



facility 439136
project 10243

Radium-228 Case Narrative

COGCC

PW NORM 2017 – 10048

Work Order Number: 1705202

1. This report consists of the analytical results and supporting documentation for one water sample received by ALS on 05/09/2017.
2. This sample was prepared according to the current revision of SOP 749.
3. The sample was 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 analysis was completed on 05/23/2017.
4. The analysis results for this sample are reported in units of pCi/L. The sample was 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. Due to uncertainty associated with the ICP-AES determination of barium concentration in the samples, the calculated yield for the method blank RA170517-2MB fell between 100% and 110%. To minimize the potential for low bias, results have been calculated conservatively assuming quantitative chemical yield (100%). The magnitude of the low bias is estimated to be less than 10% of the reported value and is acceptable according the ALS LQAP. This sample is identified with an "Y1" flag on the final reports.

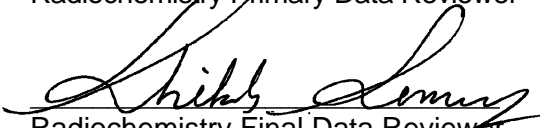


8. The requested MDC was not met for sample 1705202-1. The reported activity of this sample exceeds the achieved MDC. The results are flagged with an "M3" qualifier on final reports. Results are submitted without further qualification.
9. No further anomalous situations were noted during the preparation and analysis of this sample. 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

5/26/17
Date


Radiochemistry Final Data Reviewer

5/30/17
Date

Section 1

CHAIN OF CUSTODY

ALS -- Fort Collins

Sample Number(s) Cross-Reference Table

OrderNum: 1705202

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
439136	1705202-1		WATER	09-May-17	12:50
439136	1705202-2		WATER	09-May-17	12:50



2225 Commerce Drive, Fort Collins, Colorado 80524
 TF: (800) 443-1511 PH: (970) 490-1511 FX: (970) 490-1522

Chain-of-Custody

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

ALS WORKORDER #

1705202

[illegible]



ALS Environmental - Fort Collins
CONDITION OF SAMPLE UPON RECEIPT FORM

Client: COGCC
Project Manager: SS

Workorder No: 1705202
Initials: CAT Date: 5-10-17

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	YES	<u>NO</u>
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: ____ < green pea ____ > green pea	N/A	<u>YES</u>	NO
15. Do any water samples contain sediment? Amount Amount of sediment: ____ dusting ____ moderate ____ heavy	N/A	YES	<u>NO</u>
16. Were the samples shipped on ice?		<u>YES</u>	<u>NO</u>
17. Were cooler temperatures measured at 0.1-6.0°C? IR gun used*: <u>#2</u> #4		<u>YES</u>	<u>NO</u>
Cooler #: <u>1</u> <u>2</u>			
Temperature (°C): <u>6.0</u> <u>Amb</u>			
No. of custody seals on cooler: <u>0</u> <u>0</u>			
External µR/hr reading: <u>NA</u> <u>NA</u>			
Background µR/hr reading: <u>NA</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.

All RAD samples in the Amb cooler.

Added 3.5 Ml HNO₃ to EA. RAD and TOTAL metals bottle. Final pH < 2. HNO₃ lot no. 152495.

If applicable, was the client contacted? YES / NO / NA Contact: [Signature] Date/Time: _____

Project Manager Signature / Date: [Signature]

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: 1705202

Page: 1 of 1
Reported on: Friday, May 26, 2017
11:02:18 AM

Lab Sample ID	Client Sample ID	Sample Type	Nuclide	Result +/- 2 s TPU	MDC	DL	Units	Matrix	Prep Batch	Date Analyze	Flags
1705202-1	439136	Sample	Ra-228	2E+00 +/- 1E+00	1.8E+00	NA	pCi/l	WATER	RA170517-2	5/23/2017	M3

Comments:

Data Package ID: RA1705202-1

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



Radium-228 Analysis by GFPC

PAI 724 Rev 12

Method Blank Results

Lab Name: ALS -- Fort Collins

Work Order Number: 1705202

Client Name: COGCC

ClientProject ID: PW NORM 2017 10048

Lab ID: RA170517-2MB

Sample Matrix: WATER

Prep SOP: SOP749 Rev 4

Date Collected: 17-May-17

Date Prepared: 17-May-17

Date Analyzed: 23-May-17

Prep Batch: RA170517-2

QCBatchID: RA170517-2-1

Run ID: RA170517-2A

Count Time: 90 minutes

Final Aliquot: 1500 ml

Result Units: pCi/l

File Name: rac0523

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	DL	Lab Qualifier
15262-20-1	Ra-228	2E-02 +/- 2.4E-01	5.7E-01	1E+00	NA	Y1,U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.240E+04	3.330E+04	ug	103	40 - 110 %	Y1

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: RA1705202-1

Date Printed: Friday, May 26, 2017

ALS -- Fort Collins

LIMS Version: 6.842

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Radium-228 Analysis by GFPC

PAI 724 Rev 12

Laboratory Control Sample(s)

Lab Name: ALS -- Fort Collins

Work Order Number: 1705202

Client Name: COGCC

ClientProject ID: PW NORM 2017 10048

Lab ID: RA170517-2LCS

Sample Matrix: WATER

Prep SOP: SOP749 Rev 4

Date Collected: 17-May-17

Date Prepared: 17-May-17

Date Analyzed: 23-May-17

Prep Batch: RA170517-2

QCBatchID: RA170517-2-1

Run ID: RA170517-2A

Count Time: 90 minutes

Final Aliquot: 1500 ml

Result Units: pCi/l

File Name: rac0523

CASNO	Target Nuclide	Results +/- 2s TPU	MDC	Spike Added	% Rec	Control Limits	Lab Qualifier
15262-20-1	Ra-228	6.2E+00 +/- 1.5E+00	6E-01	6.900E+00	90.5	70 - 130	P

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.240E+04	3.120E+04	ug	96.3	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

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Radium-228 Analysis by GFPC

PAI 724 Rev 12

Laboratory Control Sample(s)

Lab Name: ALS -- Fort Collins

Work Order Number: 1705202

Client Name: COGCC

ClientProject ID: PW NORM 2017 10048

Lab ID: RA170517-2LCSD

Sample Matrix: WATER

Prep SOP: SOP749 Rev 4

Date Collected: 17-May-17

Date Prepared: 17-May-17

Date Analyzed: 23-May-17

Prep Batch: RA170517-2

QCBatchID: RA170517-2-1

Run ID: RA170517-2A

Count Time: 90 minutes

Final Aliquot: 1500 ml

Result Units: pCi/l

File Name: rac0523

CASNO	Target Nuclide	Results +/- 2s TPU	MDC	Spike Added	% Rec	Control Limits	Lab Qualifier
15262-20-1	Ra-228	6.8E+00 +/- 1.7E+00	6E-01	6.900E+00	98.7	70 - 130	P

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.240E+04	3.160E+04	ug	97.5	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: RA1705202-1

Date Printed: Friday, May 26, 2017

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Radium-228 Analysis by GFPC

PAI 724 Rev 12

Duplicate Sample Results (DER)

Lab Name: ALS -- Fort Collins

Work Order Number: 1705202

Client Name: COGCC

ClientProject ID: PW NORM 2017 10048

Field ID:
Lab ID: RA170517-2LCSD

Sample Matrix: WATER
Prep SOP: SOP749 Rev 4
Date Collected: 17-May-17
Date Prepared: 17-May-17
Date Analyzed: 23-May-17

Prep Batch: RA170517-2
QCBatchID: RA170517-2-1
Run ID: RA170517-2A
Count Time: 90 minutes

Final Aliquot: 1500 ml
Prep Basis: Unfiltered
Moisture(%): NA
Result Units: pCi/l
File Name: rac0523

CASNO	Analyte	Sample				Duplicate				DER	DER Lim
		Result +/-	2 s TPU	MDC	Flags	Result +/-	2 s TPU	MDC	Flags		
15262-20-1	Ra-228	6.2E+00 +/- 1.5E+00		6E-01	P	6.8E+00 +/- 1.7E+00		6E-01	P	0.249	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: RA1705202-1

Section 4

INDIVIDUAL SAMPLE RESULTS



Radium-228 Analysis by GFPC

PAI 724 Rev 12

Sample Results

Lab Name: ALS -- Fort Collins

Work Order Number: 1705202

Client Name: COGCC

ClientProject ID: PW NORM 2017 10048

Field ID: 439136

Lab ID: 1705202-1

Sample Matrix: WATER

Prep SOP: SOP749 Rev 4

Date Collected: 09-May-17

Date Prepared: 17-May-17

Date Analyzed: 23-May-17

Prep Batch: RA170517-2

QCBatchID: RA170517-2-1

Run ID: RA170517-2A

Count Time: 90 minutes

Report Basis: Filtered

Final Aliquot: 499 ml

Prep Basis: Filtered

Moisture(%): NA

Result Units: pCi/l

File Name: rac0523

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	DL	Lab Qualifier
15262-20-1	Ra-228	2E+00 +/- 1E+00	1.8E+00	1E+00	NA	M3

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.540E+04	3.400E+04	ug	96.1	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: RA1705202-1

Section 5

RAW DATA

5

Radium-228 Analysis by GFPC Raw Data Report

Laboratory Name: ALS -- Fort Collins

Prep SOP: SOP749

Reported on: Thursday, May 25, 2017

PAI Work Order: 1705202

Analytical SOP: PAI 724

1:06:07 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	AnRunID File Name	Count Date/Time	GrossCPM BkgCPM	BaseEff ProgEff	CntDur(min) Yield	Activity +/- 2 s TPU	MDC DeclEv	ReportUnits ReportBasis	DER RPD	%Spk. Recov Flags
1705202-1	Ra-228	5/9/2017	RA170517-2	5/19/2017	5/23/2017	WATER	500 ml	LB4100-c	RA170517-2A	5/23/2017	2,489	49.75%	90	2E+00	1.8E+00	pCi/l	NA	M3
SMP	Trg. Analyte	12:50:00 PM	RA170517-2-1	12:55:00 PM	6:35:00 AM	NA	499 ml	C3	rac0523	8:48 AM	1,722	NA	96.1%	1E+00	NA	Filtered	NA	M3
RA170517-2	Ra-228	5/17/2017	RA170517-2	5/19/2017	5/23/2017	WATER	1500 ml	LB4100-c	RA170517-2A	5/23/2017	1,711	49.49%	90	2E-02	5.7E-01	pCi/l	NA	Y1,U
MB	Trg. Analyte	9:00:03 AM	RA170517-2-1	12:55:00 PM	6:35:00 AM	NA	1500 ml	D2	rac0523	8:48 AM	1,582	NA	103.0%	2.4E-01	NA	Unfiltered	NA	Y1,U
RA170517-2	Ra-228	5/17/2017	RA170517-2	5/19/2017	5/23/2017	WATER	1500 ml	LB4100-c	RA170517-2A	5/23/2017	9,111	51.04%	90	6.2E+00	6E-01	pCi/l	NA	90.5
LCS	Trg. Analyte	9:00:03 AM	RA170517-2-1	12:55:00 PM	6:35:00 AM	NA	1500 ml	D3	rac0523	8:48 AM	1,801	NA	96.3%	1.5E+00	NA	Unfiltered	NA	P
RA170517-2	Ra-228	5/17/2017	RA170517-2	5/19/2017	5/23/2017	WATER	1500 ml	LB4100-c	RA170517-2A	5/23/2017	9,544	49.53%	90	6.8E+00	6E-01	pCi/l	0.25	98.7
LCSD	Trg. Analyte	9:00:03 AM	RA170517-2-1	12:55:00 PM	6:35:00 AM	NA	1500 ml	D4	rac0523	8:48 AM	1,716	NA	97.5%	1.7E+00	NA	Unfiltered	NA	P

Comments:

Data Package ID: RA1705202-1

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:

- 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

MDC - Minimum Detectable Concentration

DER - Duplicate Error Ratio

BDL - Below Detection Limit

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Alpha Attenuation Calibration	Beta Attenuation Calibration
$y = b^m \cdot e^{(m \cdot x - x)}$ Alpha $b=$ 0.93000 $m=$ 0.98110 $e=$ 0.8270 $x_0=$ 21.4875	$y = b^m \cdot e^{(m \cdot x - x)}$ Beta $b=$ 0.9681 $m=$ 0.9996 $e=$ 0.8174 $x_0=$ 0.0000
Alpha to Beta X-kill	Beta to Alpha X-kill
$y = b^m \cdot m^{-x}$ a → b $x_{kill} b=$ 0.2511 e → b $x_{kill} m=$ 0.9894	$y = b^m \cdot m^{-x}$ b → a $x_{kill} b=$ -1.689E+05 b → a $x_{kill} m=$ 0.0036

Background logfile: BKGABW
Date of Bkg. Cal: 5/10/2017
Alpha efficiency logfile: Am241R-0
Alpha attenuation calibration: AAM0606,
Beta efficiency logfile: RA228-06,
Beta attenuation calibration: ASR0607

Beta Activity	Base Eff	Base Cor.Fact.	Progeny Eff	Progeny Cor.Fact.
	0.4904	0.968	n/a	n/a
	0.5114	0.968	n/a	n/a
	0.5005	0.968	n/a	n/a
	0.5023	0.968	n/a	n/a
	0.4830	0.968	n/a	n/a
	0.5002	0.968	n/a	n/a
	0.4975	0.968	n/a	n/a
	0.4900	0.968	n/a	n/a
	0.4908	0.968	n/a	n/a
	0.5008	0.968	n/a	n/a
	0.4762	0.968	n/a	n/a
	0.4813	0.968	n/a	n/a
	0.4949	0.968	n/a	n/a
	0.5104	0.968	n/a	n/a
	0.4953	0.968	n/a	n/a

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Date 5/23/17SOP 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						(LB)			OLB
13						P			P
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	BKCD509W	JCB	P	BKCD523W
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	300	Dr C	
		Dr D	

Comments:

Date 5/23/17

SOP 724-12

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	6:46	JP	EFC0523	JP
1-16	Daily Bkg	—	—	60	6:57	JP	BKC0523	JP
1	1705081-9	RA170517-2	Pa228	90	8:49	JCB	RAC0523	JCB
2	10							
3	11							
4	12							
5	13							
6	14							
7	15							
8	16							
9	17							
10	1705158-1							
11	1705202-1							
13	1705203-1							
14	RA170517-2 MB							
15	LS							
16	LSO							
1	1705213-1	AB170521-2	LP	75	10:52	JCB	ABC0523	
2	-2							
3	1705271-1							
4	3							
5	5							
6	50							
7	7							
8	10							
9	12							
10	24							
11	1705356-8							
13	13							
14	130							
15	19							
16	24							
1	1705396-11				12:14		ABC0523A	
23	AB170521-2 MS							
22	1705390-1 MS							
1-16	Weekly Bkgd	—	—	1000	13:41	JCB	BKC0523W	JCB
2017 5/23/17								

Comments:

Page No.: 471472

B

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

Reviewed By / Date

JCB 5/24/17

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(cont. from page NA B)

Radiochemistry ICP Worksheet

ALS -- Fort Collins

Prep Batch: RA170517-2

Prep Procedure: Ra228

Reviewed By: iad LAD

Review Date: 5/23/2017

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
RA170517-2	CAR	2	27	0.05	IR170519-2A1	5.97227

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)	Fin ICP Conc (ug/ml)	Init Samp Mass (ug)	Ref Mass (ug)	Flag	Fin Samp Mass (ug)	% Yield	Final Sample Alq
1	1705081-1	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	0.00220	6.17448	33.00805	32438.41		31026.76	95.55%	1496
1	1705081-2	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	0.00313	6.338297	46.90618	32438.41		31849.95	98.04%	1496
1	1705081-3	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	0.00713	6.224199	106.8419	32438.41		31276.6	96.10%	1496
1	1705081-4	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	-0.0008	6.364316	0	32438.41	Z	31980.69	98.59%	1496
1	1705081-5	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	0.00023	6.379498	3.474532	32438.41		32056.98	98.81%	1496
1	1705081-6	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	0.03239	6.400591	485.5658	32438.41		32162.97	97.69%	1496
1	1705081-7	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	0.00243	6.282494	36.48259	32438.41		31569.53	97.21%	1496
1	1705081-8	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	0.06751	6.340673	1011.958	32438.41		31861.88	95.25%	1496
1	1705081-9	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	0.01327	6.150953	198.917	32438.41		30908.54	94.70%	1496
1	1705081-10	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	0.01895	6.405691	284.043	32438.41		32188.6	98.37%	1496
1	1705081-11	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	0.00440	5.904155	66.01611	32438.41		29688.38	91.27%	1496
1	1705081-12	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	0.01078	6.222576	161.5657	32438.41		31268.45	95.92%	1496
1	1705081-13	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	0.01078	6.402851	161.5657	32438.41		32174.33	98.69%	1496
1	1705081-14	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	0.00191	6.280524	28.66489	32438.41		31559.63	97.21%	1496
1	1705081-15	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	-0.0023	6.18578	0	32438.41	Z	31083.54	95.82%	1496
1	1705081-16	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	0.01078	6.440749	161.5657	32438.41		32364.76	99.28%	1496
1	1705081-17	SMP	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	0.12227	6.45425	1832.816	32438.41		32432.61	94.64%	1496
1	1705158-1	SMP	500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	0.27867	6.980008	4177.256	32438.41		35074.54	95.79%	498.7
1	1705202-1	SMP	500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	0.19580	6.767283	2995.111	32438.41		34005.6	96.13%	498.7
1	1705203-1	SMP	500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	0.54436	7.543142	8159.938	32438.41		37904.29	93.36%	498.7
1	RA170517-2	MB	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	-0.0016	6.623399	0	32438.41	Z	33282.58	102.60%	1496
1	RA170517-2	LCS	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	-0.0013	6.217303	0	32438.41	Z	31241.95	96.31%	1496
1	RA170517-2	LCSD	1500	2	1500	1	10	1499	1499	1499	25	0.05	10.05	IR170519-2A1	IR170519-2A1	-0.0015	6.293968	0	32438.41	Z	31627.19	97.50%	1496

10170519-2A1

Sample Id1	Ca	Fe	K	Mg	Na	Sr	Mn	S	Al	Ba	Pb	Ni
CCV	51.2861	19.8189	47.3486	49.7669	47.5199	0.4873	0.9833	4.8751	47.9744	0.9706	0.9601	1.0372
CCB	-0.0189	0.0142	0.1354	-0.0359	0.0275	-0.0011	0.0001	0.0201	0.0019	0.0006	0.0362	-0.0022
I 1705081-1	13.1445	0.0501	0.1729	2.4246	0.3235	0.0167	0.0099	2.4093	-0.0256	0.0022	0.0124	0.0006
I 1705081-2	19.2424	0.1311	0.4766	5.4164	13.3826	0.0306	0.0073	7.6229	0.0506	0.0031	0.0121	-0.0016
I 1705081-3	17.1787	0.1153	0.2978	5.1712	3.4324	0.0279	0.0138	2.9251	0.0082	0.0071	0.0111	-0.0038
I 1705081-4	34.9738	0.4222	0.3817	12.7570	4.6582	0.0659	0.0203	31.6317	-0.0424	-0.0008	0.0122	-0.0055
I 1705081-5	23.9962	1.6186	0.3573	9.0477	3.1593	0.0578	0.0239	17.3489	-0.0124	0.0002	0.0136	-0.0025
I 1705081-6	6.8642	0.0695	0.3425	1.6624	25.3587	0.1807	0.0188	3.4932	-0.0300	0.0324	0.0097	0.0004
I 1705081-7	10.9088	0.0565	0.2067	2.3903	1.6705	0.0220	0.0001	2.4940	-0.0424	0.0024	0.0127	-0.0040
I 1705081-8	22.6285	0.0832	0.4015	5.7378	14.4747	0.2303	0.0287	1.9903	0.0432	0.0675	0.0128	-0.0043
I 1705081-9	22.6376	0.0162	0.4214	5.4208	34.6881	0.0345	0.0041	3.0419	-0.0293	0.0133	0.0120	-0.0046
I 1705081-10	8.5838	0.0107	0.2653	2.2478	0.7875	0.0647	0.0008	0.7212	-0.0331	0.0189	0.0093	-0.0035
I 1705081-11	9.4609	0.3109	0.3395	3.0934	1.9302	0.0290	0.0149	2.0427	0.0163	0.0044	0.0097	-0.0046
I 1705081-12	11.5279	0.1096	0.3632	4.2566	16.2653	0.1997	0.0306	9.6737	0.0751	0.0108	0.0082	-0.0077
I 1705081-13	18.6077	0.2252	0.3530	6.5657	4.3314	0.0617	0.0166	4.6696	-0.0349	0.0108	0.0086	-0.0070
I 1705081-14	8.5133	0.2471	0.2839	1.6282	0.8273	0.0131	0.0015	0.4110	0.0606	0.0019	0.0045	-0.0048
I 1705081-15	-0.0616	-0.0139	0.1637	-0.1215	-0.0718	0.0012	-0.0015	0.0282	-0.0424	-0.0023	0.0087	-0.0055
I 1705081-16	19.0076	0.2843	0.3800	6.6662	4.4512	0.0597	0.0168	4.6656	-0.0042	0.0108	0.0109	-0.0083
I 1705081-17	7.4705	0.0794	0.5049	1.3802	94.7227	0.2904	0.0125	0.0363	0.0126	0.1223	0.0095	-0.0038
I 1705158-1	0.1425	-0.0077	0.3260	-0.0806	24.4256	0.0300	-0.0009	0.1531	-0.0454	0.2787	0.0100	-0.0072
I 1705202-1	0.2844	9.1760	2.3861	0.2298	105.4658	0.1438	0.0671	17.0185	-0.0392	0.1958	0.0047	-0.0049
I 1705203-1	4.4491	2.8744	1.3164	0.8091	133.8024	0.3479	0.0402	0.2699	-0.0211	0.5444	0.0055	0.0438
I RA170517-2MB	-0.0535	-0.0066	0.1346	-0.0635	0.0366	0.0014	-0.0006	0.0443	-0.0449	-0.0016	0.0024	-0.0017
I RA170517-2LCS	-0.0528	-0.0056	0.1274	-0.0773	-0.0422	0.0017	-0.0010	0.0524	-0.0362	-0.0013	0.0016	-0.0022
I RA170517-2LCSD	-0.0349	-0.0118	0.1438	-0.0884	-0.0608	0.0015	-0.0011	0.0403	-0.0393	-0.0015	0.0016	-0.0020
CCV	51.6456	19.8674	46.6725	50.3778	47.8517	0.5017	0.9861	4.9154	47.9931	1.0026	0.7183	1.0790
CCB	-0.0144	0.0059	0.1468	-0.0342	0.0117	-0.0011	0.0003	0.0363	0.0038	0.0010	0.0109	-0.0018

Sample Id1	Ca	Fe	K	Mg	Na	Sr	Mn	S	Al	Ba	Pb	Ni
CCV	51.6518	20.1794	49.2024	50.6815	49.6852	0.4992	0.9999	5.1048	49.5907	1.0033	1.0180	1.0439
CCB	0.0003	0.0081	0.0565	0.0044	0.0205	-0.0007	0.0008	0.0242	0.0356	0.0022	0.0038	0.0007
F 1705081-1	-0.0378	0.0274	0.0844	-0.0453	94.9639	0.0152	-0.0001	1.7123	0.0318	6.1745	0.2050	-0.0003
F 1705081-2	-0.0450	0.1212	0.1480	-0.0326	94.4199	0.0168	0.0001	1.8090	0.2354	6.3383	0.2596	-0.0005
F 1705081-3	-0.0421	0.0490	0.1215	-0.0387	95.1102	0.0184	0.0000	1.7486	0.1423	6.2242	0.2624	0.0003
F 1705081-4	-0.0404	0.0076	0.0464	-0.0569	92.7791	0.0532	-0.0001	1.8010	-0.0125	6.3643	0.2513	0.0004
F 1705081-5	-0.0421	0.0491	0.0983	-0.0370	94.0780	0.0326	0.0002	1.7969	0.0787	6.3795	0.2142	-0.0008
F 1705081-6	-0.0411	0.0191	0.0540	-0.0409	94.6934	0.1256	-0.0005	1.8413	0.0543	6.4006	0.2559	-0.0005
F 1705081-7	-0.0382	0.0241	0.0717	-0.0492	93.1872	0.0177	0.0000	1.7607	0.0125	6.2825	0.1700	0.0012
F 1705081-8	-0.0274	0.0858	0.1130	-0.0249	93.9276	0.1945	-0.0002	1.8695	0.2841	6.3407	0.3009	0.0024
F 1705081-9	-0.0362	0.0087	0.0856	-0.0492	92.5007	0.0228	0.0000	1.8090	-0.0044	6.1510	0.1965	-0.0012
F 1705081-10	-0.0391	0.0114	0.0848	-0.0525	93.6949	0.0671	-0.0003	1.7969	0.0312	6.4057	0.2379	0.0002
F 1705081-11	-0.0466	0.0579	0.1054	-0.0442	88.9810	0.0219	0.0001	1.6398	0.1068	5.9042	0.1932	-0.0006
F 1705081-12	-0.0470	0.1215	0.1265	0.0006	93.1288	0.0897	0.0002	1.8453	0.3896	6.2226	0.3894	0.0007
F 1705081-13	-0.0401	0.0078	0.0540	-0.0569	94.7131	0.0378	-0.0006	1.7607	0.0106	6.4029	0.1714	-0.0009
F 1705081-14	-0.0385	0.0924	0.1666	-0.0309	92.6949	0.0176	0.0005	1.7526	0.2397	6.2805	0.2363	-0.0003
F 1705081-15	-0.0457	0.0050	0.0426	-0.0574	92.7281	0.0027	-0.0005	1.6882	-0.0125	6.1858	0.0982	-0.0010
F 1705081-16	-0.0470	0.0380	0.0848	-0.0436	94.1608	0.0312	-0.0002	1.8050	0.1230	6.4407	0.2165	-0.0010
F 1705081-17	-0.0359	0.0358	0.0738	-0.0381	91.9088	0.2530	-0.0003	1.9259	0.1505	6.4543	0.3131	0.0004
F 1705158-1	-0.0434	0.0137	0.0274	-0.0596	92.8919	0.0343	-0.0006	1.9500	-0.0087	6.9800	0.2988	-0.0013
F 1705202-1	-0.0431	0.0019	0.0493	-0.0536	92.8902	0.1367	0.0006	2.2885	-0.0075	6.7673	0.3234	-0.0014
F 1705203-1	-0.0447	0.0016	0.0240	-0.0563	93.4426	0.3471	-0.0003	2.2562	-0.0056	7.5431	0.2454	-0.0011
F RA170517-2MB	-0.0466	-0.0018	0.0434	-0.0530	92.7917	0.0030	-0.0004	1.7325	-0.0062	6.6234	0.0456	0.0007
F RA170517-2LCS	-0.0486	0.0053	0.0283	-0.0613	93.2497	0.0028	-0.0006	1.6640	-0.0087	6.2173	0.0987	-0.0008
F RA170517-2LCSD	-0.0470	0.0084	0.0329	-0.0547	92.9494	0.0029	-0.0004	1.6680	-0.0106	6.2940	0.0726	-0.0009
RA170517-2RC	-0.0473	-0.0026	0.0059	-0.0624	83.1592	0.0034	-0.0006	0.0161	0.0000	5.9772	0.0034	-0.0011
CCV	51.6926	20.1574	49.4685	50.7401	49.6246	0.5039	0.9976	5.1128	49.6213	1.0099	1.0079	1.0577
CCB	0.0026	0.0095	0.0460	-0.0006	0.0405	-0.0006	0.0008	0.0161	0.0512	0.0027	0.0042	-0.0004

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: RA170517-2

Prep Procedure: Ra228

Analytical QASS / NCR? Y ☒ N ☐

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	1705081-1	SMP	1500	1496.0	ml	pCi/l		RA0523	1	7615							
1	1705081-2	SMP	1500	1496.0	ml	pCi/l			2								
1	1705081-3	SMP	1500	1496.0	ml	pCi/l			3								
1	1705081-4	SMP	1500	1496.0	ml	pCi/l			4								
1	1705081-5	SMP	1500	1496.0	ml	pCi/l			5								
1	1705081-6	SMP	1500	1496.0	ml	pCi/l			7								
1	1705081-7	SMP	1500	1496.0	ml	pCi/l			9								
1	1705081-8	SMP	1500	1496.0	ml	pCi/l			11								
1	1705081-9	SMP	1500	1496.0	ml	pCi/l		RA0523	1								
1	1705081-10	SMP	1500	1496.0	ml	pCi/l			2								
1	1705081-11	SMP	1500	1496.0	ml	pCi/l			3								
1	1705081-12	SMP	1500	1496.0	ml	pCi/l			4								
1	1705081-13	SMP	1500	1496.0	ml	pCi/l			5								
1	1705081-14	SMP	1500	1496.0	ml	pCi/l			6								
1	1705081-15	SMP	1500	1496.0	ml	pCi/l			7								
1	1705081-16	SMP	1500	1496.0	ml	pCi/l			8								
1	1705081-17	SMP	1500	1496.0	ml	pCi/l			9								
1	1705158-1	SMP	500	496.67	ml	pCi/l			10								
1	1705202-1	SMP	500	496.67	ml	pCi/l			11								
1	1705203-1	SMP	500	496.67	ml	pCi/l			13								
1	RA170517-2	MB	1500	1496.0	ml	pCi/l			14								
1	RA170517-2	LCS	1500	1496.0	ml	pCi/l			15								
1	RA170517-2	LCSD	1500	1496.0	ml	pCi/l			16								

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	92.093	DPW/ml	05/17/17	0.25	ml	RS019

Sample Barcodes

Radiochemistry Instrument Worksheet

ALS -- Fort Collins

Prep Batch: RA170517-2

Prep Procedure: Ra228

Analytical QASS / NCR? Y / **NA**

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
1705081-1 RA170517-2PS1								1705081-2 RA170517-2PS2						1705081-3 RA170517-2PS3			
1705081-4 RA170517-2PS4								1705081-5 RA170517-2PS5						1705081-6 RA170517-2PS6			
1705081-7 RA170517-2PS7								1705081-8 RA170517-2PS8						1705081-9 RA170517-2PS9			
1705081-10 RA170517-2PS10								1705081-11 RA170517-2PS11						1705081-12 RA170517-2PS12			
1705081-13 RA170517-2PS13								1705081-14 RA170517-2PS14						1705081-15 RA170517-2PS15			
1705081-16 RA170517-2PS16								1705081-17 RA170517-2PS17						1705158-1 RA170517-2PS18			
1705202-1 RA170517-2PS19								1705203-1 RA170517-2PS20						RA170517-2MB RA170517-2PS21			
RA170517-2LCS RA170517-2PS22								RA170517-2LCS RA170517-2PS23						RA170517-2CAR RA170517-2PS24			

Radiochemistry Instrument Worksheet

ALS -- Fort Collins

Prep Batch: RA170517-2

Reporting Units

LabID:	TstGrpName:	RptUnits:
1705202-1	Ra228_2012	pCi/l
1705158-1	Ra228_2012	pCi/l
1705081-1	Ra228_2012	pCi/l
1705203-1	Ra228_2012	pCi/l
1705081-2	Ra228_2012	pCi/l
1705081-3	Ra228_2012	pCi/l
1705081-4	Ra228_2012	pCi/l
1705081-5	Ra228_2012	pCi/l
1705081-6	Ra228_2012	pCi/l
1705081-7	Ra228_2012	pCi/l
1705081-8	Ra228_2012	pCi/l
1705081-9	Ra228_2012	pCi/l
1705081-10	Ra228_2012	pCi/l
1705081-11	Ra228_2012	pCi/l
1705081-12	Ra228_2012	pCi/l
1705081-13	Ra228_2012	pCi/l
1705081-14	Ra228_2012	pCi/l
1705081-15	Ra228_2012	pCi/l
1705081-16	Ra228_2012	pCi/l
1705081-17	Ra228_2012	pCi/l

2A

Radiochemistry Prep Worksheet

ALS -- Fort Collins

Prep Batch: RA170517-2

Prep Procedure: Ra228

Reviewed By: lad

Review Date: 5/23/2017

Non-Routine Pre-Treatment? ☒ Batch: NA

Prep QASS / NCR? Y / ☒ NA

Prep SOP: SOP749 Rev: 4

Prep Analyst: Lucas A. Daut

Balance: N/A

Prep SOP: NONE

Prep Date: 5/17/2017

Balance: N/A

Matrix Class: liquid

Prep Dept: RS

Samp Num	LabID	QC Type	Dish No.	Init Alq ml	Fin Alq ml	Prep Basis	Ingrrowth Date/Time	Decay Date/Time	Standards	Prep Notes
1	1705081-1	SMP	NA	1500	1496.002	Unfiltered	05/19/17 12:55	05/23/17 06:35	T1	NA
2	1705081-2	SMP		1500	1496.002	Unfiltered	05/19/17 12:55	05/23/17 06:35	T1	
3	1705081-3	SMP		1500	1496.002	Unfiltered	05/19/17 12:55	05/23/17 06:35	T1	
4	1705081-4	SMP		1500	1496.002	Unfiltered	05/19/17 12:55	05/23/17 06:35	T1	
5	1705081-5	SMP		1500	1496.002	Unfiltered	05/19/17 12:55	05/23/17 06:35	T1	
6	1705081-6	SMP		1500	1496.002	Unfiltered	05/19/17 12:55	05/23/17 06:35	T1	
7	1705081-7	SMP		1500	1496.002	Unfiltered	05/19/17 12:55	05/23/17 06:35	T1	
8	1705081-8	SMP		1500	1496.002	Unfiltered	05/19/17 12:55	05/23/17 06:35	T1	
9	1705081-9	SMP		1500	1496.002	Unfiltered	05/19/17 12:55	05/23/17 06:35	T1	
10	1705081-10	SMP		1500	1496.002	Unfiltered	05/19/17 12:55	05/23/17 06:35	T1	
11	1705081-11	SMP		1500	1496.002	Unfiltered	05/19/17 12:55	05/23/17 06:35	T1	
12	1705081-12	SMP		1500	1496.002	Unfiltered	05/19/17 12:55	05/23/17 06:35	T1	
13	1705081-13	SMP		1500	1496.002	Unfiltered	05/19/17 12:55	05/23/17 06:35	T1	
14	1705081-14	SMP		1500	1496.002	Unfiltered	05/19/17 12:55	05/23/17 06:35	T1	
15	1705081-15	SMP		1500	1496.002	Unfiltered	05/19/17 12:55	05/23/17 06:35	T1	
16	1705081-16	SMP		1500	1496.002	Unfiltered	05/19/17 12:55	05/23/17 06:35	T1	
17	1705081-17	SMP		1500	1496.002	Unfiltered	05/19/17 12:55	05/23/17 06:35	T1	
18	1705158-1	SMP		500	498.6673	Unfiltered	05/19/17 12:55	05/23/17 06:35	T1	A reduced aliquot was taken due to potential matrix interference
19	1705202-1	SMP		500	498.6673	Filtered	05/19/17 12:55	05/23/17 06:35	T1	A reduced aliquot was taken due to potential matrix interference
20	1705203-1	SMP		500	498.6673	Unfiltered	05/19/17 12:55	05/23/17 06:35	T1	A reduced aliquot was taken due to potential matrix interference
21	RA170517-2	MB		1500	1496.002	Unfiltered	05/19/17 12:55	05/23/17 06:35	T1	NA
22	RA170517-2	LCS		1500	1496.002	Unfiltered	05/19/17 12:55	05/23/17 06:35	S1,T1	
23	RA170517-2	LCS		1500	1496.002	Unfiltered	05/19/17 12:55	05/23/17 06:35	S1,T1	

Radiochemistry Prep Worksheet

ALS -- Fort Collins

Prep Batch: RA170517-2

Prep Procedure: Ra228

Reviewed By: lad LAD Review Date: 5/23/2017

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

Prep QASS / NCR? Y / ☒ NA

Prep SOP: SOP749 Rev: 4

Prep SOP: NONE

Matrix Class: liquid

Prep Analyst: Lucas A. Daut

Prep Date: 5/17/2017

Prep Dept: RS

Balance: N/A

Balance: N/A

Sample 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
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Comments

Spiked By: Lucas A. Daut Date: 5/17/2017

Yttrium Added By: Date:

Witnessed By: Andrew R. Steger Date: 5/17/2017

Witnessed By: Date:

Tracer/Carrier Solution Information

Soln #	Nuclide	SolnID	Exp Date	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
T1	BARIUM	418236	1/9/18	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	92.093	DPM/ml	05/17/17	0.25	ml	RS019

Radiochemistry Prep Worksheet

ALS -- Fort Collins

Prep Batch: RA170517-2

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 Analyst: Lucas A. Daut

Balance: N/A

Prep SOP: NONE

Prep Date: 5/17/2017

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	1705081-1	SMP		1500	1496.002	Unfiltered	5/19 12:55	5/23 6:35	T1	
2	1	1705081-2	SMP		1500	1496.002	Unfiltered			T1	
3	1	1705081-3	SMP		1500	1496.002	Unfiltered			T1	
4	1	1705081-4	SMP		1500	1496.002	Unfiltered			T1	
5	1	1705081-5	SMP		1500	1496.002	Unfiltered			T1	
6	1	1705081-6	SMP		1500	1496.002	Unfiltered			T1	
7	1	1705081-7	SMP		1500	1496.002	Unfiltered			T1	
8	1	1705081-8	SMP		1500	1496.002	Unfiltered			T1	
9	1	1705081-9	SMP		1500	1496.002	Unfiltered			T1	
10	1	1705081-10	SMP		1500	1496.002	Unfiltered			T1	
11	1	1705081-11	SMP		1500	1496.002	Unfiltered			T1	
12	1	1705081-12	SMP		1500	1496.002	Unfiltered			T1	
13	1	1705081-13	SMP		1500	1496.002	Unfiltered			T1	
14	1	1705081-14	SMP		1500	1496.002	Unfiltered			T1	
15	1	1705081-15	SMP		1500	1496.002	Unfiltered			T1	
16	1	1705081-16	SMP		1500	1496.002	Unfiltered			T1	
17	1	1705081-17	SMP		1500	1496.002	Unfiltered			T1	
18	1	1705158-1	SMP		500	498.6673	Unfiltered			T1	A reduced aliquot was taken due to potential matrix interference
19	1	1705202-1	SMP		500	498.6673	Unfiltered			T1	A reduced aliquot was taken due to potential matrix interference
20	1	1705203-1	SMP		500	498.6673	Unfiltered			T1	A reduced aliquot was taken due to potential matrix interference
21	1	RA170517-2	MB		1500	1496.002	Unfiltered			T1	
22	1	RA170517-2	LCS		1500	1496.002	Unfiltered			S1,T1	
23	1	RA170517-2	LCS		1500	1496.002	Unfiltered			S1,T1	

Radiochemistry Prep Worksheet

ALS -- Fort Collins

Prep Batch: RA170517-2

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: 5/17/2017

Prep Dept: RS

Balance: N/A

Balance: N/A

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: 5/17/2017

Witnessed By: [Signature] Date: 5/17/2017

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	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	92.093	DPM/ml	05/17/17	0.25	ml	RS019

Sample Condition Form (Liquid)				
Analyst: <u>Lucas Daut</u>				
Analysis Date: <u>5/19/17</u>			Method: <u>Prep</u>	
		Sample Condition (Visual Appearance of Analysis Aliquot at Time of Prep)		
Work Order	Sample ID	pH	Color	Remarks
1705081	1	12	Clear	None
↓	2	↓	↓	↓
	3			
	4			
	5			
	6		Cloudy	Light dusting of tan Sediment; decant
	7		Clear	None
	8			
	9			
	10			
	11			
	12			
	13			
	14		Cloudy	dusting of tan Sediment; decanted
	15		Clear	None
	16		↓	↓
	17		Cloudy	dusting of tan Sediment; decanted
	1705158		1	↓
1705202	1	Cloudy/black	black sediment present; filtered	
1705203	1	Clear	None	

Section 8

STANDARDS TRACEABILITY DOCUMENTS



Radiochemistry Solution Report

Solution Id: 418236	Name: Ba carrier	Lot:	Vendor Name:	Type: IS
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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	0.0012	0.2468	PASS	1.446	1.075	2.150	PASS	A1 (01)
A2 (02)	0.113	0.0016	0.3124	PASS	1.433	1.211	2.423	PASS	A2 (02)
A3 (03)	0.096	0.0011	0.2229	PASS	1.581	1.123	2.246	PASS	A3 (03)
A4 (04)	0.092	0.0011	0.2189	PASS	1.495	1.157	2.313	PASS	A4 (04)
B1 (05)	0.095	0.0011	0.2269	PASS	1.589	1.217	2.433	PASS	B1 (05)
B2 (06)	0.097	0.0012	0.2428	PASS	1.646	1.202	2.405	PASS	B2 (06)
B3 (07)	0.110	0.0013	0.2667	PASS	1.589	1.236	2.472	PASS	B3 (07)
B4 (08)	0.116	0.0015	0.2886	PASS	1.621	1.220	2.441	PASS	B4 (08)
C1 (09)	0.121	0.0010	0.2030	PASS	1.590	1.136	2.273	PASS	C1 (09)
C2 (10)	0.124	0.0011	0.2229	PASS	1.701	1.160	2.319	PASS	C2 (10)
C3 (11)	0.103	0.0011	0.2149	PASS	1.722	1.234	2.468	PASS	C3 (11)
C4 (12)	0.123	0.0012	0.2368	PASS	3.340	1.395	4.184	PASS	C4 (12)
D1 (13)	0.094	0.0010	0.1930	PASS	1.687	1.247	2.495	PASS	D1 (13)
D2 (14)	0.093	0.0009	0.1851	PASS	1.682	1.178	2.357	PASS	D2 (14)
D3 (15)	0.104	0.0009	0.1791	PASS	1.801	1.173	2.346	PASS	D3 (15)
D4 (16)	0.089	0.0009	0.1731	PASS	1.716	1.210	2.420	PASS	D4 (16)

Reviewed by: _____

Date: 5/10/17

Historical limits for alpha/beta set to be +/- 3 Std Deviations
JP 09/30/2016

LB4100-C
Long Instrument Background Calibration
Background Determination

Detector ID	Alpha			CPM	Flag	Beta			Flag	Detector ID
	LCL	UCL	UCL			LCL	UCL	UCL		
A1 (01)	0.077	0.0012	0.2468	1.674	PASS	1.075	2.150	2.150	PASS	A1 (01)
A2 (02)	0.086	0.0016	0.3124	1.481	PASS	1.211	2.423	2.423	PASS	A2 (02)
A3 (03)	0.084	0.0011	0.2229	1.439	PASS	1.123	2.246	2.246	PASS	A3 (03)
A4 (04)	0.107	0.0011	0.2189	1.519	PASS	1.157	2.313	2.313	PASS	A4 (04)
B1 (05)	0.073	0.0011	0.2269	1.515	PASS	1.217	2.433	2.433	PASS	B1 (05)
B2 (06)	0.122	0.0012	0.2428	1.684	PASS	1.202	2.405	2.405	PASS	B2 (06)
B3 (07)	0.098	0.0013	0.2667	1.669	PASS	1.236	2.472	2.472	PASS	B3 (07)
B4 (08)	0.103	0.0015	0.2886	1.573	PASS	1.220	2.441	2.441	PASS	B4 (08)
C1 (09)	0.112	0.0010	0.2030	1.600	PASS	1.136	2.273	2.273	PASS	C1 (09)
C2 (10)	0.111	0.0011	0.2229	1.681	PASS	1.160	2.319	2.319	PASS	C2 (10)
C3 (11)	0.103	0.0011	0.2149	1.586	PASS	1.234	2.468	2.468	PASS	C3 (11)
C4 (12)	0.133	0.0012	0.2368	2.325	PASS	1.395	4.184	4.184	PASS	C4 (12)
D1 (13)	0.085	0.0010	0.1930	1.679	PASS	1.247	2.495	2.495	PASS	D1 (13)
D2 (14)	0.091	0.0009	0.1851	1.655	PASS	1.178	2.357	2.357	PASS	D2 (14)
D3 (15)	0.116	0.0009	0.1791	1.631	PASS	1.173	2.346	2.346	PASS	D3 (15)
D4 (16)	0.089	0.0009	0.1731	1.729	PASS	1.210	2.420	2.420	PASS	D4 (16)

Reviewed by: JKB Date: 5/24/17

Historical limits for alpha/beta set to be +/- 3 Std Deviations
 JP 09/30/2016

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)	0.1980	0.1859	0.2160	PASS	0.3944	0.3641	0.4232	PASS	A1 (01)
A2 (02)	0.2068	0.1952	0.2268	PASS	0.3996	0.3753	0.4362	PASS	A2 (02)
A3 (03)	0.2078	0.2000	0.2324	PASS	0.3995	0.3769	0.4381	PASS	A3 (03)
A4 (04)	0.2078	0.1960	0.2278	PASS	0.3966	0.3791	0.4406	PASS	A4 (04)
B1 (05)	0.2334	0.2151	0.2500	PASS	0.4184	0.3905	0.4538	PASS	B1 (05)
B2 (06)	0.1975	0.1877	0.2182	PASS	0.3749	0.3547	0.4122	PASS	B2 (06)
B3 (07)	0.2202	0.2045	0.2376	PASS	0.4095	0.3736	0.4341	PASS	B3 (07)
B4 (08)	0.2170	0.2022	0.2349	PASS	0.4080	0.3756	0.4365	PASS	B4 (08)
C1 (09)	0.2139	0.1945	0.2261	PASS	0.4104	0.3758	0.4367	PASS	C1 (09)
C2 (10)	0.2161	0.2041	0.2372	PASS	0.4096	0.3833	0.4454	PASS	C2 (10)
C3 (11)	0.2093	0.1952	0.2269	PASS	0.4008	0.3726	0.4330	PASS	C3 (11)
C4 (12)	0.2171	0.2057	0.2390	PASS	0.4127	0.3878	0.4507	PASS	C4 (12)
D1 (13)	0.2181	0.1992	0.2316	PASS	0.3954	0.3737	0.4342	PASS	D1 (13)
D2 (14)	0.2105	0.1979	0.2300	PASS	0.4025	0.3729	0.4333	PASS	D2 (14)
D3 (15)	0.2139	0.2015	0.2342	PASS	0.4171	0.3809	0.4427	PASS	D3 (15)
D4 (16)	0.2200	0.2062	0.2396	PASS	0.4156	0.3833	0.4455	PASS	D4 (16)

Reviewed by: JP Date: 5/23/17

Historical Control Limits -- +/-7.5% of average from last 30 data points
Established: 01/24/17 JP

LB4100-C

Daily Instrument Performance Checks
Background Checks

Detector ID	Alpha			Flag	Beta			Flag	Detector ID
	CPM	LCL	UCL		CPM	LCL	UCL		
A1 (01)	0.067	-0.026	0.206	PASS	1.467	0.980	1.912	PASS	A1 (01)
A2 (02)	0.100	-0.017	0.243	PASS	1.683	0.969	1.897	PASS	A2 (02)
A3 (03)	0.050	-0.024	0.216	PASS	1.617	1.094	2.068	PASS	A3 (03)
A4 (04)	0.050	-0.025	0.209	PASS	1.500	1.021	1.969	PASS	A4 (04)
B1 (05)	0.150	-0.024	0.214	PASS	1.767	1.101	2.077	PASS	B1 (05)
B2 (06)	0.200	-0.024	0.218	PASS	1.567	1.149	2.143	PASS	B2 (06)
B3 (07)	0.150	-0.018	0.238	PASS	1.583	1.101	2.077	PASS	B3 (07)
B4 (08)	0.117	-0.016	0.248	PASS	1.683	1.128	2.114	PASS	B4 (08)
C1 (09)	0.150	-0.014	0.256	PASS	1.417	1.102	2.078	PASS	C1 (09)
C2 (10)	0.100	-0.012	0.260	PASS	1.567	1.196	2.206	PASS	C2 (10)
C3 (11)	0.083	-0.021	0.227	PASS	1.367	1.214	2.230	PASS	C3 (11)
C4 (12)	0.183	-0.013	0.259	PASS	2.267	2.632	4.048	FLAG-LOW	C4 (12)
D1 (13)	0.050	-0.025	0.213	PASS	1.267	1.184	2.190	PASS	D1 (13)
D2 (14)	0.017	-0.025	0.211	PASS	1.683	1.180	2.184	PASS	D2 (14)
D3 (15)	0.117	-0.021	0.229	PASS	1.683	1.281	2.321	PASS	D3 (15)
D4 (16)	0.150	-0.027	0.205	PASS	1.833	1.209	2.223	PASS	D4 (16)

Reviewed by: _____

Date: 5/23/17

Control Limits established from previous weekly background determinations.

Weekly Background File: BKC0509W

Date: 5/9/2017

Analyst: JP

0

1/0/1900

0

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)	0.2011	0.1859	0.2160	PASS	0.3913	0.3641	0.4232	PASS	A1 (01)
A2 (02)	0.2086	0.1952	0.2268	PASS	0.3828	0.3753	0.4362	PASS	A2 (02)
A3 (03)	0.2166	0.2000	0.2324	PASS	0.3954	0.3769	0.4381	PASS	A3 (03)
A4 (04)	0.2043	0.1960	0.2278	PASS	0.3978	0.3791	0.4406	PASS	A4 (04)
B1 (05)	0.2322	0.2151	0.2500	PASS	0.4175	0.3905	0.4538	PASS	B1 (05)
B2 (06)	0.1992	0.1877	0.2182	PASS	0.3713	0.3547	0.4122	PASS	B2 (06)
B3 (07)	0.2224	0.2045	0.2376	PASS	0.4116	0.3736	0.4341	PASS	B3 (07)
B4 (08)	0.2192	0.2022	0.2349	PASS	0.4048	0.3756	0.4365	PASS	B4 (08)
C1 (09)	0.2051	0.1945	0.2261	PASS	0.4043	0.3758	0.4367	PASS	C1 (09)
C2 (10)	0.2221	0.2041	0.2372	PASS	0.4150	0.3833	0.4454	PASS	C2 (10)
C3 (11)	0.2132	0.1952	0.2269	PASS	0.4010	0.3726	0.4330	PASS	C3 (11)
C4 (12)	0.2270	0.2057	0.2390	PASS	0.4191	0.3878	0.4507	PASS	C4 (12)
D1 (13)	0.2154	0.1992	0.2316	PASS	0.4014	0.3737	0.4342	PASS	D1 (13)
D2 (14)	0.2127	0.1979	0.2300	PASS	0.4014	0.3729	0.4333	PASS	D2 (14)
D3 (15)	0.2150	0.2015	0.2342	PASS	0.4120	0.3809	0.4427	PASS	D3 (15)
D4 (16)	0.2244	0.2062	0.2396	PASS	0.4054	0.3833	0.4455	PASS	D4 (16)

Reviewed by: JRS

Date: 5/24/17

Historical Control Limits -- +/-7.5% of average from last 30 data points
 Established: 01/24/17 JP

ALS Laboratory Group - Fort Collins

QUALITY ASSURANCE SUMMARY SHEET

PAR W.O. # / BATCH GAS FLOW PROPORTIONAL
 TEST GFPC / ALL COUNTER
 METHOD GFPC
 SOP/REV (PREP) -
 SOP/REV (ANAL) 724

Briefly document any QA or other problems or deviations associated with the analysis of samples. Problems could result from: log-in, color, odor, dilution, consistency, scheduling, equipment, or instrumentation, or may include documentation of minor deviations necessary due to unique DQO's or sample characteristics.

Daily Background Checks are not necessary, and therefore not performed, the day following the Weekly Background Calibration. The results of the Weekly Background Calibration will be used as that day's Daily Background Check. If the Weekly Background Calibration is outside the established control limits for a detector, the Weekly Background Calibration will be performed a second time and will be considered as the second Daily Background Check for that day.

[Large diagonal line across the section with handwritten note: MC 08/05/09]

TECHNICIAN/ANALYST

DATE 08-05-09

DEPARTMENT MANAGER

DATE 08/05/09

376920

FORM 302r6.doc (4/22/04)

Gas Proportional Counter

Instrument Calibration

**Initial Efficiency Calibration
Standards Traceability**

Instrument: LB4100-C

Calibration: Ra-228

Date of Calibration: 06/08/2015

Efficiency Log Files: **RA228-06/15**

Efficiency Instrument Files: ERA0608A-D

Source ID's: Efficiency (Ra-228 784.3020.37)
ICV/ICB's (Ra-228 966.4095.32)

NOTE: Calibration Re-Verified 06/06/16.
(See Supporting Documentation in Package)

OK
Expires
6/02/2017
JP 6/7/16

QUALITY ASSURANCE SUMMARY SHEET

ALS W.O. # / BATCH Inst. C Calibration
TEST All tests
METHOD GFPC
SOP/REV (PREP) -
SOP/REV (ANAL) 724

Briefly document any QA or other problems or deviations associated with the analysis of samples. Problems could result from: log-in, color, odor, dilution, consistency, scheduling, equipment, or instrumentation, or may include documentation of minor deviations necessary due to unique DQO's or sample characteristics.

Wm 6-3-16
ALS Fort Collins SOP 724 requires an efficiency calibration for each Gas Flow test to be performed annually for each instrument. Per Technical Manager, the efficiency calibrations performed in 2015 for Instrument C will be acceptable for another year providing the following acceptance criteria was met: 1) Plateau checks were performed and were within acceptance criteria (The beta slope at the beta voltage and the alpha slope at the beta voltage had a slope of less than 3.5%). 2) CCV's and CCB's were performed for each calibration and were within the acceptance criteria. These results for the plateau checks and the CCV's/CCB's can be found in the "Addendum" section in the back of the calibration. *Wm 6-3-16*

The instrument will be monitored with daily efficiency checks, daily background checks, and weekly background checks, as well as quarterly plateau checks as required per SOP 724. If any detectors fail any of these checks, the specific detector will be taken offline for the day and not be used to count client samples. If a detector fails its quarterly plateau check, the detector will be taken off-line until the instrument is re-calibrated for Voltage Plateaus, ROI's, and efficiency calibrations. *Wm 6-3-16*

TECHNICIAN/ANALYST

DATE 6-3-16

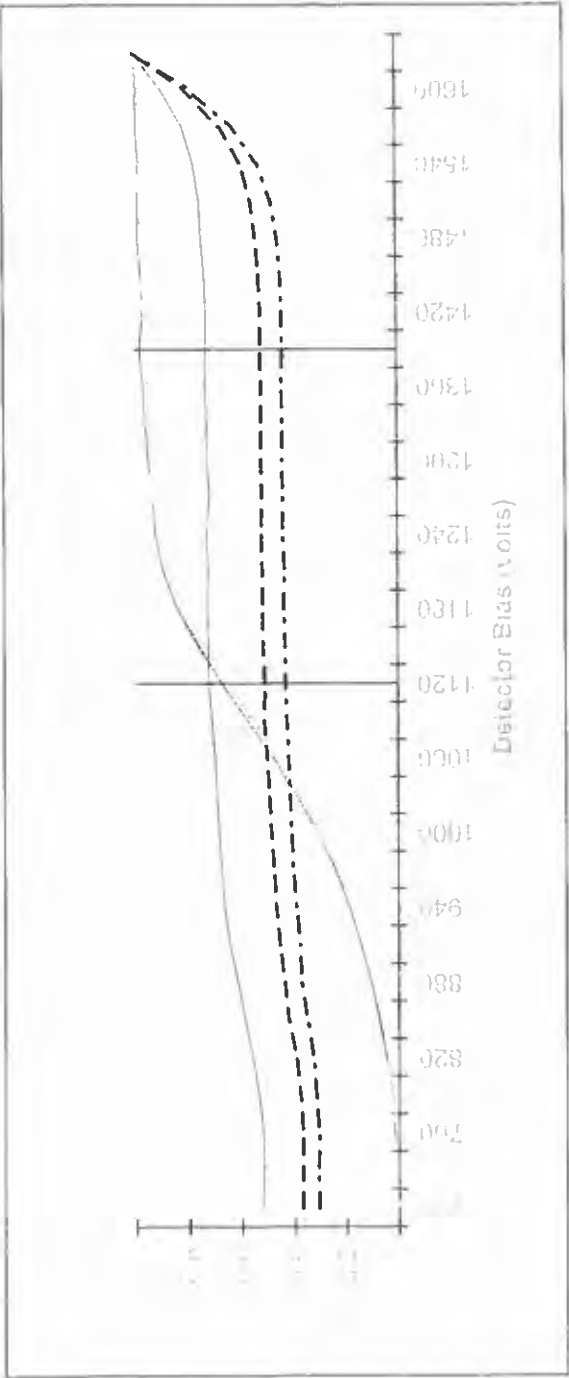
DEPARTMENT MANAGER

DATE 06/03/16

Instrument Plateaus

Unit Type: LB4100/W
Date Performed: 6/4/15 07:19
FileName: PTC0604A
Batch ID: DRAWER A PLATEAU

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



Optimum alpha beta simultaneous operating voltage: 1402.5

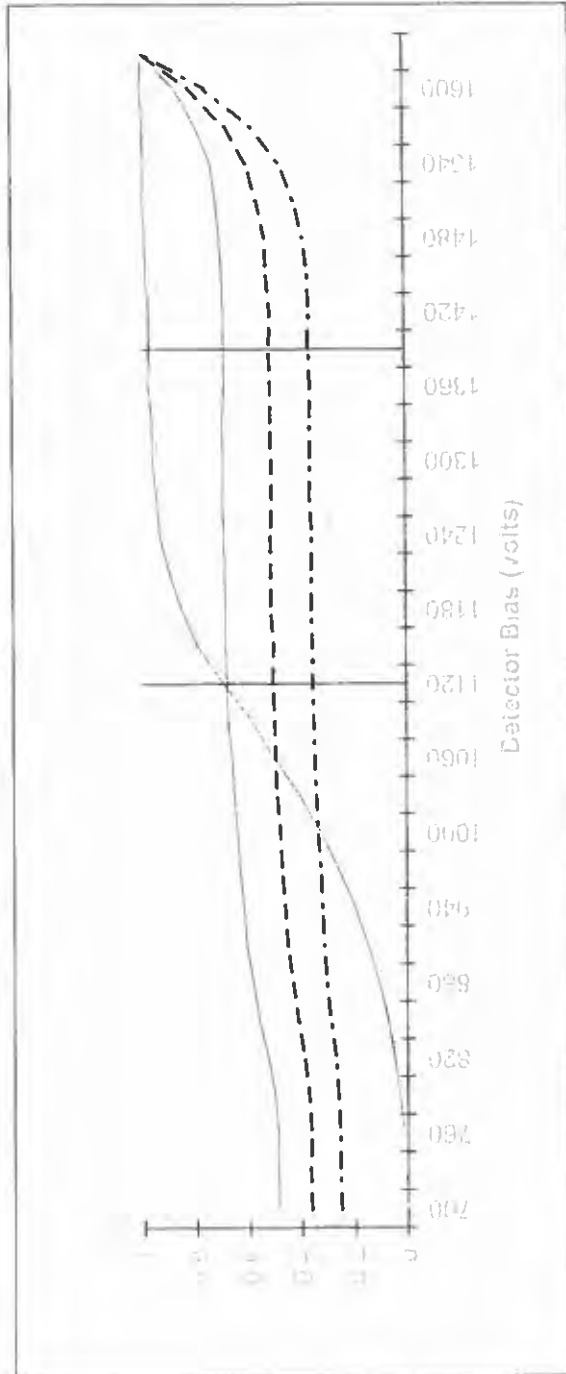
Optimum alpha only operating voltage: 1117.5

	A1	A2	A3	A4
Beta slope at beta voltage	0.98%	2.32%	2.15%	2.01%
Alpha slope at beta voltage	0.45%	0.91%	1.62%	0.57%
Alpha slope at alpha voltage	3.19%	2.18%	2.42%	3.19%

OK 6/5/15

Unit Type: LB4100/W
 Date Performed: 6/4/15 07:19
 File Name: PTC0604B
 Batch ID: DRAWER B PLATEAU

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



Optimum alpha beta simultaneous operating voltage: **1402.5**

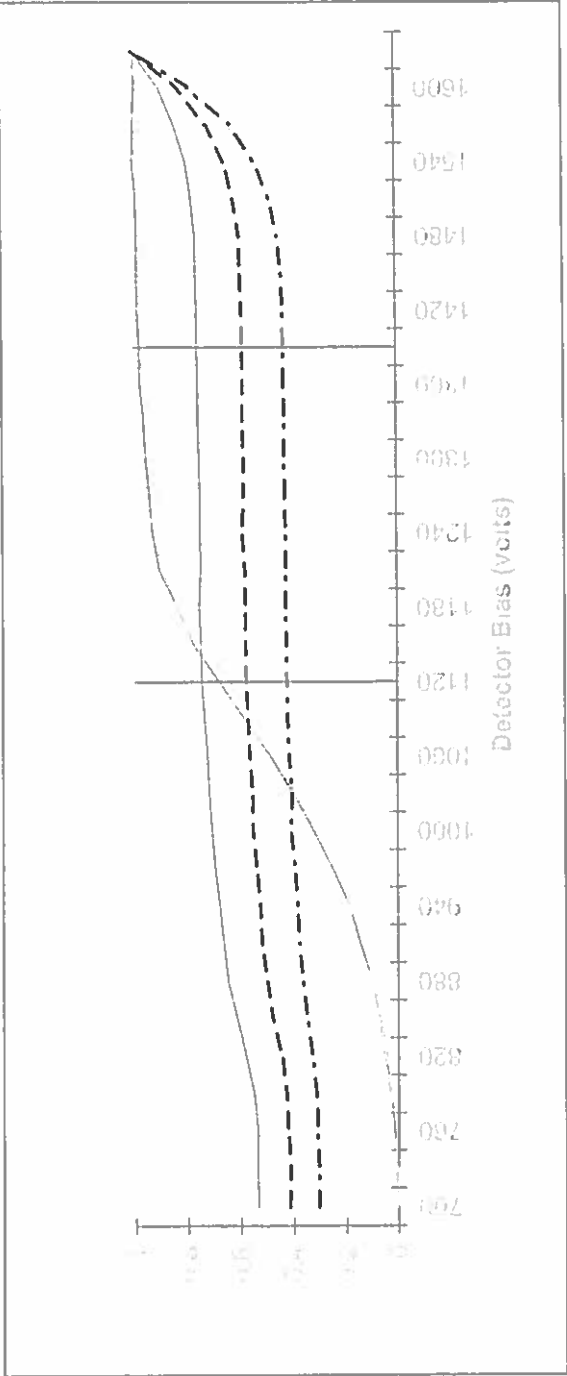
Optimum alpha only operating voltage: **1120**

OK 6/2/15 6/6/15

	B1	B2	B3	B4
Beta slope at beta voltage	1.40%	1.36%	1.60%	1.37%
Alpha slope at beta voltage	-0.18%	1.56%	1.68%	0.87%
Alpha slope at alpha voltage	2.53%	2.15%	1.16%	2.36%

Unit Type: LB4100/W
Date Performed: 6/4/15 13:32
File Name: PTC0604C
Batch ID: DRAWER C PLATEAU

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



Optimum alpha beta simultaneous operating voltage: 1402.5

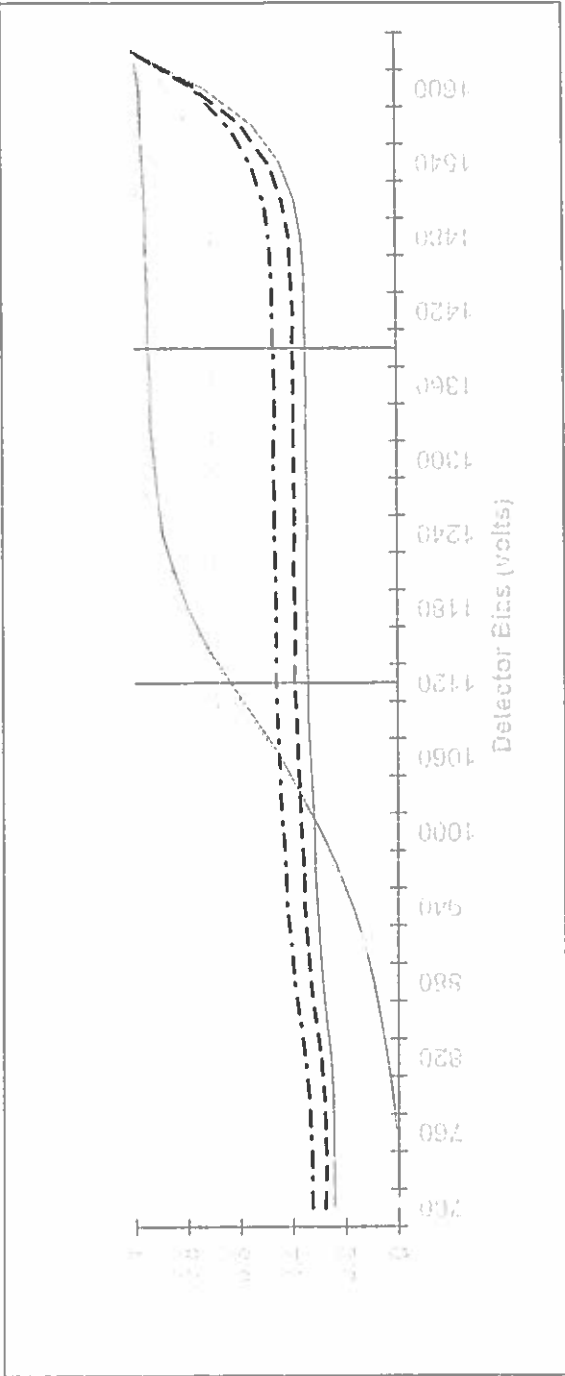
Optimum alpha only operating voltage: 1120

OK 6/5/15

	C1	C2	C3	C4
Beta slope at beta voltage	1.94%	1.64%	1.29%	1.87%
Alpha slope at beta voltage	0.69%	0.89%	0.80%	1.37%
Alpha slope at alpha voltage	3.36%	2.27%	2.34%	1.89%

Unit Type: LB4100/W
Date Performed: 6/4/15 13:33
FileName: PTC0604D
Batch ID: DRAWER D PLATEAU

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



Optimum alpha beta simultaneous operating voltage: 1402.5

Optimum alpha only operating voltage: 1120

	D1	D2	D3	D4
Beta slope at beta voltage	1.37%	0.31%	1.04%	2.34%
Alpha slope at beta voltage	1.21%	1.40%	0.81%	1.80%
Alpha slope at alpha voltage	2.81%	2.19%	2.37%	1.86%

OK TPC/5/15

3/12/15
Cs-137 / Gross Beta Mass Attenuation

Benchsheet: AB150310-1

Sources: 1515002-1 to 24 File Name ACS0312

Det	8:33	9:03	9:21	9:38	9:50	10:10	10:12	10:22	10:36	10:49	11:04	11:15	11:26	11:38	11:48	12:00	12:10	12:22	12:33	12:43	12:59	13:11	13:21	13:31
A1	1	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2
A2	2	1	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3
A3	3	2	1	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4
A4	4	3	2	1	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5
B1	5	4	3	2	1	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6
B2	6	5	4	3	2	1	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7
B3	7	6	5	4	3	2	1	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8
B4	8	7	6	5	4	3	2	1	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9
C1	9	8	7	6	5	4	3	2	1	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10
C2	10	9	8	7	6	5	4	3	2	1	24	23	22	21	20	19	18	17	16	15	14	13	12	11
C3	11	10	9	8	7	6	5	4	3	2	1	24	23	22	21	20	19	18	17	16	15	14	13	12
C4	12	11	10	9	8	7	6	5	4	3	2	1	24	23	22	21	20	19	18	17	16	15	14	13
D1	13	12	11	10	9	8	7	6	5	4	3	2	1	24	23	22	21	20	19	18	17	16	15	14
D2	14	13	12	11	10	9	8	7	6	5	4	3	2	1	24	23	22	21	20	19	18	17	16	15
D3	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	24	23	22	21	20	19	18	17	16
D4	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	24	23	22	21	20	19	18	17

6/04/2015

Plateau for Drawers A-D

A Source Used	Detectors	B Source Used
410 Am-241	A1 B1 C1 D1	406 Sr-90/Y-90
411 17,800 DPM	A2 B2 C2 D2	407 29,600 dpm
412 2-16.95	A3 B3 C3 D3	408 9-15-92
413	A4 B4 C4 D4	409

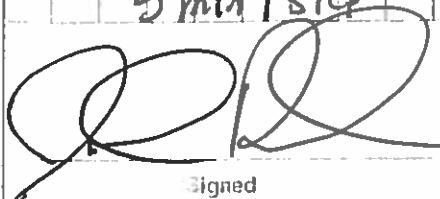
Parameters
Starting Voltage 700
End Voltage 1650
30V/Step
5 min/Step

Count Preset 40,000
Time Between Steps 0.1
Weak Check Times 0.1
Weak Check Limits 20

File Names
PTC0604A-D

Continued on Page

Read and Understood By

 03/13/15

Signed

Date

Signed

Date 60 of 140

Date 6/4/15SOP 724r 11

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						(LB)			OLB
13						P			P
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	BKC0520W			
Dr B				
Dr C				
Dr D				

Dr = Drawer

Gas Supply

P-10 Supply		P-10 Flow	
Tank 1	500	Dr A	0.1
		Dr B	
Tank 2	350	Dr C	
		Dr D	

Comments:Page No.: 453998 A

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

Reviewed By / Date JP 6/4/15

Date 6/4/15SOP 724r 11

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	Dark EFF	=	=	30	6:02	JP	EFC0604	JP
1-16	Dark Bkg	=	=	60	6:10	JP	BK0604	JP
1-4	Alpha Beta	Drawer A Plateau	Plateau	5 Min / step	7:19	JP	PTC0604A	JP
5-8	Beta Alpha	Drawer B Plateau			13:33	JP	B	
9-12	Alpha Beta						C	
13-16	Beta Alpha						D	
JP 6/5/15								

Comments:

Page No.: 453998 **B**
(cont. from page IVA **B**)

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

Reviewed By / Date JP 6/5/15

Instrument ROIs

Batch Specific:

Magenta	Event	Recycle
1	1	0.01

Drawer Specific:

	Date/Time	Official	Bias	Step
A	6-4-15 7:19	TRUE	1402.5	0
B	6-4-15 7:19	TRUE	1402.5	0
C	6-4-15 13:32	TRUE	1402.5	0
D	6-4-15 13:33	TRUE	1402.5	0

Detector Specific:

	Date/Time	Official	Thres	bLL	bUL	aLL	aUL	Time	bCntPst	bPstTm	aCntPst	aPstTm	bWkCnt	bWkTm	aWkCnt
A1	6-5-15 0:00	TRUE	0.1	0	43.71	80.56	100	35	10000	0	10000	0	0	0	0
A2	6-5-15 0:00	TRUE	0.1	0	42.85	80.21	100	35	10000	0	10000	0	0	0	0
A3	6-5-15 0:00	TRUE	0.1	0	41.58	79.82	100	35	10000	0	10000	0	0	0	0
A4	6-5-15 0:00	TRUE	0.1	0	42	76.8	100	35	10000	0	10000	0	0	0	0
B1	6-5-15 0:00	TRUE	0.1	0	44.51	86.44	100	35	10000	0	10000	0	0	0	0
B2	6-5-15 0:00	TRUE	0.1	0	42.53	77.46	100	35	10000	0	10000	0	0	0	0
B3	6-5-15 0:00	TRUE	0.1	0	41.48	76.5	100	35	10000	0	10000	0	0	0	0
B4	6-5-15 0:00	TRUE	0.1	0	41.44	77.5	100	35	10000	0	10000	0	0	0	0
C1	6-5-15 0:00	TRUE	0.1	0	40.92	77.99	100	35	10000	0	10000	0	0	0	0
C2	6-5-15 0:00	TRUE	0.1	0	41.36	77.09	100	35	10000	0	10000	0	0	0	0
C3	6-5-15 0:00	TRUE	0.1	0	37.28	71.47	100	35	10000	0	10000	0	0	0	0
C4	6-5-15 0:00	TRUE	0.1	0	42.34	78.09	100	35	10000	0	10000	0	0	0	0
D1	6-5-15 0:00	TRUE	0.1	0	38.19	71.47	100	35	10000	0	10000	0	0	0	0
D2	6-5-15 0:00	TRUE	0.1	0	39.56	73.84	100	35	10000	0	10000	0	0	0	0
D3	6-5-15 0:00	TRUE	0.1	0	38.24	72.82	100	35	10000	0	10000	0	0	0	0
D4	6-5-15 0:00	TRUE	0.1	0	40.92	77.82	100	35	10000	0	10000	0	0	0	0

ROI's

OK JP 6/5/15

6/5/2015

ROI's Set for All Drawers using Sr/Y-90 sources

Sources \rightarrow 406, 407, 408, 409: Over 50,000 counts achieved for each detector α Lower Limit + β Upper limit set to 50% to startBoth α lower limit + β upper limit moved to achieve β \rightarrow α Talk of ~~2.50%~~ ^{2.50%} ~~0.10%~~ ^{0.10%} α lower limit moved to achieve $\alpha \rightarrow \beta$ X Talk of 0.10%.

All ROI's Archived

6/5/15

After ROI's set, Interim Daily Efficiency control limits established for All 16 Detectors based on 5 individual counts

Files EFC0605A \rightarrow E. Interim limits for alpha + beta set at $\pm 10\%$ of the mean of the 5 individual counts.

Historical control limits will be established upon acquisition of 30 Data Points.

6/5/151000 minute background count run. Interim long background calibration limits set to $\pm 99\%$ for alpha, $\pm 25\%$ for beta based on 6/5/15 1000 minute count.

Historical limits will be established following the acquisition of 10 data points.

6/6/15

Gross Alpha

Am241 EFF Calibration

Benchmark: ABIZ1109-1 Source ID \rightarrow 1050 106Z JPL/6/15Log File: Am241R \rightarrow 06/15

Sources

Detectors

File names

1223001-20

A1 B1 C1 D1

EAM0606A

-22

A2 B2 C2 D2

B

-23

A3 B3 C3 D3

C

-24

A4 B4 C4 D4

D

Continued on Page

Read and Understood By



6/5/15

Signed

Date

Signed

65 of 140

Calibration Efficiencies

[illegible]

Radiochemistry Instrument Worksheet

ALS Environmental -- FC

Prep Batch: RA150603-1

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 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	1518001-1	SMP	1500	1496.0	ml	pCi/l											
1	1518001-2	SMP	1500	1496.0	ml	pCi/l											
1	1518001-3	SMP	1500	1496.0	ml	pCi/l											
1	1518001-4	SMP	1500	1496.0	ml	pCi/l											
1	1518001-5	SMP	1500	1496.0	ml	pCi/l											

See Runlog 3710 pg 71 for Calibration Information

JP Colfax
Outlier

Spiked Solution Information									
Soln #	Nuclide	SolnID	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID	
S1	Ra-228	784.3020.37	9.651.302	DPM/g	06/03/15	0.4	g	AW016	

Tracer/Carrier Solution Information									
Soln #	Nuclide	SolnID	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID	
T1	BARIUM	418225	16,024.539	pCi/ml	NA	2	ml	AW019	

Sample Barcodes

1518001-1 RA150603-1PS1		1518001-2 RA150603-1PS2		1518001-3 RA150603-1PS3	
1518001-4 RA150603-1PS4		1518001-5 RA150603-1PS5		RA150603-1CAR RA150603-1PS1	

Reporting Units

LabID	TstGrpName	RptUnits
1518001-1	Ra228_2012	pCi/l
1518001-2	Ra228_2012	pCi/l
1518001-3	Ra228_2012	pCi/l
1518001-4	Ra228_2012	pCi/l
1518001-5	Ra228_2012	pCi/l

Radiochemistry Prep Worksheet

ALS Environmental -- FC

Prep Batch: RA150603-1

Prep Procedure: Ra228

Reviewed By: dkl Review Date: 6/8/2015

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

Re-Prep? Y (N) Batch: NA

Prep QASS / NCR? Y (N) NA

Prep SOP: SOP749 Rev: 2

Prep SOP: NONE

Matrix Class: liquid

Prep Analyst: Dayna K. Lewis

Prep Date: 6/3/2015

Prep Dept: RS

Balance:

Balance:

Sample 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	1518001-1	SMP	1500	1496.002	1496.002	Unfiltered	06/04/15 13:00	06/08/15 08:15	T1.S1	
2	1	1518001-2	SMP	1500	1496.002	1496.002	Unfiltered	06/04/15 13:00	06/08/15 08:15	T1.S1	
3	1	1518001-3	SMP	1500	1496.002	1496.002	Unfiltered	06/04/15 13:00	06/08/15 08:15	T1.S1	
4	1	1518001-4	SMP	1500	1496.002	1496.002	Unfiltered	06/04/15 13:00	06/08/15 08:15	T1.S1	
5	1	1518001-5	SMP	1500	1496.002	1496.002	Unfiltered	06/04/15 13:00	06/08/15 08:15	T1.S1	

Comments

RA228 Efficiency Calibration.

Spiked By: Dayna K. Lewis Date: 6/3/2015

Yttrium Added By: Date:

Witnessed By: Jennie Kill-Bowden Date: 6/3/2015

Witnessed By: Date:

Tracer/Carrier Solution Information

Soln #	Nuclide	SolnID	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
T1	BARIUM	418225	16,024.539	pCi/ml	NA	2	ml	AW019

Spike Solution Information

Soln #	Nuclide	SolnID	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
S1	Ra-228	784.3020.37	9,651.302	DPM/g	06/03/15	0.4	g	AW016

Reagent Solution IDs*

418202 50266 51144 B0441604 K01475

*Except where otherwise noted, all reagents were applied in accordance with the specifications of the preparation methods associated with this batch.

Radiochemistry Prep Worksheet

Prep Batch: RA150603-1

ALS Environmental -- FC

Prep Batch Not Validated!!!

Reviewed By: _____ Review Date: _____

Prep Procedure: Ra228

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

Prep Analyst: Dayna K. Lewis Balance: _____
Prep Date: 6/3/2015 Balance: _____
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	1518001-1	SMP		1500	1500	Unfiltered	6/4/15 1300	6/4/15 0815	T1,S1	
2	1	1518001-2	SMP		1500	1500	Unfiltered			T1,S1	
3	1	1518001-3	SMP		1500	1500	Unfiltered			T1,S1	
4	1	1518001-4	SMP		1500	1500	Unfiltered			T1,S1	
5	1	1518001-5	SMP		1500	1500	Unfiltered			T1,S1	

Comments

RA228 Efficiency Calibration.

Spiked By: Dayna K. Lewis Date: 6/3/15 Yttrium Added By: _____ Date: _____

Witnessed By: JLCB Date: 6/3 Witnessed By: _____ Date: _____

Tracer/Carrier Solution Information

Soln #	Nuclide	SolnID	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
T1	BARIUM	418225	16,024,539	pCi/ml	NA	2	ml	AW019

Spike Solution Information

Soln #	Nuclide	SolnID	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
S1	Ra-228	784.3020.37	9,651.302	DPW/g	06/03/15	0.4	g	RS019

Reagent Solution IDs*

418202 50266 51144 B0441604 K01475

*Except where otherwise noted, all reagents were applied in accordance with the specifications of the preparation methods associated with this batch.

Sample Condition Form (Liquid)

Analyst: J

Analysis Date: 6/3/15

Method: RA 228

		Sample Condition (Visual Appearance of Analysis Aliquot at Time of Prep)		
Work Order	Sample ID	pH	Color	Remarks
1518001	1	~7	colorless	NA
↓	2	↓	↓	↓
	3			
	4			
	5			
<div>NA J 6/3/15</div>				

Radiochemistry ICP Worksheet

ALS Environmental -- FC

Prep Batch: RA150603-1

Prep Procedure: Ra228

Reviewed By: dkl

Review Date: 6/8/2015

BARIUM Recovery Results

Reference Carrier

LabID	QC Type	Car Vol	Ref Carr Dil Vol	Ref Carr ICP Dil Vol	Ref Carr ICP Run	Ref Carr ICP Conc
RA150603-1	CAR	2	25	0.05	ir150604-2a1	7.084682

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	1518001-1	SMP	1500	2	1500	1	10	1499	1499	1499	1499	0.05	10.05	ir150604-2a1	ir150604-2a1	-0.0007	6.256418	0	35600.53	Z	31438.5	88.31%	1496
1	1518001-2	SMP	1500	2	1500	1	10	1499	1499	1499	1499	0.05	10.05	ir150604-2a1	ir150604-2a1	-0.0005	6.481811	0	35600.53	Z	32571.1	91.49%	1496
1	1518001-3	SMP	1500	2	1500	1	10	1499	1499	1499	1499	0.05	10.05	ir150604-2a1	ir150604-2a1	-0.0007	6.322546	0	35600.53	Z	31770.79	89.24%	1496
1	1518001-4	SMP	1500	2	1500	1	10	1499	1499	1499	1499	0.05	10.05	ir150604-2a1	ir150604-2a1	-0.0005	6.225758	0	35600.53	Z	31284.43	87.88%	1496
1	1518001-5	SMP	1500	2	1500	1	10	1499	1499	1499	1499	0.05	10.05	ir150604-2a1	ir150604-2a1	-0.0006	6.219126	0	35600.53	Z	31251.11	87.78%	1496

1R150604-2A1

Sample Id1	Ba	Ca	Fe	K	Mg	Na	Pb	Sr	Al	Mn	Ni	S
CCV	1.0026	50.6170	20.1851	50.1012	50.2240	50.0754	1.0059	0.5020	50.1306	1.0113	1.0142	5.0216
CCB	0.0005	0.0301	0.0124	0.0494	0.0267	0.0339	0.0013	0.0002	0.0304	0.0003	-0.0007	-0.0162
I 1518001-1	-0.0007	-0.0060	-0.0039	0.0534	-0.0267	0.0492	-0.0026	-0.0003	-0.0065	-0.0014	-0.0024	0.0108
I 1518001-2	-0.0005	-0.0132	0.0013	0.0543	-0.0297	0.0306	-0.0018	-0.0003	-0.0123	-0.0014	-0.0020	0.0108
I 1518001-3	-0.0007	-0.0018	-0.0071	0.0603	-0.0191	0.0301	-0.0070	-0.0002	-0.0080	-0.0012	-0.0008	-0.0054
I 1518001-4	-0.0005	-0.0036	-0.0072	0.0097	-0.0221	0.0279	-0.0026	-0.0003	-0.0014	-0.0017	-0.0022	0.0216
I 1518001-5	-0.0006	0.0138	-0.0068	0.0130	-0.0206	0.0278	-0.0066	-0.0002	0.0007	-0.0015	0.0002	0.0108
F 1518001-1	6.2564	-0.0144	-0.0084	0.0227	-0.0236	92.0676	0.0346	0.0000	-0.0050	-0.0017	-0.0016	1.6918
F 1518001-2	6.4818	-0.0090	-0.0064	0.0713	-0.0175	92.9874	0.0448	0.0001	-0.0022	-0.0014	-0.0011	1.7996
F 1518001-3	6.3225	-0.0096	-0.0082	0.0709	-0.0259	91.0000	0.0302	0.0004	0.0022	-0.0014	0.0002	1.7457
F 1518001-4	6.2258	-0.0108	-0.0087	0.0259	-0.0229	90.2748	0.0456	0.0001	-0.0079	-0.0017	-0.0012	1.7080
F 1518001-5	6.2191	-0.0048	-0.0081	0.0373	-0.0213	90.3936	0.0322	0.0001	0.0007	-0.0015	-0.0008	1.6810
RA150603-1RC	7.0847	-0.0090	-0.0087	0.0802	-0.0168	89.0291	-0.0047	0.0001	-0.0065	-0.0012	-0.0001	0.0000
CCV	0.9982	50.4997	20.0787	49.7311	49.9169	48.9878	1.0019	0.5007	49.6495	1.0043	1.0118	4.9946
CCB	0.0009	0.0283	0.0122	0.0478	0.0274	0.0611	0.0033	0.0002	0.0361	0.0003	0.0001	-0.0108

PROJECT

784.3020.37

Ra-228

Notebook No. _____

37

Continued From Page _____

Prepare a primary dilution of (Analytical SRS 70035-307)
 KISO # 784 by diluting contents to approx 40g
 w/ 0.1 M 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 transferred = 4.7727g

3) Dilute 4/ 0.1 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

$$\frac{(2.308 \times 10^4 \text{ dpm}) (60 \frac{\text{sec}}{\text{min}}) (4.7727 \text{ g})}{(5.00794 \text{ g}) (39.2746 \text{ g})} = 33,589.8 \frac{\text{dpm}}{\text{g}}$$

Continued on Page _____

Read and Understood By

W. Lab

5/30/06

Russell

8/24/06

Signed

Date

Signed

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 $\mu\text{g/g}$ Ba carrier.

P O NUMBER 71239, Item 2

SOURCE PREPARED BY:

M. Dimitrova
M. Dimitrova, Radiochemist

Q A APPROVED:

WM R. S. J. 2-1-05

Date 6/8/15SOP 724r 11

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									

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	BK000050			
Dr B				
Dr C				
Dr D				

Dr = Drawer

Gas Supply

	P-10 Supply		P-10 Flow
Tank 1	2700	Dr A	0.1
		Dr B	
Tank 2	1200	Dr C	
		Dr D	

Comments:Page No.: 455203 **A**

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

Reviewed By / Date DP 6/8/15

Date 6/8/15SOP 724r 11

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	1065	AB150310-1	CS137 Maps	30	6:25	JP	EF0608	JP
1-16	1065	AB150423-3	Attn	30	6:33	JP	BYC0608	JP
1-16	1065	AB150603-1	Re228	30	7:34	JP	ACSO608	JP
1-4	1065	SR110623-2	EFF	30	9:55	JP	RERA0608A	JP
5-8	1065		Cal		10:02	JP	ERA0608B	
9-12	1065				10:11	JP	ERA0608C	
13-16	1065				10:18	JP	ERA0608D	
1-4	1066	SR110623-2	Sr90	30	10:13	JP	ESF0608A	
5-8	1066		EFF		10:19	JP	ESF0608B	
9-12	1066		Cal		10:24	JP	ESF0608C	
13-16	1066				10:30	JP	ESF0608D	
1	1118012-1	SR110623-1	Sr90	120	10:39	JP	SRC0608	JP
6	-2		ICV					
9	-3		ICB					
15	-4							
4	SR110623-1MB1							
7	MB2							
10	MB3							
16	MB4							
1-16	1515002-1-32	AB150310-1	CS137	30	13:01	JP	ACSO608A	JP
1	(Even this only)	AB150423-3	Monstr	120	15:50	JP	ABC0608A	JP
1	1505234-1	AB150605-1	α1B					
2	-3							
3	-3MS							
4	-5							
5	-7							
6	-9							
7	-11							
8	-11D							
9	-13							
10	1505275.6							
11	-6D							
12	-6MS							
14	1505379.2							
15	-4							
16	-6							

Comments:

Page No.: 455203 **B**
(cont. from page NA **B**)

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

Reviewed By / Date

JP 6/9/15

Date 6/9/15SOP 724r 11

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	JD	P			JD	P			P
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
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	BK00605W			
Dr B				
Dr C				
Dr D				

Dr = Drawer

Gas Supply

P-10 Supply		P-10 Flow	
Tank 1	1850	Dr A	0.1
	↓	Dr B	
Tank 2	1200	Dr C	
	↓	Dr D	

Comments:Page No.: 455204 **A**

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

Reviewed By / Date J. Galis

6/6/15

Sr90 Ring Eff Calibration (Gross Beta)

Benchsheet: AB110616-3

Source ID: ~~1051~~

1063

JP Gulch

Log File: Sr90R-06/15

Sources	Detectors
1118005-2	A1 B1 C1 D1
-3	A2 B2 C2 D2
-4	A3 B3 C3 D3
-5	A4 B4 C4 D4

File names	JP Gulch
ESR0606A	ESR0606A
ESR0606B	
C	
D	

6/6/15

Cs137 Eff Calibration (Gross Beta)

Benchsheet: AB150310-Z

Source ID: ~~1063~~

1064

JP Gulch

Log File: Cs137-06/15

Sources	Detectors
1515003-1	A1 B1 C1 D1
-3	A2 B2 C2 D2
-4	A3 B3 C3 D3
-5	A4 B4 C4 D4

File names	JP Gulch
ECS0606A	
B	
C	
D	

6/6/156/8/2015

Ra228 Efficiency Calibration

Benchsheet: RA150603-1

Source ID: 1065

Log File: Ra228-06/15

Sources	Detectors
1518001-1	A1 B1 C1 D1
-2	A2 B2 C2 D2
-3	A3 B3 C3 D3
-5	A4 B4 C4 D4

File names
ERA0608A
B
C
D

Continued on Page

Read and Understood By

6/6/15

Signed

Date

Signed

83 of 140

OUTLIER TEST

FILE	DET	SAMPLE ID	Beta CPM	Relative % diff. from mean	Within acceptability range	Outlier?	Half-life (day)	Separation Date & Time	Count Date & Time	Decay Factor	Chemical Yield	CPM Corrected
RAA0608	C2(10)	1518001-1	1658.250	1.24%	YES	NO	0.2554	6/8/2015 8:15	6/8/2015 9:07	0.9067	0.8831	2071.10
RAA0608A	C2(10)	1518001-2	1737.375	1.78%	YES	NO	0.2554	6/8/2015 8:15	6/8/2015 9:17	0.8897	0.9149	2134.34
RAA0608B	C2(10)	1518001-3	1658.250	1.29%	YES	NO	0.2554	6/8/2015 8:15	6/8/2015 9:28	0.8748	0.8924	2124.23
RAA0608C	C2(10)	1518001-4	1511.750	4.44%	YES	OUTLIER!	0.2554	6/8/2015 8:15	6/8/2015 9:38	0.8584	0.8768	2003.94
RAA0608D	C2(10)	1518001-5	1591.250	2.61%	YES	NO	0.2554	6/8/2015 8:15	6/8/2015 9:46	0.8424	0.8778	2151.90

Mean of all five plancchets:

Average= 2097.10

Std dev= 60.168655

2 Std Dev= 120.34

Sample 1518001-4 rejected as outlier.

Acceptability range

2217.44

1876.77

Relative range

+/- 5.74%

0.057382645

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

Prep Procedure: Ra228

Outlier Test

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 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	1518001-1	SMP	1500	1496.0	ml	pCi/l		RA228	10 JP								
1	1518001-2	SMP	1500	1496.0	ml	pCi/l		A	10 JP								
1	1518001-3	SMP	1500	1496.0	ml	pCi/l		B	10 JP								
1	1518001-4	SMP	1500	1496.0	ml	pCi/l		C	10 JP								
1	1518001-5	SMP	1500	1496.0	ml	pCi/l		D	10 JP								

Tracer/Carrier Solution Information										Spike Solution Information									
Soln #	Nuclide	SolnID	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID		Soln #	Nuclide	SolnID	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID	
T1	BARIUM	418225	16,024.539	pCi/ml	NA	2	ml	AW019		S1	Ra-228	784.3020	37	9,651.302	DPW/g	06/03/15	0.4	g	AW016

1518001-1	RA150603-1PS1																		
1518001-4	RA150603-1PS4																		

Reporting Units									
LabID:	TstGrpName:				RptUnits:				
1518001-1	Ra228_2012				pCi/l				
1518001-2	Ra228_2012				pCi/l				
1518001-3	Ra228_2012				pCi/l				
1518001-4	Ra228_2012				pCi/l				
1518001-5	Ra228_2012				pCi/l				

Radiochemistry Prep Worksheet

ALS Environmental -- FC

Prep Batch: RA150603-1

Prep Procedure: Ra228

Reviewed By: dkl Review Date: 6/8/2015

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

Re-Prep? Y (N) Batch: NA

Prep QASS / NCR? Y (N) NA

Prep SOP: SOP749 Rev: 2

Prep SOP: NONE

Matrix Class: liquid

Prep Analyst: Dayna K. Lewis

Prep Date: 6/3/2015

Prep Dept: RS

Balance:

Balance:

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	1518001-1	SMP	1500	1496.002	Unfiltered	Unfiltered	06/04/15 13:00	06/08/15 08:15	T1.S1	
2	1	1518001-2	SMP	1500	1496.002	Unfiltered	Unfiltered	06/04/15 13:00	06/08/15 08:15	T1.S1	
3	1	1518001-3	SMP	1500	1496.002	Unfiltered	Unfiltered	06/04/15 13:00	06/08/15 08:15	T1.S1	
4	1	1518001-4	SMP	1500	1496.002	Unfiltered	Unfiltered	06/04/15 13:00	06/08/15 08:15	T1.S1	
5	1	1518001-5	SMP	1500	1496.002	Unfiltered	Unfiltered	06/04/15 13:00	06/08/15 08:15	T1.S1	

Comments

RA228 Efficiency Calibration.

Spiked By: Dayna K. Lewis Date: 6/3/2015

Yttrium Added By: Date:

Witnessed By: Jennie Kill-Bowden Date: 6/3/2015

Witnessed By: Date:

Tracer/Carrier Solution Information					
Soln #	Nuclide	SolnID	Prep Conc	Units	Pipet ID
T1	BARIUM	418225	16,024.539	pCi/ml	NA
				2	ml
					AW019

Spike Solution Information					
Soln #	Nuclide	SolnID	Prep Conc	Units	Pipet ID
S1	Ra-228	784.3020.37	9.651	302 DPM/g	06/03/15
				0.4	g
					AW016

Reagent Solution IDs*

418202 50266 51144 B0441604 K01475

*Except where otherwise noted, all reagents were applied in accordance with the specifications of the preparation methods associated with this batch.

Radiochemistry Prep Worksheet

ALS Environmental -- FC

Prep Batch: RA150603-1

Prep Procedure: Ra228

Reviewed By: Review Date:

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

Prep SOP: SOP749 Rev: 2

Prep SOP: NONE

Matrix Class: liquid

Prep Analyst: Dayna K. Lewis

Prep Date: 6/3/2015

Prep Dept: RS

Balance:

Balance:

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	1518001-1	SMP		1500	1500	Unfiltered	6/4/15 1300	6/4/15 0815	T1.S1	
2	1	1518001-2	SMP		1500	1500	Unfiltered			T1.S1	
3	1	1518001-3	SMP		1500	1500	Unfiltered			T1.S1	
4	1	1518001-4	SMP		1500	1500	Unfiltered			T1.S1	
5	1	1518001-5	SMP		1500	1500	Unfiltered			T1.S1	

Comments

RA228 Efficiency Calibration.

Spiked By: Dayna K. Lewis

Date: 6/3/15

Yttrium Added By: Date:

Witnessed By: JKS

Date: 6/3

Witnessed By: Date:

Tracer/Carrier Solution Information

Soln #	Nuclide	SolnID	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
T1	BARIUM	418225	16.024,539	pCi/ml	NA	2	ml	AW019

Spike Solution Information

Soln #	Nuclide	SolnID	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
S1	Ra-228	784.3020.37	9,651.302	DPW/g	06/03/15	0.4	g	RS019

Reagent Solution IDs*

418202 50266 51144 B0441604 K01475

*Except where otherwise noted, all reagents were applied in accordance with the specifications of the preparation methods associated with this batch.

Sample Condition Form (Liquid)				
Analyst: <u>JS</u>				
Analysis Date: <u>6/3/15</u>		Method: <u>RA 228</u>		
		Sample Condition (Visual Appearance of Analysis Aliquot at Time of Prep)		
Work Order	Sample ID	pH	Color	Remarks
1518001	1	~7	colorless	NA
↓	2	↓	↓	↓
	3			
	4			
	5			
<div style="position: relative; height: 400px; border: 1px solid black;"> <div style="position: absolute; top: 0; right: 0; transform: rotate(45deg); transform-origin: right top;"> <p>NA JS 6/3/15</p> </div> </div>				

Radiochemistry ICP Worksheet

ALS Environmental -- FC

Prep Batch: RA150603-1

Prep Procedure: Ra228

Reviewed By: dkl

Review Date: 6/8/2015

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
RA150603-1	CAR	2	25	0.05	ir150604-2a1	7.084682

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 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	1518001-1	SMP	1500	2	1500	1	10	1499	1499	1499	0.05	10.05	ir150604-2a1	ir150604-2a1	-0.0007	6.256418	0	35600.53	Z	31438.5	88.31%	1496
1	1518001-2	SMP	1500	2	1500	1	10	1499	1499	1499	0.05	10.05	ir150604-2a1	ir150604-2a1	-0.0005	6.481811	0	35600.53	Z	32571.1	91.49%	1496
1	1518001-3	SMP	1500	2	1500	1	10	1499	1499	1499	0.05	10.05	ir150604-2a1	ir150604-2a1	-0.0007	6.322546	0	35600.53	Z	31770.79	89.24%	1496
1	1518001-4	SMP	1500	2	1500	1	10	1499	1499	1499	0.05	10.05	ir150604-2a1	ir150604-2a1	-0.0005	6.225758	0	35600.53	Z	31284.43	87.88%	1496
1	1518001-5	SMP	1500	2	1500	1	10	1499	1499	1499	0.05	10.05	ir150604-2a1	ir150604-2a1	-0.0006	6.219126	0	35600.53	Z	31251.11	87.78%	1496

1R150604-2A1

Sample Id1	Ba	Ca	Fe	K	Mg	Na	Pb	Sr	Al	Mn	Ni	S
CCV	1.0026	50.6170	20.1851	50.1012	50.2240	50.0754	1.0059	0.5020	50.1306	1.0113	1.0142	5.0216
CCB	0.0005	0.0301	0.0124	0.0494	0.0267	0.0339	0.0013	0.0002	0.0304	0.0003	-0.0007	-0.0162
I 1518001-1	-0.0007	-0.0060	-0.0039	0.0534	-0.0267	0.0492	-0.0026	-0.0003	-0.0065	-0.0014	-0.0024	0.0108
I 1518001-2	-0.0005	-0.0132	0.0013	0.0543	-0.0297	0.0306	-0.0018	-0.0003	-0.0123	-0.0014	-0.0020	0.0108
I 1518001-3	-0.0007	-0.0018	-0.0071	0.0603	-0.0191	0.0301	-0.0070	-0.0002	-0.0080	-0.0012	-0.0008	-0.0054
I 1518001-4	-0.0005	-0.0036	-0.0072	0.0097	-0.0221	0.0279	-0.0026	-0.0003	-0.0014	-0.0017	-0.0022	0.0216
I 1518001-5	-0.0006	0.0138	-0.0068	0.0130	-0.0206	0.0278	-0.0066	-0.0002	0.0007	-0.0015	0.0002	0.0108
F 1518001-1	6.2564	-0.0144	-0.0084	0.0227	-0.0236	92.0676	0.0346	0.0000	-0.0050	-0.0017	-0.0016	1.6918
F 1518001-2	6.4818	-0.0090	-0.0064	0.0713	-0.0175	92.9874	0.0448	0.0001	-0.0022	-0.0014	-0.0011	1.7996
F 1518001-3	6.3225	-0.0096	-0.0082	0.0709	-0.0259	91.0000	0.0302	0.0004	0.0022	-0.0014	0.0002	1.7457
F 1518001-4	6.2258	-0.0108	-0.0087	0.0259	-0.0229	90.2748	0.0456	0.0001	-0.0079	-0.0017	-0.0012	1.7080
F 1518001-5	6.2191	-0.0048	-0.0081	0.0373	-0.0213	90.3936	0.0322	0.0001	0.0007	-0.0015	-0.0008	1.6810
RA150603-1RC	7.0847	-0.0090	-0.0087	0.0802	-0.0168	89.0291	-0.0047	0.0001	-0.0065	-0.0012	-0.0001	0.0000
CCV	0.9982	50.4997	20.0787	49.7311	49.9169	48.9878	1.0019	0.5007	49.6495	1.0043	1.0118	4.9946
CCB	0.0009	0.0283	0.0122	0.0478	0.0274	0.0611	0.0033	0.0002	0.0361	0.0003	0.0001	-0.0108

PAI - Gas Flow Proportional Sample Analysis LB4100-A

Alpha Attenuation Calibration	Beta Attenuation Calibration
$y = b \cdot \exp(-a \cdot \ln(x - c))$	$y = b \cdot \exp(-a \cdot \ln(x - c))$
Alpha fit	Beta fit
ms	ms
0.99220	0.9904
0.3240	1.1240
25	25
21.6715	0.9900
Alpha to Beta 1-2 fit	Beta to Alpha 1-2 fit
$y = b \cdot \exp(-a \cdot \ln(x - c))$	$y = b \cdot \exp(-a \cdot \ln(x - c))$
ms	ms
0.9900	-3.3717e-01
0.3140	1.0000
25	25
0.9912	0.9911

Background logfiles: BKGAZW	Alpha prog. logfile: n/a
Date of Bkg. Cat: 4/2/15	Alpha prog. attenuation: n/a
Alpha efficiency logfile: Am241R-11M4	Beta prog. logfile: n/a
Alpha attenuation calibration: AAm0113	Beta prog. attenuation: n/a
Sets efficiency logfile: R221-01/15	
Beta attenuation calibration: ASR1119	

Unit Type: LB4100-AW
Counting Unit ID: Orange
High Voltage Mode: Simultaneous
Application Retention: C
Application Version: PA
Rev 85/09/13 JP

Det. ID	Sample ID	Count End Date & Time	Resid. Mass (mg)	Alpha Activity						Beta Activity											
				b>a			b>a xtlk			Base			Progeny			Base			Progeny		
				Gross CPM	Bkg CPM	Cor.FactL	Gross CPM	Bkg CPM	Cor.FactL	Gross CPM	Bkg CPM	Cor.FactL	Gross CPM	Bkg CPM	Cor.FactL	Gross CPM	Bkg CPM	Cor.FactL			
C2	15180001	6/8/15 3:18	8.00	18,250	0,115	5,135	0.2320	1,081	n/a	n/a	1552,250	1,741	0.4049	0.3984	n/a	n/a					

Dr 6/8/15

PAI - Gas Flow Proportional Sample Analysis LB4100-A

Alpha Attenuation Calibration		Beta Attenuation Calibration	
y = b* ^{1/m} *[e ^(mass-a)]		y = b* ^{1/m} *[e ^(mass-a)]	
Alpha ba	0.82578	Beta ba	0.8838
ms	0.89228	ms	0.9984
ss	0.8248	ss	1.8248
xb=	21.4875	xb=	0.8888

Alpha to Beta X-Cal		Beta to Alpha X-Cal	
y = b* ^{1/m} *-2		y = b* ^{1/m} *-2	
a -> b statk ms	0.2286	b -> a statk ms	-3.8278-J6
a -> b statk ms	0.2992	b -> a statk ms	0.4921

Background logfile: BKGBW
Date of Bkg. Cal: 6/2/15
Alpha efficiency logfile: AN24R-11/14
Alpha attenuation calibration: A008113
Beta efficiency logfile: RAZ28-01/15
Beta attenuation calibration: ASR1118

Unit Type: LB4100-AW
Counting Unit ID: Omega
High Voltage Mode: Simultaneous
Application Revision: C
Application Version: PA
Rev.8588/13.jp

Data file name: RAA0082A
Batch ID: RAZ28 OUTLIER TEST
Count Preset (ml): 8
Batch Endet: 6/2/15 8:25

Det. ID	Sample ID	Count End Date & Time	Count Dur. (min)	Resid. Mass (mg)	Alpha Activity				Beta Activity			
					Gross CPM	Bkg. CPM	a>b xtlk CPM	Progeny Cor.Fact.	Base Eff	Gross CPM	Bkg. CPM	a>b xtlk CPM
CZ	1518001-2	6/2/15 8:25	8.00	0.0	16.825	0.111	5.380	0.2320	1.081	1737.375	1.741	3.1081
								n/a	0.8648			n/a
								n/a	0.884			n/a

JP 6/8/15

PAI - Gas Flow Proportional Sample Analysis LB4100-A

Unit Type: LB4100-A-W
 Counting Unit ID: Orange
 High Voltage Mode: Simultaneous
 Application Revision: C
 Application Version: PA
 Rev. 6/5/08/13 JP

Data file name: RA4000088
 Batch ID: RA228 OUTLIER TEST
 Count Preset (m): 8
 Batch Ended: 6/8/15 9:34

Background logfile: BKGBBW
 Date of Bkg. Cal: 6/2/15
 Alpha efficiency logfile: AM24R-11/14
 Alpha attenuation calibration: AUM0113
 Beta efficiency logfile: BA228-01/15
 Beta attenuation calibration: ASR1110

Alpha prog. logfile: n/a
 Alpha prog. attenuation: n/a
 Beta prog. logfile: n/a
 Beta prog. attenuation: n/a

Alpha Attenuation Calibration		Beta Attenuation Calibration	
$y = b \cdot m \cdot (x^{(1/(mass-a))})$		$y = b \cdot m \cdot (x^{(1/(mass-a))})$	
Alpha ba	0.92179	Beta ba	0.9018
ms	0.92229	ms	0.9994
as	0.9248	as	1.8248
xbs	21.4875	asb	0.9999
Alpha to Beta X-talk		Beta to Alpha X-talk	
$y = b \cdot m \cdot x$		$y = b \cdot m \cdot x$	
a -> b xtalk ba	0.2306	b -> a xtalk ba	-0.0278 e m
a -> b xtalk ms	0.8992	b -> a xtalk ms	0.0021

Det. ID	Sample ID	Count End Date & Time	Count Dur. (min)	Resid. Mass (mg)	Alpha Activity					Beta Activity				
					Gross CPM	Bkg. CPM	a-b xtlk CPM	Base Eff	Cor.Fact.	Progeny Eff	Base Cor.Fact.	Progeny Eff	Cor.Fact.	Progeny Cor.Fact.
C2	1518001-3	6/8/15 9:34	8.00	0.0	20.500	0.111	5.185	0.2320	1.081	n/a	0.849	n/a	0.984	n/a

DP 6/8/15

[illegible]

Background logfile: BKGBABW
Date of Bkg. Cal: 6/3/15
Alpha efficiency logfile: Am241R-1
Alpha attenuation calibration: AAM00113
Beta efficiency logfile: Rsz228-01H
Beta attenuation calibration: ASR1119

Det.	Sample ID	Count End	Dur.	Date & Time	Resid.	Alpha Activity												Beta Activity																							
						Gross						Base						Progeny						Gross						Base						Progeny					
						Bkg.	b>a	xlk	CPM	Cor.Fact.	Eff	Bkg.	b>a	xlk	CPM	Cor.Fact.	Eff	Bkg.	b>b	xlk	CPM	Cor.Fact.	Eff	Bkg.	a>b	xlk	CPM	Cor.Fact.	Eff	Bkg.	a>b	xlk	CPM	Cor.Fact.	Eff						
C2	15130001-4	60915.8	24	8:00	0.0	18.500	0.111	4.681	0.2320	1.081	n/a	n/a	15117.50	1.741	4.2711	0.4849	n/a	n/a	15117.50	1.741	4.2711	0.4849	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a										

Dr 6/8/15

PAI - Gas Flow Proportional Sample Analysis LB4100-A

Unit Type: LB4100-4W
Counting Unit ID: Orange
High Voltage Mode: Simultaneous
Application Revision: C
Application Version: PA
Rev.05/09/13 JP

Data File Name: RA000020
Batch ID: RA0028 OUTLIER
Count Preset (m): 8
Batch Ended: 6/8/15 8:53

Background log file: BKGBBW
Date of Bkg. Cal: 6/2/15
Alpha efficiency log file: AM21R-1514
Alpha attenuation calibration: AAM0113
Beta efficiency log file: BAZ28-0715
Beta attenuation calibration: ASR1110

Alpha prog. log file: n/a
Alpha prog. attenuation: n/a
Beta prog. log file: n/a
Beta prog. attenuation: n/a

Alpha Attenuation Calibration		Beta Attenuation Calibration	
$y = b \cdot m \cdot (e^{(m \cdot \text{mass} - 1)})$		$y = b \cdot m \cdot (e^{(m \cdot \text{mass} - 1)})$	
Alpha ba	0.93370	Beta ba	0.93718
ms	0.00229	ms	0.0004
as	0.9240	as	1.8240
abs	21.0075	abs	0.0000
Alpha to Beta X-fact		Beta to Alpha X-fact	
$y = b \cdot \text{mass} \cdot s$		$y = b \cdot \text{mass} \cdot s$	
a -> b xfact ba	0.2300	b -> a xfact ba	-3.027E-06
a -> b xfact ms	0.9992	b -> a xfact ms	0.0021

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	Cor.Fact.	Base Cor.Fact.	Progeny Cor.Fact.
C2	1518001-5	6/8/15 8:53	8.00	0.0	18.825	0.111	4.1927	0.2320	1.081	n/a	0.4049	n/a
							4.2893				0.984	n/a
							1981.250					
							1.741					
												n/a

JP 6/8/15

Date 6/8/18SOP 724r 11

ALS
Low Background Gas Flow Proportional Counter Log
Instrument: LB4100A

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									OL
8									P
9						(HB)			OLBD
10						P			P
11									OL
12		(H ₂ , LB)							
13	OL				OL				
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	BKA01.024			
Dr B				
Dr C				
Dr D	OL			

Dr = Drawer

Gas Supply

P-10 Supply		P-10 Flow	
Tank 1	2700	Dr A	0.1
		Dr B	
Tank 2	1200	Dr C	
		Dr D	

Comments:Page No.: 454079 **A**

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

Reviewed By / Date JP 6/8/18

Date 6/8/15SOP 724r 11

ALS
Low Background Gas Flow Proportional Counter Log
Instrument: LB4100A

Det.	Sample ID	Batch	Test	Count Dur. (min)	Start Time	Analyst Initials	File ID	Output Initials
1-12	Daily Eff	—	—	20	6:16	JP	EFA0608	JP
1-12	Daily BK	—	—	20	6:26	JP	BKA0608	JP
1	1506071-1	AB150605-3	α1B	10	7:33	JP	ABA0608	JP
2	-2							
3	-3							
4	-4							
5	-5							
6	-6							
8	-7							
16	-8							
1	-3D				7:57	JP	ABA0608A	
2	-9							
3	-10							
4	-11							
5	-12							
6	-13							
8	-14							
10	-15							
1	-16				8:12	JP	ABA0608B	
2	-17							
3	-18							
4	-19							
5	-20							
6	AB1506053AL5							
8	BK15							
10	1506071-21	AB150605-4						
8	AB1506053MB	AB150605-3			8:30	JP	ABA0608C	
1	1506071-210	AB150605-4						
2	-22							
3	-23							
4	-24							
5	AB1506054AL5							
6	BK15							
10	MB							
1	1505401-8	AB150603-4	α1B	240	8:50	JP	ABA0608D	JP
2	-8D							
3	1505242-4							
4	-8							
5	-9							
6	-10							
10	1518001-1	KA150603-1	Rα228	8	9:07	JP	RAA0608	JP
10	-2		Outlier		9:17			A JP
10	-3				9:26			B JP
10	-4				9:36			C JP
10	-5				9:45			D JP
JP 6/8/15								

Comments:

Page No.: 454079 **B**
(cont. from page NA **B**)

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

Reviewed By / Date

JP 6/9/15

Date 6/9/15SOP 724r 11

ALS
Low Background Gas Flow Proportional Counter Log
Instrument: LB4100A

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									OL
8									P
9						(HB)			OLB
10						P			P
11									OL
12		(HLB)							
13	OL				OL				
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	BKA0602W			
Dr B				
Dr C				
Dr D	OL			

Dr = Drawer

Gas Supply

	P-10 Supply		P-10 Flow
Tank 1	1850	Dr A	0.1
		Dr B	
Tank 2	1200	Dr C	
		Dr D	

Comments:Page No.: 454081 **A**

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

Reviewed By / Date JP 6/9/15

Prepare a primary dilution of (Analytical SRS 70085-307)
R50 # 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 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

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

Continued on Page _____

Read and Understood By

D. Lab

Signed

5/30/06

Date

R. K. Kelley

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. M. [Signature] 2-1-05

Internal Calculation Verifications

ICBs

&

ICVs

Ra228 ICV/ICB 06/11/15
LB4100-C

Detector	Sample ID	Sampling Date & Time	Ingrowth Date & Time	Decay Date & Time	Crt Start Date & Time	Initial Vol	Final Vol	Count Dur	Gross CPM	Bkg CPM	Efficiency	Total Yield	Net CPM	Activity pCi/ml	TPU 2 sig	MDC	% Rec
A2	1518002-1	6/3/2015 12:00	6/4/2015 12:00	6/11/2015 8:15	6/11/2015 9:10	1500	1496	120	11,800	1,588	0.5114	0.9047	10,212	8,26E-03	2,50E-03	4.03E-04	106.7% X
B2	1518002-2	6/3/2015 12:00	6/4/2015 13:00	6/11/2015 8:15	6/11/2015 9:10	1500	1496	120	10,975	1,657	0.4908	0.9010	9,318	7,88E-03	2,40E-03	4.31E-04	101.9% X
C2	1518002-3	6/3/2015 12:00	6/4/2015 13:00	6/11/2015 8:15	6/11/2015 9:10	1500	1496	120	12,208	1,850	0.5002	0.8728	10,358	8,88E-03	2,69E-03	4.60E-04	114.7% X
D2	1518002-1	6/3/2015 12:00	6/4/2015 13:00	6/11/2015 8:15	6/11/2015 11:12	1500	1496	120	9,525	1,646	0.4949	0.9047	7,879	8,29E-03	2,53E-03	5.34E-04	107.0% X
A1	RA150603-2AMB	6/3/2015 12:00	6/4/2015 13:00	6/11/2015 8:15	6/11/2015 9:10	1500	1496	120	1,675	1,476	0.4904	0.9051	0.199	1,68E-04	2,15E-04	4.06E-04	O
B1	RA150603-2BMB	6/3/2015 12:00	6/4/2015 13:00	6/11/2015 8:15	6/11/2015 9:10	1500	1496	120	2,208	1,623	0.4900	0.9164	0.585	4,87E-04	2,77E-04	4.20E-04	O
C1	RA150603-2CMB	6/3/2015 12:00	6/4/2015 13:00	6/11/2015 8:15	6/11/2015 9:10	1500	1496	120	2,117	1,884	0.4830	0.9142	0.233	1,97E-04	2,44E-04	4.59E-04	O
D3	RA150603-2AMB	6/3/2015 12:00	6/4/2015 13:00	6/11/2015 8:15	6/11/2015 11:12	1500	1496	120	1,825	1,600	0.5104	0.9051	0.225	2,29E-04	2,73E-04	5.10E-04	O

Spike Information

Spike ID	Ref Date	Ref activity DPM/mL	Ra-228 Act DPM/mL	Spike Vol mL	Ra-228 Act Added
986.4094.32	1/1/2012	155.73	103.10	0.3	7.74E-03

DECAY and INGROWTH corrections to K (activity equation denominator)

Sample ID	Ra-228 Decay	Ac-228 Ingrowth	Ac-228 Decay	Decay during count	K
1018013-1	0.9974	1.0000	0.9015	0.8950	1236.5799
1018013-2	0.9974	1.0000	0.9015	0.8950	1181.9149
1018013-3	0.9974	1.0000	0.9015	0.8950	1168.8507
1018013-4	0.9974	1.0000	0.7164	0.8950	950.8555
RA100614-1ALCS	0.9974	1.0000	0.9015	0.8950	1186.3255
RA100614-1BLCS	0.9974	1.0000	0.9015	0.8950	1200.1569
RA100614-1CLCS	0.9974	1.0000	0.9015	0.8950	1180.1717
RA100614-1ELCS	0.9974	1.0000	0.7164	0.8950	981.0693

1 sig CU	1 sig TPU
2.56E-04	1.25E-03
2.58E-04	1.20E-03
2.76E-04	1.35E-03
2.99E-04	1.27E-03
1.05E-04	1.08E-04
1.18E-04	1.38E-04
1.18E-04	1.22E-04
1.32E-04	1.36E-04

X Acceptance Criteria = 70 - 130%

O Acceptance Criteria = Activity < MDCA and Standard MDC (1.0) achieved and [negative-activity] < 2 sigma TPU.

Ok JP 6/15/15

Alpha Attenuation Calibration		Beta Attenuation Calibration	
$y = b \cdot \ln^2(x/(mass \cdot d))$	Beta $b = 0.9683$	$y = b \cdot \ln^2(x/(mass \cdot d))$	Beta $b = 0.9683$
$r^2 = 0.99110$	$r^2 = 0.9996$	$r^2 = 0.9996$	$r^2 = 0.9996$
$a = 0.8270$	$a = 0.9174$	$a = 0.9174$	$a = 0.9174$
$d = 21.4875$	$d = 0.0000$	$d = 0.0000$	$d = 0.0000$
Alpha to Beta X-talk		Beta to Alpha X-talk	
$a \rightarrow b \text{ talk} = 0.2511$	$b \rightarrow a \text{ talk} = -1.69125$	$a \rightarrow b \text{ talk} = 0.2511$	$b \rightarrow a \text{ talk} = -1.69125$
$a \rightarrow b \text{ talk} = 0.9984$	$b \rightarrow a \text{ talk} = 0.9984$	$a \rightarrow b \text{ talk} = 0.9984$	$b \rightarrow a \text{ talk} = 0.9984$

De l'11/5

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: Standard
Rev.12/01/08 JCP

Data File Name: RAC0611A
Batch ID: RA150603-2
Count Preset (mj): 120
2
Batch Ended: 6/11/2015 13:12

Background Logfile: BKGABW
Date of Bkg. Cal: 6/6/2015
Alpha efficiency logfile: Am241R-06/15
Alpha attenuation calibration: AAM0606_0607
Beta efficiency logfile: RA228-06/15
Beta attenuation calibration: ASR0607

Alpha prog. logfile: n/a
Alpha prog. attenuation: n/a
Beta prog. logfile: n/a
Beta prog. attenuation: n/a

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.
D2	1518002-1	6/11/2015 13:12	120.00	0.0	0.275	0.093	0.028	0.2240	1.058	n/a	n/a	9.525	1.546	0.0457	0.4949	0.968
D3	RA150603-2AMB	6/11/2015 13:12	120.00	0.0	0.100	0.090	0.001	0.2222	1.058	n/a	n/a	1.825	1.600	0.0025	0.5104	0.968

Alpha Attenuation Calibration			Beta Attenuation Calibration		
y = b* ^m *[a*(mass-a0)]			y = b* ^m *[a*(mass-a0)]		
Alpha b=	0.90300		Beta b=		0.9481
m=	0.99110		m=	m=	0.9986
a=	0.3270		a=	a=	0.9174
a0=	21.4875		a0=	a0=	0.0000
Alpha to Beta X-talk			Beta to Alpha X-talk		
y = b * m ^a * mass			y = b * m ^a * mass		
a->b stalk b=	0.2511		b->a stalk b=	-1.69E-05	
a->b stalk m=	0.9984		b->a stalk m=	0.0036	

7/6/11/15

Date 6/11/15SOP 724r 11

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	TV	P			TV	P			P
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
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	BK00605W			
Dr B				
Dr C				
Dr D				

Dr = Drawer

Gas Supply

P-10 Supply		P-10 Flow	
Tank 1	1100	Dr A	0.1
		Dr B	
Tank 2	1200	Dr C	
		Dr D	

Comments:JPG/11/15

Date 6/11/15SOP 724r 11

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
-16	Daily EFF			30	7:58	JP	EFF0611	JP
-16	Daily BKS			60	8:05	JP	BKC0611	JP
2	1518002-1	RA150603-2	R ₂₂₈	120	9:09	JP	RAC0611	JP
6	-2							
10	-3							
1	RA150603-2AMB							
5	PMB							
9	CMB							
14	1518002-1	RA150603-2	R ₂₂₈	120	11:11	JP	RAC0611A	
15	RA150603-2AMB							
1	1505403-8	AB150609-1	α/B	150	11:15	JP	ABC0611	JP
2	1505419-1							
3	1505460-1							
4	1505464-1							
5	-2							
6	-3							
7	-4							
8	-5							
9	-6							
10	-7							
11	-70							
12	-7ms							
15	AB150609-1 LCS	AB150609-1	α/B	30	14:17	JP	ABC0611A	
16	LCS0							
2	1505402-1	AB150609-1		1000	14:22	JP	ABC0611B	JP
3	-2							
4	-3							
5	-4							
6	AB150609-1MB							
7	1505347-1	AB150609-1	α/B	300	15:09	JP	ABC0611C	
8	1505383-4							
9	-5							
10	1505404-1							
11	419-2							
12	-3							
14	1505472-1	AB150610-1						
15	538-2							
16	1506130-1							

Comments:

Page No.: 455206 **B**
(cont. from page N/A) **B)**

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

Reviewed By / Date JP 6/12/15

Date 6/12/15SOP 724r 11

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	✓	P			✓	P			P
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13						(HB)			OLB
14						P			P
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	BK00605W			
Dr B				
Dr C				
Dr D				

Dr = Drawer

Gas Supply

	P-10 Supply		P-10 Flow
Tank 1	700	Dr A	0.1
		Dr B	
Tank 2	1200	Dr C	
		Dr D	

Comments:

Page No.: 455207 **A**

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

Reviewed By / Date

JP 6/12/15

Radiochemistry ICP Worksheet

ALS Environmental -- FC

Prep Batch: RA150603-2

Prep Procedure: Ra228

Reviewed By: dkl

Review Date: 6/11/2015

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
RA150603-2	CAR	2	25	0.05	ir150604-2a1	6.869753

Samples

Prep Num	LabID	QC Type	Init Samp Alq (ml)	Car Vol (ml)	Samp Dil Vol (ml)	Init ICP Alq (ml)	Ref Carr Dil Vol	Ref Carr ICP Alq	Ref Carr ICP Run	Post Con Vol (ml)	Pre-Con 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	1518002-1	SMP	1500	2	1500	1	10	1499	1499	1499	1499	0.05	10.05	ir150604-2a1	ir150604-2a1	-0.0008	6.215172	0	34520.51	Z	31231.24	90.47%	1496
1	1518002-2	SMP	1500	2	1500	1	10	1499	1499	1499	1499	0.05	10.05	ir150604-2a1	ir150604-2a1	-0.0008	6.189317	0	34520.51	Z	31101.32	90.10%	1496
1	1518002-3	SMP	1500	2	1500	1	10	1499	1499	1499	1499	0.05	10.05	ir150604-2a1	ir150604-2a1	-0.0009	5.996228	0	34520.51	Z	30131.04	87.28%	1496
1	RA150603-2A	MB	1500	2	1500	1	10	1499	1499	1499	1499	0.05	10.05	ir150604-2a1	ir150604-2a1	-0.0008	6.218092	0	34520.51	Z	31245.91	90.51%	1496
1	RA150603-2B	MB	1500	2	1500	1	10	1499	1499	1499	1499	0.05	10.05	ir150604-2a1	ir150604-2a1	-0.0006	6.295535	0	34520.51	Z	31635.06	91.64%	1496
1	RA150603-2C	MB	1500	2	1500	1	10	1499	1499	1499	1499	0.05	10.05	ir150604-2a1	ir150604-2a1	-0.0008	6.280326	0	34520.51	Z	31558.64	91.42%	1496

10150604-2A1

Sample Id1	Ba	Ca	Fe	K	Mg	Na	Pb	Sr	Al	Mn	Ni	S
CCV	0.9982	50.4997	20.0787	49.7311	49.9169	48.9878	1.0019	0.5007	49.6495	1.0043	1.0118	4.9946
CCB	0.0009	0.0283	0.0122	0.0478	0.0274	0.0611	0.0033	0.0002	0.0361	0.0003	0.0001	-0.0108
I 1518002-1	-0.0008	-0.0126	-0.0052	0.0575	-0.0213	0.0468	-0.0059	-0.0003	0.0116	-0.0014	-0.0001	0.0216
I 1518002-2	-0.0008	-0.0120	0.0011	0.0567	-0.0274	0.0434	-0.0028	-0.0001	0.0022	-0.0014	-0.0013	0.0108
I 1518002-3	-0.0009	-0.0156	-0.0064	0.0615	-0.0244	0.0400	-0.0030	-0.0003	0.0072	-0.0012	-0.0003	0.0162
I RA150603-2AMB	-0.0008	-0.0132	-0.0052	-0.0036	-0.0259	0.0344	-0.0010	-0.0003	0.0073	-0.0017	-0.0016	-0.0108
I RA150603-2BMB	-0.0006	-0.0084	-0.0080	0.0049	-0.0198	0.0344	-0.0061	-0.0002	0.0058	-0.0017	-0.0019	0.0054
I RA150603-2CMB	-0.0008	-0.0192	-0.0086	0.0040	-0.0236	0.0312	-0.0039	-0.0002	0.0094	-0.0015	-0.0009	0.0162
F 1518002-1	6.2152	0.0090	-0.0071	0.0696	-0.0183	92.0695	0.0535	0.0001	0.0181	-0.0012	0.0001	1.6703
F 1518002-2	6.1893	-0.0012	-0.0079	0.0798	-0.0191	91.6792	0.0457	0.0020	0.0209	-0.0012	0.0000	1.7349
F 1518002-3	5.9962	-0.0108	-0.0079	0.0287	-0.0282	88.5340	0.0348	0.0000	0.0130	-0.0017	0.0001	1.6487
F RA150603-2AMB	6.2181	-0.0108	-0.0080	0.0223	-0.0259	90.6560	0.0320	0.0018	0.0159	-0.0017	0.0001	1.6918
F RA150603-2BMB	6.2955	-0.0138	-0.0079	0.0729	-0.0206	91.4601	0.0374	0.0003	0.0137	-0.0014	-0.0004	1.7511
F RA150603-2CMB	6.2803	-0.0090	-0.0058	0.0749	-0.0251	91.5948	0.0630	0.0020	0.0202	-0.0014	0.0004	1.7780
RA150603-2RC	6.8698	-0.0126	-0.0091	0.0729	-0.0267	86.6654	-0.0016	0.0001	0.0116	-0.0014	-0.0011	0.0000
CCV	1.0030	50.0872	19.9180	50.0777	49.7973	49.1149	0.9885	0.5009	49.7196	0.9921	1.0195	4.9084
CCB	0.0008	0.0289	0.0120	0.0506	0.0282	0.0653	0.0018	0.0002	0.0448	0.0003	0.0001	-0.0162

Radiochemistry Instrument Worksheet

ALS Environmental -- FC

Prep Batch: RA150603-2

Prep Procedure: Ra228

Analytical QASS / NCR? Y NA

Prep Num	LabID	QC Type	Init Aliq	Fin Aliq	Units	Report Units	Residual Mass (mg)	Cnt 1 File	Cnt 1 Pos Chk By	Cnt 2 File	Cnt 2 Pos Chk By	Cnt 3 File	Cnt 3 Pos Chk By	Notes
1	1518002-1	SMP	1500	1496.0	ml	pCi/l		RAC06112 JP		RAC06114 14				
1	1518002-2	SMP	1500	1496.0	ml	pCi/l		6						
1	1518002-3	SMP	1500	1496.0	ml	pCi/l		10						
1	RA150603-2A	MB	1500	1496.0	ml	pCi/l		1		RAC06114 15				
1	RA150603-2B	MB	1500	1496.0	ml	pCi/l		5						
1	RA150603-2C	MB	1500	1496.0	ml	pCi/l		9						

Spike Solution Information									
Soln #	Nuclide	SolnID	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID	
S1	Ra-228	966 4095 32	103 100	DPM/ml	06/03/15	0.25	ml	AW016	

Sample Barcodes

1518002-1 RA150603-2PS1		1518002-2 RA150603-2PS2		1518002-3 RA150603-2PS3	
RA150603-2AMB RA150603-2PS4		RA150603-2BMB RA150603-2PS5		RA150603-2CMB RA150603-2PS6	
RA150603-2CAR RA150603-2PS1					

Reporting Units

LabID:	TstGrpName:	RptUnits:
1518002-1	Ra228 2012	pCi/l
1518002-2	Ra228 2012	pCi/l
1518002-3	Ra228 2012	pCi/l

Radiochemistry Prep Worksheet

ALS Environmental -- FC

Prep Batch: RA150603-2

Prep Procedure: Ra228

Reviewed By: dkl DKL Review Date: 6/11/2015

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

Prep SOP: SOP749 Rev: 2
Prep SOP: NONE
Matrix Class: liquid

Prep Analyst: Dayna K. Lewis DKL
Prep Date: 6/3/2015
Prep Dept: RS

Balance:
Balance:

Samp Num	LabID	QC Type	Dish No.	Init Aliq ml	Fin Aliq ml	Prep Basis	Ingrowth Date/Time	Decay Date/Time	Standards	Prep Notes
1	1518002-1	SMP	1500	1496.002	Unfiltered	06/04/15 13:00	06/11/15 08:15	T1,S1		
2	1518002-2	SMP	1500	1496.002	Unfiltered	06/04/15 13:00	06/11/15 08:15	T1,S1		
3	1518002-3	SMP	1500	1496.002	Unfiltered	06/04/15 13:00	06/11/15 08:15	T1,S1		
4	RA150603-2A	MB	1500	1496.002	Unfiltered	06/04/15 13:00	06/11/15 08:15	T1		
5	RA150603-2B	MB	1500	1496.002	Unfiltered	06/04/15 13:00	06/11/15 08:15	T1		
6	RA150603-2C	MB	1500	1496.002	Unfiltered	06/04/15 13:00	06/11/15 08:15	T1		

Comments
ICV's / ICB's

Spiked By: Dayna K. Lewis Date: 6/3/2015
Witnessed By: Jennie Kill-Bowden Date: 6/3/2015

Yttrium Added By: Date:
Witnessed By: Date:

Tracer/Carrier Solution Information					
Soln #	Nuclide	SolnID	Prep Conc	Units	Pipet ID
T1	BARIUM	418225	16,024.539	pCi/ml	NA

Spike Solution Information					
Soln #	Nuclide	SolnID	Prep Conc	Units	Pipet ID
S1	Ra-228	966.4095	32	103.100	DPM/ml

Reagent Solution IDs*

418202 50266 51144 B0441604 K01475

*Except where otherwise noted, all reagents were applied in accordance with the specifications of the preparation methods associated with this batch.

Radiochemistry Prep Worksheet

ALS Environmental -- FC

Prep Batch: RA150603-2

Prep Procedure: Ra228

Prep Batch Not Validated!!!

Reviewed By:

Review Date:

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

Re-Prep? Y (N)

Batch: NA

Prep OASS / NCR? Y (N)

NA

Prep SOP: SOP749 Rev: 2

Prep SOP: NONE

Matrix Class: liquid

Prep Analyst: Dayna K. Lewis

Prep Date: 6/3/2015

Prep Dept: RS

Balance:

Balance:

Samp Num	Prep Num	LabID	QC Type	Dish No.	Init Alq ml	Fin Alq ml	Prep Basis	Ingrwth Date/Time	Decay Date/Time	Standards	Prep Notes
1	1	1518002-1	SMP		1500	1500	Unfiltered	6/3/15 1300	6/11/15 0815	T1, S1	
2	1	1518002-2	SMP		1500	1500	Unfiltered			T1, S1	
3	1	1518002-3	SMP		1500	1500	Unfiltered			T1, S1	
4	1	RA150603-2A	MB		1500	1500	Unfiltered			T1	
5	1	RA150603-2B	MB		1500	1500	Unfiltered			T1	
6	1	RA150603-2C	MB		1500	1500	Unfiltered			T1	

Comments

LCV'S / 100'S

Spiked By: Dayna K. Lewis

Date: 6/3/15

Witnessed By: JCN

Date: 6/3

Yttrium Added By:

Date:

Witnessed By:

Date:

Tracer/Carrier Solution Information

Soln #	Nuclide	SolnID	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
T1	BARIUM	418225	16,024.539	pCi/ml	NA	2	ml	AW019

Spike Solution Information

Soln #	Nuclide	SolnID	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
S1	Re-228	966 4085 32	103.100	DPM/ml	06/03/15	0.25	ml	AW016

Reagent Solution IDs*

418202	50266	51144	B0441604	K01475
--------	-------	-------	----------	--------

*Except where otherwise noted, all reagents were applied in accordance with the specifications of the preparation methods associated with this batch.

4/9/16

Project

Ra-228 966 4095-32 working Diluted

Continued from Page

Preparation of Ra-228 Spiking Solution

Date: 3/28/12

Analyst: Steve Workman

Objective: Prepare a Ra-228 spiking solution by separation of Ra-228 from a 10mg/ml thorium ICP-AES stock solution. The spiking solution is intended to be used for spiking LCS and MS samples. A preliminary test performed by using sequential precipitation to separate Ac-228 and GPC measurement indicated Ra-228 in the Th stock solution is about 70% ingrown. After separation of Ra from Th the Ra-228 activity concentration will be determined by gamma-ray measurement of Ac-228.

Procedure: 1. Split the following into ten 50ml centrifuge tubes:
5ml of 10mg/ml Th stock solution
0.04ml of 10mg/ml Ba

2. Bring each tube to 40ml volume with DI water.
3. Add 1.5ml of concentrated NH₄OH to each tube. Th(OH)₄ will precipitate and Ba/Fa will remain in solution. Shake gently for about 30 minutes to allow precipitation to be complete.
4. Centrifuge and filter supernatant through a 0.45um syringe filter into a clean 50 ml centrifuge tube (using a 50ml syringe).
5. Analyze a 50 fold dilution of one of the supernatants by ICP to verify separation of Th and Ba.
6. Add 2ml of concentrated HCl to each tube and mix.
7. Pour the filtered solutions into a preweighed 500ml volumetric flask and bring to volume. — DI H₂O PG 5/11/12
8. Weigh the full volumetric flask to determine the density of the solution.
9. Gravimetrically measure 100ml of the solution into a 125ml nalgene bottle and submit to instrument lab for gamma-ray measurement of Ac-228.

Gravimetric Data:

Weight of empty 500ml volumetric:	171.7
Weight of 500ml flask + solution:	478.7
Mass of 500ml:	307.0
Mass of 100ml:	101.4

Time of separation (beginning of Ac-228 ingrowth): 3/28/2012 13:00

Std ID: 966.4095.32

Description: Ra-228

Expiration: 4/12/2013

Activity: 155.73 dpm/mL

2s Uncertainty: 8.10 dpm/mL

Ref. Date: 1/1/2012

Ref Time: N/A

Prep Date: 3/28/2012 Prep by: SW

Matrix/Comp. 0.5M HCl

Half Life (y): 8.75E+08

Revocation Log		
Analysis Date	Initials	Expiration Date
4/05/13	JP	4/05/2014
4/10/14	JP	4/10/2015
04/09/15	JP	04/09/2016

Continued on Page

Signed

Date

Read and Understood By

Signed

Date

Due to increasing costs associated with the acquisition of a ^{228}Ra spiking solution, an attempt at generating an in-house solution from thorium ICP stock solution (ST080731-31) was undertaken. The spiking solution is intended to be used for batch QC (matrix spikes and laboratory control samples). Preliminary tests were performed by using sequential preparation to separate ingrown ^{228}Ac from the solution, which was then analyzed by gas flow proportional counting. It appeared as though the ^{228}Ra was approximately 70% ingrown from the ^{232}Th parent. This degree of ingrowth was deemed to be sufficient in order to facilitate separation and generation of ^{228}Ra into a solution that would be viable for use as a laboratory spiking solution.

In order to determine the activity concentration of the prepared ^{228}Ra solution, separation/purification of ^{228}Ra from the Thorium (and other radioactive daughter species) was performed following the procedure outlined on the accompanying spreadsheet "Preparation of Ra-228 Spiking Solution". The total volume of parent stock solution prepared was 500-mL. From this parent, 100-mL was used for analysis by gamma spectroscopy.

The solution was allowed to sit for a period long enough to ensure secular equilibrium was established between the ^{228}Ra parent and the ^{228}Ac used for gamma measurement (~15 days). A verified, NIST traceable ^{228}Ra solution (784.4095.29), was then counted by gamma spectroscopy and used to determine line specific efficiencies for the 338, 911, and 968 keV emissions of the daughter ^{228}Ac . The stock solution was then counted on the detector and the efficiencies were applied to the count data to determine line specific activities, and consequently an average total activity for ^{228}Ra . This activity determination is assumed to be acceptable based on the use of the NIST traceable standard used in the efficiency determination. Thus, traceability is maintained and the standard meets the normal ALS standard verification acceptance criteria as defined in the current revision of ALS SOPs 300, 310, and the LQAP.

The known activity that was determined by gamma spectroscopic analysis for standard 966.4095.32 is 70.15 pCi/mL, with an arbitrary reference date of 1/1/2012. This activity concentration will be input into the LIMS standards database. Results for this standard are reviewed, generated, approved, and made active with the approval of the department technical manager and operations manager.



Technical Manager

5/9/12

Date



Operations Manager

5/9/12

Date

Radiochemistry Solution Report

Solution Id: 966.4095.32	Name: Ra228 working standard	Lot:	Vendor Name:	Type: IS
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Final Vol: 500	Dept: RD	Prep By: SMW	on	3/28/2012	Reviewed By: mbc	on	5/8/2012
Units: mL	Location: SR/RA	Opened By:	on		Verified By: MBC	on	4/14/2012
Matrix: LIQUID	Expire Date: 4/9/2016	Received By:	on		Deactivated By:	on	

Comment: VERIFIED VIA STD 784.4095.28 BY GAMMA. EXP DATE 04-12-13. Mbc. Std Re-verified 04/05/13 by Gamma. New Exp Date 04/05/2014. JP 04/16/13. Standard Re-verified 4/10/14 by Gamma. New Exp Date 04/10/15 JP 04/11/14. Standard Re-verified 4/09/15 by Gamma. New Exp Date 04/09/2016. JP 04/15/15.

Component Name	Component ID	Volume Added	Units
Ra228 primary standard	966	50	mL

CompName	Act/Conc	Calibration Date	Reference Date	1/2 Life (Yrs)	Final Act/Conc	Summed Conc	Units
Ra-228	701.495	1/1/2012	4/15/2015	5.75	47.2087807696424		pCi/ml

Associated Parent IDs

966

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: Wednesday, April 15, 2015

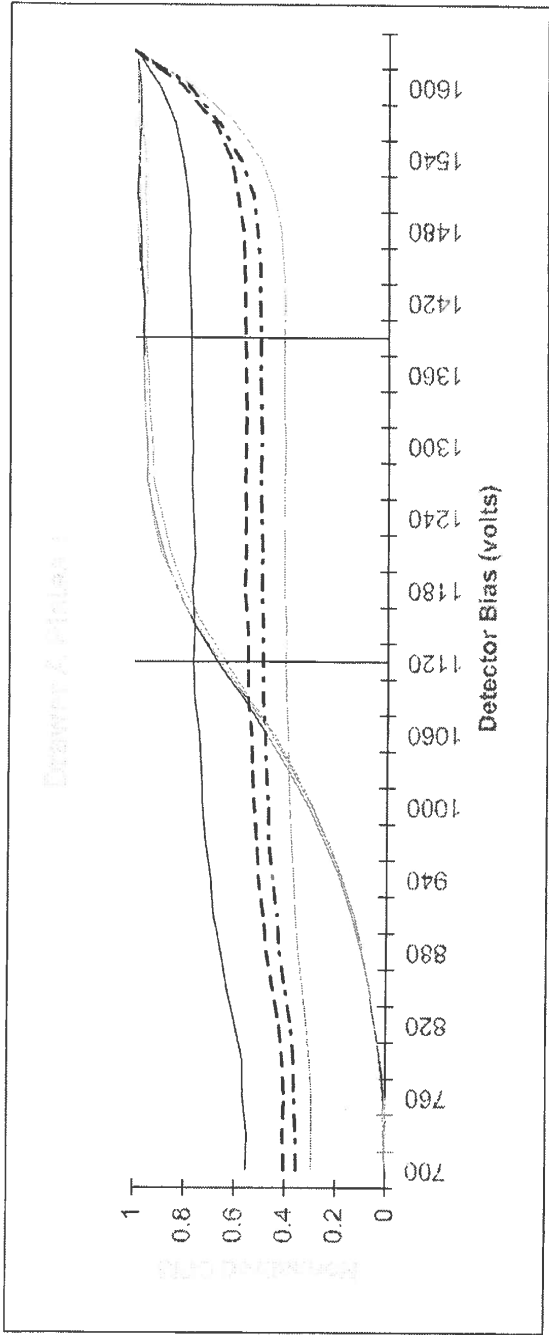
ALS Environmental -- FC

Standards DB Version: 1.11

Addendum

Unit Type: LB4100/W
Date Performed: 6/2/16 09:00
File Name: PTA0602
Batch ID: DRAWER A PLAT CHECK

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



Optimum alpha beta simultaneous operating voltage: 1402.5

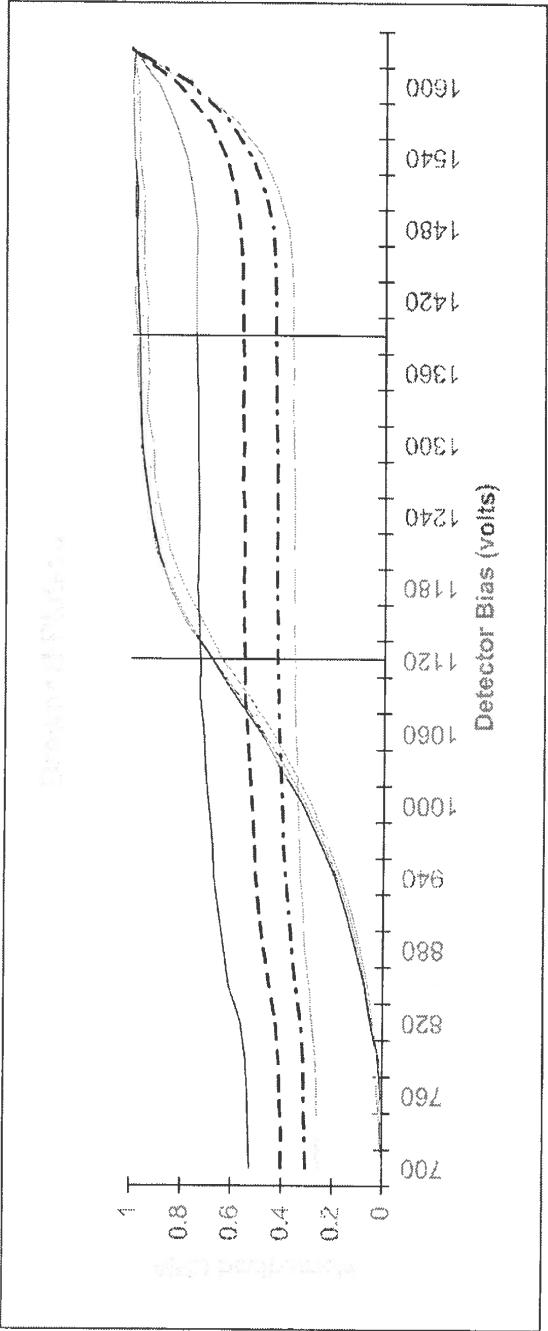
Optimum alpha only operating voltage: 1120

	A1	A2	A3	A4
Beta slope at beta voltage	1.18%	1.57%	1.58%	2.52%
Alpha slope at beta voltage	0.99%	1.20%	0.76%	0.72%
Alpha slope at alpha voltage	2.63%	3.48%	2.64%	2.19%

OK 6/3/16

Unit Type: LB4100/W
Date Performed: 6/2/16 09:00
File Name: PTB0602
Batch ID: DRAWER B PLAT CHECK

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



Optimum alpha beta simultaneous operating voltage: 1402.5

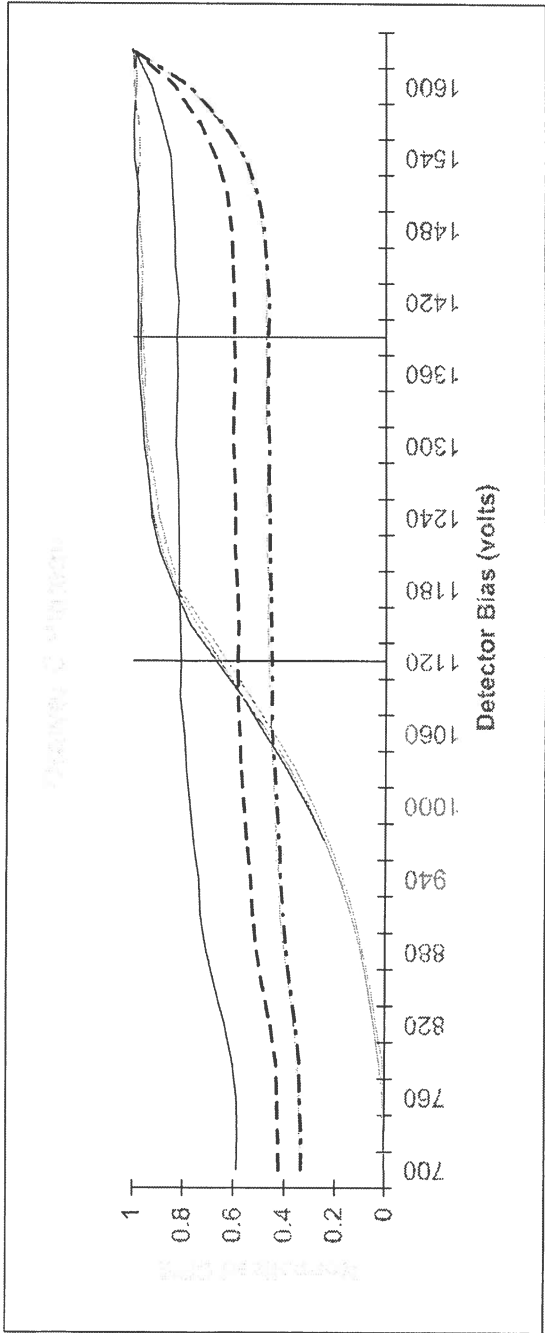
Optimum alpha only operating voltage: 1120

	B1	B2	B3	B4
Beta slope at beta voltage	1.44%	1.61%	1.23%	1.72%
Alpha slope at beta voltage	0.76%	0.74%	0.97%	1.24%
Alpha slope at alpha voltage	2.82%	2.66%	2.19%	2.27%

OK 6/3/16

Unit Type: LB4100/W
Date Performed: 6/2/16 14:38
File Name: PTC0602
Batch ID: DRAWER C PLAT CHECK

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



Optimum alpha beta simultaneous operating voltage: 1402.5

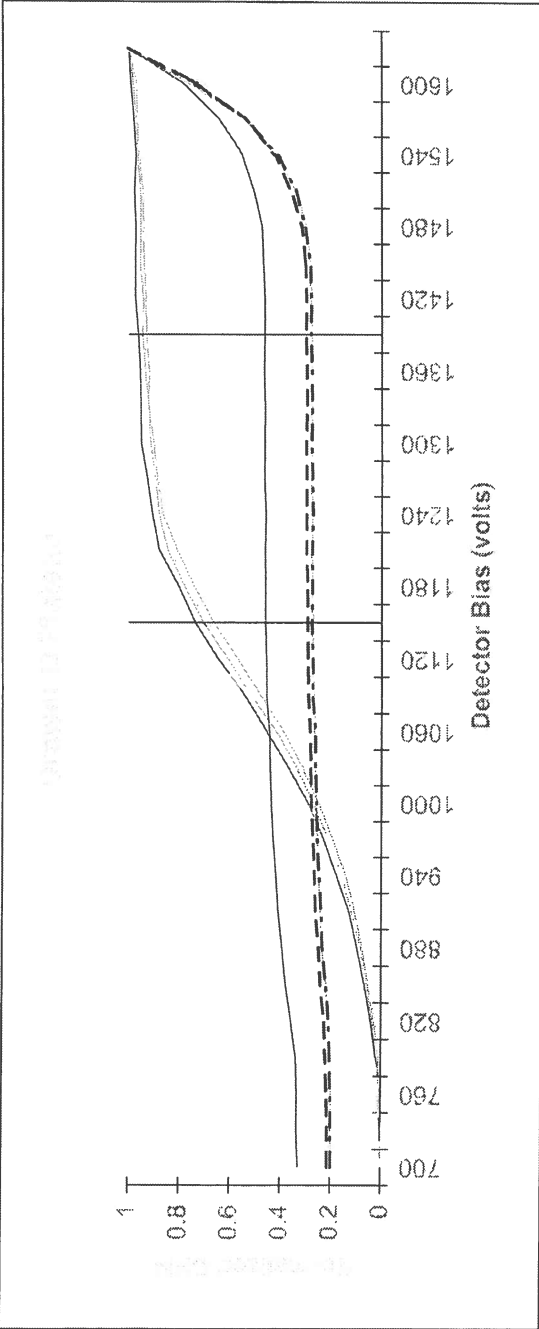
Optimum alpha only operating voltage: 1120

	C1	C2	C3	C4
Beta slope at beta voltage	1.41%	0.80%	1.18%	1.89%
Alpha slope at beta voltage	0.30%	0.41%	0.45%	0.26%
Alpha slope at alpha voltage	1.84%	1.03%	2.10%	1.37%

OK JTW/3/13

Unit Type: LB4100/W
Date Performed: 6/2/16 14:38
FileName: PTD0602
Batch ID: DRAWER D PLAT CHECK

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



Optimum alpha beta simultaneous operating voltage: 1402.5

Optimum alpha only operating voltage: 1150

	D1	D2	D3	D4
Beta slope at beta voltage	2.11%	2.90%	1.74%	0.82%
Alpha slope at beta voltage	0.97%	1.51%	2.02%	2.23%
Alpha slope at alpha voltage	1.28%	1.73%	2.15%	0.89%

OK JP 6/13/16

4/11/16 Drawn C+D removed from Instrument and sent back to Canberra in order to fix guard detector / detector slide tray connection so the 3 guard pins holding the two detectors together stop moving around and popping out when the drawers are opened & closed, resulting in \uparrow beta cpm, \downarrow gamma cpm

5-24-16 Power outage. Instrument was turned off. Turned back on when power was restored. Daily checks were performed. All in control. Instrument on-line, resumed to normal.

6-2-16

Platform check run for drawers A-D on 6-2-16.

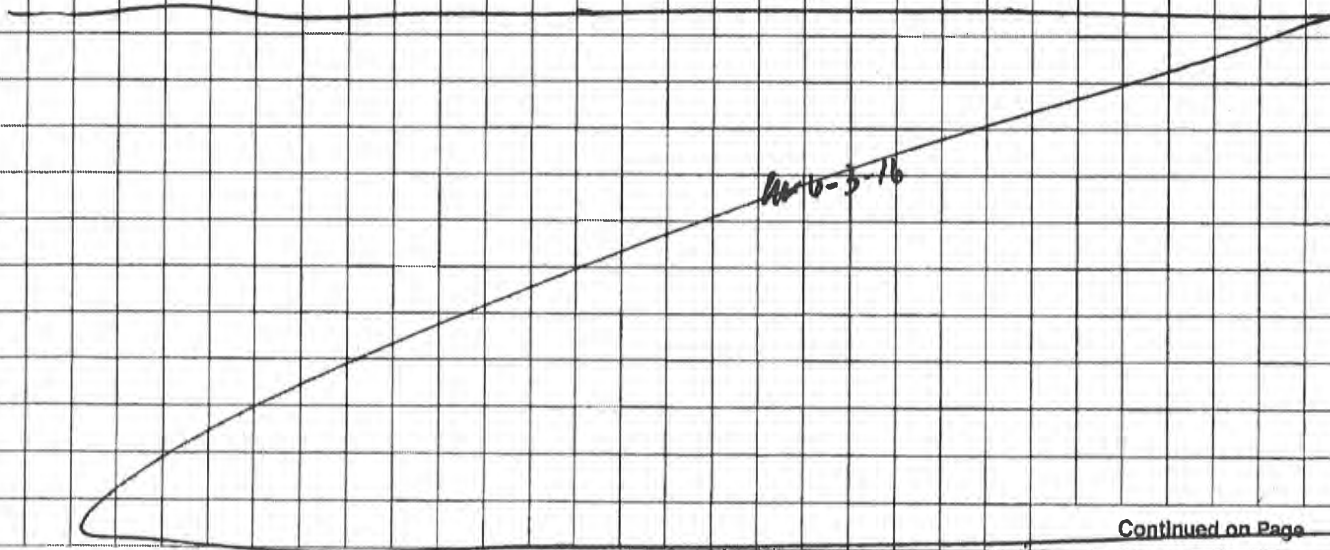
2 Sources used	Detectors	3 Sources used
410 Am241	A1 B1 C1 D1	406 Sr90/Y-90
411 17800dpm	A2 B2 C2 D2	407 29600dpm
412 2-16-95	A3 B3 C3 D3	408 9-15-95
413	A4 B4 C4 D4	409

Parameters:

Starting voltage 700 Count preset 40,000
Ending voltage 1650 Time between steps 0.1
30V/step Weak check times 0.1
5min/step Weak check limits 20

Filename:

PTA0602
PTB0602
PTC0602
PTD0602



Continued on Page

[Signature]

Signed

6-3-16

Date

Read and Understood By

[Signature]

Signed

6/3/16

Date

Date 6/2/16SOP 724r 11

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									OLB
10									P
11									
12									
13									
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	BK0531W			
Dr B				
Dr C	BK0601W			
Dr D				

Dr = Drawer

Gas Supply

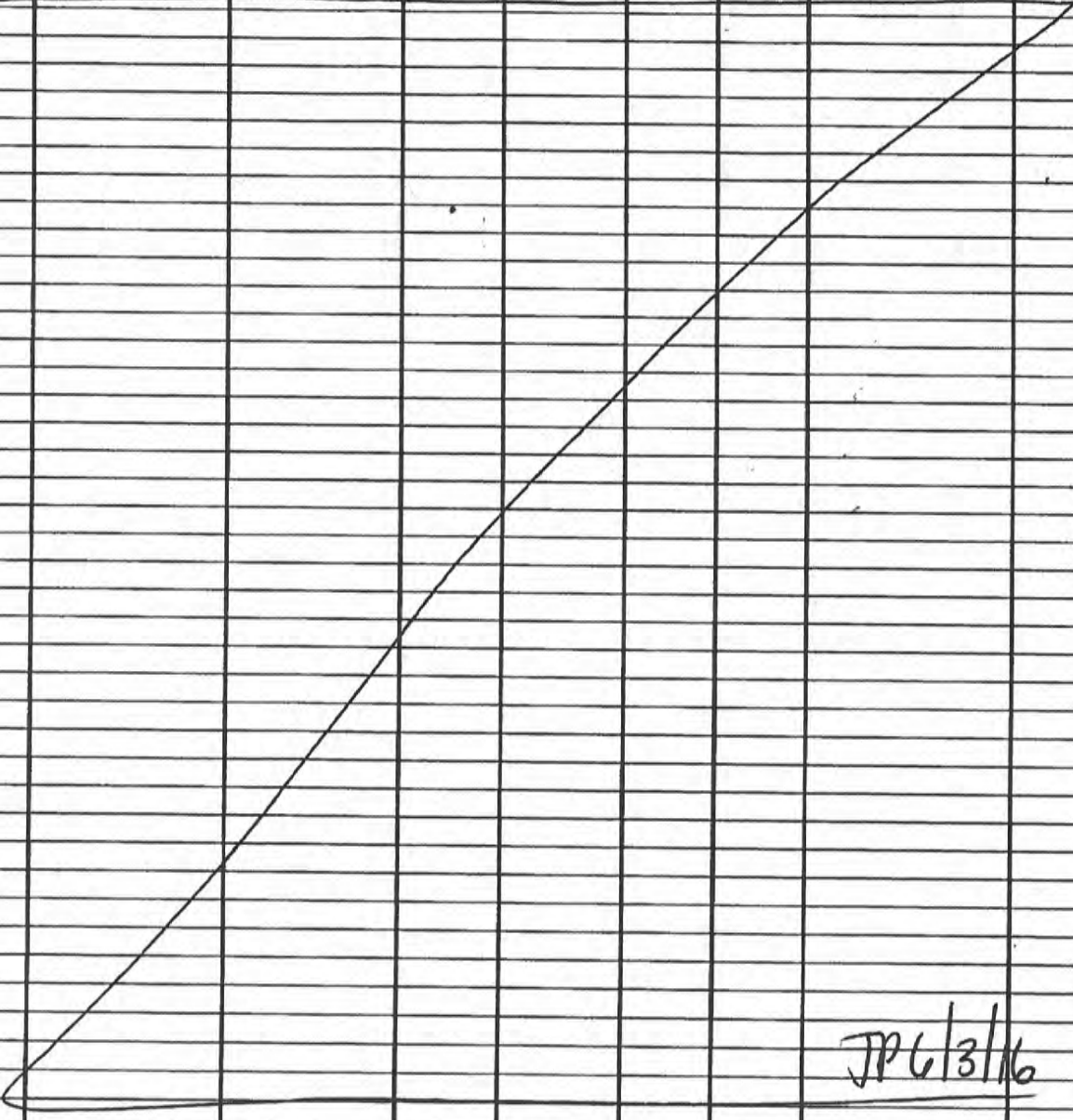
P-10 Supply		P-10 Flow	
Tank 1	1950	Dr A	10.0
		Dr B	
Tank 2	350	Dr C	
		Dr D	

Comments:Page No.: 465424 **A**

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

Reviewed By / Date UK 56-2-16
UK 6-2-16

Date 6/2/16SOP 724r 11ALS
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 EQ	—	—	30	7:33	JP	EFC0602	JP
1-16	Daily Bkg	—	—	60	7:42	JP	BK0602	JP
1-4	Alpha/Beta	Drawer A Plat Check	Plat Check	5 min/step	9:00	JP	PTA0602	JP
5-8	Beta/Alpha	Drawer B Plat Check					PTB0602	
9-12	Alpha/Beta	Drawer C Plat Check			14:38	JP	PTC0602	
13-16	Beta/Alpha	Drawer D Plat Check					PTD0602	
								
							JP 6/3/16	

Comments:

Page No.: 465424 **B**

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

Reviewed By / Date JP 6/3/16(cont. from page 11 **B**)

Ra228 ICV/ICB 06/06/16
LB4100-C

Detector	Sample ID	Sampling Date & Time	Ingrowth Date & Time	Decay Date & Time	Cnt Start Date & Time	Initial Vol	Final Vol	Count Dur	Gross CPM	Bkg CPM	Efficiency	Total Yield	Net CPM	Activity pCi/ml	TPU 2 sig	MDC	% Rec
A2	1618001-1	6/2/2016 12:00	6/2/2016 16:14	6/6/2016 8:30	6/6/2016 9:30	1500	1496	90	11,422	1,557	0.5114	0.9503	9,865	7,45E-03	2.28E-03	4.48E-04	96.0% X
B2	1618001-2	6/2/2016 12:00	6/2/2016 16:14	6/6/2016 8:30	6/6/2016 9:30	1500	1496	90	11,411	1,632	0.4908	0.9016	9,779	8.11E-03	2.48E-03	5.01E-04	104.6% X
C2	1618001-3	6/2/2016 12:00	6/2/2016 16:14	6/6/2016 8:30	6/6/2016 9:30	1500	1496	90	12,111	1,610	0.5002	0.9294	10,501	8.29E-03	2.53E-03	4.74E-04	106.9% X
D2	1618001-4	6/2/2016 12:00	6/2/2016 16:14	6/6/2016 8:30	6/6/2016 9:30	1500	1496	90	12,389	2,168	0.4949	0.8681	10,221	8.73E-03	2.67E-03	5.91E-04	112.6% X
A3	RA160601-11AMB	6/2/2016 12:00	6/2/2016 16:14	6/6/2016 8:30	6/6/2016 9:30	1500	1496	90	1,944	1,732	0.5005	0.9418	0,212	1.65E-04	2.43E-04	4.84E-04	O
B3	RA160601-11BMB	6/2/2016 12:00	6/2/2016 16:14	6/6/2016 8:30	6/6/2016 9:30	1500	1496	90	1,789	2,176	0.5008	0.9381	-0,387	-3.02E-04	2.49E-04	5.41E-04	O
C3	RA160601-11CMB	6/2/2016 12:00	6/2/2016 16:14	6/6/2016 8:30	6/6/2016 9:30	1500	1496	90	1,889	1,564	0.4975	0.9084	0,125	1.02E-04	2.34E-04	4.80E-04	O
D3	RA160601-11DMB	6/2/2016 12:00	6/2/2016 16:14	6/6/2016 8:30	6/6/2016 9:30	1500	1496	90	2,000	1,634	0.5104	0.9204	0,366	2.86E-04	2.56E-04	4.72E-04	O

Spike Information

Spike ID	Ref Date	Ref activity DPM/mL	Ra-228 Act DPM/mL	Spike Vol mL	Ra-228 Act Added
966.4095.79	10/7/2010	204.32	103.34	0.3	7.76E-03

DECAY and INGROWTH corrections to K (activity equation denominator)

Sample ID	Ra-228 Decay	Ac-228 Ingrowth	Ac-228 Decay	Decay during count	K
1618001-1	0.9987	1.0000	0.8931	0.9198	1324.0657
1618001-2	0.9987	1.0000	0.8931	0.9198	1205.6092
1618001-3	0.9987	1.0000	0.8931	0.9198	1266.5853
1618001-4	0.9987	1.0000	0.8931	0.9198	1170.5105
RA160601-11AMB	0.9987	1.0000	0.8931	0.9198	1284.2538
RA160601-11BMB	0.9987	1.0000	0.8931	0.9198	1279.9752
RA160601-11CMB	0.9987	1.0000	0.8931	0.9198	1231.2842
RA160601-11DMB	0.9987	1.0000	0.8931	0.9198	1279.8980

1 sig CU	1 sig TPU
2.71E-04	1.14E-03
2.97E-04	1.24E-03
2.91E-04	1.26E-03
3.19E-04	1.33E-03
1.19E-04	1.21E-04
1.16E-04	1.24E-04
1.16E-04	1.17E-04
1.21E-04	1.28E-04

X Acceptance Criteria = 70 - 130%

O Acceptance Criteria = Activity < MDCA and Standard MDC (1.0) achieved and |negative-activity| < 2 sigma TPU.

* RA160601-11BMB has negative activity > 2σ TPU, but < 3σ TPU
OK per SOP 715.

JP 6/7/16

PAI - Gas Flow Proportional Sample Analysis LB4100-C

Unit Type: LB4100 -C
Counting Unit ID: Magenta
High Voltage Mode: Simultaneous
Application Revision: Standard
Rev.12/07/08 JCP

Data file name: RAC0606
Batch ID: RA160601-11
Count Preset (m): 90
Batch Ended: 6/6/2016 11:01

2

Background logfile: BKGABW
Date of Bkg. Cal: 6/1/2016
Alpha efficiency logfile: AAM0606_0607
Alpha attenuation calibration: RAC28-06/15
Beta efficiency logfile: ASR0607
Beta attenuation calibration: n/a

Alpha prog. logfile: n/a
Alpha prog. attenuation: n/a
Beta prog. logfile: n/a
Beta prog. attenuation: n/a

Alpha Attenuation Calibration $y = b \cdot m^a (a^*(\text{mass} \cdot x))$	Beta Attenuation Calibration $y = b \cdot m^a (a^*(\text{mass} \cdot x))$
Alpha b= m= a= x0=	Beta b= m= a= x0=
Alpha to Beta X-talk $y = b \cdot m^a$ a -> b xtalk b= a -> b xtalk m=	Beta to Alpha X-talk $y = b \cdot m^a$ b -> a xtalk b= b -> a xtalk m=

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
A2	1618001-1	6/6/2016 11:00	90.00	0.0	0.211	0.124	0.036	0.2263	1.058	n/a	n/a	11.422	1.557	0.0219
A3	RA160601-11AMB	6/6/2016 11:00	90.00	0.0	0.200	0.095	0.001	0.2196	1.058	n/a	n/a	1.944	1.732	0.0264
B2	1618001-2	6/6/2016 11:01	90.00	0.0	0.300	0.113	0.035	0.2189	1.058	n/a	n/a	11.411	1.632	0.0470
B3	RA160601-11BMB	6/6/2016 11:01	90.00	0.0	0.156	0.104	0.000	0.2088	1.058	n/a	n/a	1.789	2.176	0.0129
C2	1618001-3	6/6/2016 11:01	90.00	0.0	0.322	0.116	0.038	0.2279	1.058	n/a	n/a	12.111	1.810	0.0518
C3	RA160601-11CMB	6/6/2016 11:01	90.00	0.0	0.156	0.108	0.000	0.2135	1.058	n/a	n/a	1.689	1.564	0.0119
D2	1618001-4	6/6/2016 11:01	90.00	0.0	0.356	0.119	0.037	0.2240	1.058	n/a	n/a	12.389	2.168	0.0594
D3	RA160601-11DWB	6/6/2016 11:01	90.00	0.0	0.144	0.101	0.001	0.2222	1.058	n/a	n/a	2.000	1.634	0.0109

JP 6/7/16
ML 6-6-16

Date

6/6/16

SOP 724r

11

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									

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	BKCP521W			
Dr B				
Dr C	BKCP601W 1003W			
Dr D				

Dr = Drawer

Gas Supply

P-10 Supply		P-10 Flow	
Tank 1	650	Dr A	10
		Dr B	
Tank 2	350	Dr C	
		Dr D	

Comments:

Date 6/6/16SOP 724r 11

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 EP	—	—	30	6:59	JP	EP060606	JP
1-16	Daily BKG	—	—	60	7:12	JP	BKG060606	JP
2	1618001-1	RA160601-11	2-228	90	9:30	u	RA060606	u
6	—	—	—	—	—	—	—	—
10	—	—	—	—	—	—	—	—
14	—	—	—	—	—	—	—	—
3	RA160601-11AMB	—	—	—	—	—	—	—
7	—	—	—	—	—	—	—	—
11	—	—	—	—	—	—	—	—
15	—	—	—	—	—	—	—	—
1	1605181-14	AB160601-2	2.1B	75	9:34	u	AB060606	—
4	—	—	—	—	—	—	—	—
5	—	—	—	—	—	—	—	—
8	—	—	—	—	—	—	—	—
9	—	—	—	—	—	—	—	—
12	—	—	—	—	—	—	—	—
13	AB160601-2 LLS	—	—	—	—	—	—	—
1	1606046-1	AB160606-1	2.1B	10	11:25	u	AB060606A	—
2	—	—	—	—	—	—	—	—
3	—	—	—	—	—	—	—	—
4	—	—	—	—	—	—	—	—
5	—	—	—	—	—	—	—	—
6	—	—	—	—	—	—	—	—
7	—	—	—	—	—	—	—	—
8	—	—	—	—	—	—	—	—
9	—	—	—	—	—	—	—	—
10	—	—	—	—	—	—	—	—
11	—	—	—	—	—	—	—	—
12	—	—	—	—	—	—	—	—
13	—	—	—	—	—	—	—	—
14	—	—	—	—	—	—	—	—
15	—	—	—	—	—	—	—	—
16	—	—	—	—	—	—	—	—
1	—	—	—	—	11:43	—	AB060606B	—
2	—	—	—	—	—	—	—	—
3	—	—	—	—	—	—	—	—
4	—	—	—	—	—	—	—	—
5	—	—	—	—	—	—	—	—
6	AB160606-1A LLS	—	—	—	—	—	—	—
7	—	—	—	—	—	—	—	—
8	—	—	—	—	—	—	—	—
9	1606046-21	AB160606-2	—	—	—	—	—	—
10	—	—	—	—	—	—	—	—
11	—	—	—	—	—	—	—	—
12	—	—	—	—	—	—	—	—
13	—	—	—	—	—	—	—	—
14	AB160606-2MB	—	—	—	—	—	—	—

Comments:

Page No.: 465426 **B**
(cont. from page WA **B**)

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

Reviewed By / Date u 6-6-16

Radiochemistry ICP Worksheet

ALS Environmental -- FC

Prep Batch: RA160601-11

Prep Procedure: Ra228

Reviewed By: sji

Review Date: 6/6/2016

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
RA160601-11	CAR	2	27	0.05	10.05	IR160602-2A1	5.905627

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 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	1618001-1	SMP	1500	2	1500	1	1499	1499	1499	25	0.05	10.05	IR160602-2A1	IR160602-2A1	-0.0007	6.061118	0	32049.84	Z	30457.12	95.03%	1496
1	1618001-2	SMP	1500	2	1500	1	1499	1499	1499	25	0.05	10.05	IR160602-2A1	IR160602-2A1	-0.0007	5.750334	0	32049.84	Z	28895.43	90.16%	1496
1	1618001-3	SMP	1500	2	1500	1	1499	1499	1499	25	0.05	10.05	IR160602-2A1	IR160602-2A1	-0.0006	5.92755	0	32049.84	Z	29785.94	92.94%	1496
1	1618001-4	SMP	1500	2	1500	1	1499	1499	1499	25	0.05	10.05	IR160602-2A1	IR160602-2A1	-0.0007	5.536992	0	32049.84	Z	27823.38	86.81%	1496
1	RA160601-11A	MB	1500	2	1500	1	1499	1499	1499	25	0.05	10.05	IR160602-2A1	IR160602-2A1	-0.0006	6.006879	0	32049.84	Z	30184.57	94.18%	1496
1	RA160601-11B	MB	1500	2	1500	1	1499	1499	1499	25	0.05	10.05	IR160602-2A1	IR160602-2A1	-0.0007	5.983223	0	32049.84	Z	30065.7	93.81%	1496
1	RA160601-11C	MB	1500	2	1500	1	1499	1499	1499	25	0.05	10.05	IR160602-2A1	IR160602-2A1	-0.0007	5.793636	0	32049.84	Z	29113.02	90.84%	1496
1	RA160601-11E	MB	1500	2	1500	1	1499	1499	1499	25	0.05	10.05	IR160602-2A1	IR160602-2A1	-0.0007	5.870391	0	32049.84	Z	29498.71	92.04%	1496

10160602-2A

Sample Id1	Ca	Fe	K	Mg	Na	Sr	Mn	S	Al	Ba	Pb	Ni
CCV	49.7705	19.6805	48.7493	48.4416	49.3697	0.4909	0.9721	4.7102	47.7603	0.9852	0.9584	1.0575
CCB	0.0557	0.0333	0.1252	0.0543	0.0545	0.0004	0.0011	0.0000	0.1426	0.0007	-0.0020	0.0009
I 1618001-1	-0.0140	0.0049	0.0616	-0.0072	-0.0090	-0.0003	-0.0003	-0.0105	0.1152	-0.0007	-0.0006	0.0023
I 1618001-2	-0.0179	-0.0034	0.0601	-0.0115	-0.0095	-0.0003	0.0000	-0.0035	0.1057	-0.0007	-0.0029	-0.0005
I 1618001-3	-0.0196	-0.0003	0.0705	-0.0048	-0.0103	-0.0002	-0.0003	-0.0035	0.1146	-0.0006	-0.0022	0.0003
I 1618001-4	-0.0112	-0.0032	0.0422	-0.0096	-0.0105	-0.0002	-0.0002	-0.0035	0.1184	-0.0007	-0.0023	0.0001
I RA160601-11AMB	-0.0210	-0.0041	0.0442	-0.0062	-0.0101	-0.0002	-0.0001	-0.0035	0.1267	-0.0006	-0.0027	0.0007
I RA160601-11BMB	-0.0199	-0.0054	0.0626	-0.0125	-0.0104	-0.0003	-0.0003	-0.0035	0.1209	-0.0007	-0.0019	-0.0002
I RA160601-11CMB	-0.0196	-0.0041	0.0363	-0.0010	-0.0091	-0.0003	-0.0002	-0.0105	0.1305	-0.0007	0.0001	-0.0002
I RA160601-11DMB	-0.0230	0.0084	0.0740	-0.0086	-0.0102	-0.0003	-0.0003	0.0000	0.1279	-0.0007	-0.0025	-0.0012
Z	-0.0126	-0.0034	0.0536	-0.0130	101.2024	0.0001	-0.0004	1.7563	0.1311	6.9240	0.0869	0.0044
Z	-0.0146	0.0055	0.0914	-0.0091	102.8258	0.0000	0.0000	1.7318	0.1197	6.8321	0.0566	0.0021
Z	-0.0182	-0.0031	0.1043	-0.0034	93.3999	0.0001	-0.0001	1.5677	0.1177	6.2429	0.0667	0.0018
Z	-0.0199	-0.0012	0.1003	-0.0053	114.7748	0.0001	-0.0003	2.0112	0.1101	7.9883	0.0847	0.0003
Z	-0.0176	-0.0023	0.1222	-0.0010	131.4571	0.0003	-0.0001	2.4686	0.1165	9.5907	0.1246	0.0019
Z	-0.0188	-0.0038	0.0894	-0.0091	92.8087	0.0002	-0.0003	1.5992	0.1114	6.1094	0.1104	0.0003
Z	-0.0193	-0.0029	0.1147	-0.0010	101.0485	0.0000	0.0000	1.7668	0.1101	6.7922	0.1329	0.0006
Z	-0.0224	-0.0040	0.0993	-0.0134	107.7285	0.0000	-0.0004	2.1718	0.1108	7.4211	1.0740	-0.0004
Z	-0.0213	-0.0036	0.0924	-0.0072	96.7437	0.0000	-0.0002	-0.0105	0.1152	6.8936	-0.0002	0.0004
CCV	49.9583	19.7471	49.0503	48.5664	49.4246	0.4938	0.9729	4.7242	47.9295	0.9960	0.9531	1.0643
CCB	0.0591	0.0352	0.1371	0.0624	0.0718	0.0005	0.0012	-0.0035	0.1667	0.0014	0.0020	0.0013
F 1618001-1	-0.0084	-0.0025	0.0765	-0.0096	90.9063	0.0001	-0.0001	1.5258	0.1229	6.0611	0.0752	0.0036
F 1618001-2	-0.0115	0.0021	0.1018	-0.0024	89.7677	0.0000	-0.0001	1.4420	0.1298	5.7503	0.0483	0.0030
F 1618001-3	-0.0165	-0.0026	0.0735	-0.0024	89.8020	0.0000	-0.0001	1.4874	0.1336	5.9276	0.0662	0.0008
F 1618001-4	-0.0137	0.0035	0.1078	-0.0010	85.4919	0.0000	-0.0001	1.3827	0.1311	5.5370	0.0587	0.0002
F RA160601-11AMB	-0.0171	-0.0018	0.0934	-0.0048	90.9014	0.0001	-0.0001	1.5084	0.1273	6.0069	0.0763	0.0008
F RA160601-11BMB	-0.0132	-0.0012	0.0934	-0.0048	91.4378	0.0002	-0.0001	1.5468	0.1292	5.9832	0.1065	0.0003
F RA160601-11CMB	-0.0148	-0.0008	0.1028	-0.0024	89.1801	0.0000	0.0000	1.4490	0.1298	5.7936	0.1138	0.0002
F RA160601-11DMB	-0.0157	-0.0033	0.1277	0.0019	89.4338	0.0001	0.0000	1.7353	0.1260	5.8704	0.8334	0.0006
RA160601-11RC	-0.0171	-0.0036	0.0844	-0.0062	85.9017	0.0000	-0.0001	0.0140	0.1203	5.9056	0.0028	0.0003
CCV	50.0823	19.7983	49.2465	48.6769	49.5944	0.4959	0.9748	4.6823	48.0064	0.9978	0.9502	1.0745
CCB	0.0624	0.0357	0.1500	0.0696	0.0749	0.0005	0.0012	-0.0035	0.1807	0.0013	0.0007	0.0004

Radiochemistry Instrument Worksheet

ALS Environmental -- FC

Prep Batch: RA160601-11

Prep Procedure: Ra228

Analytical QASS / NCR? Y / N *MP*

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	1618001-1	SMP	1500	1496.0	ml	pCi/l											
1	1618001-2	SMP	1500	1496.0	ml	pCi/l											
1	1618001-3	SMP	1500	1496.0	ml	pCi/l											
1	1618001-4	SMP	1500	1496.0	ml	pCi/l											
1	RA160601-11A	MB	1500	1496.0	ml	pCi/l											
1	RA160601-11B	MB	1500	1496.0	ml	pCi/l											
1	RA160601-11C	MB	1500	1496.0	ml	pCi/l											
1	RA160601-11E	MB	1500	1496.0	ml	pCi/l											

Tracer/Carrier Solution Information

Soln #	Nuclide	SolnID	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
T1	BARIUM	418230	16,024.623	pCi/ml	NA	2	ml	AW017

Spike Solution Information

Soln #	Nuclide	SolnID	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
S1	Ra-228	1014.4095.79	103.368	DPM/ml	06/01/16	0.25	ml	AW016

Sample Barcodes

1618001-1 RA160601-11PS1		1618001-2 RA160601-11PS2		1618001-3 RA160601-11PS3	
1618001-4 RA160601-11PS4		RA160601-11AMB RA160601-11PS5		RA160601-11BMB RA160601-11PS6	
RA160601-11CMB RA160601-11PS7		RA160601-11EMB RA160601-11PS8		RA160601-11CAR RA160601-11PS9	

Reporting Units

LabID:	TstGrpName:	RptUnits:
1618001-1	Ra228_2012	pCi/l
1618001-2	Ra228_2012	pCi/l
1618001-3	Ra228_2012	pCi/l
1618001-4	Ra228_2012	pCi/l

Radiochemistry Prep Worksheet

ALS Environmental -- FC

Prep Batch: RA160601-11

Prep Procedure: Ra228

Reviewed By: sjj/1 Review Date: 6/6/2016

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

Prep SOP: SOP749 Rev: 2
Prep SOP: NONE
Matrix Class: liquid
Prep Analyst: Samuel J. Ingram
Prep Date: 6/1/2016
Prep Dept: RS
Balance: N/A
Balance: N/A

Samp Num	LabID	QC Type	Dish No.	Init Aliq ml	Fin Aliq ml	Prep Basis	Ingrowth Date/Time	Decay Date/Time	Standards	Prep Notes
1	1618001-1	SMP	NA	1500	1496.002	Unfiltered	06/02/16 16:14	06/06/16 08:30	S1, T1	
2	1618001-2	SMP		1500	1496.002	Unfiltered	06/02/16 16:14	06/06/16 08:30	S1, T1	
3	1618001-3	SMP		1500	1496.002	Unfiltered	06/02/16 16:14	06/06/16 08:30	S1, T1	
4	1618001-4	SMP		1500	1496.002	Unfiltered	06/02/16 16:14	06/06/16 08:30	S1, T1	
5	1618001-11A	MB		1500	1496.002	Unfiltered	06/02/16 16:14	06/06/16 08:30	T1	
6	1618001-11B	MB		1500	1496.002	Unfiltered	06/02/16 16:14	06/06/16 08:30	T1	
7	1618001-11C	MB		1500	1496.002	Unfiltered	06/02/16 16:14	06/06/16 08:30	T1	
8	1618001-11E	MB		1500	1496.002	Unfiltered	06/02/16 16:14	06/06/16 08:30	T1	

Comments

Spiked By: Samuel J. Ingram Date: 6/1/2016
Witnessed By: Bryan A. Terry Date: 6/1/2016

Yttrium Added By: NA Date: NA
Witnessed By: NA Date: NA

Tracer/Carrier Solution Information					
Soln #	Nuclide	SolnID	Prep Conc	Units	Pipet ID
T1	BARIUM	418230	16,024.623	pCi/ml	NA
				2	ml
					AW017

Spike Solution Information					
Soln #	Nuclide	SolnID	Prep Conc	Units	Pipet ID
S1	Ra-228	1014.4095.79	103.368	DPM/ml	06/01/16
				0.25	ml
					AW016

Reagent Solution IDs*

418202 50266 51144 B0441604 K01475

*Except where otherwise noted, all reagents were applied in accordance with the specifications of the preparation methods associated with this batch.

Radiochemistry Prep Worksheet

Prep Batch: RA160601-11

ALS Environmental -- FC

Prep Procedure: Ra228

Prep Batch Not Validated!!!

Reviewed By: Review Date:

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

Prep SOP: SOP749 Rev: 2

Prep SOP: NONE

Matrix Class: liquid

Prep Analyst: Samuel J. Ingram

Prep Date: 6/1/2016

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	1618001-1	SMP		1500	1500	Unfiltered	6-2-16 1614	6-6-16 0800	S1,T1	
2	1	1618001-2	SMP		1500	1500	Unfiltered			S1,T1	
3	1	1618001-3	SMP		1500	1500	Unfiltered			S1,T1	
4	1	1618001-4	SMP		1500	1500	Unfiltered			S1,T1	
5	1	RA160601-11A	MB		1500	1500	Unfiltered			T1	
6	1	RA160601-11B	MB		1500	1500	Unfiltered			T1	
7	1	RA160601-11C	MB		1500	1500	Unfiltered			T1	
8	1	RA160601-11D	MB		1500	1500	Unfiltered			T1	

Comments: Sample Returned EMB to import Data

Spiked By: Samuel J. Ingram Date: 6-1-16

Witnessed By: BKT Date: 6/1/16

Yttrium Added By:

Witnessed By:

Date:

Date:

Tracer/Carrier Solution Information

Soln #	Nuclide	SolnID	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
T1	BARIUM	418230	16,024.623	pCi/ml	NA	2	ml	AW017

Spike Solution Information

Soln #	Nuclide	SolnID	Prep Conc	Units	Prep Date	Aliquot	Units	Pipet ID
S1	Ra-228	1014.4095.79	103.368	DPM/ml	06/01/16	0.25	ml	AW016

Reagent Solution IDs*

418202	50266	51144	B0441604	K01475
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*Except where otherwise noted, all reagents were applied in accordance with the specifications of the preparation methods associated with this batch.

Exp 12/1/16

Exp: 4/2/2017

Sample Condition Form (Liquid)				
Analyst: <u>Sami Iyem</u>				
Analysis Date: <u>6.6.16</u>		Method: <u>Prep</u>		
		Sample Condition (Visual Appearance of Analysis Aliquot at Time of Prep)		
Work Order	Sample ID	pH	Color	Remarks
<u>1618001</u>	<u>1</u>	<u>7</u>	<u>colorless</u>	<u>D.I. Water</u>
<u>↓</u>	<u>2</u>	<u>↓</u>	<u>↓</u>	<u>↓</u>
<u>↓</u>	<u>3</u>	<u>↓</u>	<u>↓</u>	<u>↓</u>
<u>↓</u>	<u>4</u>	<u>↓</u>	<u>↓</u>	<u>↓</u>

Project

Continued from Page

Ra-228 working standard 1014.4095.79

Prepare a working dilution of RSO# 1014

12/11/15

1. Density of 8% HNO₃, lot # 0000084176

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:

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

12/11/15

JP 4/15/15

Sind 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

JP 4/15/15

Continued on Page

Signed

Date

Read and Understood By

Signed

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.

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Gaithersburg, Maryland 20899
Certificate Issue Date: 14 November 2012

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

SRM 4339b

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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>.

Radiochemistry Solution Report

Solution Id: 418230	Name: Barium carrier	Lot:	Vendor Name:	Type: IS
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Final Vol: 4000	Dept: RD	Prep By TDE	Reviewed By piw	on 12/1/2015
Units: mL	Location: SR/RA	Opened By	Verified By PJW	on 12/1/2015
Matrix: LIQUID	ExpireDate: 12/1/2016	Received By	Deactivated By	on

Comment:

Component Name		Component ID	Volume Added	Units
Barium Stable Carrier Source<1>		3756 B07592	114.015	g

CompName	Calibrated Primary Act/Conc	Calibration Reference Date	1/2 Life (Yrs)	Final Act/Conc	Summed Conc	Units
BARIUM	562193.5	1/26/2016		16024.62		pCi/ml

Associated Parent IDs

3756 B07592

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

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

Date Printed: Tuesday, January 26, 2016

ALS Environmental -- FC

Standards DB Version: 1.11

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