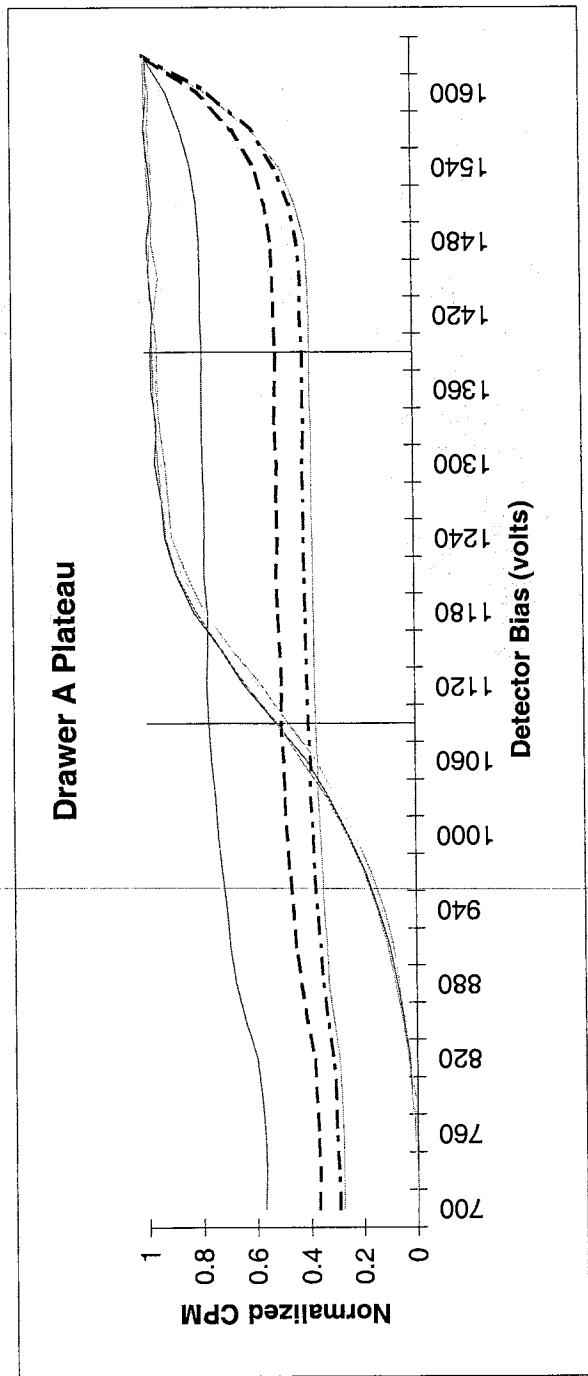
Source ID's: Efficiency (Ra-228 784.3020.37)
ICV/ICB's (Ra-228 1014.4095.79)

OK JP 6/22/17
Expires 06/05/2018

Instrument Plateaus

Unit Type: LB4100/W
Date Performed: 6/6/17 08:23
File Name: PTC0606A
Batch ID: DRAWER A PLATEAU

Unit Id: Magenta
Application Revision: 2
Application Version: Standard

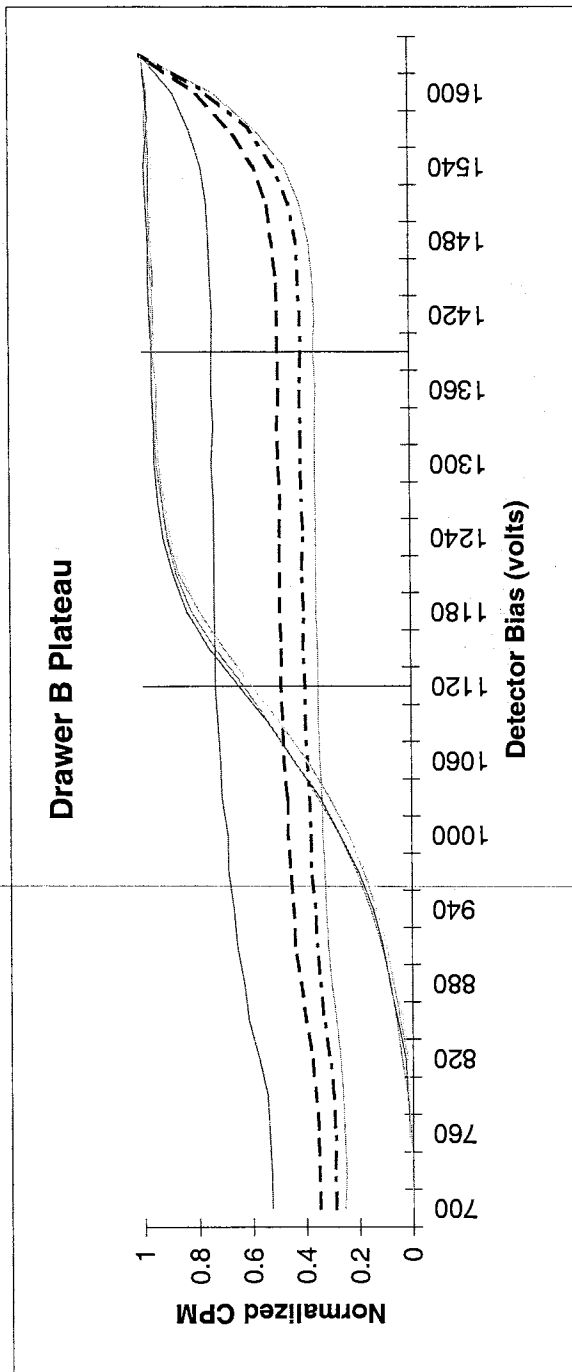


Optimum alpha beta simultaneous operating voltage:		1402.5	
Optimum alpha only operating voltage:		1087.5	
	A1	A2	A3
Beta slope at beta voltage	1.47%	1.71%	0.53%
Alpha slope at beta voltage	0.19%	0.63%	1.60%
Alpha slope at alpha voltage	3.18%	2.44%	3.36%
	A4		
			3.64%
			1.64%
			3.18%

OK JRG 6/9/17

Unit Type: LB4100/W
 Date Performed: 6/6/17 08:23
 File Name: PTC0606B
 Batch ID: DRAWER B PLATEAU

Unit Id: Magenta
 Application Revision: 2
 Application Version: Standard



Optimum alpha beta simultaneous operating voltage: 1402.5

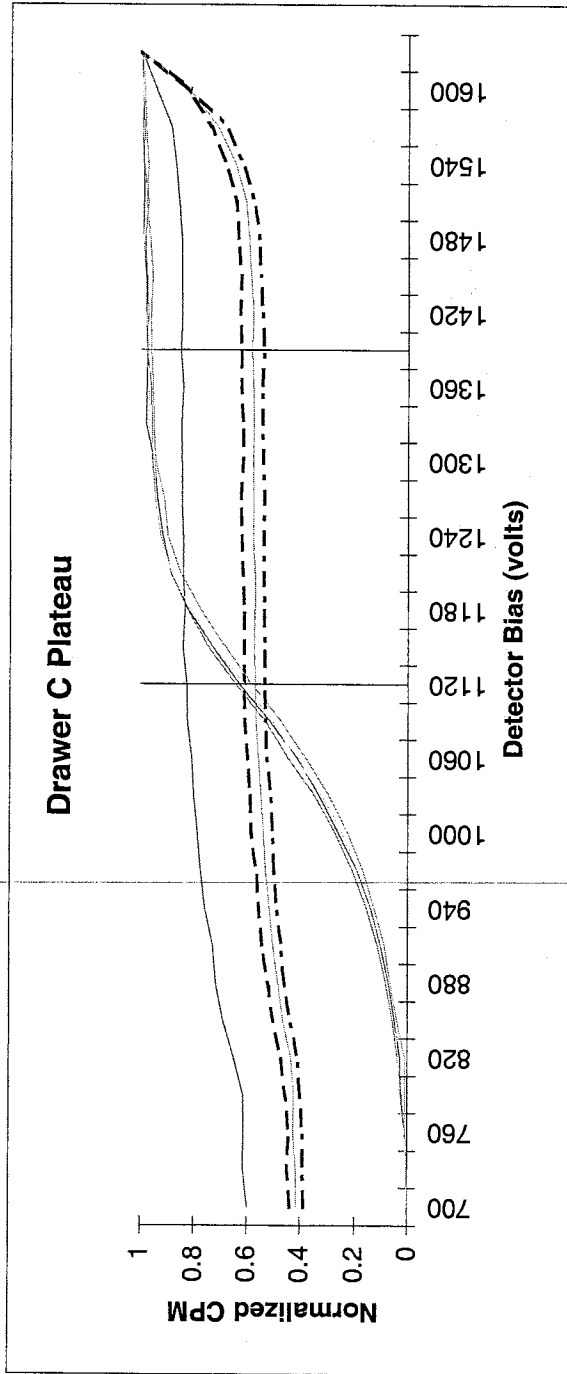
Optimum alpha only operating voltage: 1120

	B1	B2	B3	B4
Beta slope at beta voltage	1.46%	0.21%	1.67%	1.02%
Alpha slope at beta voltage	0.74%	0.41%	1.47%	0.77%
Alpha slope at alpha voltage	2.44%	2.07%	2.12%	2.16%

OK JP 6/9/17

Unit Type: LB4100/W
 Date Performed: 6/5/17 16:24
 FileName: PTC0605C
 Batch ID: DRAWER C PLATEAU

Unit Id: Magenta
 Application Revision: 2
 Application Version: Standard



Optimum alpha beta simultaneous operating voltage: 1402.5

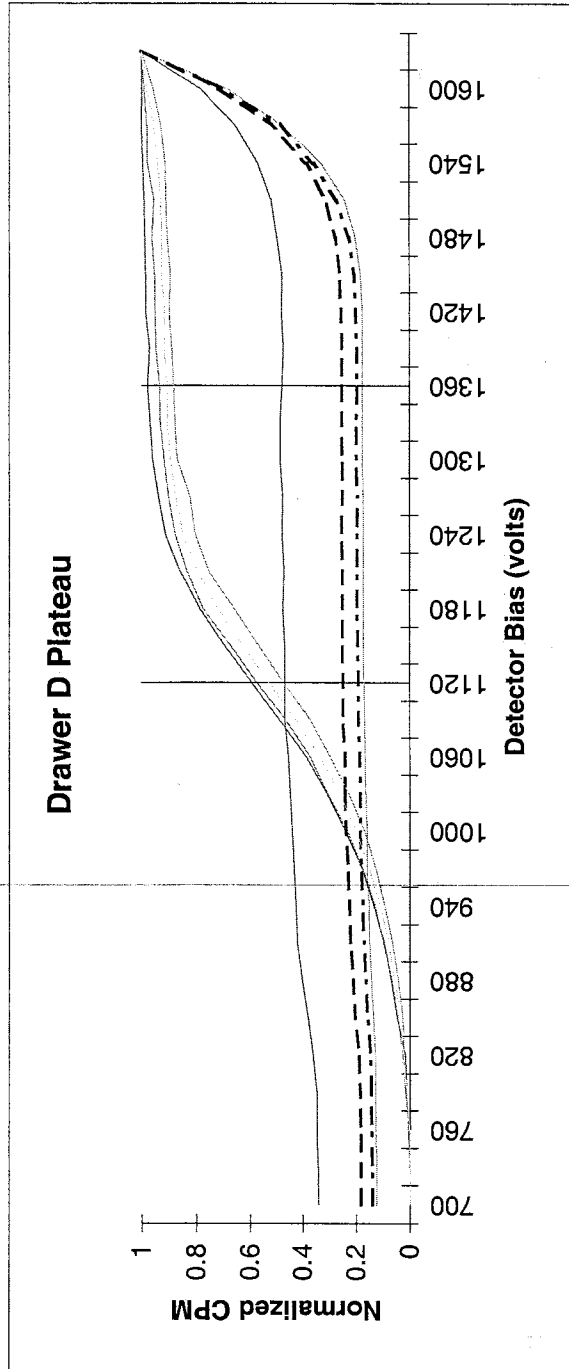
Optimum alpha only operating voltage: 1120

	C1	C2	C3	C4
Beta slope at beta voltage	0.01%	1.81%	0.66%	1.49%
Alpha slope at beta voltage	0.09%	0.91%	1.33%	0.91%
Alpha slope at alpha voltage	2.85%	1.52%	2.04%	1.53%

OK M6/9/17

Unit Type: LB4100/W
 Date Performed: 6/5/17 16:24
 FileName: PTC0605D
 Batch ID: DRAWER D PLATEAU

Unit Id: Magenta
 Application Revision: 2
 Application Version: Standard



Optimum alpha beta simultaneous operating voltage: **1372.5**

Optimum alpha only operating voltage: **1120**

	D1	D2	D3	D4
Beta slope at beta voltage	1.86%	2.83%	2.42%	2.14%
Alpha slope at beta voltage	-1.26%	0.56%	0.63%	0.33%
Alpha slope at alpha voltage	3.38%	3.01%	3.50%	3.06%

OUT 6/19/17

Date 6/6/17SOP 724r 12

ALS
Low Background Gas Flow Proportional Counter Log
Instrument: LB4100C

Instrument Daily Response and Background Checks

Det.	Daily Response Check				Background Check				Det. Status
	Start 1	Status	Start 2	Status	Start 1	Status	Start 2	Status	
1	<u>Jul 5</u>	<u>P</u>			<u>Jul 5</u>	<u>P</u>			<u>P</u>
2									
3									
4									
5									
6									
7									
8									
9						<u>Hβ</u>	<u>Jul 5</u>	<u>P</u>	
10						<u>P</u>			
11									
12						<u>Hβ</u>			<u>OL</u>
13						<u>P</u>			<u>P</u>
14									
15									
16									

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

Weekly Background Calibration

	Current Calib. File ID	Weekly Calib. Started	Status	File ID
Dr A	<u>BK0523 BK0524</u>			
Dr B				
Dr C				
Dr D				

Dr = Drawer

Gas Supply

P-10 Supply		P-10 Flow	
Tank 1		Dr A	<u>10</u>
		Dr B	
Tank 2		Dr C	
		Dr D	

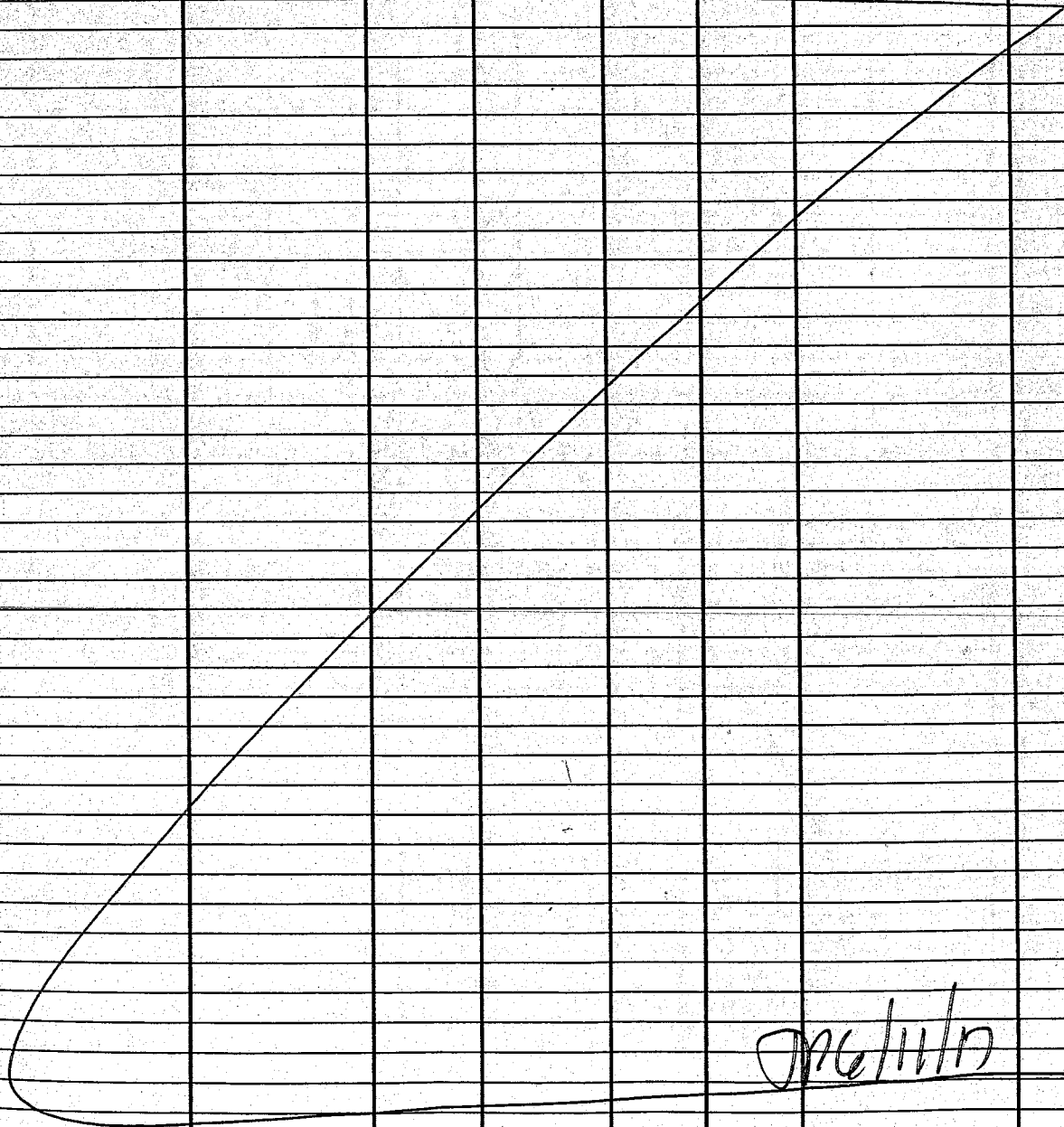
Comments:

Date 6/5/17SOP 724r 12

ALS

Low Background Gas Flow Proportional Counter Log

Instrument: **LB4100C**

Det.	Sample ID	Batch	Test	Count Dur. (min)	Start Time	Analyst Initials	File ID	Output Initials
1-16	Daily Eff	—	—	30	820	JLB	PTC0605	JLB
1-16	Daily Bkgd	—	—	60	833	JLB	BK0605	JLB
9	↓	—	—	60	905	JLB	PTC0605A	JLB
1-16	Alpha/Beta	Drawer A Plat.	Platenum	5 min/sec	1009		PTC0605A	
5-8	Beta/MoX	Drawer B Platenum					PTC0605B	
9-12	Alpha/Beta	Drawer C Platenum			1650		PTC0605C	
13-16	Beta/Alpha	Drawer D Platenum			↓		PTC0605D	
								

Comments:

Page No.: 471486**B**(cont. from page 117)**B)**

Form 780r8.doc (6/23/06)

Reviewed By / Date JP 6/11/17

63 of 117

4/4/17 Drawers A+B removal from Instrument and sent back to Canberra to fix guard detector / Slide tray connection so the 3 guard pins holding the two together don't become loose over time due to opening and closing the drawers resulting in \uparrow beta cpm, \downarrow guard cpm

5/1/17 Drawers A+B received back from Canberra. Drawers re-installed in the instrument, daily performance check ^{JP 5/1/17} run after allowing time for the gas to purge. ^{Weeks Long} Background calibration performed. Drawers A+B are now back on line.

6/5/17 Voltage Plateau

Plateau Check run for drawers A-D

α sources used	detectors	β sources used
410 Am-241	A1 B1 C1 D1	406 Sr 90/Y90
411 17500 dpm	A2 B2 C2 D2	407 29660 dpm
412 2/16/95	A3 B3 C3 D3	408 9/15/95
413	A4 B4 C4 D4	409

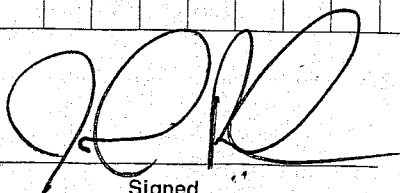
Parameters:

Starting voltage 700	Count preset 40000	File names
End voltage 1650	Time bin steps 0.1	PTC0605A
70V/skip	Weak check Pres 0.1	PTC0605B
5min/step	Weak check limits 20	

6/7/17

ROIS Set for all drawers using Sr/Y90 sources
Sources \rightarrow 406, 407, 408, + 409: over 40,000 counts achieved at each detector. α lower limit + β upper limit set to 50% to start
Both α lower limit + β upper limit moved to achieve $\beta \rightarrow \alpha$ talk of 2.5%. α lower limit moved to achieve $\alpha \rightarrow \beta$ talk of 0.10%
All ROIs archived

Continued on Page

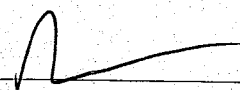


Signed

6/11/17

Date

Read and Understood By



Signed

6/13/17

Date

Instrument ROIs

LB4100 -C Water Sample Counting Parameters

Certainty requirement for MDA and flags

Maximum count time (min)	95%
Typical Residual Mass (mg)	360.00
Typical Sample Volume (l)	50.00
	0.10

Action level for flags (pCi/l)

Activity Multiplier	1.200E+02
Mass Error (%)	1.000E+00
Volume Error (%)	1.00%
	1.00%

	Alpha		Beta	
	eff.	bkg.	eff.	MDA (pCi/l)
A1	15.92%	0.078	37.98%	1.812E+00
A2	16.59%	0.094	37.36%	1.889E+00
A3	16.06%	0.096	37.67%	1.971E+00
A4	16.20%	0.083	38.95%	1.831E+00

Batch Specific:

Event	Recycle
Magenta 1	0

Drawer Specific:

Date/Time	Official	Bias	Step
A 6-6-17 8:23	TRUE	1402.5	0
B 6-6-17 8:23	TRUE	1402.5	0
C 6-5-17 16:24	TRUE	1402.5	0
D 6-5-17 16:24	TRUE	1372.5	0

Detector Specific:

Date/Time	Official	Threshold	bLL	bUL	aLL	aUL
A1 6-7-17 0:00	TRUE	0.1	0	40.07	80.17	100
A2 6-7-17 0:00	TRUE	0.1	0	38.87	77.48	100
A3 6-7-17 0:00	TRUE	0.1	0	36.33	74.84	100
A4 6-7-17 0:00	TRUE	0.1	0	35.53	72.18	100
B1 6-7-17 0:00	TRUE	0.1	0	39.75	79.58	100
B2 6-7-17 0:00	TRUE	0.1	0	40.63	77.85	100
B3 6-7-17 0:00	TRUE	0.1	0	36.99	75.53	100
B4 6-7-17 0:00	TRUE	0.1	0	36.53	74.87	100
C1 6-7-17 0:00	TRUE	0.1	0	36.53	73.52	100
C2 6-7-17 0:00	TRUE	0.1	0	37.82	75.5	100
C3 6-7-17 0:00	TRUE	0.1	0	33.33	70.13	100
C4 6-7-17 0:00	TRUE	0.1	0	35.45	72.25	100
D1 6-7-17 0:00	TRUE	0.1	0	25.76	53.3	100
D2 6-7-17 0:00	TRUE	0.1	0	24.2	46.69	100
D3 6-7-17 0:00	TRUE	0.1	0	18.87	40.7	100
D4 6-7-17 0:00	TRUE	0.1	0	22.24	47.03	100

OK JP 6/17

4/4/17 Drawers A+B removal from Instrument and sent back to Canberra to fix guard detector / Slide tray connection so the 3 guard pins holding the two together don't become loose over time due to opening and closing the drawers resulting in \uparrow beta cpm, \downarrow guard cpm

5/1/17 Drawers A+B received back from Canberra. Drawers re-installed in the instrument, daily performance check run after allowing time for the gas to purge. ^{5/1/17} Weekly Long Background calibration performed. Drawers A+B are now back online.

6/5/17 Voltage Plateau

~~Plateau Check~~ run for drawers A-D

2 sources used

detectors

β sources used

410 Am-241

A1 B1 C1 D1

406 Sr 90/Y90

411 17800 dpm

A2 B2 C2 D2

407 29660 dpm

412 2/16/95

A3 B3 C3 D3

408 9/15/95

413

A4 B4 C4 D4

409

Parameters:

Starting voltage 700

Count preset 40000

File names:

End voltage 1650

Time betw steps 0.1

PTC0605A

30V/skip

Weak check freq 0.1

PTC0605B

5min/step

Weak check limits 20

6/7/17

ROTS set for all drawers using Sr/Y-90 sources

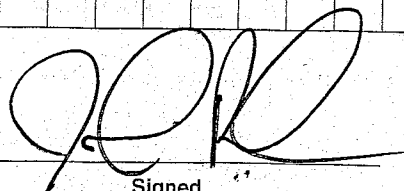
Sources \rightarrow 406, 407, 408, + 409: over 40,000 counts achieved at each detector. α lower limit + β upper limit set to 50% to start

Both α lower limit + β upper limit moved to achieve $\beta \rightarrow \alpha$ talk of

2.5%. α lower limit moved to achieve $\alpha \rightarrow \beta$ talk of 0.10%

All ROTS archived

Continued on Page



Signed

6/11/17

Date

Read and Understood By



Signed

6/13/17

Date

Calibration Efficiencies

Source Database for OSUM

Number of sources in table: 140

Application Revision:

Control ID	Isotope	Type	Half-Life	DPM	Std dev	Date	Status	Alpha/Beta Archive File
1080	Ra-228	Beta	2100.1875	16794.9	554.23	28-Jan-05	ALS	RA228-06/17

[illegible]

Radiochemistry Instrument Worksheet

ALS -- Fort Collins

Prep Batch: RA170615-1

Prep Procedure: Ra228 Eff Ca Source ID: 1080

Analytical QASS / NCR? Y NA

Prep Num	LabID	QC Type	Init Alq	Fin Alq	Units	Report Units	Residual Mass (mg)	Cnt 1 File	Cnt 1 Inst/Det	Cnt 1 Pos Chk By	Cnt 2 File	Cnt 2 Inst/Det	Cnt 2 Pos Chk By	Cnt 3 File	Cnt 3 Inst/Det	Cnt 3 Pos Chk By	Notes
1	1718016-1	SMP	1500	1496.0	ml	pCi/l											
1	1718016-2	SMP	1500	1496.0	ml	pCi/l											
1	1718016-3	SMP	1500	1496.0	ml	pCi/l											
1	1718016-4	SMP	1500	1496.0	ml	pCi/l											
1	1718016-5	SMP	1500	1496.0	ml	pCi/l											

See Maintenance Log 3710 pg 89

Outlier

7/26/1917

Tracer/Carrier Solution Information

Soln #	Nuclide	SolnID	Exp Date	Prep Date	Prep Conc	Units	Aliquot	Units	Pipet ID
T1	BARIUM	418236	1/19/18	NA	16,022.768	pCi/ml	2	ml	RS031

Spike Solution Information

Soln #	Nuclide	SolnID	Exp Date	Prep Date	Prep Conc	Units	Aliquot	Units	Pipet ID
S1	Ra-228	784.3020.37	5/23/18	06/15/17	7,552.998	DPM/g	0.5	g	RS034

Sample Barcodes

1718016-1 RA170615-1PS1	1718016-2 RA170615-1PS2	1718016-3 RA170615-1PS3
1718016-4 RA170615-1PS4	1718016-5 RA170615-1PS5	1718016-1CAR RA170615-1PS6

Reporting Units

LabID:	IstGrpName:	RptUnits:
1718016-1	Ra228_2012	pCi/l
1718016-2	Ra228_2012	pCi/l
1718016-3	Ra228_2012	pCi/l
1718016-4	Ra228_2012	pCi/l
1718016-5	Ra228_2012	pCi/l

Radiochemistry Prep Worksheet

ALS -- Fort Collins

Prep Batch: RA170615-1

Prep Procedure: Ra228

Reviewed By: lad LAD Review Date: 6/19/2017

Non-Routine Pre-Treatment? ☒ Y ☐ N Batch: N/A

Re-Prep? ☒ Y ☐ N Batch: N/A

Prep QASS / NCR? Y / ☒ N/A

Prep SOP: SOP749 Rev: 4

Prep Analyst: Lucas A. Daut LAD

Balance: N/A

Prep Date: 6/15/2017

Balance: N/A

Matrix Class: liquid

Prep Dept: RS

Samp Num	Prep Num	LabID	QC Type	Dish No.	Init Alq ml	Fin Alq ml	Prep Basis	Ingrowth Date/Time	Decay Date/Time	Standards	Prep Notes
1	1	1718016-1	SMP	N/A	1500	1496.002	Unfiltered	06/16/17 17:00	06/19/17 07:05	T1.S1	
2	1	1718016-2	SMP		1500	1496.002	Unfiltered	06/16/17 17:00	06/19/17 07:05	T1.S1	
3	1	1718016-3	SMP		1500	1496.002	Unfiltered	06/16/17 17:00	06/19/17 07:05	T1.S1	
4	1	1718016-4	SMP		1500	1496.002	Unfiltered	06/16/17 17:00	06/19/17 07:05	T1.S1	
5	1	1718016-5	SMP		1500	1496.002	Unfiltered	06/16/17 17:00	06/19/17 07:05	T1.S1	

Comments

Spiked By: Lucas A. Daut Date: 6/15/2017

Date:

Witnessed By: Andrew R. Steger Date: 6/15/2017

Date:

Tracer/Carrier Solution Information									
Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
T1	BARIIUM	418236	1/17/18	16,022.768	pCi/ml	NA	2	ml	RS031

Spike Solution Information									
Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
S1	Ra-228	784.3020.37	3/23/16	7,552.998	DPM/g	06/15/17	0.5	g	RS034

Radiochemistry Prep Worksheet

ALS -- Fort Collins

Prep Batch: RA170615-1

Prep Procedure: Ra228

Prep Batch Not Validated!!!

Reviewed By: LAD

Review Date:

Non-Routine Pre-Treatment? Y / N Batch:

Re-Prep? Y / N Batch:

Prep QASS / NCR? Y / N

Prep SOP: SOP749 Rev: 4

Prep SOP: NONE

Matrix Class: liquid

Prep Analyst: Lucas A. Daut

Prep Date: 6/15/2017

Prep Dept: RS

Balance: N/A

Balance: N/A

Samp Num	Prep Num	LabID	QC Type	Dish No.	Init Alq ml	Fin Alq ml	Prep Basis	Ingrowth Date/Time	Decay Date/Time	Standards	Prep Notes
1	1	1718016-1	SMP		1500	1496.002	Unfiltered	6/16	6/19	T1,S1	Norp
2	1	1718016-2	SMP		1500	1496.002	Unfiltered	17:06	07:05	T1,S1	
3	1	1718016-3	SMP		1500	1496.002	Unfiltered			T1,S1	
4	1	1718016-4	SMP		1500	1496.002	Unfiltered			T1,S1	
5	1	1718016-5	SMP		1500	1496.002	Unfiltered			T1,S1	

Comments

Spiked By: Lucas A. Daut Date: 6/15/2017

Date:

* Yttrium Added By:

Witnessed By: Andrew R. Steger Date: 6/15/2017

Date:

Witnessed By:

Tracer/Carrier Solution Information

Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
T1	BARIUM	418236		16,022.768	pCi/ml	NA	2	ml	RS031

Spike Solution Information

Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
S1	Ra-228	784.3020.37		7,552.998	DPM/g	06/15/17	0.5	g	RS034

Radiochemistry ICP Worksheet

ALS -- Fort Collins

Prep Batch: RA170615-1

Prep Procedure: Ra228

Reviewed By: Iad LAD

Review Date: 6/19/2017

BARIUM Recovery Results

Reference Carrier

LabID	QC Type	Car Vol	Ref Carr Dil Vol	Ref Carr ICP Alq	Ref Carr ICP Dil Vol	Ref Carr ICP Run	Ref Carr ICP Conc
RA170615-1	CAR	2	27	0.05	10.05	IR170616-2A1	5.898432

Samples

Prep Num	LabID	QC Type	Init Samp Alq (ml)	Car Vol (ml)	Samp Dil Vol (ml)	Init ICP Alq (ml)	Init ICP Dil Vol (ml)	Pre- Con Vol (ml)	Post Con Vol (ml)	Pre- Sep Vol (ml)	Post Sep Vol (ml)	Fin ICP Alq (ml)	Fin ICP Dil Vol (ml)	Initial ICP Run	Final ICP Run	Init ICP Conc (ug/ml)	Fin ICP Conc (ug/ml)	Init Samp Mass (ug)	Ref Mass (ug)	Flag	Fin Samp Mass (ug)	% Yield	Final Sample Alq
1	1718016-1	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170616-2A1	IR170616-2A1	-0.0003	6.272993	0	32010.79	Z	31521.79	98.47%	1496
1	1718016-2	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170616-2A1	IR170616-2A1	0.06616	6.105323	991.7684	32010.79		30679.25	92.96%	1496
1	1718016-3	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170616-2A1	IR170616-2A1	0.09805	6.286881	1469.783	32010.79		31591.58	94.36%	1496
1	1718016-4	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170616-2A1	IR170616-2A1	0.00095	6.337784	14.29576	32010.79		31847.36	99.45%	1496
1	1718016-5	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170616-2A1	IR170616-2A1	-0.0011	6.307981	0	32010.79	Z	31697.6	99.02%	1496

Sample Id1	Ca	Fe	K	Mg	Na	Sr	Mn	S	Al	Ba	Pb	Ni
CCV	50.1627	20.0214	50.4050	50.1827	49.1171	0.5053	1.0018	4.9726	50.4533	1.0028	0.9822	1.0083
CCB	0.0121	0.0074	0.0354	0.0154	0.0394	0.0002	0.0002	0.0000	0.0078	0.0008	0.0028	0.0007
I 1718016-1	-0.1052	-0.0075	-0.0529	-0.0689	-0.4648	-0.0020	-0.0014	-0.0365	-0.0561	-0.0003	0.0084	0.0000
I 1718016-2	12.3449	0.0132	-0.0618	-0.0592	-0.4595	0.0035	-0.0008	-0.0182	-0.0496	0.0662	0.0039	-0.0003
I 1718016-3	11.9360	0.0215	-0.0927	-0.0711	-0.4650	0.0035	-0.0009	-0.0182	-0.0385	0.0981	0.0025	-0.0011
I 1718016-4	0.1444	-0.0038	-0.0797	-0.0700	-0.4919	-0.0020	-0.0015	-0.0319	-0.0509	0.0010	-0.0001	-0.0013
I 1718016-5	-0.1068	-0.0009	-0.0752	-0.0729	-0.4911	-0.0021	-0.0015	-0.0411	-0.0476	-0.0011	-0.0001	-0.0002
F 1718016-1	-0.0999	-0.0096	-0.0598	-0.0598	87.1920	-0.0015	-0.0014	1.5693	-0.0477	6.2730	0.0550	0.0000
F 1718016-2	-0.1042	-0.0088	-0.0638	-0.0723	86.3241	-0.0014	-0.0014	1.4781	-0.0457	6.1053	0.0382	0.0002
F 1718016-3	-0.1045	-0.0134	-0.0793	-0.0791	86.9998	-0.0015	-0.0015	1.5602	-0.0437	6.2869	0.0435	-0.0021
F 1718016-4	-0.1058	-0.0126	-0.0740	-0.0803	86.5104	-0.0015	-0.0017	1.5648	-0.0542	6.3378	0.0474	-0.0012
F 1718016-5	-0.1032	-0.0129	-0.0598	-0.0746	86.2083	-0.0014	-0.0017	1.5648	-0.0470	6.3080	0.0560	-0.0018
RA170615-1RC	-0.1032	-0.0097	-0.0667	-0.0763	80.7188	-0.0010	-0.0015	0.0046	-0.0542	5.8984	0.0030	-0.0002
CCV	49.7949	19.8872	50.1529	49.8850	49.3913	0.5013	0.9950	4.9863	50.1172	0.9971	0.9879	1.0063
CCB	0.0189	0.0100	0.0382	0.0131	0.0394	0.0001	0.0001	0.0137	0.0235	0.0008	0.0038	-0.0005

Date 6/19/17SOP 724r 12

ALS
Low Background Gas Flow Proportional Counter Log
Instrument: LB4100C

Instrument Daily Response and Background Checks

Det.	Daily Response Check				Background Check				Det. Status
	Start 1	Status	Start 2	Status	Start 1	Status	Start 2	Status	
1	JP	P			JP	P			P
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16	✓	✓			✓	(HBR)			OLB

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

Weekly Background Calibration

	Current Calib. File ID	Weekly Calib. Started	Status	File ID
Dr A	BKCOL67W			
Dr B				
Dr C				
Dr D				

Dr = Drawer

Gas Supply

P-10 Supply		P-10 Flow	
Tank 1	2250	Dr A	10
		Dr B	
Tank 2	1050	Dr C	
		Dr D	✓

Comments:

Date 6/19/17SOP 724r 12ALS
Low Background Gas Flow Proportional Counter Log
Instrument: LB4100C

Det.	Sample ID	Batch	Test	Count Dur. (min)	Start Time	Analyst Initials	File ID	Output Initials
1-16	Daily Eff	==	==	30	6:42	JP	EFC0619	JP
1-16	Daily Bkg	==	==	60	6:53	JP	BKC0619	JP
1	17180616-1	RA170615-1	Ra228	8	8:08	JP	RAC0619	JP
1	-2	↓	EffCal	↓	8:16	JP	A	JP
1	-3	↓	Outlier	↓	8:26	JP	B	JP
1	-4	↓	↓	↓	8:34	JP	C	JP
1	-5	↓	↓	↓	8:43	JP	D	JP
1-4	1080	RA170615-1	Ra228	30	9:51	JP	ERA0619A	JP
5-8	↓	↓	EffCal	↓	9:03	JP	B	JP
9-12	↓	↓	↓	↓	9:11	JP	C	JP
13-16	↓	↓	↓	↓	9:20	JP	D	JP
1	1706344-1	AB170616-1	2B	10	9:37	JMB	ABC0619	JMB
2	2	↓	↓	↓	↓	↓	↓	↓
3	3	↓	↓	↓	↓	↓	↓	↓
4	4	↓	↓	↓	↓	↓	↓	↓
5	5	↓	↓	↓	↓	↓	↓	↓
6	6	↓	↓	↓	↓	↓	↓	↓
7	7	↓	↓	↓	↓	↓	↓	↓
8	8	↓	↓	↓	↓	↓	↓	↓
9	9	↓	↓	↓	↓	↓	↓	↓
10	10	↓	↓	↓	↓	↓	↓	↓
11	11	↓	↓	↓	↓	↓	↓	↓
12	12	↓	↓	↓	↓	↓	↓	↓
13	13	↓	↓	↓	↓	↓	↓	↓
14	14	↓	↓	↓	↓	↓	↓	↓
15	15	↓	↓	↓	↓	↓	↓	↓
1	70	↓	↓	↓	9:58	↓	ABC0619A	↓
2	16	↓	↓	↓	↓	↓	↓	↓
3	17	↓	↓	↓	↓	↓	↓	↓
4	18	↓	↓	↓	↓	↓	↓	↓
5	19	↓	↓	↓	↓	↓	↓	↓
6	20	↓	↓	↓	↓	↓	↓	↓
7	AB170616-1AUS	↓	↓	↓	↓	↓	↓	↓
8	BUS	↓	↓	↓	↓	↓	↓	↓
9	MB	↓	↓	↓	↓	↓	↓	↓
10	1706344-21	AB170616-2	↓	↓	↓	↓	↓	↓
11	22	↓	↓	↓	↓	↓	↓	↓
12	23	↓	↓	↓	↓	↓	↓	↓
13	24	↓	↓	↓	↓	↓	↓	↓
14	25	↓	↓	↓	↓	↓	↓	↓
15	AB170616-2MB	↓	↓	↓	↓	↓	↓	↓
1	AUS	↓	↓	↓	10:13	↓	ABC0619B	↓
2	BUS	↓	↓	↓	↓	↓	↓	↓
3	1706344-21A	↓	↓	↓	↓	↓	↓	↓
1	1706185-1	AB170617-14	↓	30	10:41	JMB	ABC0619C	↓
2	2	↓	↓	↓	↓	↓	↓	↓
3	3	↓	↓	↓	↓	↓	↓	↓

Comments:

Date 6/20/17SOP 724r 12

ALS
Low Background Gas Flow Proportional Counter Log
Instrument: LB4100C

Instrument Daily Response and Background Checks

Det.	Daily Response Check				Background Check				Det. Status
	Start 1	Status	Start 2	Status	Start 1	Status	Start 2	Status	
1	JP	P			JP	P			P
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16	✓	✓			✓	(HB)			OLB

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

Weekly Background Calibration

	Current Calib. File ID	Weekly Calib. Started	Status	File ID
Dr A	BK0607W			
Dr B	↓			
Dr C				
Dr D	✓			

Dr = Drawer

Gas Supply

P-10 Supply		P-10 Flow	
Tank 1	1950	Dr A	10
	↓	Dr B	↓
Tank 2	1050	Dr C	
	↓	Dr D	↓

Comments:

6/14/17 Cs 137 (gross Beta) Mass Attenuation Curve
Bench sheets: AB160510-2 Source: 1617003-1-18

Det	1117	1133	1146	1202	1216	1229	1273	1300	1326	1342	1360	1426	1440	1454	1509	1532	1547	1602	Filename
A1	1	17	18	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	ACS0614
D2	2	1	17	18	16	15	14	13	12	11	10	9	8	7	6	5	4	3	
A3	3	2	1	17	18	16	15	14	13	12	11	10	9	8	7	6	5	4	
A4	4	3	2	1	17	18	16	15	14	13	12	11	10	9	8	7	6	5	
B1	5	4	3	2	1	17	18	16	15	14	13	12	11	10	9	8	7	6	
B2	6	5	4	3	2	1	17	18	16	15	14	13	12	11	10	9	8	7	
B3	7	6	5	4	3	2	1	17	18	16	15	14	13	12	11	10	9	8	
B4	8	7	6	5	4	3	2	1	17	18	16	15	14	13	12	11	10	9	
C1	9	8	7	6	5	4	3	2	1	17	18	16	15	14	13	12	11	10	
C2	10	9	8	7	6	5	4	3	2	1	17	18	16	15	14	13	12	11	
C3	11	10	9	8	7	6	5	4	3	2	1	17	18	16	15	14	13	12	
C4	12	11	10	9	8	7	6	5	4	3	2	1	17	18	16	15	14	13	
D1	13	12	11	10	9	8	7	6	5	4	3	2	1	17	18	16	15	14	
D2	14	13	12	11	10	9	8	7	6	5	4	3	2	1	17	18	16	15	
D3	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	17	18	16	
D4	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	17	18	

6/19/17 → Ra228 Efficiency Calibration
Bench sheet: RA170615-1 Source ID: 1080
Log File: Ra228-06/17

Sources

1718016-1
↓
-3
-4
-5

Detectors

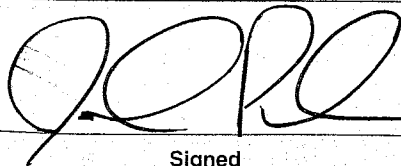
A1 B1 C1 D1
A2 B2 C2 D2
A3 B3 C3 D3
A4 B4 C4 D4

File names

ERA0619A
↓
B
C
D

Continued on Page

Read and Understood By



Signed

6/19/17

Date



Signed

6/20/17

Date
83 of 117

OUTLIER TEST

FILE	DET	SAMPLE ID	Beta CPM	Relative % diff. from mean	Within acceptability range	Outlier?	Half-life (days)	Separation Date & Time	Count Date & Time	Decay Factor	Chemical Yield	CPM Corrected
RAC0619	A1(1)	1718016-1	1594.625	2.52%	YES	NO	0.2554	6/19/2017 7:05	6/19/2017 8:08	0.8880	0.9847	1823.55
RAC0619A	A1(1)	1718016-2	1580.625	3.91%	YES	OUTLIER	0.2554	6/19/2017 7:05	6/19/2017 8:16	0.8748	0.9296	1943.76
RAC0619B	A1(1)	1718016-3	1522.000	0.45%	YES	NO	0.2554	6/19/2017 7:05	6/19/2017 8:26	0.8584	0.9436	1878.98
RAC0619C	A1(1)	1718016-4	1562.250	0.69%	YES	NO	0.2554	6/19/2017 7:05	6/19/2017 8:34	0.8456	0.9945	1857.76
RAC0619D	A1(1)	1718016-5	1522.250	1.15%	YES	NO	0.2554	6/19/2017 7:05	6/19/2017 8:43	0.8314	0.9902	1849.15

Mean of all five plachnets:

Average= 1870.64
Std dev= 45.447438
2 Std Dev= 90.89

Acceptability range

1961.53
1779.75

Relative range

+/- 4.86%

0.048590254

Sample 1718016-2 rejected as outlier.

Criteria: Potential outliers fall outside acceptability range; which is the mean of all five measurements +/- 2 std dev per the Grubbs statistical test.

OK JP 6/19/17

Alpha Attenuation Calibration	Beta Attenuation Calibration
$y = b'm/(a'(m+ x))$ α = 0.90300 β = 0.99110 γ = 0.9270 δ = 21.4875	$y = b''m'/(a''(m'+ x))$ α' = 0.9881 β' = 0.9996 γ' = 0.9174 δ' = 0.0000
$y = b'm''/(a''(m''+ x))$ α'' = 0.9511 β'' = 0.9894 γ'' = 0.9511 δ'' = 0.0036	$y = b'''m'''/(a'''(m''' + x))$ α''' = 0.9511 β''' = 0.9894 γ''' = 0.9511 δ''' = 0.0036

Alpha Attenuation Calibration	Beta Attenuation Calibration
$y = b'm/(a'(m+ x))$ α = 0.90300 β = 0.99110 γ = 0.9270 δ = 21.4875	$y = b''m'/(a''(m'+ x))$ α' = 0.9881 β' = 0.9996 γ' = 0.9174 δ' = 0.0000
$y = b'm''/(a''(m''+ x))$ α'' = 0.9511 β'' = 0.9894 γ'' = 0.9511 δ'' = 0.0036	$y = b'''m'''/(a'''(m''' + x))$ α''' = 0.9511 β''' = 0.9894 γ''' = 0.9511 δ''' = 0.0036

Det. ID	Sample ID	Count End Date & Time	Count Dur. (min)	Resid. Mass (mg)	Alpha Activity												Beta Activity											
					Gross			Bkg. b>a xtlk			Base			Progeny			Gross			Bkg. a>b xtlk			Base			Progeny		
					CPM	Eff	Cor.Fact.	CPM	Eff	Cor.Fact.	CPM	Eff	Cor.Fact.	CPM	Eff	Cor.Fact.	CPM	Eff	Cor.Fact.	CPM	Eff	Cor.Fact.	CPM	Eff	Cor.Fact.	CPM	Eff	Cor.Fact.
A1	1718016-1	6/19/2017 8:16	8.00	0.0	16.625	0.078	5.735	0.2138	1.058	n/a	n/a	1594.825	1.436	0.4904	0.988	n/a	n/a											

TP 6/6/17

PAI - Gas Flow Proportional Sample Analysis LB4100-C

Unit Type: LB4100-C
Counting Unit ID: Magenta
High Voltage Mode: Simultaneous
Application Revision: Standard
Rev.12/01/08 JCP

Data file name: RAC0619A
Batch ID: RA170615-1
Count Preset (m): 8
Batch Ended: 6/19/2017 8:25

Background logfile: BKGABW
Date of Bkg. Cal: 6/8/2017
Alpha efficiency logfile: Am241R-06/15
Alpha prog. logfile: n/a
Alpha attenuation calibration: AAM0606, 0607
Alpha prog. attenuation: n/a
Beta efficiency logfile: RA228-06/15
Beta prog. logfile: n/a
Beta attenuation calibration: ASR0607
Beta prog. attenuation: n/a

Alpha Attenuation Calibration $y = b'm^a(e^{(mass \times 0)})$	Beta Attenuation Calibration $y = b'm^a(e^{(mass \times 0)})$
Alpha b= 0.90300 m= 0.99110 a= 0.8270 x0= 21.4875	Beta b= 0.9681 m= 0.9996 a= 0.9174 x0= 0.0000
Alpha to Beta X-talk $y = b'm^a$ a -> b xtalk b= 0.2511 b -> a xtalk m= 0.8884	Beta to Alpha X-talk $y = b'm^a + m$ b -> a xtalk b= -1.69E-05 a -> b xtalk m= 0.0036

Det. ID	Sample ID	Count End Date & Time	Count Dur. (min)	Resid. Mass (mg)	Alpha Activity						Beta Activity					
					Gross CPM	Bkg. CPM	b>a xtlk CPM	Alpha Base Eff	Alpha Cor.Fact	Progeny Eff	Progeny Cor.Fact	Gross CPM	Bkg. CPM	a>b xtlk CPM	Beta Base Eff	Beta Cor.Fact
A1	1718016-2	6/19/2017 8:25	8.00	0.0	15.875	0.078	5.685	0.2138	1.058	n/a	n/a	1580.625	1.436	3.9666	0.4904	0.968
															n/a	n/a

JP 6/19/17

PAI - Gas Flow Proportional Sample Analysis LB4100-C

Unit Type: LB4100-C
 Counting Unit ID: Magenta
 High Voltage Mode: Simultaneous
 Application Revision: Standard
 Rev.12/01/08 JCP

Background logfile: BKGABW
 Date of Bkg. Cal: 6/8/2017
 Alpha efficiency logfile: AAM0606_0607
 Alpha attenuation calibration: AAM0606_0607
 Beta efficiency logfile: RAC28-06/15
 Beta attenuation calibration: ASR0607

Data file name: RAC0619B
 Batch ID: RA170615-1
 Count Preset (m): 8
 Batch Ended: 6/19/2017 8:34

Alpha Attenuation Calibration $y = b'm^*(e^{(mass-x)})$	Beta Attenuation Calibration $y = b'm^*(e^{(mass-x)})$
Alpha b= 0.90300 m= 0.99110 a= 0.8270 x0= 21.4875	Beta b= 0.9681 m= 0.9996 a= 0.9174 x0= 0.0000
Alpha to Beta X-talk $y = b'm^*mass$	Beta to Alpha X-talk $y = b'm^*mass$
a->b xtalk b= 0.2511 a->b xtalk m= 0.9984	Beta to Alpha X-talk $y = b'm^*mass$ b->a xtalk b= -1.69E-05 b->a xtalk m= 0.0036

Det. ID	Sample ID	Count End Date & Time	Count Dur. (min)	Resid. Mass (mg)	Alpha Activity						Beta Activity					
					Gross CPM	Bkg. CPM	b>a xtlk CPM	Base Eff	Cor.Fact.	Progeny Eff	Gross CPM	Bkg. CPM	a>b xtlk CPM	Base Eff	Cor.Fact.	Progeny Eff
A1	1718015-3	6/19/2017 8:34	8.00	0.0	13.375	0.078	5.474	0.2138	1.058	n/a	1522.000	1.436	3.3389	0.4904	0.968	n/a

JP 6/19/17

2
 3
 4
 5
 6
 7
 8
 9
 10
 11
 12
 13
 14
 15
 16
 17
 18
 19
 20
 21
 22
 23
 24
 25
 26
 27
 28
 29
 30
 31
 32
 33
 34
 35
 36
 37
 38
 39
 40
 41
 42
 43
 44
 45
 46
 47
 48
 49
 50
 51
 52
 53
 54
 55
 56
 57
 58
 59
 60
 61
 62
 63
 64
 65
 66
 67
 68
 69
 70
 71
 72
 73
 74
 75
 76
 77
 78
 79
 80
 81
 82
 83
 84
 85
 86
 87
 88
 89
 90
 91
 92
 93
 94
 95
 96
 97
 98
 99
 100
 101
 102
 103
 104
 105
 106
 107
 108
 109
 110
 111
 112
 113
 114
 115
 116
 117
 118
 119
 120
 121
 122
 123
 124
 125
 126
 127
 128
 129
 130
 131
 132
 133
 134
 135
 136
 137
 138
 139
 140
 141
 142
 143
 144
 145
 146
 147
 148
 149
 150
 151
 152
 153
 154
 155
 156
 157
 158
 159
 160
 161
 162
 163
 164
 165
 166
 167
 168
 169
 170
 171
 172
 173
 174
 175
 176
 177
 178
 179
 180
 181
 182
 183
 184
 185
 186
 187
 188
 189
 190
 191
 192
 193
 194
 195
 196
 197
 198
 199
 200
 201
 202
 203
 204
 205
 206
 207
 208
 209
 210
 211
 212
 213
 214
 215
 216
 217
 218
 219
 220
 221
 222
 223
 224
 225
 226
 227
 228
 229
 230
 231
 232
 233
 234
 235
 236
 237
 238
 239
 240
 241
 242
 243
 244
 245
 246
 247
 248
 249
 250
 251
 252
 253
 254
 255
 256
 257
 258
 259
 260
 261
 262
 263
 264
 265
 266
 267
 268
 269
 270
 271
 272
 273
 274
 275
 276
 277
 278
 279
 280
 281
 282
 283
 284
 285
 286
 287
 288
 289
 290
 291
 292
 293
 294
 295
 296
 297
 298
 299
 300
 301
 302
 303
 304
 305
 306
 307
 308
 309
 310
 311
 312
 313
 314
 315
 316
 317
 318
 319
 320
 321
 322
 323
 324
 325
 326
 327
 328
 329
 330
 331
 332
 333
 334
 335
 336
 337
 338
 339
 340
 341
 342
 343
 344
 345
 346
 347
 348
 349
 350
 351
 352
 353
 354
 355
 356
 357
 358
 359
 360
 361
 362
 363
 364
 365
 366
 367
 368
 369
 370
 371
 372
 373
 374
 375
 376
 377
 378
 379
 380
 381
 382
 383
 384
 385
 386
 387
 388
 389
 390
 391
 392
 393
 394
 395
 396
 397
 398
 399
 400
 401
 402
 403
 404
 405
 406
 407
 408
 409
 410
 411
 412
 413
 414
 415
 416
 417
 418
 419
 420
 421
 422
 423
 424
 425
 426
 427
 428
 429
 430
 431
 432
 433
 434
 435
 436
 437
 438
 439
 440
 441
 442
 443
 444
 445
 446
 447
 448
 449
 450
 451
 452
 453
 454
 455
 456
 457
 458
 459
 460
 461
 462
 463
 464
 465
 466
 467
 468
 469
 470
 471
 472
 473
 474
 475
 476
 477
 478
 479
 480
 481
 482
 483
 484
 485
 486
 487
 488
 489
 490
 491
 492
 493
 494
 495
 496
 497
 498
 499
 500
 501
 502
 503
 504
 505
 506
 507
 508
 509
 510
 511
 512
 513
 514
 515
 516
 517
 518
 519
 520
 521
 522
 523
 524
 525
 526

Background logfile: BKGABW
Date of Bkg. Cal: 6/8/2017
Alpha efficiency logfile: Am241R-06
Alpha attenuation calibration: AAM0606,
Beta efficiency logfile: RA228-06/
Beta attenuation calibration: ASR0607

Alpha Attenuation Calibration	Beta Attenuation Calibration
$y = b^*m^*(e^{(mass \cdot x)})$ $\alpha = 0.903000$ $\alpha > \alpha \text{ xtal} = b$ $\alpha > \alpha \text{ xtal} = m$ $\alpha > \alpha \text{ xtal} = e$	$y = b^*m^*(e^{(mass \cdot x)})$ $\beta = 0.9981$ $\beta = 0.9996$ $\beta = 0.9814$ $\beta = 0.0000$
$y = b^*m^{\text{-}mass}$ $\alpha = 0.2511$ $\alpha > \alpha \text{ xtal} = b$ $\alpha > \alpha \text{ xtal} = m$ $\alpha > \alpha \text{ xtal} = e$	$y = b^*m^{\text{-}mass}$ $\beta = -1.689E-05$ $\beta > \beta \text{ xtal} = b$ $\beta > \beta \text{ xtal} = m$ $\beta > \beta \text{ xtal} = e$

Det. ID	Sample ID	Count End Date & Time	Count (min)	Resid. Mass (mg)	Alpha Activity										Beta Activity				
					Gross					Base					Progeny				
					Bkg. CPM	b>a xlik CPM	Eff	Cor.Fact	Progeny Eff	Bkg. CPM	b>a xlik CPM	Eff	Cor.Fact	Progeny CPM	a>b xlik CPM	Base CPM	Eff	Cor.Fact	Progeny Eff
A1	1718016-4	6/19/2017 8:43	8.00	0.0	14.625	0.078	5.619	0.2138	1.058	n/a	n/a	1582.250	1.436	3.8528	0.4904	0.968	n/a	n/a	

Dr C. J. C.

Alpha Attenuation Calibration $y = b'm^a(e^{(mass-x)})$	Beta Attenuation Calibration $y = b'm^a(e^{(mass-x)})$
Alpha b= m= a= x0= Alpha to Beta X-talk $y = b'm^a \cdot mass$	Beta b= m= a= x0= Beta to Alpha X-talk $y = b'm^a \cdot mass$
0.90300 0.99110 0.8270 21.4875 0.2511 0.9984	0.9651 0.9996 0.9174 0.0000 -1.69E-05 0.0036

Background logfile: BKGABW
Date of Bkg. Cal: 6/8/2017
Alpha efficiency logfile: Am241R-06/15
Alpha attenuation calibration: AAM0606_0607Alpha prog. logfile: n/a
Beta efficiency logfile: RA228-06/15
Beta attenuation calibration: ASH0607
Beta prog. logfile: n/a

Unit Type: LB4100-C
Counting Unit ID: Magenta
High Voltage Mode: Simultaneous
Application Revision: Standard
Rev. 12/01/08 JCP
Data file name: RAC0619D
Batch ID: RA170615-1
Count Preset (m): 8
Batch Ended: 6/19/2017 8:51

Det. ID	Sample ID	Count End Date & Time	Count Dur. (min)	Resid. Mass (mg)	Alpha Activity					Beta Activity				
					Gross CPM	Bkg. CPM	b>a xtlk CPM	Base Eff	Progeny Eff	Base Cor.Fact.	Gross CPM	Bkg. CPM	a>b xtlk CPM	Base Cor.Fact.
A1	1718016-5	6/19/2017 8:51	8.00	0.0	14.125	0.078	5.475	0.2138	1.058	n/a	1522.250	1.436	3.5272	0.4904
										n/a				n/a

TP 6/19/17

Date 6/19/17SOP 724r 12

ALS
Low Background Gas Flow Proportional Counter Log
Instrument: LB4100C

Instrument Daily Response and Background Checks

Det.	Daily Response Check				Background Check				Det. Status
	Start 1	Status	Start 2	Status	Start 1	Status	Start 2	Status	
1	JP	P			JP	P			P
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16	✓	✓			✓	(CHB)			OLB

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

Weekly Background Calibration

	Current Calib. File ID	Weekly Calib. Started	Status	File ID
Dr A	BK0607W			
Dr B				
Dr C				
Dr D	✓			

Dr = Drawer

Gas Supply

P-10 Supply		P-10 Flow	
Tank 1	2250	Dr A	10
		Dr B	
Tank 2	1050	Dr C	
		Dr D	✓

Comments:

Date 6/19/17SOP 724r 12ALS
Low Background Gas Flow Proportional Counter Log
Instrument: **LB4100C**

Det.	Sample ID	Batch	Test	Count Dur. (min)	Start Time	Analyst Initials	File ID	Output Initials
1-16	Daily EFP	—	—	30	6:42	JP	EFC0619	JP
1-16	Daily Bkg	—	—	60	6:53	JP	BKC0619	JP
1	1718016-1	RA170615-1	Ra228	8	8:08	JP	RAC0619	JP
1	↓ -2	↓	EFCal	↓	8:16	JP	↓ A	JP
1	↓ -3	↓	CvH1er	↓	8:26	JP	↓ B	JP
1	↓ -4	↓	↓	↓	8:34	JP	↓ C	JP
1	↓ -5	↓	↓	↓	8:43	JP	↓ D	JP
1-4	1080	RA170615-1	Ra228	30	9:54	JP	ERA0619A	JP
5-8	↓	↓	EFCal	↓	9:03	JP	↓ B	JP
9-12	↓	↓	↓	↓	9:11	JP	↓ C	JP
13-16	↓	↓	↓	↓	9:20	JP	↓ D	JP
1	1706344-1	AB170616-1	AB	10	9:37	JP	ABC0619	JP
2	2	↓	↓	↓	↓	↓	↓	↓
3	3	↓	↓	↓	↓	↓	↓	↓
4	4	↓	↓	↓	↓	↓	↓	↓
5	5	↓	↓	↓	↓	↓	↓	↓
6	6	↓	↓	↓	↓	↓	↓	↓
7	7	↓	↓	↓	↓	↓	↓	↓
8	8	↓	↓	↓	↓	↓	↓	↓
9	9	↓	↓	↓	↓	↓	↓	↓
10	10	↓	↓	↓	↓	↓	↓	↓
11	11	↓	↓	↓	↓	↓	↓	↓
12	12	↓	↓	↓	↓	↓	↓	↓
13	13	↓	↓	↓	↓	↓	↓	↓
14	14	↓	↓	↓	↓	↓	↓	↓
15	15	↓	↓	↓	↓	↓	↓	↓
1	70	↓	↓	↓	9:58	↓	ABC0619A	↓
2	16	↓	↓	↓	↓	↓	↓	↓
3	17	↓	↓	↓	↓	↓	↓	↓
4	18	↓	↓	↓	↓	↓	↓	↓
5	19	↓	↓	↓	↓	↓	↓	↓
6	20	↓	↓	↓	↓	↓	↓	↓
7	AB170616-1AUS	↓	↓	↓	↓	↓	↓	↓
8	BLUS	↓	↓	↓	↓	↓	↓	↓
9	MS	↓	↓	↓	↓	↓	↓	↓
10	1706344-21	AB170616-2	↓	↓	↓	↓	↓	↓
11	22	↓	↓	↓	↓	↓	↓	↓
12	23	↓	↓	↓	↓	↓	↓	↓
13	24	↓	↓	↓	↓	↓	↓	↓
14	25	↓	↓	↓	↓	↓	↓	↓
15	AB170616-2MB	↓	↓	↓	↓	↓	↓	↓
1	ALUS	↓	↓	↓	10:13	↓	ABC0619B	↓
2	BLUS	↓	↓	↓	↓	↓	↓	↓
3	1706344-21A	↓	↓	↓	↓	↓	↓	↓
1	1706185-1	AB170616-14	↓	30	10:41	JP	ABC0619C	↓
2	2	↓	↓	↓	↓	↓	↓	↓
3	3	↓	↓	↓	↓	↓	↓	↓

Comments:

Page No.: 473504

B

(cont. from page NA)

B)

Form 780r8.doc (6/23/06)

Reviewed By / Date

JPB 6/19/17

91 of 117

Date 6/20/17SOP 724r 12

ALS
Low Background Gas Flow Proportional Counter Log
Instrument: LB4100C

Instrument Daily Response and Background Checks

Det.	Daily Response Check				Background Check				Det. Status
	Start 1	Status	Start 2	Status	Start 1	Status	Start 2	Status	
1	JP	P			JP	P			P
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16	✓	✓			✓	(HB)			NB

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

Weekly Background Calibration

	Current Calib. File ID	Weekly Calib. Started	Status	File ID
Dr A	BK0607W			
Dr B				
Dr C				
Dr D	✓			

Dr = Drawer

Gas Supply

P-10 Supply		P-10 Flow	
Tank 1	1950	Dr A	10
	✓	Dr B	✓
Tank 2	1050	Dr C	
	✓	Dr D	✓

Comments:

Radiochemistry Instrument Worksheet

ALS -- Fort Collins

Prep Batch: RA170615-1

Prep Procedure: Ra228

Outlier

Analytical QASS / NCR? Y

WA

Prep Num	LabID	QC Type	Init Alq	Fin Alq	Units	Report Units	Residual Mass (mg)	Cnt 1 File	Cnt 1 Inst/Det	Cnt 1 Pos Chk By	Cnt 2 File	Cnt 2 Inst/Det	Cnt 2 Pos Chk By	Cnt 3 File	Cnt 3 Inst/Det	Cnt 3 Pos Chk By	Notes
1	1718016-1	SMP	1500	1496.0	ml	pCi/l		RA00619	1	JP							JP6/19/17
1	1718016-2	SMP	1500	1496.0	ml	pCi/l		A	1	JP							Outlier
1	1718016-3	SMP	1500	1496.0	ml	pCi/l		B	1	JP							
1	1718016-4	SMP	1500	1496.0	ml	pCi/l		C	1	JP							
1	1718016-5	SMP	1500	1496.0	ml	pCi/l		D	1	JP							JP6/19/17

Tracer/Carrier Solution Information

Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
T1	BARIUM	418236	1/19/18	16,022.768	pCi/ml	NA	2	ml	RS031

Spike Solution Information

Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
S1	Ra-228	784.3020.37	5/23/18	7.552.998	DPM/g	06/15/17	0.5	g	RS034

Sample Barcodes

1718016-1 RA170615-1PS1		1718016-2 RA170615-1PS2	
1718016-4 RA170615-1PS4		1718016-5 RA170615-1PS5	

Reporting Units

LabID	TstGrpName	RptUnits
1718016-1	Ra228_2012	pCi/l
1718016-2	Ra228_2012	pCi/l
1718016-3	Ra228_2012	pCi/l
1718016-4	Ra228_2012	pCi/l
1718016-5	Ra228_2012	pCi/l

Radiochemistry Prep Worksheet

ALS -- Fort Collins

Prep Batch: RA170615-1

Prep Procedure: Ra228

Reviewed By: lad LAD Review Date: 6/19/2017

Non-Routine Pre-Treatment? Y / ☒ Batch: NA Re-Prep? Y / ☒ Batch: NA Prep QASS / NCR? Y / ☒ NA

Prep SOP: SOP749 Rev: 4
Prep SOP: NONE
Matrix Class: liquid

Prep Analyst: Lucas A. Daut LAD
Prep Date: 6/15/2017
Prep Dept: RS
Balance: N/A
Balance: N/A

Samp Num	Prep Num	LabID	QC Type	Dish No.	Init Aliq ml	Fin Aliq ml	Prep Basis	Ingrowth Date/Time	Decay Date/Time	Standards	Prep Notes
1	1	1718016-1	SMP	NA	1500	1496.002	Unfiltered	06/16/17 17:00	06/19/17 07:05	T1, S1	
2	1	1718016-2	SMP		1500	1496.002	Unfiltered	06/16/17 17:00	06/19/17 07:05	T1, S1	
3	1	1718016-3	SMP		1500	1496.002	Unfiltered	06/16/17 17:00	06/19/17 07:05	T1, S1	
4	1	1718016-4	SMP		1500	1496.002	Unfiltered	06/16/17 17:00	06/19/17 07:05	T1, S1	
5	1	1718016-5	SMP		1500	1496.002	Unfiltered	06/16/17 17:00	06/19/17 07:05	T1, S1	

Comments

Spiked By: Lucas A. Daut Date: 6/15/2017

Yttrium Added By: Date:

Witnessed By: Andrew R. Steger

Date: 6/15/2017

Witnessed By: Date:

Tracer/Carrier Solution Information

Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
T1	BARIUM	418236	1/19/18	16,022.768	pCi/ml	NA	2	ml	RS031

Spike Solution Information

Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
S1	Ra-228	784.3020.37	3/23/16	7,552.998	DPW/g	06/15/17	0.5	g	RS034

Radiochemistry Prep Worksheet

ALS -- Fort Collins

Prep Batch: RA170615-1

Prep Procedure: Ra228

Prep Batch Not Validated!!!

Reviewed By: LAD Review Date: _____

Non-Routine Pre-Treatment? Y / N Batch: _____ Re-Prep? Y / N Batch: _____ Prep QASS / NCR? Y / N _____

Prep SOP: SOP749 Rev: 4

Prep SOP: NONE

Matrix Class: liquid

Prep Analyst: Lucas A. Daut

Prep Date: 6/15/2017

Prep Dept: RS

Balance: N/A

Balance: N/A

Samp Num	Prep Num	LabID	QC Type	Dish No.	Init Alq ml	Fin Alq ml	Prep Basis	Ingrowth Date/Time	Decay Date/Time	Standards	Prep Notes
1	1	1718016-1	SMP		1500	1496.002	Unfiltered	6/16	6/19	T1,S1	None
2	1	1718016-2	SMP		1500	1496.002	Unfiltered	17:06	07:05	T1,S1	
3	1	1718016-3	SMP		1500	1496.002	Unfiltered			T1,S1	
4	1	1718016-4	SMP		1500	1496.002	Unfiltered			T1,S1	
5	1	1718016-5	SMP		1500	1496.002	Unfiltered			T1,S1	

Comments

Spiked By: Lucas A. Daut Date: 6/15/2017

Witnessed By: Andrew R. Steger Date: 6/15/2017

Yttrium Added By: _____ Date: _____

Witnessed By: _____ Date: _____

Tracer/Carrier Solution Information

Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
T1	BARIIUM	418236		16,022.768	pCi/ml	NA	2	ml	RS031

Spike Solution Information

Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
S1	Ra-228	784.3020.37		7,552.998	CPM/g	06/15/17	0.5	g	RS034

Radiochemistry ICP Worksheet

ALS -- Fort Collins

Prep Batch: RA170615-1

Prep Procedure: Ra228

Reviewed By: Iad LAD

Review Date: 6/19/2017

BARIUM Recovery Results

Reference Carrier

LabID	QC Type	Carr Vol	Ref Carr Dil Vol	Ref Carr ICP Alq	Ref Carr ICP Run	Ref Carr ICP Conc
RA170615-1	CAR	2	27	0.05	IR170616-2A1	5.898432

Samples

Prep Num	LabID	QC Type	Init Samp Alq (ml)	Car Vol (ml)	Samp Dil Vol (ml)	Init ICP Alq (ml)	Init ICP Dil Vol (ml)	Pre-Con Vol (ml)	Post-Con Vol (ml)	Pre-Sep Vol (ml)	Post-Sep Vol (ml)	Fin ICP Alq (ml)	Fin ICP Dil Vol (ml)	Initial ICP Run	Final ICP Run	Init Conc (ug/ml)	Init Samp Mass (ug)	Fin Conc (ug/ml)	Fin Samp Mass (ug)	% Yield	Final Sample Alq
1	1718016-1	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170616-2A1	IR170616-2A1	-0.0003	0	6.272993	31521.79	98.47%	1496
1	1718016-2	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170616-2A1	IR170616-2A1	0.06616	991.7684	6.105323	30679.25	92.96%	1496
1	1718016-3	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170616-2A1	IR170616-2A1	0.09805	1469.783	6.286881	31591.58	94.36%	1496
1	1718016-4	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170616-2A1	IR170616-2A1	0.00095	14.29576	6.337784	31847.36	99.45%	1496
1	1718016-5	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170616-2A1	IR170616-2A1	-0.0011	0	6.307981	31697.6	99.02%	1496

IR170616-2A1

Sample Id1	Ca	Fe	K	Mg	Na	Sr	Mn	S	Al	Ba	Pb	Ni
CCV	50.1627	20.0214	50.4050	50.1827	49.1171	0.5053	1.0018	4.9726	50.4533	1.0028	0.9822	1.0083
CCB	0.0121	0.0074	0.0354	0.0154	0.0394	0.0002	0.0002	0.0000	0.0078	0.0008	0.0028	0.0007
I 1718016-1	-0.1052	-0.0075	-0.0529	-0.0689	-0.4648	-0.0020	-0.0014	-0.0365	-0.0561	-0.0003	0.0084	0.0000
I 1718016-2	12.3449	0.0132	-0.0618	-0.0592	-0.4595	0.0035	-0.0008	-0.0182	-0.0496	0.0662	0.0039	-0.0003
I 1718016-3	11.9360	0.0215	-0.0927	-0.0711	-0.4650	0.0035	-0.0009	-0.0182	-0.0385	0.0981	0.0025	-0.0011
I 1718016-4	0.1444	-0.0038	-0.0797	-0.0700	-0.4919	-0.0020	-0.0015	-0.0319	-0.0509	0.0010	-0.0001	-0.0013
I 1718016-5	-0.1068	-0.0009	-0.0752	-0.0729	-0.4911	-0.0021	-0.0015	-0.0411	-0.0476	-0.0011	-0.0001	-0.0002
F 1718016-1	-0.0999	-0.0096	-0.0598	-0.0598	87.1920	-0.0015	-0.0014	1.5693	-0.0477	6.2730	0.0550	0.0000
F 1718016-2	-0.1042	-0.0088	-0.0638	-0.0723	86.3241	-0.0014	-0.0014	1.4781	-0.0457	6.1053	0.0382	0.0002
F 1718016-3	-0.1045	-0.0134	-0.0793	-0.0791	86.9998	-0.0015	-0.0015	1.5602	-0.0437	6.2869	0.0435	-0.0021
F 1718016-4	-0.1058	-0.0126	-0.0740	-0.0803	86.5104	-0.0015	-0.0017	1.5648	-0.0542	6.3378	0.0474	-0.0012
F 1718016-5	-0.1032	-0.0129	-0.0598	-0.0746	86.2083	-0.0014	-0.0017	1.5648	-0.0470	6.3080	0.0560	-0.0018
RA170615-1RC	-0.1032	-0.0097	-0.0667	-0.0763	80.7188	-0.0010	-0.0015	0.0046	-0.0542	5.8984	0.0030	-0.0002
CCV	49.7949	19.8872	50.1529	49.8850	49.3913	0.5013	0.9950	4.9863	50.1172	0.9971	0.9879	1.0063
CCB	0.0189	0.0100	0.0382	0.0131	0.0394	0.0001	0.0001	0.0137	0.0235	0.0008	0.0038	-0.0005

Prepare a primary dilution of (Analytical SRS 70035-307)
 RSO # 784 by diluting contents to approx 40g
 w/ 0.1 N HCl in a 40 ml VOA vial.

1) Prepare 2L 0.1 M HCl by diluting 83 ml conc. HCl, Fischer
 lot # 060506, in 2L DI water.

2) Transfer contents of ampoule to 40 ml VOA vial.
 Mass of VOA vial w/ lid = 24.9925g (Bal 12)
 vial + STD 784 = 29.7652g
 net std transferal = 4.7727g

3) Dilute w/ 0.1 ^{0.1 M HCl} M HCl
 Mass of vial (from above) = 24.9925g
 vial + std + 0.1 M HCl = 64.2671g (Bal 12)
 net mass of std = 39.2746g

4) Final Activity Calc.

$$\frac{(2.308 \times 10^4 \text{ dpm}) (60 \frac{\text{dpm}}{\text{g}}) (4.7727 \text{ g})}{(5.00994 \text{ g}) (39.2746 \text{ g})} = 33,589.8 \frac{\text{dpm}}{\text{g}}$$

Continued on Page _____

Read and Understood By



Signed

5/30/06

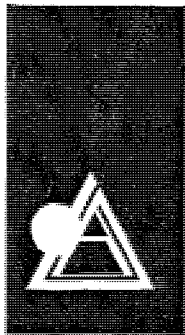
Date



Signed

8/24/06

Date



ANALYTICS

RSO # 784
Rec'd 2/2/05
JCS

1380 Seaboard Industrial Blvd.
Atlanta, Georgia 30318 • U.S.A.

Phone (404) 352-8677
Fax (404) 352-2837

CERTIFICATE OF CALIBRATION

Standard Radionuclide Source

70035-307

Ra-228 5 mL Liquid in Flame Sealed Vial

This standard radionuclide source was prepared gravimetrically from a calibrated master solution. The master solution was calibrated using a germanium gamma spectrometer system.

Radionuclide purity and calibration were checked with a germanium gamma spectrometer system. The nuclear decay rate and assay date for this source are given below.

ANALYTICS maintains traceability to the National Institute of Standards and Technology through Measurements Assurance Programs as described in USNRC Reg. Guide 4.15, Revision 1.

ISOTOPE:	Ra-228
ACTIVITY (dps):	2.308 E4
HALF-LIFE:	5.75 years
CALIBRATION DATE:	January 28, 2005 12:00 EST
RELATIVE EXPANDED UNCERTAINTY (k=2):	3.3%

Impurities: γ -impurities (other than decay products) <0.1%

5.00994 grams 0.1M HCl solution with 25 μ g/g Ba carrier.

P O NUMBER 71239, Item 2

SOURCE PREPARED BY: M. Dimitrova
M. Dimitrova, Radiochemist

Q A APPROVED: W. J. [Signature] 2-1-05

Radiochemistry Solution Report

Solution Id: 418236	Name: Ba carrier	Type: IS
Lot:	Vendor Name:	

Final Vol: 4000	Dept: RD	Prep By SDW	on	1/19/2017	Reviewed By tde	on	1/26/2017
Units: mL	Location: RS	Opened By	on		Verified By SDW	on	1/19/2017
Matrix: LIQUID	ExpireDate: 1/19/2018	Received By	on		Deactivated By	on	

Comment:

Component Name	Component ID	Volume Added	Units
Barium Stable Carrier Source<1>	3756 B07592	114.0018	g

Calibrated Primary Calibration Reference

CompName	Act/Conc	Date	1/2 Life (Yrs)	Final Act/Conc	Summed Conc	Units
BARIUM	562193.5	3/9/2017		16022.77		pCi/ml

Associated Parent IDs

3756 B07592

Abbreviations: NC = Not Calculated for reagents when the volume added is not entered.
NE = Not Entered

(Prnt) = Secular equilibrium; parent half life used to calculate concentration.

Date Printed: Thursday, March 09, 2017

ALS Environmental -- FC

Standards DB Version: 1.111

Page 1 of 1

Internal Calculation Verifications

ICBs

&

ICVs

Rad Preliminary Data Report

Laboratory Name: ALS -- Fort Collins
Analytical Run: RA170612-13A

Prep SOP: SOP749
Analytical SOP: PAI 724

Sample ID QC Type	Nuclide Type	Sample Date/Time	Prep Batch QC Batch ID	Ingrrowth Date /Time	Decay Date/Time	Matrix %Moist.	Samp Aliq Analy Aliq	Inst ID Det ID	File Name	Count Date/Time	Gross CPM Bkg CPM	Base Eff Prog Eff	CntDur(min) Yield	Activity +/- 2 s TPU	MDC Dec Lev	Report Units Report Basis	DER RPD	%Spk. Recov Flags
1718017-1 SMP	Ra-228 Trg. Analyte		RA170612-13 RA170612-13-1	6/16/2017 3:05:00 PM	6/20/2017 7:10:00 AM	Liquid NA	1500 ml 1500 ml	LB4100-C A1	RAC0620	6/20/2017 8:03 AM	10,233 1,436	48.75% NA	90 99.3%	6.6 1.6	0.5 NA	pCi/l Unfiltered	NA NA	96.1
1718017-2 SMP	Ra-228 Trg. Analyte		RA170612-13 RA170612-13-1	6/16/2017 3:05:00 PM	6/20/2017 7:10:00 AM	Liquid NA	1500 ml 1500 ml	LB4100-C B3	RAC0620	6/20/2017 8:03 AM	9,900 1,545	48.05% NA	90 97.1%	6.5 1.6	0.5 NA	pCi/l Unfiltered	NA NA	94.6
1718017-3 SMP	Ra-228 Trg. Analyte		RA170612-13 RA170612-13-1	6/16/2017 3:05:00 PM	6/20/2017 7:10:00 AM	Liquid NA	1500 ml 1500 ml	LB4100-C C3	RAC0620	6/20/2017 8:03 AM	11,678 1,640	48.03% NA	90 94.8%	8.0 1.9	0.5 NA	pCi/l Unfiltered	NA NA	116
1718017-4 SMP	Ra-228 Trg. Analyte		RA170612-13 RA170612-13-1	6/16/2017 3:05:00 PM	6/20/2017 7:10:00 AM	Liquid NA	1500 ml 1500 ml	LB4100-C D1	RAC0620	6/20/2017 8:03 AM	9,856 1,614	45.96% NA	90 97.0%	6.7 1.6	0.5 NA	pCi/l Unfiltered	NA NA	97.7
RA170612-13A MB	Ra-228 Trg. Analyte	6/12/2017 9:19:38 AM	RA170612-13 RA170612-13-1	6/16/2017 3:05:00 PM	6/20/2017 7:10:00 AM	Liquid NA	1500 ml 1500 ml	LB4100-C A3	RAC0620	6/20/2017 8:03 AM	1,767 1,510	48.51% NA	90 93.3%	0.21 0.24	0.51 NA	pCi/l Unfiltered	NA NA	U
RA170612-13B MB	Ra-228 Trg. Analyte	6/12/2017 9:19:38 AM	RA170612-13 RA170612-13-1	6/16/2017 3:05:00 PM	6/20/2017 7:10:00 AM	Liquid NA	1500 ml 1500 ml	LB4100-C B1	RAC0620	6/20/2017 8:03 AM	1,833 1,613	48.03% NA	90 97.3%	0.17 0.23	0.51 NA	pCi/l Unfiltered	NA NA	U
RA170612-13C MB	Ra-228 Trg. Analyte	6/12/2017 9:19:38 AM	RA170612-13 RA170612-13-1	6/16/2017 3:05:00 PM	6/20/2017 7:10:00 AM	Liquid NA	1500 ml 1500 ml	LB4100-C C2	RAC0620	6/20/2017 8:03 AM	2,222 1,659	47.03% NA	90 95.6%	0.45 0.28	0.53 NA	pCi/l Unfiltered	NA NA	U
RA170612-13E MB	Ra-228 Trg. Analyte	6/12/2017 9:19:38 AM	RA170612-13 RA170612-13-1	6/16/2017 3:05:00 PM	6/20/2017 7:10:00 AM	Liquid NA	1500 ml 1500 ml	LB4100-C D3	RAC0620	6/20/2017 8:03 AM	2,011 1,665	47.02% NA	90 95.5%	0.28 0.26	0.53 NA	pCi/l Unfiltered	NA NA	U

Control Limits => 70-130%

Comments:

Qualifiers/Flags:

- U - Result is less than the sample specific MDC.
- Y1 - Chemical Yield is in control at 100-110%. Quantitative yield is assumed.
- Y2 - Chemical Yield outside default limits.
- W - DER is greater than Warning Limit of 1.42
- D - DER is greater than Control Limit of 2.13
- + - Duplicate RPD not within limits.
- LT - Result is less than Request MDC, greater than sample specific MDC
- * - Aliquot Basis is 'As Received' while the Report Basis is 'Dry Weight'.
- * - Aliquot Basis is 'Dry Weight' while the Report Basis is 'As Received'.

M - Requested MDC not met.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

L - LCS Recovery below lower control limit.

H - LCS Recovery above upper control limit.

P - LCS, Matrix Spike Recovery within control limits.

N - Matrix Spike Recovery outside control limits

NC - Not Calculated for duplicate results less than 5 times MDC

B - Analyte concentration greater than MDC.

B3 - Analyte concentration greater than MDC but less than Requested MDC.

Notes:

- The Tracer results are not yield corrected (i.e. activity measured not activity added).
- Where sample time is not available, 12:00 PM (Mountain) is used for decay correction.

Abbreviations:

TR - Tracer TA - Target Analyte
TPU - Total Propagated Uncertainty (see PAI SOP 743)
MDC - Minimum Detectable Concentration (see PAI SOP 709)
DER - Duplicate Error Ratio
BDL - Below Detection Limit

PAI - Gas Flow Proportional Sample Analysis LB4100-C

Alpha Attenuation Calibration $y = b'm^*(e^{(m-mass-x0)})$	Beta Attenuation Calibration $y = b'm^*(e^{(m-mass-x0)})$
Alpha b= m= a= x0= Alpha to Beta X-talk $y = b'm^m-mass$	Beta b= m= a= x0= Beta to Alpha X-talk $y = b'm^m+ m$
0.93000 0.99110 0.8270 21.4875	0.9681 0.9996 0.9174 0.0000
0.2511 0.8984	-1.69E-05 0.0036

Background logfile: BKGABW
Date of Bkg. Cal: 6/8/2017
Alpha efficiency logfile: Am_WIPE-06/17
Alpha attenuation calibration: AAM0606, 0607
Beta efficiency logfile: R4228-06/17
Beta attenuation calibration: ASR0607

Unit Type: LB4100 -C
Counting Unit ID: Magenta
High Voltage Mode: Simultaneous
Application Revision: Standard
Rev 12/01/06 JCP
Data file name: RAC0620
Batch ID: RA170612-13
Count Preset (m): 90
Batch Ended: 6/20/2017 9:43

Det. ID	Sample ID	Count End Date & Time	Count Dur. (min)	Resid. Mass (mg)	Alpha Activity						Beta Activity							
					Gross CPM	Bkg. CPM	b-a xtlk CPM	Base Eff	Base Cor.Fact.	Progeny Eff	Progeny Cor.Fact.	Gross CPM	Bkg. CPM	a-b xtlk CPM	Base Eff	Base Cor.Fact.	Progeny Eff	Progeny Cor.Fact.
A1	1718017-1	6/20/2017 9:42	90.00	0.0	0.444	0.078	0.032	0.2716	1.058	n/a	n/a	10.233	1.436	0.0920	0.4875	0.968	n/a	
A3	RA170612-13AMB	6/20/2017 9:42	90.00	0.0	0.289	0.096	0.001	0.2667	1.058	n/a	n/a	1.767	1.510	0.0484	0.4851	0.968	n/a	
C2	RA170612-13CMB	6/20/2017 9:43	90.00	0.0	0.300	0.112	0.002	0.2618	1.058	n/a	n/a	2.222	1.659	0.0472	0.4703	0.968	n/a	
C3	1718017-3	6/20/2017 9:43	90.00	0.0	0.422	0.096	0.036	0.2629	1.058	n/a	n/a	11.678	1.640	0.0819	0.4803	0.968	n/a	
B1	RA170612-13BMB	6/20/2017 9:43	90.00	0.0	0.222	0.091	0.001	0.2653	1.058	n/a	n/a	1.833	1.613	0.0329	0.4803	0.968	n/a	
B3	1718017-2	6/20/2017 9:43	90.00	0.0	0.278	0.084	0.030	0.2589	1.058	n/a	n/a	9.900	1.545	0.0487	0.4805	0.968	n/a	
D1	1718017-4	6/20/2017 9:43	90.00	0.0	0.433	0.095	0.030	0.2582	1.058	n/a	n/a	9.856	1.614	0.0850	0.4596	0.968	n/a	
D3	RA170612-13EMB	6/20/2017 9:43	90.00	0.0	0.289	0.171	0.001	0.2627	1.058	n/a	n/a	2.011	1.665	0.0296	0.4702	0.968	n/a	

JP 6/20/17

Date 6/20/17SOP 724r 12

ALS
Low Background Gas Flow Proportional Counter Log
Instrument: LB4100C

Instrument Daily Response and Background Checks

Det.	Daily Response Check				Background Check				Det. Status
	Start 1	Status	Start 2	Status	Start 1	Status	Start 2	Status	
1	JP	P			JP	P			P
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16	✓	✓			✓	(HB)			NUB

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

Weekly Background Calibration

	Current Calib. File ID	Weekly Calib. Started	Status	File ID
Dr A	3K0607W			
Dr B				
Dr C				
Dr D				

Dr = Drawer

Gas Supply

P-10 Supply		P-10 Flow	
Tank 1	1950	Dr A	10
		Dr B	
Tank 2	1050	Dr C	
		Dr D	

Comments:

Date 6/20/17SOP 724r 12

ALS

Low Background Gas Flow Proportional Counter Log

Instrument: LB4100C

Det.	Sample ID	Batch	Test	Count Dur. (min)	Start Time	Analyst Initials	File ID	Output Initials
1-16	Daily EFP	—	—	30	6:40	JP	EFC0620	JP
1-16	Daily Bkg	—	—	60	6:50	JP	BKC0620	JP
1	1718017-1	RA170612-13	Ra228	90	8:12	JP	RAC0620	JP
7	-2							
11	-3							
13	-4							
3	RA170612-13AMB							
5	BMB							
10	CMB							
15	EMB							
13	1706003-8	SR170604-1	5C90	120	9:52	JMS	SRC0620	JP
14	-13							
15	1706053-6							
1	1706051-3			90	10:00		SRC0620A	
2	6							
3	8							
4	11							
5	14							
6	18							
7	20							
8	1706053-8							
9	SR170604-14S							
10	USP							
11	AB170518-4US	AB170518-4	✓B	30	10:35		ABC0620	
12	AB170604-14S	AB170604-1	✓B	30	11:20	JMS	ABC0620A	
1	1706133-3	AB170609-3		240	12:02		ABC0620B	
2	-30							
3	1706157							
4	1706158-1							
5	2							
6	3							
7	1706230-1							
8	17056455-1	AB170612-1						
9	10							
10	AB170612-1							
11	1706057-1	AB170609-3		1000	12:11		ABC0620C	
12	1706156-1							
13	1706163-1							
14	AB1706093MB							
15	AB170613-3MB	AB170613-3			12:13		ABC0620D	
1	1706024-1	AB170620-2		30	16:07		ABC0620E	
2	1706025-1							
3	-1MS							
4	1706369-1							
5	-10							
6	AB170620-2MB							
7	US							

Comments:

Page No.: 473506

B

(cont. from page NA

B)

Form 780r8.doc (6/23/06)

Reviewed By / Date

JP 6/21/17 of 117

Date 6/21/17SOP 724r 12

ALS
Low Background Gas Flow Proportional Counter Log
Instrument: LB4100C

Instrument Daily Response and Background Checks

Det.	Daily Response Check				Background Check				Det. Status
	Start 1	Status	Start 2	Status	Start 1	Status	Start 2	Status	
1	JP	P			JP	P			P
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16						(H ₂ 17B)			OL

Det = Detector; α = Alpha; β = Beta; P = Pass; H = High; L = Low; OL = Offline; R = Recount; W = Weekly; NP = Not Processed

Weekly Background Calibration

	Current Calib. File ID	Weekly Calib. Started	Status	File ID
Dr A	BKCO607W			
Dr B				
Dr C				
Dr D				

Dr = Drawer

Gas Supply

P-10 Supply		P-10 Flow	
Tank 1	1600	Dr A	10
		Dr B	
Tank 2	1050	Dr C	
		Dr D	

Comments:

Page No.: 473508 **A**

Form 780r8.doc (6/23/06)

Reviewed By / Date

JP 6/21/17

106 of 117

Radiochemistry Instrument Worksheet

ALS -- Fort Collins

Prep Batch: RA170612-13

Prep Procedure: Ra228

Analytical QASS / NCR? Y *QNA*

Prep Num	LabID	QC Type	Init Alq	Fin Alq	Units	Report Units	Residual Mass (mg)	Cnt 1 Ins/Det	Cnt 1 Pos Chk By	Cnt 2 File	Cnt 2 Ins/Det	Cnt 2 Pos Chk By	Cnt 3 File	Cnt 3 Ins/Det	Cnt 3 Pos Chk By	Notes
1	1718017-1	SMP	1500	1496.0	ml	pCi/l										
1	1718017-2	SMP	1500	1496.0	ml	pCi/l										
1	1718017-3	SMP	1500	1496.0	ml	pCi/l										
1	1718017-4	SMP	1500	1496.0	ml	pCi/l										
1	RA170612-13A	MB	1500	1496.0	ml	pCi/l										
1	RA170612-13B	MB	1500	1496.0	ml	pCi/l										
1	RA170612-13C	MB	1500	1496.0	ml	pCi/l										
1	RA170612-13E	MB	1500	1496.0	ml	pCi/l										

RAC0620 1 700

JP 6/20/17

Tracer/Carrier Solution Information

Soln #	Nuclide	SolnID	Exp Date	Units	Prep Date	Aliquot	Units	Pipet ID
T1	BARIUM	418236	1/19/18	16,022.768 pCi/ml	NA	2	ml	RS031

Spike Solution Information

Soln #	Nuclide	SolnID	Exp Date	Units	Prep Date	Aliquot	Units	Pipet ID
S1	Ra-228	1014.4095.79	3/23/18	91.306 DPM/ml	06/12/17	0.25	ml	RS019

Sample Barcodes

1718017-1 RA170612-13PS1		1718017-2 RA170612-13PS2		1718017-3 RA170612-13PS3	
1718017-4 RA170612-13PS4		RA170612-13AMB RA170612-13PS5		RA170612-13BMB RA170612-13PS6	
RA170612-13CMB RA170612-13PS7		RA170612-13EMB RA170612-13PS8		RA170612-13CAR RA170612-13PS9	

Reporting Units

LabID	TstGrpName	RptUnits
1718017-1	Ra228_2012	pCi/l
1718017-2	Ra228_2012	pCi/l
1718017-3	Ra228_2012	pCi/l
1718017-4	Ra228_2012	pCi/l

Radiochemistry ICP Worksheet

ALS -- Fort Collins

Prep Batch: RA170612-13

Prep Procedure: Ra228

Reviewed By: Iad LAD Review Date: 6/20/2017

BARIUM Recovery Results

Reference Carrier

LabID	QC Type	Carr Vol	Ref Carr Dil Vol	Ref Carr ICP Alq	Ref Carr ICP Run	Ref Carr ICP Conc
RA170612-13	CAR	2	27	0.05	IR170614-2A1	6.073369

Samples

Prep Num	LabID	QC Type	Init Samp Alq (ml)	Car Vol (ml)	Samp Dil Vol (ml)	Init ICP Alq (ml)	Pre-Con Vol (ml)	Post-Con Vol (ml)	Pre-Sep Vol (ml)	Post-Sep Vol (ml)	Fin ICP Alq (ml)	Fin ICP Dil Vol (ml)	Initial ICP Run	Final ICP Run	Init Conc (ug/ml)	Fin ICP Conc (ug/ml)	Init Samp Mass (ug)	Ref Mass (ug)	Flag	Fin Samp Mass (ug)	% Yield	Final Sample Alq
1	1718017-1	SMP	1500	2	1500	1	10	1499	1499	1499	0.05	10.05	IR170614-2A1	IR170614-2A1	-0.0005	6.511771	0	32960.17	Z	32721.65	99.28%	1496
1	1718017-2	SMP	1500	2	1500	1	10	1499	1499	1499	0.05	10.05	IR170614-2A1	IR170614-2A1	-0.0009	6.369473	0	32960.17	Z	32006.6	97.11%	1496
1	1718017-3	SMP	1500	2	1500	1	10	1499	1499	1499	0.05	10.05	IR170614-2A1	IR170614-2A1	-0.0011	6.220398	0	32960.17	Z	31257.5	94.83%	1496
1	1718017-4	SMP	1500	2	1500	1	10	1499	1499	1499	0.05	10.05	IR170614-2A1	IR170614-2A1	-0.0009	6.359601	0	32960.17	Z	31956.99	96.96%	1496
1	RA170612-13A	MB	1500	2	1500	1	10	1499	1499	1499	0.05	10.05	IR170614-2A1	IR170614-2A1	-0.0012	6.120568	0	32960.17	Z	30755.85	93.31%	1496
1	RA170612-13B	MB	1500	2	1500	1	10	1499	1499	1499	0.05	10.05	IR170614-2A1	IR170614-2A1	-0.0011	6.382908	0	32960.17	Z	32074.11	97.31%	1496
1	RA170612-13C	MB	1500	2	1500	1	10	1499	1499	1499	0.05	10.05	IR170614-2A1	IR170614-2A1	-0.0012	6.268415	0	32960.17	Z	31498.79	95.57%	1496
1	RA170612-13E	MB	1500	2	1500	1	10	1499	1499	1499	0.05	10.05	IR170614-2A1	IR170614-2A1	-6E-05	6.263625	0	32960.17	Z	31474.72	95.49%	1496

Sample Id1	Ca	Fe	K	Mg	Na	Sr	Mn	S	Al	Ba	Pb	Ni
CCV	50.3317	20.1072	50.9221	50.4221	50.3459	0.5069	1.0057	5.0169	50.7250	1.0168	1.0168	1.0131
CCB	0.0255	0.0110	0.0230	0.0172	0.0490	0.0003	0.0005	-0.0042	0.0373	0.0008	0.0023	-0.0012
I 1718017-1	-0.0550	-0.0189	-0.0202	-0.0677	-0.0105	-0.0006	-0.0020	-0.0042	-0.0454	-0.0005	-0.0011	-0.0009
I 1718017-2	-0.0594	-0.0194	-0.0235	-0.0661	-0.0556	-0.0007	-0.0018	0.0000	-0.0535	-0.0009	-0.0023	-0.0010
I 1718017-3	-0.0591	-0.0177	-0.0346	-0.0634	-0.0735	-0.0008	-0.0017	0.0085	-0.0454	-0.0011	-0.0030	-0.0014
I 1718017-4	-0.0575	-0.0096	-0.0156	-0.0607	-0.0495	-0.0007	-0.0016	0.0042	0.0012	-0.0009	-0.0026	0.0003
I RA170612-13AMB	-0.0613	-0.0209	-0.0481	-0.0677	-0.0782	-0.0008	-0.0020	0.0085	-0.0491	-0.0012	-0.0024	-0.0006
I RA170612-13BMB	-0.0600	-0.0196	-0.0276	-0.0607	-0.0774	-0.0007	-0.0020	-0.0042	-0.0485	-0.0011	-0.0052	-0.0006
I RA170612-13CMB	-0.0597	-0.0197	-0.0362	-0.0634	-0.0772	-0.0007	-0.0020	0.0000	-0.0491	-0.0012	-0.0004	-0.0020
I RA170612-13DMB	-0.0594	-0.0190	-0.0366	-0.0639	-0.0791	-0.0007	-0.0018	0.0042	-0.0504	-0.0001	-0.0017	-0.0021
F 1718017-1	-0.0440	-0.0153	-0.0374	-0.0671	93.9554	0.0000	-0.0017	1.6737	-0.0435	6.5118	0.0421	-0.0007
F 1718017-2	-0.0547	-0.0172	-0.0325	-0.0682	93.2354	-0.0001	-0.0020	1.6229	-0.0404	6.3695	0.0406	-0.0012
F 1718017-3	-0.0531	-0.0192	-0.0383	-0.0703	89.8964	-0.0001	-0.0020	1.6314	-0.0423	6.2204	0.0567	-0.0012
F 1718017-4	-0.0522	-0.0193	-0.0181	-0.0618	92.1948	0.0000	-0.0020	1.6610	-0.0510	6.3596	0.0502	-0.0007
F RA170612-13AMB	-0.0563	-0.0197	-0.0457	-0.0687	88.4809	-0.0002	-0.0018	1.5381	-0.0448	6.1206	0.0405	-0.0018
F RA170612-13BMB	-0.0563	-0.0173	-0.0407	-0.0661	92.6239	-0.0001	-0.0018	1.6229	-0.0460	6.3829	0.0635	-0.0008
F RA170612-13CMB	-0.0553	-0.0192	-0.0403	-0.0693	91.7990	-0.0001	-0.0020	1.6017	-0.0435	6.2684	0.0507	-0.0002
F RA170612-13DMB	-0.0560	-0.0202	-0.0416	-0.0720	92.5634	-0.0002	-0.0020	1.5975	-0.0466	6.2636	0.0459	-0.0011
RA170612-13RC	-0.0541	-0.0191	-0.0350	-0.0677	85.9417	0.0004	-0.0018	0.0085	-0.0460	6.0734	-0.0021	-0.0011
CCV	50.0072	19.9678	50.9681	50.1015	50.4180	0.5059	0.9972	4.9831	50.7170	1.0172	0.9980	1.0148
CCB	0.0267	0.0122	0.0218	0.0295	0.0544	0.0003	0.0004	-0.0042	0.0410	0.0009	0.0020	0.0009

Radiochemistry Prep Worksheet

ALS -- Fort Collins

Prep Batch: RA170612-13

Prep Procedure: Ra228

Reviewed By: lad LAD Review Date: 6/20/2017

Non-Routine Pre-Treatment? Y / ☒ Batch: NA

Re-Prep? Y / ☒ Batch: NA

Prep QASS / NCR? Y / ☒ NA

Prep SOP: SOP749 Rev: 4

Prep SOP: NONE

Matrix Class: liquid

Prep Analyst: Lucas A. Daut LAD

Prep Date: 6/12/2017

Prep Dept: RS

Balance: N/A

Balance: N/A

Samp Num	Prep Num	LabID	QC Type	Dish No.	Init Aliq ml	Fin Aliq ml	Prep Basis	Ingrowth Date/Time	Decay Date/Time	Standards	Prep Notes
1	1	1718017-1	SMP	NA	1500	1496.002	Unfiltered	06/16/17 15:05	06/20/17 07:10	S1,T1	
2	1	1718017-2	SMP		1500	1496.002	Unfiltered	06/16/17 15:05	06/20/17 07:10	S1,T1	
3	1	1718017-3	SMP		1500	1496.002	Unfiltered	06/16/17 15:05	06/20/17 07:10	S1,T1	
4	1	1718017-4	SMP		1500	1496.002	Unfiltered	06/16/17 15:05	06/20/17 07:10	S1,T1	
5	1	RA170612-13A	MB		1500	1496.002	Unfiltered	06/16/17 15:05	06/20/17 07:10	T1	
6	1	RA170612-13B	MB		1500	1496.002	Unfiltered	06/16/17 15:05	06/20/17 07:10	T1	
7	1	RA170612-13C	MB		1500	1496.002	Unfiltered	06/16/17 15:05	06/20/17 07:10	T1	
8	1	RA170612-13E	MB		1500	1496.002	Unfiltered	06/16/17 15:05	06/20/17 07:10	T1	

Comments

ICV's and ICB's for Ra 228

Spiked By: Lucas A. Daut Date: 6/12/2017

Yttrium Added By:

Date:

Witnessed By: Andrew R. Steger

Date: 6/12/2017

Witnessed By:

Date:

Tracer/Carrier Solution Information

Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
T1	BARIUM	418236	6/19/18	16,022.768	pCi/ml	NA	2	ml	RS031

Spike Solution Information

Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
S1	Ra-228	1014.4095.79	3/23/18	91.306	DPM/ml	06/12/17	0.25	ml	RS019

Radiochemistry Prep Worksheet

ALS -- Fort Collins

Prep Batch: RA170612-13

Prep Procedure: Ra228

Prep Batch Not Validated!!!

Reviewed By: LAND Review Date:

Non-Routine Pre-Treatment? Y / N Batch: _____

Re-Prep? Y / N Batch: _____

Prep QASS / NCR? Y / N

Prep SOP: SOP749 Rev: 4

Prep SOP: NONE

Matrix Class: liquid

Prep Analyst: Lucas A. Daut

Prep Date: 6/12/2017

Prep Dept: RS

Balance: N/A

Balance: N/A

Samp Num	LabID	QC Type	Dish No.	Init Alq ml	Fin Alq ml	Prep Basis	Ingrowth Date/Time	Decay Date/Time	Standards	Prep Notes
1	1718017-1	SMP		1500	1500	Unfiltered	6/14/16 4:20		S1,T1	
2	1718017-2	SMP		1500	1500	Unfiltered	6/13/16 07:10		S1,T1	
3	1718017-3	SMP		1500	1500	Unfiltered			S1,T1	
4	1718017-4	SMP		1500	1500	Unfiltered			S1,T1	
5	RA170612-13A	MB		1500	1500	Unfiltered			T1	
6	RA170612-13B	MB		1500	1500	Unfiltered			T1	
7	RA170612-13C	MB		1500	1500	Unfiltered			T1	
8	RA170612-13D	MB		1500	1500	Unfiltered			T1	

Comments

ICV's and ICB's for Ra 228

Spiked By: at RAG Date: 6/12/2017

Yttrium Added By: _____

Date: _____

Witnessed By: _____ Date: 6/12/2017

Witnessed By: _____

Date: _____

Tracer/Carrier Solution Information

Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
T1	BARUM	418236	1/19/18	16,022.768	pCi/ml	NA	2	ml	RS031

Spike Solution Information

Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
S1	Ra-228	1014.4095.79	3/23/18	91.306	DPM/ml	06/12/17	0.25	ml	RS019

Prepare a working dilution of RSO# 1014

12/16/15

1. Density of 8% HNO₃, lot # 0006084176

Mass of 100mL vol. flask: 68.3149g

Balance # 12

Mass of flask & 100mL acid: 172.2758g

Balance# 12

Net Mass: 103.9609g

Density: 1.0396 g/mL

2. Mass of RSO# 1014 transferred:

Mass of open empty nalgene: 48.3028g

Balance# 12

Mass of nalgene & standard: 53.2851g

Balance# 12

Net mass of standard transferred: 4.9823g

Balance# NA

3. Dilute to final volume:

Mass of nalgene, standard, & diluent: 344.91g

Balance# 26

Mass of empty nalgene (from above): 48.3028g

Balance# 12

Net mass of new dilution: 296.6072g

Balance# NA

4. Final activity calculation:

$$195 \text{ Bq/g} \left(\frac{60 \text{ dpm}}{1 \text{ Bq}} \right) \left(\frac{4.9823 \text{ g}}{296.6072 \text{ g}} \right) (1.0396 \text{ g/mL}) = 204.32 \text{ dpm/mL}$$

12/16/15

JP 4/15/15

Std ID: 1014.4095.79

Description: Ra-228

Expiration: 4/9/2016

Activity: 204.32 dpm/mL

2s Uncertainty: 14.71 dpm/mL

Ref. Date: 10/7/2010

Ref Time: N/A

Prep Date: 1/16/2015 Prep by: TE

Matrix/Comp. 8% HNO₃

Half Life (y): 5.75E+00

Reverification Log		
Analysis Date	Initials	Expiration Date
4/2/2016	JP	4/02/2017
3/23/2017	JP	3/23/2018

JP 4/15/15

Continued on Page _____

7 Elett

Signed

1/16/15

Date

[Signature]

Received and Understood By

Signed

4/15/15

Date



1502
1014
National Institute of Standards & Technology

Certificate

Standard Reference Material® 4339b

Radium-228 Radioactivity Standard

This Standard Reference Material (SRM) consists of a solution of a standardized and certified quantity of radioactive radium-228 in a suitably stable and homogeneous matrix. It is intended primarily for the calibration of instruments that are used to measure radioactivity and for the monitoring of radiochemical procedures. A unit of SRM 4339b consists of approximately 5 mL of a solution, whose composition is specified in Tables 1 and 2, contained in a flame-sealed borosilicate-glass ampoule [1].

The certified radium-228 massic activity value, at a Reference Time of 1200 EST, 07 October 2010, is:

$$(195 \pm 14) \text{ Bq}\cdot\text{g}^{-1}$$

A NIST certified value, as used within the context of this certificate, is a value for which NIST has the highest confidence in its uncertainty assessment. It is a "measurement result" [2] obtained directly or indirectly from a "primary reference measurement procedure" [3]. The certified value is traceable to the derived SI unit, Becquerel (Bq).

Additional physical, chemical, and radiological properties for this SRM, as well as details on the standardization method, are given in Tables 1 and 2. Uncertainties for the certified quantities are expanded ($k=2$). The uncertainties are calculated according to the ISO and NIST Guides [4,5]. Table 3 contains a specification of the components that comprise the uncertainty analyses.

Expiration of Certification: The certification of SRM 4339b is valid indefinitely, within the measurement uncertainty specified, provided that the SRM is handled and stored properly and that no evaporation or change in composition has occurred. The solution matrix, in an unopened ampoule, is homogeneous and stable within its half-life-dependent useful lifetime provided the SRM is handled in accordance with instructions given in this certificate (see "Instructions for Handling and Storage"). Periodic recertification of this SRM is not required. The certification is nullified if the SRM is damaged, contaminated, or otherwise modified.

Maintenance of SRM Certification: NIST will monitor this SRM over the period of its certification. If substantive technical changes occur that affect the certification, NIST will notify the purchaser. Registration (see attached sheet) will facilitate notification.

Radiological and Chemical Hazard: Consult the Safety Data Sheet (SDS), enclosed with the SRM shipment, for radiological and chemical hazard information.

This SRM was prepared in the Physical Measurement Laboratory, Radiation and Biomolecular Physics Division, Radioactivity Group, M.P. Unterwiesing, Group Leader. The overall technical direction and physical measurement leading to certification and photon-emitting impurity analyses were provided by L. Pibida of the NIST Radioactivity Group, with production assistance by J. LaRosa, R. Collé, and L. Laureano-Pérez. Alpha-emitting impurity analyses were provided by J. LaRosa.

Support aspects involved in the issuance of this SRM were coordinated through the NIST Office of Reference Materials.

Lisa R. Kram, Chief
Radiation and Biomolecular Physics Division

Gaithersburg, Maryland 20899
Certificate Issue Date: 14 November 2012

Robert L. Watters, Jr., Director
Office of Reference Materials

SRM 4339b

Page 1 of 4

Table 1. Certified Massic Activity of SRM 4339b

Radionuclide	Radium-228 ^(a)
Reference time	1200 EST, 07 October 2010
Massic activity of the solution	195 Bq·g ⁻¹
Relative expanded uncertainty ($k = 2$)	7.2 % ^(b)

^(a) The final ²²⁸Ra purification from the ²³²Th mother solution was performed on 02 September 2010 0920 EST.

^(b) The uncertainties on certified values are expanded uncertainties, $U = k u_c$. The quantity u_c is the combined standard uncertainty calculated according to the ISO and NIST Guides [4,5]. The combined standard uncertainty is multiplied by a coverage factor of $k = 2$ and was chosen to obtain what is assumed to be an approximate 95 % level of confidence.

Table 2. Uncertified Information of SRM 4339b

Source description	Liquid in a flame-sealed 5 mL borosilicate-glass ampoule [1]
Solution composition	1.3 mol·L ⁻¹ HNO ₃ with 19.8 µg·g ⁻¹ Ba ⁺²
Solution density	(1.034 ± 0.002) g·mL ⁻¹ at 20.8 °C ^(a)
Solution mass	(5.180 ± 0.003) g ^(a)
Photon-emitting impurities	²²⁶ Ra: < 0.5 Bq·g ⁻¹ ^(b)
Alpha-emitting impurities	²³² Th: < 0.08 Bq·g ⁻¹ ^(c)
Half-lives used	²²⁸ Ra: (5.75 ± 0.04) a ^(d) [6] ²²⁸ Ac: (6.15 ± 0.02) h [7] ²²⁶ Ra: (1600 ± 7) a [8] ²³² Th: (14.02 ± 0.06) × 10 ⁹ a [9]
Calibration methods (and instruments)	The certified massic activity for ²²⁸ Ra was obtained by high-resolution gamma-ray spectrometry of three master solution ampoules (eleven separate determinations), as measured on three to five different spectrometers and geometries on each ampoule, and used assumed nuclear data for probabilities per decay for 16 gamma-ray transitions. Confirmatory measurements were performed by 2πα spectrometry of ingrown ²²⁸ Th with a planar, ion-implanted Si detector.

^(a) The stated uncertainty is two times the standard uncertainty. See reference 5.

^(b) Based on gamma-ray spectrometry of forced-fitted peak at 186.2 keV and assuming a probability per decay of 0.0355 [6].

^(c) The maximum ²³²Th activity concentration in ²²⁸Ra.

^(d) The stated uncertainty is the standard uncertainty. See reference 5.

Table-3. Uncertainty-Evaluation for the Massic Activity of SRM-4339b

Uncertainty component		Assessment Type ^(a)	Relative standard uncertainty contribution on massic activity of ²²⁶ Ra (%)
1	Gamma-ray spectrometry precision; relative standard deviation of the grand mean on the average massic gamma-ray emission rates for 16 measured ²²⁶ Ac gamma-ray transitions. Each mean in the grand mean is based on 11 determinations with three sources in three to five different detectors. The uncertainty in the determination of the massic gamma-ray emission rate for any one transition in a given determination ranged from typically 0.5 % to 1.5 %. The relative standard deviation of the mean for the average of the 16 lines, for any one determination, was typically 1 %; whereas the relative standard deviation of the grand mean for the average of the 16 lines across all 11 determinations is 0.34 % ^(b) . Data passes normality test.	A	0.84
2	Uncertainty due to assumed gamma-ray probabilities per decay for the measured ²²⁶ Ac transitions [7]. The uncertainty on each transition has a shared (correlated) component of 2.5 % (see comments in [7]).	B	3.5
3	Detection efficiencies not embodied within component 1	B	0.4
4	Mass determinations for dilution factors and counting source preparations	B	0.1
5	Decay corrections for ²²⁶ Ra half-life uncertainty of 0.7 % [6]	B	0.003
6	Effect of ²²⁶ Ra and ²²⁶ Ac half-life uncertainties on secular equilibrium ratio	B	0.02
Relative combined standard uncertainty			3.6
Relative expanded uncertainty ($k = 2$)			7.2

^(a) Letter A denotes evaluation by statistical methods; B denotes evaluation by other methods.

^(b) Average massic gamma-ray emission rates of 11 geometries (R_g) for 16 measured ²²⁶Ac gamma-ray transitions with their respective energy (E_γ); assumed gamma-ray probabilities per decay (I_γ) and standard deviation of the mean (S_m).

E_γ (keV)	Assumed I_γ (%) [1]	Mean R_g (s ⁻¹ g ⁻¹) ⁽ⁱ⁾	S_m (%) ⁽ⁱⁱ⁾
129.065	2.50	1347	0.38
153.967	0.754	421.6	0.40
209.249	3.97	2264	0.55
270.245	3.55	2014	0.33
328.004	3.04	1822	0.43
338.32	11.4	6712	0.43
409.46	2.02	1185	0.29
463.002	4.45	2645	0.33
755.313	1.03	593.3	0.46
772.291	1.52	899.2	0.53
794.942	4.31	2588	0.35
835.704	1.7	995.3	0.42
911.196	26.2	15609	0.29
964.786	4.99	3007	0.35
968.96	15.9	9582	0.30
1588.2	3.06	1889	0.28

(i) Grand mean for $n = 11$ determinations with three sources in three to five different detectors.

(ii) Relative standard deviation of the grand mean on R_g for $n = 11$.

INSTRUCTIONS FOR HANDLING AND STORAGE

Handling: If the ampoule is transported, it should be packed, marked, labeled, and shipped in accordance with the applicable national, international, and carrier regulations. The solution in the ampoule is a dangerous good (hazardous material) because of both the radioactivity and the strong acid. The ampoule should be opened only by persons qualified to handle both radioactive material and alkaline and/or acidic solutions. Appropriate shielding and/or distance should be used to minimize personnel exposure. Refer to SDS for further information.

Storage: SRM 4339b should be stored and used at a temperature between 5 °C and 65 °C. The ampoule (or any subsequent container) should always be clearly marked as containing radioactive material.

REFERENCES

- [1] NIST Physical Measurement Laboratory; *Storage and Handling of Radioactive Standard Reference Materials, Ampoule Specifications and Opening Procedure*, available at <http://www.nist.gov/pml/div682/grp04/srm.cfm> (accessed Nov 2012). Note: This SRM is contained in a generic borosilicate-glass ampoule and not in the standard NIST ampoule.
- [2] JCGM 200:2012; *International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM)* (2008 version with Minor Corrections), 3rd edition; Joint Committee for Guides in Metrology: BIPM, Sevres Cedex, France; p. 19 (2012); available at http://www.bipm.org/utls/common/documents/jcgm/JCGM_200_2012.pdf (accessed Nov 2012).
- [3] JCGM 200:2012; *International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM)* (2008 version with Minor Corrections), 3rd edition; Joint Committee for Guides in Metrology: BIPM, Sevres Cedex, France; p. 18 (2012); available at http://www.bipm.org/utls/common/documents/jcgm/JCGM_200_2012.pdf (accessed Nov 2012).
- [4] JCGM 100:2008; *Guide to the Expression of Uncertainty in Measurement*; (ISO GUM 1995 with Minor Corrections), Joint Committee for Guides in Metrology: BIPM, Sevres Cedex, France (2008); available at http://www.bipm.org/utls/common/documents/jcgm/JCGM_100_2008_E.pdf (accessed Nov 2012).
- [5] Taylor, B.N.; Kuyatt, C.E.; *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*; NIST Technical Note 1297, U.S. Government Printing Office: Washington, DC (1994); available at <http://physics.nist.gov/Pubs/> (accessed Nov 2012).
- [6] Luca, A.; June 2009, ²²⁸Ra. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Ra-228_tables.pdf (accessed Nov 2012).
- [7] Pearce, A.; January 2010, ²²⁸Ac. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Ac-228_tables.pdf (accessed Nov 2012).
- [8] Christé, V. and M.M. Bé; December 2006, ²²⁸Ra. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Ra-226_tables.pdf (accessed Nov 2012).
- [9] Arinc, A.; September 2008, ²³²Th. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Th-232_tables.pdf (accessed Nov 2012).

Users of this SRM should ensure that the Certificate in their possession is current. This can be accomplished by contacting the SRM Program: telephone (301) 975-2200; fax (301) 948-3730; e-mail srminfo@nist.gov; or via the Internet at <http://www.nist.gov/srm>.

Radiochemistry Solution Report

Solution Id: 418236 Name: Ba carrier Type: IS
 Vendor Name: Lot:

Final Vol: 4000 Dept: RD Prep By: SDW Reviewed By: on 1/26/2017
 Units: mL Location: RS Opened By: Verified By: SDW on 1/19/2017
 Matrix: LIQUID ExpireDate: 1/19/2018 Received By: Deactivated By: on

Comment:

Component Name	Component ID	Volume Added	Units
Barium Stable Carrier Source<1>	3756 B07592	114.0018	g

Calibrated Primary Calibration Reference

CompName	Act/Conc	Date	1/2 Life (Yrs)	Final Act/Conc	Summed Conc	Units
BARIUM	562193.5	3/9/2017		16022.77		pCi/ml

Associated Parent IDs

3756 B07592

Abbreviations: NC = Not Calculated for reagents when the volume added is not entered. (Print) = Secular equilibrium; parent half life used to calculate concentration.
 NE = Not Entered

Date Printed: Thursday, March 09, 2017

ALS Environmental -- FC

Standards DB Version: 1.111

Page 1 of 1