WSRC-TR-2006-00093
Revision 0

NEPHELINE FORMATION STUDY FOR SLUDGE BATCH 4 (SB4): PHASE 3 EXPERIMENTAL RESULTS

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Prepared for the U.S. Department of Energy Under
Contract Number DEAC09-96SR18500

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Prepared For
U.S. Department of Energy

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Keywords: *glass, durability, crystallization, nepheline*

Retention: *permanent*

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SAVANNAH RIVER NATIONAL LABORATORY

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EXECUTIVE SUMMARY

This Phase 3 study was undertaken to complement the previous phases of the nepheline formation studies[1, 2] by continuing the investigation into the ability of the nepheline discriminator to predict the occurrence of nepheline crystallization in Sludge Batch 4 (SB4) glasses and into the impact of such phases on the durability of the SB4 glasses. The Phase 3 study had two primary objectives. The first was to continue to demonstrate the ability of the discriminator value to adequately predict the nepheline formation potential for specific glass systems of interest. The second was to generate additional data that have a high probability of supporting the SB4 variability study. To support these two objectives, sixteen glasses were selected based on the most recent SB4 compositional projection, Case 15C Blend 1.[3] Four different frits were included, based on previous assessments of projected operating windows and melt rate,[4, 5] with four WLs selected for each frit. Eight of these frit-sludge combinations covered WLs which tightly bound the nepheline discriminator value of 0.62, with the intent of refining this value to a level of confidence where it can be incorporated into offline administrative controls and/or the Process Composition Control System (PCCS) to support Slurry Mix Evaporator (SME) acceptability decisions. The remaining eight frit-sludge combinations targeted lower WLs (35 and 40%) and were prepared and analyzed to contribute needed data to the ComPro™ database[6] to support a potential variability study for SB4.

Each Phase 3 glass was batched and melted following established SRNL procedures.[7, 8] Specimens of each glass were heat-treated to simulate cooling along the centerline of a DWPF-type canister (ccc)[9] to gauge the effects of thermal history on the product performance. Visual observations on both quenched and ccc glasses were documented. A representative sample from each glass was submitted to the SRNL Process Science Analytical Laboratory (PSAL) for chemical analysis to confirm that the as-fabricated glasses corresponded to the defined target compositions. The Product Consistency Test (PCT)[10] was performed in triplicate on each Phase 3 quenched and ccc glass to assess chemical durability. The experimental test matrix also included the Environmental Assessment (EA) glass[11] and the Approved Reference Material (ARM) glass. Representative samples of all Phase 3 ccc glasses were submitted to Analytical Development (AD) for X-ray diffraction (XRD) analysis.

Chemical composition measurements indicated that the experimental glasses were close to their target compositions. The chemical composition data suggest essentially full retention of SO_4^{2-} in the glass (i.e., no volatilization during the fabrication process). There were no signs of a salt layer on any of the Phase 3 glasses upon cooling. These results suggest that the 0.6 wt% SO_4^{2-} limit is applicable for the SB4 system.

PCT results showed that all of the Phase 3 quenched glasses were acceptable as compared with the EA reference glass. The highest normalized release for boron (NL [B]) for the quenched glasses was 1.26 g/L, as compared to 16.695 g/L for the EA glass.[11] The durabilities of some of the ccc glasses, particularly those with higher WLs, were statistically greater than their quenched counterparts. However, this was shown to be of little practical significance, as the durabilities of the ccc glasses were also all considerably better than that of the EA reference glass, with the highest NL [B] being 3.23 g/L. All but one of the glasses in the Phase 3 study had durabilities that were predictable based on the ΔG_P model. The glass that was not predicable using the model contained both spinel and nepheline, and had a nepheline discriminator value of less than 0.62. Since the glass was not homogenous, it is expected that the model will not correctly predict its performance.[12] Also, a glass with a nepheline discriminator value of less than 0.62 is likely to be screened out from production at DWPF upon implementation of a nepheline discriminator in PCCS.

Visual observations and PCT results indicated that all of the Phase 3 quenched glasses were amorphous. For the ccc glasses, XRD results indicated that the lower WL glasses (35 and 40 wt%) in each frit-sludge group were amorphous. The higher WL glasses in each frit-sludge group were shown by XRD to contain spinel (trevorite, $NiFe_2O_4$). XRD showed that two of the highest WL glasses contained nepheline ($NaAlSiO_4$) as well. It is possible that some of the other high WL glasses also contained some nepheline, but that the amount of nepheline crystallization was below the detection limit associated with XRD (estimated to be ~0.5 wt%). Nepheline crystallization was shown to result in a decrease in durability for some of the high WL glasses. In the worst case (within the glasses studied here), the NL [B] increased from 1.26 g/L (quenched) to 3.23 g/L (ccc). However, this NL [B] is still acceptable as compared to the EA reference glass (16.695 g/L).[11]

The results of the Phase 3 study concur with the earlier phases of the nepheline studies in that a nepheline discriminator of 0.62 appears to be the appropriate value for screening out glasses with the potential for nepheline crystallization (and therefore reduced chemical durabilities) upon slow cooling. The nepheline discriminator was also useful in screening out a glass that would be unpredictable by the ΔG_P model.[12] Further discussion of a nepheline discriminator for possible inclusion in DWPF process controls will be addressed in a forthcoming report.

With respect to frit selection for SB4, the Phase 3 results indicate that Frits 418, 425, 501 and 502 are all acceptable candidates, based on chemical durability and devitrification upon slow cooling. Differences in chemical durability and devitrification behavior were relatively small between the four frits studied as part of Phase 3. The results also indicate that WLs of 35-40 wt% should produce acceptable glasses with these frits. However, melt rate is also an important factor in frit selection. Melt rate studies on these frits are currently underway, and will likely have a significant impact on frit selection due to the high Al_2O_3 content of SB4.

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AD	Analytical Development
ANOVA	Analysis of Variance
ARM	Approved Reference Material glass
ARP	Actinide Removal Process
bc	bias-corrected
CBU	Closure Business Unit
ccc	centerline canister cooled
DWPF	Defense Waste Processing Facility
EA	Environmental Assessment glass
HLW	High Level Waste
ICP-AES	Inductively Coupled Plasma – Atomic Emission Spectroscopy
LM	lithium-metaborate dissolution
LWO	Liquid Waste Operations
MAR	Measurement Acceptability Region
PCCS	Product Composition Control System
PCT	Product Consistency Test
PF	sodium peroxide fusion dissolution
PSAL	Process Science Analytical Laboratory
SB4 / SB5	Sludge Batch 4 / Sludge Batch 5
SME	Slurry Mix Evaporator
SRL	Savannah River Laboratory
SRNL	Savannah River National Laboratory
T_L	liquidus temperature
WL	Waste Loading (weight percent)
XRD	X-Ray Diffraction

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1.0 Introduction

Crystallization (or devitrification) is an important factor in the processing and performance of nuclear waste glass. In terms of processing, the Defense Waste Processing Facility (DWPF) uses a liquidus temperature (T_L) model[13] and an imposed T_L limit for feed acceptability to avoid bulk devitrification within the melter. In terms of product quality or the durability of the waste form, the impact of devitrification depends on the type and extent of crystallization.

Numerous studies[9, 14-19] have assessed the potential for devitrification in various high level waste (HLW) glasses and its impact on durability. These studies generally agree that the impact of devitrification on durability is dependent upon the type and extent of crystallization. For example, a strong increase in the rate of glass dissolution (or decrease in durability) was observed in previous studies[16, 20, 21] of glasses that formed aluminum-containing crystals, such as $NaAlSiO_4$ (nepheline) and $LiAlSi_2O_6$, or crystalline SiO_2. This is in contrast to the results from a study by Bickford and Jantzen.[14] Their results indicated that the formation of spinel had little or no effect on the durability of Savannah River Laboratory (SRL) 165- or SRL 131-based glasses, while the formation of acmite produced a small but noticeable increase in the rate of dissolution of the matrix glass. The impact of devitrification on durability is complex and depends on several interrelated factors including the change in residual glass composition, the development of internal stress or microcracks, and preferential attack at the glass – crystal interface.

While the addition of Al_2O_3 to borosilicate glasses generally enhances the durability of the waste form (through creation of network-forming tetrahedral Na^+-$[AlO_{4/2}]^-$ pairs), nepheline formation, which depends in part on the Al_2O_3 content, can result in severe deterioration of the chemical durability of the glass through residual glass compositional changes. Three moles of glass forming oxides (Al_2O_3 and $2SiO_2$) are removed from the continuous glass phase per each mole of Na_2O as nepheline crystallizes. Therefore, nepheline formation produces an Al_2O_3 and SiO_2 deficient continuous glass matrix (relative to the same composition without crystallization) which reduces the durability of the final product. The magnitude of the reduction ultimately depends on the extent (volume fraction) of crystallization.

Li *et al.*[18, 22] indicated that sodium alumino-borosilicate glasses are prone to nepheline crystallization if their compositions projected on the Na_2O-Al_2O_3-SiO_2 ternary fall within or close to the nepheline primary phase field. In particular, glasses with $SiO_2/(SiO_2+Na_2O+Al_2O_3) > 0.62$, where the chemical formulae stand for the mass fractions in the glass, do not tend to precipitate nepheline as a primary crystalline phase. The potential for formation of nepheline and/or other aluminum/silicon-containing crystals exists in the Sludge Batch 4 (SB4) system based on the projected compositional views coupled with the initial frit development strategy. Compositional projections of Sludge Batch 4 (SB4)[23] indicate that the sludge will be enriched in Al_2O_3 relative to the Al_2O_3 concentrations of previous sludge batches processed through the DWPF. Candidate frits have been identified which range in Na_2O concentration from 8-13% by mass for the SB4 compositional projections.[24] The combination of high Al_2O_3 and Na_2O concentrations, coupled with lower SiO_2 concentrations as waste loadings are increased (given the primary source of SiO_2 is from the frit), shifts the composition toward the nepheline phase field, raising the potential for nepheline crystallization. Therefore, strategic frit development efforts[4] have been made to suppress the development of nepheline formation by lowering the Na_2O content while increasing B_2O_3, Fe_2O_3, and/or Li_2O concentration in the frit.

Peeler *et al.*[1, 25] provided insight into the potential impact of nepheline formation on SB4 glasses based on the Lilliston[23] SB4 compositional projections. In that study (referred to as Phase 1), twelve SB4-based glasses were fabricated (only two of which were prone to nepheline formation using the 0.62 value[22] as a guide) and the durability of each was measured. The results indicated that all the glasses in the study (both quenched and centerline canister cooled (ccc)) had a durability as defined by the Product Consistency Test (PCT)[10] that was acceptable. More specifically, the normalized boron release (NL [B]) values for all the Phase 1 nepheline glasses were much lower than the Environmental Assessment (EA) glass value of 16.695 g/L.[11] The most durable glass was NEPH-04 (quenched) with a NL [B] of 0.61 g/L, while the least durable glass was NEPH-01 (ccc) with a NL [B] of 2.47 g/L (based on the measured composition).

The Phase 1 PCT results suggested that for the two glasses prone to nepheline formation (NEPH-01 and NEPH-02), a statistically significant difference in PCT response was observed between the quenched and ccc versions but the impact on durability was of little or no practical concern. When the PCT responses were coupled with the X-ray diffraction (XRD) results and/or visual observations, it was concluded that the formation of nepheline in these glasses did have a negative impact on durability. However, the impact (as seen by a difference between the quenched and ccc PCT responses), while statistically significant, was not of practical concern.

The results of the Phase 1 study suggested that the 0.62 value, as proposed by Li *et al.*,[22] appeared to be a reasonable guide to monitor the potential for nepheline formation in the alumino-borosilicate based SB4 glass system. The results also suggested that the presence of nepheline in the glasses studied during this phase had little or no practical impact on durability as measured by the PCT. This latter statement must be qualified to some extent given that only two glasses were selected which were actually prone to nepheline formation based on the general guide and that the volume fraction of nepheline formed based on XRD results was relatively low (~ 0.5 vol.%). Given that the waste loadings (WLs) for the Phase 1 glasses were limited to 40%, if higher WLs were considered, the potential for nepheline formation (and potentially the volume fraction of crystallization) could increase, and the likelihood of observing a significant and practical difference in PCT response could be realized.

After issuance of the Phase 1 report, revised compositional projections from the Closure Business Unit (CBU) for SB4 were issued.[26, 27] These revised projections were framed around three decision areas: the sodium molarity of the sludge (at values of 1M Na^+ and 1.6M Na^+), the Sludge Batch 3 (SB3) heel that will be included in the batch (expressed in inches of SB3 sludge with values of 0, 40, and 127"), and the introduction of an Actinide Removal Process (ARP) stream into the sludge (which was represented by six options: no ARP, ARP-A, ARP-E, ARP-K, ARP-M, and ARP-V). In response to these revised projections, candidate frits whose operating windows (i.e., waste loading intervals that meet Product Composition Control System (PCCS) Measurement Acceptability Region (MAR) criteria) are robust to and/or selectively optimal for these sludge options were identified via a paper study approach.[28] The results of that paper study indicated that candidate frits are available for the various SB4 options which provide relatively large operating windows. Besides the revised compositional projections, the primary difference between this second assessment[28] and the first[24] was that the 0.62 nepheline discriminator value was used as a screening tool to evaluate the potential impact of nepheline formation on the projected operating windows. The results of activating the nepheline discriminator[28] indicated that access to higher WLs for almost all SB4 frit – sludge options was restricted when the nepheline discriminator was applied. That is, a relatively large WL interval was available in which all PCCS MAR criteria were satisfied except for the nepheline discriminator value. This suggested possible issues associated with crystallization and its impact on durability. Therefore, the value of the nepheline discriminator was challenged to determine if access to those higher WLs could be regained without compromising durability.

Twenty eight glasses were identified for Phase 2 of the nepheline study[29] that intentionally challenged the nepheline discriminator value based on the 1.6M Na^+, 40" and 1.6M Na^+, 127" sludge options.[26, 27] These Phase 2 glasses were selected to complement the Phase 1 study[1] by continuing the investigation into the ability of the nepheline discriminator to predict the crystallization of nepheline in SB4 glasses and the impact of nepheline crystallization on durability. In general, the Phase 2 glasses were selected to cover WLs over which nepheline was the only criterion restricting acceptability. The primary difference between the Phase 1 and Phase 2 nepheline studies is that Phase 2 challenged the nepheline discriminator for all glasses – not just a few select glasses as in Phase 1. In order to meet this objective, WLs of ~ 40% or higher were targeted for the Phase 2 glasses whereas 40% was the maximum WL used during Phase 1. As previously mentioned, the probability of nepheline formation increases when WL increases (at higher WLs, Al_2O_3 and Na_2O concentrations increase and the SiO_2 concentration decreases).

The Phase 2 glasses were fabricated and the durability of each (as measured by the PCT) was assessed for both quenched and ccc samples. All of the Phase 2 quenched glasses had normalized boron releases of less than 1.19 g/L, which is approximately an order of magnitude better than the EA benchmark glass.[11] However, the potential for crystallization was suppressed kinetically in the quenched glasses. That is, the glasses may be prone to nepheline formation but the rapid cooling limited the formation of nepheline (or other crystalline phases).

For the ccc glasses, visual observations suggested that as the targeted WL within a specific frit – sludge system was increased, the degree of crystallization became more extensive. This is not unexpected as the slower cooling provides a glass with a composition that is thermodynamically favorable for nepheline formation (i.e., a composition that falls within the nepheline primary phase field) the kinetic opportunity to devitrify. XRD results indicated the presence of nepheline, trevorite ($NiFe_2O_4$), and/or lithium silicate (Li_2SiO_3) in select Phase 2 ccc glasses. In general, as the WL increased within a specific frit – sludge system, the glass transitioned from amorphous or from containing crystalline phase(s) such as spinels at the lowest WL, to spinel and nepheline at the intermediate WL, and ultimately to spinel, nepheline, and lithium silicate at the highest WL. As a result, the difference between the quenched and ccc PCT response for each specific frit system increased as WL increased. Coupling this trend with the crystallization results, one can easily explain the durability responses as a function of WL. As WL increased within a specific frit – sludge system, the durability of the ccc based glasses decreased due to the formation of nepheline and/or lithium silicate. These trends are in agreement with previous observations that the impact on durability is dependent upon the type and extent of crystallization and the resulting change to the residual glass composition.

The results of the Phase 1 and Phase 2 studies suggest that the 0.62 value is a reasonable guide to monitor SB4 – frit systems for potential nepheline formation upon ccc. The significance of "ccc" in this sentence is based on the fact that none of the Phase 1 or Phase 2 quenched glasses showed any sign of nepheline formation (based on the PCT response) although some of the Phase 2 glasses had nepheline discriminator values as low as 0.541. It was only when the glass was provided the kinetic opportunity to devitrify through the slow ccc schedule that nepheline formed and had an adverse impact on durability.

In Phase 2, the lower WL glasses showed no significant or practical differences in durability when comparing quenched and ccc glasses, which is consistent with the Phase 1 results. It was only at the higher WLs that nepheline formation had a significant impact on durability, where ccc glasses had normalized releases for boron that exceeded that of the EA glass. The practical implication to DWPF is that higher WL glasses should be avoided for these types of glass systems (i.e., those containing high Al_2O_3 and Na_2O). The primary question becomes: how can potential nepheline formation regions be avoided or controlled in DWPF if necessary? A formal recommendation of the specific path was not made in the Phase 2 report,[2] but a general discussion was provided on available options. These included: (1) use of an administrative control on waste loading, (2) implementation of a nepheline discriminator value in the Product Composition Control System (PCCS), or (3) strategic frit development efforts to mitigate nepheline formation.

For Phase 3 of the nepheline study, 16 glasses have been selected to complement the earlier work[1, 2] by continuing the investigation into the ability of the nepheline discriminator to predict the occurrence of nepheline crystallization in SB4 glasses and into the impact of such phases on the durability of the SB4 glasses. The Phase 3 study has two primary objectives. The first is to continue to demonstrate the ability of the discriminator value to adequately predict the nepheline formation potential for specific glass systems of interest. The second is to generate additional data that have a high probability of supporting the SB4 variability study. To support these two objectives, glasses were selected to cover WLs that tightly bound the nepheline discriminator value of 0.62, with the intent of refining this value to a level of confidence where it can be incorporated into offline administrative controls and/or the PCCS to support Slurry Mix Evaporator (SME) acceptability decisions. In addition, glasses targeting lower WLs (35 and 40%) were prepared and analyzed to contribute needed data to the ComPro™ database in anticipation of a variability study for SB4.

The results of this study will provide valuable input for the frit development efforts and subsequent feedback to Liquid Waste Operations (LWO) regarding the viability of four of the frit options under consideration and the need for incorporating a nepheline discriminator into administrative or process controls. Additional data provided through other studies, such as melt rate information, will also influence the frit recommendation decision for SB4 vitrification. The work was initiated by a Technical Task Request[30] and is covered by a Technical Task and QA Plan.[31]

2.0 Experimental Procedure

2.1 Glass Selection

A detailed description of the Phase 3 glass selection process has been given in a previous report.[32] A brief summary is provided below. It should be noted that although the primary focus of these glasses is SB4, the Phase 3 data will be applicable to other high Al_2O_3 waste streams, such as SB5.

In selecting the Phase 3 glasses, a window of nepheline discriminator values was first determined using the Phase 1 and 2 results. The lower end of the window was set at a value of 0.59, where it was expected that the glasses would begin to have a measurable difference in PCT response between the quenched and ccc specimens, but would not have unacceptable (EA-like) responses. The upper end of the window was set at 0.62, as the previous phases of the work have shown this value to be a reliable indicator of the potential for nepheline crystallization in ccc glasses.

The frits considered in this study, including two frits (Frit 418 and Frit 425) used for the earlier frit development efforts,[28] are described in Table 2-1. These frits are currently primary candidates for use with SB4 based on previous assessments of projected operating windows and melt rate.[4, 5]

Table 2-1. Composition (as mass fractions) of Candidate Frits

Frit ID	B_2O_3	Li_2O	Na_2O	SiO_2
418	0.08	0.08	0.08	0.76
425	0.08	0.08	0.10	0.74
501	0.09	0.10	0.05	0.76
502	0.08	0.11	0.05	0.76

Only one sludge option, Case 15C Blend 1 (~96 inch SB3 heel, 1.4 M Na^+ before blending),[3] was employed in the Phase 3 selection process as this option is seen as providing the most likely representation of SB4. This sludge option was combined with the four frits in Table 2-1 in a paper study where the PCCS MAR assessments and nepheline discriminator values were determined for a WL interval of 25 to 60%.[4] The WLs for each sludge – frit combination that gave nepheline discriminator values at the upper and lower bounds of the window described above were then chosen for this Phase 3 study. The paper study indicated that some of the higher WLs chosen will produce glasses that have an unacceptable T_L or viscosity based on the PCCS MAR results. This was intentionally disregarded in favor of concentrating on the potential for nepheline formation.

In addition, glass compositions at WLs of 35 and 40% (a range more likely to be used by DWPF) were chosen to contribute needed data to the ComPro™ database[6] in anticipation of a variability study for SB4. The 16 glass compositions generated by the selection process are given in Table 2-2. Unique identifiers for these glasses are provided in the first row of the table, and the value of the nepheline discriminator for each glass is also included.

Table 2-2. Target Compositions of Glasses Selected for SB4 Case 15C Blend 1 in wt%

Glass ID	NEPH 3-41	NEPH 3-42	NEPH 3-43	NEPH 3-44	NEPH 3-45	NEPH 3-46	NEPH 3-47	NEPH 3-48	NEPH 3-49	NEPH 3-50	NEPH 3-51	NEPH 3-52	NEPH 3-53	NEPH 3-54	NEPH 3-55	NEPH 3-56
Frit ID	418	418	418	418	501	501	501	501	425	425	425	425	502	502	502	502
%WL	35	40	46	50	35	40	47	51	35	40	44	48	35	40	48	51
neph. discrim.	0.702	0.667	0.624	0.593	0.721	0.685	0.631	0.599	0.684	0.650	0.622	0.594	0.721	0.685	0.623	0.599
Al_2O_3	8.682	9.922	11.411	12.403	8.682	9.922	11.659	12.651	8.682	9.922	10.915	11.907	8.682	9.922	11.907	12.651
B_2O_3	5.200	4.800	4.320	4.000	5.850	5.400	4.770	4.410	5.200	4.800	4.480	4.160	5.200	4.800	4.160	3.920
BaO	0.044	0.050	0.058	0.063	0.044	0.050	0.059	0.064	0.044	0.050	0.056	0.061	0.044	0.050	0.061	0.064
CaO	0.836	0.955	1.098	1.194	0.836	0.955	1.122	1.218	0.836	0.955	1.051	1.146	0.836	0.955	1.146	1.218
Ce_2O_3	0.052	0.060	0.069	0.075	0.052	0.060	0.070	0.076	0.052	0.060	0.066	0.072	0.052	0.060	0.072	0.076
Cr_2O_3	0.074	0.085	0.098	0.106	0.074	0.085	0.100	0.108	0.074	0.085	0.093	0.102	0.074	0.085	0.102	0.108
CuO	0.021	0.024	0.028	0.030	0.021	0.024	0.028	0.031	0.021	0.024	0.026	0.029	0.021	0.024	0.029	0.031
Fe_2O_3	9.298	10.626	12.220	13.283	9.298	10.626	12.486	13.548	9.298	10.626	11.689	12.751	9.298	10.626	12.751	13.548
K_2O	0.120	0.138	0.158	0.172	0.120	0.138	0.162	0.175	0.120	0.138	0.151	0.165	0.120	0.138	0.165	0.175
La_2O_3	0.038	0.043	0.050	0.054	0.038	0.043	0.051	0.055	0.038	0.043	0.048	0.052	0.038	0.043	0.052	0.055
Li_2O	5.200	4.800	4.320	4.000	6.500	6.000	5.300	4.900	5.200	4.800	4.480	4.160	7.150	6.600	5.720	5.390
MgO	0.873	0.998	1.148	1.248	0.873	0.998	1.173	1.273	0.873	0.998	1.098	1.198	0.873	0.998	1.198	1.273
MnO	1.918	2.192	2.521	2.740	1.918	2.192	2.576	2.795	1.918	2.192	2.411	2.630	1.918	2.192	2.630	2.795
Na_2O	12.928	13.632	14.477	15.040	10.978	11.832	13.027	13.711	14.228	14.832	15.315	15.798	10.978	11.832	13.198	13.711
NiO	0.552	0.631	0.726	0.789	0.552	0.631	0.741	0.804	0.552	0.631	0.694	0.757	0.552	0.631	0.757	0.804
PbO	0.032	0.036	0.042	0.045	0.032	0.036	0.043	0.046	0.032	0.036	0.040	0.043	0.032	0.036	0.043	0.046
SO_4^{2-}	0.468	0.535	0.615	0.669	0.468	0.535	0.629	0.682	0.468	0.535	0.589	0.642	0.468	0.535	0.642	0.682
SiO_2	50.840	47.245	42.932	40.057	50.840	47.245	42.213	39.338	49.540	46.045	43.250	40.454	50.840	47.245	41.494	39.338
ThO_2	0.023	0.026	0.030	0.033	0.023	0.026	0.031	0.034	0.023	0.026	0.029	0.032	0.023	0.026	0.032	0.034
TiO_2	0.009	0.011	0.012	0.013	0.009	0.011	0.013	0.014	0.009	0.011	0.012	0.013	0.009	0.011	0.013	0.014
U_3O_8	2.674	3.056	3.515	3.820	2.674	3.056	3.591	3.897	2.674	3.056	3.362	3.667	2.674	3.056	3.667	3.897
ZnO	0.034	0.039	0.045	0.049	0.034	0.039	0.046	0.050	0.034	0.039	0.043	0.047	0.034	0.039	0.047	0.050
ZrO_2	0.083	0.095	0.109	0.119	0.083	0.095	0.111	0.121	0.083	0.095	0.104	0.114	0.083	0.095	0.114	0.121

2.2 Glass Fabrication

Each Phase 3 glass was prepared from the proper proportions of reagent-grade metal oxides, carbonates, H_3BO_3, and salts in 150-g batches.[7] The raw materials were thoroughly mixed and placed into a 95% Platinum/5% Gold 250-mL crucible. The batch was placed into a high-temperature furnace at the target melt temperature of 1150°C.[8] After an isothermal hold at 1150°C for 1.0 h, the crucible was removed from the furnace. The glass was poured onto a clean stainless steel plate and allowed to air cool (quench). The glass pour patty was used as a sampling stock for the various property measurements (i.e., chemical composition and durability).

Approximately 25 g of each glass was heat-treated to simulate cooling along the centerline of a DWPF-type canister[9] to gauge the effects of thermal history on the product performance. This cooling schedule is referred to as the ccc curve. Visual observations on both quenched and ccc glasses were documented.[a]

2.3 Property Measurements

This section provides a general discussion of the chemical composition analyses, the PCTs, and the XRD analyses of the Phase 3 glasses.

2.3.1 *Compositional Analysis*

To confirm that the as-fabricated glasses corresponded to the defined target compositions, a representative sample from each glass was submitted to the SRNL Process Science Analytical Laboratory (PSAL) for chemical analysis under the auspices of an analytical plan. The plan (see Appendix A) identified the cations to be analyzed and the dissolution techniques (i.e., sodium peroxide fusion [PF] and lithium-metaborate [LM]) to be used. The samples prepared by LM were used to measure for barium (Ba), calcium (Ca), cerium (Ce), chromium (Cr), copper (Cu), potassium (K), lanthanum (La), magnesium (Mg), sodium (Na), lead (Pb), sulfur (S), thorium (Th), titanium (Ti), zinc (Zn), and zirconium (Zr) concentrations. Samples prepared by PF were used to measure for aluminum (Al), boron (B), iron (Fe), lithium (Li), manganese (Mn), nickel (Ni), silicon (Si), and uranium (U). Each glass was prepared in duplicate for each cation dissolution technique (PF and LM). All of the prepared samples were analyzed (twice for each element of interest) by Inductively Coupled Plasma – Atomic Emission Spectroscopy (ICP-AES) with the instrumentation being re-calibrated between the duplicate analyses. The analytical plan was developed in such a way as to provide the opportunity to evaluate potential sources of error. Glass standards were also intermittently measured to assess the performance of the ICP-AES instrument over the course of these analyses.

2.3.2 *SO_4^{2-} Solubility*

Although not a primary focus of the Phase 3 work, SO_4^{2-} solubility is a secondary concern in this study. The applicability of the current 0.6 wt% SO_4^{2-} limit (established for the Frit 418 – SB3 system[33]) to SB4 was investigated. From Table 2-2, the targeted SO_4^{2-} concentrations in the Phase 3 glasses range from 0.468 to 0.682 wt%. Previous tests have suggested that the use of reagent grade raw materials is conservative with respect to SO_4^{2-} retention and/or volatility.[b] Since the Phase 3 glasses have both high SO_4^{2-} concentrations and are batched from reagent grade raw materials, the

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[a] WSRC-NB-2006-00016 contains the visual observations of the quenched and ccc glasses as well as the results of the XRD and PCT analyses for the Phase 3 glasses.

[b] Previous results have indicated that the use of raw materials (reagent grade chemicals) to produce the glasses minimizes SO_4^{2-} volatilization during the fabrication process. Since volatilization is anticipated in slurry-fed melters, this approach will provide a conservative measure of SO_4^{2-} retention in the glass.

ability of the glasses to retain the targeted SO_4^{2-} concentrations will provide valuable insight into the applicability of the SO_4^{2-} limit to SB4. Both visual observations (i.e., formation of a salt layer on the surface of the glass indicating that SO_4^{2-} limit has been exceeded) and a comparison of measured versus targeted SO_4^{2-} concentrations were used to support this assessment.

2.3.3 *Product Consistency Test (PCT)*

The PCT[10] was performed in triplicate on each Phase 3 quenched and ccc glass to assess chemical durability. Also included in the experimental test matrix was the EA glass,[11] the Approved Reference Material (ARM) glass, and blanks from the sample cleaning batch. Samples were ground, washed, and prepared according to the standard procedure.[10] Fifteen milliliters of Type I American Society for Testing and Materials (ASTM) water were added to 1.5 g of glass in stainless steel vessels. The vessels were closed, sealed, and placed in an oven at 90 ± 2°C where the samples were maintained for 7 days. Once cooled, the resulting solutions were sampled (filtered and acidified), then labeled and analyzed by PSAL under the auspices of two analytical plans (see Appendices B and C).[a] The aim of the plans was to provide an opportunity to assess the consistency (repeatability) of the PCT and analytical procedures to evaluate the chemical durability of the Phase 3 glasses. Normalized release rates were calculated based on targeted, measured, and bias-corrected (bc) compositions using the average of the logs of the leachate concentrations.

2.3.4 *X-Ray Diffraction Analysis*

Although visual observations for crystallization were performed and documented, representative samples for all ccc Phase 3 glasses were submitted to Analytical Development (AD) for X-ray diffraction (XRD) analysis. The quenched glasses were not submitted for XRD analyses based on visual observations and the PCT responses. Samples were run under conditions providing a detection limit of approximately 0.5 vol%. That is, if crystals (or undissolved solids) were present at 0.5 vol% or greater, the diffractometer will not only be capable of detecting the crystals but will also allow a qualitative determination of the type of crystal(s) present. Otherwise, a characteristically high background devoid of crystalline spectral peaks indicates that the glass product is amorphous, suggesting either a completely amorphous product or that the degree of crystallization is below the detection limit.

[a] One analytical plan (SRNL-SCS-2006-00003) was developed to assess the PCT solutions resulting from the NEPH3-41 to NEPH3-48 glasses, while a second plan (SRNL-SCS-2006-00007) was developed for the NEPH3-49 to NEPH3-56 glasses.

3.0 Results and Discussion

3.1 A Statistical Review of the Chemical Composition Measurements for the Phase 3 Nepheline Glasses

In this section, the measured versus targeted compositions of the 16 Phase 3 Nepheline study glasses (NEPH3-41 through NEPH3-56) are presented and compared. The targeted compositions for these glasses are provided in Table 2-2 (also shown in Table D1 of Appendix D). Chemical composition measurements for these glasses were conducted by PSAL following the analytical plan provided in Appendix A as described in Section 2.3.1. For each study glass, measurements were obtained from samples prepared in duplicate by both the LM and PF dissolution methods.

Table D2 in Appendix D provides the elemental concentration measurements derived from the samples prepared using LM, and Table D3 in Appendix D provides the measurements derived from the samples prepared using PF. Measurements for standards (Batch 1 and a uranium standard, U_{std}) that were included in the PSAL analytical plan along with the study glasses are also provided in these two tables.

The elemental concentrations were converted to oxide concentrations by multiplying the values for each element by the gravimetric factor for the corresponding oxide. During this process, an elemental concentration that was determined to be below the detection limit of the analytical procedures used by the PSAL was reduced to half of that detection limit as the oxide concentration was determined.

In the sections that follow, the analytical sequences of the measurements are explored, the measurements of the standards are investigated and used for bias correction, the measurements for each glass are reviewed, the average chemical compositions (measured and bias-corrected) for each glass are determined, and comparisons are made between the measurements and the targeted compositions for the glasses.

3.1.1 *Measurements in Analytical Sequence*

Exhibit D1 in Appendix D provides plots of the measurements generated by the PSAL for samples prepared using the LM method. The plots are in analytical sequence with different symbols and colors being used to represent each of the study and standard glasses. Similar plots for the samples prepared using the PF method are provided in Exhibit D2 in Appendix D. These plots include all of the measurement data from Tables D2 and D3. A review of these plots indicates no significant patterns or trends in the analytical process over the course of these measurements, and there appear to be no obvious outliers in these chemical composition measurements. One minor exception is the measurement of Na_2O concentration in glass NEPH3-44. The Na_2O measurements for this single glass varied by 2.5 to 3 wt%, which should not cause any difficulty in evaluating the results.

3.1.2 *Batch 1 and Uranium Standard Results*

In this section, the PSAL measurements of the chemical compositions of the Batch 1 and uranium standard (U_{std}) glasses are reviewed. These measurements are investigated across the ICP analytical blocks, and the results are used to bias correct the measurements for the study glasses.

Exhibit D3 in Appendix D provides statistical analyses of the Batch 1 and U_{std} results generated by the LM prep method by block for each oxide of interest. The results include analysis of variance (ANOVA) investigations looking for statistically significant differences between the block means for each of the oxides for each of the standards. The results from the statistical tests for the Batch 1 standard may be summarized as follows: BaO, CaO, Ce_2O_3, Cr_2O_3, CuO, MgO, Na_2O, TiO_2, and ZrO_2

have measurements that indicate a significant ICP calibration effect on the block averages at the 5% significance level. For the U_{std}, CaO, Ce_2O_3, Cr_2O_3, CuO, MgO, MnO, Na_2O, ThO_2 (a detection limit effect), and TiO_2 have measurements that indicate a significant ICP calibration effect on the block averages at the 5% significance level. The reference values for the oxide concentrations of the standard are given in the header for each set of measurements in the exhibit.

Exhibit D4 in Appendix D provides a similar set of analyses for the measurements derived from samples prepared via the PF method. The results from the statistical tests for the Batch 1 standard may be summarized as follows: only B_2O_3 has measurements that indicate a significant ICP calibration effect on the block averages at the 5% significance level. For the U_{std}, none of the oxides have measurements that indicate a significant ICP calibration effect on the block averages at the 5% significance level. The reference values for the oxide concentrations of the standard are given in the headers for each set of measurements in the exhibit.

Some of these results provide incentive for adjusting the measurements by the effect of the ICP calibration. Therefore, the oxide measurements of the study glasses were bias corrected for the effect of the ICP calibration on each of the analytical blocks. The basis for this bias correction is presented as part of Exhibits D3 and D4 – the average measurement for Batch 1 for each ICP block/sub-block for Al_2O_3, B_2O_3, BaO, CaO, Cr_2O_3, CuO, Fe_2O_3, K_2O, Li_2O, MgO, MnO, Na_2O, NiO, SiO_2, and TiO_2 and the average measurement for U_{std} for each ICP set/block for U_3O_8. The Batch 1 results served as the basis for bias correcting all of the oxides (that were bias corrected) except uranium. The U_{std} results were used to bias correct for uranium. For the other oxides, the Batch 1 results were used to conduct the bias correction as long as the reference value for the oxide concentration in the Batch 1 glass was greater than or equal to 0.1 wt%. Applying this approach and based upon the information in the exhibits, the Batch 1 results were used to bias correct the Al_2O_3, B_2O_3, BaO, CaO, Cr_2O_3, CuO, Fe_2O_3, K_2O, Li_2O, MgO, MnO, Na_2O, NiO, SiO_2, and TiO_2 measurements. No bias correction was conducted for Ce_2O_3, La_2O_3, PbO, SO_4^{2-}, ThO_2, ZnO, or ZrO_2.

The bias correction was conducted as follows. For each oxide, let $\bar{a}_{ij}$ be the average measurement for the i^{th} oxide at analytical block j for Batch 1 (or U_{std} for uranium), and let t_i be the reference value for the i^{th} oxide for Batch 1 (or for U_{std} if uranium). The averages and reference values are provided in Exhibits D3 and D4. Let $\bar{c}_{ijk}$ be the average measurement for the i^{th} oxide at analytical block j for the k^{th} glass. The bias adjustment was conducted as follows:

$$\bar{c}_{ijk} \bullet \left(1 - \frac{\bar{a}_{ij} - t_i}{\bar{a}_{ij}}\right) = \bar{c}_{ijk} \bullet \frac{t_i}{\bar{a}_{ij}}$$

Bias-corrected measurements are indicated by a "bc" suffix, and such adjustments were performed for all of the oxides of this study except for Ce_2O_3, La_2O_3, PbO, SO_4^{2-}, ThO_2, ZnO, and ZrO_2. Both measured and measured "bc" values are included in the discussion that follows. In these discussions, the measured values for Ce_2O_3, La_2O_3, PbO, SO_4^{2-}, ThO_2, ZnO, and ZrO_2 are duplicated as the measured-bc values for completeness (e.g., to allow a sum of oxides to be computed for the bias-corrected results). These bias-corrected values are the same as the original, measured Ce_2O_3, La_2O_3, PbO, SO_4^{2-}, ThO_2, ZnO, and ZrO_2 values.

3.1.3 *Composition Measurements by Glass Number*

Exhibits D5 and D6 in Appendix D provide plots of the oxide concentration measurements by Glass ID # (including both Batch 1, labeled as glass numbered 100 and U_{std}, labeled as glass numbered 200) for the measured and bc values for the LM and PF preparation methods, respectively. Different symbols and colors are used to represent the different glasses. These plots show the individual measurements across the duplicates of each preparation method and the two ICP calibrations. A review of the plots presented in these exhibits reveals the repeatability of the four individual oxide values for each glass. The sole exception is the Na_2O concentration of glass NEPH3-44, which should not have a significant impact on the results presented here. More detailed discussions of the average, measured chemical compositions of the study glasses are provided in the sections that follow.

3.1.4 *Measured versus Targeted Compositions*

The four measurements for each oxide for each glass (over both preparation methods) were averaged to determine a representative chemical composition for each glass. These determinations were conducted both for the measured and for the bias-corrected data. A sum of oxides was also computed for each glass based upon both the measured and bias-corrected values. Exhibit D7 in Appendix D provides plots showing results for each glass for each oxide to help highlight the comparisons among the measured, bias-corrected, and targeted values.

Table D4 in Appendix D provides a summary of the average compositions as well as the targeted compositions and some associated differences and relative differences. Notice that the targeted sums of oxides for the standard glasses do not sum to 100% due to an incomplete coverage of the oxides in the Batch 1 (glass # 100) and U_{std} (glass # 200) glasses. All of the sums of oxides (both measured and bias-corrected) for the study glasses fall within the interval of 95 to 105 wt%. Entries in Table D4 show the relative differences between the measured or bias-corrected values and the targeted values. These differences are shaded when they are greater than or equal to 5%. Overall, these comparisons between the measured and targeted compositions suggest only minor difficulties in hitting the targeted compositions for some of the oxides (including CaO, Fe_2O_3, and NiO) for some of the glasses. These should have no impact on the conclusions drawn to support the objectives of this report.

3.1.5 *SO_4^{2-} Retention*

Although not the primary focus of the Phase 3 study, a secondary concern is the potential need to redefine the SO_4^{2-} solubility limit for SB4. The compositional analysis, coupled with the visual observations of the as-fabricated glasses (see Section 3.3.1), will serve as primary indicators to determine whether the current 0.6 wt% SO_4^{2-} limit (established for the Frit 418 – SB3 system[33]) is still applicable for SB4. From Table 2-2, the targeted SO_4^{2-} concentrations in the Phase 3 glasses range from 0.468 wt% (NEPH3-41) to 0.682 wt% (NEPH3-48).

Figure 3-1 summarizes the targeted versus measured SO_4^{2-} concentrations in glass. The purple line represents the targeted concentrations as noted in Table 2-2. The red data points represent the measured SO_4^{2-} concentrations in the glass, while the green data points are the measured, bias-corrected values. The data suggest essentially full retention in the glass (i.e., no solubility or volatilization issues during the fabrication process). Although the visual observations are discussed in Section 3.3.1 in more detail, there were no signs of a salt layer on any of the Phase 3 glasses upon fabrication. Coupling the analytical measurements with visual observations of the as-fabricated glasses, the results suggest that the 0.6 wt% SO_4^{2-} limit is applicable for these frit - SB4 systems. The degree of SO_4^{2-} retention does not appear to be frit-dependent for the systems studied here. If the SO_4^{2-} concentration in the SB4 feed to DWPF contains the projected levels, then no issues with SO_4^{2-} solubility are anticipated.

Oxide=SO_4^{2-} (wt%)

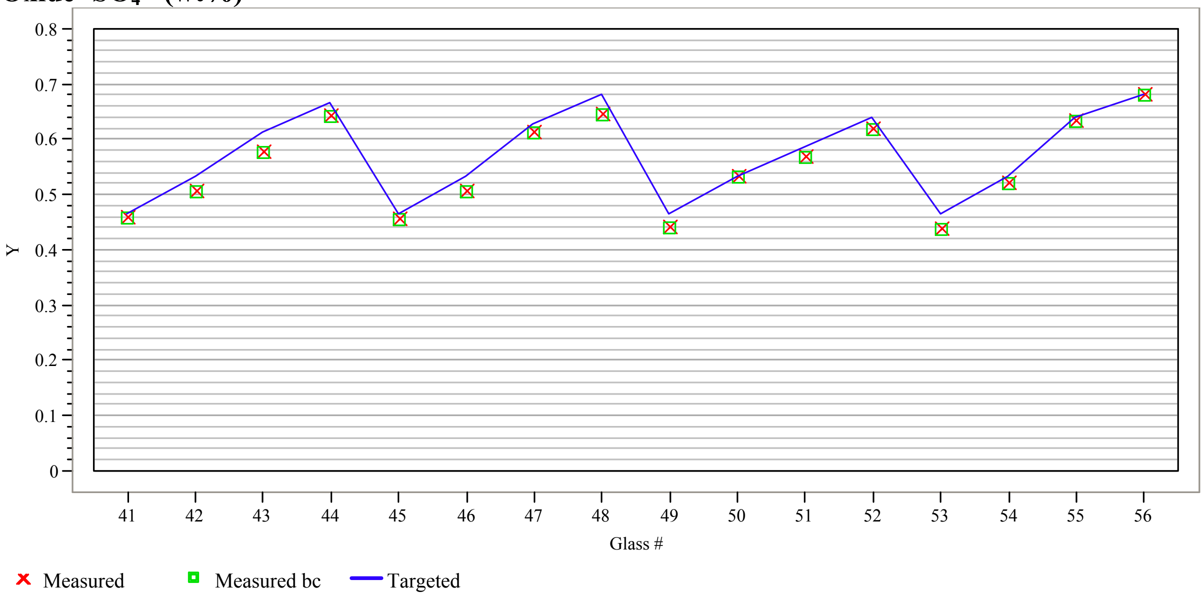


Figure 3-1. Targeted versus measured SO_4^{2-} values for the Phase 3 glasses.

3.2 A Statistical Review of the PCT Measurements

The nepheline study glasses, after being batched and fabricated, were subjected to the 7-day PCT to assess their durabilities.[10] Durability is the critical product quality metric for DWPF glass studies. Two heat treatments (quenched and ccc) were used during the fabrication of each of the study glasses. Both heat treatments for each study glass were subjected to the PCT (in triplicate). PCTs were also conducted in triplicate for samples of the EA glass and for samples of the ARM glass. Blanks (samples consisting only of ASTM Type I water) were also submitted for the PCT.

Analytical plans, presented in the appendices, were provided to the PSAL to support the measurement of the compositions of the solutions resulting from the PCTs which were conducted in two parts. Samples of a multi-element, standard solution were also included in the analytical plans as a check of the accuracy of the ICP-AES instrument used for these measurements. In this and the following sections, the measurements generated by the PSAL for these PCTs are presented and reviewed.

Table E1 in Appendix E provides the elemental leachate concentration measurements determined by the PSAL for the solution samples generated by the PCTs. One of the quality control checkpoints for the PCT procedure is solution-weight loss over the course of the 7-day test. None of these PCT results indicated a solution-weight loss problem. Any measurement in Table E1 below the detection limit of the analytical procedure (indicated by a “<”) was replaced by ½ of the detection limit in subsequent analyses. In addition to adjustments for detection limits, the values were adjusted for the dilution factors: the values for the study glasses, the blanks, and the ARM glass in Table E1 were multiplied by 1.6667 to determine the values in parts per million (ppm) and the values for EA were multiplied by 16.6667. Table E2 in Appendix E provides the resulting measurements.

One of the important objectives of this study is the investigation of the effects of heat treatment on the PCTs. In the sections that follow, the analytical sequence of the measurements is explored, the measurements of the standards are investigated and used to assess the overall accuracy of the ICP measurement process, the measurements for each glass are reviewed, plots are provided that explore the effects of heat treatment on the PCTs for these glasses, the PCTs are normalized using the compositions (targeted, measured, and bias-corrected) presented in Table D4, and the normalized PCTs are compared to durability predictions for these compositions generated from the current DWPF models.[12]

3.2.1 *Measurements in Analytical Sequence*

Exhibits E1 and E2 in Appendix E provide plots of the leachate concentrations (ppm) in analytical sequence as generated by the PSAL for all of the data and for the data from only the study glasses, respectively. A different color and symbol are used for each study glass or standard. No problems are seen in these plots.

3.2.2 *Results for the Samples of the Multi-Element Solution Standard*

Exhibit E3 in Appendix E provides analyses of the PSAL measurements of the samples of the multi-element solution standard by ICP analytical (or calibration) block. An ANOVA investigating for statistically significant differences among the part/block averages for these samples for each element of interest is included in these exhibits. These results indicate a statistically significant (at approximately a 5% level) difference among only the B average measurements over these parts/blocks. However, no bias correction of the PCT results for the study glasses was conducted. This approach was taken since the triplicate PCTs for a single study glass were placed in different ICP blocks. Averaging the ppm's for each set of triplicates helps to minimize the impact of the ICP effects.

Table 3-1 summarizes the average measurements and the reference values for the four primary elements of interest. The results indicate consistent and accurate measurements from the PSAL processes used to conduct these analyses.

Table 3-1. Results from Samples of the Multi-Element Solution Standard

Analytical Part/Block	Avg B (ppm)	Avg Li (ppm)	Avg Na (ppm)	Avg Si (ppm)
1/1	19.4	9.7	82.2	49.4
1/2	20.8	9.6	79.3	49.4
1/3	21.0	9.7	80.1	49.3
2/1	20.5	9.7	81.3	49.1
2/2	21.1	9.7	83.3	49.6
2/3	21.2	9.8	77.5	49.9
Grand Average	20.7	9.7	80.6	49.5
Reference Value	20	10	81	50
% difference	3.3%	-3.2%	-0.5%	-1.1%

3.2.3 *Measurements by Glass Number*

Exhibit E4 in Appendix E provides plots of the leachate concentrations for each type of submitted sample: the study glasses and the standards (EA (101), ARM (102), the multi-element solution standard (100), and blanks (103)). Exhibit E5 in Appendix E provides plots of the leachate concentrations for the PCT results of the study glasses only. These plots allow for the assessment of the repeatability of the measurements, which suggests some scatter in the triplicate values for some analytes for some of the glasses. Also, note that the results from the two heat treatments are shown for each study glass and that some differences between the two sets of values are evident.

3.2.4 *Normalized PCT Results*

PCT leachate concentrations are typically normalized using the cation composition (expressed as a weight percent) in the glass to obtain a grams-per-liter (g/L) leachate concentration. The normalization of the PCTs is usually conducted using the measured compositions of the glasses. This is the preferred normalization process for the PCTs. For completeness, the targeted cation and the bias-corrected cation compositions were also used to conduct this normalization.

As is the usual convention, the common logarithm of the normalized PCT (normalized leachate, NL) for each element of interest was determined and used for comparison. To accomplish this computation, one must:

1. Determine the common logarithm of the elemental parts per million (ppm) leachate concentration for each of the triplicates and each of the elements of interest (these values are provided in Table E2 of Appendix E),

2. Average the common logarithms over the triplicates for each element of interest, and then

Normalizing Using Measured Composition (preferred method)

3. Subtract a quantity equal to 1 plus the common logarithm of the average cation measured concentration (expressed as a weight percent of the glass) from the average computed in step 2.

Or Normalizing Using Target Composition

3. Subtract a quantity equal to 1 plus the common logarithm of the target cation concentration (expressed as a weight percent of the glass) from the average computed in step 2.

Or Normalizing Using Measured Bias-Corrected Composition

3. Subtract a quantity equal to 1 plus the common logarithm of the measured bias-corrected cation concentration (expressed as a weight percent of the glass) from the average computed in step 2.

Exhibit E6 in Appendix E provides scatter plots for these results and offers an opportunity to investigate the consistency in the leaching across the elements for the glasses of this study. All combinations of the normalizations of the PCTs (i.e., those generated using the targeted, measured, and bias-corrected compositional views) and both heat treatments are represented in the series of scatter plots. Consistency in the leaching across the elements is typically demonstrated by a high degree of linear correlation among the values for pairs of these elements. For the study glasses, the ccc results demonstrate a higher degree of correlation than do the quenched results. This may be due to the limited range of PCT responses for the quenched glasses as opposed to the ccc glasses, as revealed by the scale of the axes of the two sets of PCT measurements in the scatter plots of Exhibit E6. Table 3-2 summarizes the normalized PCTs for the glasses of this study.

Table 3-2. Normalized Release Values for the Nepheline Phase 3 Glasses

Glass ID	Heat Treatment	Composition	log NL [B(g/L)]	log NL [Li(g/L)]	log NL [Na(g/L)]	log NL [Si(g/L)]	NL B(g/L)	NL Li(g/L)	NL Na(g/L)	NL Si(g/L)
ARM	-	reference	-0.265	-0.217	-0.257	-0.517	0.54	0.61	0.55	0.30
EA	-	reference	1.243	0.956	1.120	0.576	17.51	9.03	13.17	3.77
NEPH3-41	quenched	measured	-0.170	-0.112	-0.131	-0.282	0.68	0.77	0.74	0.52
NEPH3-41	quenched	measured bc	-0.174	-0.120	-0.120	-0.288	0.67	0.76	0.76	0.52
NEPH3-41	quenched	target	-0.201	-0.129	-0.120	-0.300	0.63	0.74	0.76	0.50
NEPH3-41	ccc	measured	-0.182	-0.114	-0.153	-0.287	0.66	0.77	0.70	0.52
NEPH3-41	ccc	measured bc	-0.186	-0.121	-0.142	-0.292	0.65	0.76	0.72	0.51
NEPH3-41	ccc	target	-0.213	-0.130	-0.141	-0.305	0.61	0.74	0.72	0.50
NEPH3-42	quenched	measured	-0.062	-0.089	-0.068	-0.267	0.87	0.81	0.86	0.54
NEPH3-42	quenched	measured bc	-0.056	-0.098	-0.056	-0.276	0.88	0.80	0.88	0.53
NEPH3-42	quenched	target	-0.071	-0.101	-0.067	-0.284	0.85	0.79	0.86	0.52
NEPH3-42	ccc	measured	-0.107	-0.091	-0.085	-0.275	0.78	0.81	0.82	0.53
NEPH3-42	ccc	measured bc	-0.100	-0.099	-0.074	-0.284	0.79	0.80	0.84	0.52
NEPH3-42	ccc	target	-0.115	-0.102	-0.084	-0.292	0.77	0.79	0.82	0.51
NEPH3-43	quenched	measured	-0.070	-0.078	0.007	-0.259	0.85	0.83	1.02	0.55
NEPH3-43	quenched	measured bc	-0.064	-0.087	0.001	-0.269	0.86	0.82	1.00	0.54
NEPH3-43	quenched	target	-0.064	-0.086	0.000	-0.264	0.86	0.82	1.00	0.54
NEPH3-43	ccc	measured	-0.047	0.002	0.001	-0.230	0.90	1.01	1.00	0.59
NEPH3-43	ccc	measured bc	-0.041	-0.006	-0.005	-0.239	0.91	0.99	0.99	0.58
NEPH3-43	ccc	target	-0.041	-0.005	-0.005	-0.235	0.91	0.99	0.99	0.58
NEPH3-44	quenched	measured	0.025	-0.067	0.000	-0.249	1.06	0.86	1.00	0.56
NEPH3-44	quenched	measured bc	0.021	-0.074	0.012	-0.255	1.05	0.84	1.03	0.56
NEPH3-44	quenched	target	-0.009	-0.078	0.034	-0.251	0.98	0.84	1.08	0.56
NEPH3-44	ccc	measured	0.036	0.026	0.011	-0.225	1.09	1.06	1.03	0.60
NEPH3-44	ccc	measured bc	0.032	0.019	0.022	-0.230	1.08	1.04	1.05	0.59
NEPH3-44	ccc	target	0.002	0.015	0.045	-0.227	1.01	1.03	1.11	0.59
NEPH3-45	quenched	measured	-0.134	-0.060	-0.125	-0.255	0.73	0.87	0.75	0.56
NEPH3-45	quenched	measured bc	-0.139	-0.068	-0.131	-0.261	0.73	0.86	0.74	0.55
NEPH3-45	quenched	target	-0.147	-0.071	-0.134	-0.261	0.71	0.85	0.74	0.55
NEPH3-45	ccc	measured	-0.134	-0.053	-0.127	-0.251	0.73	0.89	0.75	0.56
NEPH3-45	ccc	measured bc	-0.139	-0.060	-0.133	-0.256	0.73	0.87	0.74	0.55
NEPH3-45	ccc	target	-0.147	-0.064	-0.136	-0.256	0.71	0.86	0.73	0.55
NEPH3-46	quenched	measured	-0.097	-0.061	-0.088	-0.260	0.80	0.87	0.82	0.55
NEPH3-46	quenched	measured bc	-0.101	-0.068	-0.094	-0.265	0.79	0.85	0.81	0.54
NEPH3-46	quenched	target	-0.109	-0.070	-0.085	-0.260	0.78	0.85	0.82	0.55
NEPH3-46	ccc	measured	-0.071	-0.012	-0.081	-0.234	0.85	0.97	0.83	0.58
NEPH3-46	ccc	measured bc	-0.075	-0.019	-0.087	-0.240	0.84	0.96	0.82	0.58
NEPH3-46	ccc	target	-0.083	-0.021	-0.079	-0.235	0.83	0.95	0.83	0.58
NEPH3-47	quenched	measured	-0.001	-0.019	0.003	-0.230	1.00	0.96	1.01	0.59
NEPH3-47	quenched	measured bc	0.005	-0.028	0.014	-0.240	1.01	0.94	1.03	0.58
NEPH3-47	quenched	target	0.006	-0.026	0.015	-0.234	1.01	0.94	1.03	0.58

Table 3-2. Normalized Release Values for the Nepheline Phase 3 Glasses (continued)

Glass ID	Heat Treatment	Composition	log NL [B(g/L)]	log NL [Li(g/L)]	log NL [Na(g/L)]	log NL [Si(g/L)]	NL B(g/L)	NL Li(g/L)	NL Na(g/L)	NL Si(g/L)
NEPH3-47	ccc	measured	-0.040	0.024	-0.014	-0.213	0.91	1.06	0.97	0.61
NEPH3-47	ccc	measured bc	-0.033	0.015	-0.002	-0.223	0.93	1.04	0.99	0.60
NEPH3-47	ccc	target	-0.032	0.016	-0.002	-0.217	0.93	1.04	1.00	0.61
NEPH3-48	quenched	measured	-0.002	-0.001	0.078	-0.199	1.00	1.00	1.20	0.63
NEPH3-48	quenched	measured bc	0.005	-0.010	0.072	-0.209	1.01	0.98	1.18	0.62
NEPH3-48	quenched	target	0.014	-0.010	0.076	-0.205	1.03	0.98	1.19	0.62
NEPH3-48	ccc	measured	0.170	0.214	0.126	-0.115	1.48	1.64	1.34	0.77
NEPH3-48	ccc	measured bc	0.177	0.205	0.120	-0.125	1.50	1.60	1.32	0.75
NEPH3-48	ccc	target	0.186	0.204	0.125	-0.121	1.54	1.60	1.33	0.76
NEPH3-49	quenched	measured	-0.117	-0.100	-0.044	-0.266	0.76	0.79	0.90	0.54
NEPH3-49	quenched	measured bc	-0.110	-0.109	-0.051	-0.275	0.78	0.78	0.89	0.53
NEPH3-49	quenched	target	-0.118	-0.112	-0.025	-0.275	0.76	0.77	0.95	0.53
NEPH3-49	ccc	measured	-0.106	-0.063	-0.063	-0.255	0.78	0.87	0.86	0.56
NEPH3-49	ccc	measured bc	-0.099	-0.072	-0.070	-0.265	0.80	0.85	0.85	0.54
NEPH3-49	ccc	target	-0.107	-0.075	-0.044	-0.264	0.78	0.84	0.90	0.54
NEPH3-50	quenched	measured	-0.064	-0.079	0.006	-0.238	0.86	0.83	1.01	0.58
NEPH3-50	quenched	measured bc	-0.058	-0.087	0.017	-0.247	0.88	0.82	1.04	0.57
NEPH3-50	quenched	target	-0.059	-0.089	0.012	-0.247	0.87	0.81	1.03	0.57
NEPH3-50	ccc	measured	-0.059	-0.047	-0.017	-0.237	0.87	0.90	0.96	0.58
NEPH3-50	ccc	measured bc	-0.052	-0.055	-0.006	-0.246	0.89	0.88	0.99	0.57
NEPH3-50	ccc	target	-0.053	-0.057	-0.010	-0.247	0.88	0.88	0.98	0.57
NEPH3-51	quenched	measured	0.023	-0.045	0.063	-0.222	1.05	0.90	1.16	0.60
NEPH3-51	quenched	measured bc	0.019	-0.052	0.056	-0.228	1.04	0.89	1.14	0.59
NEPH3-51	quenched	target	-0.009	-0.060	0.058	-0.232	0.98	0.87	1.14	0.59
NEPH3-51	ccc	measured	0.153	0.087	0.071	-0.170	1.42	1.22	1.18	0.68
NEPH3-51	ccc	measured bc	0.149	0.080	0.065	-0.176	1.41	1.20	1.16	0.67
NEPH3-51	ccc	target	0.121	0.072	0.067	-0.180	1.32	1.18	1.17	0.66
NEPH3-52	quenched	measured	0.032	-0.033	0.097	-0.191	1.08	0.93	1.25	0.64
NEPH3-52	quenched	measured bc	0.039	-0.041	0.090	-0.201	1.09	0.91	1.23	0.63
NEPH3-52	quenched	target	0.036	-0.043	0.095	-0.207	1.09	0.91	1.24	0.62
NEPH3-52	ccc	measured	0.045	0.033	0.094	-0.172	1.11	1.08	1.24	0.67
NEPH3-52	ccc	measured bc	0.052	0.024	0.088	-0.182	1.13	1.06	1.22	0.66
NEPH3-52	ccc	target	0.049	0.022	0.092	-0.188	1.12	1.05	1.24	0.65
NEPH3-53	quenched	measured	-0.051	-0.020	-0.045	-0.213	0.89	0.96	0.90	0.61
NEPH3-53	quenched	measured bc	-0.056	-0.027	-0.051	-0.218	0.88	0.94	0.89	0.61
NEPH3-53	quenched	target	-0.065	-0.031	-0.044	-0.223	0.86	0.93	0.90	0.60
NEPH3-53	ccc	measured	0.048	0.252	0.029	-0.029	1.12	1.79	1.07	0.94
NEPH3-53	ccc	measured bc	0.044	0.245	0.023	-0.034	1.11	1.76	1.05	0.93
NEPH3-53	ccc	target	0.035	0.241	0.030	-0.039	1.08	1.74	1.07	0.91
NEPH3-54	quenched	measured	-0.016	0.023	-0.020	-0.198	0.96	1.05	0.96	0.63
NEPH3-54	quenched	measured bc	-0.010	0.014	-0.008	-0.208	0.98	1.03	0.98	0.62
NEPH3-54	quenched	target	-0.014	0.011	-0.014	-0.204	0.97	1.02	0.97	0.63
NEPH3-54	ccc	measured	0.007	0.080	0.004	-0.160	1.02	1.20	1.01	0.69
NEPH3-54	ccc	measured bc	0.013	0.071	0.016	-0.169	1.03	1.18	1.04	0.68
NEPH3-54	ccc	target	0.009	0.068	0.010	-0.165	1.02	1.17	1.02	0.68

Table 3-2. Normalized Release Values for the Nepheline Phase 3 Glasses (continued)

Glass ID	Heat Treatment	Composition	log NL [B(g/L)]	log NL [Li(g/L)]	log NL [Na(g/L)]	log NL [Si(g/L)]	NL B(g/L)	NL Li(g/L)	NL Na(g/L)	NL Si(g/L)
NEPH3-55	quenched	measured	0.074	0.022	0.055	-0.181	1.19	1.05	1.14	0.66
NEPH3-55	quenched	measured bc	0.070	0.015	0.067	-0.186	1.18	1.03	1.17	0.65
NEPH3-55	quenched	target	0.045	0.003	0.063	-0.194	1.11	1.01	1.16	0.64
NEPH3-55	ccc	measured	0.218	0.250	0.099	-0.066	1.65	1.78	1.26	0.86
NEPH3-55	ccc	measured bc	0.214	0.242	0.110	-0.071	1.64	1.75	1.29	0.85
NEPH3-55	ccc	target	0.189	0.231	0.107	-0.080	1.55	1.70	1.28	0.83
NEPH3-56	quenched	measured	0.099	0.031	0.086	-0.162	1.26	1.07	1.22	0.69
NEPH3-56	quenched	measured bc	0.096	0.023	0.098	-0.167	1.25	1.06	1.25	0.68
NEPH3-56	quenched	target	0.066	0.015	0.096	-0.174	1.17	1.04	1.25	0.67
NEPH3-56	ccc	measured	0.509	0.494	0.208	0.083	3.23	3.12	1.61	1.21
NEPH3-56	ccc	measured bc	0.506	0.487	0.219	0.078	3.20	3.07	1.66	1.20
NEPH3-56	ccc	target	0.476	0.479	0.218	0.071	2.99	3.01	1.65	1.18

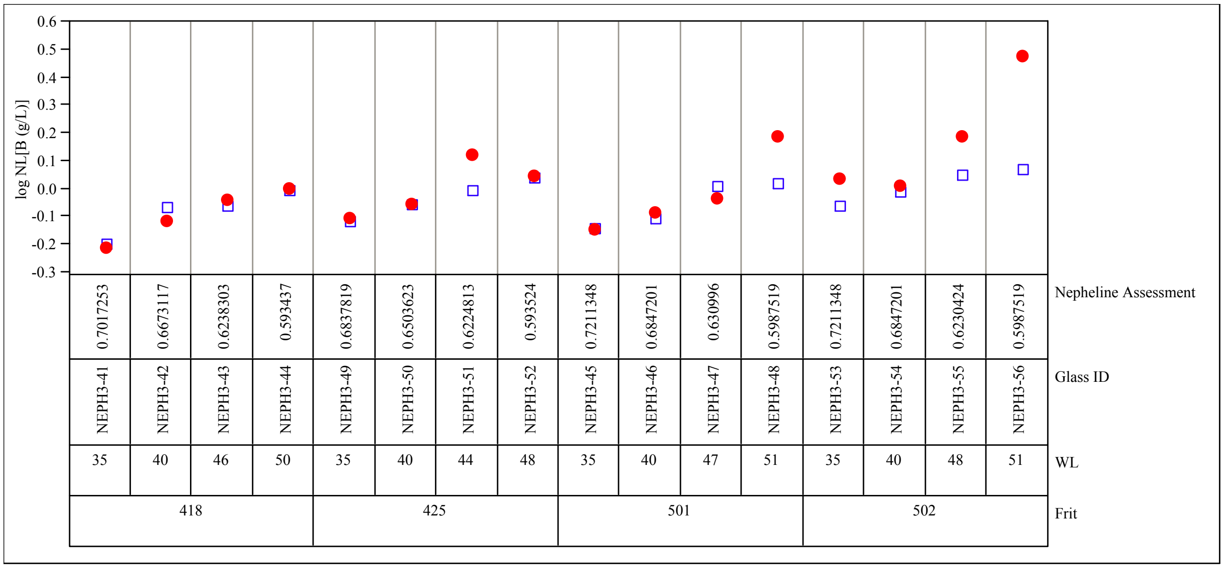
3.2.5 *Effects of Heat Treatment on PCTs*

Exhibit E7 in Appendix E provides a series of plots and statistical comparisons that show the effects of heat treatment on the common logarithm ppm-responses of interest of the triplicate PCTs for each element for each study glass. The ccc version of a given glass yielded measurements indicating a significantly (at the 5% significance level) larger mean log(ppm) response than the quenched version of the glass for a given element if the **Prob>t** value in the exhibit is 0.05 or smaller.

As shown in Table 3-2, all of the Phase 3 quenched glasses have normalized boron releases less than 1.20 g/L, which in terms of acceptability are approximately an order of magnitude better than the EA benchmark glass that has a reported NL [B] of 16.695 g/L.[11] The range of measured, normalized boron releases for the quenched glasses is from 0.67 g/L (NEPH3-41) to 1.25 g/L (NEPH3-56). The results suggest that even though some of the glasses may be prone to nepheline formation based on the 0.62 nepheline discriminator value, all Phase 3 quenched glasses are acceptable. However, the potential for crystallization was suppressed in the quenched glasses in terms of kinetics. That is, the glasses may be prone to nepheline formation but the rapid cooling limited or prevented the formation of nepheline or other crystalline phases. As observed in the Phase 1 and 2 glasses, it was only in the slowly cooled (ccc) glasses where the impact of nepheline on durability response was observed.

Also shown in Table 3-2 are the normalized releases based on the ccc version of each Phase 3 glass for each compositional view. As will be discussed further in Sections 3.3.1 (Visual Observations) and 3.3.2 (XRD Results), the ccc cooling schedule generally resulted in devitrification, with the extent of crystallization generally increasing with increasing WL. This is not unexpected, as the slower cooling rate provides a thermodynamically favorable (compositional-wise) glass the kinetic opportunity to devitrify. The measured, normalized boron releases for the Phase 3 ccc glasses range from 0.65 g/L (NEPH3-41) to 3.20 g/L (NEPH3-56). While these values span a wider PCT response as compared to the quenched versions of these glasses, their responses are still well below that of the EA glass (16.695 g/L).[11]

Figure 3-2 shows the PCT responses for boron, normalized based on measured compositions, for both the quenched and ccc glasses. The value of the nepheline discriminator (calculated from the measured compositions) for each glass is also shown. The PCT responses are indicated by the symbol (□) for the quenched glasses and the symbol (●) for the ccc glasses.



(□) quenched glasses, (•) ccc glasses

Figure 3-2. Normalized boron release and nepheline discriminator values for the quenched and ccc Phase 3 glasses.

Some general trends are evident upon examination of Figure 3-2. For the quenched glasses, the NL [B] values generally increase with increasing WL for each of the sludge-frit systems. A similar trend is seen for the ccc glasses, with a few exceptions in the Frit 425 and Frit 502 systems. Though troubling from a visual perspective, these variations in the trend are of little practical importance, since all of the normalized release values are still well below that of the EA reference glass.

Glasses NEPH3-48, NEPH3-51, NEPH3-53, NEPH3-55 and NEPH3-56 show statistically significant differences in the quenched versus ccc normalized boron release. However, these differences are of little practical importance due to the relatively low values of NL [B].

Table 3-3 lists the nepheline discriminator values for each of the Phase 3 glasses, calculated using either the target, measured, or measured-bc compositions. If a nepheline discriminator value of 0.62 were to be implemented, based on the target compositions, two of the ccc glasses with high NL [B] responses (NEPH3-48 and NEPH3-56) would be screened out by the discriminator. The highest NL [B] response for the Phase 3 glasses would then be 1.65 g/L (glass NEPH3-55ccc), which is an order of magnitude less than the EA reference glass.[11] If the nepheline discriminator values calculated using the measured compositions were used in the screening, the highest NL [B] response for the Phase 3 ccc glasses would then be 1.12 g/L (glass NEPH3-53).

Table 3-3. Values of the nepheline discriminator calculated for each glass using the measured, measured bias-corrected, and targeted compositions.
(Values below 0.62 are highlighted.)

Glass ID	Nepheline Discriminator Values		
	Measured	Measured bc	Targeted
NEPH3-41	0.688	0.694	0.702
NEPH3-42	0.656	0.664	0.667
NEPH3-43	0.620	0.623	0.624
NEPH3-44	0.580	0.587	0.593
NEPH3-45	0.718	0.719	0.721
NEPH3-46	0.681	0.682	0.685
NEPH3-47	0.621	0.629	0.631
NEPH3-48	0.594	0.598	0.599
NEPH3-49	0.670	0.673	0.684
NEPH3-50	0.640	0.649	0.650
NEPH3-51	0.617	0.619	0.622
NEPH3-52	0.584	0.587	0.594
NEPH3-53	0.713	0.714	0.721
NEPH3-54	0.677	0.685	0.685
NEPH3-55	0.612	0.618	0.623
NEPH3-56	0.588	0.595	0.599

Use of a value of 0.62 and the measured compositions for screening with the nepheline discriminator eliminates all but one of the glasses that showed a statistical difference in NL [B] between the quenched and ccc specimens. This one remaining glass (NEPH3-53) showed only a small difference in NL [B], 0.89 g/L versus 1.12 g/L, between the quenched and ccc samples, respectively.

Exhibit E8 in Appendix E provides a series of plots that show the effects of heat treatment on the PCT response based on the three different compositional views: measured, measured bias-corrected, and targeted. These plots allow for an assessment of the differences in PCT responses from a practical perspective, and reinforce the above discussion.

3.2.6 *Predicted versus Measured PCTs*

As seen in Table 3-2, the durabilities for the Phase 3 glasses are all acceptable (i.e. NL [B] less than 3.24 g/L) as compared to the EA reference glass. It should be noted though that some of the ccc glasses exhibited varying amounts of crystallization. Since the current durability model[12] is only applicable to homogeneous glasses, the inability of the model to predict the PCT response for those ccc glasses which resulted in devitrification is not surprising.

Exhibit E9 in Appendix E provides plots of the DWPF models that relate the logarithm of the normalized PCT (for each element of interest) to a linear function of a free energy of hydration term (ΔG_p, kcal/100g glass) derived from all of the glass compositional views and heat treatments.[12] Prediction limits (at a 95% confidence) for an individual PCT result are also plotted along with the linear fit. The EA and ARM results are also indicated on these plots. Exhibit E10 in Appendix E provides a version of these plots for the quenched glasses only while Exhibit E11 in Appendix E provides a version for ccc glasses only. Figure 3-3 shows the log NL [B] versus ΔG_P for the quenched and ccc glasses.

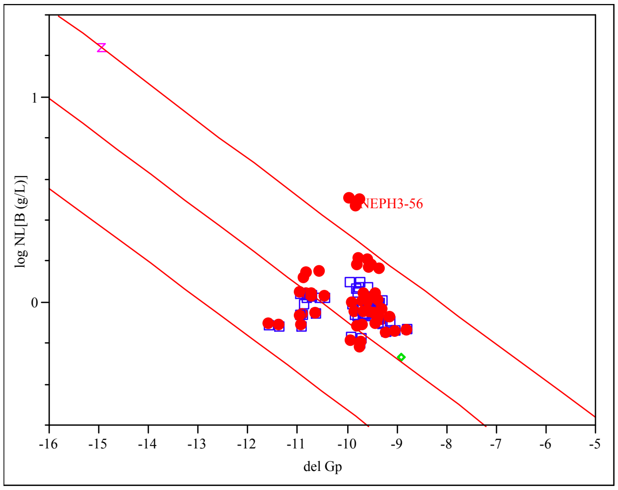


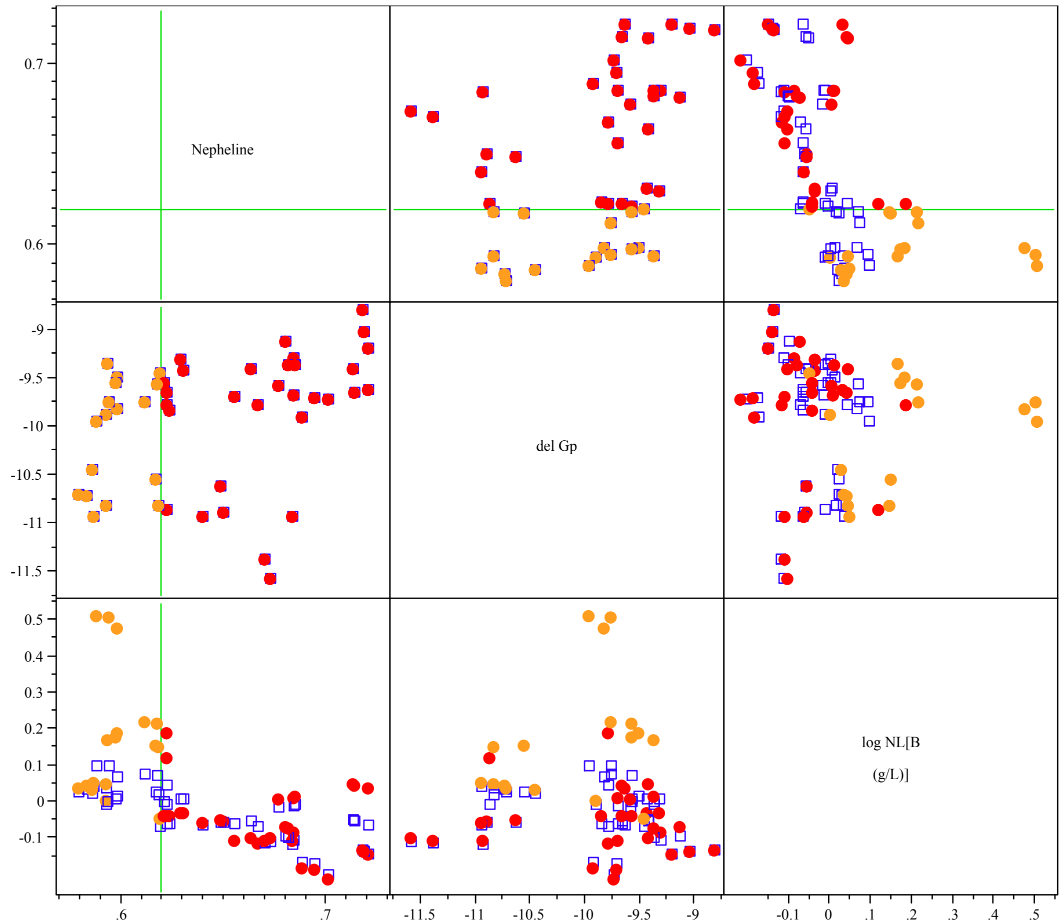
Figure 3-3. NL [B] versus ΔG_P for the quenched (□) and ccc (●) Phase 3 glasses.

As shown in Figure 3-3, all of the quenched Phase 3 glasses are predictable by the ΔG_P model. Also, with the exception of NEPH3-56, all of the ccc glasses are predictable by the ΔG_P model. Since NEPH3-56ccc is not a homogeneous glass (and contains nepheline, as will be shown below in Section 3.3), it is not surprising that the model is not able to predict its durability. While the PCT response of NEPH3-56ccc is acceptable, it is not predictable. All of the Phase 3 glasses remaining after a nepheline discriminator screening would be both acceptable as compared to the EA reference glass and predictable using the ΔG_P model. The relationship between predictability and the nepheline discriminator is explored in the next section.

3.2.7 *Values of the Nepheline Constraint and Predictability*

Li *et al.* proposed 0.62 as the critical value for the nepheline discriminator.[22] Glass compositions with a nepheline discriminator value of less than 0.62 are prone to nepheline crystallization.[22] Figure 3-4 provides a scatter plot matrix of the values for PCT response for boron, for the nepheline constraint, and for ΔG_P. In this plot, the PCT response is provided for both the quenched (□) and ccc (● or ●) versions of the glass. The two different colors used to represent the ccc results allow for the distinction between those glasses that satisfy the nepheline constraint (●) and those that fail it (●).

Based on Figure 3-4, the PCT results for the ccc version of NEPH3-56 (i.e., the three compositional views of the ccc version of NEPH3-56), while unpredictable by the ΔG_P model (see Figure 3-3), also correspond to compositional views that fail the nepheline constraint. As discussed earlier, this glass would be screened out of DWPF processing if a nepheline discriminator value of 0.62 were to be implemented.



(□) quenched glasses, (•) ccc glasses that satisfy the nepheline constraint, (•) ccc glasses that do not satisfy the nepheline constraint

Figure 3-4. Scatter Plot Matrix of log NL[B g/L], Nepheline Constraint, and ΔG_P

3.3 Homogeneity

In this section, the primary interest is the possible formation of nepheline (and/or other crystalline phases) in the Phase 3 ccc glasses which could be responsible for the measurable and sometimes statistically significant differences in PCT responses as compared to their quenched counterparts. Table 3-4 summarizes the visual and XRD results for the quenched and ccc Phase 3 glasses. It should be noted that only the ccc versions of the glasses were submitted for XRD analysis given that the visual observations and durability responses suggested no significant crystallization in the quenched glasses. That is, with normalized boron releases ranging from 0.67 g/L to 1.26 g/L, there is no evidence of nepheline formation in the quenched glasses – even if present, the impact is of no practical concern.

Prior to discussing the results, a few words regarding the terminology used in the tables are warranted. The use of "homogeneous" for visual observations indicates that the sample was classified as a single-phase system (i.e., no evidence of crystallization). The term "surface crystals" (used as a descriptor for visual observations) implies that the surface of the glass was characterized by the presence of crystallization while the cross-section of bulk glass appeared homogeneous (i.e., single-phase, black and shiny). Surface crystallization in the Phase 3 glasses was apparent through the presence of a “textured” surface that ranged in appearance from a “dull or matte” surface to a “highly metallic-like” surface.

The XRD results are more qualitative in nature. As previously mentioned, only the ccc glasses were submitted for XRD analysis based on both the PCT responses as well as visual observations of the quenched glasses. The PCT responses of the quenched glasses were “acceptable and predictable” and visual observations suggested only the presence of surface devitrification on the higher WL glasses. Historically, surface devitrification occurs as WLs increase, and this is typically the result of spinel formation for DWPF type glasses. The Phase 3 PCT responses suggested that for those quenched glasses that were classified as having “surface crystallization” or a “metallic haze on the surface”, spinel formation was highly probable – which is consistent with recent observations and the inert effect on the PCT response. For the ccc glasses, the XRD results suggested that the glass was either amorphous or contained some degree of crystallization. The presence of a characteristically high background devoid of crystalline spectral lines indicates that the glass product is amorphous (suggesting either a completely amorphous product or that the degree of crystallization is below the detection limit – approximately 0.5 vol% in glass). In terms of crystallization, the XRD results indicated the presence of spinel (Trevorite, $NiFe_2O_4$) and nepheline ($NaAlSiO_4$). For a more detailed description of the visual observations and XRD results of both the quenched and ccc glasses, see WSRC-NB-2006-00016.

3.3.1 *Visual Observations*

Visual observations of the quenched Phase 3 glasses indicate that nine glasses were homogeneous, while the remaining seven glasses were characterized by a metallic haze on the surface with the bulk (cross-section) being homogeneous. The nine quenched glasses classified as visually homogeneous were generally lower WL glasses within their respective frit series.

The noted surface crystallization on the seven quenched, high WL glasses is consistent with historical, visual observations of DWPF-based glasses, especially those targeting higher waste loadings. More specifically, use of descriptions such as a dull or matte texture and/or metallic-like surface is common for DWPF-type glasses targeting higher WLs and/or having undergone a slow cooling schedule. Previous XRD analyses have indicated that the textured or metallic-like surfaces are typically a result of spinels that precipitate during the cooling process. This is in-line with glass theory which suggests that as WL increases, the concentrations of Fe_2O_3, NiO, Cr_2O_3, and/or MnO also increase, enhancing the likelihood of spinel devitrification. Based on the PCT responses for the quenched glasses, spinel formation resulting in the metallic haze is reasonable as spinels have been shown to have no impact on the durability response.[14]

A metallic haze, either somewhat shiny or dull, characterized the surface of all 16 ccc glasses. The primary difference among the ccc glasses is the degree of devitrification visually observed within the bulk glass. That is, when examining the cross-sections of the heat treated samples, visual observations ranged from “shiny and clean” (indicating a homogeneous glass) to “devitrified”. In general, the transition from homogeneous to partially devitrified and completely devitrified resulted as WL increased within a specific frit – sludge system. For example, consider NEPH3-46ccc through NEPH3-48ccc (from Table 3-4). The visual observations suggest that the bulk of the heat treated sample was homogeneous at 40% WL (NEPH3-46ccc), partially devitrified at 47% WL (NEPH3-47ccc), and completely devitrified at 51% WL (NEPH3-48ccc).

In general, visual observations indicate that devitrification was more prevalent in the ccc glasses than in the quenched glasses, as expected, given kinetics are more favorable for devitrification during the slower cooling cycle.

Table 3-4. Visual observations and XRD results for the Phase 3 glasses.

Glass	Frit ID	Target WL	Heat Treatment	Visual	XRD
NEPH3-41	418	35	quenched	Patty - black, shiny, homogeneous; Crucible - clean with bubbles	-
NEPH3-41	418	35	ccc	Surface – shiny, metallic; Bulk - shiny and clean	Amorphous
NEPH3-42	418	40	quenched	Patty - black, shiny, homogeneous; Crucible - clean with bubbles	-
NEPH3-42	418	40	ccc	Surface – shiny, metallic with crystals; Bulk - black, shiny, clean	Amorphous
NEPH3-43	418	46	quenched	Patty - black, shiny, homogeneous; Crucible - clean with bubbles	-
NEPH3-43	418	46	ccc	Surface - dull metallic with crystals; Bulk - shiny, black, some crystals	$NiFe_2O_4$
NEPH3-44	418	50	quenched	Patty - shiny metallic haze; Crucible – clean with bubbles	-
NEPH3-44	418	50	ccc	Surface - crusty, metallic with crystals; Bulk - black matte, crystals	$NiFe_2O_4$, $NaAlSiO_4$
NEPH3-45	501	35	quenched	Patty - black, shiny, homogeneous; Crucible - clean with bubbles	-
NEPH3-45	501	35	ccc	Surface - metallic haze; Bulk - black, shiny, clean	Amorphous
NEPH3-46	501	40	quenched	Patty - black, shiny, homogeneous; Crucible - clean with bubbles	-
NEPH3-46	501	40	ccc	Surface - metallic haze with crystals; Bulk - black, shiny, clean	Amorphous
NEPH3-47	501	47	quenched	Patty - black, shiny with a few hazy swirls; Crucible - clean with bubbles	-
NEPH3-47	501	47	ccc	Surface – dull, metallic haze with crystals; Bulk – black, shiny with crystals	$NiFe_2O_4$
NEPH3-48	501	51	quenched	Patty – a few shiny, metallic spots; Crucible - clean with bubbles	-
NEPH3-48	501	51	ccc	Surface - dull and crusty; Bulk - black matte with crystals, devitrified	$NiFe_2O_4$
NEPH3-49	425	35	quenched	Patty - black, shiny, homogeneous; Crucible - clean with bubbles	-
NEPH3-49	425	35	ccc	Surface - metallic haze; Bulk – clean	Amorphous
NEPH3-50	425	40	quenched	Patty - black, shiny, homogeneous; Crucible - clean with bubbles	-
NEPH3-50	425	40	ccc	Surface – metallic haze with many crystals; Bulk – clean	Amorphous
NEPH3-51	425	44	quenched	Patty - black, shiny with a few milky swirls; Crucible - clean with bubbles	-
NEPH3-51	425	44	ccc	Surface – dull and crusty; Bulk – clean	$NiFe_2O_4$
NEPH3-52	425	48	quenched	Patty - shiny metallic surface; Crucible - clean with bubbles	-
NEPH3-52	425	48	ccc	Surface – metallic haze with heavy crystallization; Bulk – crystals	$NiFe_2O_4$
NEPH3-53	502	35	quenched	Patty - black, shiny, homogeneous; Crucible - clean with bubbles	-
NEPH3-53	502	35	ccc	Surface – metallic haze with crystals; Bulk – clean	Amorphous
NEPH3-54	502	40	quenched	Patty - black, shiny, homogeneous; Crucible - clean with bubbles	-
NEPH3-54	502	40	ccc	Surface – dull, metallic haze with some crystals; Bulk – clean	Amorphous
NEPH3-55	502	48	quenched	Patty – shiny, metallic surface; Crucible - clean with bubbles	-
NEPH3-55	502	48	ccc	Surface – dull metallic haze with crystals; Bulk – crystals	$NiFe_2O_4$
NEPH3-56	502	51	quenched	Patty – shiny, metallic surface; Crucible - clean with bubbles	-
NEPH3-56	502	51	ccc	Surface – dull and crusty; Bulk - crystals	$NiFe_2O_4$, $NaAlSiO_4$

3.3.2 *XRD Results*

The XRD results shown in Table 3-4 provide a technical basis for making decisions regarding the impact of nepheline formation on durability. The PCT data (as shown in Figure 3-2) indicate that, in general, as WL increased within a given frit-sludge system, the difference in NL [B] between quenched and ccc glasses increased. This same type of response was seen in the Phase 2 study.[2] Since the higher WL glasses challenge the nepheline discriminator value of 0.62, it is not surprising that nepheline crystallization and a reduction in durability occurred in some of the Phase 3 glasses.

XRD results indicated that the low WL glasses (i.e. 35 and 40 wt%) were amorphous in each of the four frit-sludge groups. This agrees well with the PCT data, in that no statistical or practical difference in NL [B] response was seen between the quenched and ccc versions of each glass, with the exception of NEPH3-53. This exception is not of practical concern, as the NL [B] for NEPH3-53ccc was only 1.12 g/L (based on measured composition), which is more than an order of magnitude below that of the EA reference glass and which fell within the prediction uncertainty of the ΔG_P model for boron.

The higher WL ccc glasses (> 40% WL) in each frit-sludge group were shown by XRD to contain spinel (trevorite, $NiFe_2O_4$). This is expected, since as WL increases, the spinel formers (Fe, Mn, Ni and Cr) increase in concentration, resulting in precipitation of spinels in the glass upon slow cooling. Two of the highest WL glasses, NEPH3-44 and NEPH3-56, also contained nepheline ($NaAlSiO_4$). It is possible that some of the other high WL glasses, such as NEPH3-48, NEPH3-51 and NEPH3-55 also contain some nepheline, but that the amount of nepheline crystallization was below the detection limit of the XRD instrument. The presence of small amounts of nepheline would explain the difference in PCT responses between the quenched and ccc versions of these glasses. While a statistical difference in NL [B] response for these three glasses between the two cooling conditions was seen, the difference is small and of little practical concern, since the NL [B] values for the ccc glasses are well below that of the EA reference glass and the PCT responses fell within the uncertainty bands of the ΔG_P models.

The effect of nepheline crystallization is shown most clearly by NEPH3-56ccc. For this glass, the PCT response shows a significant difference between the quenched and ccc specimens, and XRD indicates that nepheline crystallization has occurred. As previously noted, nepheline formation can result in a severe deterioration of the chemical durability of the glass through changes in the composition of the residual glass (i.e., a continuous glass matrix which is Al_2O_3 and/or SiO_2 deficient). The primary driver for the reduction in durability is the removal of three moles of glass forming oxides (Al_2O_3 and $2SiO_2$) per each mole of Na_2O from the continuous glass phase when nepheline crystallizes. Therefore, nepheline formation produces an Al_2O_3 and SiO_2 deficient continuous glass matrix (relative to the same composition which is void of crystals) which reduces the durability of the final product. The magnitude of the reduction ultimately depends on the extent of crystallization. For NEPH3-56ccc, the NL [B] is still acceptable as compared to the EA reference glass (3.23 vs. 16.695 g/L). However, the glass's unpredictability by the ΔG_P model suggests, once again, that glasses with nepheline discriminator values below the 0.62 limit may be of concern for processing at the DWPF.

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4.0 Conclusions

The results of this Phase 3 study concur with the earlier phases in that a nepheline discriminator of 0.62 appears to be the appropriate value for screening out glasses with the potential for nepheline crystallization upon slow cooling (and therefore reduced chemical durability). For the glasses studied here, the nepheline discriminator was also successful in screening out glasses that would be unpredictable by the ΔG_P model. Further discussion of a nepheline discriminator for possible inclusion in DWPF process controls will be addressed in a forthcoming report.

Chemical composition measurements indicated that the experimental glasses were close to their target compositions. The targeted SO_4^{2-} concentrations in the Phase 3 glasses ranged from 0.468 to 0.682 wt%. The chemical composition data suggest essentially full retention of SO_4^{2-} in the glass (i.e., no solubility or volatilization issues during the fabrication process). There were no signs of a salt layer on any of the Phase 3 glasses. The degree of SO_4^{2-} retention did not appear to be frit-dependent for these four frits. Coupling the analytical measurements with visual observations of the as-fabricated glasses, the results suggest that the 0.6 wt% SO_4^{2-} limit is applicable for the SB4 systems evaluated in this study.

PCT results showed that all of the Phase 3 quenched glasses were acceptable as compared with the EA reference glass. The durabilities of some of the ccc glasses, particularly those with higher WLs, were statistically greater than their quenched counterparts. However, this was shown to be of little practical significance, as the durabilities of the ccc glasses were also all below that of the EA reference glass.

The glass that was not predicable contained both spinel and nepheline, had a nepheline discriminator value of less than 0.62 and was slow cooled. Since the glass was not homogenous, it is expected that the ΔG_P models will not correctly predict its performance.

Visual observations and PCT results indicated that all of the Phase 3 quenched glasses were amorphous. For the ccc glasses, XRD results indicated that the lower WL glasses (35 and 40 wt%) in each frit-sludge group were amorphous, which was consistent with visual observations and PCT response.

The higher WL glasses (> 40% WL) in each frit-sludge group were shown by XRD to contain spinel (trevorite, $NiFe_2O_4$). XRD showed that two of the highest WL glasses contained nepheline ($NaAlSiO_4$) as well. It is possible that some of the other high WL glasses also contained some nepheline, but that the amount of nepheline crystallization was below the detection limit associated with XRD. Nepheline crystallization was shown to result in a decrease in durability for some of the high WL ccc glasses. In the worst case (for the glasses studied here), the NL [B] increased from 1.26 g/L (quenched) to 3.23 g/L (ccc) for glass NEPH3-56. However, this NL [B] is still acceptable as compared to the EA reference glass (16.695 g/L).[11]

With respect to frit selection for SB4, the Phase 3 results indicate that Frits 418, 425, 501, and 502 are all good candidates, based on chemical durability and devitrification upon slow cooling. Differences in chemical durability and devitrification behavior were relatively small between the four frits studied as part of Phase 3. The results also indicate that WLs of 35-40 wt% are attainable with these frits, producing glasses with acceptable durability responses. However, melt rate is also an important factor in frit selection. Melt rate studies on these frits are currently underway and will likely have a significant impact on frit selection due to the high Al_2O_3 content of SB4.

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5.0 Recommendations

The path forward for evaluating the impact of nepheline formation on SB4-based glasses should include an assessment of the impact of implementing a nepheline discriminator value of 0.62 as an administrative control at DWPF, based on the results of the Phase 1 – 3 studies and the on-going Frit 503 study. A determination should be made as to whether the nepheline discriminator would screen out all of the existing data that are either unacceptable (based on PCT responses) and/or unpredictable (using the ΔG_P models).

In addition, the impact of measurement uncertainty (MAR) on the projected operating windows for the frit-SB4 systems of interest must be made. The nepheline discriminator value of 0.62 does not yet have a measurement uncertainty associated with it. An assessment must be made to determine whether the inclusion of measurement uncertainty in the nepheline discriminator will restrict the range of WLs available to DWPF.

Finally, the impact of applying a nepheline discriminator to process controls must be evaluated for glasses that have already been fabricated at DWPF. Future work should identify what impact, if any, implementation of the nepheline discriminator would have on acceptability of historical glass compositions.

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Appendix A

An Analytical Plan for Measuring the Chemical Compositions of the Nepheline Phase 3 Study Glasses

(SRNL-SCS-2006-00006)

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SRNL-SCS-2006-00006

February 14, 2006

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wo – without glass identifiers

R. A. Baker, Technical Reviewer — Date: 2/22/2006

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AN ANALYTICAL PLAN FOR MEASURING THE CHEMICAL COMPOSITIONS OF THE NEPHELINE PHASE 3 STUDY GLASSES (U)

1.0 EXECUTIVE SUMMARY

A study is being conducted by the Savannah River National Laboratory (SRNL) for the Defense Waste Processing Facility (DWPF) that involves investigating the potential impact of nepheline formation on the durability of high level waste glasses. To address this issue, several glass compositions were identified for their potential for the formation of nepheline as part of the frit development activities for Sludge Batch 4 (SB4). Sixteen of these glasses were selected to be batched and fabricated as Phase 3 of the nepheline study. These glasses complemented the earlier studies by continuing the investigation into the ability of the nepheline discriminator to predict the occurrence of a nepheline primary crystalline phase for SB4 glasses and into the impact of such phases on the durability of the SB4 glasses.

The chemical compositions of these 16 Phase 3 glasses are to be determined by SRNL's Process Science Analytical Laboratory (PSAL). This memorandum provides an analytical plan to direct and support these measurements at PSAL.

2.0 INTRODUCTION

A study is being conducted by the Savannah River National Laboratory (SRNL) for the Defense Waste Processing Facility (DWPF) that involves investigating the potential impact of nepheline formation on the durability of high level waste glasses [1]. To address this issue, sixteen glass compositions were identified for their potential for the formation of nepheline as part of the frit development activities for Sludge Batch 4 (SB4). These glasses make up the Phase 3 study, which has two primary objectives. The first is to continue to demonstrate the ability of the discriminator value to adequately predict nepheline formation potential for specific glass systems of interest. The second is to generate additional data that have a high probability of supporting the SB4 variability study. To support these two objectives, glasses were selected to cover waste loadings (WLs) that tightly bound the nepheline discriminator value of 0.62 [2], with the intent of refining this value to a level of confidence where it can be incorporated into offline administrative controls and/or the Product Composition Control System (PCCS) to support Slurry Mix Evaporator (SME) acceptability decisions. In addition, glasses targeting lower WLs (35 and 40%) will be prepared and analyzed to contribute needed data to the ComPro™ database [3] in anticipation of a variability study for SB4.

The chemical compositions of the 16 Phase 3 glasses are to be determined by SRNL's Process Science Analytical Laboratory (PSAL). This memorandum provides an analytical plan to direct and support these measurements at PSAL.

3.0 ANALYTICAL PLAN

The analytical procedures used by PSAL to determine cation concentrations for a glass sample include steps for sample preparation and for instrument calibration. Each glass is to be prepared in duplicate by each of two dissolution methods: lithium metaborate fusion (LM) and sodium peroxide fusion (PF).

The primary measurements of interest are to be acquired as follows. The samples prepared by LM are to be measured for barium (Ba), calcium (Ca), cerium (Ce), chromium (Cr), copper (Cu), potassium (K), lanthanum (La), magnesium (Mg), manganese (Mn), sodium (Na), lead (Pb), sulfur (S), thorium (Th), titanium (Ti), zinc (Zn), and zirconium (Zr) concentrations. Samples prepared by PF are to be measured for aluminum (Al), boron (B), iron (Fe), lithium (Li), nickel (Ni), silicon (Si), and uranium (U). Samples dissolved by both preparation methods are to be measured using Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP-AES). It should be noted that some of these elements are minor components that may be near detection limits for most, if not all, of the study glasses.

Randomizing the preparation steps and blocking and randomizing the measurements for the ICP-AES are of primary concern in the development of this analytical plan. The sources of uncertainty for the analytical procedure used by PSAL to determine the cation concentrations for the submitted glass samples are dominated by the dissolution step in the preparation of the sample and by the calibrations of the ICP-AES.

Samples of glass standards will be included in the analytical plan to provide an opportunity for checking the performance of the instrumentation over the course of the analyses and for potential bias correction. Specifically, several samples of Waste Compliance Plan (WCP) Batch 1 (BCH) [4] and a uranium standard glass (Ustd) are included in this analytical plan. The reference compositions of these glasses are provided in Table 1.

Table 1: Oxide Compositions of WCP Batch 1 (BCH) and of Ustd (wt%)

Oxide/ Anion	BCH (wt %)	Ustd (wt %)
Al_2O_3	4.877	4.1
B_2O_3	7.777	9.209
BaO	0.151	0
CaO	1.22	1.301
Cr_2O_3	0.107	0
Cs_2O	0.06	0
CuO	0.399	0
Fe_2O_3	12.839	13.196
K_2O	3.327	2.999
Li_2O	4.429	3.057
MgO	1.419	1.21
MnO	1.726	2.892
Na_2O	9.003	11.795
Nd_2O_3	0.147	0
NiO	0.751	1.12
RuO_2	0.0214	0
SiO_2	50.22	45.353
SO_3	0	0
TiO_2	0.677	1.049
U_3O_8	0	2.406
ZrO_2	0.098	0

Each glass sample submitted to PSAL will be prepared in duplicate by the LM and PF dissolution methods. Every prepared sample will be read twice by ICP-AES, with the instrument being calibrated before each of these two sets of readings. This will lead to four measurements for each cation of interest for each submitted glass.

Table 2 presents identifying codes, G01 through G16, for the 16 glasses fabricated for this nepheline study. The table provides a naming convention that is to be used in analyzing the glasses and reporting the measurements of their compositions.[a]

[a] Renaming these samples helps to ensure that they will be processed as blind samples within PSAL. Table 2 is not shown in its entirety in the copies going to PSAL.

Table 2: Glass Identifiers[a] to Establish Blind Samples for PSAL

Glass ID	Sample ID	Glass ID	Sample ID
NEPH3-41	G06	NEPH3-49	G13
NEPH3-42	G08	NEPH3-50	G04
NEPH3-43	G14	NEPH3-51	G03
NEPH3-44	G01	NEPH3-52	G09
NEPH3-45	G12	NEPH3-53	G05
NEPH3-46	G07	NEPH3-54	G16
NEPH3-47	G15	NEPH3-55	G10
NEPH3-48	G02	NEPH3-56	G11

3.1 PREPARATION OF THE SAMPLES

Each of the 16 glasses included in this analytical plan is to be prepared in duplicate by the LM and PF dissolution methods. Thus, the total number of prepared glass samples is determined by $16 \cdot 2 \cdot 2 = 64$, not including the samples of the BCH and Ustd glass standards that are to be prepared.

Table 3 provides blocking and (random) sequencing schema for conducting the preparation steps of the analytical procedures. One block of preparation work is provided for each preparation method to facilitate the scheduling of activities by work shift. The identifier for each of the prepared samples indicates the sample identifier (ID), preparation method, and duplicate number.

[a] The nomenclature NEPH3-41 stands for a nepheline glass ("NEPH"), Phase 3 ("3"), with the identifying number 41 ("-41"). The Phase 1 and Phase 2 studied glasses with numbers 1 through 12 and 13 through 40, respectively.

Table 3: Preparation Blocks by Dissolution Method

LM (Lithium Metaborate)	PF (Peroxide Fusion)
G14LM1	G07PF1
G04LM1	G13PF1
G16LM1	G10PF1
G07LM1	G09PF1
G02LM1	G15PF1
G14LM2	G03PF1
G04LM2	G06PF1
G16LM2	G04PF1
G07LM2	G07PF2
G10LM1	G14PF1
G13LM1	G01PF1
G06LM1	G08PF1
G05LM1	G05PF1
G02LM2	G02PF1
G12LM1	G16PF1
G05LM2	G12PF1
G11LM1	G14PF2
G09LM1	G11PF1
G01LM1	G06PF2
G10LM2	G08PF2
G08LM1	G12PF2
G13LM2	G09PF2
G15LM1	G15PF2
G03LM1	G13PF2
G09LM2	G10PF2
G15LM2	G04PF2
G06LM2	G03PF2
G08LM2	G01PF2
G12LM2	G11PF2
G01LM2	G16PF2
G11LM2	G05PF2
G03LM2	G02PF2

3.2 ICP-AES Calibration Blocks

The glass samples prepared by the LM and PF dissolution methods are to be analyzed using ICP-AES instrumentation calibrated for the particular preparation method. After the initial set of cation concentration measurements, the ICP-AES instrumentation is to be recalibrated and a second set of concentration measurements for the cations determined.

Randomized plans for measuring cation concentrations in the LM-prepared and PF-prepared samples are provided in Table 4. The cations to be measured are specified as part of the table. In the tables, the sample identifiers for the 16 study glasses have been modified by the addition of a suffix (a “1”or a “2”) to indicate whether the measurement was made during the first or second (respectively) calibration of the ICP-AES instrumentation. The identifiers for the BCH and Ustd samples have been modified to indicate the ICP-AES calibration and that each of these prepared samples is to be read 3 times (mirrored in the corresponding suffix of 1, 2, or 3) per block and calibration.

Table 4: ICP-AES Blocks & Calibration Groups by Preparation Method

LM Glass Samples				PF Glass Samples			
Used to Measure Elemental Ba, Ca, Ce, Cr, Cu, K, La, Mg, Mn, Na, Pb, S, Th, Ti, Zn, & Zr				Used to Measure Elemental Al, B, Fe, Li, Ni, Si, & U			
Block 1		**Block 2**		**Block 1**		**Block 2**	
Calibration 1	**Calibration 2**	**Calibration 1**	**Calibration 2**	**Calibration 1**	**Calibration 2**	**Calibration 1**	**Calibration 2**
BCHLM111	BCHLM121	BCHLM211	BCHLM221	BCHPF111	BCHPF121	BCHPF211	BCHPF221
UstdLM111	UstdLM121	UstdLM211	UstdLM221	UstdPF111	UstdPF121	UstdPF211	UstdPF221
G14LM21	G07LM22	G04LM21	G08LM22	G10PF21	G10PF12	G15PF11	G02PF22
G13LM21	G03LM12	G06LM21	G06LM12	G06PF21	G11PF22	G08PF11	G04PF22
G05LM21	G14LM22	G16LM11	G16LM22	G11PF21	G05PF12	G13PF11	G16PF22
G12LM21	G09LM12	G08LM21	G08LM12	G03PF21	G12PF22	G14PF21	G14PF22
G03LM11	G12LM22	G11LM21	G01LM22	G07PF21	G06PF12	G16PF21	G09PF12
G13LM11	G05LM22	G06LM11	G06LM22	G05PF11	G01PF12	G04PF21	G02PF12
G09LM21	G12LM12	G10LM11	G15LM12	G06PF11	G07PF22	G14PF11	G14PF12
G07LM21	G13LM22	G01LM21	G04LM22	G11PF11	G06PF22	G09PF21	G16PF12
BCHLM112	BCHLM122	BCHLM212	BCHLM222	BCHPF112	BCHPF122	BCHPF212	BCHPF222
UstdLM112	UstdLM122	UstdLM212	UstdLM222	UstdPF112	UstdPF122	UstdPF212	UstdPF222
G02LM21	G02LM12	G04LM11	G16LM12	G12PF21	G11PF12	G02PF11	G09PF22
G09LM11	G03LM22	G11LM11	G04LM12	G05PF21	G05PF22	G02PF21	G08PF12
G02LM11	G02LM22	G10LM21	G10LM22	G01PF21	G12PF12	G09PF11	G04PF12
G05LM11	G09LM22	G01LM11	G15LM22	G01PF11	G07PF12	G04PF11	G08PF22
G12LM11	G14LM12	G15LM11	G10LM12	G12PF11	G03PF22	G15PF21	G15PF22
G07LM11	G13LM12	G08LM11	G11LM22	G10PF11	G03PF12	G08PF21	G13PF12
G03LM21	G05LM12	G16LM21	G11LM12	G07PF11	G10PF22	G13PF21	G15PF12
G14LM11	G07LM12	G15LM21	G01LM12	G03PF11	G01PF22	G16PF11	G13PF22
BCHLM113	BCHLM123	BCHLM213	BCHLM223	BCHPF113	BCHPF123	BCHPF213	BCHPF223
UstdLM113	UstdLM123	UstdLM213	UstdLM223	UstdPF113	UstdPF123	UstdPF213	UstdPF223

4.0 CONCLUDING COMMENTS

In summary, this analytical plan identifies two preparation blocks in Table 3 and eight ICP-AES calibration blocks in Table 4 for use by PSAL. The sequencing of the activities associated with each of the steps in the analytical procedures has been randomized. The size of each of the blocks was selected so that it could be completed in a single work shift.

If a problem is discovered while measuring samples in a calibration block, the instrument should be re-calibrated and the block of samples re-measured in its entirety. If for some reason the measurements are not conducted in the sequences presented in this report, a record should be made of the actual order used along with any explanative comments.

The analytical plan indicated in the preceding tables should be modified by the personnel of PSAL to include any calibration check standards and/or other standards that are part of their routine operating procedures. It is also recommended that the solutions resulting from each of the prepared samples be archived for some period, considering the “shelf-life” of the solutions, in case questions arise during data analysis. This would allow for the solutions to be rerun without additional preparations, thus minimizing cost.

5.0 REFERENCES

[1] Fox, K.M., T.B. Edwards, and D.K. Peeler, "Nepheline Formation Potential in Sludge Batch 4 (SB4) and its Impact on Durability: Selecting Glasses for a Phase 3 Study," WSRC-TR-2006-00053, Revision 0, 2006.

[2] Li, H., P. Hrma, J.D. Vienna, M. Qian, Y. Su, and D.E. Smith, "Effects of Al_2O_3, B_2O_3, Na_2O, and SiO_2 on Nepheline Formation in Borosilicate Glasses: Chemical and Physical Correlations," **Journal of Non-Crystalline Solids**, 331, pgs. 202-216, 2003.

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[4] Jantzen, C.M., J.B. Pickett, K.G. Brown, T.B. Edwards, and D.C. Beam, "Process/ Product Models for the Defense Waste Processing Facility (DWPF): Part I. Predicting Glass Durability from Composition Using a Thermodynamic Hydration Energy Reaction Model (THERMO™) (U)," WSRC-TR-93-673, Revision 1, Volume 2, Table B.1, pp. B.9, 1995.

Appendix B

An Analytical Plan for Measuring PCT Solutions for the First Set of Glasses from the Phase 3 Nepheline Study

(SRNL-SCS-2006-00003)

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SRNL-SCS-2006-00003

February 8, 2006

To: K. M. Fox, SRNL

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Statistical Consulting Section

wo – without glass identifiers

R. A. Baker, Technical Reviewer — Date: 2/14/2006

R. C. Tuckfield, Manager, Statistical Consulting Section — Date: 2/14/2006

AN ANALYTICAL PLAN FOR MEASURING PCT SOLUTIONS FOR THE FIRST SET OF GLASSES FROM THE PHASE 3 NEPHELINE STUDY (U)

1.0 EXECUTIVE SUMMARY

A study is being conducted by the Savannah River National Laboratory (SRNL) for the Defense Waste Processing Facility (DWPF) that involves investigating the potential impact of nepheline formation on the durability of high level waste glasses. To address this issue, several glass compositions were identified for their potential for the formation of nepheline as part of the frit development activities for Sludge Batch 4 (SB4). Sixteen of these glasses were selected to be batched and fabricated as Phase 3 of the nepheline study; the durability of the glasses is to be measured using the Product Consistency Test (PCT) as defined in ASTM C-1285-2002. Two heat treatments were utilized during the fabrication of each of these glasses. Specifically, each of the 16 glasses was quenched (i.e., rapidly cooled) and cooled in accordance with the centerline-canister-cooling (ccc) regime. Both heat treatments of each glass are to be subjected to the PCT.

To complete the full complement of PCTs, the 16 glasses were grouped into two sets based on the frits that were combined with SB4. The first set of PCTs covered the glasses that were developed using Frits 418 and 501, while the second set of PCTs covered the glasses that were developed using Frits 425 and 502. Both sets of PCTs are to be submitted to SRNL's Process Science Analytical Laboratory (PSAL) for measurement. This memorandum provides an analytical plan for the measurement of the first set of PCTs by PSAL.

2.0 INTRODUCTION

A study is being conducted by the Savannah River National Laboratory (SRNL) for the Defense Waste Processing Facility (DWPF) that involves investigating the potential impact of nepheline formation on the durability of high level waste glasses [1]. To address this issue, 16 glass compositions were selected for their potential for the formation of nepheline as part of the frit development activities for Sludge Batch 4 (SB4). The specific SB4 option being considered is Case 15C Blend 1 as defined by Shah [2]. The glasses were selected to be batched and fabricated as Phase 3 of the nepheline study; the durability of the glasses is to be measured using the Product Consistency Test (PCT) as defined in ASTM C-1285-2002 [3]. Two heat treatments were utilized during the fabrication of each of these glasses. Specifically, each of the 16 glasses was quenched (i.e., rapidly cooled) and cooled in accordance with the centerline-canister-cooling (ccc) regime. Both heat treatments of each glass are to be subjected to the PCT.

To complete the full complement of PCTs, the 16 glasses were grouped into two sets based on the frits that were combined with SB4. The first set of PCTs covered the glasses (NEPH3-41 through NEPH3-48) that were developed using Frits 418 and 501, while the second set of PCTs covered the glasses (NEPH3-49 through NEPH3-56) that were developed using Frits 425 and 502. This analytical study plan addresses the PCT solutions for NEPH3-41 through NEPH3-48 (or set #1) for both quenched and ccc heat treatments. A separate analytical plan will be developed for the second set (NEPH3-49 through NEPH3-56). Both sets of PCTs are to be submitted to SRNL's Process Science Analytical Laboratory (PSAL) for measurement. Table 1 presents a listing of the glasses covered by this memorandum.

Table 1: Identifiers for Glasses Covered by this Plan[a]

NEPH3-41	NEPH3-45
NEPH3-41ccc	NEPH3-45ccc
NEPH3-42	NEPH3-46
NEPH3-42ccc	NEPH3-46ccc
NEPH3-43	NEPH3-47
NEPH3-43ccc	NEPH3-47ccc
NEPH3-44	NEPH3-48
NEPH3-44ccc	NEPH3-48ccc

3.0 DISCUSSION

Each of the study glasses of Table 1 is to be subjected to the PCT in triplicate. In addition to PCTs for the study glasses, triplicate PCTs are to be conducted on a sample of the Approved Reference Material – One (ARM-1) glass and a sample of the Environmental Assessment (EA) glass. Two reagent blank samples are also to be included in these tests. This results in 56 sample solutions being required to complete these PCTs.

The leachates from these tests will be diluted by adding 4 mL of 0.4 M HNO_3 to 6 mL of the leachate (a 6:10 volume to volume, v:v, dilution) before being submitted to PSAL. The leachates of EA will

[a] The nomenclature NEPH3-41 stands for a nepheline glass ("NEPH"), Phase 3 ("3"), with the identifying number 41 ("41"). The Phase 1 and 2 studies contained glasses 1 through 12 and 13 through 40, respectively.

be further diluted (1:10 v:v) with deionized water prior to submission to PSAL in order to prevent problems with the nebulizer. Note that additional dilutions for the ccc versions of one or more of the study glasses may be needed due to a possibly low durability of some of the glasses. Upon termination of the PCT, a decision is to be made (by the technicians and a PSAL representative, if called by the technician) as to whether any other dilution is needed for these solutions to mitigate any potential gelling issues. Any extra dilutions are to be reported, and guidance is to be given as to how the dilutions are to be handled in the statistical assessment of the measurement data. More specifically, PSAL will be responsible for indicating if any additional dilutions were made and how they were, or how they should be, accounted for in the reported measurements.

Table 2 presents identifying codes, F01 through F56, for the individual solutions required for the PCTs of the select study glasses and of the standards (EA, ARM-1, and blanks). This provides a naming convention that is to be used by PSAL in analyzing the solutions and reporting the relevant concentration measurements.[a]

Table 2: Identifiers for the PCT Solutions Covered by this Plan

Original Sample	Solution Identifier	Original Sample	Solution Identifier	Original Sample	Solution Identifier
NEPH3-41	F37	NEPH3-44ccc	F36	NEPH3-48	F38
NEPH3-41	F09	NEPH3-44ccc	F22	NEPH3-48	F14
NEPH3-41	F17	NEPH3-44ccc	F42	NEPH3-48	F18
NEPH3-41ccc	F32	NEPH3-45	F55	NEPH3-48ccc	F47
NEPH3-41ccc	F11	NEPH3-45	F16	NEPH3-48ccc	F20
NEPH3-41ccc	F41	NEPH3-45	F40	NEPH3-48ccc	F33
NEPH3-42	F52	NEPH3-45ccc	F28	EA	F50
NEPH3-42	F05	NEPH3-45ccc	F02	EA	F53
NEPH3-42	F06	NEPH3-45ccc	F04	EA	F46
NEPH3-42ccc	F39	NEPH3-46	F25	ARM-1	F08
NEPH3-42ccc	F30	NEPH3-46	F35	ARM-1	F29
NEPH3-42ccc	F23	NEPH3-46	F45	ARM-1	F13
NEPH3-43	F10	NEPH3-46ccc	F07	blank	F26
NEPH3-43	F49	NEPH3-46ccc	F19	blank	F12
NEPH3-43	F54	NEPH3-46ccc	F56		
NEPH3-43ccc	F34	NEPH3-47	F01		
NEPH3-43ccc	F44	NEPH3-47	F27		
NEPH3-43ccc	F51	NEPH3-47	F31		
NEPH3-44	F15	NEPH3-47ccc	F48		
NEPH3-44	F24	NEPH3-47ccc	F03		
NEPH3-44	F21	NEPH3-47ccc	F43		

4.0 ANALYTICAL PLAN

The analytical plan for PSAL is provided in this section. Each of the solution samples submitted to PSAL is to be analyzed only once for each of the following: boron (B), barium (Ba), cadmium (Cd),

[a] Renaming these samples ensures that they will be processed as blind samples by PSAL. This table does not contain the solution identifiers for those on the distribution list with a “wo” following their names.

chromium (Cr), iron (Fe), lithium (Li), sodium (Na), lead (Pb), silicon (Si), thorium (Th), and uranium (U). B, Li, Na, and Si are the elements that are to be used in the assessment of glass durability; the other elements are being monitored to address solution disposal issues in SRNL upon termination of the PCTs. The measurements are to be made in parts per million (ppm).

The analytical procedure used by PSAL to determine the concentrations utilizes an Inductively Coupled Plasma – Atomic Emission Spectrometer (ICP-AES). The PCT solutions (as identified in Table 2) are grouped in three ICP-AES blocks for processing by PSAL in Table 3. Each block requires a different calibration of the ICP-AES.

Table 3: ICP-AES Calibration Blocks for Leachate Measurements

Block 1	Block 2	Block 3
std-b1-1	std-b2-1	std-b3-1
F52	F05	F06
F39	F30	F23
F08	F27	F46
F01	F03	F31
F48	F35	F43
F26	F19	F45
F25	F09	F56
F07	F11	F17
F37	F29	F41
F32	F53	F12
std-b1-2	std-b2-2	std-b3-2
F15	F24	F21
F36	F22	F42
F38	F14	F18
F47	F20	F33
F50	F49	F13
F10	F44	F54
F34	F16	F51
F55	F02	F40
F28	std-b2-3	F04
std-b1-3		std-b3-3

A multi-element solution standard (denoted by “std-bi-j” where i=1 to 3 represents the block number and j=1, 2, and 3 represents the position in the block) was added at the beginning, middle, and end of each of the three blocks. This standard may be useful in checking and correcting for bias in the concentration measurements arising from the ICP calibrations.

5.0 SUMMARY

In summary, this analytical plan provides identifiers for the PCT solutions in Table 2 and three ICP-AES calibration blocks in Table 3 for PSAL to use in conducting the boron (B), barium (Ba), cadmium (Cd), chromium (Cr), iron (Fe), lithium (Li), sodium (Na), lead (Pb), silicon (Si), thorium (Th), and uranium (U) concentration measurements for the PCT study of this select subset of the Phase 3 nepheline glasses. The sequencing of the activities associated with each of the steps in the analytical procedure has been randomized. The size of the blocks was selected so that the block could be completed in a single work shift. If for some reason the measurements are not conducted in the sequence presented in this memorandum, the actual order should be recorded along with any explanative comments.

The analytical plan indicated in the preceding tables should be modified by the personnel of PSAL to include any calibration check standards and/or other standards that are part of their standard operating procedures.

6.0 REFERENCES

[1] Fox, K.M., T.B. Edwards, and D.K. Peeler, "Nepheline Formation Potential in Sludge Batch 4 (SB4) and its Impact on Durability: Selecting Glasses for a Phase 3 Study," WSRC-TR-2006-00053, Revision 0, 2006.

[2] Shah, H.B., "Estimate of Sludge Batch 4 Calcine Composition Additional Cases for Final Recommendation," CBU-PIT-2006-00011, Revision 0, 2006.

[3] ASTM C-1285-2002, "Standard Test Methods for Determining Chemical Durability of Nuclear Waste Glasses: The Product Consistency Test (PCT)," ASTM, 2002.

Appendix C

An Analytical Plan for Measuring PCT Solutions for the Second Set of Glasses from the Phase 3 Nepheline Study

SRNL-SCS-2006-00007

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SRNL-SCS-2006-00007

February 27, 2006

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wo – without glass identifiers

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R. C. Tuckfield, Manager
Statistical Consulting Section — Date: 2/28/2006

An Analytical Plan for Measuring PCT Solutions for the Second Set of Glasses from the Phase 3 Nepheline Study (U)

1.0 EXECUTIVE SUMMARY

A study is being conducted by the Savannah River National Laboratory (SRNL) for the Defense Waste Processing Facility (DWPF) that involves investigating the potential impact of nepheline formation on the durability of high level waste glasses. To address this issue, several glass compositions were identified for their potential for the formation of nepheline as part of the frit development activities for Sludge Batch 4 (SB4). Sixteen of these glasses were selected to be batched and fabricated as Phase 3 of the nepheline study; the durability of the glasses is to be measured using the Product Consistency Test (PCT) as defined in ASTM C-1285-2002. Two heat treatments were utilized during the fabrication of each of these glasses. Specifically, each of the 16 glasses was quenched (i.e., rapidly cooled) and cooled in accordance with the centerline-canister-cooling (ccc) regime. Both heat treatments of each glass are to be subjected to the PCT.

To complete the full complement of PCTs, the 16 glasses were grouped into two sets based on the frits that were combined with SB4. The first set of PCTs covered the glasses that were developed using Frits 418 and 501, while the second set of PCTs covered the glasses that were developed using Frits 425 and 502. Both sets of PCTs are to be submitted to SRNL's Process Science Analytical Laboratory (PSAL) for measurement. This memorandum provides an analytical plan for the measurement of the second set of PCTs by PSAL.

2.0 INTRODUCTION

A study is being conducted by the Savannah River National Laboratory (SRNL) for the Defense Waste Processing Facility (DWPF) that involves investigating the potential impact of nepheline formation on the durability of high level waste glasses [1]. To address this issue, 16 glass compositions were selected for their potential for the formation of nepheline as part of the frit development activities for Sludge Batch 4 (SB4). The specific SB4 option being considered is Case 15C Blend 1 as defined by Shah [2]. The glasses were selected to be batched and fabricated as Phase 3 of the nepheline study [1]; the durability of the glasses is to be measured using the Product Consistency Test (PCT) as defined in ASTM C-1285-2002 [3]. Two heat treatments were utilized during the fabrication of each of these glasses. Specifically, each of the 16 glasses was quenched (i.e., rapidly cooled) and cooled in accordance with the centerline-canister-cooling (ccc) regime. Both heat treatments of each glass are to be subjected to the PCT.

To complete the full complement of PCTs, the 16 glasses were grouped into two sets based on the frits that were combined with SB4. The first set of PCTs covered the glasses (NEPH3-41 through NEPH3-48)[a] that were developed using Frits 418 and 501, while the second set of PCTs covered the glasses (NEPH3-49 through NEPH3-56) that were developed using Frits 425 and 502. This analytical study plan addresses the PCT solutions for NEPH3-49 through NEPH3-56 (or set #2) for both quenched and ccc heat treatments. A separate analytical plan was previously developed for the first set (NEPH3-41 through NEPH3-48) [4]. Both sets of PCTs are to be submitted to SRNL's Process Science Analytical Laboratory (PSAL) for measurement. Table 1 presents a listing of the glasses covered by this memorandum.

Table 1: Identifiers for Glasses Covered by this Plan

NEPH3-49	NEPH3-53
NEPH3-49ccc	NEPH3-53ccc
NEPH3-50	NEPH3-54
NEPH3-50ccc	NEPH3-54ccc
NEPH3-51	NEPH3-55
NEPH3-51ccc	NEPH3-55ccc
NEPH3-52	NEPH3-56
NEPH3-52ccc	NEPH3-56ccc

3.0 DISCUSSION

Each of the study glasses of Table 1 is to be subjected to the PCT in triplicate. In addition to PCTs for the study glasses, triplicate PCTs are to be conducted on a sample of the Approved Reference Material – One (ARM-1) glass and a sample of the Environmental Assessment (EA) glass. Two reagent blank samples are also to be included in these tests. This results in 56 sample solutions being required to complete these PCTs.

The leachates from these tests will be diluted by adding 4 mL of 0.4 M HNO_3 to 6 mL of the leachate (a 6:10 volume to volume, v:v, dilution) before being submitted to PSAL. The leachates of EA will

[a] The nomenclature NEPH3-41 stands for a nepheline glass ("NEPH"), Phase 3 ("3"), with the identifying number 41 ("41"). The Phase 1 and 2 studies contained glasses 1 through 12 and 13 through 40, respectively. Phase 3 covers glasses 41 through 56.

be further diluted (1:10 v:v) with deionized water prior to submission to PSAL in order to prevent problems with the nebulizer. Note that additional dilutions for the ccc versions of one or more of the study glasses may be needed due to a possibly low durability of some of the glasses. Upon termination of the PCT, a decision is to be made (by the technicians and a PSAL representative, if called by the technician) as to whether any other dilution is needed for these solutions to mitigate any potential gelling issues. Any extra dilutions are to be reported, and guidance is to be given as to how the dilutions are to be handled in the statistical assessment of the measurement data. More specifically, PSAL will be responsible for indicating if any additional dilutions were made and how they were, or how they should be, accounted for in the reported measurements.

Table 2 presents identifying codes, H01 through H56, for the individual solutions required for the PCTs of the select study glasses and of the standards (EA, ARM-1, and blanks). This provides a naming convention that is to be used by PSAL in analyzing the solutions and reporting the relevant concentration measurements.[a]

Table 2: Identifiers for the PCT Solutions

Original Sample	Solution Identifier	Original Sample	Solution Identifier	Original Sample	Solution Identifier
NEPH3-49	H31	NEPH3-52ccc	H47	NEPH3-56	H04
NEPH3-49	H44	NEPH3-52ccc	H32	NEPH3-56	H14
NEPH3-49	H06	NEPH3-52ccc	H16	NEPH3-56	H48
NEPH3-49ccc	H53	NEPH3-53	H37	NEPH3-56ccc	H07
NEPH3-49ccc	H52	NEPH3-53	H29	NEPH3-56ccc	H35
NEPH3-49ccc	H55	NEPH3-53	H13	NEPH3-56ccc	H45
NEPH3-50	H38	NEPH3-53ccc	H36	EA	H43
NEPH3-50	H24	NEPH3-53ccc	H50	EA	H54
NEPH3-50	H46	NEPH3-53ccc	H02	EA	H11
NEPH3-50ccc	H05	NEPH3-54	H33	ARM-1	H09
NEPH3-50ccc	H22	NEPH3-54	H15	ARM-1	H17
NEPH3-50ccc	H41	NEPH3-54	H20	ARM-1	H49
NEPH3-51	H03	NEPH3-54ccc	H26	blank	H19
NEPH3-51	H34	NEPH3-54ccc	H18	blank	H56
NEPH3-51	H39	NEPH3-54ccc	H21		
NEPH3-51ccc	H40	NEPH3-55	H23		
NEPH3-51ccc	H10	NEPH3-55	H08		
NEPH3-51ccc	H51	NEPH3-55	H27		
NEPH3-52	H42	NEPH3-55ccc	H25		
NEPH3-52	H30	NEPH3-55ccc	H28		
NEPH3-52	H01	NEPH3-55ccc	H12		

4.0 ANALYTICAL PLAN

The analytical plan for PSAL is provided in this section. Each of the solution samples submitted to PSAL is to be analyzed only once for each of the following: boron (B), barium (Ba), cadmium (Cd),

[a] Renaming these samples ensures that they will be processed as blind samples by PSAL. This table does not contain the solution identifiers for those on the distribution list with a "wo" following their names.

chromium (Cr), iron (Fe), lithium (Li), sodium (Na), lead (Pb), silicon (Si), thorium (Th), and uranium (U). B, Li, Na, and Si are the elements that are to be used in the assessment of glass durability; the other elements are being monitored to address solution disposal issues in SRNL upon termination of the PCTs. The measurements are to be made in parts per million (ppm). The analytical procedure used by PSAL to determine the concentrations utilizes an Inductively Coupled Plasma – Atomic Emission Spectrometer (ICP-AES). The PCT solutions (as identified in Table 2) are grouped in three ICP-AES blocks for processing by PSAL in Table 3. Each block requires a different calibration of the ICP-AES.

Table 3: ICP-AES Calibration Blocks for Leachate Measurements

Block 1	Block 2	Block 3
std-b1-1	std-b2-1	std-b3-1
H43	H52	H55
H07	H15	H21
H09	H22	H39
H26	H34	H11
H04	H18	H01
H47	H50	H27
H23	H28	H41
H33	H24	H13
H19	H30	H20
H31	H29	H49
std-b1-2	std-b2-2	std-b3-2
H40	H54	H56
H38	H14	H46
H05	H17	H48
H53	H44	H12
H37	H35	H16
H42	H10	H06
H36	H32	H02
H03	H08	H51
H25	std-b2-3	H45
std-b1-3		std-b3-3

A multi-element solution standard (denoted by "std-bi-j" where i=1 to 3 represents the block number and j=1, 2, and 3 represents the position in the block) was added at the beginning, middle, and end of each of the three blocks. This standard may be useful in checking and correcting for bias in the concentration measurements arising from the ICP calibrations.

5.0 SUMMARY

In summary, this analytical plan provides identifiers for the PCT solutions in Table 2 and three ICP-AES calibration blocks in Table 3 for PSAL to use in conducting the boron (B), barium (Ba), cadmium (Cd), chromium (Cr), iron (Fe), lithium (Li), sodium (Na), lead (Pb), silicon (Si), thorium (Th), and uranium (U) concentration measurements for the PCT study of this select subset of the Phase 3 nepheline glasses. The sequencing of the activities associated with each of the steps in the analytical procedure has been randomized. The size of the blocks was selected so that the block could be completed in a single work shift. If for some reason the measurements are not conducted in the sequence presented in this memorandum, the actual order should be recorded along with any explanative comments.

The analytical plan indicated in the preceding tables should be modified by the personnel of PSAL to include any calibration check standards and/or other standards that are part of their standard operating procedures.

6.0 REFERENCES

[1] Fox, K.M., T.B. Edwards, and D.K. Peeler, "Nepheline Formation Potential in Sludge Batch 4 (SB4) and its Impact on Durability: Selecting Glasses for a Phase 3 Study," WSRC-TR-2006-00053, Revision 0, 2006.

[2] Shah, H.B., "Estimate of Sludge Batch 4 Calcine Composition Additional Cases for Final Recommendation," CBU-PIT-2006-00011, Revision 0, 2006.

[3] ASTM C-1285-2002, "Standard Test Methods for Determining Chemical Durability of Nuclear Waste Glasses: The Product Consistency Test (PCT)," ASTM, 2002.

[4] Edwards, T.B., "An Analytical Plan for Measuring PCT Solutions for the First Set of Glasses from the Phase 3 Nepheline Study (U)," SRNL-SCS-2006-00003, February 8, 2006

Appendix D

Tables and Exhibits Supporting the Analysis of the Chemical Composition Measurements of the Nepheline Phase 3 Study Glasses

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Table D1. Targeted Oxide Concentrations (as wt%'s) for the Phase 3 Nepheline Study Glasses

"NS" Glasses

Glass #	Al2O3	B2O3	BaO	CaO	Ce2O3	Cr2O3	CuO	Fe2O3	K2O	La2O3	Li2O	MgO	MnO	Na2O	NiO	PbO	SO4	SiO2	ThO2	TiO2	U3O8	ZnO	ZrO2	Sum
NEPH3-41	8.682	5.200	0.044	0.836	0.052	0.074	0.021	9.298	0.120	0.038	5.200	0.873	1.918	12.928	0.552	0.032	0.468	50.840	0.023	0.009	2.674	0.034	0.083	100.000
NEPH3-42	9.922	4.800	0.050	0.955	0.060	0.085	0.024	10.626	0.138	0.043	4.800	0.998	2.192	13.632	0.631	0.036	0.535	47.245	0.026	0.011	3.056	0.039	0.095	100.000
NEPH3-43	11.411	4.320	0.058	1.098	0.069	0.098	0.028	12.220	0.158	0.050	4.320	1.148	2.521	14.477	0.726	0.042	0.615	42.932	0.030	0.012	3.515	0.045	0.109	100.000
NEPH3-44	12.403	4.000	0.063	1.194	0.075	0.106	0.030	13.283	0.172	0.054	4.000	1.248	2.740	15.040	0.789	0.045	0.669	40.057	0.033	0.013	3.820	0.049	0.119	100.000
NEPH3-45	8.682	5.850	0.044	0.836	0.052	0.074	0.021	9.298	0.120	0.038	6.500	0.873	1.918	10.978	0.552	0.032	0.468	50.840	0.023	0.009	2.674	0.034	0.083	100.000
NEPH3-46	9.922	5.400	0.050	0.955	0.060	0.085	0.024	10.626	0.138	0.043	6.000	0.998	2.192	11.832	0.631	0.036	0.535	47.245	0.026	0.011	3.056	0.039	0.095	100.000
NEPH3-47	11.659	4.770	0.059	1.122	0.070	0.100	0.028	12.486	0.162	0.051	5.300	1.173	2.576	13.027	0.741	0.043	0.629	42.213	0.031	0.013	3.591	0.046	0.111	100.000
NEPH3-48	12.651	4.410	0.064	1.218	0.076	0.108	0.031	13.548	0.175	0.055	4.900	1.273	2.795	13.711	0.804	0.046	0.682	39.338	0.034	0.014	3.897	0.050	0.121	100.000
NEPH3-49	8.682	5.200	0.044	0.836	0.052	0.074	0.021	9.298	0.120	0.038	5.200	0.873	1.918	14.228	0.552	0.032	0.468	49.540	0.023	0.009	2.674	0.034	0.083	100.000
NEPH3-50	9.922	4.800	0.050	0.955	0.060	0.085	0.024	10.626	0.138	0.043	4.800	0.998	2.192	14.832	0.631	0.036	0.535	46.045	0.026	0.011	3.056	0.039	0.095	100.000
NEPH3-51	10.915	4.480	0.056	1.051	0.066	0.093	0.026	11.689	0.151	0.048	4.480	1.098	2.411	15.315	0.694	0.040	0.589	43.250	0.029	0.012	3.362	0.043	0.104	100.000
NEPH3-52	11.907	4.160	0.061	1.146	0.072	0.102	0.029	12.751	0.165	0.052	4.160	1.198	2.630	15.798	0.757	0.043	0.642	40.454	0.032	0.013	3.667	0.047	0.114	100.000
NEPH3-53	8.682	5.200	0.044	0.836	0.052	0.074	0.021	9.298	0.120	0.038	7.150	0.873	1.918	10.978	0.552	0.032	0.468	50.840	0.023	0.009	2.674	0.034	0.083	100.000
NEPH3-54	9.922	4.800	0.050	0.955	0.060	0.085	0.024	10.626	0.138	0.043	6.600	0.998	2.192	11.832	0.631	0.036	0.535	47.245	0.026	0.011	3.056	0.039	0.095	100.000
NEPH3-55	11.907	4.160	0.061	1.146	0.072	0.102	0.029	12.751	0.165	0.052	5.720	1.198	2.630	13.198	0.757	0.043	0.642	41.494	0.032	0.013	3.667	0.047	0.114	100.000
NEPH3-56	12.651	3.920	0.064	1.218	0.076	0.108	0.031	13.548	0.175	0.055	5.390	1.273	2.795	13.711	0.804	0.046	0.682	39.338	0.034	0.014	3.897	0.050	0.121	100.000

Table D2. Measured Elemental Concentrations (wt%) for Samples Prepared Using Lithium Metaborate

Glass ID	Laboratory ID	Block	Sub-Block	Analytical Sequence	Ba	Ca	Ce	Cr	Cu	K	La	Mg	Mn	Na	Pb	S	Th	Ti	Zn	Zr
Batch 1	BCHLM111	1	1	1	0.136	0.874	0.023	0.068	0.339	2.96	<0.010	0.851	1.32	6.69	<0.020	<0.100	<0.010	0.415	<0.010	0.061
Ustd	UstdLM111	1	1	2	<0.010	0.942	0.017	0.165	0.034	2.67	<0.010	0.715	2.14	8.79	<0.020	<0.100	0.063	0.588	<0.010	<0.010
NEPH3-43	G14LM21	1	1	3	0.051	0.707	0.037	0.068	0.033	0.136	0.041	0.668	1.88	10.3	0.038	0.192	0.096	0.013	0.039	0.082
NEPH3-49	G13LM21	1	1	4	0.037	0.538	0.031	0.049	0.026	0.106	0.029	0.505	1.47	10.4	0.030	0.143	0.072	0.011	0.050	0.059
NEPH3-53	G05LM21	1	1	5	0.038	0.549	0.033	0.049	0.027	0.100	0.030	0.521	1.48	8.08	0.029	0.146	0.076	0.011	0.030	0.062
NEPH3-45	G12LM21	1	1	6	0.039	0.550	0.034	0.046	0.028	0.106	0.032	0.511	1.48	8.00	0.034	0.150	0.075	0.011	0.039	0.058
NEPH3-51	G03LM11	1	1	7	0.047	0.685	0.041	0.062	0.032	0.131	0.039	0.644	1.84	11.1	0.034	0.190	0.095	0.014	0.036	0.072
NEPH3-49	G13LM11	1	1	8	0.040	0.690	0.035	0.050	0.025	0.120	0.031	0.571	1.46	11.3	0.030	0.148	0.073	0.011	0.030	0.064
NEPH3-52	G09LM21	1	1	9	0.054	0.752	0.049	0.068	0.033	0.146	0.042	0.723	2.00	11.7	0.039	0.208	0.099	0.012	0.042	0.082
NEPH3-46	G07LM21	1	1	10	0.043	0.608	0.040	0.057	0.031	0.120	0.037	0.582	1.68	8.49	0.038	0.166	0.084	0.013	0.032	0.054
Batch 1	BCHLM112	1	1	11	0.138	0.894	0.022	0.069	0.336	2.88	<0.010	0.863	1.30	6.34	<0.020	<0.100	<0.010	0.418	<0.010	0.061
Ustd	UstdLM112	1	1	12	<0.010	0.933	0.017	0.166	0.033	2.59	<0.010	0.716	2.12	8.39	<0.020	<0.100	0.064	0.597	<0.010	<0.010
NEPH3-48	G02LM21	1	1	13	0.053	0.784	0.043	0.067	0.037	0.164	0.043	0.705	2.08	9.99	0.043	0.212	0.105	0.014	0.054	0.086
NEPH3-52	G09LM11	1	1	14	0.052	0.743	0.048	0.070	0.032	0.145	0.041	0.670	1.99	11.0	0.037	0.201	0.097	0.012	0.041	0.080
NEPH3-48	G02LM11	1	1	15	0.054	0.791	0.044	0.067	0.035	0.158	0.044	0.726	2.14	9.74	0.044	0.216	0.107	0.014	0.043	0.088
NEPH3-53	G05LM11	1	1	16	0.036	0.546	0.033	0.050	0.025	0.106	0.029	0.496	1.48	7.78	0.027	0.145	0.073	0.010	0.029	0.059
NEPH3-45	G12LM11	1	1	17	0.040	0.559	0.035	0.046	0.027	0.103	0.032	0.518	1.51	7.52	0.034	0.153	0.076	0.011	0.046	0.057
NEPH3-46	G07LM11	1	1	18	0.045	0.654	0.041	0.057	0.032	0.127	0.037	0.595	1.75	8.47	0.038	0.169	0.087	0.013	0.033	0.057
NEPH3-51	G03LM21	1	1	19	0.046	0.689	0.040	0.059	0.031	0.146	0.038	0.619	1.87	10.7	0.031	0.189	0.092	0.013	0.034	0.069
NEPH3-43	G14LM11	1	1	20	0.050	0.730	0.037	0.066	0.034	0.140	0.040	0.669	1.96	10.2	0.037	0.191	0.096	0.013	0.050	0.079
Batch 1	BCHLM113	1	1	21	0.139	0.913	0.022	0.070	0.343	2.81	<0.010	0.864	1.33	6.17	<0.020	<0.100	<0.010	0.423	<0.010	0.063
Ustd	UstdLM113	1	1	22	<0.010	0.948	0.016	0.164	0.033	2.58	<0.010	0.712	2.21	8.37	<0.020	<0.100	0.063	0.600	<0.010	<0.010
Batch 1	BCHLM121	1	2	1	0.139	0.871	<0.010	0.062	0.339	2.98	<0.010	0.848	1.34	6.82	<0.020	<0.100	<0.010	0.406	<0.010	0.045
Ustd	UstdLM121	1	2	2	<0.010	0.930	<0.010	0.156	0.028	2.67	<0.010	0.706	2.18	9.03	<0.020	<0.100	0.048	0.585	<0.010	<0.010
NEPH3-46	G07LM22	1	2	3	0.043	0.613	0.040	0.056	0.031	0.120	0.037	0.584	1.72	9.07	0.037	0.166	0.083	0.011	0.031	0.052
NEPH3-51	G03LM12	1	2	4	0.047	0.691	0.040	0.061	0.031	0.131	0.039	0.649	1.90	11.5	0.032	0.189	0.094	0.012	0.035	0.071
NEPH3-43	G14LM22	1	2	5	0.049	0.718	0.036	0.067	0.032	0.136	0.040	0.672	1.97	10.8	0.036	0.189	0.095	0.011	0.037	0.081
NEPH3-52	G09LM12	1	2	6	0.051	0.754	0.048	0.070	0.031	0.145	0.041	0.680	2.04	11.9	0.036	0.206	0.097	0.010	0.040	0.079
NEPH3-45	G12LM22	1	2	7	0.039	0.562	0.033	0.045	0.027	0.107	0.031	0.518	1.52	8.24	0.032	0.152	0.073	0.009	0.038	0.057
NEPH3-53	G05LM22	1	2	8	0.038	0.558	0.033	0.048	0.026	0.101	0.030	0.531	1.53	8.26	0.028	0.147	0.075	0.008	0.029	0.061
NEPH3-45	G12LM12	1	2	9	0.039	0.553	0.033	0.045	0.025	0.101	0.032	0.524	1.52	8.17	0.032	0.151	0.074	0.009	0.045	0.055
NEPH3-49	G13LM22	1	2	10	0.037	0.555	0.031	0.049	0.026	0.110	0.029	0.512	1.51	10.7	0.028	0.151	0.071	0.008	0.050	0.058
Batch 1	BCHLM122	1	2	11	0.129	0.862	<0.010	0.052	0.321	2.92	<0.010	0.839	1.34	6.67	<0.020	<0.100	<0.010	0.397	<0.010	0.036
Ustd	UstdLM122	1	2	12	<0.010	0.936	<0.010	0.152	0.023	2.61	<0.010	0.699	2.17	8.82	<0.020	<0.100	0.038	0.578	<0.010	<0.010
NEPH3-48	G02LM12	1	2	13	0.054	0.802	0.044	0.067	0.035	0.160	0.044	0.731	2.15	10.3	0.043	0.214	0.106	0.013	0.042	0.086
NEPH3-51	G03LM22	1	2	14	0.045	0.690	0.039	0.059	0.030	0.145	0.037	0.621	1.87	11.7	0.031	0.190	0.089	0.010	0.033	0.068
NEPH3-48	G02LM22	1	2	15	0.052	0.812	0.043	0.067	0.036	0.170	0.043	0.721	2.11	10.5	0.042	0.219	0.104	0.012	0.053	0.086
NEPH3-52	G09LM22	1	2	16	0.053	0.765	0.049	0.068	0.032	0.147	0.042	0.727	2.07	12.1	0.036	0.209	0.098	0.010	0.041	0.082
NEPH3-43	G14LM12	1	2	17	0.049	0.739	0.036	0.066	0.034	0.141	0.040	0.677	1.94	11.0	0.036	0.199	0.095	0.011	0.048	0.078

Table D2. Measured Elemental Concentrations (wt%) for Samples Prepared Using Lithium Metaborate (continued)

NEPH3-49	G13LM12	1	2	18	0.040	0.709	0.034	0.049	0.024	0.122	0.030	0.576	1.51	11.8	0.027	0.147	0.072	0.009	0.029	0.063
NEPH3-53	G05LM12	1	2	19	0.036	0.552	0.032	0.050	0.024	0.106	0.029	0.500	1.46	8.49	0.026	0.147	0.071	0.008	0.028	0.057
NEPH3-46	G07LM12	1	2	20	0.044	0.661	0.041	0.056	0.032	0.128	0.037	0.602	1.73	9.28	0.037	0.172	0.085	0.011	0.032	0.055
Batch 1	BCHLM123	1	2	21	0.129	0.856	<0.010	0.053	0.320	3.02	<0.010	0.839	1.31	6.81	<0.020	<0.100	<0.010	0.397	<0.010	0.037
Ustd	UstdLM123	1	2	22	<0.010	0.940	<0.010	0.152	0.023	2.71	<0.010	0.701	2.14	9.09	<0.020	<0.100	0.039	0.588	<0.010	<0.010
Batch 1	BCHLM211	2	1	1	0.120	0.823	<0.010	0.053	0.304	2.96	<0.010	0.847	1.34	6.83	<0.020	<0.100	<0.010	0.397	<0.010	0.032
Ustd	UstdLM211	2	1	2	<0.010	0.892	<0.010	0.146	<0.010	2.69	<0.010	0.698	2.16	8.99	<0.020	<0.100	0.034	0.572	<0.010	<0.010
NEPH3-50	G04LM21	2	1	3	0.042	0.597	0.031	0.057	0.026	0.118	0.033	0.582	1.71	11.3	0.031	0.183	0.079	0.009	0.034	0.062
NEPH3-41	G06LM21	2	1	4	0.036	0.519	0.031	0.049	0.024	0.099	0.027	0.510	1.50	9.92	0.026	0.157	0.069	0.008	0.034	0.056
NEPH3-54	G16LM11	2	1	5	0.045	0.599	0.011	0.051	0.025	0.109	0.033	0.598	1.70	9.16	0.034	0.180	0.081	0.010	0.033	0.064
NEPH3-42	G08LM21	2	1	6	0.041	0.592	0.037	0.056	0.023	0.107	0.031	0.576	1.67	10.4	0.031	0.172	0.078	0.009	0.036	0.065
NEPH3-56	G11LM21	2	1	7	0.054	0.761	0.051	0.060	0.031	0.145	0.039	0.728	2.09	10.6	0.039	0.233	0.102	0.009	0.042	0.081
NEPH3-41	G06LM11	2	1	8	0.036	0.532	0.031	0.049	0.026	0.103	0.026	0.511	1.46	9.95	0.026	0.159	0.069	0.008	0.035	0.055
NEPH3-55	G10LM11	2	1	9	0.050	0.723	0.025	0.061	0.027	0.137	0.040	0.691	1.95	10.4	0.038	0.219	0.096	0.009	0.039	0.078
NEPH3-44	G01LM21	2	1	10	0.052	0.740	0.039	0.062	0.029	0.143	0.040	0.708	2.06	13.1	0.038	0.219	0.097	0.009	0.040	0.077
Batch 1	BCHLM212	2	1	11	0.111	0.813	<0.010	0.043	0.291	2.88	<0.010	0.841	1.29	7.05	<0.020	<0.100	<0.010	0.374	<0.010	0.017
Ustd	UstdLM212	2	1	12	<0.010	0.874	<0.010	0.140	<0.010	2.62	<0.010	0.701	2.12	9.11	<0.020	<0.100	0.025	0.542	<0.010	<0.010
NEPH3-50	G04LM11	2	1	13	0.041	0.613	0.032	0.056	0.024	0.124	0.033	0.580	1.65	11.2	0.031	0.190	0.080	0.008	0.031	0.063
NEPH3-56	G11LM11	2	1	14	0.054	0.780	0.051	0.062	0.032	0.149	0.040	0.728	2.06	10.6	0.039	0.239	0.103	0.009	0.044	0.083
NEPH3-55	G10LM21	2	1	15	0.050	0.725	0.025	0.061	0.030	0.136	0.040	0.696	1.98	10.1	0.038	0.221	0.096	0.009	0.043	0.078
NEPH3-44	G01LM11	2	1	16	0.053	0.765	0.040	0.060	0.030	0.144	0.041	0.720	2.01	11.2	0.039	0.225	0.102	0.009	0.044	0.079
NEPH3-47	G15LM11	2	1	17	0.048	0.719	0.039	0.057	0.028	0.140	0.037	0.679	1.95	9.95	0.040	0.212	0.091	0.009	0.034	0.076
NEPH3-42	G08LM11	2	1	18	0.042	0.614	0.038	0.057	0.024	0.111	0.031	0.583	1.67	10.0	0.031	0.179	0.079	0.009	0.034	0.067
NEPH3-54	G16LM21	2	1	19	0.045	0.604	0.011	0.050	0.025	0.111	0.033	0.588	1.68	8.96	0.033	0.180	0.081	0.010	0.033	0.064
NEPH3-47	G15LM21	2	1	20	0.049	0.721	0.039	0.058	0.029	0.138	0.037	0.683	1.96	10.1	0.039	0.212	0.092	0.010	0.039	0.077
Batch 1	BCHLM213	2	1	21	0.112	0.826	<0.010	0.043	0.298	2.97	<0.010	0.847	1.29	6.76	<0.020	<0.100	<0.010	0.376	<0.010	0.021
Ustd	UstdLM213	2	1	22	<0.010	0.886	<0.010	0.139	<0.010	2.67	<0.010	0.698	2.07	9.05	<0.020	<0.100	0.025	0.540	<0.010	<0.010
Batch 1	BCHLM221	2	2	1	0.128	0.839	0.016	0.061	0.320	2.98	<0.010	0.850	1.35	6.67	<0.020	<0.100	<0.010	0.375	<0.010	0.036
Ustd	UstdLM221	2	2	2	<0.010	0.914	<0.010	0.156	0.021	2.69	<0.010	0.707	2.21	8.97	<0.020	<0.100	0.044	0.553	<0.010	<0.010
NEPH3-42	G08LM22	2	2	3	0.042	0.610	0.040	0.058	0.026	0.111	0.032	0.574	1.75	10.0	0.032	0.161	0.082	0.006	0.036	0.066
NEPH3-41	G06LM12	2	2	4	0.036	0.536	0.033	0.050	0.028	0.103	0.027	0.500	1.55	9.59	0.027	0.149	0.070	0.005	0.034	0.057
NEPH3-54	G16LM22	2	2	5	0.046	0.618	0.013	0.052	0.028	0.112	0.034	0.591	1.78	8.96	0.034	0.168	0.085	0.007	0.033	0.066
NEPH3-42	G08LM12	2	2	6	0.042	0.622	0.040	0.059	0.026	0.110	0.032	0.580	1.73	10.1	0.032	0.163	0.081	0.006	0.034	0.068
NEPH3-44	G01LM22	2	2	7	0.053	0.778	0.042	0.064	0.032	0.151	0.042	0.711	2.17	12.9	0.041	0.209	0.104	0.007	0.041	0.079
NEPH3-41	G06LM22	2	2	8	0.037	0.545	0.033	0.050	0.026	0.105	0.028	0.512	1.53	9.96	0.028	0.148	0.072	0.005	0.034	0.058
NEPH3-47	G15LM12	2	2	9	0.049	0.732	0.041	0.059	0.031	0.141	0.037	0.670	2.06	10.0	0.040	0.197	0.094	0.006	0.034	0.078
NEPH3-50	G04LM22	2	2	10	0.042	0.626	0.033	0.058	0.028	0.122	0.034	0.578	1.77	11.4	0.032	0.170	0.082	0.006	0.033	0.064
Batch 1	BCHLM222	2	2	11	0.122	0.859	0.011	0.056	0.317	3.02	<0.010	0.840	1.35	6.99	<0.020	<0.100	<0.010	0.370	<0.010	0.026
Ustd	UstdLM222	2	2	12	<0.010	0.917	<0.010	0.152	0.020	2.70	<0.010	0.698	2.23	9.08	<0.020	<0.100	0.040	0.553	<0.010	<0.010
NEPH3-54	G16LM12	2	2	13	0.045	0.617	0.013	0.052	0.027	0.112	0.033	0.584	1.83	8.50	0.035	0.167	0.084	0.007	0.033	0.066
NEPH3-50	G04LM12	2	2	14	0.041	0.615	0.033	0.056	0.025	0.122	0.033	0.566	1.79	10.8	0.030	0.169	0.079	0.005	0.030	0.063

Table D2. Measured Elemental Concentrations (wt%) for Samples Prepared Using Lithium Metaborate (continued)

NEPH3-55	G10LM22	2	2	15	0.050	0.747	0.027	0.061	0.032	0.138	0.041	0.683	2.15	9.74	0.039	0.202	0.098	0.006	0.042	0.080
NEPH3-47	G15LM22	2	2	16	0.049	0.729	0.041	0.059	0.031	0.138	0.037	0.672	2.12	9.69	0.040	0.194	0.094	0.007	0.038	0.078
NEPH3-55	G10LM12	2	2	17	0.050	0.742	0.027	0.061	0.028	0.140	0.040	0.680	2.17	9.63	0.038	0.201	0.098	0.006	0.037	0.079
NEPH3-56	G11LM22	2	2	18	0.053	0.785	0.053	0.060	0.033	0.149	0.040	0.712	2.21	10.2	0.039	0.217	0.105	0.006	0.041	0.083
NEPH3-56	G11LM12	2	2	19	0.053	0.781	0.053	0.062	0.033	0.149	0.040	0.709	2.23	10.2	0.039	0.217	0.103	0.006	0.042	0.084
NEPH3-44	G01LM12	2	2	20	0.053	0.770	0.042	0.061	0.031	0.144	0.041	0.703	2.14	11.0	0.040	0.202	0.103	0.007	0.043	0.080
Batch 1	BCHLM223	2	2	21	0.122	0.838	0.011	0.055	0.313	2.98	<0.010	0.836	1.38	6.82	<0.020	<0.100	<0.010	0.362	<0.010	0.030
Ustd	UstdLM223	2	2	22	<0.010	0.898	<0.010	0.149	0.019	2.65	<0.010	0.687	2.28	8.86	<0.020	<0.100	0.039	0.541	<0.010	<0.010

Table D3. Measured Elemental Concentrations (wt%) for Samples Prepared Using Peroxide Fusion

Glass ID	PSAL ID	Block	Sub-Block	Analytical Sequence	Al	B	Fe	Li	Ni	Si	U
Batch 1	Batch 1	1	1	1	2.51	2.25	9.00	2.02	0.539	22.6	<0.100
Ustd	Ustd	1	1	2	2.13	2.87	8.85	1.40	0.767	19.8	1.90
NEPH3-55	G10	1	1	3	6.25	1.08	8.52	2.56	0.475	18.5	3.00
NEPH3-41	G06	1	1	4	4.63	1.38	6.11	2.31	0.385	22.4	2.18
NEPH3-56	G11	1	1	5	6.72	1.03	8.96	2.43	0.542	18.1	3.16
NEPH3-51	G03	1	1	6	5.79	1.22	8.20	1.99	0.512	19.7	2.78
NEPH3-46	G07	1	1	7	5.37	1.55	7.33	2.72	0.477	22.2	2.60
NEPH3-53	G05	1	1	8	4.72	1.43	6.42	3.21	0.407	23.2	2.18
NEPH3-41	G06	1	1	9	4.63	1.42	6.28	2.31	0.391	22.8	2.27
NEPH3-56	G11	1	1	10	6.64	0.97	8.50	2.37	0.511	17.5	3.06
Batch 1	Batch 1	1	1	11	2.54	2.20	8.94	1.98	0.551	22.7	<0.100
Ustd	Ustd	1	1	12	2.13	2.64	9.12	1.39	0.788	20.0	1.96
NEPH3-45	G12	1	1	13	4.73	1.80	6.54	2.97	0.416	23.8	2.21
NEPH3-53	G05	1	1	14	4.74	1.52	6.66	3.25	0.426	23.4	2.17
NEPH3-44	G01	1	1	15	6.69	1.09	8.62	1.81	0.561	18.5	3.16
NEPH3-44	G01	1	1	16	6.60	1.06	8.76	1.79	0.578	18.6	3.14
NEPH3-45	G12	1	1	17	4.67	1.60	6.23	2.90	0.394	23.2	2.16
NEPH3-55	G10	1	1	18	6.23	1.12	9.00	2.51	0.489	19.0	3.05
NEPH3-46	G07	1	1	19	5.37	1.54	7.35	2.70	0.482	22.1	2.61
NEPH3-51	G03	1	1	20	5.87	1.21	8.32	2.02	0.513	20.2	2.75
Batch 1	Batch 1	1	1	21	2.56	2.30	9.65	2.02	0.600	23.8	<0.100
Ustd	Ustd	1	1	22	2.17	2.72	9.38	1.41	0.818	20.7	1.96
Batch 1	Batch 1	1	2	1	2.58	2.69	9.39	2.03	0.571	23.3	<0.100
Ustd	Ustd	1	2	2	2.17	2.94	8.98	1.41	0.767	19.9	1.94
NEPH3-55	G10	1	2	3	6.24	1.37	8.70	2.52	0.475	18.5	2.99
NEPH3-56	G11	1	2	4	6.74	1.25	8.95	2.42	0.522	17.8	3.13
NEPH3-53	G05	1	2	5	4.71	1.65	6.45	3.22	0.397	23.1	2.09
NEPH3-45	G12	1	2	6	4.73	1.82	6.26	2.93	0.380	23.2	2.15
NEPH3-41	G06	1	2	7	4.68	1.65	6.64	2.34	0.402	23.3	2.17
NEPH3-44	G01	1	2	8	6.74	1.24	9.04	1.83	0.590	19.0	3.18
NEPH3-46	G07	1	2	9	5.45	1.70	7.22	2.75	0.474	22.0	2.52
NEPH3-41	G06	1	2	10	4.72	1.56	6.17	2.34	0.376	22.8	2.17
Batch 1	Batch 1	1	2	11	2.72	2.42	9.11	2.03	0.561	23.0	<0.100
Ustd	Ustd	1	2	12	2.16	2.84	9.07	1.41	0.781	20.1	1.92
NEPH3-56	G11	1	2	13	6.86	1.27	9.06	2.45	0.547	18.1	3.06
NEPH3-53	G05	1	2	14	4.79	1.66	6.56	3.26	0.414	23.1	2.12
NEPH3-45	G12	1	2	15	4.84	1.83	6.43	2.97	0.392	23.7	2.18
NEPH3-46	G07	1	2	16	5.49	1.73	7.33	2.75	0.466	22.0	2.58
NEPH3-51	G03	1	2	17	5.82	1.37	7.90	1.99	0.493	19.5	2.72
NEPH3-51	G03	1	2	18	5.91	1.37	7.96	2.03	0.484	19.7	2.76
NEPH3-55	G10	1	2	19	6.88	1.27	8.78	2.59	0.473	19.2	3.02
NEPH3-44	G01	1	2	20	6.75	1.21	8.79	1.81	0.556	18.5	3.10
Batch 1	Batch 1	1	2	21	2.62	2.49	9.70	2.06	0.588	23.8	<0.100
Ustd	Ustd	1	2	22	2.20	2.93	9.65	1.44	0.829	20.9	1.90
Batch 1	Batch 1	2	1	1	2.52	2.46	8.88	2.00	0.544	22.5	<0.100
Ustd	Ustd	2	1	2	2.17	3.01	9.39	1.41	0.795	20.3	1.90
NEPH3-47	G15	2	1	3	6.39	1.57	8.21	2.42	0.508	19.5	2.92
NEPH3-42	G08	2	1	4	5.36	1.47	6.90	2.14	0.425	20.9	2.39
NEPH3-49	G13	2	1	5	4.65	1.62	6.22	2.30	0.387	22.0	2.24
NEPH3-43	G14	2	1	6	6.22	1.36	8.31	1.95	0.530	19.5	2.77
NEPH3-54	G16	2	1	7	5.38	1.50	7.48	2.97	0.453	21.7	2.48
NEPH3-50	G04	2	1	8	5.43	1.51	7.62	2.19	0.457	21.3	2.45
NEPH3-43	G14	2	1	9	6.27	1.39	8.81	1.99	0.538	20.4	2.94
NEPH3-52	G09	2	1	10	6.37	1.26	8.71	1.87	0.535	18.2	3.02
Batch 1	Batch 1	2	1	11	2.53	2.35	8.70	1.98	0.529	22.4	<0.100

**Table D3. Measured Elemental Concentrations (wt%)
for Samples Prepared Using Peroxide Fusion (continued)**

Glass ID	PSAL ID	Block	Sub-Block	Analytical Sequence	Al	B	Fe	Li	Ni	Si	U
Ustd	Ustd	2	1	12	2.12	2.75	8.60	1.38	0.733	19.6	1.85
NEPH3-48	G02	2	1	13	6.76	1.48	9.07	2.22	0.560	18.1	3.25
NEPH3-48	G02	2	1	14	6.85	1.41	9.13	2.24	0.568	18.3	3.17
NEPH3-52	G09	2	1	15	6.38	1.33	9.19	1.89	0.563	18.5	3.02
NEPH3-50	G04	2	1	16	5.47	1.52	7.63	2.19	0.480	21.3	2.51
NEPH3-47	G15	2	1	17	6.46	1.52	8.63	2.42	0.534	19.8	2.97
NEPH3-42	G08	2	1	18	5.47	1.49	7.61	2.21	0.481	22.0	2.50
NEPH3-49	G13	2	1	19	4.80	1.65	6.88	2.38	0.418	23.3	2.25
NEPH3-54	G16	2	1	20	5.50	1.52	7.78	3.03	0.475	22.4	2.52
Batch 1	Batch 1	2	1	21	2.62	2.52	9.67	2.05	0.588	23.8	<0.100
Ustd	Ustd	2	1	22	2.19	2.93	9.62	1.42	0.828	20.7	1.94
Batch 1	Batch 1	2	2	1	2.55	2.59	9.19	2.01	0.548	22.9	<0.100
Ustd	Ustd	2	2	2	2.12	2.90	9.01	1.39	0.755	19.9	1.92
NEPH3-48	G02	2	2	3	6.85	1.44	8.88	2.23	0.547	18.1	3.24
NEPH3-50	G04	2	2	4	5.37	1.52	7.37	2.16	0.445	20.8	2.50
NEPH3-54	G16	2	2	5	5.35	1.52	7.45	2.95	0.455	21.5	2.53
NEPH3-43	G14	2	2	6	6.31	1.35	8.43	1.98	0.511	19.7	2.84
NEPH3-52	G09	2	2	7	6.38	1.29	8.91	1.89	0.529	18.2	3.09
NEPH3-48	G02	2	2	8	6.78	1.36	9.00	2.22	0.546	18.1	3.27
NEPH3-43	G14	2	2	9	6.20	1.35	8.47	1.97	0.510	19.8	2.98
NEPH3-54	G16	2	2	10	5.40	1.46	7.37	2.97	0.432	21.6	2.54
Batch 1	Batch 1	2	2	11	2.70	2.42	9.31	2.05	0.551	23.3	<0.100
Ustd	Ustd	2	2	12	2.17	2.79	8.99	1.41	0.759	20.0	1.97
NEPH3-52	G09	2	2	13	6.36	1.33	8.50	1.89	0.514	18.0	3.04
NEPH3-42	G08	2	2	14	5.37	1.45	6.95	2.15	0.409	20.8	2.45
NEPH3-50	G04	2	2	15	5.40	1.49	7.32	2.17	0.460	20.8	2.49
NEPH3-42	G08	2	2	16	5.38	1.44	7.17	2.18	0.433	21.2	2.53
NEPH3-47	G15	2	2	17	6.40	1.48	8.24	2.41	0.504	19.4	3.04
NEPH3-49	G13	2	2	18	4.74	1.59	6.54	2.35	0.392	22.8	2.33
NEPH3-47	G15	2	2	19	6.41	1.46	8.18	2.43	0.494	19.5	2.98
NEPH3-49	G13	2	2	20	4.76	1.58	6.52	2.37	0.386	22.6	2.31
Batch 1	Batch 1	2	2	21	2.57	2.38	8.94	2.01	0.539	22.9	<0.100
Ustd	Ustd	2	2	22	2.16	2.74	8.59	1.40	0.732	19.5	1.94

Table D4. Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide by Nepheline Study Glass

(100 -Batch 1; 200 -U std)

Glass #	Oxide	Measured (wt%)	Measured-bc (wt%)	Targeted (wt%)	Diff of Measured	Diff of Meas-bc	% Diff of Measured	% Diff of Meas-bc
41	Al2O3 (wt%)	8.8145	8.7921	8.6820	0.1325	0.1101	1.5%	1.3%
41	B2O3 (wt%)	4.8379	4.8831	5.2000	-0.3621	-0.3169	-7.0%	-6.1%
41	BaO (wt%)	0.0405	0.0460	0.0440	-0.0035	0.0020	-8.0%	4.5%
41	CaO (wt%)	0.7458	0.7806	0.8360	-0.0902	-0.0554	-10.8%	-6.6%
41	Ce2O3 (wt%)	0.0375	0.0375	0.0520	-0.0145	-0.0145	-27.9%	-27.9%
41	Cr2O3 (wt%)	0.0723	0.1032	0.0740	-0.0017	0.0292	-2.2%	39.5%
41	CuO (wt%)	0.0325	0.0338	0.0210	0.0115	0.0128	55.0%	60.8%
41	Fe2O3 (wt%)	9.0071	8.6984	9.2980	-0.2909	-0.5996	-3.1%	-6.4%
41	K2O (wt%)	0.1235	0.1150	0.1200	0.0035	-0.0050	2.9%	-4.2%
41	La2O3 (wt%)	0.0317	0.0317	0.0380	-0.0063	-0.0063	-16.7%	-16.7%
41	Li2O (wt%)	5.0055	5.0894	5.2000	-0.1945	-0.1106	-3.7%	-2.1%
41	MgO (wt%)	0.8428	0.8550	0.8730	-0.0302	-0.0180	-3.5%	-2.1%
41	MnO (wt%)	1.9497	1.9547	1.9180	0.0317	0.0367	1.7%	1.9%
41	Na2O (wt%)	13.2845	12.9460	12.9280	0.3565	0.0180	2.8%	0.1%
41	NiO (wt%)	0.4944	0.5134	0.5520	-0.0576	-0.0386	-10.4%	-7.0%
41	PbO (wt%)	0.0288	0.0288	0.0320	-0.0032	-0.0032	-10.0%	-10.0%
41	SO4 (wt%)	0.4591	0.4591	0.4680	-0.0089	-0.0089	-1.9%	-1.9%
41	SiO2 (wt%)	48.8295	49.4073	50.8400	-2.0105	-1.4327	-4.0%	-2.8%
41	ThO2 (wt%)	0.0797	0.0797	0.0230	0.0567	0.0567	246.3%	246.3%
41	TiO2 (wt%)	0.0108	0.0117	0.0090	0.0018	0.0027	20.5%	29.7%
41	U3O8 (wt%)	2.5913	2.7394	2.6740	-0.0827	0.0654	-3.1%	2.4%
41	ZnO (wt%)	0.0426	0.0426	0.0340	0.0086	0.0086	25.4%	25.4%
41	ZrO2 (wt%)	0.0763	0.0763	0.0830	-0.0067	-0.0067	-8.0%	-8.0%
41	Sum (wt%)	97.4384	97.7247	99.9990	-2.5606	-2.2743	-2.6%	-2.3%
42	Al2O3 (wt%)	10.1939	10.1930	9.9220	0.2719	0.2710	2.7%	2.7%
42	B2O3 (wt%)	4.7091	4.6364	4.8000	-0.0909	-0.1636	-1.9%	-3.4%
42	BaO (wt%)	0.0466	0.0530	0.0500	-0.0034	0.0030	-6.8%	6.0%
42	CaO (wt%)	0.8528	0.8927	0.9550	-0.1022	-0.0623	-10.7%	-6.5%
42	Ce2O3 (wt%)	0.0454	0.0454	0.0600	-0.0146	-0.0146	-24.4%	-24.4%
42	Cr2O3 (wt%)	0.0840	0.1198	0.0850	-0.0010	0.0348	-1.1%	41.0%
42	CuO (wt%)	0.0310	0.0321	0.0240	0.0070	0.0081	29.1%	33.9%
42	Fe2O3 (wt%)	10.2331	10.0824	10.6260	-0.3929	-0.5436	-3.7%	-5.1%
42	K2O (wt%)	0.1322	0.1232	0.1380	-0.0058	-0.0148	-4.2%	-10.8%
42	La2O3 (wt%)	0.0369	0.0369	0.0430	-0.0061	-0.0061	-14.1%	-14.1%
42	Li2O (wt%)	4.6718	4.7658	4.8000	-0.1282	-0.0342	-2.7%	-0.7%
42	MgO (wt%)	0.9589	0.9728	0.9980	-0.0391	-0.0252	-3.9%	-2.5%
42	MnO (wt%)	2.2015	2.2071	2.1920	0.0095	0.0151	0.4%	0.7%
42	Na2O (wt%)	13.6485	13.3007	13.6320	0.0165	-0.3313	0.1%	-2.4%
42	NiO (wt%)	0.5561	0.5968	0.6310	-0.0749	-0.0342	-11.9%	-5.4%
42	PbO (wt%)	0.0339	0.0339	0.0360	-0.0021	-0.0021	-5.7%	-5.7%
42	SO4 (wt%)	0.5056	0.5056	0.5350	-0.0294	-0.0294	-5.5%	-5.5%
42	SiO2 (wt%)	45.4066	46.4134	47.2450	-1.8384	-0.8316	-3.9%	-1.8%
42	ThO2 (wt%)	0.0910	0.0910	0.0260	0.0650	0.0650	250.1%	250.1%
42	TiO2 (wt%)	0.0125	0.0135	0.0110	0.0015	0.0025	13.7%	22.5%
42	U3O8 (wt%)	2.9097	3.0922	3.0560	-0.1463	0.0362	-4.8%	1.2%
42	ZnO (wt%)	0.0436	0.0436	0.0390	0.0046	0.0046	11.7%	11.7%
42	ZrO2 (wt%)	0.0898	0.0898	0.0950	-0.0052	-0.0052	-5.4%	-5.4%
42	Sum (wt%)	97.4946	98.3410	99.9990	-2.5044	-1.6580	-2.5%	-1.7%
43	Al2O3 (wt%)	11.8094	11.8078	11.4110	0.3984	0.3968	3.5%	3.5%
43	B2O3 (wt%)	4.3871	4.3193	4.3200	0.0671	-0.0007	1.6%	0.0%
43	BaO (wt%)	0.0555	0.0557	0.0580	-0.0025	-0.0023	-4.2%	-4.0%
43	CaO (wt%)	1.0123	1.0054	1.0980	-0.0857	-0.0926	-7.8%	-8.4%
43	Ce2O3 (wt%)	0.0428	0.0428	0.0690	-0.0262	-0.0262	-38.0%	-38.0%
43	Cr2O3 (wt%)	0.0976	0.1159	0.0980	-0.0004	0.0179	-0.4%	18.2%
43	CuO (wt%)	0.0416	0.0398	0.0280	0.0136	0.0118	48.7%	42.3%
43	Fe2O3 (wt%)	12.1596	11.9802	12.2200	-0.0604	-0.2398	-0.5%	-2.0%

Table D4. Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide by Nepheline Study Glass (continued)

(100 -Batch 1; 200 -U std)

Glass #	Oxide	Measured (wt%)	Measured-bc (wt%)	Targeted (wt%)	Diff of Measured	Diff of Meas-bc	% Diff of Measured	% Diff of Meas-bc
43	K2O (wt%)	0.1665	0.1571	0.1580	0.0085	-0.0009	5.4%	-0.6%
43	La2O3 (wt%)	0.0472	0.0472	0.0500	-0.0028	-0.0028	-5.6%	-5.6%
43	Li2O (wt%)	4.2466	4.3320	4.3200	-0.0734	0.0120	-1.7%	0.3%
43	MgO (wt%)	1.1135	1.1203	1.1480	-0.0345	-0.0277	-3.0%	-2.4%
43	MnO (wt%)	2.5017	2.5270	2.5210	-0.0193	0.0060	-0.8%	0.2%
43	Na2O (wt%)	14.2551	14.4606	14.4770	-0.2219	-0.0164	-1.5%	-0.1%
43	NiO (wt%)	0.6646	0.7132	0.7260	-0.0614	-0.0128	-8.5%	-1.8%
43	PbO (wt%)	0.0396	0.0396	0.0420	-0.0024	-0.0024	-5.7%	-5.7%
43	SO4 (wt%)	0.5775	0.5775	0.6150	-0.0375	-0.0375	-6.1%	-6.1%
43	SiO2 (wt%)	42.4651	43.4059	42.9320	-0.4669	0.4739	-1.1%	1.1%
43	ThO2 (wt%)	0.1087	0.1087	0.0300	0.0787	0.0787	262.2%	262.2%
43	TiO2 (wt%)	0.0200	0.0198	0.0120	0.0080	0.0078	66.8%	65.2%
43	U3O8 (wt%)	3.3990	3.6122	3.5150	-0.1160	0.0972	-3.3%	2.8%
43	ZnO (wt%)	0.0541	0.0541	0.0450	0.0091	0.0091	20.3%	20.3%
43	ZrO2 (wt%)	0.1081	0.1081	0.1090	-0.0009	-0.0009	-0.9%	-0.9%
43	Sum (wt%)	99.3732	100.6503	100.0020	-0.6288	0.6483	-0.6%	0.6%
44	Al2O3 (wt%)	12.6502	12.6180	12.4030	0.2472	0.2150	2.0%	1.7%
44	B2O3 (wt%)	3.7029	3.7381	4.0000	-0.2971	-0.2619	-7.4%	-6.5%
44	BaO (wt%)	0.0589	0.0669	0.0630	-0.0041	0.0039	-6.5%	6.3%
44	CaO (wt%)	1.0679	1.1179	1.1940	-0.1261	-0.0761	-10.6%	-6.4%
44	Ce2O3 (wt%)	0.0477	0.0477	0.0750	-0.0273	-0.0273	-36.4%	-36.4%
44	Cr2O3 (wt%)	0.0903	0.1288	0.1060	-0.0157	0.0228	-14.9%	21.5%
44	CuO (wt%)	0.0382	0.0396	0.0300	0.0082	0.0096	27.3%	32.1%
44	Fe2O3 (wt%)	12.5849	12.1541	13.2830	-0.6981	-1.1289	-5.3%	-8.5%
44	K2O (wt%)	0.1753	0.1633	0.1720	0.0033	-0.0087	1.9%	-5.1%
44	La2O3 (wt%)	0.0481	0.0481	0.0540	-0.0059	-0.0059	-11.0%	-11.0%
44	Li2O (wt%)	3.8967	3.9621	4.0000	-0.1033	-0.0379	-2.6%	-0.9%
44	MgO (wt%)	1.1782	1.1953	1.2480	-0.0698	-0.0527	-5.6%	-4.2%
44	MnO (wt%)	2.7051	2.7115	2.7400	-0.0349	-0.0285	-1.3%	-1.0%
44	Na2O (wt%)	16.2434	15.8294	15.0400	1.2034	0.7894	8.0%	5.2%
44	NiO (wt%)	0.7269	0.7549	0.7890	-0.0621	-0.0341	-7.9%	-4.3%
44	PbO (wt%)	0.0425	0.0425	0.0450	-0.0025	-0.0025	-5.4%	-5.4%
44	SO4 (wt%)	0.6404	0.6404	0.6690	-0.0286	-0.0286	-4.3%	-4.3%
44	SiO2 (wt%)	39.8979	40.3714	40.0570	-0.1591	0.3144	-0.4%	0.8%
44	ThO2 (wt%)	0.1155	0.1155	0.0330	0.0825	0.0825	250.0%	250.0%
44	TiO2 (wt%)	0.0133	0.0144	0.0130	0.0003	0.0014	2.6%	10.7%
44	U3O8 (wt%)	3.7086	3.9207	3.8200	-0.1114	0.1007	-2.9%	2.6%
44	ZnO (wt%)	0.0523	0.0523	0.0490	0.0033	0.0033	6.7%	6.7%
44	ZrO2 (wt%)	0.1064	0.1064	0.1190	-0.0126	-0.0126	-10.6%	-10.6%
44	Sum (wt%)	99.7917	99.8392	100.0020	-0.2103	-0.1628	-0.2%	-0.2%
45	Al2O3 (wt%)	8.9610	8.9379	8.6820	0.2790	0.2559	3.2%	2.9%
45	B2O3 (wt%)	5.6751	5.7392	5.8500	-0.1749	-0.1108	-3.0%	-1.9%
45	BaO (wt%)	0.0438	0.0439	0.0440	-0.0002	-0.0001	-0.4%	-0.2%
45	CaO (wt%)	0.7780	0.7726	0.8360	-0.0580	-0.0634	-6.9%	-7.6%
45	Ce2O3 (wt%)	0.0395	0.0395	0.0520	-0.0125	-0.0125	-24.0%	-24.0%
45	Cr2O3 (wt%)	0.0665	0.0789	0.0740	-0.0075	0.0049	-10.1%	6.6%
45	CuO (wt%)	0.0335	0.0320	0.0210	0.0125	0.0110	59.5%	52.6%
45	Fe2O3 (wt%)	9.1000	8.7900	9.2980	-0.1980	-0.5080	-2.1%	-5.5%
45	K2O (wt%)	0.1256	0.1185	0.1200	0.0056	-0.0015	4.6%	-1.3%
45	La2O3 (wt%)	0.0372	0.0372	0.0380	-0.0008	-0.0008	-2.0%	-2.0%
45	Li2O (wt%)	6.3349	6.4413	6.5000	-0.1651	-0.0587	-2.5%	-0.9%
45	MgO (wt%)	0.8586	0.8638	0.8730	-0.0144	-0.0092	-1.7%	-1.1%
45	MnO (wt%)	1.9465	1.9662	1.9180	0.0285	0.0482	1.5%	2.5%
45	Na2O (wt%)	10.7604	10.9164	10.9780	-0.2176	-0.0616	-2.0%	-0.6%
45	NiO (wt%)	0.5033	0.5228	0.5520	-0.0487	-0.0292	-8.8%	-5.3%
45	PbO (wt%)	0.0355	0.0355	0.0320	0.0035	0.0035	11.1%	11.1%
45	SO4 (wt%)	0.4539	0.4539	0.4680	-0.0141	-0.0141	-3.0%	-3.0%
45	SiO2 (wt%)	50.2201	50.8183	50.8400	-0.6199	-0.0217	-1.2%	0.0%

Table D4. Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide by Nepheline Study Glass (continued)

(100 -Batch 1; 200 -U std)

Glass #	Oxide	Measured (wt%)	Measured-bc (wt%)	Targeted (wt%)	Diff of Measured	Diff of Meas-bc	% Diff of Measured	% Diff of Meas-bc
45	ThO2 (wt%)	0.0848	0.0848	0.0230	0.0618	0.0618	268.6%	268.6%
45	TiO2 (wt%)	0.0167	0.0165	0.0090	0.0077	0.0075	85.3%	83.4%
45	U3O8 (wt%)	2.5648	2.7114	2.6740	-0.1092	0.0374	-4.1%	1.4%
45	ZnO (wt%)	0.0523	0.0523	0.0340	0.0183	0.0183	53.8%	53.8%
45	ZrO2 (wt%)	0.0767	0.0767	0.0830	-0.0063	-0.0063	-7.6%	-7.6%
45	Sum (wt%)	98.7685	99.5497	99.9990	-1.2305	-0.4493	-1.2%	-0.4%
46	Al2O3 (wt%)	10.2411	10.2147	9.9220	0.3191	0.2927	3.2%	2.9%
46	B2O3 (wt%)	5.2484	5.3025	5.4000	-0.1516	-0.0975	-2.8%	-1.8%
46	BaO (wt%)	0.0488	0.0489	0.0500	-0.0012	-0.0011	-2.3%	-2.1%
46	CaO (wt%)	0.8871	0.8810	0.9550	-0.0679	-0.0740	-7.1%	-7.8%
46	Ce2O3 (wt%)	0.0474	0.0474	0.0600	-0.0126	-0.0126	-20.9%	-20.9%
46	Cr2O3 (wt%)	0.0826	0.0980	0.0850	-0.0024	0.0130	-2.8%	15.3%
46	CuO (wt%)	0.0394	0.0378	0.0240	0.0154	0.0138	64.3%	57.3%
46	Fe2O3 (wt%)	10.4475	10.0918	10.6260	-0.1785	-0.5342	-1.7%	-5.0%
46	K2O (wt%)	0.1491	0.1406	0.1380	0.0111	0.0026	8.0%	1.9%
46	La2O3 (wt%)	0.0434	0.0434	0.0430	0.0004	0.0004	0.9%	0.9%
46	Li2O (wt%)	5.8774	5.9759	6.0000	-0.1226	-0.0241	-2.0%	-0.4%
46	MgO (wt%)	0.9796	0.9856	0.9980	-0.0184	-0.0124	-1.8%	-1.2%
46	MnO (wt%)	2.2209	2.2434	2.1920	0.0289	0.0514	1.3%	2.3%
46	Na2O (wt%)	11.8995	12.0681	11.8320	0.0675	0.2361	0.6%	2.0%
46	NiO (wt%)	0.6041	0.6274	0.6310	-0.0269	-0.0036	-4.3%	-0.6%
46	PbO (wt%)	0.0404	0.0404	0.0360	0.0044	0.0044	12.2%	12.2%
46	SO4 (wt%)	0.5041	0.5041	0.5350	-0.0309	-0.0309	-5.8%	-5.8%
46	SiO2 (wt%)	47.2250	47.7884	47.2450	-0.0200	0.5434	0.0%	1.2%
46	ThO2 (wt%)	0.0964	0.0964	0.0260	0.0704	0.0704	270.9%	270.9%
46	TiO2 (wt%)	0.0200	0.0198	0.0110	0.0090	0.0088	82.0%	80.2%
46	U3O8 (wt%)	3.0394	3.2131	3.0560	-0.0166	0.1571	-0.5%	5.1%
46	ZnO (wt%)	0.0398	0.0398	0.0390	0.0008	0.0008	2.1%	2.1%
46	ZrO2 (wt%)	0.0736	0.0736	0.0950	-0.0214	-0.0214	-22.5%	-22.5%
46	Sum (wt%)	99.8552	100.5822	99.9990	-0.1438	0.5832	-0.1%	0.6%
47	Al2O3 (wt%)	12.1211	12.1198	11.6590	0.4621	0.4608	4.0%	4.0%
47	B2O3 (wt%)	4.8540	4.7793	4.7700	0.0840	0.0093	1.8%	0.2%
47	BaO (wt%)	0.0544	0.0619	0.0590	-0.0046	0.0029	-7.7%	4.9%
47	CaO (wt%)	1.0148	1.0623	1.1220	-0.1072	-0.0597	-9.6%	-5.3%
47	Ce2O3 (wt%)	0.0469	0.0469	0.0700	-0.0231	-0.0231	-33.1%	-33.1%
47	Cr2O3 (wt%)	0.0851	0.1214	0.1000	-0.0149	0.0214	-14.9%	21.4%
47	CuO (wt%)	0.0372	0.0386	0.0280	0.0092	0.0106	33.0%	38.0%
47	Fe2O3 (wt%)	11.8880	11.7128	12.4860	-0.5980	-0.7732	-4.8%	-6.2%
47	K2O (wt%)	0.1677	0.1563	0.1620	0.0057	-0.0057	3.5%	-3.5%
47	La2O3 (wt%)	0.0434	0.0434	0.0510	-0.0076	-0.0076	-14.9%	-14.9%
47	Li2O (wt%)	5.2100	5.3149	5.3000	-0.0900	0.0149	-1.7%	0.3%
47	MgO (wt%)	1.1210	1.1372	1.1730	-0.0520	-0.0358	-4.4%	-3.1%
47	MnO (wt%)	2.6115	2.6174	2.5760	0.0355	0.0414	1.4%	1.6%
47	Na2O (wt%)	13.3924	13.0510	13.0270	0.3654	0.0240	2.8%	0.2%
47	NiO (wt%)	0.6490	0.6965	0.7410	-0.0920	-0.0445	-12.4%	-6.0%
47	PbO (wt%)	0.0428	0.0428	0.0430	-0.0002	-0.0002	-0.4%	-0.4%
47	SO4 (wt%)	0.6104	0.6104	0.6290	-0.0186	-0.0186	-3.0%	-3.0%
47	SiO2 (wt%)	41.8233	42.7499	42.2130	-0.3897	0.5369	-0.9%	1.3%
47	ThO2 (wt%)	0.1055	0.1055	0.0310	0.0745	0.0745	240.5%	240.5%
47	TiO2 (wt%)	0.0133	0.0144	0.0130	0.0003	0.0014	2.6%	10.6%
47	U3O8 (wt%)	3.5111	3.7312	3.5910	-0.0799	0.1402	-2.2%	3.9%
47	ZnO (wt%)	0.0451	0.0451	0.0460	-0.0009	-0.0009	-1.9%	-1.9%
47	ZrO2 (wt%)	0.1043	0.1043	0.1110	-0.0067	-0.0067	-6.0%	-6.0%
47	Sum (wt%)	99.5525	100.3635	100.0010	-0.4485	0.3625	-0.4%	0.4%
48	Al2O3 (wt%)	12.8675	12.8658	12.6510	0.2165	0.2148	1.7%	1.7%
48	B2O3 (wt%)	4.5803	4.5097	4.4100	0.1703	0.0997	3.9%	2.3%
48	BaO (wt%)	0.0595	0.0596	0.0640	-0.0045	-0.0044	-7.1%	-6.9%
48	CaO (wt%)	1.1155	1.1079	1.2180	-0.1025	-0.1101	-8.4%	-9.0%

Table D4. Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide by Nepheline Study Glass (continued)

(100 -Batch 1; 200 -U std)

Glass #	Oxide	Measured (wt%)	Measured-bc (wt%)	Targeted (wt%)	Diff of Measured	Diff of Meas-bc	% Diff of Measured	% Diff of Meas-bc
48	Ce2O3 (wt%)	0.0510	0.0510	0.0760	-0.0250	-0.0250	-33.0%	-33.0%
48	Cr2O3 (wt%)	0.0979	0.1163	0.1080	-0.0101	0.0083	-9.3%	7.7%
48	CuO (wt%)	0.0448	0.0428	0.0310	0.0138	0.0118	44.4%	38.2%
48	Fe2O3 (wt%)	12.8959	12.7057	13.5480	-0.6521	-0.8423	-4.8%	-6.2%
48	K2O (wt%)	0.1963	0.1852	0.1750	0.0213	0.0102	12.2%	5.8%
48	La2O3 (wt%)	0.0510	0.0510	0.0550	-0.0040	-0.0040	-7.2%	-7.2%
48	Li2O (wt%)	4.7956	4.8921	4.9000	-0.1044	-0.0079	-2.1%	-0.2%
48	MgO (wt%)	1.1952	1.2025	1.2730	-0.0778	-0.0705	-6.1%	-5.5%
48	MnO (wt%)	2.7373	2.7651	2.7950	-0.0577	-0.0299	-2.1%	-1.1%
48	Na2O (wt%)	13.6586	13.8572	13.7110	-0.0524	0.1462	-0.4%	1.1%
48	NiO (wt%)	0.7066	0.7584	0.8040	-0.0974	-0.0456	-12.1%	-5.7%
48	PbO (wt%)	0.0463	0.0463	0.0460	0.0003	0.0003	0.7%	0.7%
48	SO4 (wt%)	0.6449	0.6449	0.6820	-0.0371	-0.0371	-5.4%	-5.4%
48	SiO2 (wt%)	38.8283	39.6883	39.3380	-0.5097	0.3503	-1.3%	0.9%
48	ThO2 (wt%)	0.1200	0.1200	0.0340	0.0860	0.0860	253.1%	253.1%
48	TiO2 (wt%)	0.0221	0.0219	0.0140	0.0081	0.0079	57.9%	56.4%
48	U3O8 (wt%)	3.8118	4.0510	3.8970	-0.0852	0.1540	-2.2%	4.0%
48	ZnO (wt%)	0.0598	0.0598	0.0500	0.0098	0.0098	19.5%	19.5%
48	ZrO2 (wt%)	0.1168	0.1168	0.1210	-0.0042	-0.0042	-3.4%	-3.4%
48	Sum (wt%)	98.7030	99.9193	100.0010	-1.2980	-0.0817	-1.3%	-0.1%
49	Al2O3 (wt%)	8.9515	8.9502	8.6820	0.2695	0.2682	3.1%	3.1%
49	B2O3 (wt%)	5.1840	5.1041	5.2000	-0.0160	-0.0959	-0.3%	-1.8%
49	BaO (wt%)	0.0430	0.0431	0.0440	-0.0010	-0.0009	-2.3%	-2.1%
49	CaO (wt%)	0.8717	0.8658	0.8360	0.0357	0.0298	4.3%	3.6%
49	Ce2O3 (wt%)	0.0384	0.0384	0.0520	-0.0136	-0.0136	-26.2%	-26.2%
49	Cr2O3 (wt%)	0.0720	0.0855	0.0740	-0.0020	0.0115	-2.7%	15.5%
49	CuO (wt%)	0.0316	0.0303	0.0210	0.0106	0.0093	50.5%	44.1%
49	Fe2O3 (wt%)	9.3502	9.2121	9.2980	0.0522	-0.0859	0.6%	-0.9%
49	K2O (wt%)	0.1379	0.1301	0.1200	0.0179	0.0101	14.9%	8.4%
49	La2O3 (wt%)	0.0349	0.0349	0.0380	-0.0031	-0.0031	-8.2%	-8.2%
49	Li2O (wt%)	5.0593	5.1611	5.2000	-0.1407	-0.0389	-2.7%	-0.7%
49	MgO (wt%)	0.8971	0.9026	0.8730	0.0241	0.0296	2.8%	3.4%
49	MnO (wt%)	1.9207	1.9400	1.9180	0.0027	0.0220	0.1%	1.1%
49	Na2O (wt%)	14.8954	15.1155	14.2280	0.6674	0.8875	4.7%	6.2%
49	NiO (wt%)	0.5036	0.5405	0.5520	-0.0484	-0.0115	-8.8%	-2.1%
49	PbO (wt%)	0.0310	0.0310	0.0320	-0.0010	-0.0010	-3.2%	-3.2%
49	SO4 (wt%)	0.4411	0.4411	0.4680	-0.0269	-0.0269	-5.7%	-5.7%
49	SiO2 (wt%)	48.5086	49.5825	49.5400	-1.0314	0.0425	-2.1%	0.1%
49	ThO2 (wt%)	0.0819	0.0819	0.0230	0.0589	0.0589	256.2%	256.2%
49	TiO2 (wt%)	0.0163	0.0161	0.0090	0.0073	0.0071	80.7%	78.7%
49	U3O8 (wt%)	2.6915	2.8601	2.6740	0.0175	0.1861	0.7%	7.0%
49	ZnO (wt%)	0.0495	0.0495	0.0340	0.0155	0.0155	45.5%	45.5%
49	ZrO2 (wt%)	0.0824	0.0824	0.0830	-0.0006	-0.0006	-0.7%	-0.7%
49	Sum (wt%)	99.8937	101.2986	99.9990	-0.1053	1.2996	-0.1%	1.3%
50	Al2O3 (wt%)	10.2364	10.2357	9.9220	0.3144	0.3137	3.2%	3.2%
50	B2O3 (wt%)	4.8620	4.7868	4.8000	0.0620	-0.0132	1.3%	-0.3%
50	BaO (wt%)	0.0463	0.0527	0.0500	-0.0037	0.0027	-7.3%	5.3%
50	CaO (wt%)	0.8574	0.8975	0.9550	-0.0976	-0.0575	-10.2%	-6.0%
50	Ce2O3 (wt%)	0.0378	0.0378	0.0600	-0.0222	-0.0222	-37.0%	-37.0%
50	Cr2O3 (wt%)	0.0829	0.1184	0.0850	-0.0021	0.0334	-2.4%	39.3%
50	CuO (wt%)	0.0322	0.0335	0.0240	0.0082	0.0095	34.3%	39.4%
50	Fe2O3 (wt%)	10.7013	10.5439	10.6260	0.0753	-0.0821	0.7%	-0.8%
50	K2O (wt%)	0.1464	0.1363	0.1380	0.0084	-0.0017	6.1%	-1.2%
50	La2O3 (wt%)	0.0390	0.0390	0.0430	-0.0040	-0.0040	-9.3%	-9.3%
50	Li2O (wt%)	4.6879	4.7824	4.8000	-0.1121	-0.0176	-2.3%	-0.4%
50	MgO (wt%)	0.9560	0.9698	0.9980	-0.0420	-0.0282	-4.2%	-2.8%
50	MnO (wt%)	2.2338	2.2391	2.1920	0.0418	0.0471	1.9%	2.1%
50	Na2O (wt%)	15.0639	14.6801	14.8320	0.2319	-0.1519	1.6%	-1.0%

Table D4. Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide by Nepheline Study Glass (continued)

(100 -Batch 1; 200 -U std)

Glass #	Oxide	Measured (wt%)	Measured-bc (wt%)	Targeted (wt%)	Diff of Measured	Diff of Meas-bc	% Diff of Measured	% Diff of Meas-bc
50	NiO (wt%)	0.5860	0.6289	0.6310	-0.0450	-0.0021	-7.1%	-0.3%
50	PbO (wt%)	0.0334	0.0334	0.0360	-0.0026	-0.0026	-7.2%	-7.2%
50	SO4 (wt%)	0.5333	0.5333	0.5350	-0.0017	-0.0017	-0.3%	-0.3%
50	SiO2 (wt%)	45.0323	46.0309	46.0450	-1.0127	-0.0141	-2.2%	0.0%
50	ThO2 (wt%)	0.0910	0.0910	0.0260	0.0650	0.0650	250.1%	250.1%
50	TiO2 (wt%)	0.0117	0.0126	0.0110	0.0007	0.0016	6.1%	14.3%
50	U3O8 (wt%)	2.9333	3.1175	3.0560	-0.1227	0.0615	-4.0%	2.0%
50	ZnO (wt%)	0.0398	0.0398	0.0390	0.0008	0.0008	2.1%	2.1%
50	ZrO2 (wt%)	0.0851	0.0851	0.0950	-0.0099	-0.0099	-10.4%	-10.4%
50	Sum (wt%)	99.3292	100.1254	99.9990	-0.6698	0.1264	-0.7%	0.1%
51	Al2O3 (wt%)	11.0489	11.0217	10.9150	0.1339	0.1067	1.2%	1.0%
51	B2O3 (wt%)	4.1617	4.2026	4.4800	-0.3183	-0.2774	-7.1%	-6.2%
51	BaO (wt%)	0.0516	0.0517	0.0560	-0.0044	-0.0043	-7.8%	-7.6%
51	CaO (wt%)	0.9637	0.9570	1.0510	-0.0873	-0.0940	-8.3%	-8.9%
51	Ce2O3 (wt%)	0.0469	0.0469	0.0660	-0.0191	-0.0191	-29.0%	-29.0%
51	Cr2O3 (wt%)	0.0881	0.1046	0.0930	-0.0049	0.0116	-5.3%	12.4%
51	CuO (wt%)	0.0388	0.0371	0.0260	0.0128	0.0111	49.3%	42.9%
51	Fe2O3 (wt%)	11.5734	11.1813	11.6890	-0.1156	-0.5077	-1.0%	-4.3%
51	K2O (wt%)	0.1665	0.1571	0.1510	0.0155	0.0061	10.3%	4.0%
51	La2O3 (wt%)	0.0449	0.0449	0.0480	-0.0031	-0.0031	-6.5%	-6.5%
51	Li2O (wt%)	4.3219	4.3946	4.4800	-0.1581	-0.0854	-3.5%	-1.9%
51	MgO (wt%)	1.0501	1.0565	1.0980	-0.0479	-0.0415	-4.4%	-3.8%
51	MnO (wt%)	2.4145	2.4390	2.4110	0.0035	0.0280	0.1%	1.2%
51	Na2O (wt%)	15.1650	15.3835	15.3150	-0.1500	0.0685	-1.0%	0.4%
51	NiO (wt%)	0.6369	0.6616	0.6940	-0.0571	-0.0324	-8.2%	-4.7%
51	PbO (wt%)	0.0345	0.0345	0.0400	-0.0055	-0.0055	-13.8%	-13.8%
51	SO4 (wt%)	0.5677	0.5677	0.5890	-0.0213	-0.0213	-3.6%	-3.6%
51	SiO2 (wt%)	42.3047	42.8110	43.2500	-0.9453	-0.4390	-2.2%	-1.0%
51	ThO2 (wt%)	0.1053	0.1053	0.0290	0.0763	0.0763	263.0%	263.0%
51	TiO2 (wt%)	0.0204	0.0202	0.0120	0.0084	0.0082	70.3%	68.5%
51	U3O8 (wt%)	3.2457	3.4314	3.3620	-0.1163	0.0694	-3.5%	2.1%
51	ZnO (wt%)	0.0429	0.0429	0.0430	-0.0001	-0.0001	-0.1%	-0.1%
51	ZrO2 (wt%)	0.0946	0.0946	0.1040	-0.0094	-0.0094	-9.1%	-9.1%
51	Sum (wt%)	98.1887	98.8475	100.0020	-1.8133	-1.1545	-1.8%	-1.2%
52	Al2O3 (wt%)	12.0408	12.0394	11.9070	0.1338	0.1324	1.1%	1.1%
52	B2O3 (wt%)	4.1939	4.1289	4.1600	0.0339	-0.0311	0.8%	-0.7%
52	BaO (wt%)	0.0586	0.0587	0.0610	-0.0024	-0.0023	-3.9%	-3.7%
52	CaO (wt%)	1.0543	1.0471	1.1460	-0.0917	-0.0989	-8.0%	-8.6%
52	Ce2O3 (wt%)	0.0568	0.0568	0.0720	-0.0152	-0.0152	-21.1%	-21.1%
52	Cr2O3 (wt%)	0.1009	0.1198	0.1020	-0.0011	0.0178	-1.1%	17.5%
52	CuO (wt%)	0.0401	0.0383	0.0290	0.0111	0.0093	38.1%	32.2%
52	Fe2O3 (wt%)	12.6207	12.4348	12.7510	-0.1303	-0.3162	-1.0%	-2.5%
52	K2O (wt%)	0.1756	0.1656	0.1650	0.0106	0.0006	6.4%	0.4%
52	La2O3 (wt%)	0.0487	0.0487	0.0520	-0.0033	-0.0033	-6.4%	-6.4%
52	Li2O (wt%)	4.0582	4.1398	4.1600	-0.1018	-0.0202	-2.4%	-0.5%
52	MgO (wt%)	1.1608	1.1679	1.1980	-0.0372	-0.0301	-3.1%	-2.5%
52	MnO (wt%)	2.6147	2.6410	2.6300	-0.0153	0.0110	-0.6%	0.4%
52	Na2O (wt%)	15.7379	15.9661	15.7980	-0.0601	0.1681	-0.4%	1.1%
52	NiO (wt%)	0.6811	0.7310	0.7570	-0.0759	-0.0260	-10.0%	-3.4%
52	PbO (wt%)	0.0399	0.0399	0.0430	-0.0031	-0.0031	-7.3%	-7.3%
52	SO4 (wt%)	0.6172	0.6172	0.6420	-0.0248	-0.0248	-3.9%	-3.9%
52	SiO2 (wt%)	38.9887	39.8528	40.4540	-1.4653	-0.6012	-3.6%	-1.5%
52	ThO2 (wt%)	0.1112	0.1112	0.0320	0.0792	0.0792	247.6%	247.6%
52	TiO2 (wt%)	0.0183	0.0182	0.0130	0.0053	0.0052	41.1%	39.7%
52	U3O8 (wt%)	3.5877	3.8129	3.6670	-0.0793	0.1459	-2.2%	4.0%
52	ZnO (wt%)	0.0510	0.0510	0.0470	0.0040	0.0040	8.6%	8.6%
52	ZrO2 (wt%)	0.1091	0.1091	0.1140	-0.0049	-0.0049	-4.3%	-4.3%
52	Sum (wt%)	98.1662	99.3961	100.0000	-1.8338	-0.6039	-1.8%	-0.6%

Table D4. Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide by Nepheline Study Glass (continued)

(100 -Batch 1; 200 -U std)

Glass #	Oxide	Measured (wt%)	Measured-bc (wt%)	Targeted (wt%)	Diff of Measured	Diff of Meas-bc	% Diff of Measured	% Diff of Meas-bc
53	Al2O3 (wt%)	8.9562	8.9344	8.6820	0.2742	0.2524	3.2%	2.9%
53	B2O3 (wt%)	5.0391	5.0894	5.2000	-0.1609	-0.1106	-3.1%	-2.1%
53	BaO (wt%)	0.0413	0.0414	0.0440	-0.0027	-0.0026	-6.1%	-5.9%
53	CaO (wt%)	0.7713	0.7660	0.8360	-0.0647	-0.0700	-7.7%	-8.4%
53	Ce2O3 (wt%)	0.0384	0.0384	0.0520	-0.0136	-0.0136	-26.2%	-26.2%
53	Cr2O3 (wt%)	0.0720	0.0855	0.0740	-0.0020	0.0115	-2.7%	15.5%
53	CuO (wt%)	0.0319	0.0306	0.0210	0.0109	0.0096	52.0%	45.5%
53	Fe2O3 (wt%)	9.3252	9.0075	9.2980	0.0272	-0.2905	0.3%	-3.1%
53	K2O (wt%)	0.1244	0.1173	0.1200	0.0044	-0.0027	3.6%	-2.2%
53	La2O3 (wt%)	0.0346	0.0346	0.0380	-0.0034	-0.0034	-9.0%	-9.0%
53	Li2O (wt%)	6.9646	7.0817	7.1500	-0.1854	-0.0683	-2.6%	-1.0%
53	MgO (wt%)	0.8490	0.8542	0.8730	-0.0240	-0.0188	-2.7%	-2.2%
53	MnO (wt%)	1.9207	1.9401	1.9180	0.0027	0.0221	0.1%	1.2%
53	Na2O (wt%)	10.9896	11.1491	10.9780	0.0116	0.1711	0.1%	1.6%
53	NiO (wt%)	0.5230	0.5432	0.5520	-0.0290	-0.0088	-5.3%	-1.6%
53	PbO (wt%)	0.0296	0.0296	0.0320	-0.0024	-0.0024	-7.4%	-7.4%
53	SO4 (wt%)	0.4382	0.4382	0.4680	-0.0298	-0.0298	-6.4%	-6.4%
53	SiO2 (wt%)	49.6318	50.2242	50.8400	-1.2082	-0.6158	-2.4%	-1.2%
53	ThO2 (wt%)	0.0839	0.0839	0.0230	0.0609	0.0609	264.9%	264.9%
53	TiO2 (wt%)	0.0154	0.0153	0.0090	0.0064	0.0063	71.4%	69.5%
53	U3O8 (wt%)	2.5235	2.6676	2.6740	-0.1505	-0.0064	-5.6%	-0.2%
53	ZnO (wt%)	0.0361	0.0361	0.0340	0.0021	0.0021	6.2%	6.2%
53	ZrO2 (wt%)	0.0807	0.0807	0.0830	-0.0023	-0.0023	-2.8%	-2.8%
53	Sum (wt%)	98.5205	99.2889	99.9990	-1.4785	-0.7101	-1.5%	-0.7%
54	Al2O3 (wt%)	10.2175	10.2168	9.9220	0.2955	0.2948	3.0%	3.0%
54	B2O3 (wt%)	4.8299	4.7552	4.8000	0.0299	-0.0448	0.6%	-0.9%
54	BaO (wt%)	0.0505	0.0574	0.0500	0.0005	0.0074	1.0%	14.8%
54	CaO (wt%)	0.8528	0.8927	0.9550	-0.1022	-0.0623	-10.7%	-6.5%
54	Ce2O3 (wt%)	0.0141	0.0141	0.0600	-0.0459	-0.0459	-76.6%	-76.6%
54	Cr2O3 (wt%)	0.0749	0.1068	0.0850	-0.0101	0.0218	-11.9%	25.7%
54	CuO (wt%)	0.0329	0.0341	0.0240	0.0089	0.0101	36.9%	42.0%
54	Fe2O3 (wt%)	10.7513	10.5930	10.6260	0.1253	-0.0330	1.2%	-0.3%
54	K2O (wt%)	0.1337	0.1246	0.1380	-0.0043	-0.0134	-3.1%	-9.7%
54	La2O3 (wt%)	0.0390	0.0390	0.0430	-0.0040	-0.0040	-9.3%	-9.3%
54	Li2O (wt%)	6.4156	6.5449	6.6000	-0.1844	-0.0551	-2.8%	-0.8%
54	MgO (wt%)	0.9788	0.9930	0.9980	-0.0192	-0.0050	-1.9%	-0.5%
54	MnO (wt%)	2.2564	2.2616	2.1920	0.0644	0.0696	2.9%	3.2%
54	Na2O (wt%)	11.9905	11.6844	11.8320	0.1585	-0.1476	1.3%	-1.2%
54	NiO (wt%)	0.5774	0.6197	0.6310	-0.0536	-0.0113	-8.5%	-1.8%
54	PbO (wt%)	0.0366	0.0366	0.0360	0.0006	0.0006	1.7%	1.7%
54	SO4 (wt%)	0.5205	0.5205	0.5350	-0.0145	-0.0145	-2.7%	-2.7%
54	SiO2 (wt%)	46.6367	47.6709	47.2450	-0.6083	0.4259	-1.3%	0.9%
54	ThO2 (wt%)	0.0942	0.0942	0.0260	0.0682	0.0682	262.2%	262.2%
54	TiO2 (wt%)	0.0142	0.0153	0.0110	0.0032	0.0043	28.9%	38.9%
54	U3O8 (wt%)	2.9686	3.1549	3.0560	-0.0874	0.0989	-2.9%	3.2%
54	ZnO (wt%)	0.0411	0.0411	0.0390	0.0021	0.0021	5.3%	5.3%
54	ZrO2 (wt%)	0.0878	0.0878	0.0950	-0.0072	-0.0072	-7.6%	-7.6%
54	Sum (wt%)	99.6150	100.5584	99.9990	-0.3840	0.5594	-0.4%	0.6%
55	Al2O3 (wt%)	12.0928	12.0578	11.9070	0.1858	0.1508	1.6%	1.3%
55	B2O3 (wt%)	3.8961	3.9272	4.1600	-0.2639	-0.2328	-6.3%	-5.6%
55	BaO (wt%)	0.0558	0.0635	0.0610	-0.0052	0.0025	-8.5%	4.0%
55	CaO (wt%)	1.0274	1.0754	1.1460	-0.1186	-0.0706	-10.4%	-6.2%
55	Ce2O3 (wt%)	0.0305	0.0305	0.0720	-0.0415	-0.0415	-57.7%	-57.7%
55	Cr2O3 (wt%)	0.0892	0.1274	0.1020	-0.0128	0.0254	-12.6%	24.9%
55	CuO (wt%)	0.0366	0.0380	0.0290	0.0076	0.0090	26.3%	31.0%
55	Fe2O3 (wt%)	12.5099	12.0834	12.7510	-0.2411	-0.6676	-1.9%	-5.2%
55	K2O (wt%)	0.1659	0.1546	0.1650	0.0009	-0.0104	0.6%	-6.3%
55	La2O3 (wt%)	0.0472	0.0472	0.0520	-0.0048	-0.0048	-9.2%	-9.2%

Table D4. Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide by Nepheline Study Glass (continued)

(100 -Batch 1; 200 -U std)

Glass #	Oxide	Measured (wt%)	Measured-bc (wt%)	Targeted (wt%)	Diff of Measured	Diff of Meas-bc	% Diff of Measured	% Diff of Meas-bc
55	Li2O (wt%)	5.4791	5.5711	5.7200	-0.2409	-0.1489	-4.2%	-2.6%
55	MgO (wt%)	1.1401	1.1566	1.1980	-0.0579	-0.0414	-4.8%	-3.5%
55	MnO (wt%)	2.6631	2.6684	2.6300	0.0331	0.0384	1.3%	1.5%
55	Na2O (wt%)	13.4362	13.0927	13.1980	0.2382	-0.1053	1.8%	-0.8%
55	NiO (wt%)	0.6083	0.6317	0.7570	-0.1487	-0.1253	-19.6%	-16.5%
55	PbO (wt%)	0.0412	0.0412	0.0430	-0.0018	-0.0018	-4.2%	-4.2%
55	SO4 (wt%)	0.6314	0.6314	0.6420	-0.0106	-0.0106	-1.7%	-1.7%
55	SiO2 (wt%)	40.2188	40.6968	41.4940	-1.2752	-0.7972	-3.1%	-1.9%
55	ThO2 (wt%)	0.1104	0.1104	0.0320	0.0784	0.0784	244.9%	244.9%
55	TiO2 (wt%)	0.0125	0.0135	0.0130	-0.0005	0.0005	-3.8%	3.6%
55	U3O8 (wt%)	3.5553	3.7586	3.6670	-0.1117	0.0916	-3.0%	2.5%
55	ZnO (wt%)	0.0501	0.0501	0.0470	0.0031	0.0031	6.6%	6.6%
55	ZrO2 (wt%)	0.1064	0.1064	0.1140	-0.0076	-0.0076	-6.7%	-6.7%
55	Sum (wt%)	98.0041	98.1338	100.0000	-1.9959	-1.8662	-2.0%	-1.9%
56	Al2O3 (wt%)	12.7352	12.7025	12.6510	0.0842	0.0515	0.7%	0.4%
56	B2O3 (wt%)	3.6385	3.6622	3.9200	-0.2815	-0.2578	-7.2%	-6.6%
56	BaO (wt%)	0.0597	0.0679	0.0640	-0.0043	0.0039	-6.7%	6.1%
56	CaO (wt%)	1.0868	1.1377	1.2180	-0.1312	-0.0803	-10.8%	-6.6%
56	Ce2O3 (wt%)	0.0609	0.0609	0.0760	-0.0151	-0.0151	-19.9%	-19.9%
56	Cr2O3 (wt%)	0.0892	0.1274	0.1080	-0.0188	0.0194	-17.4%	17.9%
56	CuO (wt%)	0.0404	0.0419	0.0310	0.0094	0.0109	30.2%	35.2%
56	Fe2O3 (wt%)	12.6779	12.2435	13.5480	-0.8701	-1.3045	-6.4%	-9.6%
56	K2O (wt%)	0.1783	0.1661	0.1750	0.0033	-0.0089	1.9%	-5.1%
56	La2O3 (wt%)	0.0466	0.0466	0.0550	-0.0084	-0.0084	-15.2%	-15.2%
56	Li2O (wt%)	5.2046	5.2919	5.3900	-0.1854	-0.0981	-3.4%	-1.8%
56	MgO (wt%)	1.1927	1.2100	1.2730	-0.0803	-0.0630	-6.3%	-5.0%
56	MnO (wt%)	2.7729	2.7792	2.7950	-0.0221	-0.0158	-0.8%	-0.6%
56	Na2O (wt%)	14.0192	13.6613	13.7110	0.3082	-0.0497	2.2%	-0.4%
56	NiO (wt%)	0.6751	0.7010	0.8040	-0.1289	-0.1030	-16.0%	-12.8%
56	PbO (wt%)	0.0420	0.0420	0.0460	-0.0040	-0.0040	-8.7%	-8.7%
56	SO4 (wt%)	0.6786	0.6786	0.6820	-0.0034	-0.0034	-0.5%	-0.5%
56	SiO2 (wt%)	38.2400	38.6940	39.3380	-1.0980	-0.6440	-2.8%	-1.6%
56	ThO2 (wt%)	0.1175	0.1175	0.0340	0.0835	0.0835	245.6%	245.6%
56	TiO2 (wt%)	0.0125	0.0135	0.0140	-0.0015	-0.0005	-10.6%	-3.8%
56	U3O8 (wt%)	3.6585	3.8677	3.8970	-0.2385	-0.0293	-6.1%	-0.8%
56	ZnO (wt%)	0.0526	0.0526	0.0500	0.0026	0.0026	5.2%	5.2%
56	ZrO2 (wt%)	0.1118	0.1118	0.1210	-0.0092	-0.0092	-7.6%	-7.6%
56	Sum (wt%)	97.3914	97.4777	100.0010	-2.6096	-2.5233	-2.6%	-2.5%
100	Al2O3 (wt%)	4.8844	4.8770	4.8770	0.0074	0.0000	0.2%	0.0%
100	B2O3 (wt%)	7.8002	7.7770	7.7770	0.0232	0.0000	0.3%	0.0%
100	BaO (wt%)	0.1419	0.1510	0.1510	-0.0091	0.0000	-6.0%	0.0%
100	CaO (wt%)	1.1972	1.2200	1.2200	-0.0228	0.0000	-1.9%	0.0%
100	Ce2O3 (wt%)	0.0132	0.0132	0.0000	0.0132	0.0132		
100	Cr2O3 (wt%)	0.0834	0.1070	0.1070	-0.0236	0.0000	-22.0%	0.0%
100	CuO (wt%)	0.4007	0.3990	0.3990	0.0017	0.0000	0.4%	0.0%
100	Fe2O3 (wt%)	13.1628	12.8390	12.8390	0.3238	0.0000	2.5%	0.0%
100	K2O (wt%)	3.5496	3.3270	3.3270	0.2226	0.0000	6.7%	0.0%
100	La2O3 (wt%)	0.0059	0.0059	0.0000	0.0059	0.0059		
100	Li2O (wt%)	4.3489	4.4290	4.4290	-0.0801	0.0000	-1.8%	0.0%
100	MgO (wt%)	1.4047	1.4190	1.4190	-0.0143	0.0000	-1.0%	0.0%
100	MnO (wt%)	1.7151	1.7260	1.7260	-0.0109	0.0000	-0.6%	0.0%
100	Na2O (wt%)	9.0563	9.0030	9.0030	0.0533	0.0000	0.6%	0.0%
100	NiO (wt%)	0.7114	0.7510	0.7510	-0.0396	0.0000	-5.3%	0.0%
100	PbO (wt%)	0.0108	0.0108	0.0000	0.0108	0.0108		
100	SO4 (wt%)	0.1498	0.1498	0.0000	0.1498	0.1498		
100	SiO2 (wt%)	49.3822	50.2200	50.2200	-0.8378	0.0000	-1.7%	0.0%
100	ThO2 (wt%)	0.0057	0.0057	0.0000	0.0057	0.0057		
100	TiO2 (wt%)	0.6547	0.6770	0.6770	-0.0223	0.0000	-3.3%	0.0%

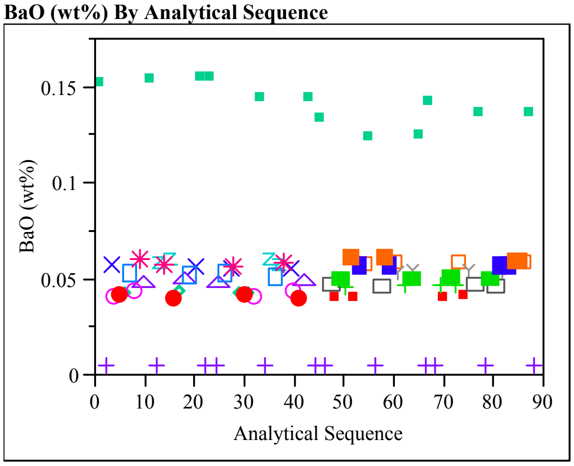
Table D4. Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide by Nepheline Study Glass (continued)

(100 -Batch 1; 200 -U std)

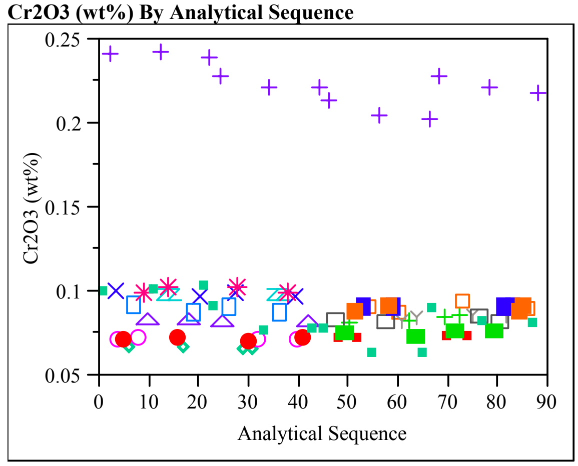
Glass #	Oxide	Measured (wt%)	Measured-bc (wt%)	Targeted (wt%)	Diff of Measured	Diff of Meas-bc	% Diff of Measured	% Diff of Meas-bc
100	U3O8 (wt%)	0.0590	0.0625	0.0000	0.0590	0.0625		
100	ZnO (wt%)	0.0062	0.0062	0.0000	0.0062	0.0062		
100	ZrO2 (wt%)	0.0523	0.0523	0.0980	-0.0457	-0.0457	-46.6%	-46.6%
100	Sum of Oxides (wt%)	98.7963	99.2284	99.0200	-0.2237	0.2084	-0.2%	0.2%
200	Al2O3 (wt%)	4.0766	4.0712	4.1000	-0.0234	-0.0288	-0.6%	-0.7%
200	B2O3 (wt%)	9.1391	9.1216	9.2090	-0.0699	-0.0874	-0.8%	-0.9%
200	BaO (wt%)	0.0056	0.0060	0.0000	0.0056	0.0060		
200	CaO (wt%)	1.2838	1.3085	1.3010	-0.0172	0.0075	-1.3%	0.6%
200	Ce2O3 (wt%)	0.0093	0.0093	0.0000	0.0093	0.0093		
200	Cr2O3 (wt%)	0.2237	0.2905	0.0000	0.2237	0.2905		
200	CuO (wt%)	0.0260	0.0253	0.0000	0.0260	0.0253		
200	Fe2O3 (wt%)	13.0162	12.6971	13.1960	-0.1798	-0.4989	-1.4%	-3.8%
200	K2O (wt%)	3.1972	2.9970	2.9990	0.1982	-0.0020	6.6%	-0.1%
200	La2O3 (wt%)	0.0059	0.0059	0.0000	0.0059	0.0059		
200	Li2O (wt%)	3.0266	3.0824	3.0570	-0.0304	0.0254	-1.0%	0.8%
200	MgO (wt%)	1.1661	1.1779	1.2100	-0.0439	-0.0321	-3.6%	-2.7%
200	MnO (wt%)	2.8008	2.8183	2.8920	-0.0912	-0.0737	-3.2%	-2.5%
200	Na2O (wt%)	11.9691	11.9002	11.7950	0.1741	0.1052	1.5%	0.9%
200	NiO (wt%)	0.9917	1.0468	1.1200	-0.1283	-0.0732	-11.5%	-6.5%
200	PbO (wt%)	0.0108	0.0108	0.0000	0.0108	0.0108		
200	SO4 (wt%)	0.1498	0.1498	0.0000	0.1498	0.1498		
200	SiO2 (wt%)	43.0356	43.7670	45.3530	-2.3174	-1.5860	-5.1%	-3.5%
200	ThO2 (wt%)	0.0495	0.0495	0.0000	0.0495	0.0495		
200	TiO2 (wt%)	0.9503	0.9834	1.0490	-0.0987	-0.0656	-9.4%	-6.3%
200	U3O8 (wt%)	2.2700	2.4060	2.4060	-0.1360	0.0000	-5.7%	0.0%
200	ZnO (wt%)	0.0062	0.0062	0.0000	0.0062	0.0062		
200	ZrO2 (wt%)	0.0068	0.0068	0.0000	0.0068	0.0068		
200	Sum (wt%)	97.4166	97.9374	99.6870	-2.2704	-1.7496	-2.3%	-1.8%

Exhibit D1. Oxide Measurements in Analytical Sequence for Samples Prepared Using the LM Method

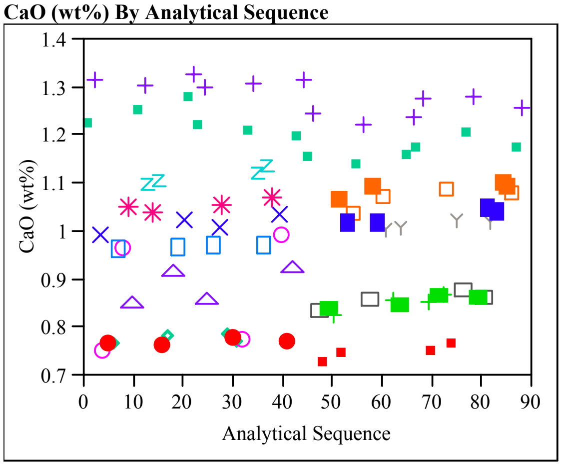
BaO (wt%) By Analytical Sequence



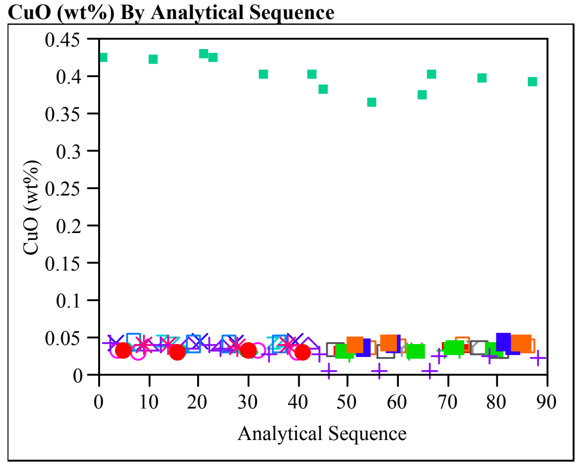
Cr2O3 (wt%) By Analytical Sequence



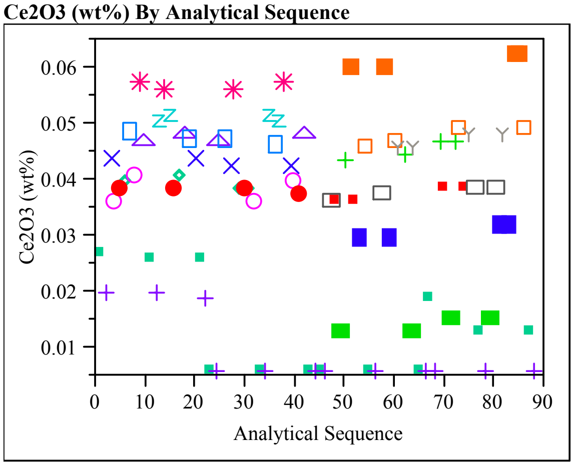
CaO (wt%) By Analytical Sequence



CuO (wt%) By Analytical Sequence



Ce2O3 (wt%) By Analytical Sequence



K2O (wt%) By Analytical Sequence

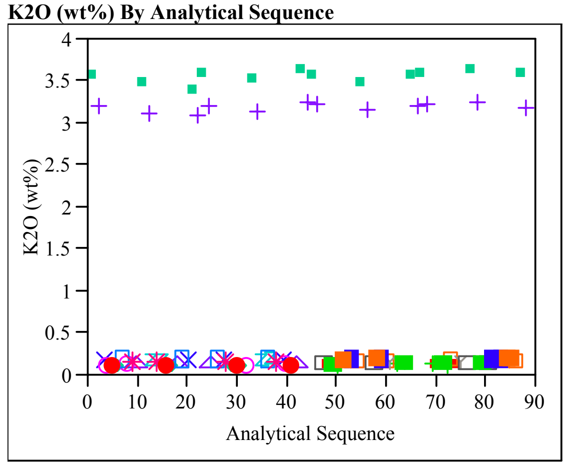
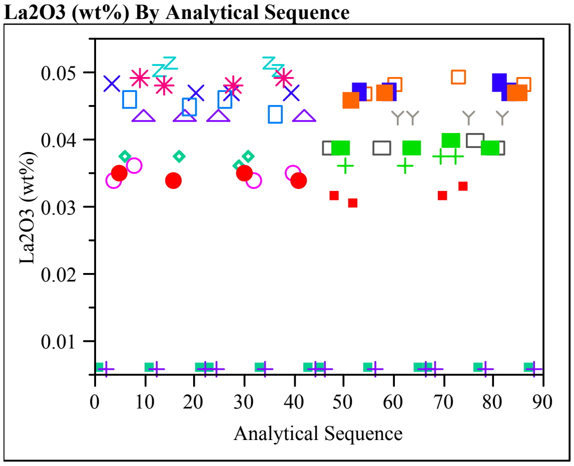
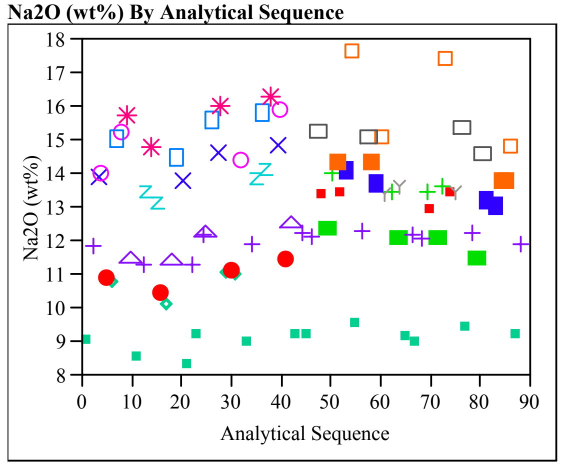


Exhibit D1. Oxide Measurements in Analytical Sequence for Samples Prepared Using the LM Method (continued)

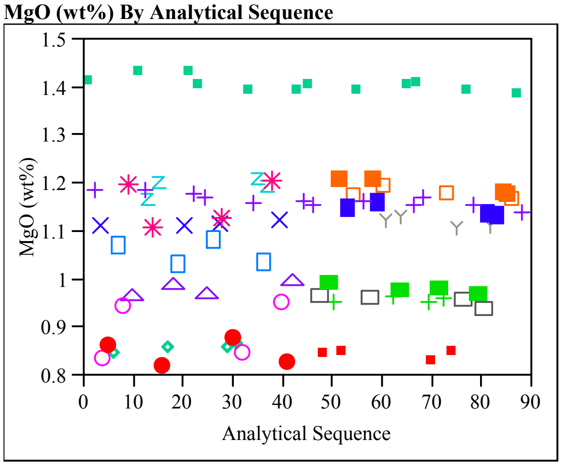
La2O3 (wt%) By Analytical Sequence



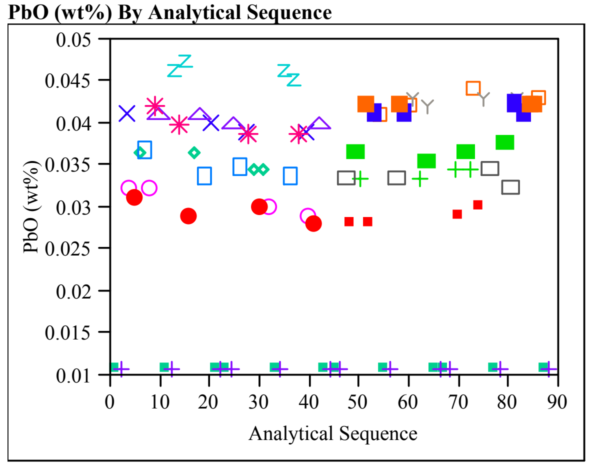
Na2O (wt%) By Analytical Sequence



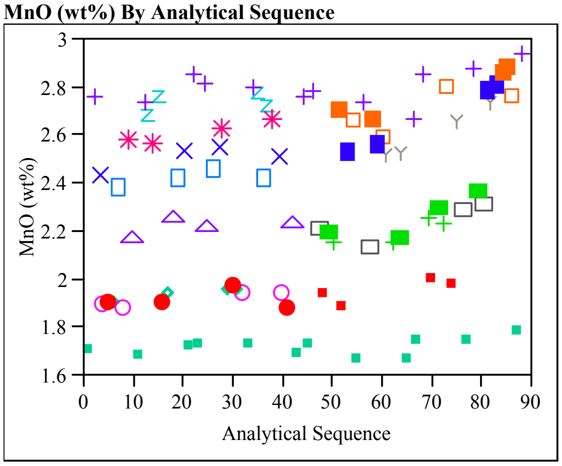
MgO (wt%) By Analytical Sequence



PbO (wt%) By Analytical Sequence



MnO (wt%) By Analytical Sequence



SO4 (wt%) By Analytical Sequence

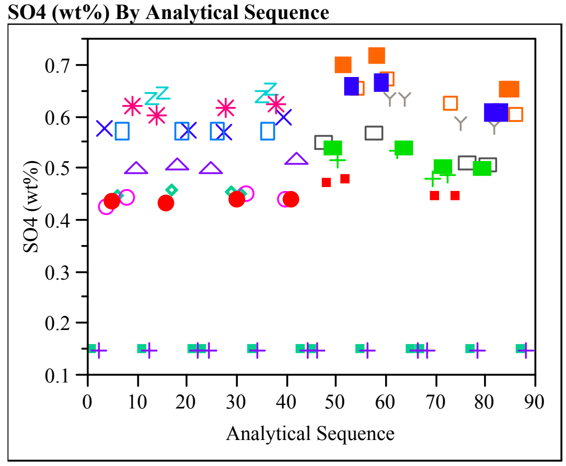
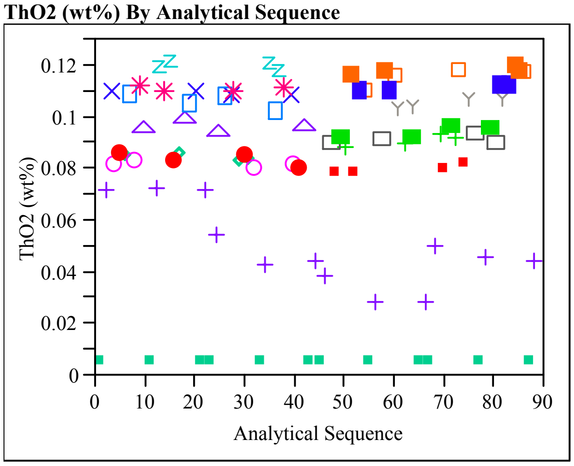
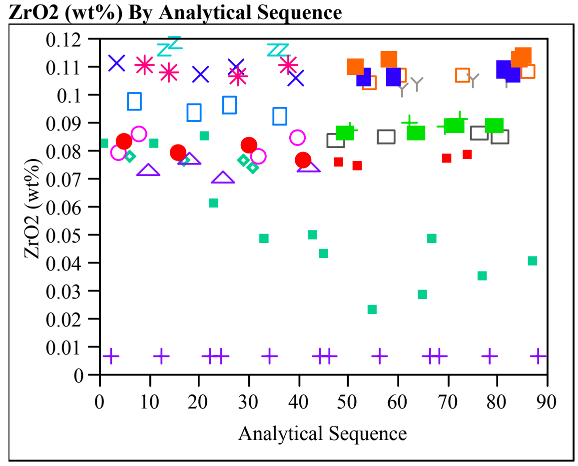


Exhibit D1. Oxide Measurements in Analytical Sequence for Samples Prepared Using the LM Method (continued)

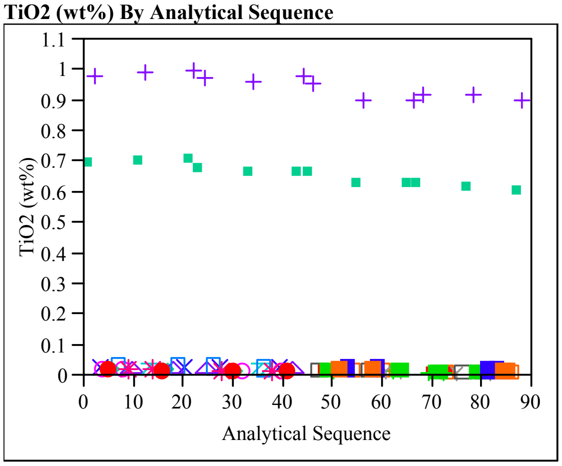
ThO2 (wt%) By Analytical Sequence



ZrO2 (wt%) By Analytical Sequence



TiO2 (wt%) By Analytical Sequence



ZnO (wt%) By Analytical Sequence

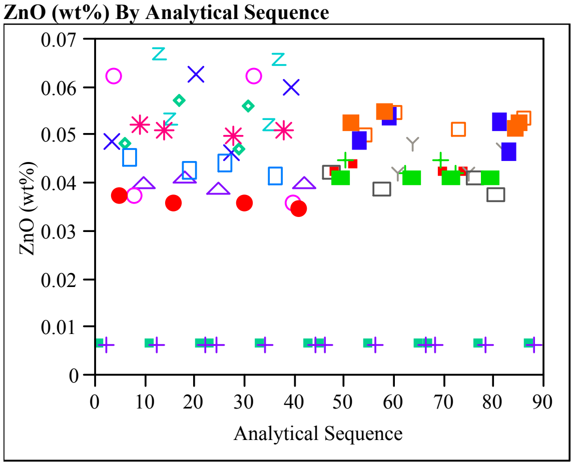
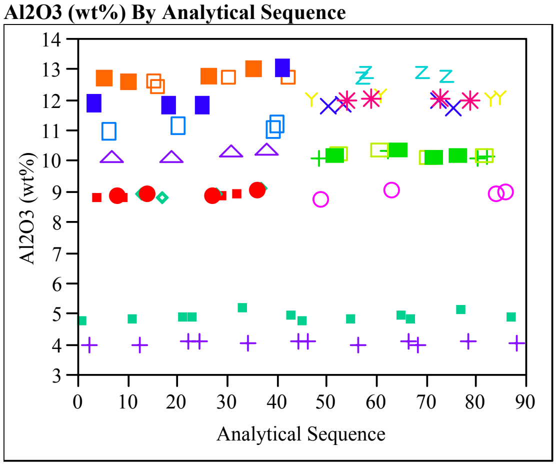
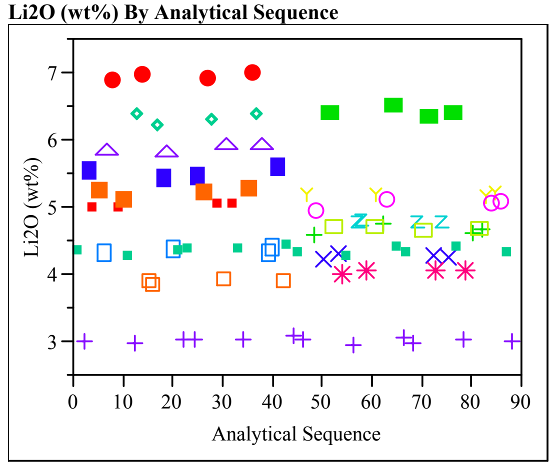


Exhibit D2. Oxide Measurements in Analytical Sequence for Samples Prepared Using the PF Method

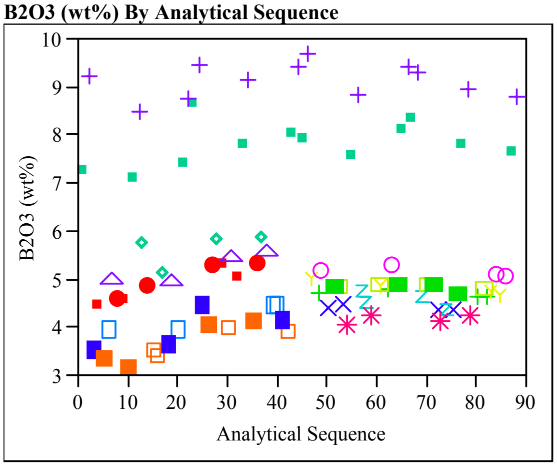
Al2O3 (wt%) By Analytical Sequence



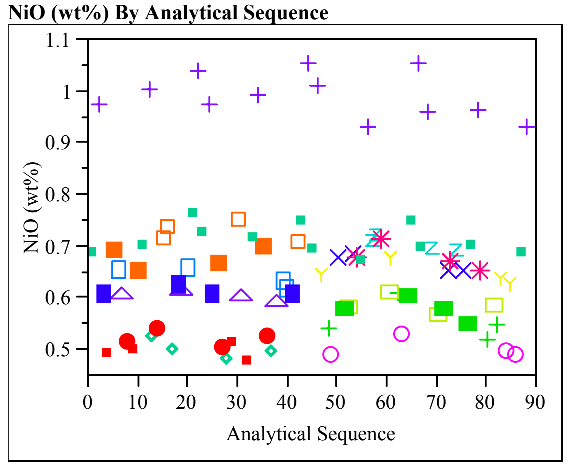
Li2O (wt%) By Analytical Sequence



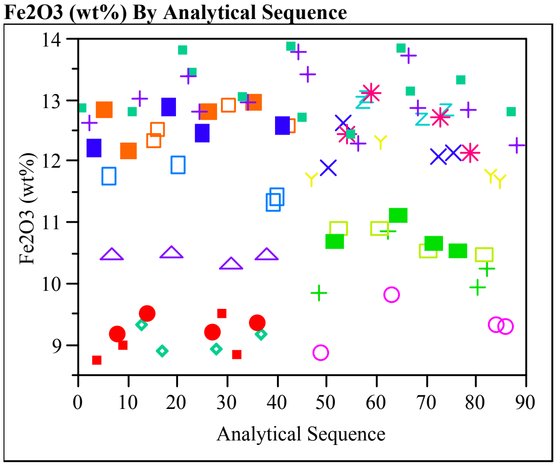
B2O3 (wt%) By Analytical Sequence



NiO (wt%) By Analytical Sequence



Fe2O3 (wt%) By Analytical Sequence



SiO2 (wt%) By Analytical Sequence

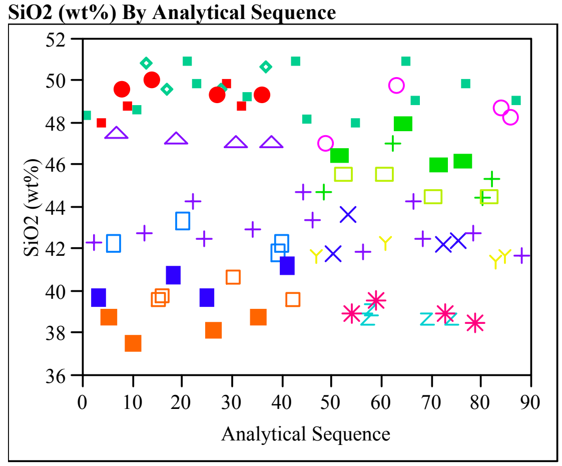


Exhibit D2. Oxide Measurements in Analytical Sequence for Samples Prepared Using the PF Method (continued)

U3O8 (wt%) By Analytical Sequence

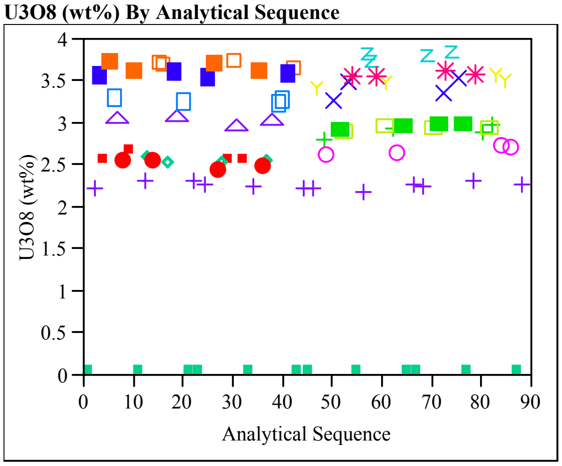
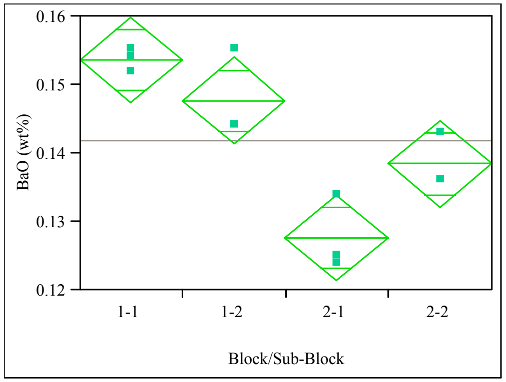


Exhibit D3. PSAL Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method

Glass ID=Batch 1

Oneway Analysis of BaO (wt%) By Block/Sub-Block
Reference Value = 0.151 wt%



Oneway Anova
Summary of Fit

Rsquare	0.866533
Adj Rsquare	0.816483
Root Mean Square Error	0.004737
Mean of Response	0.141889
Observations (or Sum Wgts)	12

Analysis of Variance

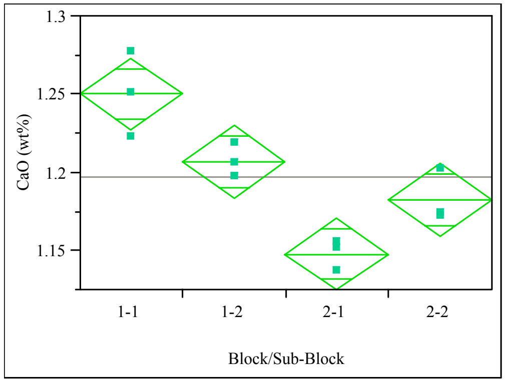
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00116544	0.000388	17.3133	0.0007
Error	8	0.00017951	0.000022		
C. Total	11	0.00134495			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.153705	0.00273	0.14740	0.16001
1-2	3	0.147750	0.00273	0.14144	0.15406
2-1	3	0.127653	0.00273	0.12135	0.13396
2-2	3	0.138446	0.00273	0.13214	0.14475

Std Error uses a pooled estimate of error variance

Oneway Analysis of CaO (wt%) By Block/Sub-Block
Reference Value = 1.220 wt%



Oneway Anova
Summary of Fit

Rsquare	0.871825
Adj Rsquare	0.823759
Root Mean Square Error	0.017476
Mean of Response	1.197249
Observations (or Sum Wgts)	12

Analysis of Variance

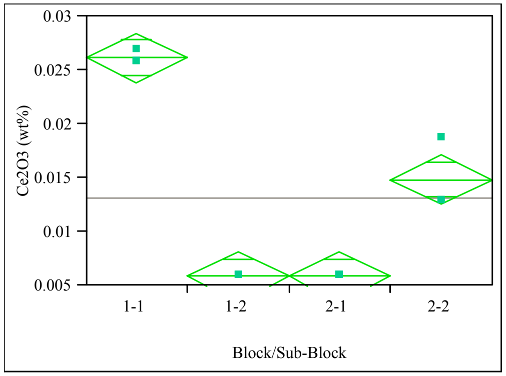
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.01661878	0.005540	18.1382	0.0006
Error	8	0.00244329	0.000305		
C. Total	11	0.01906206			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	1.25042	0.01009	1.2272	1.2737
1-2	3	1.20751	0.01009	1.1842	1.2308
2-1	3	1.14828	0.01009	1.1250	1.1715
2-2	3	1.18279	0.01009	1.1595	1.2061

Std Error uses a pooled estimate of error variance

Oneway Analysis of Ce2O3 (wt%) By Block/Sub-Block
Reference Value = 0 wt%



Oneway Anova
Summary of Fit

Rsquare	0.972322
Adj Rsquare	0.961943
Root Mean Square Error	0.001724
Mean of Response	0.013177
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00083540	0.000278	93.6795	<.0001
Error	8	0.00002378	0.000003		
C. Total	11	0.00085918			

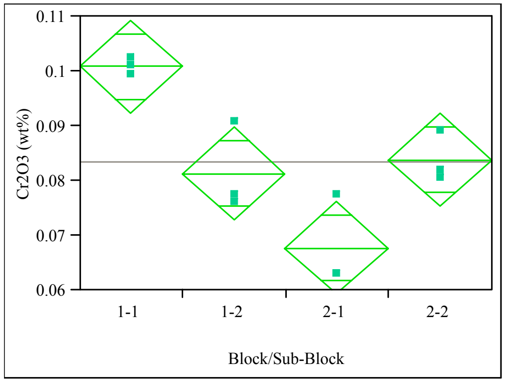
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.026159	0.00100	0.02386	0.02845
1-2	3	0.005857	0.00100	0.00356	0.00815
2-1	3	0.005857	0.00100	0.00356	0.00815
2-2	3	0.014836	0.00100	0.01254	0.01713

Std Error uses a pooled estimate of error variance

Exhibit D3. PSAL Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method (continued)

Oneway Analysis of Cr2O3 (wt%) By Block/Sub-Block
Reference Value = 0.107 wt%



Oneway Anova
Summary of Fit

Rsquare	0.838522
Adj Rsquare	0.777967
Root Mean Square Error	0.006329
Mean of Response	0.083433
Observations (or Sum Wgts)	12

Analysis of Variance

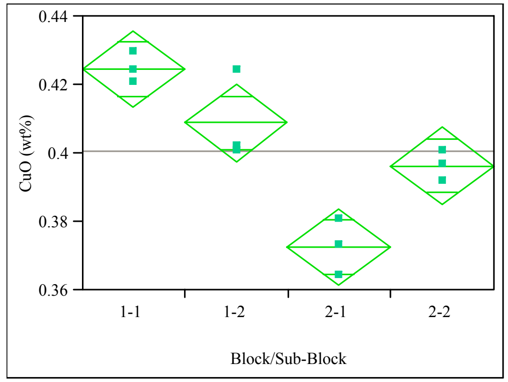
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00166398	0.000555	13.8474	0.0016
Error	8	0.00032044	0.000040		
C. Total	11	0.00198442			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.100850	0.00365	0.09242	0.10928
1-2	3	0.081362	0.00365	0.07294	0.08979
2-1	3	0.067721	0.00365	0.05929	0.07615
2-2	3	0.083798	0.00365	0.07537	0.09222

Std Error uses a pooled estimate of error variance

Oneway Analysis of CuO (wt%) By Block/Sub-Block
Reference Value = 0.399 wt%



Oneway Anova
Summary of Fit

Rsquare	0.884755
Adj Rsquare	0.841538
Root Mean Square Error	0.008428
Mean of Response	0.40068
Observations (or Sum Wgts)	12

Analysis of Variance

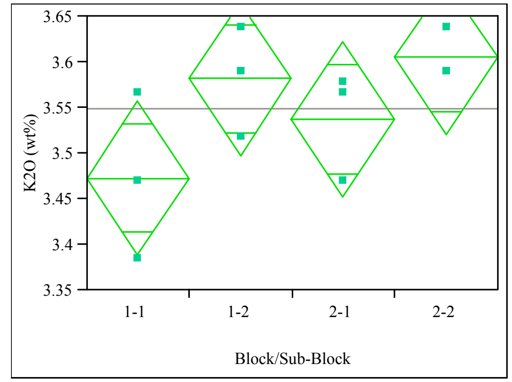
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00436293	0.001454	20.4724	0.0004
Error	8	0.00056830	0.000071		
C. Total	11	0.00493123			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.424777	0.00487	0.41356	0.43600
1-2	3	0.408921	0.00487	0.39770	0.42014
2-1	3	0.372619	0.00487	0.36140	0.38384
2-2	3	0.396403	0.00487	0.38518	0.40762

Std Error uses a pooled estimate of error variance

Oneway Analysis of K2O (wt%) By Block/Sub-Block
Reference Value = 3.327 wt%



Oneway Anova
Summary of Fit

Rsquare	0.485362
Adj Rsquare	0.292373
Root Mean Square Error	0.063551
Mean of Response	3.549555
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.03047228	0.010157	2.5150	0.1321
Error	8	0.03231030	0.004039		
C. Total	11	0.06278258			

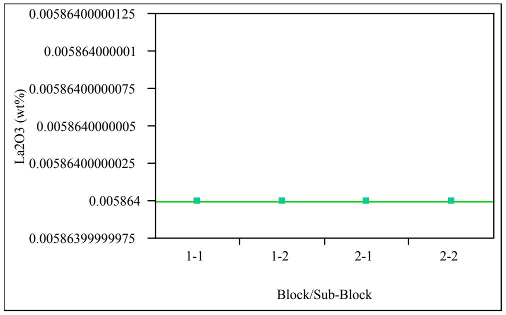
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	3.47326	0.03669	3.3887	3.5579
1-2	3	3.58168	0.03669	3.4971	3.6663
2-1	3	3.53751	0.03669	3.4529	3.6221
2-2	3	3.60577	0.03669	3.5212	3.6904

Std Error uses a pooled estimate of error variance

Exhibit D3. PSAL Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method (continued)

Oneway Analysis of La2O3 (wt%) By Block/Sub-Block
Reference Value = 0 wt%



Oneway Anova
Summary of Fit

Rsquare	.
Adj Rsquare	.
Root Mean Square Error	0
Mean of Response	0.005864
Observations (or Sum Wgts)	12

Analysis of Variance

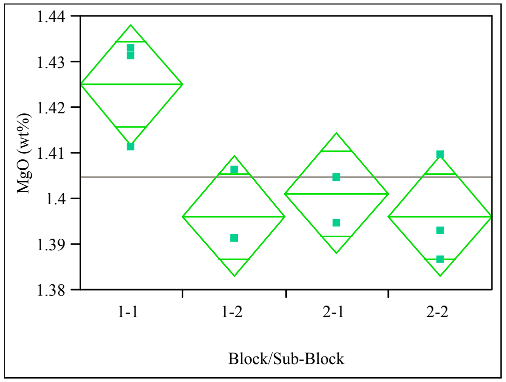
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0	0	.	.
Error	8	0	0		
C. Total	11	0			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.005864	0	0.00586	0.00586
1-2	3	0.005864	0	0.00586	0.00586
2-1	3	0.005864	0	0.00586	0.00586
2-2	3	0.005864	0	0.00586	0.00586

Std Error uses a pooled estimate of error variance

Oneway Analysis of MgO (wt%) By Block/Sub-Block
Reference Value = 1.419 wt%



Oneway Anova
Summary of Fit

Rsquare	0.683212
Adj Rsquare	0.564417
Root Mean Square Error	0.009927
Mean of Response	1.404718
Observations (or Sum Wgts)	12

Analysis of Variance

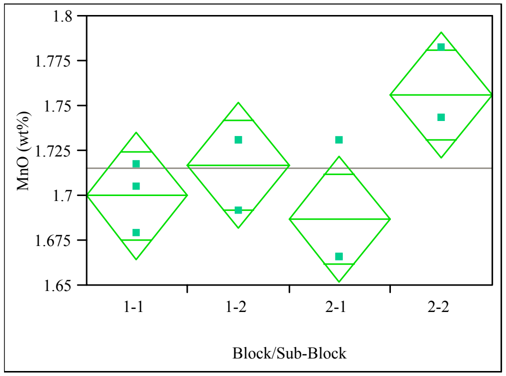
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00170016	0.000567	5.7512	0.0214
Error	8	0.00078832	0.000099		
C. Total	11	0.00248848			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	1.42503	0.00573	1.4118	1.4382
1-2	3	1.39629	0.00573	1.3831	1.4095
2-1	3	1.40126	0.00573	1.3880	1.4145
2-2	3	1.39629	0.00573	1.3831	1.4095

Std Error uses a pooled estimate of error variance

Oneway Analysis of MnO (wt%) By Block/Sub-Block
Reference Value = 1.726 wt%



Oneway Anova
Summary of Fit

Rsquare	0.591837
Adj Rsquare	0.438776
Root Mean Square Error	0.026357
Mean of Response	1.715144
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00805812	0.002686	3.8667	0.0560
Error	8	0.00555732	0.000695		
C. Total	11	0.01361545			

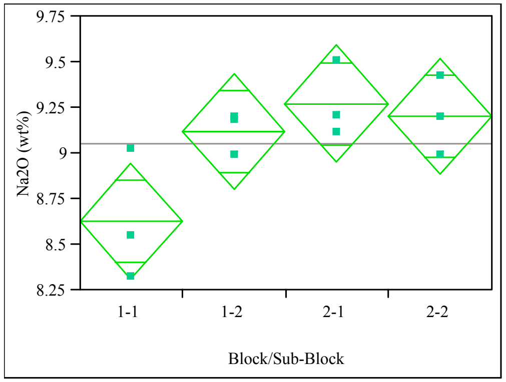
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	1.70008	0.01522	1.6650	1.7352
1-2	3	1.71730	0.01522	1.6822	1.7524
2-1	3	1.68717	0.01522	1.6521	1.7223
2-2	3	1.75603	0.01522	1.7209	1.7911

Std Error uses a pooled estimate of error variance

Exhibit D3. PSAL Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method (continued)

Oneway Analysis of Na2O (wt%) By Block/Sub-Block
Reference Value = 9.003 wt%



Oneway Anova
Summary of Fit

Rsquare	0.627815
Adj Rsquare	0.488246
Root Mean Square Error	0.23912
Mean of Response	9.056313
Observations (or Sum Wgts)	12

Analysis of Variance

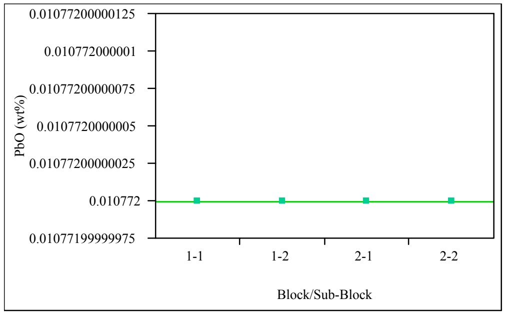
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.7716029	0.257201	4.4982	0.0395
Error	8	0.4574256	0.057178		
C. Total	11	1.2290286			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	8.62720	0.13806	8.3088	8.9456
1-2	3	9.12147	0.13806	8.8031	9.4398
2-1	3	9.27424	0.13806	8.9559	9.5926
2-2	3	9.20235	0.13806	8.8840	9.5207

Std Error uses a pooled estimate of error variance

Oneway Analysis of PbO (wt%) By Block/Sub-Block
Reference Value = 0 wt%



Oneway Anova
Summary of Fit

Rsquare	0
Adj Rsquare	-0.375
Root Mean Square Error	2.12e-18
Mean of Response	0.010772
Observations (or Sum Wgts)	12

Analysis of Variance

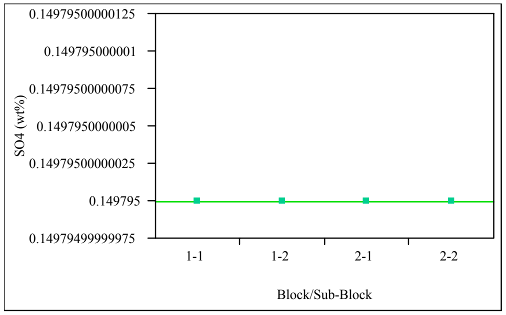
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0	0	0.0000	1.0000
Error	8	3.6111e-35	4.514e-36		
C. Total	11	3.6111e-35			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.010772	1.227e-18	0.01077	0.01077
1-2	3	0.010772	1.227e-18	0.01077	0.01077
2-1	3	0.010772	1.227e-18	0.01077	0.01077
2-2	3	0.010772	1.227e-18	0.01077	0.01077

Std Error uses a pooled estimate of error variance

Oneway Analysis of SO4 (wt%) By Block/Sub-Block
Reference Value = 0 wt%



Oneway Anova
Summary of Fit

Rsquare	.
Adj Rsquare	.
Root Mean Square Error	0
Mean of Response	0.149795
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0	0	.	.
Error	8	0	0		
C. Total	11	0			

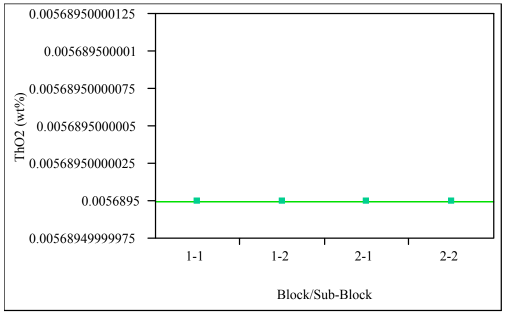
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.149795	0	0.14979	0.14979
1-2	3	0.149795	0	0.14979	0.14979
2-1	3	0.149795	0	0.14979	0.14979
2-2	3	0.149795	0	0.14979	0.14979

Std Error uses a pooled estimate of error variance

Exhibit D3. PSAL Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method (continued)

Oneway Analysis of ThO2 (wt%) By Block/Sub-Block
Reference Value = 0 wt%



Oneway Anova
Summary of Fit

Rsquare	.
Adj Rsquare	.
Root Mean Square Error	0
Mean of Response	0.005689
Observations (or Sum Wgts)	12

Analysis of Variance

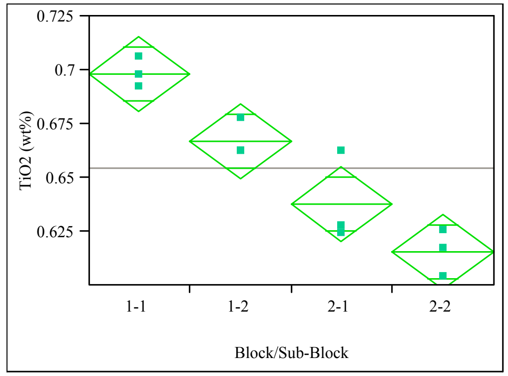
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0	0	.	.
Error	8	0	0		
C. Total	11	0			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.005689	0	0.00569	0.00569
1-2	3	0.005689	0	0.00569	0.00569
2-1	3	0.005689	0	0.00569	0.00569
2-2	3	0.005689	0	0.00569	0.00569

Std Error uses a pooled estimate of error variance

Oneway Analysis of TiO2 (wt%) By Block/Sub-Block
Reference Value = 0.677 wt%



Oneway Anova
Summary of Fit

Rsquare	0.893891
Adj Rsquare	0.8541
Root Mean Square Error	0.013151
Mean of Response	0.65469
Observations (or Sum Wgts)	12

Analysis of Variance

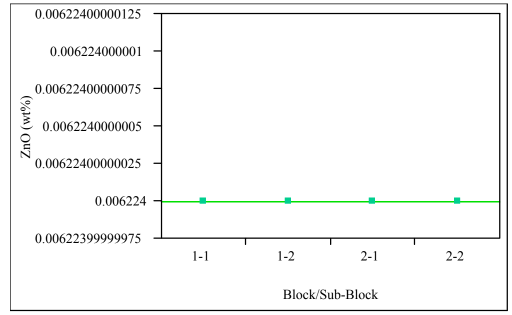
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.01165659	0.003886	22.4647	0.0003
Error	8	0.00138369	0.000173		
C. Total	11	0.01304028			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.698336	0.00759	0.68083	0.71585
1-2	3	0.667200	0.00759	0.64969	0.68471
2-1	3	0.637732	0.00759	0.62022	0.65524
2-2	3	0.615492	0.00759	0.59798	0.63300

Std Error uses a pooled estimate of error variance

Oneway Analysis of ZnO (wt%) By Block/Sub-Block
Reference Value = 0 wt%



Oneway Anova
Summary of Fit

Rsquare	.
Adj Rsquare	.
Root Mean Square Error	0
Mean of Response	0.006224
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0	0	.	.
Error	8	0	0		
C. Total	11	0			

Means for Oneway Anova

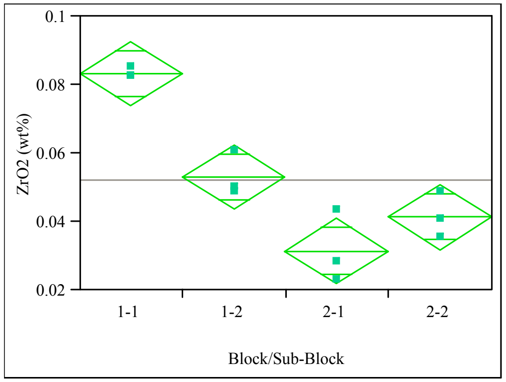
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.006224	0	0.00622	0.00622
1-2	3	0.006224	0	0.00622	0.00622
2-1	3	0.006224	0	0.00622	0.00622
2-2	3	0.006224	0	0.00622	0.00622

Std Error uses a pooled estimate of error variance

Exhibit D3. PSAL Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method (continued)

Glass ID=Ustd

Oneway Analysis of ZrO_2 (wt%) By Block/Sub-Block
Reference Value = 0.098 wt%



Oneway Anova
Summary of Fit

Rsquare	0.917782
Adj Rsquare	0.88695
Root Mean Square Error	0.007126
Mean of Response	0.052343
Observations (or Sum Wgts)	12

Analysis of Variance

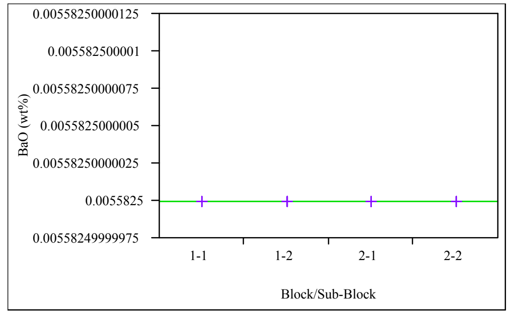
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00453535	0.001512	29.7675	0.0001
Error	8	0.00040629	0.000051		
C. Total	11	0.00494164			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.083299	0.00411	0.07381	0.09279
1-2	3	0.053131	0.00411	0.04364	0.06262
2-1	3	0.031519	0.00411	0.02203	0.04101
2-2	3	0.041425	0.00411	0.03194	0.05091

Std Error uses a pooled estimate of error variance

Oneway Analysis of BaO (wt%) By Block/Sub-Block
Reference Value = 0 wt%



Oneway Anova
Summary of Fit

Rsquare	.
Adj Rsquare	.
Root Mean Square Error	0
Mean of Response	0.005583
Observations (or Sum Wgts)	12

Analysis of Variance

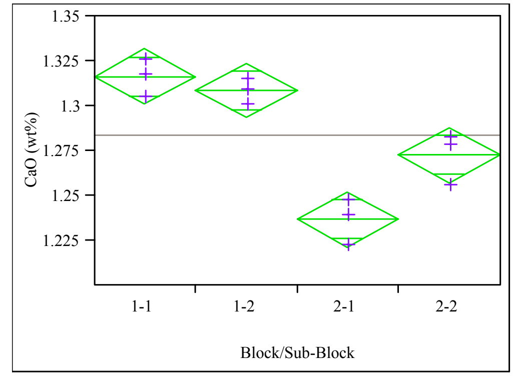
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0	0	.	.
Error	8	0	0		
C. Total	11	0			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.005583	0	0.00558	0.00558
1-2	3	0.005583	0	0.00558	0.00558
2-1	3	0.005583	0	0.00558	0.00558
2-2	3	0.005583	0	0.00558	0.00558

Std Error uses a pooled estimate of error variance

Oneway Analysis of CaO (wt%) By Block/Sub-Block
Reference Value = 1.301 wt%



Oneway Anova
Summary of Fit

Rsquare	0.91924
Adj Rsquare	0.888955
Root Mean Square Error	0.01151
Mean of Response	1.283766
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.01206307	0.004021	30.3530	0.0001
Error	8	0.00105980	0.000132		
C. Total	11	0.01312287			

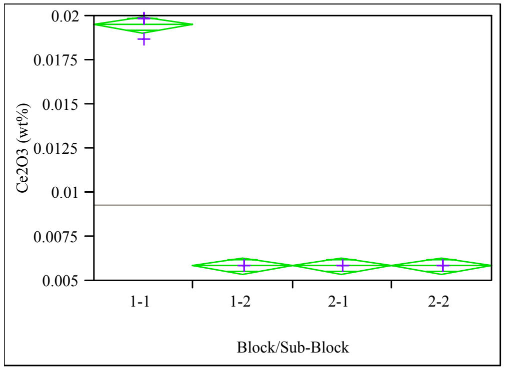
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	1.31665	0.00665	1.3013	1.3320
1-2	3	1.30872	0.00665	1.2934	1.3240
2-1	3	1.23689	0.00665	1.2216	1.2522
2-2	3	1.27281	0.00665	1.2575	1.2881

Std Error uses a pooled estimate of error variance

Exhibit D3. PSAL Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method (continued)

Oneway Analysis of Ce2O3 (wt%) By Block/Sub-Block
Reference Value = 0 wt%



Oneway Anova
Summary of Fit

Rsquare	0.997828
Adj Rsquare	0.997013
Root Mean Square Error	0.000338
Mean of Response	0.009273
Observations (or Sum Wgts)	12

Analysis of Variance

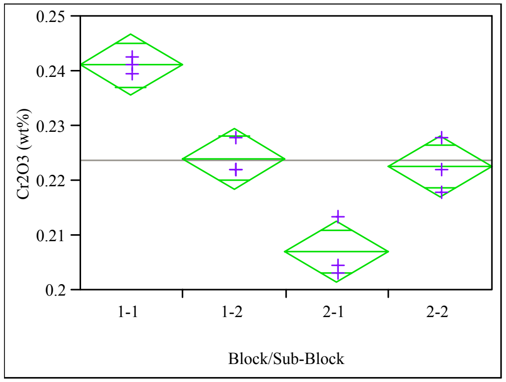
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00042016	0.000140	1225	<.0001
Error	8	0.00000091	1.143e-7		
C. Total	11	0.00042107			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.019522	0.00020	0.01907	0.01997
1-2	3	0.005857	0.00020	0.00541	0.00631
2-1	3	0.005857	0.00020	0.00541	0.00631
2-2	3	0.005857	0.00020	0.00541	0.00631

Std Error uses a pooled estimate of error variance

Oneway Analysis of Cr2O3 (wt%) By Block/Sub-Block
Reference Value = 0 wt%



Oneway Anova
Summary of Fit

Rsquare	0.925417
Adj Rsquare	0.897448
Root Mean Square Error	0.004198
Mean of Response	0.223747
Observations (or Sum Wgts)	12

Analysis of Variance

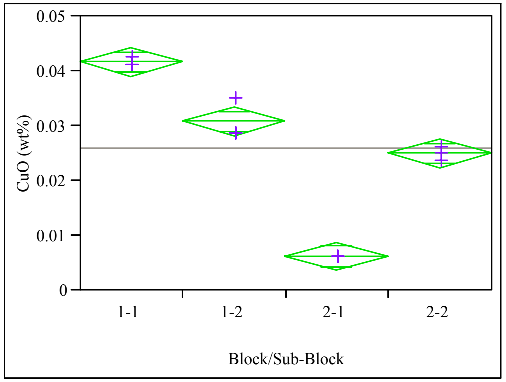
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00174943	0.000583	33.0875	<.0001
Error	8	0.00014099	0.000018		
C. Total	11	0.00189042			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.241164	0.00242	0.23557	0.24675
1-2	3	0.224112	0.00242	0.21852	0.22970
2-1	3	0.207060	0.00242	0.20147	0.21265
2-2	3	0.222650	0.00242	0.21706	0.22824

Std Error uses a pooled estimate of error variance

Oneway Analysis of CuO (wt%) By Block/Sub-Block
Reference Value = 0 wt%



Oneway Anova
Summary of Fit

Rsquare	0.984969
Adj Rsquare	0.979333
Root Mean Square Error	0.001946
Mean of Response	0.025975
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00198526	0.000662	174.7471	<.0001
Error	8	0.00003030	0.000004		
C. Total	11	0.00201556			

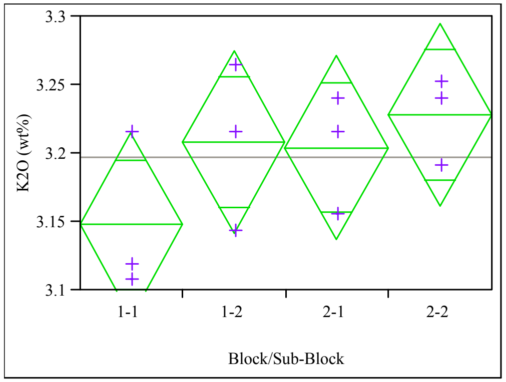
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.041727	0.00112	0.03914	0.04432
1-2	3	0.030878	0.00112	0.02829	0.03347
2-1	3	0.006259	0.00112	0.00367	0.00885
2-2	3	0.025036	0.00112	0.02245	0.02763

Std Error uses a pooled estimate of error variance

Exhibit D3. PSAL Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method (continued)

Oneway Analysis of K2O (wt%) By Block/Sub-Block
Reference Value = 2.999 wt%



Oneway Anova
Summary of Fit

Rsquare	0.345597
Adj Rsquare	0.100196
Root Mean Square Error	0.050272
Mean of Response	3.197209
Observations (or Sum Wgts)	12

Analysis of Variance

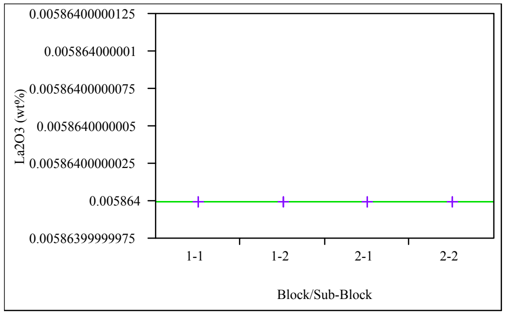
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.01067739	0.003559	1.4083	0.3097
Error	8	0.02021812	0.002527		
C. Total	11	0.03089551			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	3.14802	0.02902	3.0811	3.2150
1-2	3	3.20825	0.02902	3.1413	3.2752
2-1	3	3.20424	0.02902	3.1373	3.2712
2-2	3	3.22833	0.02902	3.1614	3.2953

Std Error uses a pooled estimate of error variance

Oneway Analysis of La2O3 (wt%) By Block/Sub-Block
Reference Value = 0 wt%



Oneway Anova
Summary of Fit

Rsquare	.
Adj Rsquare	.
Root Mean Square Error	0
Mean of Response	0.005864
Observations (or Sum Wgts)	12

Analysis of Variance

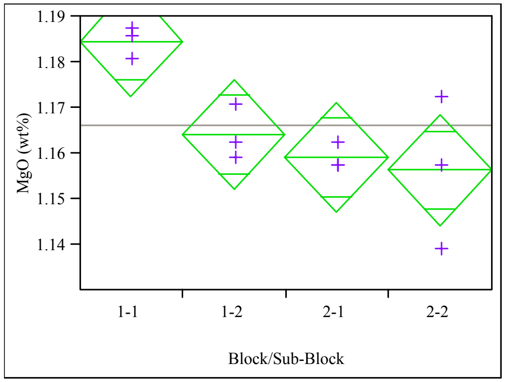
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0	0	.	.
Error	8	0	0		
C. Total	11	0			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.005864	0	0.00586	0.00586
1-2	3	0.005864	0	0.00586	0.00586
2-1	3	0.005864	0	0.00586	0.00586
2-2	3	0.005864	0	0.00586	0.00586

Std Error uses a pooled estimate of error variance

Oneway Analysis of MgO (wt%) By Block/Sub-Block
Reference Value = 1.21 wt%



Oneway Anova
Summary of Fit

Rsquare	0.688065
Adj Rsquare	0.57109
Root Mean Square Error	0.009108
Mean of Response	1.166061
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00146389	0.000488	5.8821	0.0202
Error	8	0.00066366	0.000083		
C. Total	11	0.00212755			

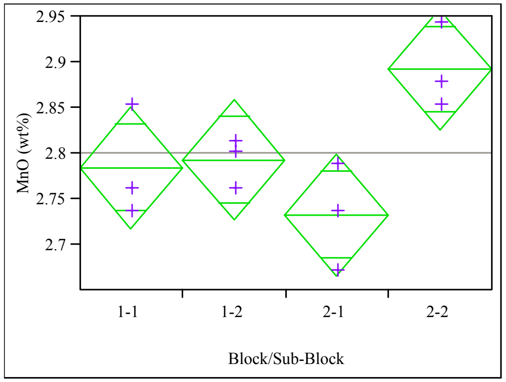
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	1.18458	0.00526	1.1725	1.1967
1-2	3	1.16413	0.00526	1.1520	1.1763
2-1	3	1.15915	0.00526	1.1470	1.1713
2-2	3	1.15639	0.00526	1.1443	1.1685

Std Error uses a pooled estimate of error variance

Exhibit D3. PSAL Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method (continued)

Oneway Analysis of MnO (wt%) By Block/Sub-Block
Reference Value = 2.892 wt%



Oneway Anova
Summary of Fit

Rsquare	0.665661
Adj Rsquare	0.540283
Root Mean Square Error	0.050008
Mean of Response	2.800828
Observations (or Sum Wgts)	12

Analysis of Variance

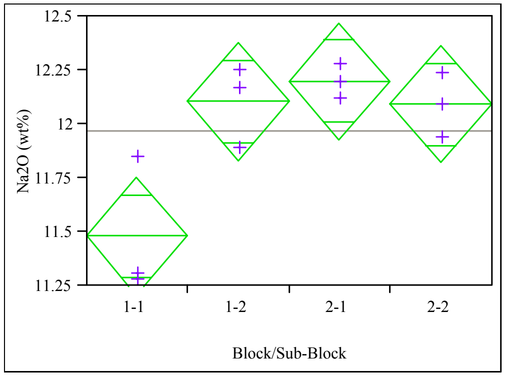
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.03983213	0.013277	5.3093	0.0263
Error	8	0.02000637	0.002501		
C. Total	11	0.05983849			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	2.78469	0.02887	2.7181	2.8513
1-2	3	2.79330	0.02887	2.7267	2.8599
2-1	3	2.73304	0.02887	2.6665	2.7996
2-2	3	2.89229	0.02887	2.8257	2.9589

Std Error uses a pooled estimate of error variance

Oneway Analysis of Na2O (wt%) By Block/Sub-Block
Reference Value = 11.795 wt%



Oneway Anova
Summary of Fit

Rsquare	0.744945
Adj Rsquare	0.6493
Root Mean Square Error	0.20436
Mean of Response	11.96912
Observations (or Sum Wgts)	12

Analysis of Variance

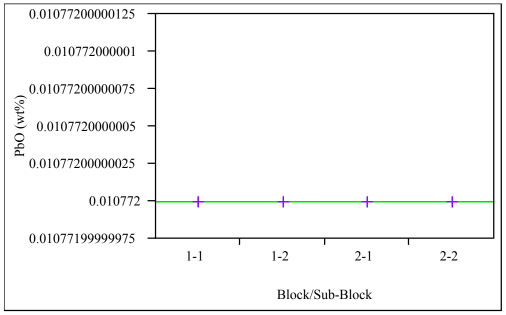
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.9758303	0.325277	7.7886	0.0093
Error	8	0.3341049	0.041763		
C. Total	11	1.3099351			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	11.4805	0.11799	11.208	11.753
1-2	3	12.1050	0.11799	11.833	12.377
2-1	3	12.1994	0.11799	11.927	12.471
2-2	3	12.0916	0.11799	11.819	12.364

Std Error uses a pooled estimate of error variance

Oneway Analysis of PbO (wt%) By Block/Sub-Block
Reference Value = 0 wt%



Oneway Anova
Summary of Fit

Rsquare	0
Adj Rsquare	-0.375
Root Mean Square Error	2.12e-18
Mean of Response	0.010772
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0	0	0.0000	1.0000
Error	8	3.6111e-35	4.514e-36		
C. Total	11	3.6111e-35			

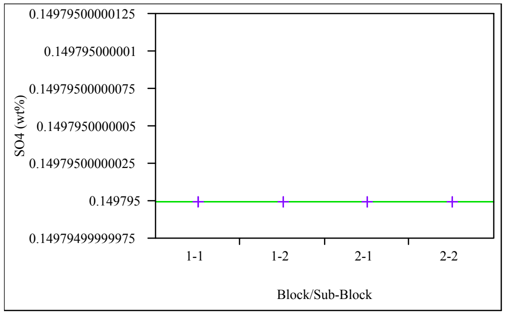
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.010772	1.227e-18	0.01077	0.01077
1-2	3	0.010772	1.227e-18	0.01077	0.01077
2-1	3	0.010772	1.227e-18	0.01077	0.01077
2-2	3	0.010772	1.227e-18	0.01077	0.01077

Std Error uses a pooled estimate of error variance

Exhibit D3. PSAL Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method (continued)

Oneway Analysis of SO4 (wt%) By Block/Sub-Block
Reference Value = 0 wt%



Oneway Anova
Summary of Fit

Rsquare	.
Adj Rsquare	.
Root Mean Square Error	0
Mean of Response	0.149795
Observations (or Sum Wgts)	12

Analysis of Variance

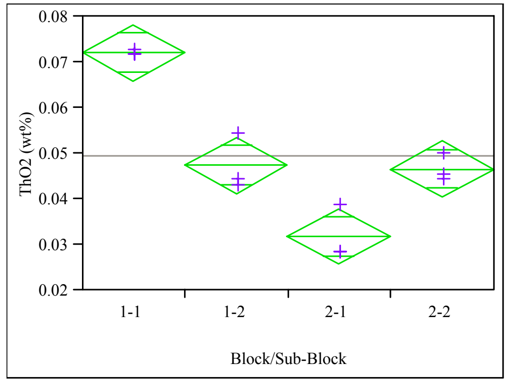
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0	0	.	.
Error	8	0	0		
C. Total	11	0			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.149795	0	0.14979	0.14979
1-2	3	0.149795	0	0.14979	0.14979
2-1	3	0.149795	0	0.14979	0.14979
2-2	3	0.149795	0	0.14979	0.14979

Std Error uses a pooled estimate of error variance

Oneway Analysis of ThO2 (wt%) By Block/Sub-Block
Reference Value = 0 wt%



Oneway Anova
Summary of Fit

Rsquare	0.937186
Adj Rsquare	0.913631
Root Mean Square Error	0.004575
Mean of Response	0.049499
Observations (or Sum Wgts)	12

Analysis of Variance

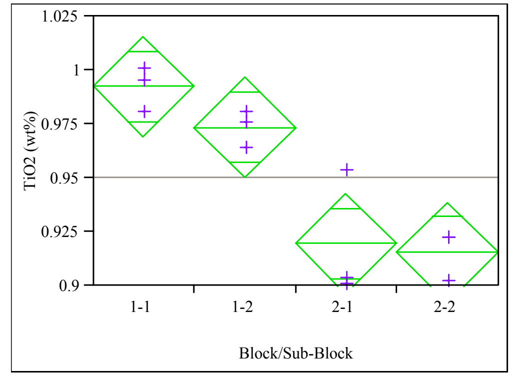
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00249856	0.000833	39.7869	<.0001
Error	8	0.00016746	0.000021		
C. Total	11	0.00266603			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.072067	0.00264	0.06598	0.07816
1-2	3	0.047412	0.00264	0.04132	0.05350
2-1	3	0.031861	0.00264	0.02577	0.03795
2-2	3	0.046654	0.00264	0.04056	0.05275

Std Error uses a pooled estimate of error variance

Oneway Analysis of TiO2 (wt%) By Block/Sub-Block
Reference Value = 1.049 wt%



Oneway Anova
Summary of Fit

Rsquare	0.846739
Adj Rsquare	0.789266
Root Mean Square Error	0.017388
Mean of Response	0.950343
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.01336279	0.004454	14.7329	0.0013
Error	8	0.00241868	0.000302		
C. Total	11	0.01578147			

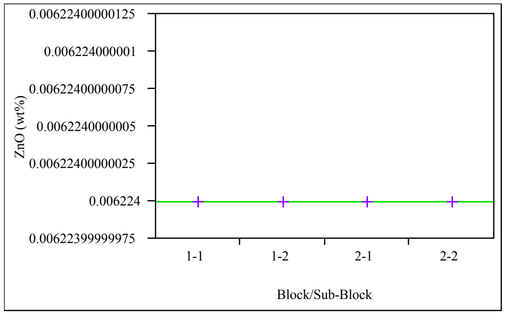
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.992460	0.01004	0.96931	1.0156
1-2	3	0.973556	0.01004	0.95041	0.9967
2-1	3	0.919624	0.01004	0.89647	0.9428
2-2	3	0.915732	0.01004	0.89258	0.9389

Std Error uses a pooled estimate of error variance

Exhibit D3. PSAL Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method (continued)

Oneway Analysis of ZnO (wt%) By Block/Sub-Block
Reference Value = 0 wt%



Oneway Anova
Summary of Fit

Rsquare	.
Adj Rsquare	.
Root Mean Square Error	0
Mean of Response	0.006224
Observations (or Sum Wgts)	12

Analysis of Variance

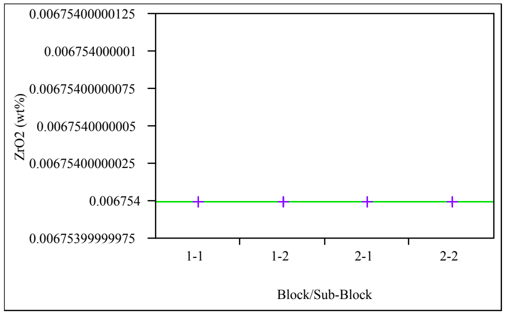
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0	0	.	.
Error	8	0	0		
C. Total	11	0			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.006224	0	0.00622	0.00622
1-2	3	0.006224	0	0.00622	0.00622
2-1	3	0.006224	0	0.00622	0.00622
2-2	3	0.006224	0	0.00622	0.00622

Std Error uses a pooled estimate of error variance

Oneway Analysis of ZrO2 (wt%) By Block/Sub-Block
Reference Value = 0 wt%



Oneway Anova
Summary of Fit

Rsquare	.
Adj Rsquare	.
Root Mean Square Error	0
Mean of Response	0.006754
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0	0	.	.
Error	8	0	0		
C. Total	11	0			

Means for Oneway Anova

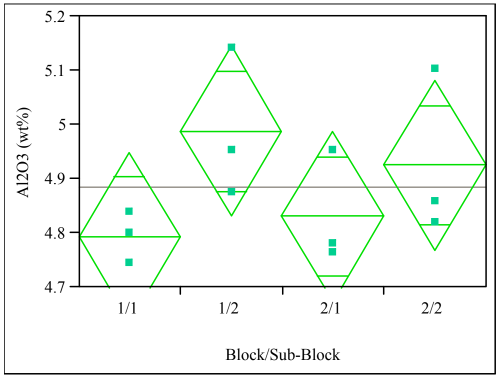
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.006754	0	0.00675	0.00675
1-2	3	0.006754	0	0.00675	0.00675
2-1	3	0.006754	0	0.00675	0.00675
2-2	3	0.006754	0	0.00675	0.00675

Std Error uses a pooled estimate of error variance

Exhibit D4: PSAL Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the PF Method

Glass ID=Batch 1

Oneway Analysis of Al2O3 (wt%) By Block/Sub-Block
Reference Value = 4.877 wt%



Oneway Anova
Summary of Fit

Rsquare	0.390963
Adj Rsquare	0.162574
Root Mean Square Error	0.11762
Mean of Response	4.884358
Observations (or Sum Wgts)	12

Analysis of Variance

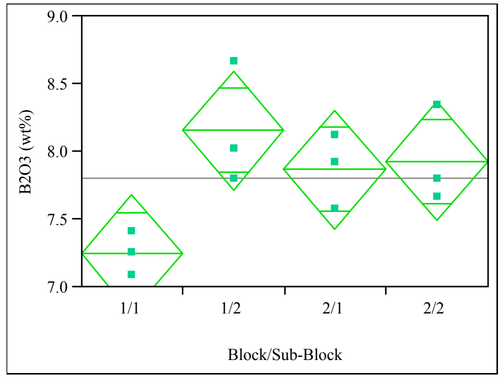
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.07104718	0.023682	1.7118	0.2414
Error	8	0.11067652	0.013835		
C. Total	11	0.18172370			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	4.79303	0.06791	4.6364	4.9496
1/2	3	4.98828	0.06791	4.8317	5.1449
2/1	3	4.83082	0.06791	4.6742	4.9874
2/2	3	4.92530	0.06791	4.7687	5.0819

Std Error uses a pooled estimate of error variance

Oneway Analysis of B2O3 (wt%) By Block/Sub-Block
Reference Value = 7.777 wt%



Oneway Anova
Summary of Fit

Rsquare	0.611875
Adj Rsquare	0.466328
Root Mean Square Error	0.329942
Mean of Response	7.800208
Observations (or Sum Wgts)	12

Analysis of Variance

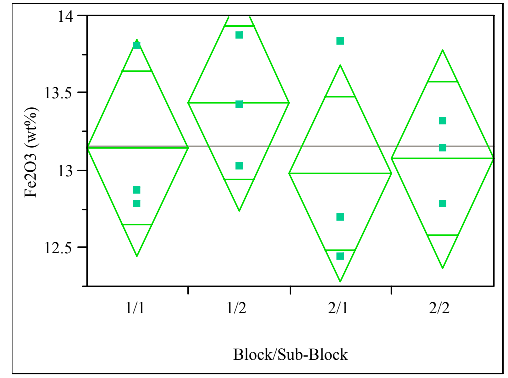
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	1.3729501	0.457650	4.2040	0.0463
Error	8	0.8708915	0.108861		
C. Total	11	2.2438416			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	7.24478	0.19049	6.8055	7.6841
1/2	3	8.15708	0.19049	7.7178	8.5964
2/1	3	7.86729	0.19049	7.4280	8.3066
2/2	3	7.93169	0.19049	7.4924	8.3710

Std Error uses a pooled estimate of error variance

Oneway Analysis of Fe2O3 (wt%) By Block/Sub-Block
Reference Value = 12.839 wt%



Oneway Anova
Summary of Fit

Rsquare	0.134355
Adj Rsquare	-0.19026
Root Mean Square Error	0.527247
Mean of Response	13.16277
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.3451706	0.115057	0.4139	0.7477
Error	8	2.2239178	0.277990		
C. Total	11	2.5690884			

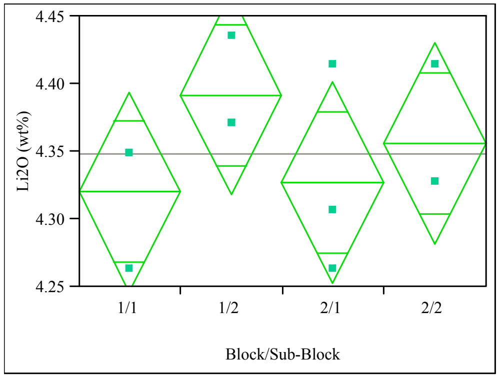
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	13.1485	0.30441	12.447	13.850
1/2	3	13.4392	0.30441	12.737	14.141
2/1	3	12.9864	0.30441	12.284	13.688
2/2	3	13.0770	0.30441	12.375	13.779

Std Error uses a pooled estimate of error variance

Exhibit D4: PSAL Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the PF Method (continued)

Oneway Analysis of Li2O (wt%) By Block/Sub-Block
Reference Value = 4.429 wt%



Oneway Anova
Summary of Fit

Rsquare	0.279279
Adj Rsquare	0.009009
Root Mean Square Error	0.055588
Mean of Response	4.348858
Observations (or Sum Wgts)	12

Analysis of Variance

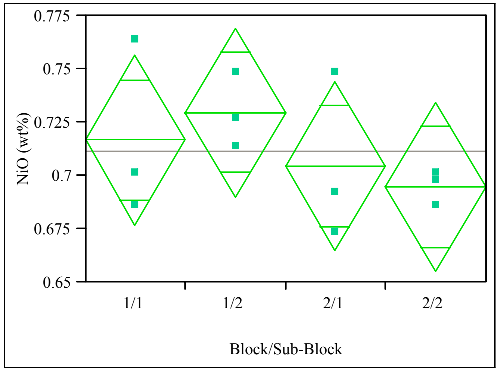
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00957896	0.003193	1.0333	0.4282
Error	8	0.02471988	0.003090		
C. Total	11	0.03429884			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	4.32015	0.03209	4.2461	4.3942
1/2	3	4.39192	0.03209	4.3179	4.4659
2/1	3	4.32733	0.03209	4.2533	4.4013
2/2	3	4.35603	0.03209	4.2820	4.4300

Std Error uses a pooled estimate of error variance

Oneway Analysis of NiO (wt%) By Block/Sub-Block
Reference Value = 0.751 wt%



Oneway Anova
Summary of Fit

Rsquare	0.222504
Adj Rsquare	-0.06906
Root Mean Square Error	0.029911
Mean of Response	0.711434
Observations (or Sum Wgts)	12

Analysis of Variance

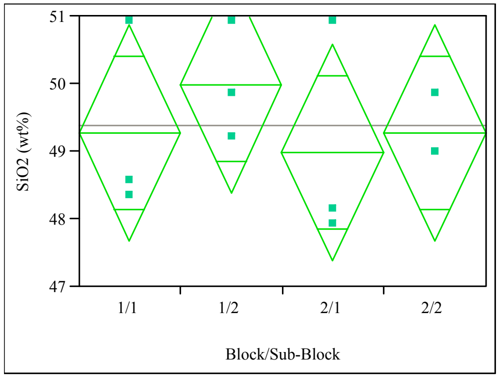
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00204822	0.000683	0.7631	0.5458
Error	8	0.00715711	0.000895		
C. Total	11	0.00920534			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	0.716842	0.01727	0.67702	0.75666
1/2	3	0.729567	0.01727	0.68974	0.76939
2/1	3	0.704541	0.01727	0.66472	0.74436
2/2	3	0.694785	0.01727	0.65496	0.73461

Std Error uses a pooled estimate of error variance

Oneway Analysis of SiO2 (wt%) By Block/Sub-Block
Reference Value = 50.22 wt%



Oneway Anova
Summary of Fit

Rsquare	0.12313
Adj Rsquare	-0.2057
Root Mean Square Error	1.205434
Mean of Response	49.38217
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	1.632322	0.54411	0.3745	0.7740
Error	8	11.624575	1.45307		
C. Total	11	13.256898			

Means for Oneway Anova

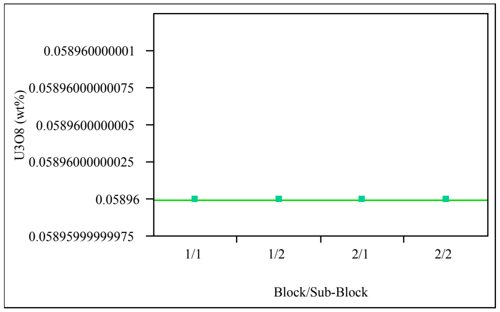
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	49.2752	0.69596	47.670	50.880
1/2	3	49.9883	0.69596	48.383	51.593
2/1	3	48.9900	0.69596	47.385	50.595
2/2	3	49.2752	0.69596	47.670	50.880

Std Error uses a pooled estimate of error variance

Exhibit D4: PSAL Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the PF Method (continued)

Glass ID=Ustd

Oneway Analysis of U3O8 (wt%) By Block/Sub-Block
Reference Value = 0 wt%



Oneway Anova
Summary of Fit

Rsquare	.
Adj Rsquare	.
Root Mean Square Error	0
Mean of Response	0.05896
Observations (or Sum Wgts)	12

Analysis of Variance

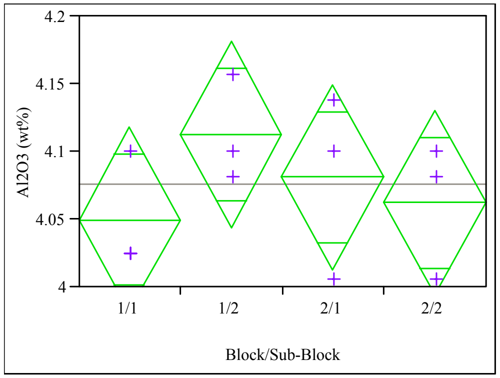
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0	0	.	.
Error	8	0	0		
C. Total	11	0			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	0.058960	0	0.05896	0.05896
1/2	3	0.058960	0	0.05896	0.05896
2/1	3	0.058960	0	0.05896	0.05896
2/2	3	0.058960	0	0.05896	0.05896

Std Error uses a pooled estimate of error variance

Oneway Analysis of Al2O3 (wt%) By Block/Sub-Block
Reference Value = 4.1 wt%



Oneway Anova
Summary of Fit

Rsquare	0.241747
Adj Rsquare	-0.0426
Root Mean Square Error	0.051458
Mean of Response	4.076596
Observations (or Sum Wgts)	12

Analysis of Variance

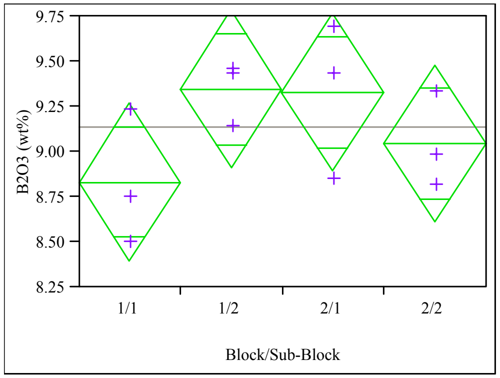
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00675365	0.002251	0.8502	0.5045
Error	8	0.02118325	0.002648		
C. Total	11	0.02793690			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	4.04983	0.02971	3.9813	4.1183
1/2	3	4.11281	0.02971	4.0443	4.1813
2/1	3	4.08132	0.02971	4.0128	4.1498
2/2	3	4.06243	0.02971	3.9939	4.1309

Std Error uses a pooled estimate of error variance

Oneway Analysis of B2O3 (wt%) By Block/Sub-Block
Reference Value = 9.209 wt%



Oneway Anova
Summary of Fit

Rsquare	0.38915
Adj Rsquare	0.160082
Root Mean Square Error	0.326387
Mean of Response	9.13915
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.5429248	0.180975	1.6988	0.2439
Error	8	0.8522295	0.106529		
C. Total	11	1.3951544			

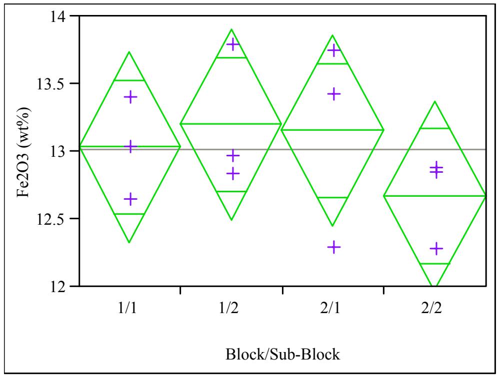
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	8.83326	0.18844	8.3987	9.2678
1/2	3	9.34844	0.18844	8.9139	9.7830
2/1	3	9.32698	0.18844	8.8924	9.7615
2/2	3	9.04792	0.18844	8.6134	9.4825

Std Error uses a pooled estimate of error variance

Exhibit D4: PSAL Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the PF Method (continued)

Oneway Analysis of Fe2O3 (wt%) By Block/Sub-Block
Reference Value = 13.196 wt%



Oneway Anova
Summary of Fit

Rsquare	0.18905
Adj Rsquare	-0.11506
Root Mean Square Error	0.527651
Mean of Response	13.01623
Observations (or Sum Wgts)	12

Analysis of Variance

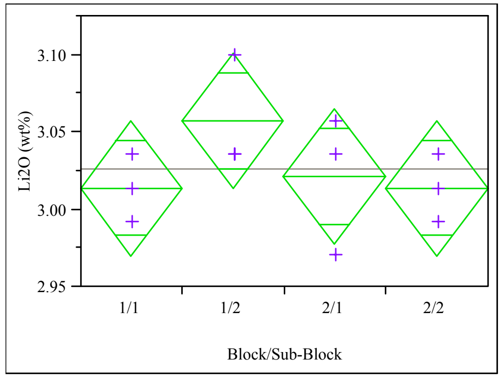
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.5192378	0.173079	0.6217	0.6206
Error	8	2.2273245	0.278416		
C. Total	11	2.7465623			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	13.0341	0.30464	12.332	13.737
1/2	3	13.2009	0.30464	12.498	13.903
2/1	3	13.1580	0.30464	12.456	13.861
2/2	3	12.6719	0.30464	11.969	13.374

Std Error uses a pooled estimate of error variance

Oneway Analysis of Li2O (wt%) By Block/Sub-Block
Reference Value = 3.057 wt%



Oneway Anova
Summary of Fit

Rsquare	0.306502
Adj Rsquare	0.04644
Root Mean Square Error	0.032886
Mean of Response	3.026619
Observations (or Sum Wgts)	12

Analysis of Variance

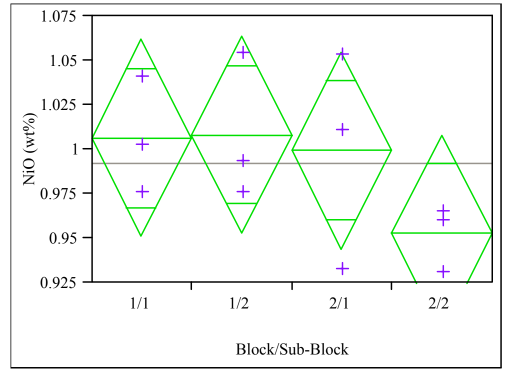
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00382386	0.001275	1.1786	0.3770
Error	8	0.00865196	0.001081		
C. Total	11	0.01247582			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	3.01406	0.01899	2.9703	3.0578
1/2	3	3.05712	0.01899	3.0133	3.1009
2/1	3	3.02124	0.01899	2.9775	3.0650
2/2	3	3.01406	0.01899	2.9703	3.0578

Std Error uses a pooled estimate of error variance

Oneway Analysis of NiO (wt%) By Block/Sub-Block
Reference Value = 1.12 wt%



Oneway Anova
Summary of Fit

Rsquare	0.311292
Adj Rsquare	0.053027
Root Mean Square Error	0.041493
Mean of Response	0.991702
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00622550	0.002075	1.2053	0.3683
Error	8	0.01377339	0.001722		
C. Total	11	0.01999889			

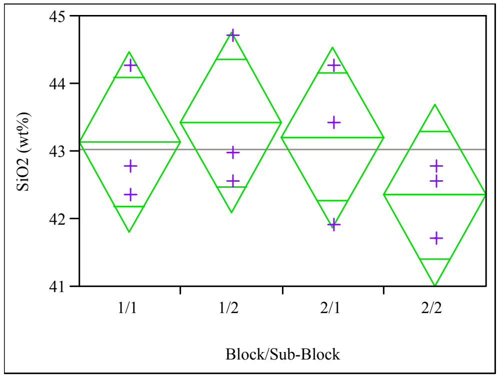
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	1.00655	0.02396	0.95130	1.0618
1/2	3	1.00824	0.02396	0.95300	1.0635
2/1	3	0.99934	0.02396	0.94409	1.0546
2/2	3	0.95268	0.02396	0.89744	1.0079

Std Error uses a pooled estimate of error variance

Exhibit D4: PSAL Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the PF Method (continued)

Oneway Analysis of SiO2 (wt%) By Block/Sub-Block
Reference Value = 45.353 wt%



Oneway Anova
Summary of Fit

Rsquare	0.195751
Adj Rsquare	-0.10584
Root Mean Square Error	1.005319
Mean of Response	43.03558
Observations (or Sum Wgts)	12

Analysis of Variance

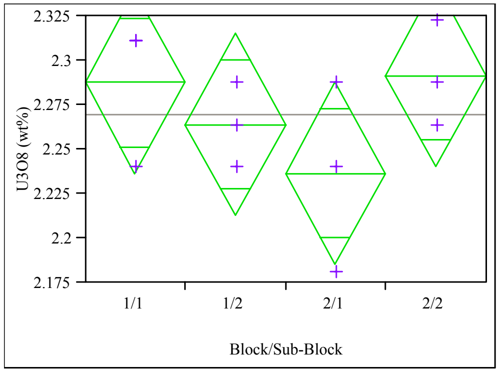
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	1.967940	0.65598	0.6491	0.6053
Error	8	8.085335	1.01067		
C. Total	11	10.053275			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	43.1426	0.58042	41.804	44.481
1/2	3	43.4278	0.58042	42.089	44.766
2/1	3	43.2139	0.58042	41.875	44.552
2/2	3	42.3581	0.58042	41.020	43.697

Std Error uses a pooled estimate of error variance

Oneway Analysis of U3O8 (wt%) By Block/Sub-Block
Reference Value = 2.406 wt%



Oneway Anova
Summary of Fit

Rsquare	0.328084
Adj Rsquare	0.076115
Root Mean Square Error	0.038513
Mean of Response	2.26996
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00579380	0.001931	1.3021	0.3389
Error	8	0.01186571	0.001483		
C. Total	11	0.01765951			

Means for Oneway Anova

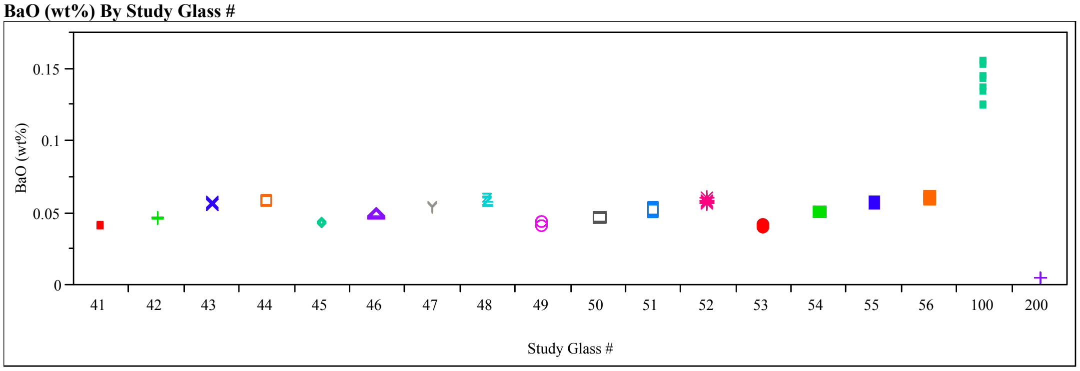
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	2.28765	0.02224	2.2364	2.3389
1/2	3	2.26406	0.02224	2.2128	2.3153
2/1	3	2.23655	0.02224	2.1853	2.2878
2/2	3	2.29158	0.02224	2.2403	2.3429

Std Error uses a pooled estimate of error variance

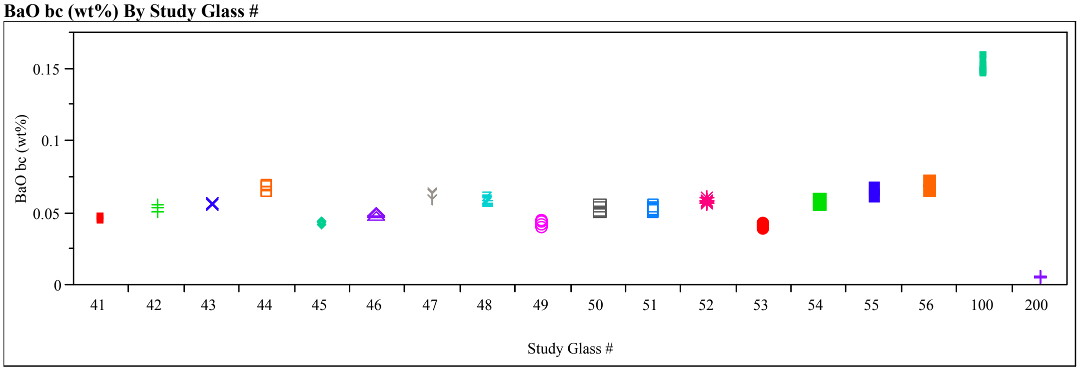
Exhibit D5. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass # for the Glasses Prepared Using the LM Method

(100 – Batch 1; 200 – Ustd)

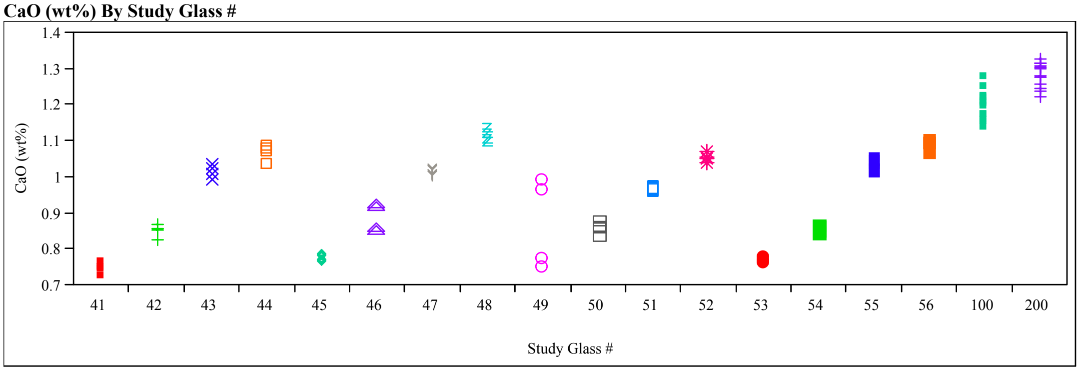
BaO (wt%) By Study Glass #



BaO bc (wt%) By Study Glass #



CaO (wt%) By Study Glass #



CaO bc (wt%) By Study Glass #

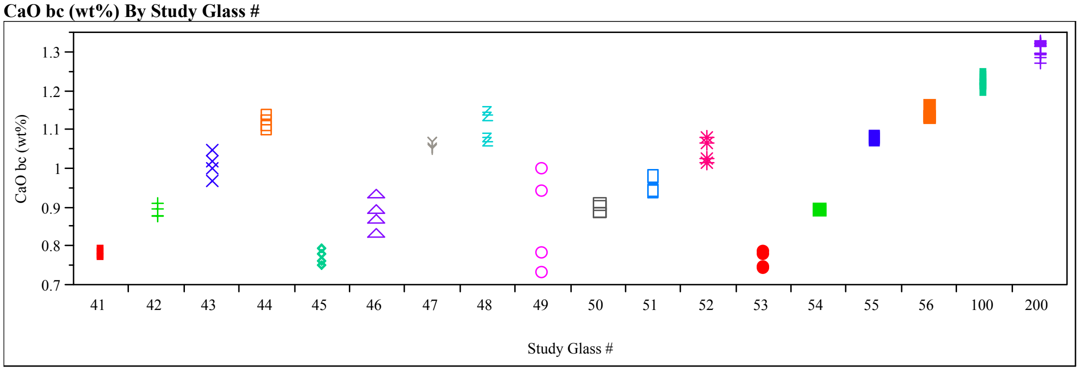
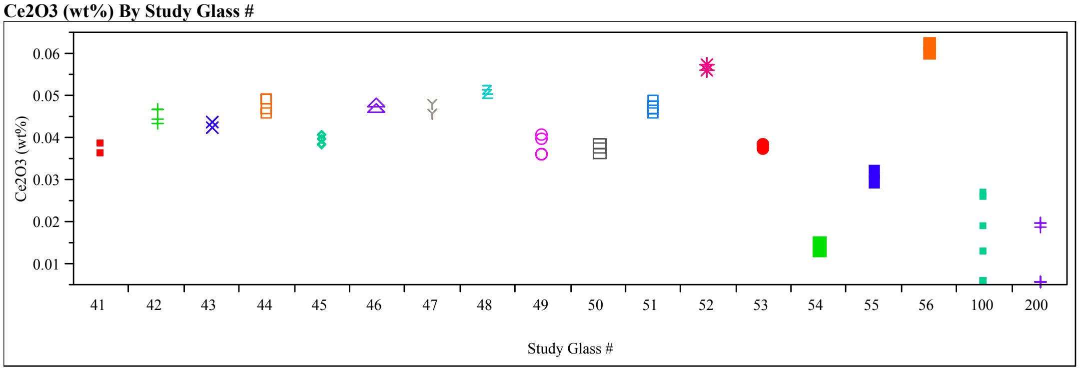


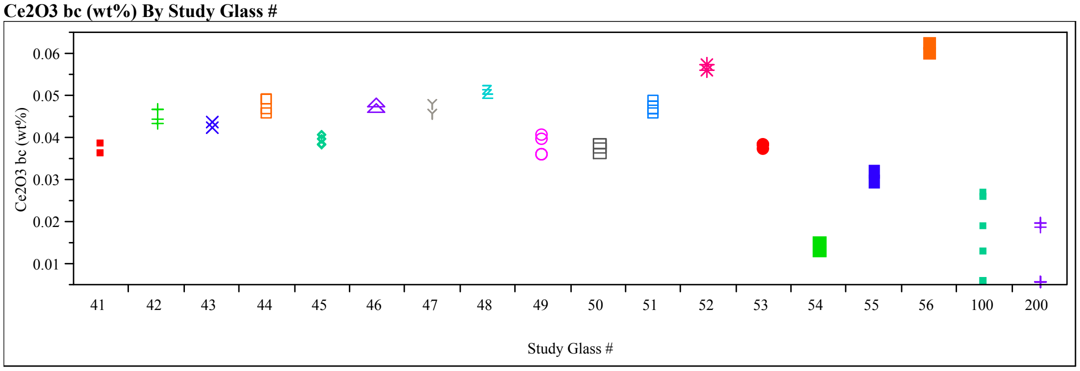
Exhibit D5. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass # for the Glasses Prepared Using the LM Method (continued)

(100 – Batch 1; 200 – Ustd)

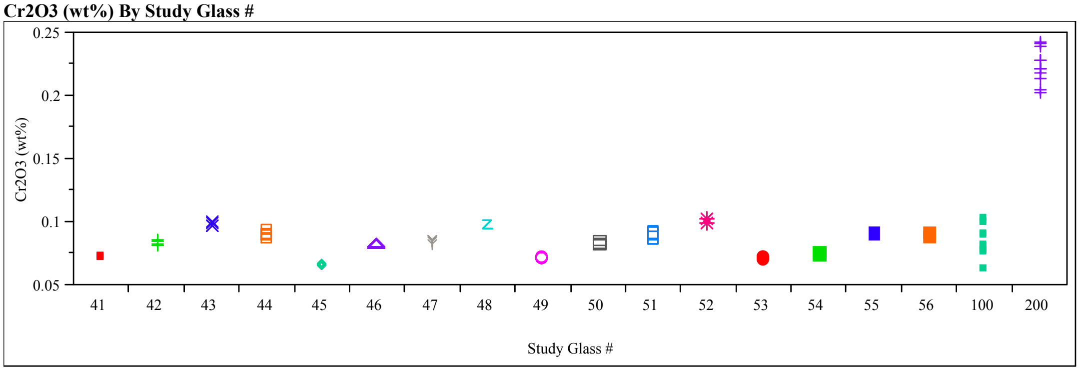
Ce2O3 (wt%) By Study Glass #



Ce2O3 bc (wt%) By Study Glass #



Cr2O3 (wt%) By Study Glass #



Cr2O3 bc (wt%) By Study Glass #

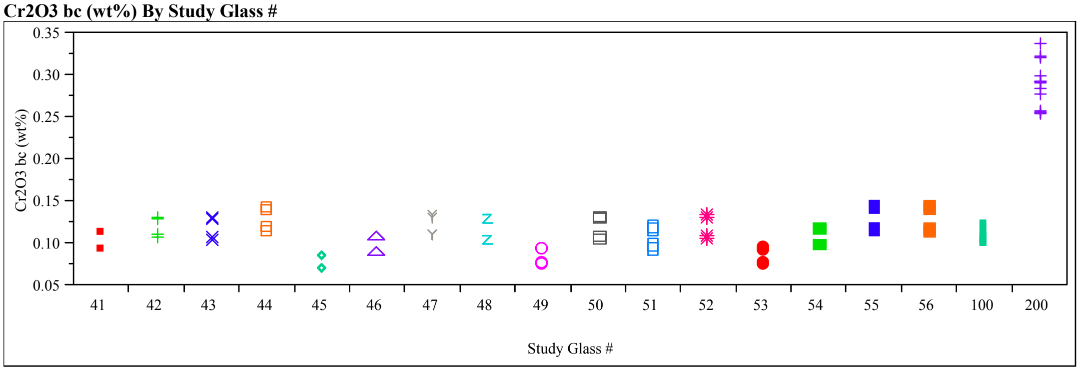
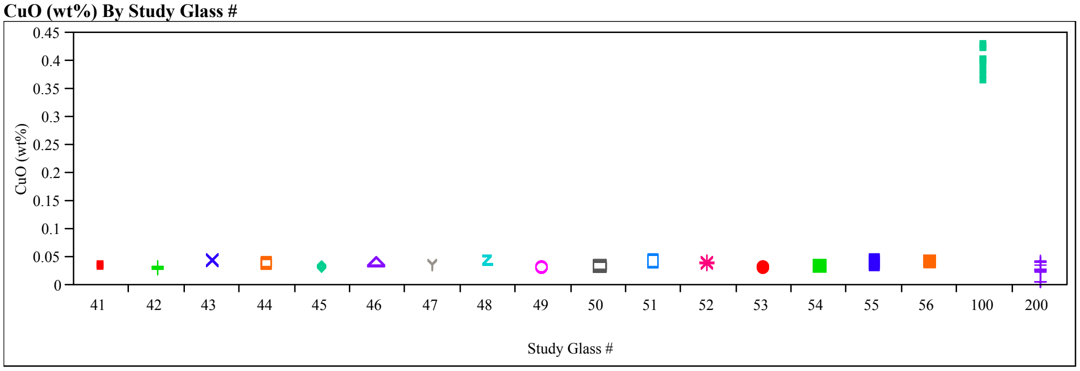


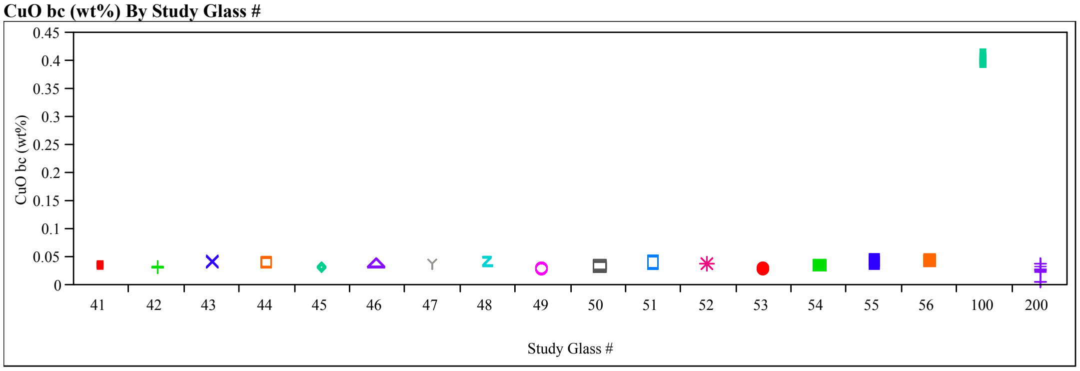
Exhibit D5. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass # for the Glasses Prepared Using the LM Method (continued)

(100 – Batch 1; 200 – Ustd)

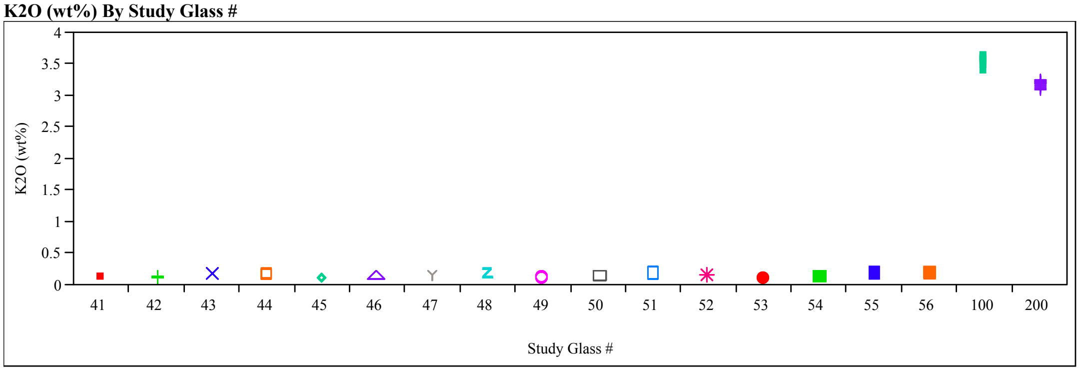
CuO (wt%) By Study Glass #



CuO bc (wt%) By Study Glass #



K2O (wt%) By Study Glass #



K2O bc (wt%) By Study Glass #

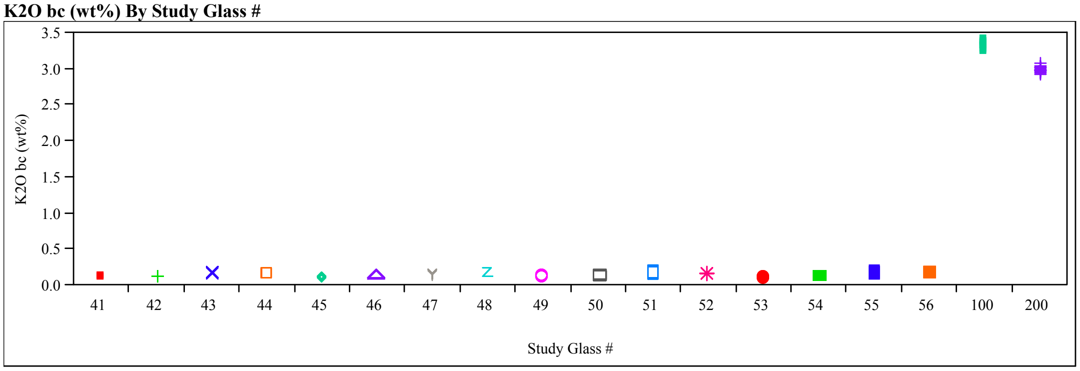
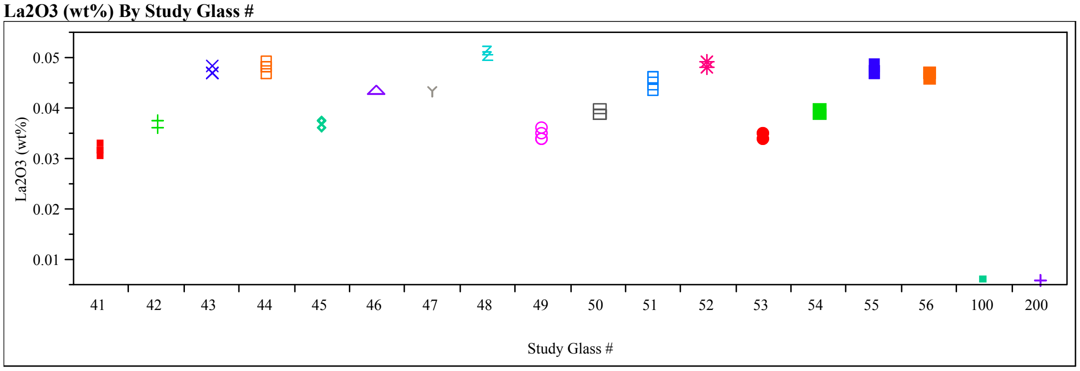


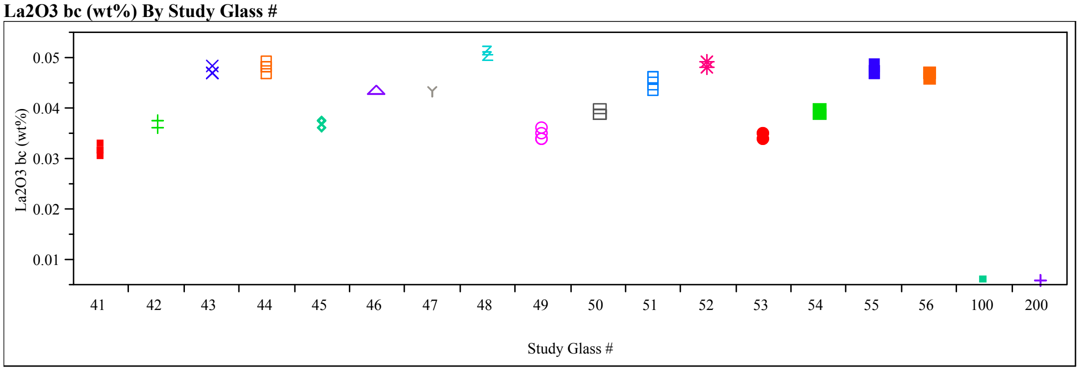
Exhibit D5. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass # for the Glasses Prepared Using the LM Method (continued)

(100 – Batch 1; 200 – Ustd)

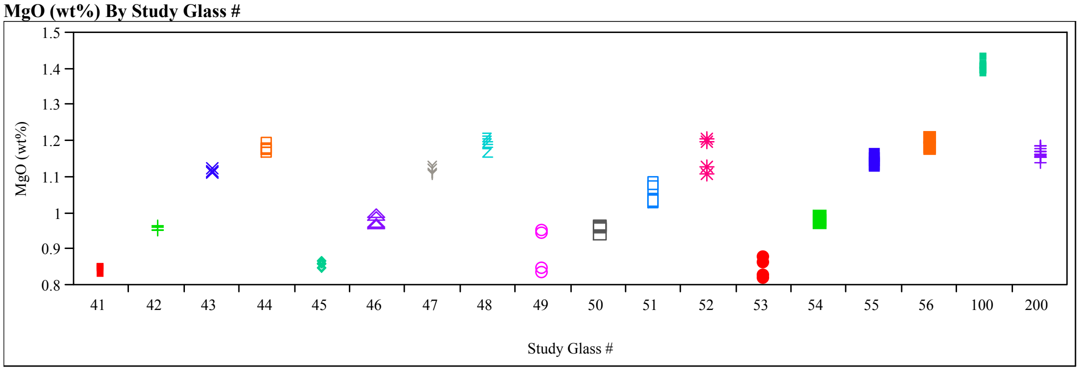
La2O3 (wt%) By Study Glass #



La2O3 bc (wt%) By Study Glass #



MgO (wt%) By Study Glass #



MgO bc (wt%) By Study Glass #

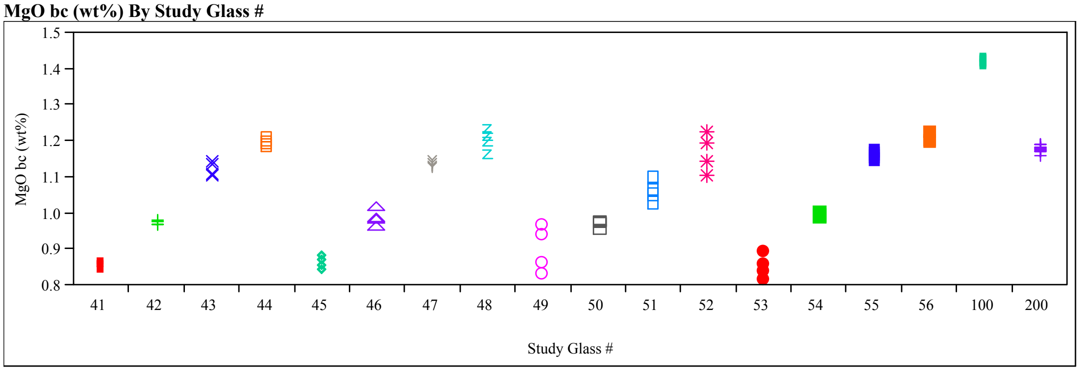
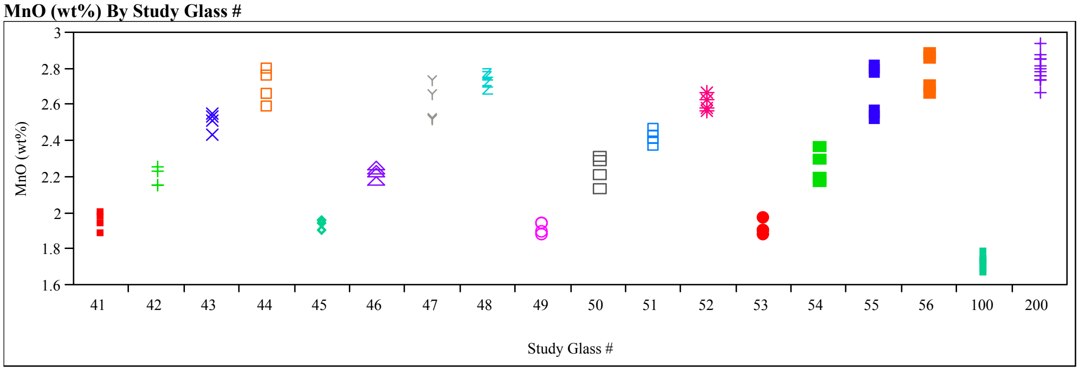


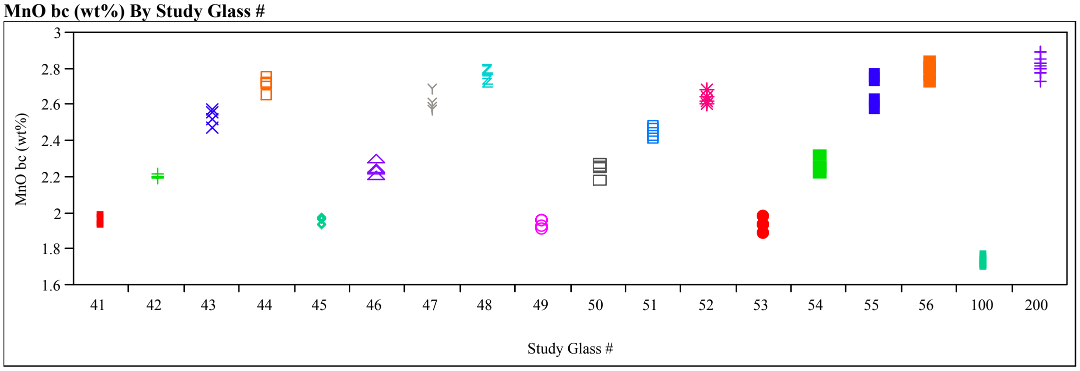
Exhibit D5. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass # for the Glasses Prepared Using the LM Method (continued)

(100 – Batch 1; 200 – Ustd)

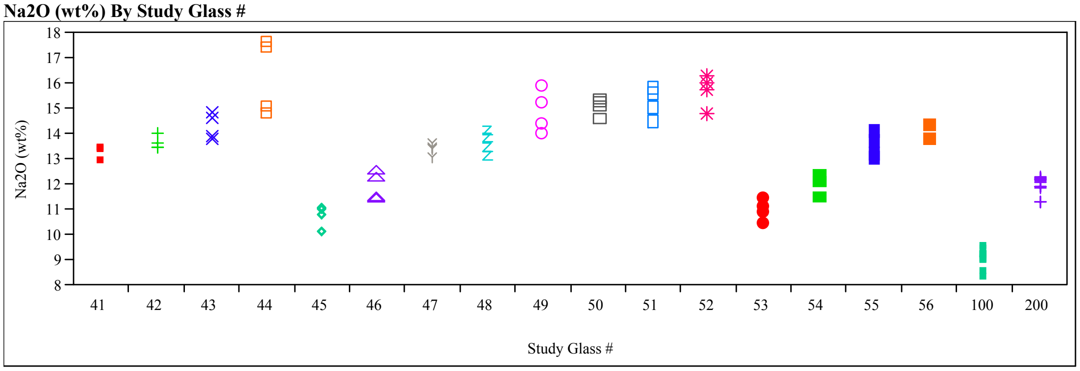
MnO (wt%) By Study Glass #



MnO bc (wt%) By Study Glass #



Na2O (wt%) By Study Glass #



Na2O bc (wt%) By Study Glass #

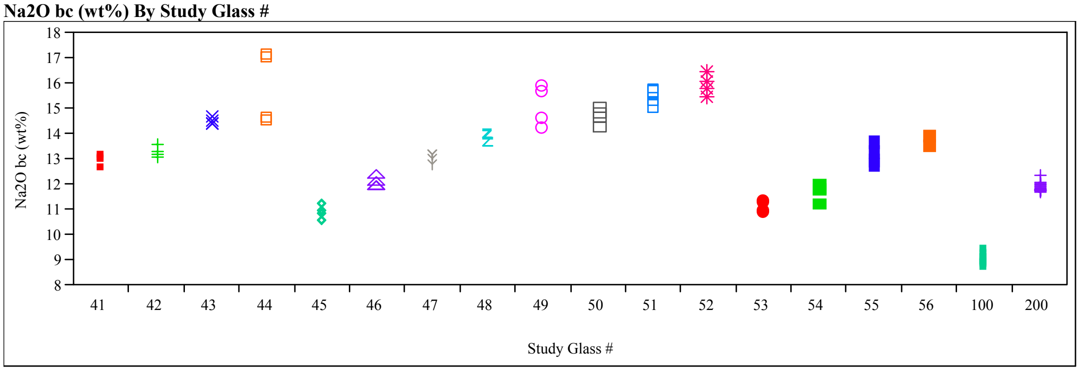
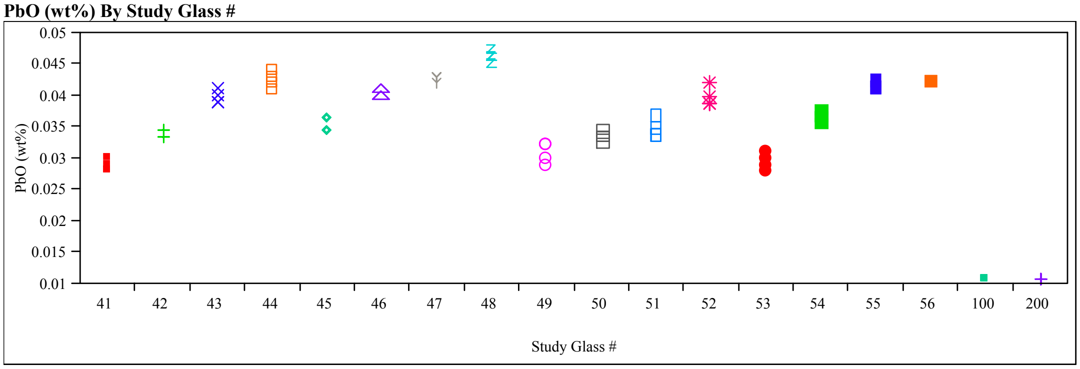


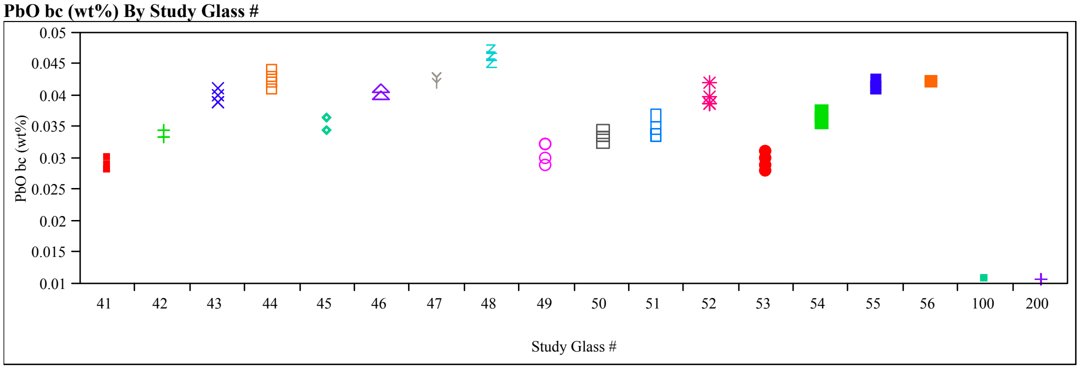
Exhibit D5. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass # for the Glasses Prepared Using the LM Method (continued)

(100 – Batch 1; 200 – Ustd)

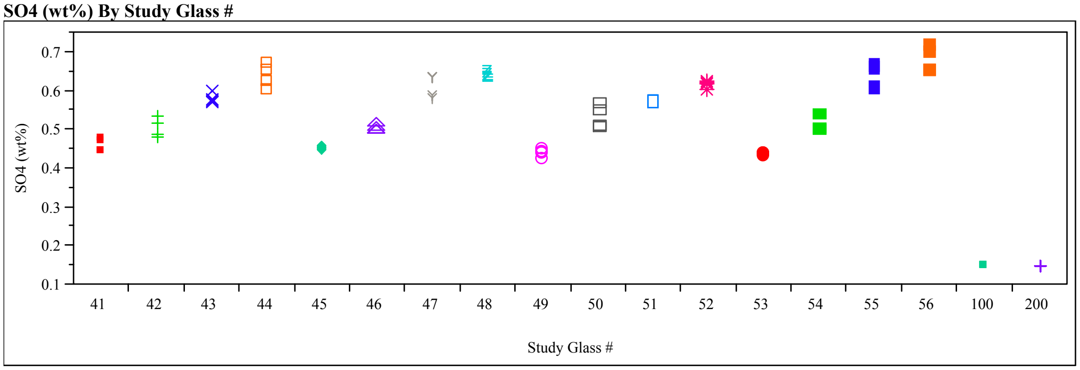
PbO (wt%) By Study Glass #



PbO bc (wt%) By Study Glass #



SO4 (wt%) By Study Glass #



SO4 bc (wt%) By Study Glass #

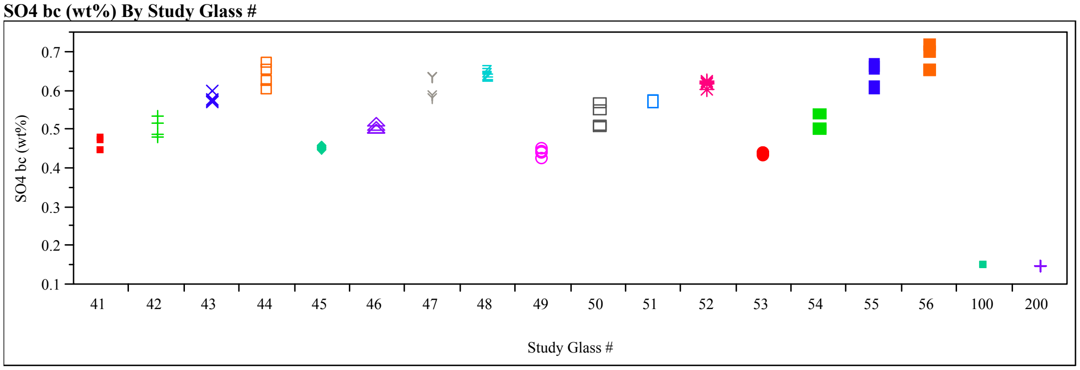
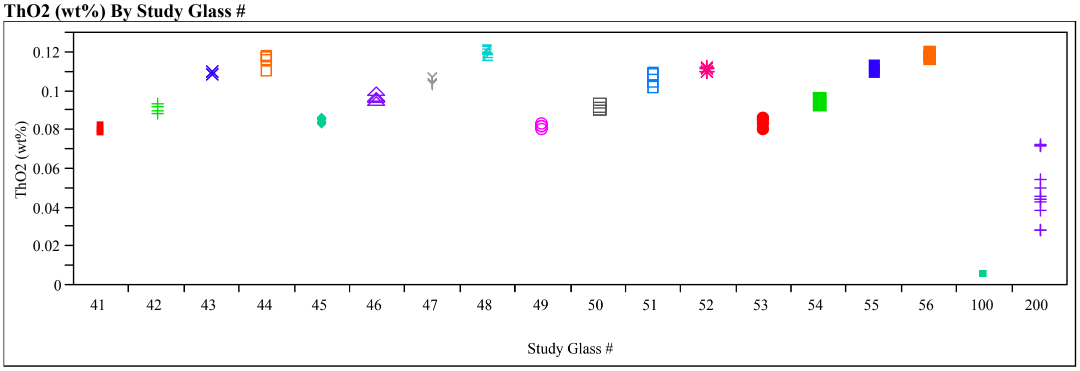


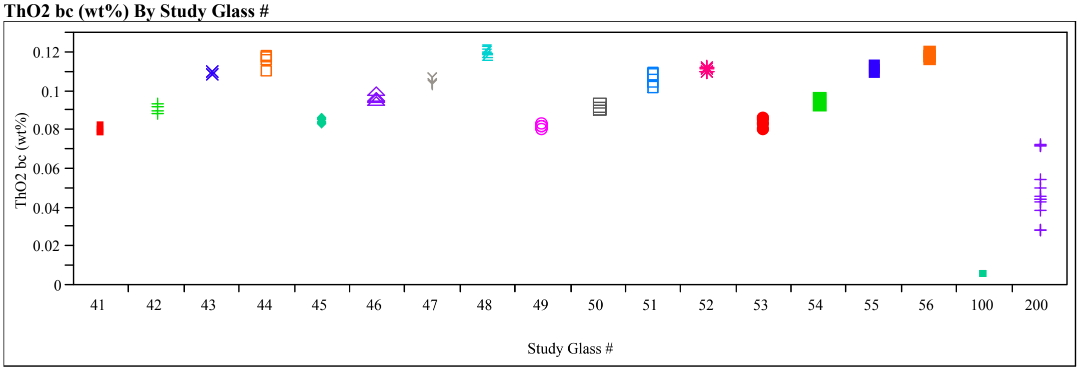
Exhibit D5. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass # for the Glasses Prepared Using the LM Method (continued)

(100 – Batch 1; 200 – Ustd)

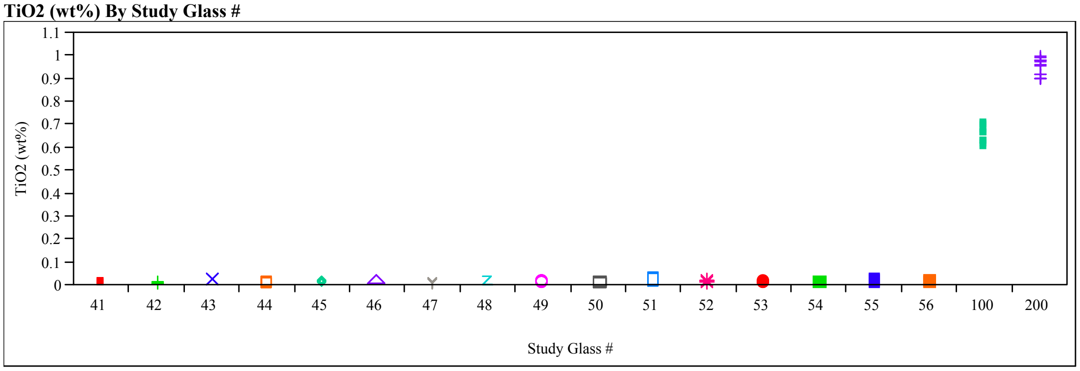
ThO2 (wt%) By Study Glass #



ThO2 bc (wt%) By Study Glass #



TiO2 (wt%) By Study Glass #



TiO2 bc (wt%) By Study Glass #

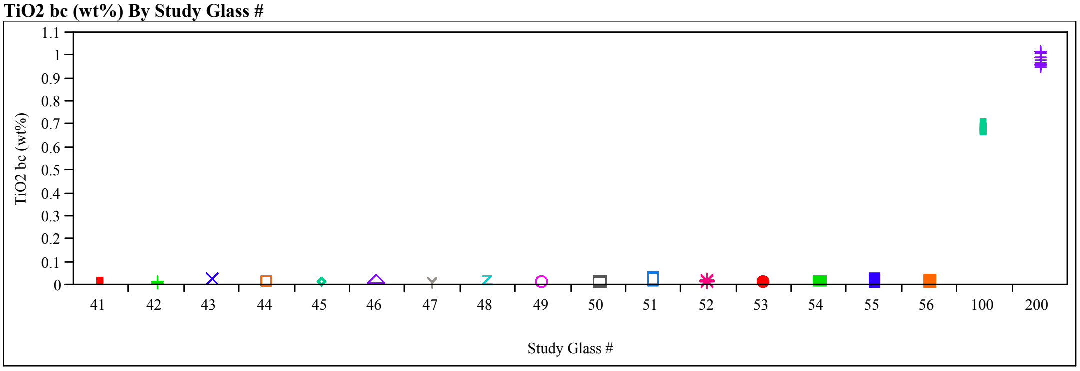
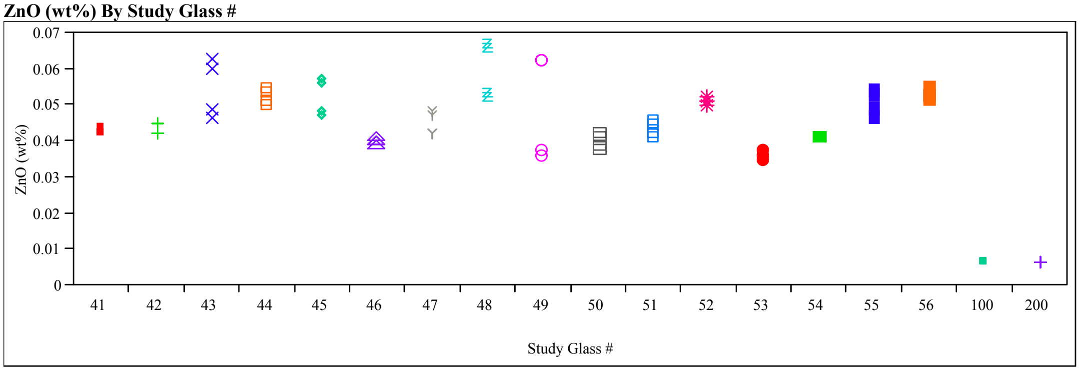


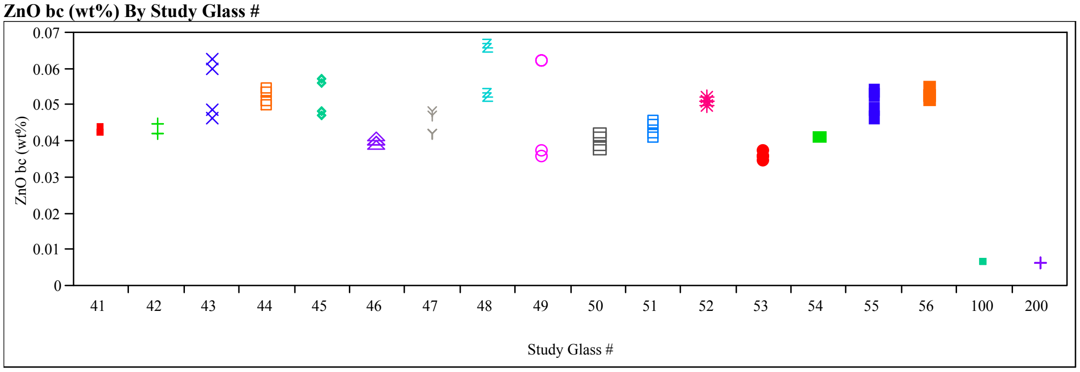
Exhibit D5. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass # for the Glasses Prepared Using the LM Method (continued)

(100 – Batch 1; 200 – Ustd)

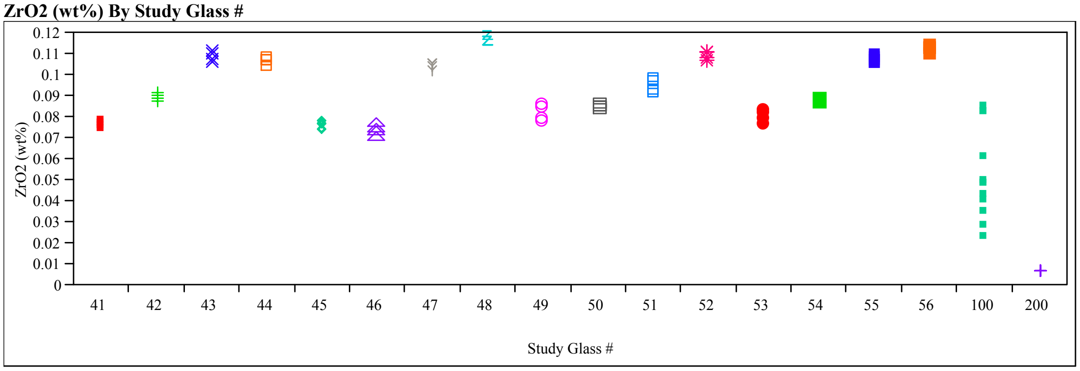
ZnO (wt%) By Study Glass #



ZnO bc (wt%) By Study Glass #



ZrO2 (wt%) By Study Glass #



ZrO2 bc (wt%) By Study Glass #

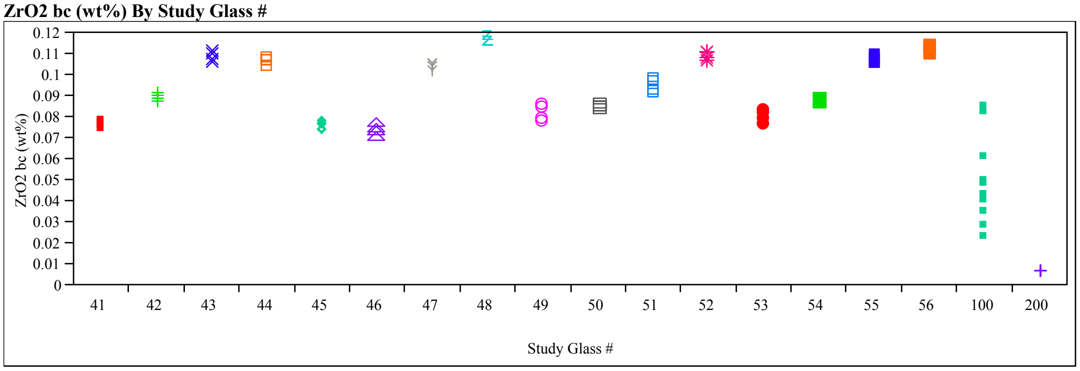
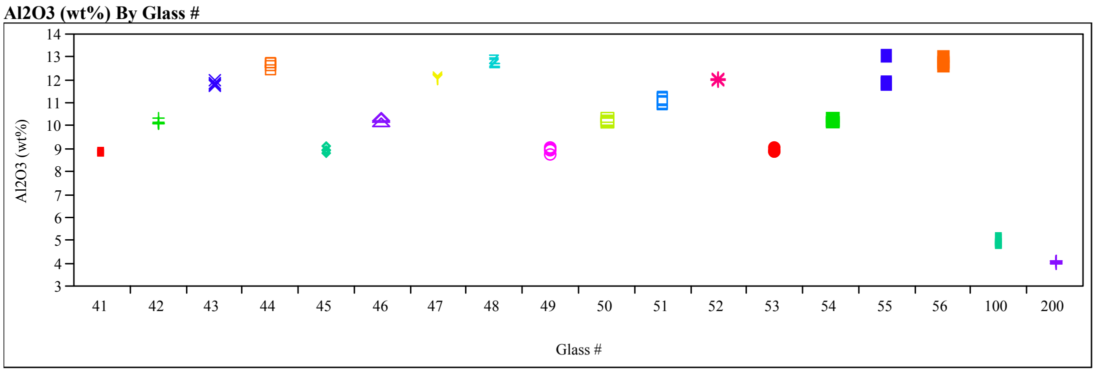
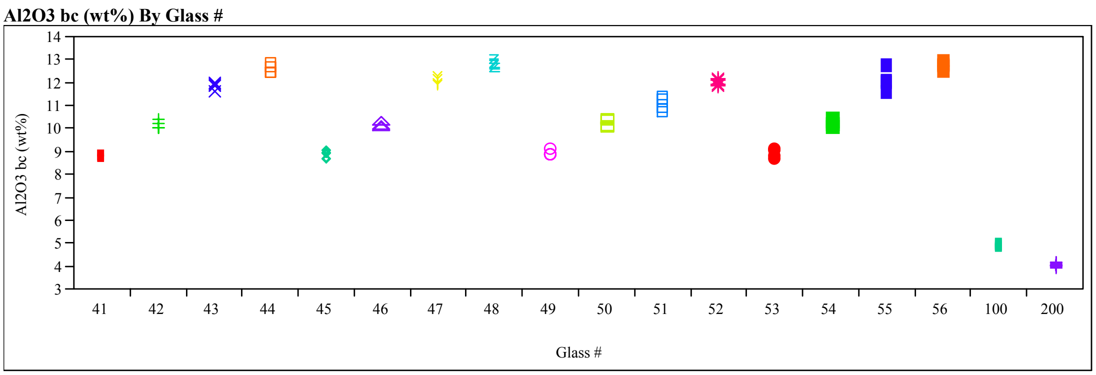


Exhibit D6. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass # for the Glasses Prepared Using the PF Method

(100 – Batch 1; 200 – Ustd)





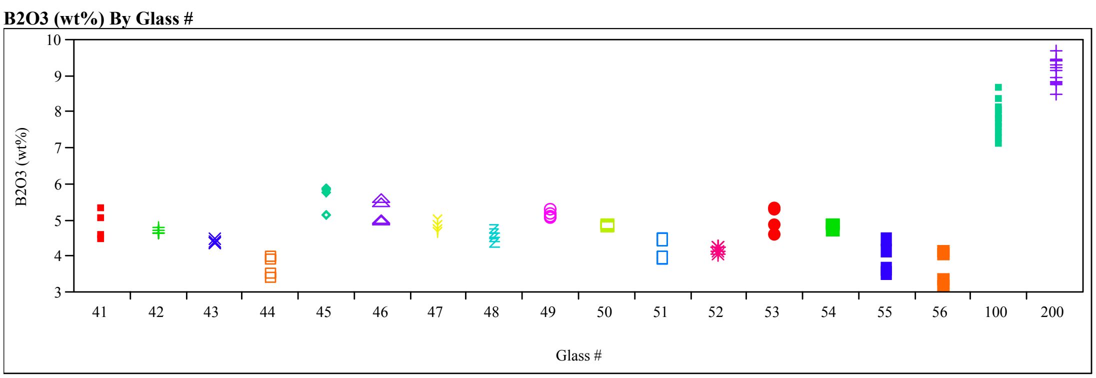
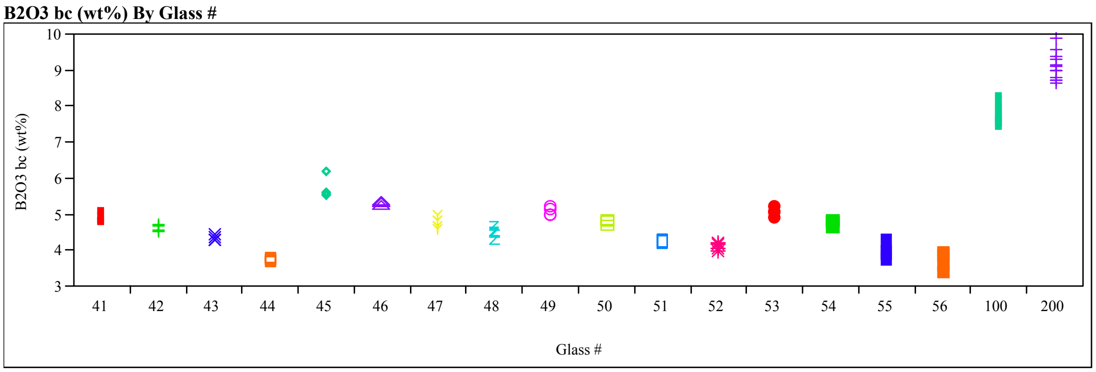
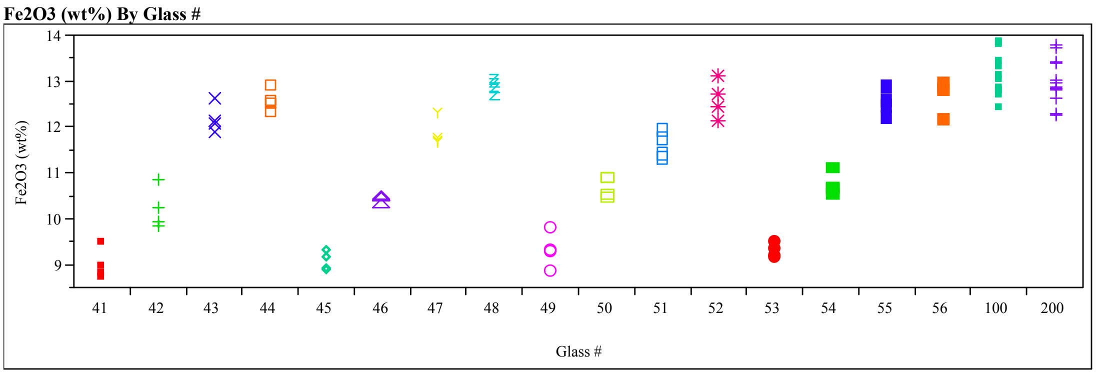
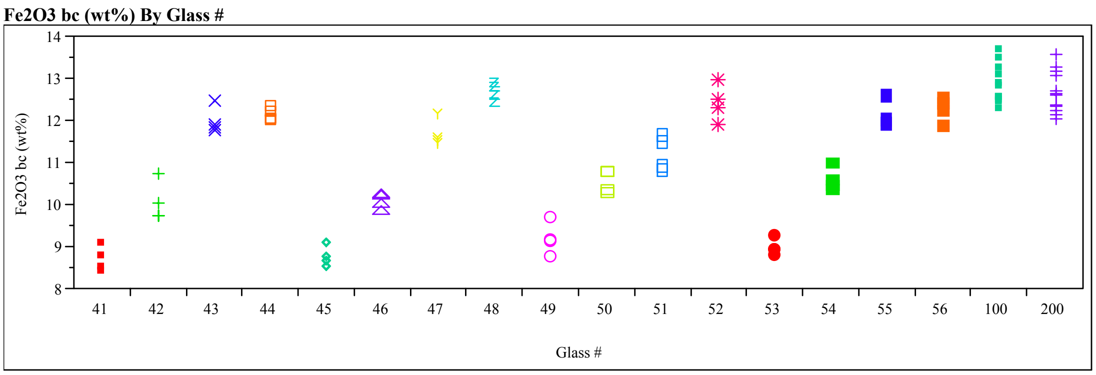


Exhibit D6. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass # for the Glasses Prepared Using the PF Method (continued)

(100 – Batch 1; 200 – Ustd)







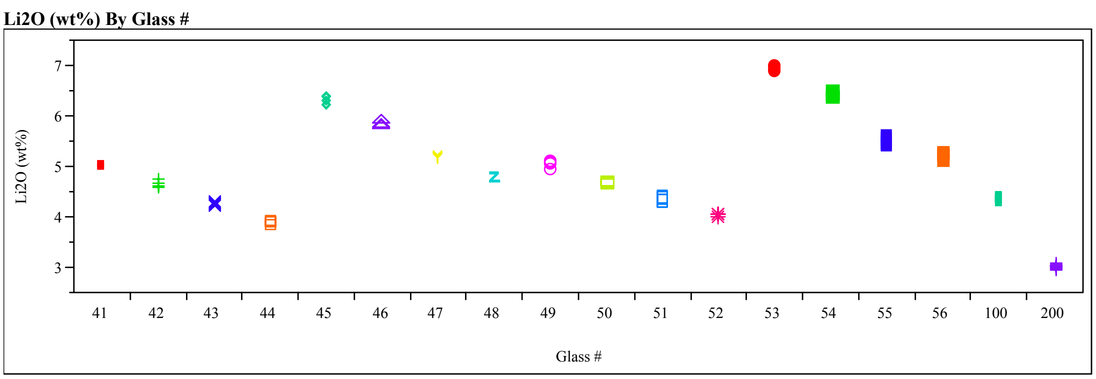
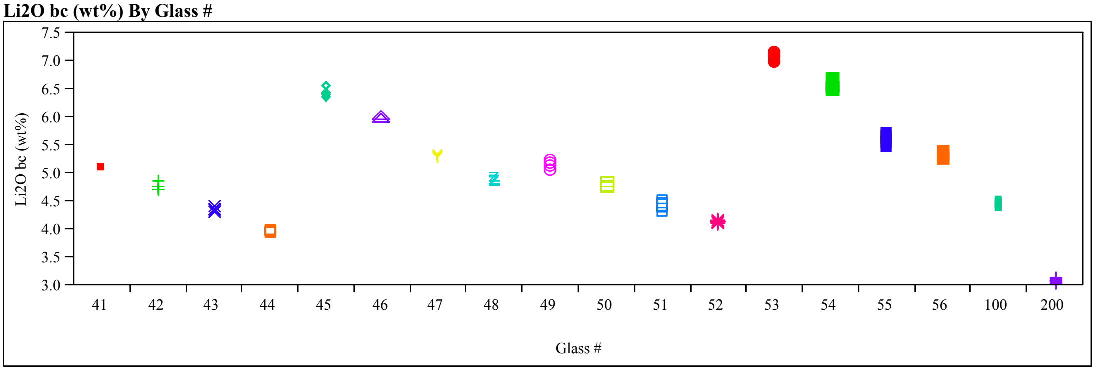
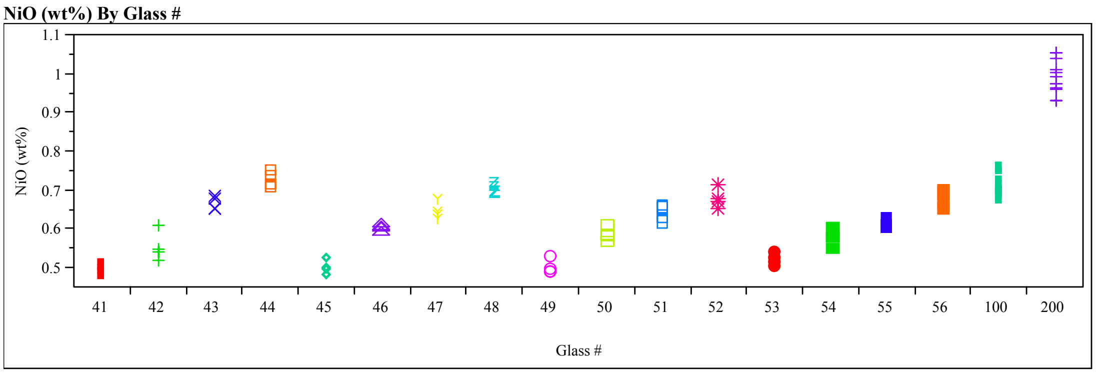


Exhibit D6. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass # for the Glasses Prepared Using the PF Method (continued)

(100 – Batch 1; 200 – Ustd)





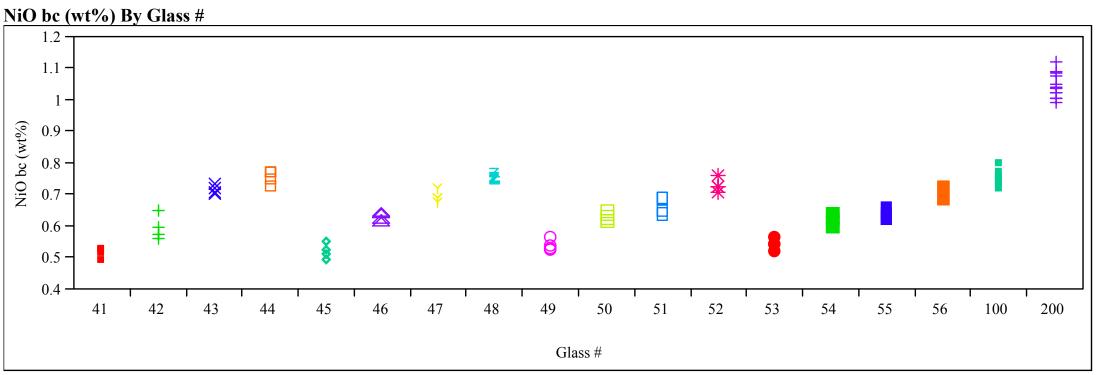
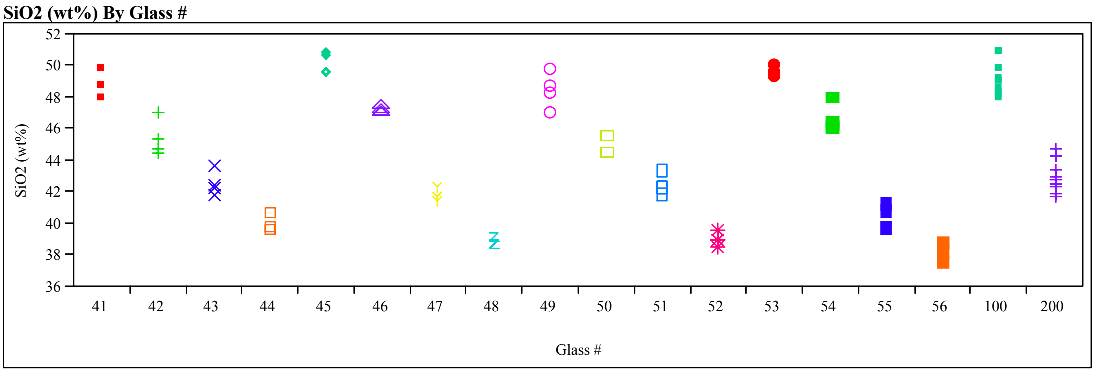
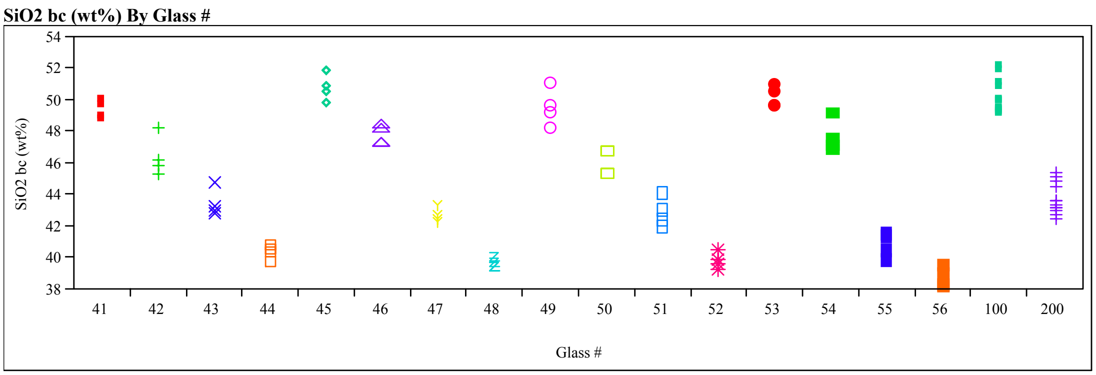


Exhibit D6. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass # for the Glasses Prepared Using the PF Method (continued)

(100 – Batch 1; 200 – Ustd)





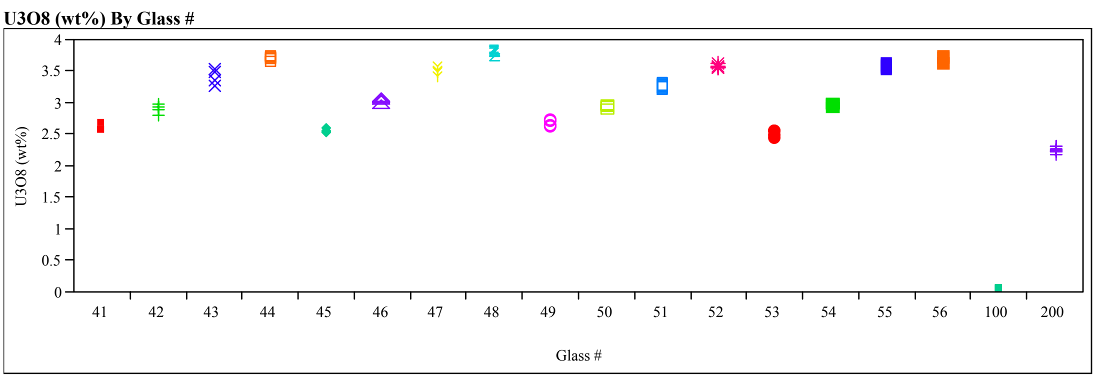


Exhibit D6. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass # for the Glasses Prepared Using the PF Method (continued)

(100 – Batch 1; 200 – Ustd)

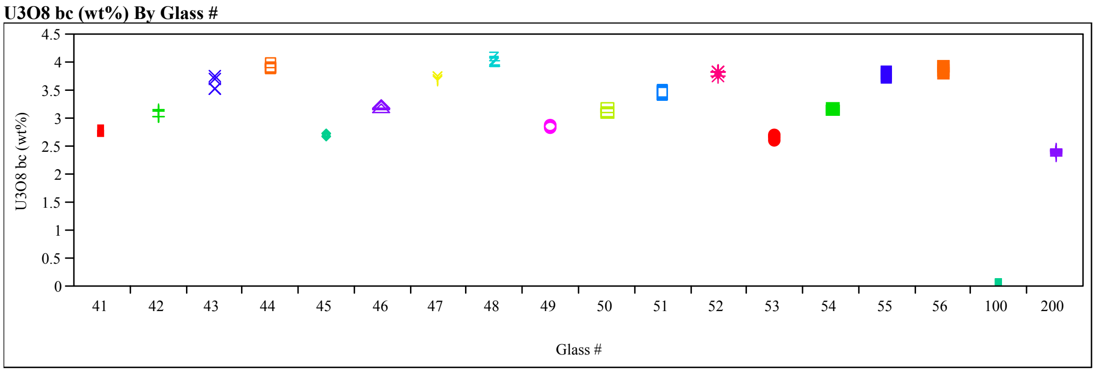
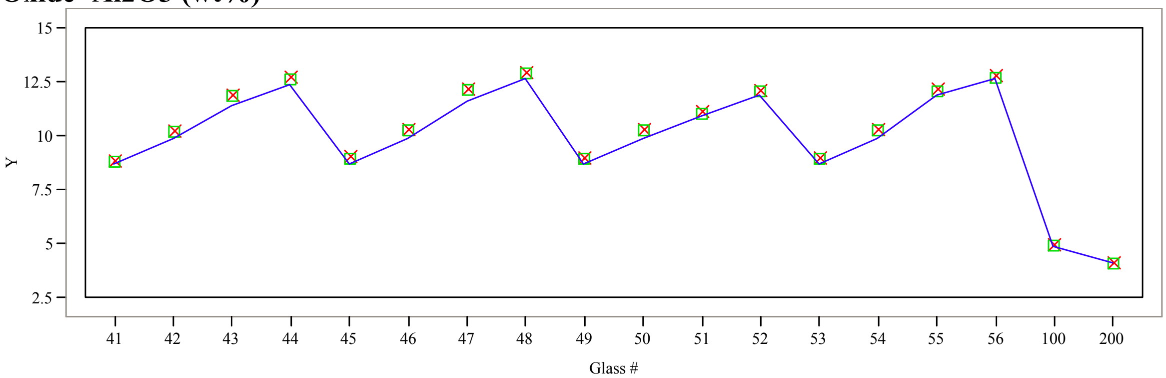


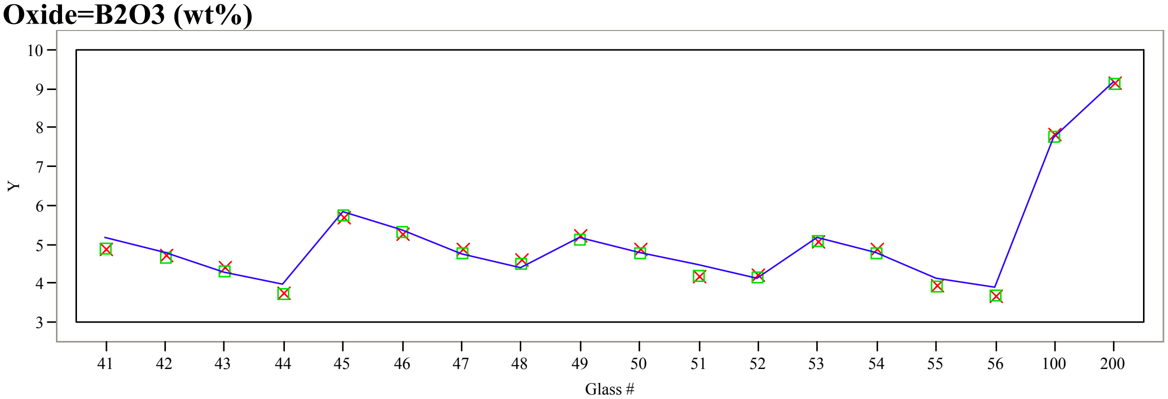
Exhibit D7. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass # by Oxide

(100 – Batch 1; 200 – Ustd)

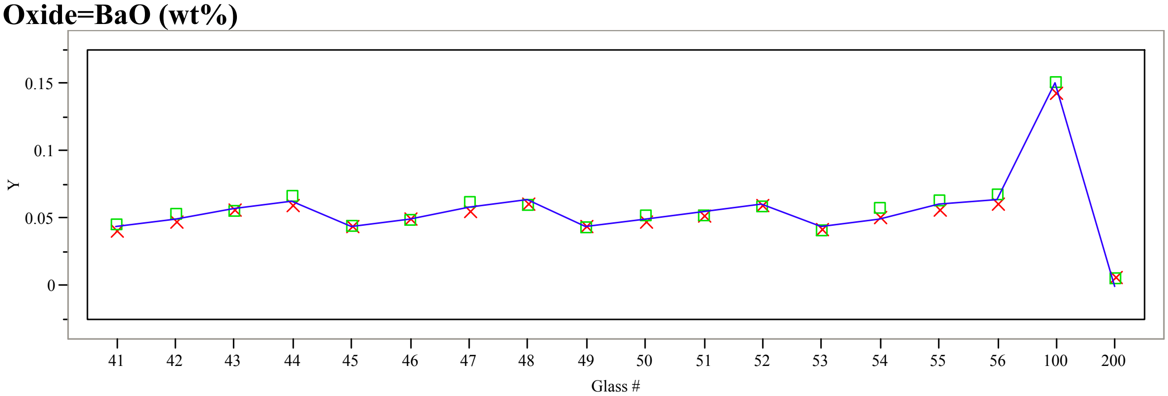
Oxide=Al2O3 (wt%)



Oxide=B2O3 (wt%)



Oxide=BaO (wt%)

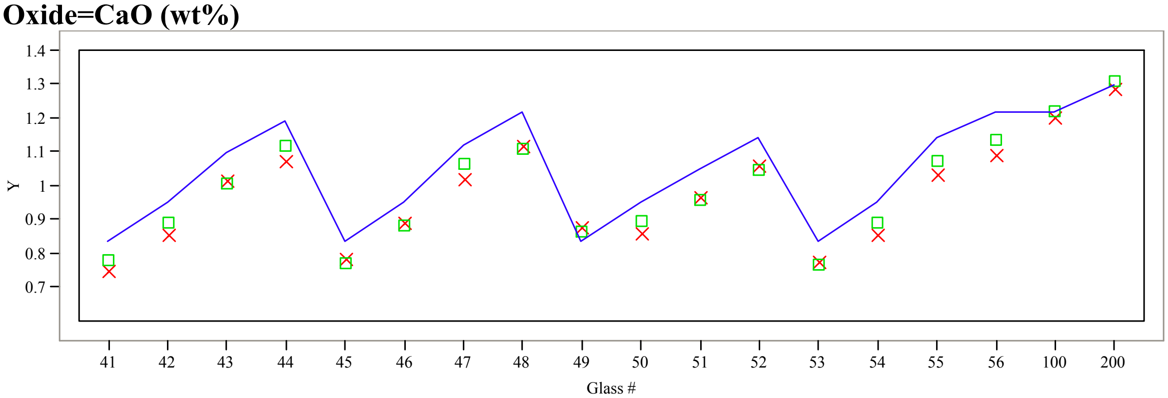


Y × Measured ▫ Measured bc — Targeted

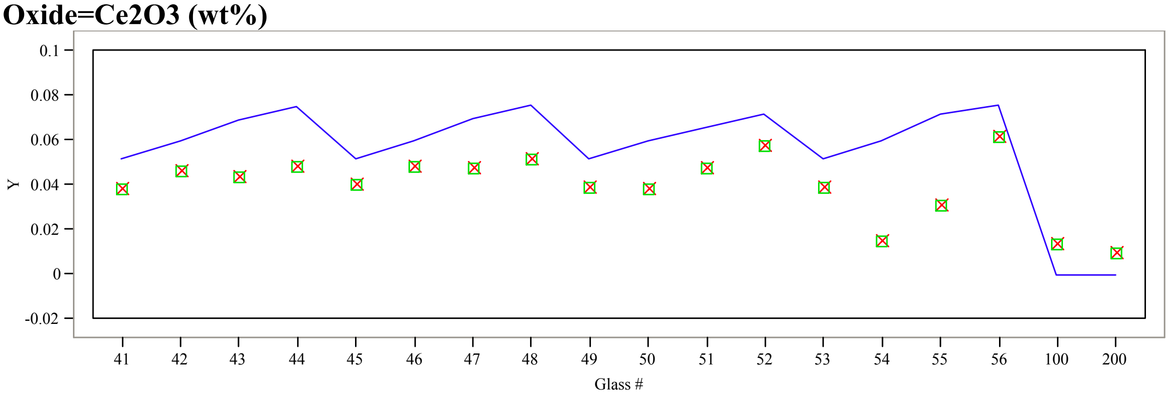
Exhibit D7. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass # by Oxide (continued)

(100 – Batch 1; 200 – Ustd)

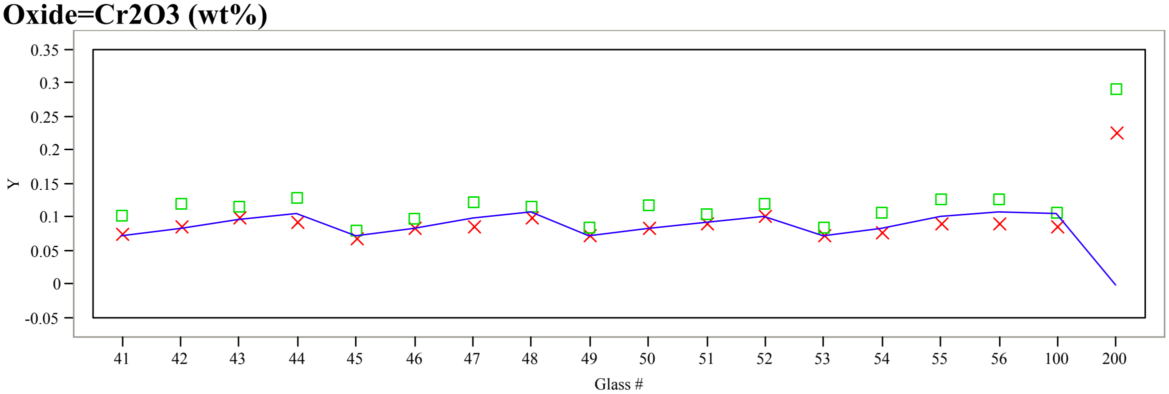
Oxide=CaO (wt%)



Oxide=Ce2O3 (wt%)



Oxide=Cr2O3 (wt%)

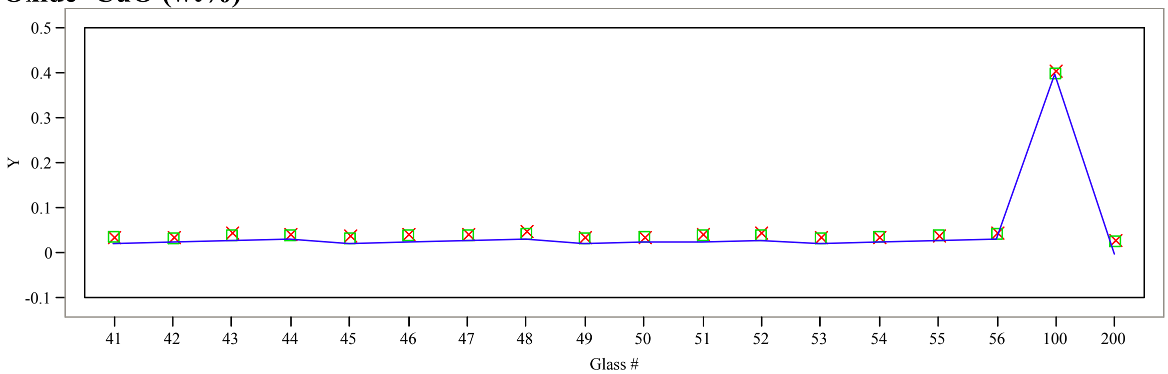


Y ✕ Measured ▫ Measured bc — Targeted

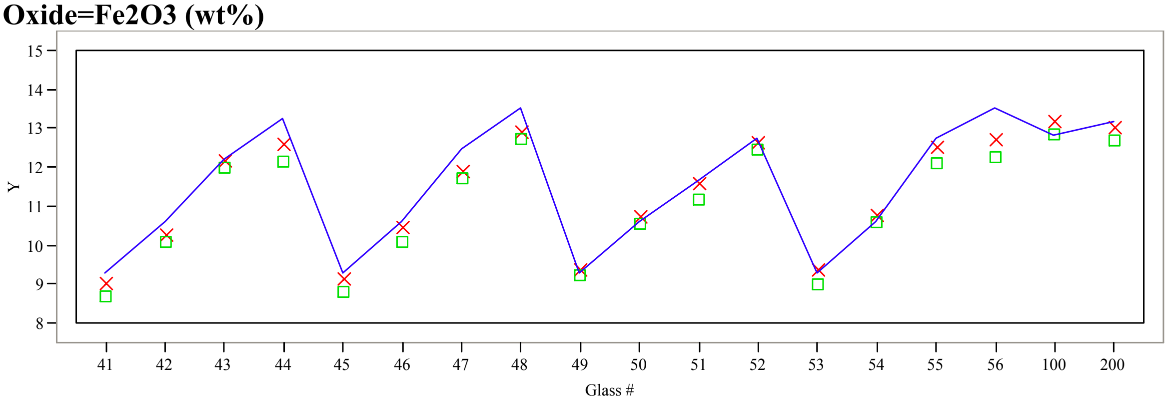
Exhibit D7. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass # by Oxide (continued)

(100 – Batch 1; 200 – Ustd)

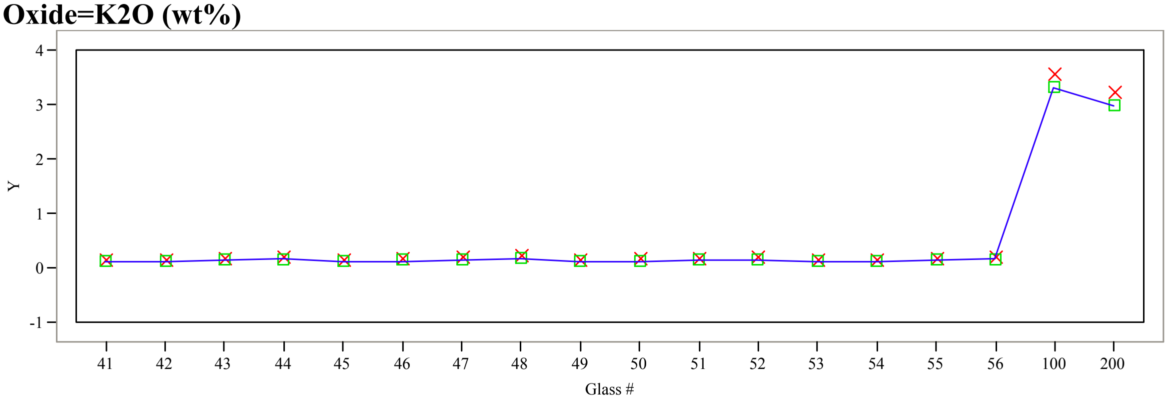
Oxide=CuO (wt%)



Oxide=Fe2O3 (wt%)



Oxide=K2O (wt%)



Y × Measured □ Measured bc — Targeted

Exhibit D7. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass # by Oxide (continued)

(100 – Batch 1; 200 – Ustd)

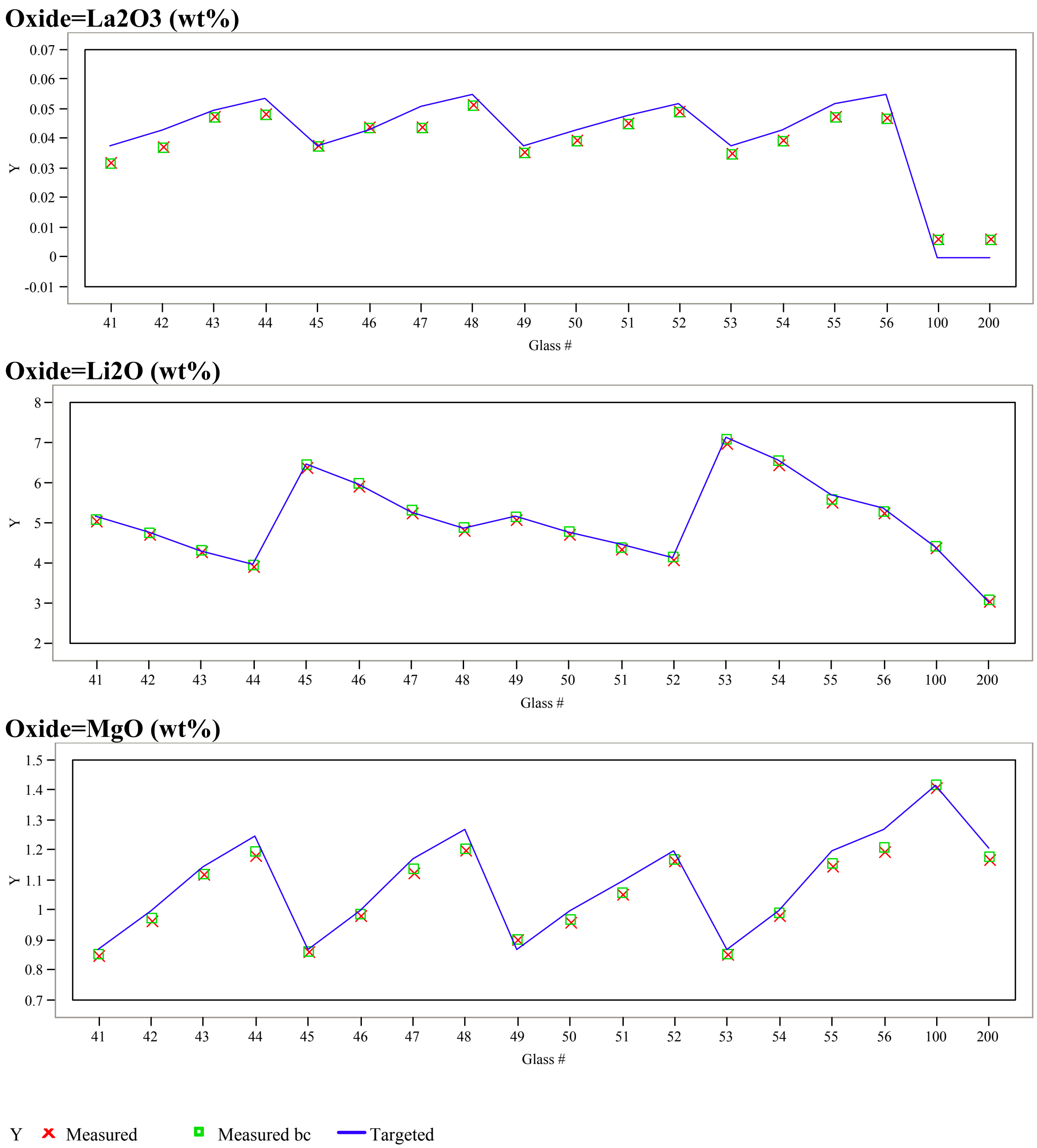
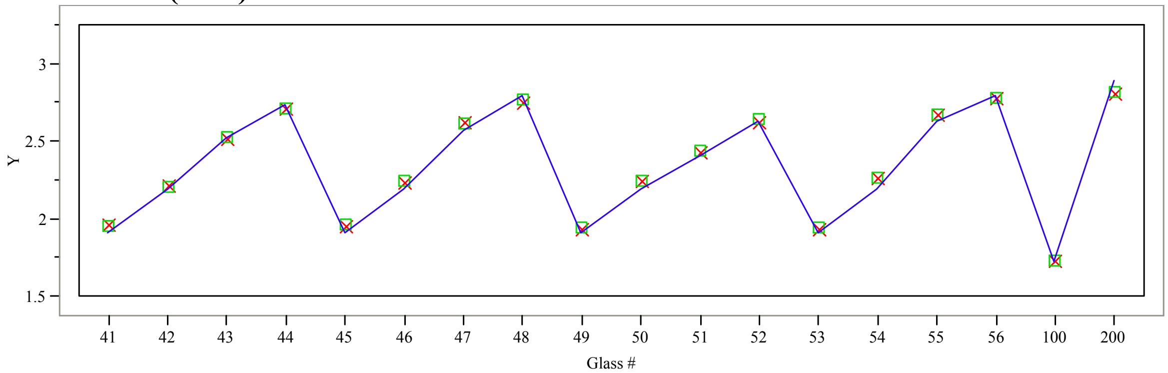


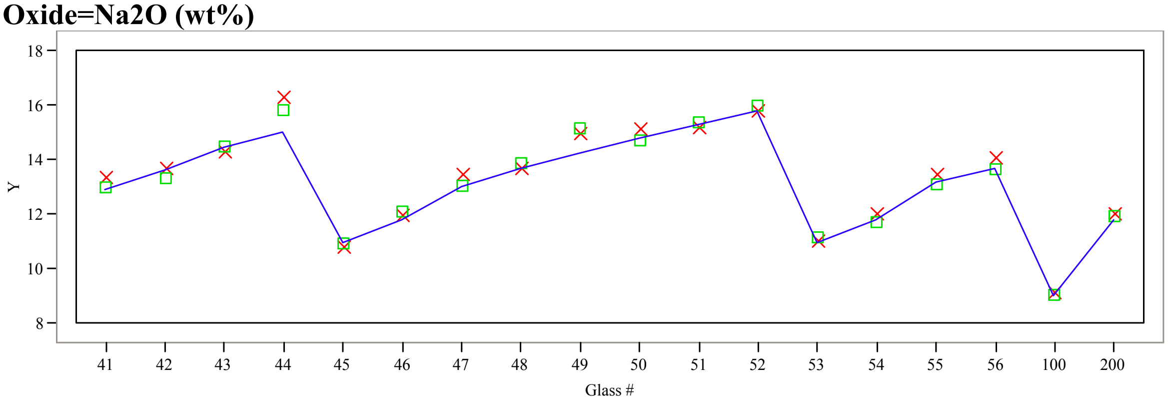
Exhibit D7. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass # by Oxide (continued)

(100 – Batch 1; 200 – Ustd)

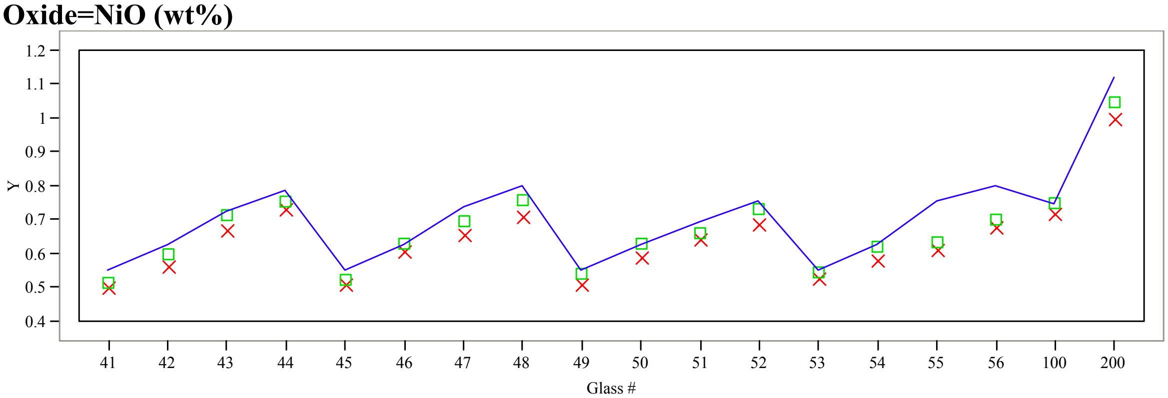
Oxide=MnO (wt%)



Oxide=Na2O (wt%)



Oxide=NiO (wt%)

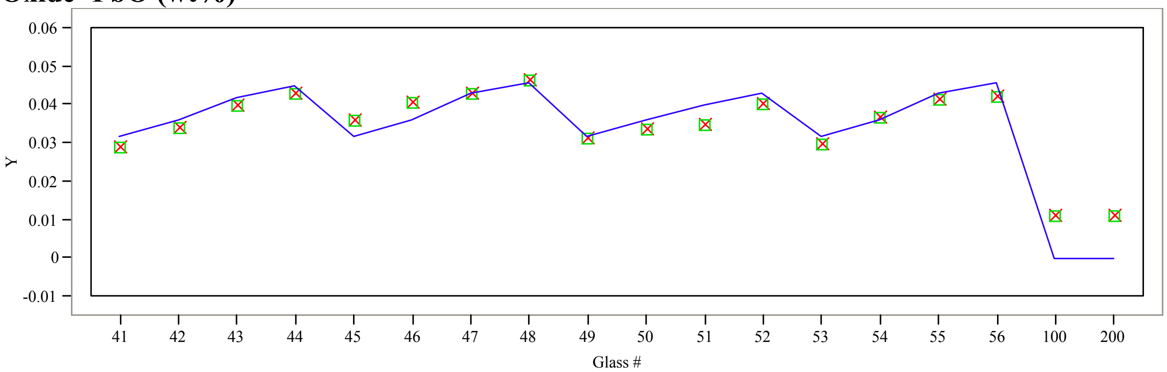


Y × Measured ▫ Measured bc — Targeted

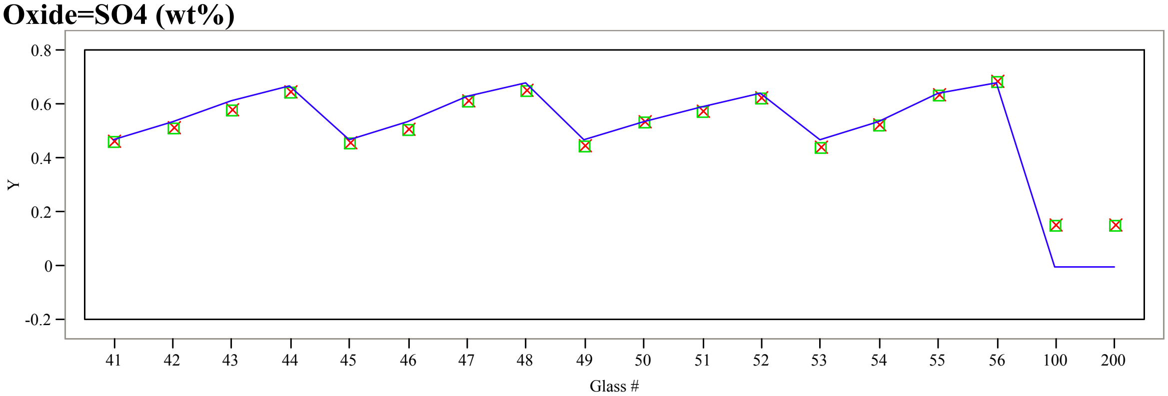
Exhibit D7. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass # by Oxide (continued)

(100 – Batch 1; 200 – Ustd)

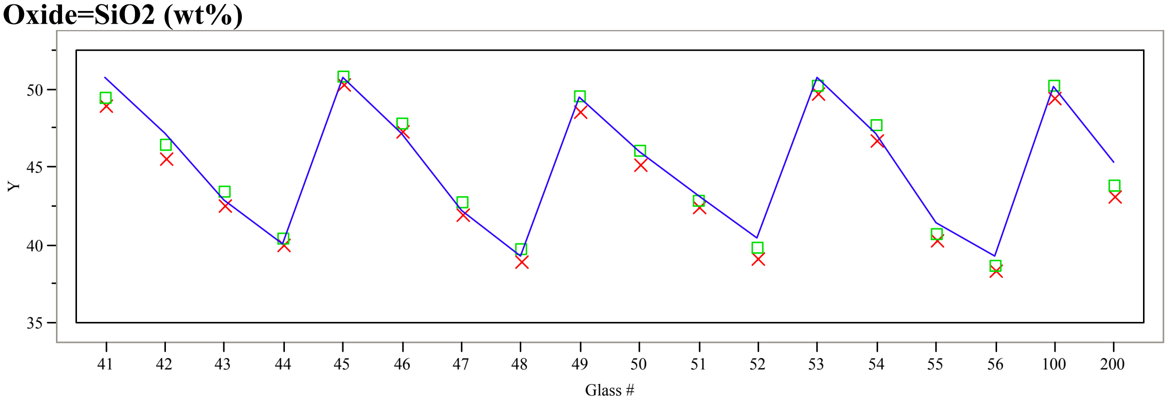
Oxide=PbO (wt%)



Oxide=SO4 (wt%)



Oxide=SiO2 (wt%)

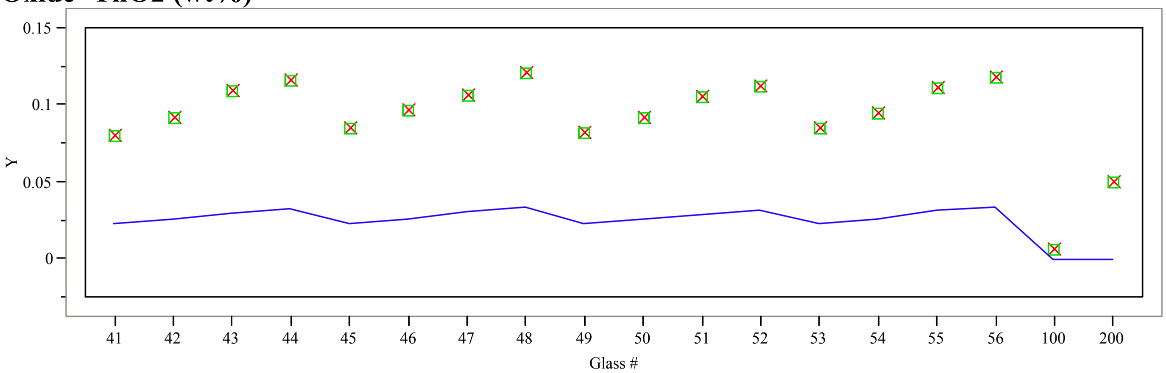


Y × Measured □ Measured bc — Targeted

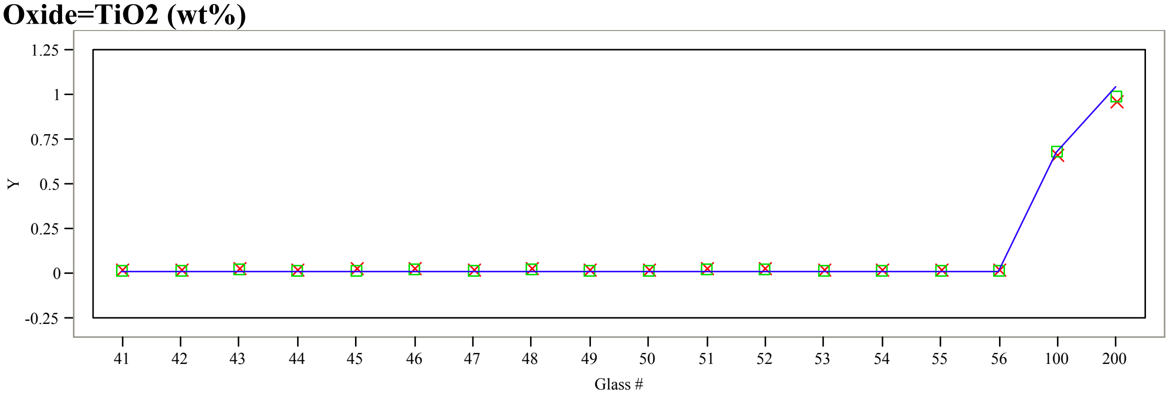
Exhibit D7. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass # by Oxide (continued)

(100 – Batch 1; 200 – Ustd)

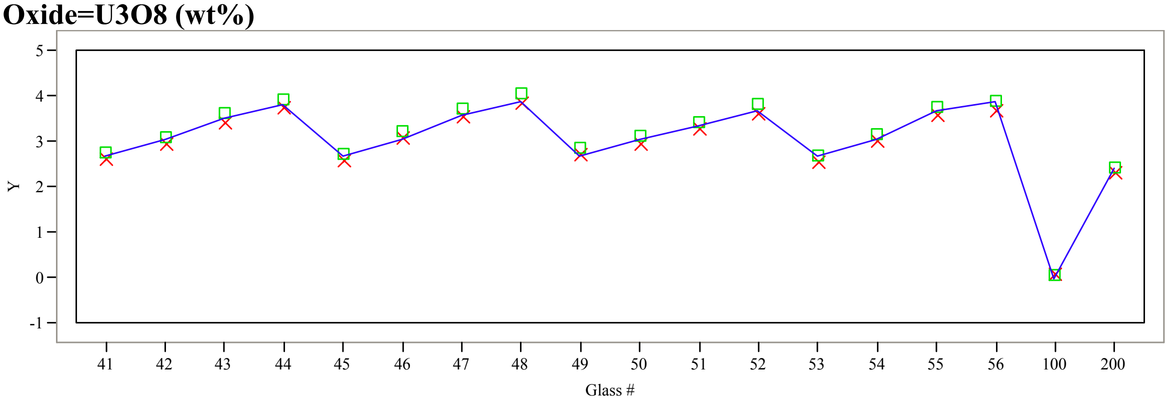
Oxide=ThO2 (wt%)



Oxide=TiO2 (wt%)



Oxide=U3O8 (wt%)

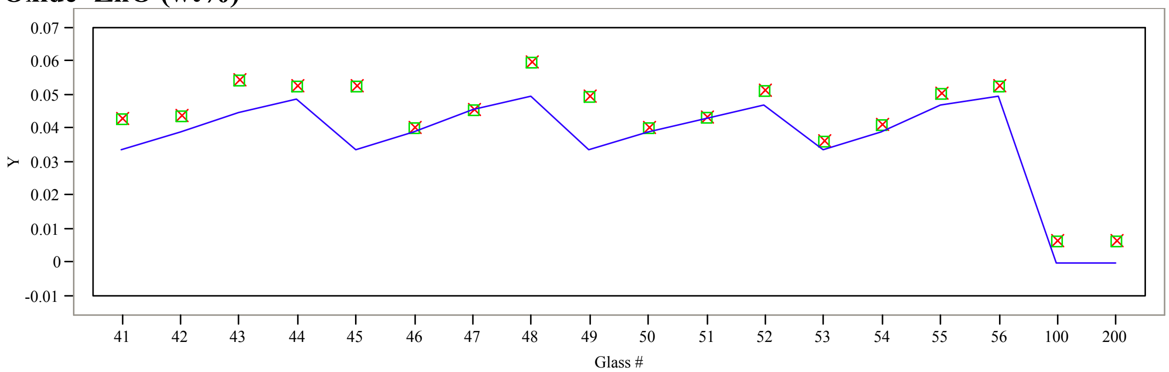


Y × Measured ▫ Measured bc — Targeted

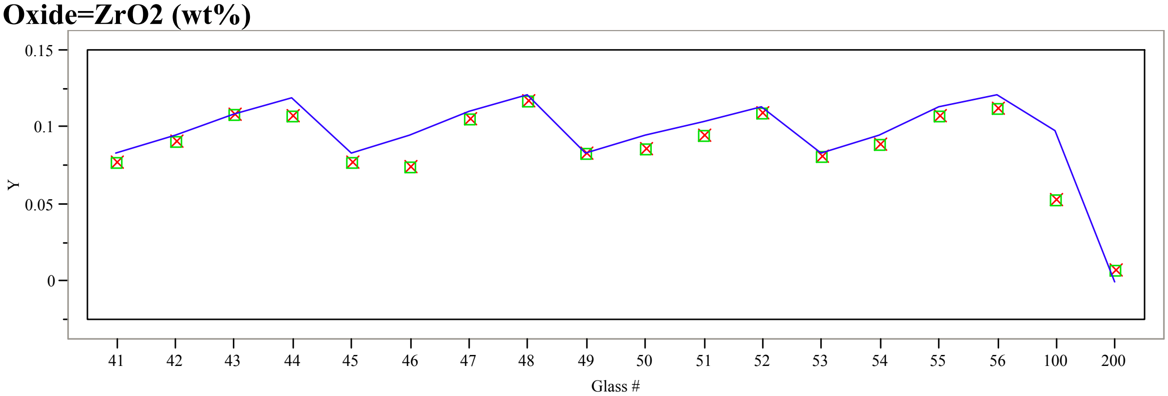
Exhibit D7. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass # by Oxide (continued)

(100 – Batch 1; 200 – Ustd)

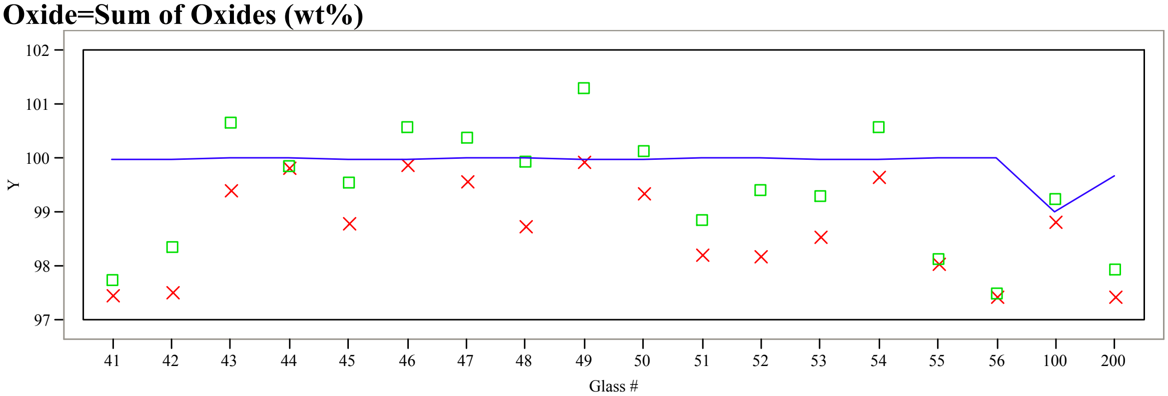
Oxide=ZnO (wt%)



Oxide=ZrO2 (wt%)



Oxide=Sum of Oxides (wt%)



Y × Measured (wt%) □ Measured bc (wt%) — Targeted (wt%)

Appendix E

Tables and Exhibits Supporting the Analysis of the PCT Results for the Nepheline Phase 3 Study Glasses

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Table E1. Laboratory Measurements of the PCT Solutions for the Nepheline Study Glasses

Part	Glass ID	Heat Treatment	Laboratory ID	Block	Seq	B ar	Ba ar	Cd ar	Cr ar	Fe ar	Li ar	Na ar	Pb ar	Si ar	Th ar	U ar
1	Soln Std		STD-B1-1 Cs	1	1	19.4	<0.010	<0.080	<0.010	4.10	9.79	83.1	<0.020	50.0	<0.100	<0.200
1	NEPH3-42	quenched	F52	1	2	6.97	<0.010	<0.080	<0.010	4.07	10.3	51.4	<0.020	67.8	<0.100	1.80
1	NEPH3-42ccc	ccc	F39	1	3	6.29	<0.010	<0.080	<0.010	3.40	10.4	49.0	<0.020	67.1	<0.100	1.79
1	ARM-1		F08	1	4	10.7	<0.010	<0.080	<0.010	<0.004	8.24	23.4	<0.020	38.7	<0.100	<0.200
1	NEPH3-47	quenched	F01	1	5	8.26	<0.010	<0.080	<0.010	4.27	13.8	60.0	<0.020	68.6	<0.100	1.70
1	NEPH3-47ccc	ccc	F48	1	6	7.61	<0.010	<0.080	<0.010	3.98	15.3	58.6	<0.020	71.7	<0.100	1.67
1	blank		F26	1	7	<0.080	<0.010	<0.080	<0.010	<0.004	<0.500	0.247	<0.020	<0.200	<0.100	<0.200
1	NEPH3-46	quenched	F25	1	8	7.04	<0.010	<0.080	<0.010	4.26	14.2	44.1	<0.020	72.5	<0.100	1.70
1	NEPH3-46ccc	ccc	F07	1	9	7.64	<0.010	<0.080	<0.010	4.72	15.9	45.2	<0.020	76.9	<0.100	1.80
1	NEPH3-41	quenched	F37	1	10	5.45	<0.010	<0.080	<0.010	4.18	10.7	44.9	<0.020	70.6	<0.100	2.05
1	NEPH3-41ccc	ccc	F32	1	11	5.26	<0.010	<0.080	<0.010	4.40	10.6	43.0	<0.020	69.6	<0.100	1.89
1	Soln Std		STD-B1-2	1	12	19.4	<0.010	<0.080	<0.010	3.87	9.62	81.1	<0.020	48.8	<0.100	<0.200
1	NEPH3-44	quenched	F15	1	13	6.60	<0.010	<0.080	<0.010	4.19	9.16	72.4	<0.020	62.5	<0.100	1.77
1	NEPH3-44ccc	ccc	F36	1	14	6.84	<0.010	<0.080	<0.010	3.04	11.5	74.6	<0.020	66.5	<0.100	1.54
1	NEPH3-48	quenched	F38	1	15	7.77	<0.010	<0.080	<0.010	5.41	13.3	73.2	<0.020	68.4	<0.100	1.64
1	NEPH3-48ccc	ccc	F47	1	16	12.0	<0.010	<0.080	<0.010	3.14	21.9	82.3	<0.020	83.0	<0.100	1.96
1	EA		F50	1	17	37.5	<0.010	<0.080	<0.010	<0.004	11.0	103	<0.020	53.0	<0.100	<0.200
1	NEPH3-43	quenched	F10	1	18	6.70	<0.010	<0.080	<0.010	4.20	10.1	66.0	<0.020	66.1	<0.100	1.63
1	NEPH3-43ccc	ccc	F34	1	19	6.87	<0.010	<0.080	<0.010	5.14	12.1	65.4	<0.020	71.1	<0.100	1.90
1	NEPH3-45	quenched	F55	1	20	7.15	<0.010	<0.080	<0.010	4.68	15.4	36.4	<0.020	78.5	<0.100	2.40
1	NEPH3-45ccc	ccc	F28	1	21	7.20	<0.010	<0.080	<0.010	4.32	15.8	36.8	<0.020	79.3	<0.100	2.08
1	Soln Std		STD-B1-3	1	22	19.4	<0.010	<0.080	<0.010	3.90	9.71	82.4	<0.020	49.4	<0.100	<0.200
1	Soln Std		STD-B2-1	2	1	21.8	<0.010	<0.080	<0.010	4.21	9.66	79.0	<0.020	49.5	<0.100	<0.200
1	NEPH3-42	quenched	F05	2	2	7.91	<0.010	<0.080	<0.010	3.70	10.9	52.5	<0.020	71.0	<0.100	1.72
1	NEPH3-42ccc	ccc	F30	2	3	7.01	<0.010	<0.080	<0.010	3.78	10.7	48.8	<0.020	68.9	<0.100	1.71
1	NEPH3-47	quenched	F27	2	4	9.08	<0.010	<0.080	<0.010	4.43	14.1	60.9	<0.020	69.7	<0.100	1.73
1	NEPH3-47ccc	ccc	F03	2	5	8.32	<0.010	<0.080	<0.010	4.05	15.4	57.0	<0.020	72.5	<0.100	1.67
1	NEPH3-46	quenched	F35	2	6	7.95	<0.010	<0.080	<0.010	4.33	14.2	43.2	<0.020	72.7	<0.100	1.72
1	NEPH3-46ccc	ccc	F19	2	7	8.45	<0.010	<0.080	<0.010	4.70	16.0	43.5	<0.020	77.1	<0.100	1.83
1	NEPH3-41	quenched	F09	2	8	6.15	<0.010	<0.080	<0.010	3.92	10.8	42.7	<0.020	71.4	<0.100	2.23
1	NEPH3-41ccc	ccc	F11	2	9	6.12	<0.010	<0.080	<0.010	3.63	10.8	40.9	<0.020	70.4	<0.100	1.86
1	ARM-1		F29	2	10	11.3	<0.010	<0.080	<0.010	<0.004	8.67	23.7	<0.020	39.8	<0.100	<0.200
1	EA		F53	2	11	38.3	<0.010	<0.080	<0.010	<0.004	11.1	101	<0.020	53.7	<0.100	<0.200
1	Soln Std		STD-B2-2	2	12	20.7	<0.010	<0.080	<0.010	4.02	9.70	79.2	<0.020	50.0	<0.100	<0.200
1	NEPH3-44	quenched	F24	2	13	7.53	<0.010	<0.080	<0.010	4.59	9.32	72.1	<0.020	63.2	<0.100	1.63
1	NEPH3-44ccc	ccc	F22	2	14	7.54	<0.010	<0.080	<0.010	2.69	11.4	73.7	<0.020	66.0	<0.100	1.59
1	NEPH3-48	quenched	F14	2	15	8.73	<0.010	<0.080	<0.010	5.52	13.4	72.0	<0.020	69.2	<0.100	1.82
1	NEPH3-48ccc	ccc	F20	2	16	12.7	<0.010	<0.080	<0.010	3.34	21.7	81.2	<0.020	83.3	<0.100	1.92
1	NEPH3-43	quenched	F49	2	17	6.96	<0.010	<0.080	<0.010	5.40	10.0	65.6	<0.020	66.7	<0.100	1.97

Table E1. Laboratory Measurements of the PCT Solutions for the Nepheline Study Glasses (continued)

Part	Glass ID	Heat Treatment	Laboratory ID	Block	Seq	B ar	Ba ar	Cd ar	Cr ar	Fe ar	Li ar	Na ar	Pb ar	Si ar	Th ar	U ar
1	NEPH3-43ccc	ccc	F44	2	18	7.41	<0.010	<0.080	<0.010	5.36	11.9	63.8	<0.020	70.6	<0.100	1.87
1	NEPH3-45	quenched	F16	2	19	7.95	<0.010	<0.080	<0.010	4.98	15.5	36.1	<0.020	79.2	<0.100	2.16
1	NEPH3-45ccc	ccc	F02	2	20	7.81	<0.010	<0.080	<0.010	5.19	15.5	35.4	<0.020	79.1	<0.100	2.18
1	Soln Std		STD-B2-3	2	21	19.8	<0.010	<0.080	<0.010	4.10	9.55	79.6	<0.020	48.8	<0.100	<0.200
1	Soln Std		STD-B3-1	3	1	22.1	<0.010	<0.080	<0.010	3.92	9.77	80.5	<0.020	49.4	<0.100	0.25
1	NEPH3-42	quenched	F06	3	2	7.96	<0.010	<0.080	<0.010	3.45	10.6	52.1	<0.020	68.0	<0.100	1.96
1	NEPH3-42ccc	ccc	F23	3	3	7.34	<0.010	<0.080	<0.010	3.82	10.6	52.2	<0.020	67.0	<0.100	1.90
1	EA		F46	3	4	34.9	<0.010	<0.080	<0.010	<0.004	10.1	91.8	<0.020	48.0	<0.100	<0.200
1	NEPH3-47	quenched	F31	3	5	9.77	<0.010	<0.080	<0.010	4.71	13.8	59.1	<0.020	68.8	<0.100	1.91
1	NEPH3-47ccc	ccc	F43	3	6	8.89	<0.010	<0.080	<0.010	4.30	15.3	57.7	<0.020	71.2	<0.100	1.81
1	NEPH3-46	quenched	F45	3	7	8.57	<0.010	<0.080	<0.010	4.19	14.3	42.6	<0.020	73.1	<0.100	1.92
1	NEPH3-46ccc	ccc	F56	3	8	8.88	<0.010	<0.080	<0.010	4.85	15.9	43.1	<0.020	77.6	<0.100	2.03
1	NEPH3-41	quenched	F17	3	9	6.75	<0.010	<0.080	<0.010	4.55	10.8	43.5	<0.020	72.4	<0.100	2.28
1	NEPH3-41ccc	ccc	F41	3	10	6.47	<0.010	<0.080	<0.010	3.86	10.8	40.8	<0.020	72.2	<0.100	2.34
1	blank		F12	3	11	<0.080	<0.010	<0.080	<0.010	<0.004	<0.500	<0.080	<0.020	<0.200	<0.100	<0.200
1	Soln Std		STD-B3-2	3	12	20.4	<0.010	<0.080	<0.010	3.96	9.62	79.8	<0.020	49.0	<0.100	<0.200
1	NEPH3-44	quenched	F21	3	13	7.84	<0.010	<0.080	<0.010	4.88	9.47	72.6	<0.020	63.3	<0.100	2.06
1	NEPH3-44ccc	ccc	F42	3	14	8.16	<0.010	<0.080	<0.010	2.82	11.7	74.3	<0.020	67.3	<0.100	1.95
1	NEPH3-48	quenched	F18	3	15	9.03	<0.010	<0.080	<0.010	5.64	13.3	73.0	<0.020	69.0	<0.100	1.97
1	NEPH3-48ccc	ccc	F33	3	16	13.2	<0.010	<0.080	<0.010	3.43	22.0	80.4	<0.020	84.2	<0.100	2.11
1	ARM-1		F13	3	17	12.4	<0.010	<0.080	<0.010	<0.004	8.85	24.3	<0.020	40.5	<0.100	<0.200
1	NEPH3-43	quenched	F54	3	18	7.21	<0.010	<0.080	<0.010	5.34	9.55	61.9	<0.020	64.0	<0.100	2.45
1	NEPH3-43ccc	ccc	F51	3	19	7.73	<0.010	<0.080	<0.010	5.30	11.7	61.8	<0.020	68.8	<0.100	2.00
1	NEPH3-45	quenched	F40	3	20	8.25	<0.010	<0.080	<0.010	5.67	15.2	35.3	<0.020	77.0	<0.100	2.30
1	NEPH3-45ccc	ccc	F04	3	21	8.34	<0.010	<0.080	<0.010	4.79	15.6	35.1	<0.020	78.8	<0.100	2.45
1	Soln Std		STD-B-3-3	3	22	20.5	<0.010	<0.080	<0.010	3.89	9.62	80.1	<0.020	49.6	<0.100	<0.200
2	Soln Std		STD-B1-1	1	1	21.8	<0.010	<0.080	<0.010	4.44	9.67	81.0	<0.020	49.4	<0.100	1.88
2	EA		H43	1	2	38.6	<0.010	<0.080	<0.010	<0.004	11.0	97.7	<0.020	53.2	<0.100	<0.200
2	NEPH3-56ccc	ccc	H07	1	3	22.1	<0.010	<0.080	<0.010	5.57	44.7	101	<0.020	128	0.116	1.81
2	ARM-1		H09	1	4	12.7	<0.010	<0.080	<0.010	<0.004	9.09	25.4	<0.020	39.2	<0.100	1.94
2	NEPH3-54ccc	ccc	H26	1	5	9.53	<0.010	<0.080	<0.010	9.15	23.8	54.7	<0.020	96.9	<0.100	1.72
2	NEPH3-56	quenched	H04	1	6	8.25	<0.010	<0.080	<0.010	7.31	15.3	75.9	<0.020	72.1	<0.100	<0.200
2	NEPH3-52ccc	ccc	H47	1	7	8.64	<0.010	<0.080	<0.010	4.15	12.3	86.8	<0.020	72.9	<0.100	1.58
2	NEPH3-55	quenched	H23	1	8	8.47	<0.010	<0.080	<0.010	5.80	15.8	67.1	<0.020	72.8	<0.100	<0.200
2	NEPH3-54	quenched	H33	1	9	8.05	<0.010	<0.080	<0.010	5.32	16.9	49.1	<0.020	78.0	<0.100	2.16
2	blank		H19	1	10	0.251	<0.010	<0.080	<0.010	<0.004	<0.500	<0.100	<0.020	<0.200	<0.100	3.08
2	NEPH3-49	quenched	H31	1	11	7.02	<0.010	<0.080	<0.010	5.74	10.9	58.8	<0.020	71.6	<0.100	2.20
2	Soln Std		STD-B1-2	1	12	20.0	<0.010	<0.080	<0.010	4.36	9.64	80.6	<0.020	49.3	<0.100	1.85
2	NEPH3-51ccc	ccc	H40	1	13	10.6	<0.010	<0.080	<0.010	5.56	14.5	78.7	<0.020	78.3	<0.100	1.97
2	NEPH3-50	quenched	H38	1	14	7.63	<0.010	<0.080	<0.010	5.96	10.7	68.4	<0.020	71.8	<0.100	2.30
2	NEPH3-50ccc	ccc	H05	1	15	7.72	<0.010	<0.080	<0.010	4.95	11.6	65.7	<0.020	72.3	<0.100	2.23

Table E1. Laboratory Measurements of the PCT Solutions for the Nepheline Study Glasses (continued)

Part	Glass ID	Heat Treatment	Laboratory ID	Block	Seq	B ar	Ba ar	Cd ar	Cr ar	Fe ar	Li ar	Na ar	Pb ar	Si ar	Th ar	U ar
2	NEPH3-49ccc	ccc	H53	1	16	7.41	<0.010	<0.080	<0.010	5.74	11.9	56.5	<0.020	74.5	<0.100	2.06
2	NEPH3-53	quenched	H37	1	17	7.86	<0.010	<0.080	<0.010	6.66	17.8	42.8	<0.020	82.1	<0.100	<0.200
2	NEPH3-52	quenched	H42	1	18	8.22	<0.010	<0.080	<0.010	6.47	10.6	88.6	<0.020	70.8	<0.100	1.83
2	NEPH3-53ccc	ccc	H36	1	19	10.1	<0.010	<0.080	<0.010	13.8	34.6	53.1	<0.020	130	<0.100	1.88
2	NEPH3-51	quenched	H03	1	20	8.07	<0.010	<0.080	<0.010	5.21	10.8	78.1	<0.020	71.0	<0.100	3.24
2	NEPH3-55ccc	ccc	H25	1	21	11.2	<0.010	<0.080	<0.010	5.51	26.8	76.0	<0.020	95.0	<0.100	1.88
2	Soln Std		STD-B1-3	1	22	19.7	<0.010	<0.080	<0.010	4.28	9.66	82.4	<0.020	48.7	<0.100	2.06
2	Soln Std		STD-B2-1	2	1	21.9	<0.010	<0.080	<0.010	4.40	9.69	81.6	<0.020	49.5	<0.100	1.99
2	NEPH3-49ccc	ccc	H52	2	2	7.61	<0.010	<0.080	<0.010	5.92	12.2	58.9	<0.020	76.3	<0.100	2.25
2	NEPH3-54	quenched	H15	2	3	8.01	<0.010	<0.080	<0.010	5.29	16.5	50.9	<0.020	76.7	<0.100	1.79
2	NEPH3-50ccc	ccc	H22	2	4	7.87	<0.010	<0.080	<0.010	5.34	11.6	65.4	<0.020	72.9	<0.100	<0.200
2	NEPH3-51	quenched	H34	2	5	8.11	<0.010	<0.080	<0.010	5.72	10.8	78.7	<0.020	71.3	<0.100	<0.200
2	NEPH3-54ccc	ccc	H18	2	6	8.24	<0.010	<0.080	<0.010	5.57	17.1	51.3	<0.020	79.2	<0.100	1.86
2	NEPH3-53ccc	ccc	H50	2	7	10.4	<0.010	<0.080	<0.010	14.2	34.2	53.8	<0.020	129	<0.100	1.87
2	NEPH3-55ccc	ccc	H28	2	8	12.2	<0.010	<0.080	<0.010	6.00	26.8	77.3	<0.020	95.6	<0.100	1.85
2	NEPH3-50	quenched	H24	2	9	7.86	<0.010	<0.080	<0.010	6.23	10.9	70.3	<0.020	72.5	<0.100	2.31
2	NEPH3-52	quenched	H30	2	10	8.00	<0.010	<0.080	<0.010	8.12	10.0	87.2	<0.020	68.6	<0.100	2.26
2	NEPH3-53	quenched	H29	2	11	8.42	<0.010	<0.080	<0.010	6.46	18.6	46.7	<0.020	85.6	<0.100	3.21
2	Soln Std		STD-B2-2	2	12	20.7	<0.010	<0.080	<0.010	4.32	9.68	83.8	<0.020	49.7	<0.100	2.14
2	EA		H54	2	13	38.9	<0.010	<0.080	<0.010	<0.004	11.1	102	<0.020	53.7	<0.100	<0.200
2	NEPH3-56	quenched	H14	2	14	8.75	<0.010	<0.080	<0.010	6.52	15.5	79.7	<0.020	72.8	<0.100	2.10
2	ARM-1		H17	2	15	13.1	<0.010	<0.080	<0.010	0.039	9.27	27.5	<0.020	39.9	<0.100	2.68
2	NEPH3-49	quenched	H44	2	16	7.32	<0.010	<0.080	<0.010	5.84	11.1	63.4	<0.020	72.8	<0.100	<0.200
2	NEPH3-56ccc	ccc	H35	2	17	21.5	<0.010	<0.080	<0.010	5.72	45.1	107	<0.020	128	0.115	<0.200
2	NEPH3-51ccc	ccc	H10	2	18	11.2	<0.010	<0.080	<0.010	5.80	14.7	82.8	<0.020	79.7	<0.100	<0.200
2	NEPH3-52ccc	ccc	H32	2	19	8.55	<0.010	<0.080	<0.010	4.22	12.3	91.9	<0.020	74.3	<0.100	2.41
2	NEPH3-55	quenched	H08	2	20	8.42	<0.010	<0.080	<0.010	6.63	16.0	71.2	<0.020	74.3	<0.100	2.00
2	Soln Std		STD-B2-3	2	21	20.8	<0.010	<0.080	<0.010	4.27	9.70	84.6	<0.020	49.7	<0.100	3.05
2	Soln Std		STD-B3-1	3	1	21.2	<0.010	<0.080	<0.010	4.26	9.72	80.0	<0.020	48.8	<0.100	1.82
2	NEPH3-49ccc	ccc	H55	3	2	7.68	<0.010	<0.080	<0.010	5.82	12.5	56.5	<0.020	76.0	<0.100	<0.200
2	NEPH3-54ccc	ccc	H21	3	3	9.71	<0.010	<0.080	<0.010	7.92	24.4	55.8	<0.020	96.7	<0.100	2.28
2	NEPH3-51	quenched	H39	3	4	8.36	<0.010	<0.080	<0.010	4.78	11.0	77.1	<0.020	71.0	<0.100	3.14
2	EA		H11	3	5	39.0	<0.010	<0.080	<0.010	<0.004	11.1	99.1	<0.020	53.8	<0.100	2.22
2	NEPH3-52	quenched	H01	3	6	9.06	<0.010	<0.080	<0.010	6.15	10.9	86.7	<0.020	71.9	<0.100	<0.200
2	NEPH3-55	quenched	H27	3	7	8.94	<0.010	<0.080	<0.010	7.46	16.4	65.6	<0.020	76.1	<0.100	1.75
2	NEPH3-50ccc	ccc	H41	3	8	8.15	<0.010	<0.080	<0.010	4.90	12.0	62.3	<0.020	74.4	<0.100	1.77
2	NEPH3-53	quenched	H13	3	9	8.77	<0.010	<0.080	<0.010	6.55	19.3	43.0	<0.020	88.4	<0.100	1.96
2	NEPH3-54	quenched	H20	3	10	10.1	<0.010	<0.080	<0.010	8.28	24.0	53.1	<0.020	95.2	<0.100	1.70
2	ARM-1		H49	3	11	12.7	<0.010	<0.080	<0.010	<0.004	9.23	24.6	<0.020	40.0	<0.100	1.73
2	Soln Std		STD-B3-2	3	12	21.0	<0.010	<0.080	<0.010	4.20	9.74	78.4	<0.020	50.1	<0.100	3.04
2	blank		H56	3	13	0.279	<0.010	<0.080	<0.010	<0.004	<0.500	<0.100	<0.020	<0.200	<0.100	<0.200

Table E1. Laboratory Measurements of the PCT Solutions for the Nepheline Study Glasses (continued)

Part	Glass ID	Heat Treatment	Laboratory ID	Block	Seq	B ar	Ba ar	Cd ar	Cr ar	Fe ar	Li ar	Na ar	Pb ar	Si ar	Th ar	U ar
2	NEPH3-50	quenched	H46	3	14	7.95	<0.010	<0.080	<0.010	5.75	11.1	65.2	<0.020	75.0	<0.100	2.03
2	NEPH3-56	quenched	H48	3	15	8.54	<0.010	<0.080	<0.010	7.37	15.9	72.9	<0.020	76.8	<0.100	<0.200
2	NEPH3-55ccc	ccc	H12	3	16	12.6	<0.010	<0.080	<0.010	6.22	27.8	72.1	<0.020	100	<0.100	<0.200
2	NEPH3-52ccc	ccc	H16	3	17	8.83	<0.010	<0.080	<0.010	4.35	12.0	82.4	<0.020	73.4	<0.100	2.21
2	NEPH3-49	quenched	H06	3	18	7.81	<0.010	<0.080	<0.010	6.04	11.6	57.5	<0.020	77.0	<0.100	1.95
2	NEPH3-53ccc	ccc	H02	3	19	11.0	<0.010	<0.080	<0.010	14.5	35.3	50.1	<0.020	132	<0.100	<0.200
2	NEPH3-51ccc	ccc	H51	3	20	11.3	<0.010	<0.080	<0.010	5.59	15.0	77.0	<0.020	82.5	<0.100	1.57
2	NEPH3-56ccc	ccc	H45	3	21	22.0	<0.010	<0.080	<0.010	6.12	45.9	94.5	<0.020	134	0.103	2.19
2	Soln Std		STD-B-3-3	3	22	21.3	<0.010	<0.080	<0.010	4.32	9.79	74.0	<0.020	50.8	<0.100	<0.200

Table E2. PSAL Measurements of the PCT Solutions for the Study Glasses After Appropriate Adjustments

Part	Glass ID	Heat Treatment	Laboratory ID	Block	Seq	B (ppm)	Ba (ppm)	Cd (ppm)	Cr (pp)	Fe (ppm)	Li (ppm)	Na (ppm)	Pb (ppm)	Si (ppm)	Th (ppm)	U (ppm)
1	Soln Std		STD-B1-1 Cs	1	1	19.4	0.005	0.04	0.005	4.1	9.79	83.1	0.01	50	0.05	0.1
1	NEPH3-42	quenched	F52	1	2	11.616899	0.0083335	0.066668	0.0083335	6.783469	17.16701	85.66838	0.016667	113.00226	0.083335	3.00006
1	NEPH3-42ccc	ccc	F39	1	3	10.483543	0.0083335	0.066668	0.0083335	5.66678	17.33368	81.6683	0.016667	111.83557	0.083335	2.983393
1	ARM-1		F08	1	4	17.83369	0.0083335	0.066668	0.0083335	0.0033334	13.733608	39.00078	0.016667	64.50129	0.083335	0.16667
1	NEPH3-47	quenched	F01	1	5	13.766942	0.0083335	0.066668	0.0083335	7.116809	23.00046	100.002	0.016667	114.33562	0.083335	2.83339
1	NEPH3-47ccc	ccc	F48	1	6	12.683587	0.0083335	0.066668	0.0083335	6.633466	25.50051	97.66862	0.016667	119.50239	0.083335	2.783389
1	blank		F26	1	7	0.066668	0.0083335	0.066668	0.0083335	0.0033334	0.416675	0.4116749	0.016667	0.16667	0.083335	0.16667
1	NEPH3-46	quenched	F25	1	8	11.733568	0.0083335	0.066668	0.0083335	7.100142	23.66714	73.50147	0.016667	120.83575	0.083335	2.83339
1	NEPH3-46ccc	ccc	F07	1	9	12.733588	0.0083335	0.066668	0.0083335	7.866824	26.50053	75.33484	0.016667	128.16923	0.083335	3.00006
1	NEPH3-41	quenched	F37	1	10	9.083515	0.0083335	0.066668	0.0083335	6.966806	17.83369	74.83483	0.016667	117.66902	0.083335	3.416735
1	NEPH3-41ccc	ccc	F32	1	11	8.766842	0.0083335	0.066668	0.0083335	7.33348	17.66702	71.6681	0.016667	116.00232	0.083335	3.150063
1	Soln Std		STD-B1-2	1	12	19.4	0.005	0.04	0.005	3.87	9.62	81.1	0.01	48.8	0.05	0.1
1	NEPH3-44	quenched	F15	1	13	11.00022	0.0083335	0.066668	0.0083335	6.983473	15.266972	120.66908	0.016667	104.16875	0.083335	2.950059
1	NEPH3-44ccc	ccc	F36	1	14	11.400228	0.0083335	0.066668	0.0083335	5.066768	19.16705	124.33582	0.016667	110.83555	0.083335	2.566718
1	NEPH3-48	quenched	F38	1	15	12.950259	0.0083335	0.066668	0.0083335	9.016847	22.16711	122.00244	0.016667	114.00228	0.083335	2.733388
1	NEPH3-48ccc	ccc	F47	1	16	20.0004	0.0083335	0.066668	0.0083335	5.233438	36.50073	137.16941	0.016667	138.3361	0.083335	3.266732
1	EA		F50	1	17	625.00125	0.0833335	0.666668	0.0833335	0.0333334	183.3337	1716.6701	0.166667	883.3351	0.833335	1.66667
1	NEPH3-43	quenched	F10	1	18	11.16689	0.0083335	0.066668	0.0083335	7.00014	16.83367	110.0022	0.016667	110.16887	0.083335	2.716721
1	NEPH3-43ccc	ccc	F34	1	19	11.450229	0.0083335	0.066668	0.0083335	8.566838	20.16707	109.00218	0.016667	118.50237	0.083335	3.16673
1	NEPH3-45	quenched	F55	1	20	11.916905	0.0083335	0.066668	0.0083335	7.800156	25.66718	60.66788	0.016667	130.83595	0.083335	4.00008
1	NEPH3-45ccc	ccc	F28	1	21	12.00024	0.0083335	0.066668	0.0083335	7.200144	26.33386	61.33456	0.016667	132.16931	0.083335	3.466736
1	Soln Std		STD-B1-3	1	22	19.4	0.005	0.04	0.005	3.9	9.71	82.4	0.01	49.4	0.05	0.1
1	Soln Std		STD-B2-1	2	1	21.8	0.005	0.04	0.005	4.21	9.66	79	0.01	49.5	0.05	0.1
1	NEPH3-42	quenched	F05	2	2	13.183597	0.0083335	0.066668	0.0083335	6.16679	18.16703	87.50175	0.016667	118.3357	0.083335	2.866724
1	NEPH3-42ccc	ccc	F30	2	3	11.683567	0.0083335	0.066668	0.0083335	6.300126	17.83369	81.33496	0.016667	114.83563	0.083335	2.850057
1	NEPH3-47	quenched	F27	2	4	15.133636	0.0083335	0.066668	0.0083335	7.383481	23.50047	101.50203	0.016667	116.16899	0.083335	2.883391
1	NEPH3-47ccc	ccc	F03	2	5	13.866944	0.0083335	0.066668	0.0083335	6.750135	25.66718	95.0019	0.016667	120.83575	0.083335	2.783389
1	NEPH3-46	quenched	F35	2	6	13.250265	0.0083335	0.066668	0.0083335	7.216811	23.66714	72.00144	0.016667	121.16909	0.083335	2.866724
1	NEPH3-46ccc	ccc	F19	2	7	14.083615	0.0083335	0.066668	0.0083335	7.83349	26.6672	72.50145	0.016667	128.50257	0.083335	3.050061

Table E2. PSAL Measurements of the PCT Solutions for the Study Glasses After Appropriate Adjustments (continued)

Part	Glass ID	Heat Treatment	Laboratory ID	Block	Seq	B (ppm)	Ba (ppm)	Cd (ppm)	Cr (pp)	Fe (ppm)	Li (ppm)	Na (ppm)	Pb (ppm)	Si (ppm)	Th (ppm)	U (ppm)
1	NEPH3-41	quenched	F09	2	8	10.250205	0.0083335	0.066668	0.0083335	6.533464	18.00036	71.16809	0.016667	119.00238	0.083335	3.716741
1	NEPH3-41ccc	ccc	F11	2	9	10.200204	0.0083335	0.066668	0.0083335	6.050121	18.00036	68.16803	0.016667	117.33568	0.083335	3.100062
1	ARM-1		F29	2	10	18.83371	0.0083335	0.066668	0.0083335	0.0033334	14.450289	39.50079	0.016667	66.33466	0.083335	0.16667
1	EA		F53	2	11	638.33461	0.0833335	0.666668	0.0833335	0.0333334	185.00037	1683.3367	0.166667	895.00179	0.833335	1.66667
1	Soln Std		STD-B2-2	2	12	20.7	0.005	0.04	0.005	4.02	9.7	79.2	0.01	50	0.05	0.1
1	NEPH3-44	quenched	F24	2	13	12.550251	0.0083335	0.066668	0.0083335	7.650153	15.533644	120.16907	0.016667	105.33544	0.083335	2.716721
1	NEPH3-44ccc	ccc	F22	2	14	12.566918	0.0083335	0.066668	0.0083335	4.483423	19.00038	122.83579	0.016667	110.0022	0.083335	2.650053
1	NEPH3-48	quenched	F14	2	15	14.550291	0.0083335	0.066668	0.0083335	9.200184	22.33378	120.0024	0.016667	115.33564	0.083335	3.033394
1	NEPH3-48ccc	ccc	F20	2	16	21.16709	0.0083335	0.066668	0.0083335	5.566778	36.16739	135.33604	0.016667	138.83611	0.083335	3.200064
1	NEPH3-43	quenched	F49	2	17	11.600232	0.0083335	0.066668	0.0083335	9.00018	16.667	109.33552	0.016667	111.16889	0.083335	3.283399
1	NEPH3-43ccc	ccc	F44	2	18	12.350247	0.0083335	0.066668	0.0083335	8.933512	19.83373	106.33546	0.016667	117.66902	0.083335	3.116729
1	NEPH3-45	quenched	F16	2	19	13.250265	0.0083335	0.066668	0.0083335	8.300166	25.83385	60.16787	0.016667	132.00264	0.083335	3.600072
1	NEPH3-45ccc	ccc	F02	2	20	13.016927	0.0083335	0.066668	0.0083335	8.650173	25.83385	59.00118	0.016667	131.83597	0.083335	3.633406
1	Soln Std		STD-B2-3	2	21	19.8	0.005	0.04	0.005	4.1	9.55	79.6	0.01	48.8	0.05	0.1
1	Soln Std		STD-B3-1	3	1	22.1	0.005	0.04	0.005	3.92	9.77	80.5	0.01	49.4	0.05	0.25
1	NEPH3-42	quenched	F06	3	2	13.266932	0.0083335	0.066668	0.0083335	5.750115	17.66702	86.83507	0.016667	113.3356	0.083335	3.266732
1	NEPH3-42ccc	ccc	F23	3	3	12.233578	0.0083335	0.066668	0.0083335	6.366794	17.66702	87.00174	0.016667	111.6689	0.083335	3.16673
1	EA		F46	3	4	581.66783	0.0833335	0.666668	0.0833335	0.0333334	168.33367	1530.00306	0.166667	800.0016	0.833335	1.66667
1	NEPH3-47	quenched	F31	3	5	16.283659	0.0083335	0.066668	0.0083335	7.850157	23.00046	98.50197	0.016667	114.66896	0.083335	3.183397
1	NEPH3-47ccc	ccc	F43	3	6	14.816963	0.0083335	0.066668	0.0083335	7.16681	25.50051	96.16859	0.016667	118.66904	0.083335	3.016727
1	NEPH3-46	quenched	F45	3	7	14.283619	0.0083335	0.066668	0.0083335	6.983473	23.83381	71.00142	0.016667	121.83577	0.083335	3.200064
1	NEPH3-46ccc	ccc	F56	3	8	14.800296	0.0083335	0.066668	0.0083335	8.083495	26.50053	71.83477	0.016667	129.33592	0.083335	3.383401
1	NEPH3-41	quenched	F17	3	9	11.250225	0.0083335	0.066668	0.0083335	7.583485	18.00036	72.50145	0.016667	120.66908	0.083335	3.800076
1	NEPH3-41ccc	ccc	F41	3	10	10.783549	0.0083335	0.066668	0.0083335	6.433462	18.00036	68.00136	0.016667	120.33574	0.083335	3.900078
1	blank		F12	3	11	0.066668	0.0083335	0.066668	0.0083335	0.0033334	0.416675	0.066668	0.016667	0.16667	0.083335	0.16667
1	Soln Std		STD-B3-2	3	12	20.4	0.005	0.04	0.005	3.96	9.62	79.8	0.01	49	0.05	0.1
1	NEPH3-44	quenched	F21	3	13	13.066928	0.0083335	0.066668	0.0083335	8.133496	15.783649	121.00242	0.016667	105.50211	0.083335	3.433402
1	NEPH3-44ccc	ccc	F42	3	14	13.600272	0.0083335	0.066668	0.0083335	4.700094	19.50039	123.83581	0.016667	112.16891	0.083335	3.250065
1	NEPH3-48	quenched	F18	3	15	15.050301	0.0083335	0.066668	0.0083335	9.400188	22.16711	121.6691	0.016667	115.0023	0.083335	3.283399
1	NEPH3-48ccc	ccc	F33	3	16	22.00044	0.0083335	0.066668	0.0083335	5.716781	36.6674	134.00268	0.016667	140.33614	0.083335	3.516737
1	ARM-1		F13	3	17	20.66708	0.0083335	0.066668	0.0083335	0.0033334	14.750295	40.50081	0.016667	67.50135	0.083335	0.16667

Table E2. PSAL Measurements of the PCT Solutions for the Study Glasses After Appropriate Adjustments (continued)

Part	Glass ID	Heat Treatment	Laboratory ID	Block	Seq	B (ppm)	Ba (ppm)	Cd (ppm)	Cr (pp)	Fe (ppm)	Li (ppm)	Na (ppm)	Pb (ppm)	Si (ppm)	Th (ppm)	U (ppm)
1	NEPH3-43	quenched	F54	3	18	12.016907	0.0083335	0.066668	0.0083335	8.900178	15.916985	103.16873	0.016667	106.6688	0.083335	4.083415
1	NEPH3-43ccc	ccc	F51	3	19	12.883591	0.0083335	0.066668	0.0083335	8.83351	19.50039	103.00206	0.016667	114.66896	0.083335	3.3334
1	NEPH3-45	quenched	F40	3	20	13.750275	0.0083335	0.066668	0.0083335	9.450189	25.33384	58.83451	0.016667	128.3359	0.083335	3.83341
1	NEPH3-45ccc	ccc	F04	3	21	13.900278	0.0083335	0.066668	0.0083335	7.983493	26.00052	58.50117	0.016667	131.33596	0.083335	4.083415
1	Soln Std		STD-B-3-3	3	22	20.5	0.005	0.04	0.005	3.89	9.62	80.1	0.01	49.6	0.05	0.1
2	Soln Std		STD-B1-1	1	1	21.8	0.005	0.04	0.005	4.44	9.67	81	0.01	49.4	0.05	1.88
2	EA		H43	1	2	643.33462	0.0833335	0.666668	0.0833335	0.0333334	183.3337	1628.33659	0.166667	886.66844	0.833335	1.66667
2	NEPH3-56ccc	ccc	H07	1	3	36.83407	0.0083335	0.066668	0.0083335	9.283519	74.50149	168.3367	0.016667	213.3376	0.1933372	3.016727
2	ARM-1		H09	1	4	21.16709	0.0083335	0.066668	0.0083335	0.0033334	15.150303	42.33418	0.016667	65.33464	0.083335	3.233398
2	NEPH3-54ccc	ccc	H26	1	5	15.883651	0.0083335	0.066668	0.0083335	15.250305	39.66746	91.16849	0.016667	161.50323	0.083335	2.866724
2	NEPH3-56	quenched	H04	1	6	13.750275	0.0083335	0.066668	0.0083335	12.183577	25.50051	126.50253	0.016667	120.16907	0.083335	0.16667
2	NEPH3-52ccc	ccc	H47	1	7	14.400288	0.0083335	0.066668	0.0083335	6.916805	20.50041	144.66956	0.016667	121.50243	0.083335	2.633386
2	NEPH3-55	quenched	H23	1	8	14.116949	0.0083335	0.066668	0.0083335	9.66686	26.33386	111.83557	0.016667	121.33576	0.083335	0.16667
2	NEPH3-54	quenched	H33	1	9	13.416935	0.0083335	0.066668	0.0083335	8.866844	28.16723	81.83497	0.016667	130.0026	0.083335	3.600072
2	blank		H19	1	10	0.4183417	0.0083335	0.066668	0.0083335	0.0033334	0.416675	0.083335	0.016667	0.16667	0.083335	5.133436
2	NEPH3-49	quenched	H31	1	11	11.700234	0.0083335	0.066668	0.0083335	9.566858	18.16703	98.00196	0.016667	119.33572	0.083335	3.66674
2	Soln Std		STD-B1-2	1	12	20	0.005	0.04	0.005	4.36	9.64	80.6	0.01	49.3	0.05	1.85
2	NEPH3-51ccc	ccc	H40	1	13	17.66702	0.0083335	0.066668	0.0083335	9.266852	24.16715	131.16929	0.016667	130.50261	0.083335	3.283399
2	NEPH3-50	quenched	H38	1	14	12.716921	0.0083335	0.066668	0.0083335	9.933532	17.83369	114.00228	0.016667	119.66906	0.083335	3.83341
2	NEPH3-50ccc	ccc	H05	1	15	12.866924	0.0083335	0.066668	0.0083335	8.250165	19.33372	109.50219	0.016667	120.50241	0.083335	3.716741
2	NEPH3-49ccc	ccc	H53	1	16	12.350247	0.0083335	0.066668	0.0083335	9.566858	19.83373	94.16855	0.016667	124.16915	0.083335	3.433402
2	NEPH3-53	quenched	H37	1	17	13.100262	0.0083335	0.066668	0.0083335	11.100222	29.66726	71.33476	0.016667	136.83607	0.083335	0.16667
2	NEPH3-52	quenched	H42	1	18	13.700274	0.0083335	0.066668	0.0083335	10.783549	17.66702	147.66962	0.016667	118.00236	0.083335	3.050061
2	NEPH3-53ccc	ccc	H36	1	19	16.83367	0.0083335	0.066668	0.0083335	23.00046	57.66782	88.50177	0.016667	216.671	0.083335	3.133396
2	NEPH3-51	quenched	H03	1	20	13.450269	0.0083335	0.066668	0.0083335	8.683507	18.00036	130.16927	0.016667	118.3357	0.083335	5.400108
2	NEPH3-55ccc	ccc	H25	1	21	18.66704	0.0083335	0.066668	0.0083335	9.183517	44.66756	126.6692	0.016667	158.3365	0.083335	3.133396
2	Soln Std		STD-B1-3	1	22	19.7	0.005	0.04	0.005	4.28	9.66	82.4	0.01	48.7	0.05	2.06
2	Soln Std		STD-B2-1	2	1	21.9	0.005	0.04	0.005	4.4	9.69	81.6	0.01	49.5	0.05	1.99
2	NEPH3-49ccc	ccc	H52	2	2	12.683587	0.0083335	0.066668	0.0083335	9.866864	20.33374	98.16863	0.016667	127.16921	0.083335	3.750075
2	NEPH3-54	quenched	H15	2	3	13.350267	0.0083335	0.066668	0.0083335	8.816843	27.50055	84.83503	0.016667	127.83589	0.083335	2.983393
2	NEPH3-50ccc	ccc	H22	2	4	13.116929	0.0083335	0.066668	0.0083335	8.900178	19.33372	109.00218	0.016667	121.50243	0.083335	0.16667

Table E2. PSAL Measurements of the PCT Solutions for the Study Glasses After Appropriate Adjustments (continued)

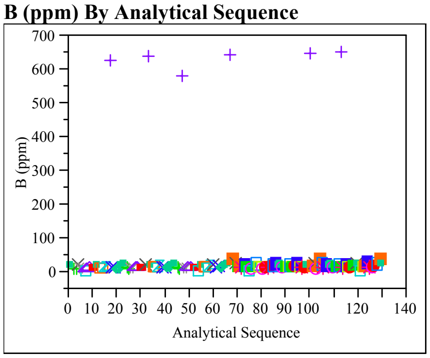
Part	Glass ID	Heat Treatment	Laboratory ID	Block	Seq	B (ppm)	Ba (ppm)	Cd (ppm)	Cr (pp)	Fe (ppm)	Li (ppm)	Na (ppm)	Pb (ppm)	Si (ppm)	Th (ppm)	U (ppm)
2	NEPH3-51	quenched	H34	2	5	13.516937	0.0083335	0.066668	0.0083335	9.533524	18.00036	131.16929	0.016667	118.83571	0.083335	0.16667
2	NEPH3-54ccc	ccc	H18	2	6	13.733608	0.0083335	0.066668	0.0083335	9.283519	28.50057	85.50171	0.016667	132.00264	0.083335	3.100062
2	NEPH3-53ccc	ccc	H50	2	7	17.33368	0.0083335	0.066668	0.0083335	23.66714	57.00114	89.66846	0.016667	215.0043	0.083335	3.116729
2	NEPH3-55ccc	ccc	H28	2	8	20.33374	0.0083335	0.066668	0.0083335	10.0002	44.66756	128.83591	0.016667	159.33652	0.083335	3.083395
2	NEPH3-50	quenched	H24	2	9	13.100262	0.0083335	0.066668	0.0083335	10.383541	18.16703	117.16901	0.016667	120.83575	0.083335	3.850077
2	NEPH3-52	quenched	H30	2	10	13.3336	0.0083335	0.066668	0.0083335	13.533604	16.667	145.33624	0.016667	114.33562	0.083335	3.766742
2	NEPH3-53	quenched	H29	2	11	14.033614	0.0083335	0.066668	0.0083335	10.766882	31.00062	77.83489	0.016667	142.66952	0.083335	5.350107
2	Soln Std		STD-B2-2	2	12	20.7	0.005	0.04	0.005	4.32	9.68	83.8	0.01	49.7	0.05	2.14
2	EA		H54	2	13	648.33463	0.0833335	0.666668	0.0833335	0.0333334	185.00037	1700.0034	0.166667	895.00179	0.833335	1.66667
2	NEPH3-56	quenched	H14	2	14	14.583625	0.0083335	0.066668	0.0083335	10.866884	25.83385	132.83599	0.016667	121.33576	0.083335	3.50007
2	ARM-1		H17	2	15	21.83377	0.0083335	0.066668	0.0083335	0.0650013	15.450309	45.83425	0.016667	66.50133	0.083335	4.466756
2	NEPH3-49	quenched	H44	2	16	12.200244	0.0083335	0.066668	0.0083335	9.733528	18.50037	105.66878	0.016667	121.33576	0.083335	0.16667
2	NEPH3-56ccc	ccc	H35	2	17	35.83405	0.0083335	0.066668	0.0083335	9.533524	75.16817	178.3369	0.016667	213.3376	0.1916705	0.16667
2	NEPH3-51ccc	ccc	H10	2	18	18.66704	0.0083335	0.066668	0.0083335	9.66686	24.50049	138.00276	0.016667	132.83599	0.083335	0.16667
2	NEPH3-52ccc	ccc	H32	2	19	14.250285	0.0083335	0.066668	0.0083335	7.033474	20.50041	153.16973	0.016667	123.83581	0.083335	4.016747
2	NEPH3-55	quenched	H08	2	20	14.033614	0.0083335	0.066668	0.0083335	11.050221	26.6672	118.66904	0.016667	123.83581	0.083335	3.3334
2	Soln Std		STD-B2-3	2	21	20.8	0.005	0.04	0.005	4.27	9.7	84.6	0.01	49.7	0.05	3.05
2	Soln Std		STD-B3-1	3	1	21.2	0.005	0.04	0.005	4.26	9.72	80	0.01	48.8	0.05	1.82
2	NEPH3-49ccc	ccc	H55	3	2	12.800256	0.0083335	0.066668	0.0083335	9.700194	20.83375	94.16855	0.016667	126.6692	0.083335	0.16667
2	NEPH3-54ccc	ccc	H21	3	3	16.183657	0.0083335	0.066668	0.0083335	13.200264	40.66748	93.00186	0.016667	161.16989	0.083335	3.800076
2	NEPH3-51	quenched	H39	3	4	13.933612	0.0083335	0.066668	0.0083335	7.966826	18.3337	128.50257	0.016667	118.3357	0.083335	5.233438
2	EA		H11	3	5	650.0013	0.0833335	0.666668	0.0833335	0.0333334	185.00037	1651.66997	0.166667	896.66846	0.833335	37.000074
2	NEPH3-52	quenched	H01	3	6	15.100302	0.0083335	0.066668	0.0083335	10.250205	18.16703	144.50289	0.016667	119.83573	0.083335	0.16667
2	NEPH3-55	quenched	H27	3	7	14.900298	0.0083335	0.066668	0.0083335	12.433582	27.33388	109.33552	0.016667	126.83587	0.083335	2.916725
2	NEPH3-50ccc	ccc	H41	3	8	13.583605	0.0083335	0.066668	0.0083335	8.16683	20.0004	103.83541	0.016667	124.00248	0.083335	2.950059
2	NEPH3-53	quenched	H13	3	9	14.616959	0.0083335	0.066668	0.0083335	10.916885	32.16731	71.6681	0.016667	147.33628	0.083335	3.266732
2	NEPH3-54	quenched	H20	3	10	16.83367	0.0083335	0.066668	0.0083335	13.800276	40.0008	88.50177	0.016667	158.66984	0.083335	2.83339
2	ARM-1		H49	3	11	21.16709	0.0083335	0.066668	0.0083335	0.0033334	15.383641	41.00082	0.016667	66.668	0.083335	2.883391
2	Soln Std		STD-B3-2	3	12	21	0.005	0.04	0.005	4.2	9.74	78.4	0.01	50.1	0.05	3.04
2	blank		H56	3	13	0.4650093	0.0083335	0.066668	0.0083335	0.0033334	0.416675	0.083335	0.016667	0.16667	0.083335	0.16667
2	NEPH3-50	quenched	H46	3	14	13.250265	0.0083335	0.066668	0.0083335	9.583525	18.50037	108.66884	0.016667	125.0025	0.083335	3.383401

Table E2. PSAL Measurements of the PCT Solutions for the Study Glasses After Appropriate Adjustments (continued)

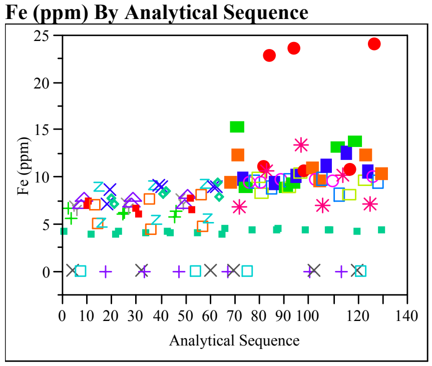
Part	Glass ID	Heat Treatment	Laboratory ID	Block	Seq	B (ppm)	Ba (ppm)	Cd (ppm)	Cr (pp)	Fe (ppm)	Li (ppm)	Na (ppm)	Pb (ppm)	Si (ppm)	Th (ppm)	U (ppm)
2	NEPH3-56	quenched	H48	3	15	14.233618	0.0083335	0.066668	0.0083335	12.283579	26.50053	121.50243	0.016667	128.00256	0.083335	0.16667
2	NEPH3-55ccc	ccc	H12	3	16	21.00042	0.0083335	0.066668	0.0083335	10.366874	46.33426	120.16907	0.016667	166.67	0.083335	0.16667
2	NEPH3-52ccc	ccc	H16	3	17	14.716961	0.0083335	0.066668	0.0083335	7.250145	20.0004	137.33608	0.016667	122.33578	0.083335	3.683407
2	NEPH3-49	quenched	H06	3	18	13.016927	0.0083335	0.066668	0.0083335	10.066868	19.33372	95.83525	0.016667	128.3359	0.083335	3.250065
2	NEPH3-53ccc	ccc	H02	3	19	18.3337	0.0083335	0.066668	0.0083335	24.16715	58.83451	83.50167	0.016667	220.0044	0.083335	0.16667
2	NEPH3-51ccc	ccc	H51	3	20	18.83371	0.0083335	0.066668	0.0083335	9.316853	25.0005	128.3359	0.016667	137.50275	0.083335	2.616719
2	NEPH3-56ccc	ccc	H45	3	21	36.6674	0.0083335	0.066668	0.0083335	10.200204	76.50153	157.50315	0.016667	223.3378	0.1716701	3.650073
2	Soln Std		STD-B-3-3	3	22	21.3	0.005	0.04	0.005	4.32	9.79	74	0.01	50.8	0.05	0.1

Exhibit E1. Laboratory PCT Measurements in Analytical Sequence for Study Glasses, EA, ARM, Blanks, and Solution Standards

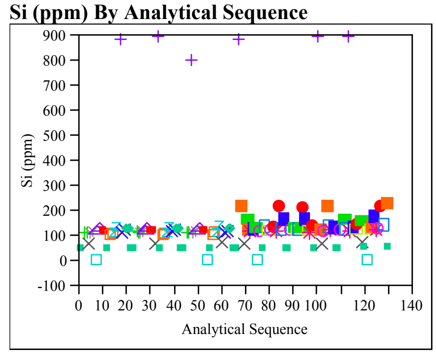
B (ppm) By Analytical Sequence



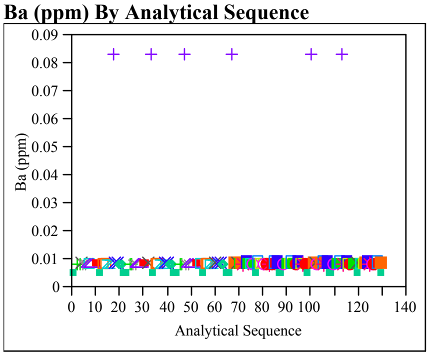
Fe (ppm) By Analytical Sequence



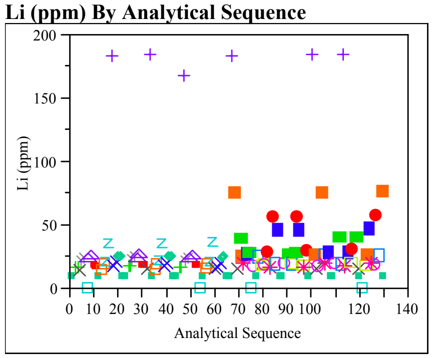
Si (ppm) By Analytical Sequence



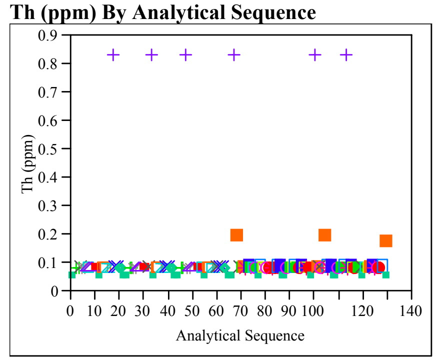
Ba (ppm) By Analytical Sequence



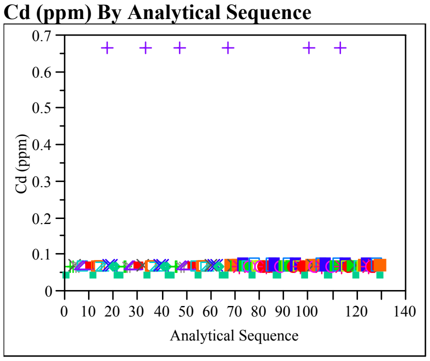
Li (ppm) By Analytical Sequence



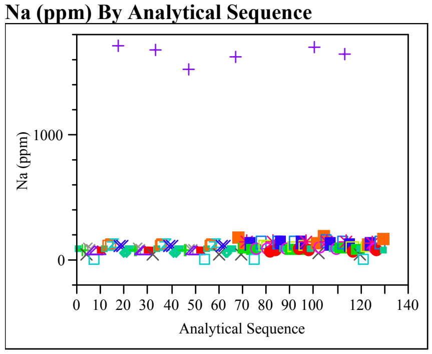
Th (ppm) By Analytical Sequence



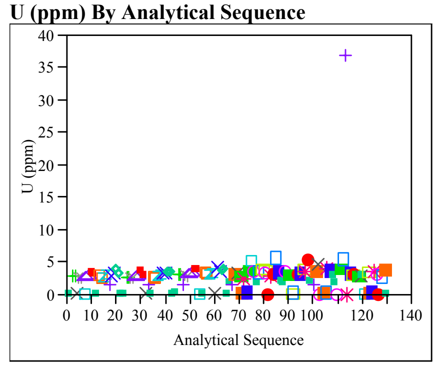
Cd (ppm) By Analytical Sequence



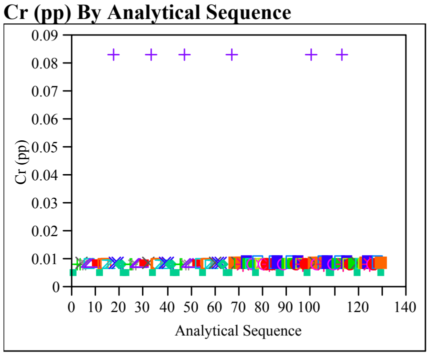
Na (ppm) By Analytical Sequence



U (ppm) By Analytical Sequence



Cr (pp) By Analytical Sequence



Pb (ppm) By Analytical Sequence

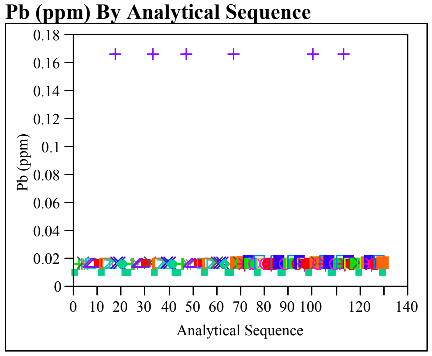
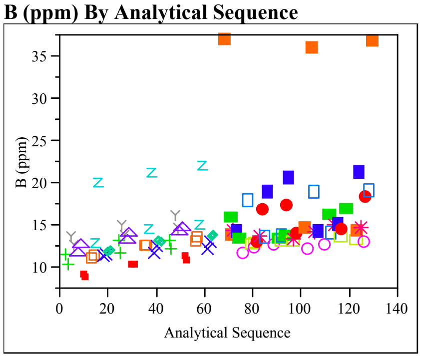
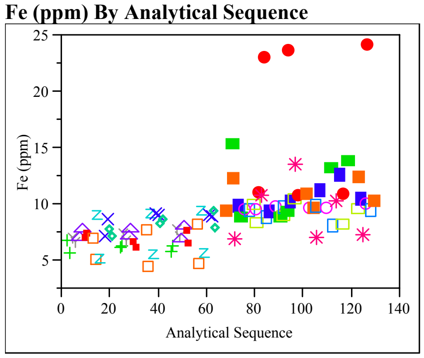


Exhibit E2. Laboratory PCT Measurements in Analytical Sequence for Study Glasses

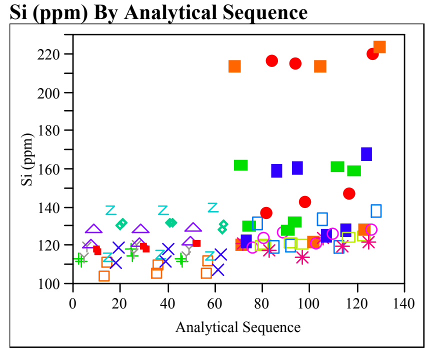
B (ppm) By Analytical Sequence



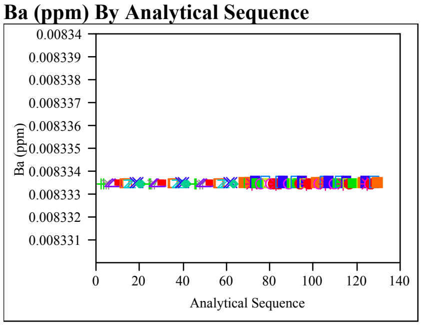
Fe (ppm) By Analytical Sequence



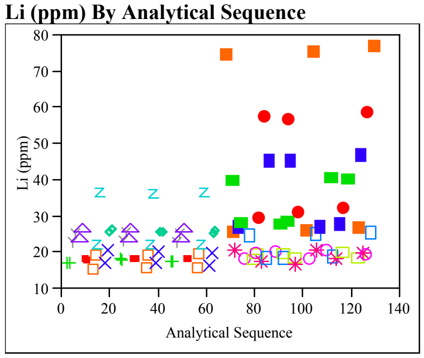
Si (ppm) By Analytical Sequence



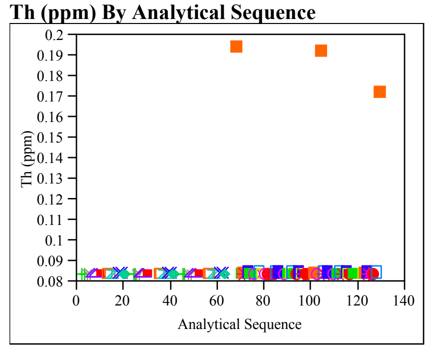
Ba (ppm) By Analytical Sequence



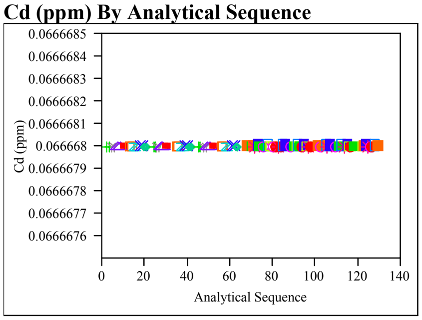
Li (ppm) By Analytical Sequence



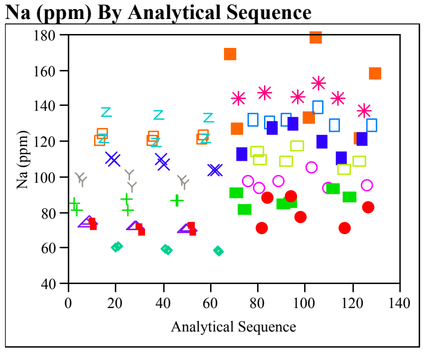
Th (ppm) By Analytical Sequence



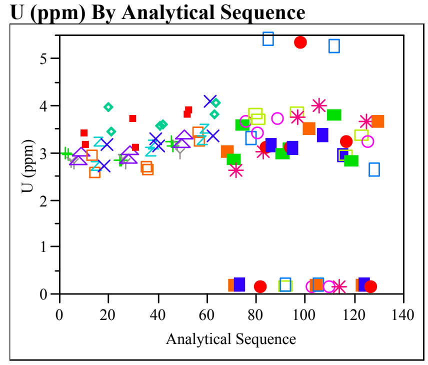
Cd (ppm) By Analytical Sequence



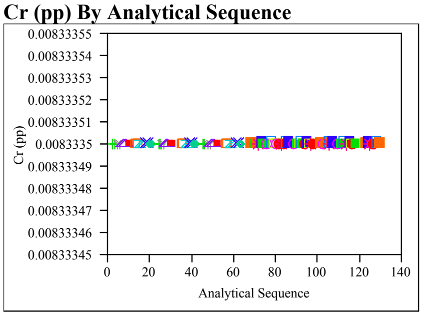
Na (ppm) By Analytical Sequence



U (ppm) By Analytical Sequence



Cr (pp) By Analytical Sequence



Pb (ppm) By Analytical Sequence

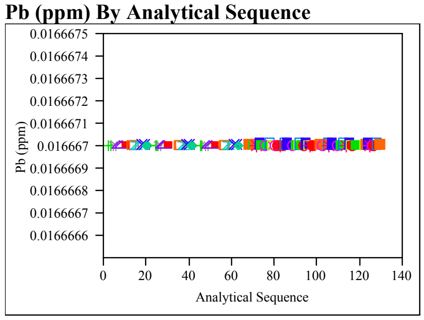
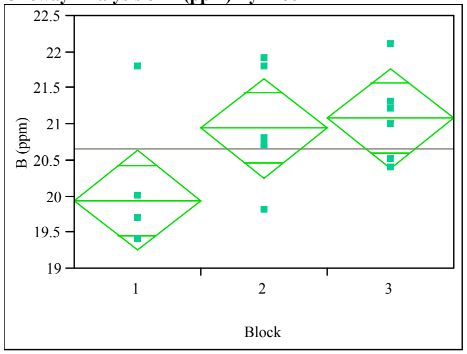


Exhibit E3. Measurements of the Multi-Element Solution Standard by Set and ICP Block

Oneway Analysis of B (ppm) By Block



Oneway Anova
Summary of Fit

Rsquare	0.328824
Adj Rsquare	0.239333
Root Mean Square Error	0.791553
Mean of Response	20.66111
Observations (or Sum Wgts)	18

Analysis of Variance

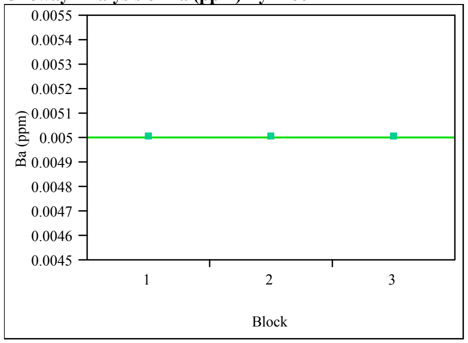
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	2	4.604444	2.30222	3.6744	0.0503
Error	15	9.398333	0.62656		
C. Total	17	14.002778			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	6	19.9500	0.32315	19.261	20.639
2	6	20.9500	0.32315	20.261	21.639
3	6	21.0833	0.32315	20.395	21.772

Std Error uses a pooled estimate of error variance

Oneway Analysis of Ba (ppm) By Block



Oneway Anova
Summary of Fit

Rsquare	1
Adj Rsquare	1
Root Mean Square Error	0
Mean of Response	0.005
Observations (or Sum Wgts)	18

Analysis of Variance

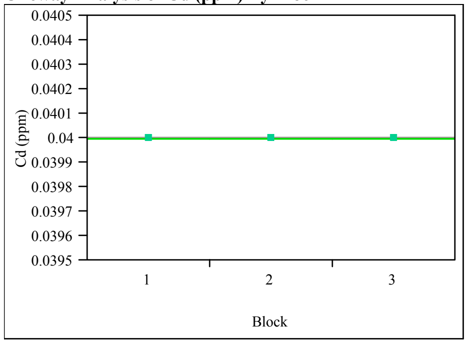
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	2	1.3542e-35	6.771e-36	.	.
Error	15	0	0		
C. Total	17	1.3542e-35			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	6	0.005000	0	0.00500	0.00500
2	6	0.005000	0	0.00500	0.00500
3	6	0.005000	0	0.00500	0.00500

Std Error uses a pooled estimate of error variance

Oneway Analysis of Cd (ppm) By Block



Oneway Anova
Summary of Fit

Rsquare	1
Adj Rsquare	1
Root Mean Square Error	0
Mean of Response	0.04
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	2	8.6667e-34	4.333e-34	.	.
Error	15	0	0		
C. Total	17	8.6667e-34			

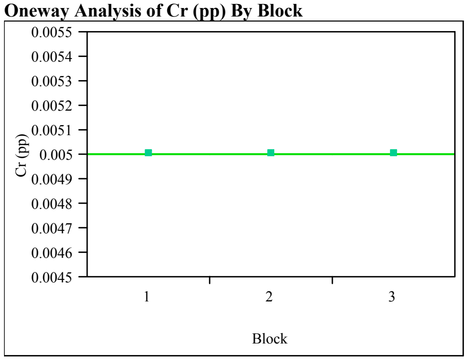
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	6	0.040000	0	0.04000	0.04000
2	6	0.040000	0	0.04000	0.04000
3	6	0.040000	0	0.04000	0.04000

Std Error uses a pooled estimate of error variance

Exhibit E3. Measurements of the Multi-Element Solution Standard by Set and ICP Block (continued)

Oneway Analysis of Cr (pp) By Block



Oneway Anova
Summary of Fit

Rsquare	1
Adj Rsquare	1
Root Mean Square Error	0
Mean of Response	0.005
Observations (or Sum Wgts)	18

Analysis of Variance

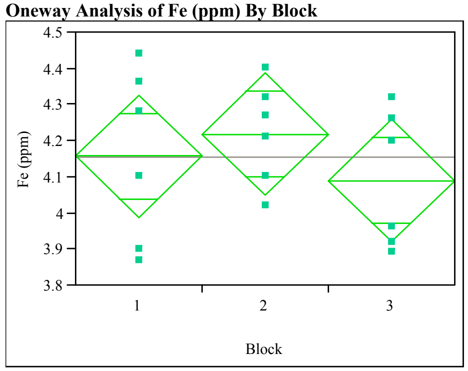
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	2	1.3542e-35	6.771e-36	.	.
Error	15	0	0		
C. Total	17	1.3542e-35			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	6	0.005000	0	0.00500	0.00500
2	6	0.005000	0	0.00500	0.00500
3	6	0.005000	0	0.00500	0.00500

Std Error uses a pooled estimate of error variance

Oneway Analysis of Fe (ppm) By Block



Oneway Anova
Summary of Fit

Rsquare	0.080171
Adj Rsquare	-0.04247
Root Mean Square Error	0.194451
Mean of Response	4.156667
Observations (or Sum Wgts)	18

Analysis of Variance

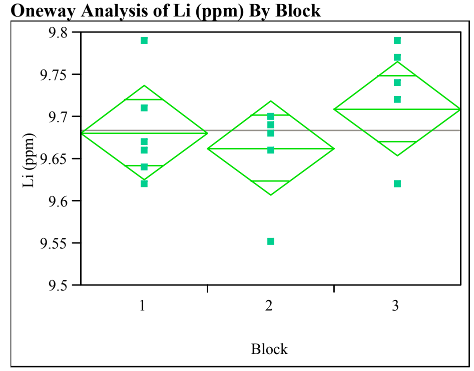
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	2	0.04943333	0.024717	0.6537	0.5343
Error	15	0.56716667	0.037811		
C. Total	17	0.61660000			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	6	4.15833	0.07938	3.9891	4.3275
2	6	4.22000	0.07938	4.0508	4.3892
3	6	4.09167	0.07938	3.9225	4.2609

Std Error uses a pooled estimate of error variance

Oneway Analysis of Li (ppm) By Block



Oneway Anova
Summary of Fit

Rsquare	0.096066
Adj Rsquare	-0.02446
Root Mean Square Error	0.064507
Mean of Response	9.685
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	2	0.00663333	0.003317	0.7971	0.4688
Error	15	0.06241667	0.004161		
C. Total	17	0.06905000			

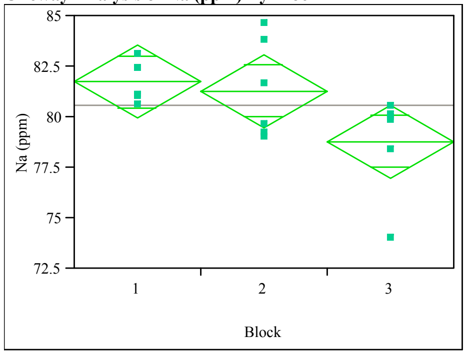
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	6	9.68167	0.02633	9.6255	9.7378
2	6	9.66333	0.02633	9.6072	9.7195
3	6	9.71000	0.02633	9.6539	9.7661

Std Error uses a pooled estimate of error variance

Exhibit E3. Measurements of the Multi-Element Solution Standard by Set and ICP Block (continued)

Oneway Analysis of Na (ppm) By Block



Oneway Anova
Summary of Fit

Rsquare	0.319596
Adj Rsquare	0.228876
Root Mean Square Error	2.081879
Mean of Response	80.62222
Observations (or Sum Wgts)	18

Analysis of Variance

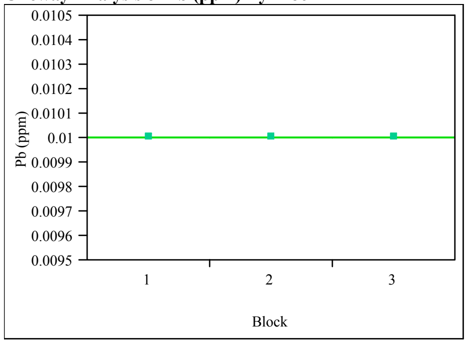
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	2	30.537778	15.2689	3.5229	0.0557
Error	15	65.013333	4.3342		
C. Total	17	95.551111			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	6	81.7667	0.84992	79.955	83.578
2	6	81.3000	0.84992	79.488	83.112
3	6	78.8000	0.84992	76.988	80.612

Std Error uses a pooled estimate of error variance

Oneway Analysis of Pb (ppm) By Block



Oneway Anova
Summary of Fit

Rsquare	1
Adj Rsquare	1
Root Mean Square Error	0
Mean of Response	0.01
Observations (or Sum Wgts)	18

Analysis of Variance

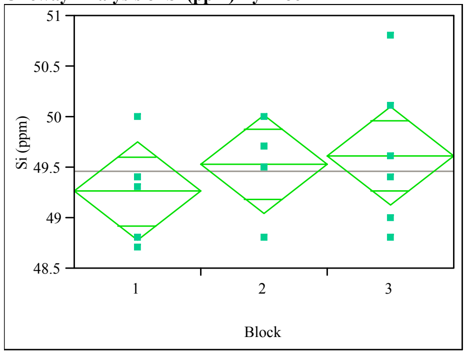
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	2	5.4167e-35	2.708e-35	.	.
Error	15	0	0		
C. Total	17	5.4167e-35			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	6	0.010000	0	0.01000	0.01000
2	6	0.010000	0	0.01000	0.01000
3	6	0.010000	0	0.01000	0.01000

Std Error uses a pooled estimate of error variance

Oneway Analysis of Si (ppm) By Block



Oneway Anova
Summary of Fit

Rsquare	0.079332
Adj Rsquare	-0.04342
Root Mean Square Error	0.557076
Mean of Response	49.47222
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	2	0.4011111	0.200556	0.6463	0.5380
Error	15	4.6550000	0.310333		
C. Total	17	5.0561111			

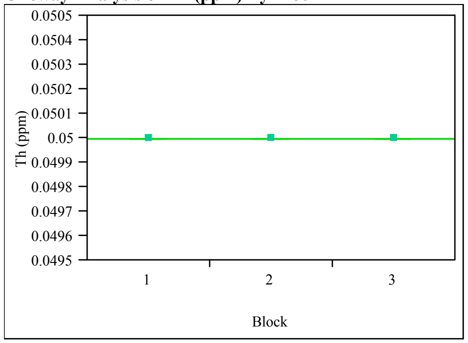
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	6	49.2667	0.22743	48.782	49.751
2	6	49.5333	0.22743	49.049	50.018
3	6	49.6167	0.22743	49.132	50.101

Std Error uses a pooled estimate of error variance

Exhibit E3. Measurements of the Multi-Element Solution Standard by Set and ICP Block (continued)

Oneway Analysis of Th (ppm) By Block



Oneway Anova
Summary of Fit

Rsquare	0
Adj Rsquare	-0.13333
Root Mean Square Error	7.6e-18
Mean of Response	0.05
Observations (or Sum Wgts)	18

Analysis of Variance

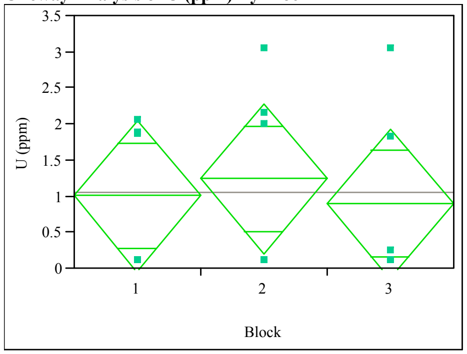
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	2	0	0	0.0000	1.0000
Error	15	8.6667e-34	5.778e-35		
C. Total	17	8.6667e-34			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	6	0.050000	3.103e-18	0.05000	0.05000
2	6	0.050000	3.103e-18	0.05000	0.05000
3	6	0.050000	3.103e-18	0.05000	0.05000

Std Error uses a pooled estimate of error variance

Oneway Analysis of U (ppm) By Block



Oneway Anova
Summary of Fit

Rsquare	0.017072
Adj Rsquare	-0.11398
Root Mean Square Error	1.193448
Mean of Response	1.054444
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	2	0.371078	0.18554	0.1303	0.8788
Error	15	21.364767	1.42432		
C. Total	17	21.735844			

Means for Oneway Anova

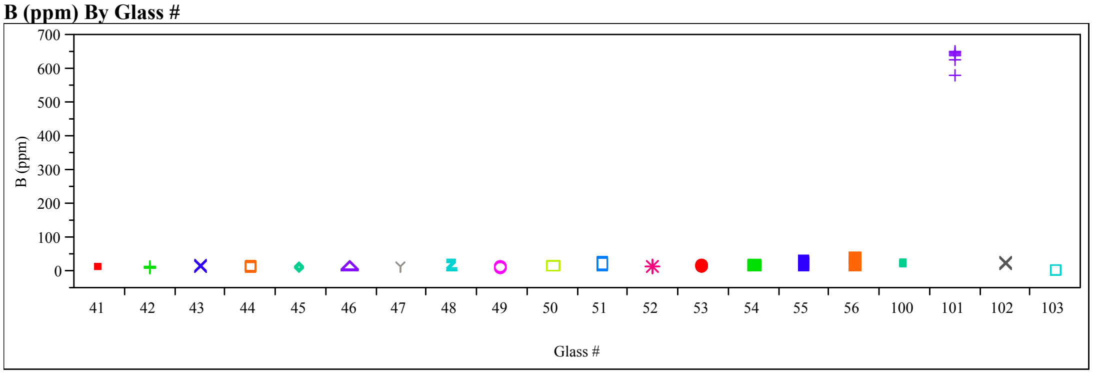
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	6	1.01500	0.48722	-0.0235	2.0535
2	6	1.24667	0.48722	0.2082	2.2852
3	6	0.90167	0.48722	-0.1368	1.9402

Std Error uses a pooled estimate of error variance

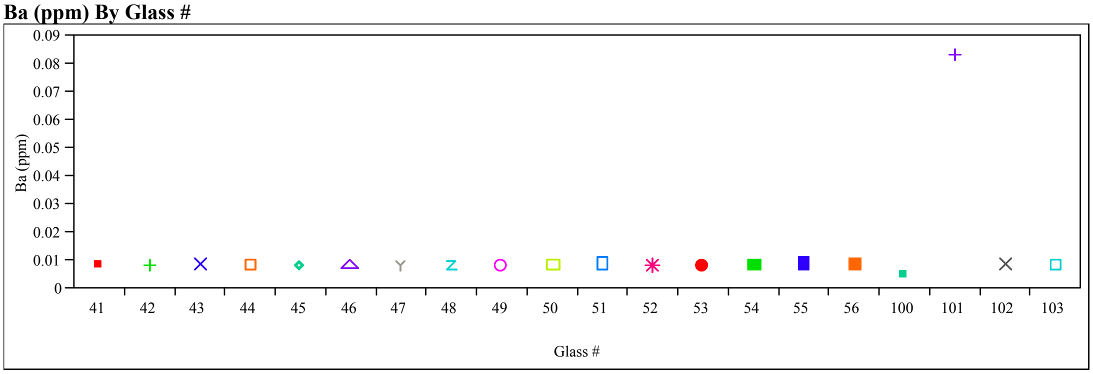
Exhibit E4. Laboratory PCT Measurements by Glass Number for Study Glasses and Standards

(100 – Solution Standard; 101 – EA; 102 – ARM; 103 – Blanks)

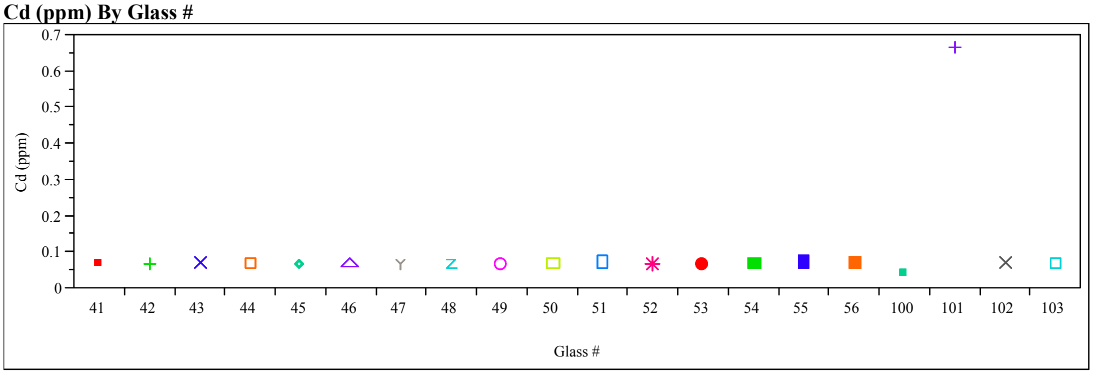
B (ppm) By Glass #



Ba (ppm) By Glass #



Cd (ppm) By Glass #



Cr (pp) By Glass #

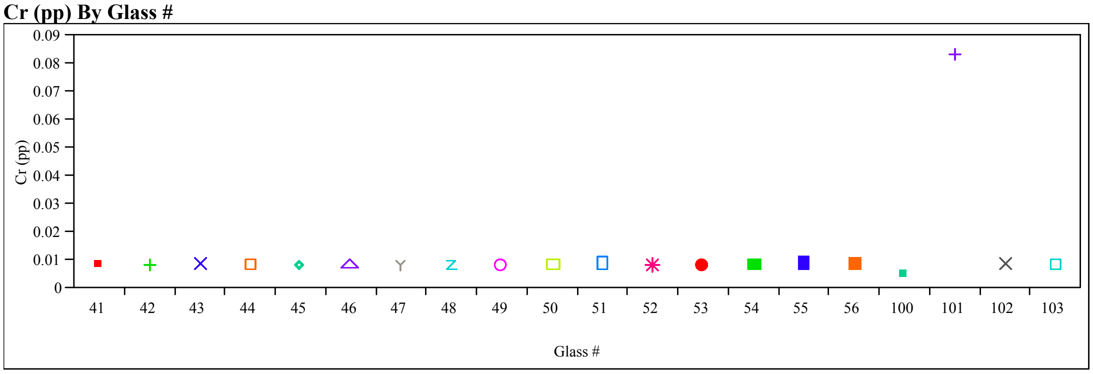
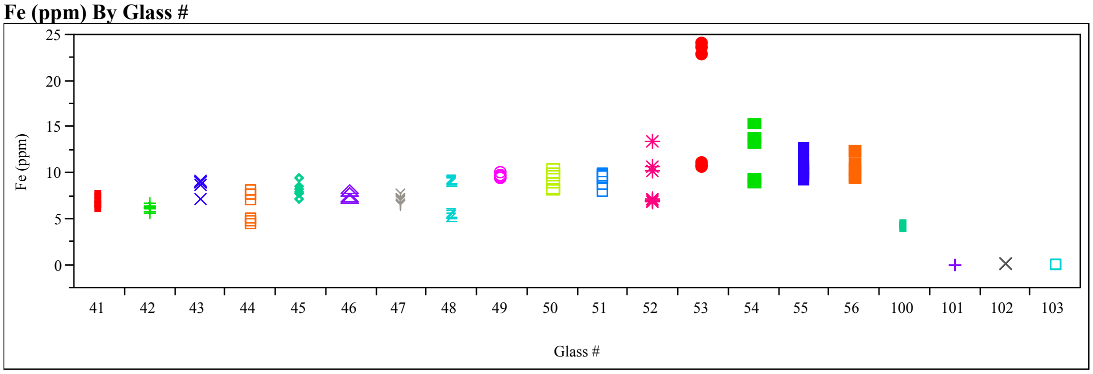


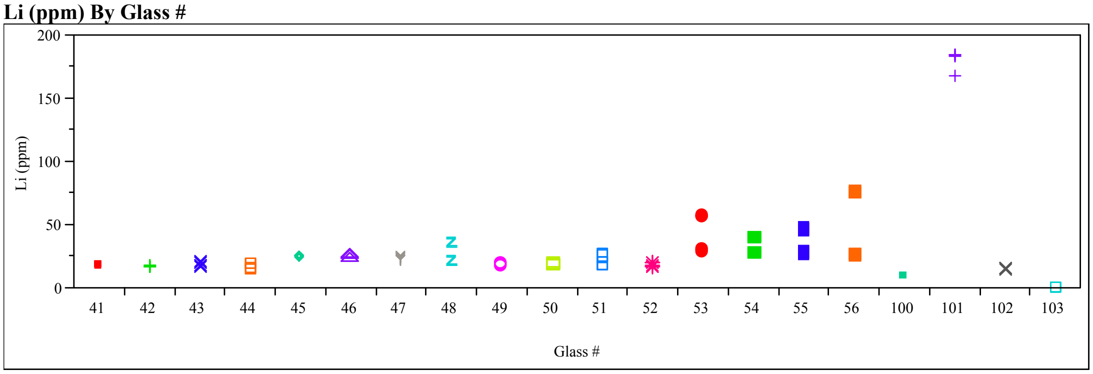
Exhibit E4. Laboratory PCT Measurements by Glass Number for Study Glasses and Standards (continued)

(100 – Solution Standard; 101 – EA; 102 – ARM; 103 – Blanks)

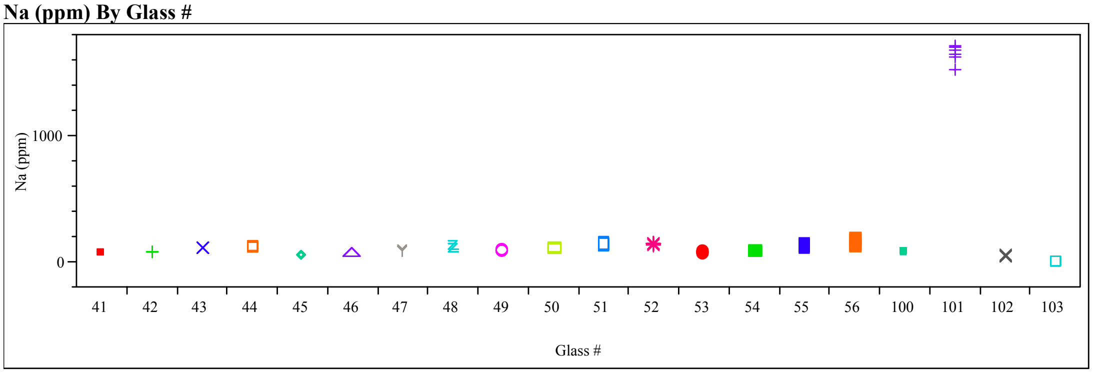
Fe (ppm) By Glass #



Li (ppm) By Glass #



Na (ppm) By Glass #



Pb (ppm) By Glass #

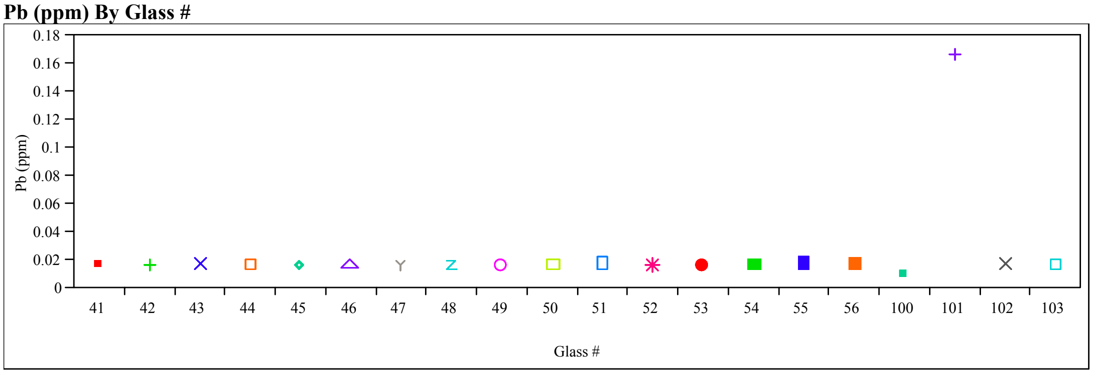
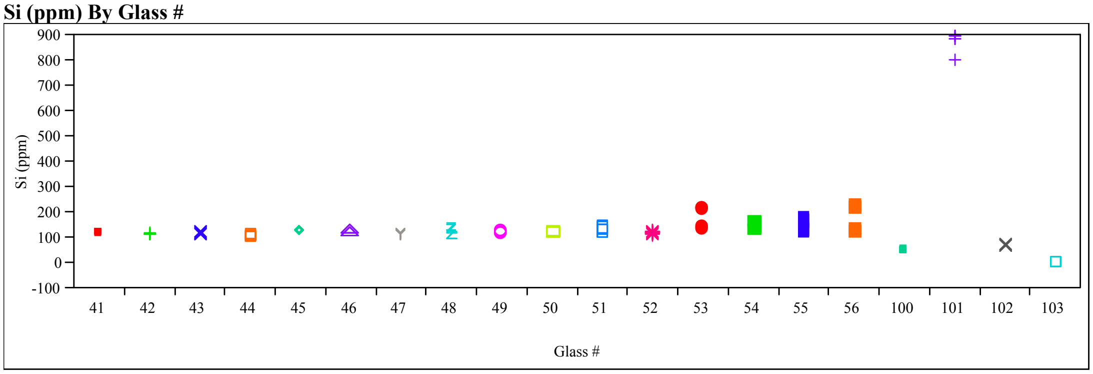


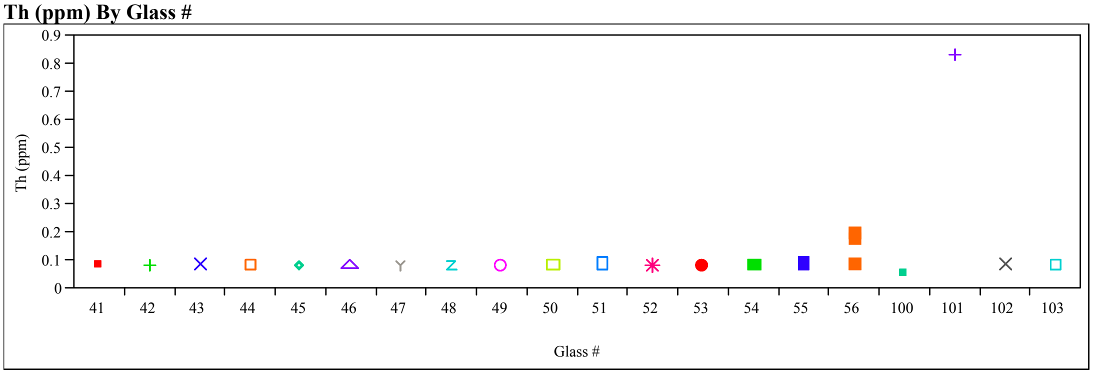
Exhibit E4. Laboratory PCT Measurements by Glass Number for Study Glasses and Standards (continued)

(100 – Solution Standard; 101 – EA; 102 – ARM; 103 – Blanks)

Si (ppm) By Glass #



Th (ppm) By Glass #



U (ppm) By Glass #

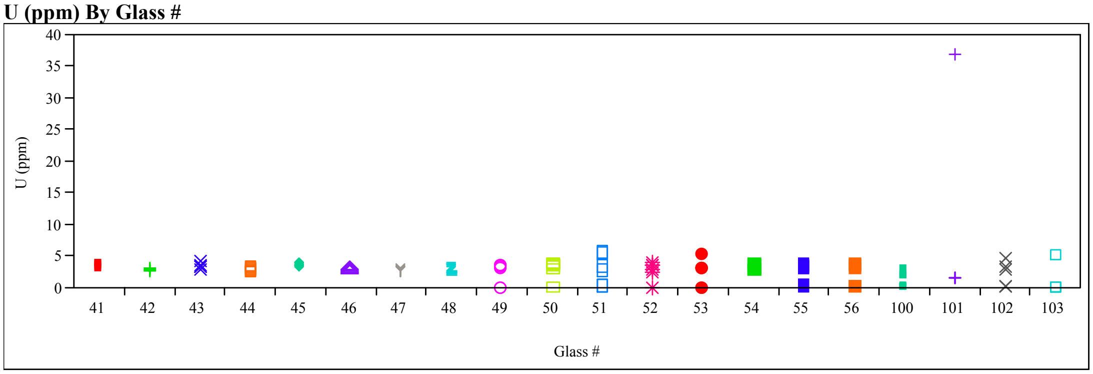
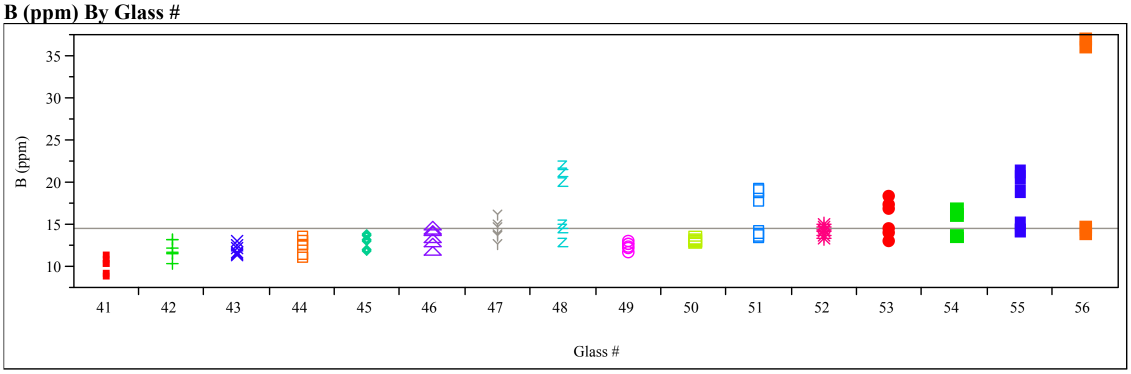
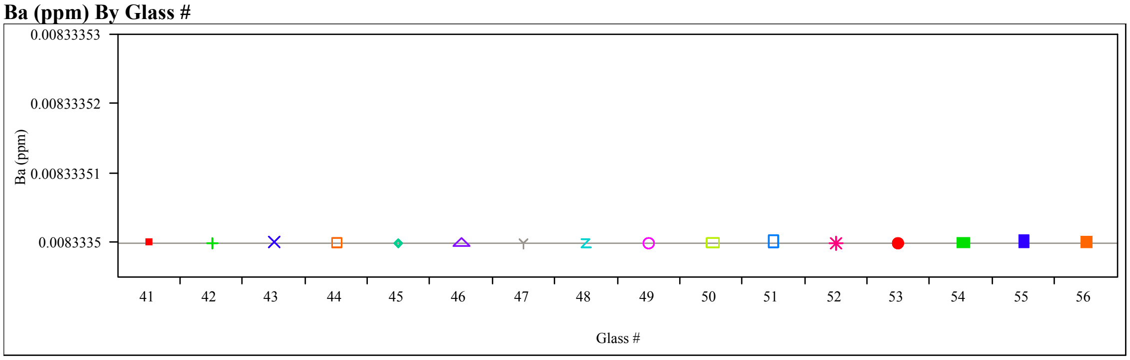


Exhibit E5. Laboratory PCT Measurements by Glass Number for Study Glasses

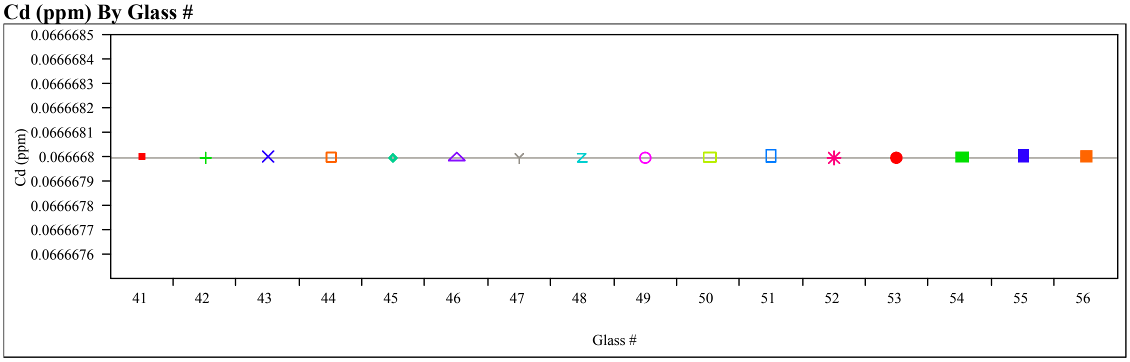
B (ppm) By Glass #



Ba (ppm) By Glass #



Cd (ppm) By Glass #



Cr (pp) By Glass #

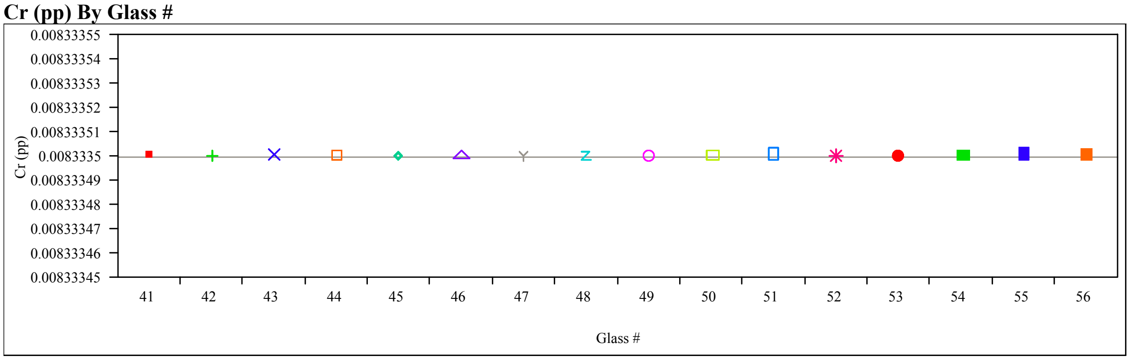
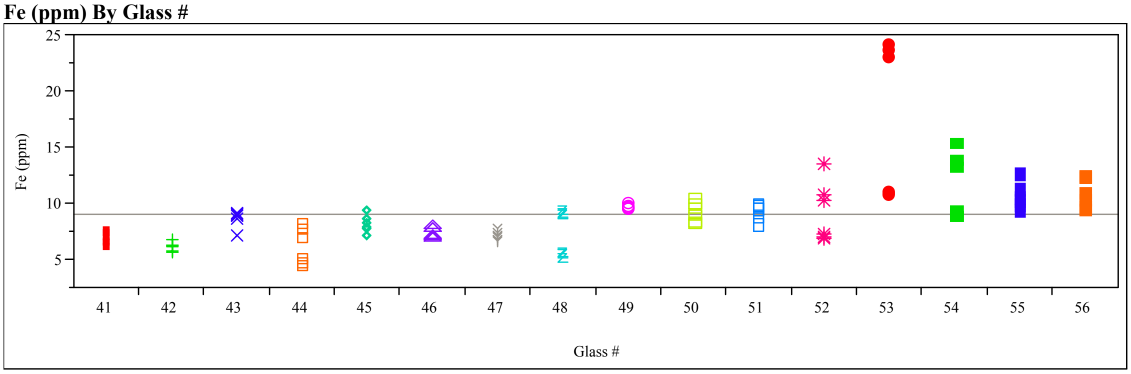
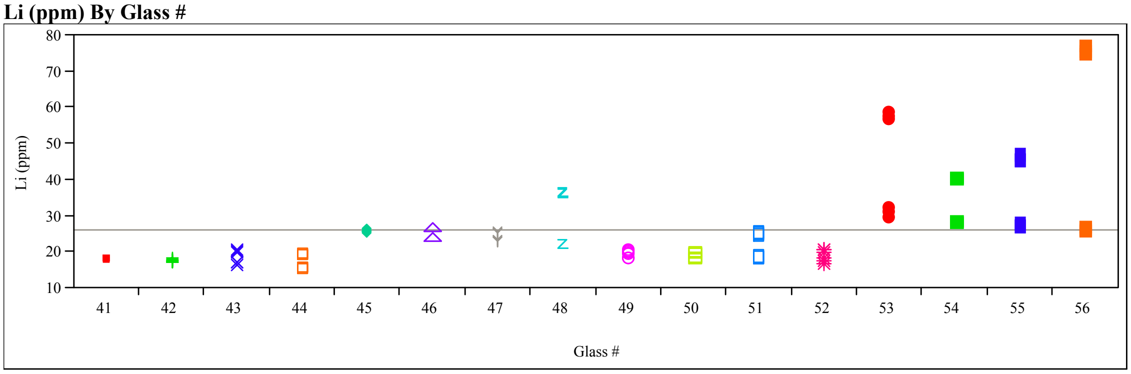


Exhibit E5. Laboratory PCT Measurements by Glass Number for Study Glasses (continued)

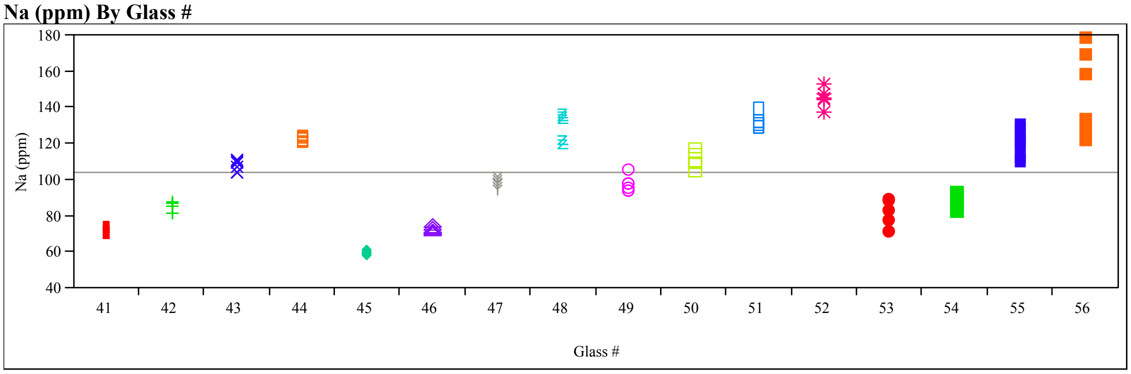
Fe (ppm) By Glass #



Li (ppm) By Glass #



Na (ppm) By Glass #



Pb (ppm) By Glass #

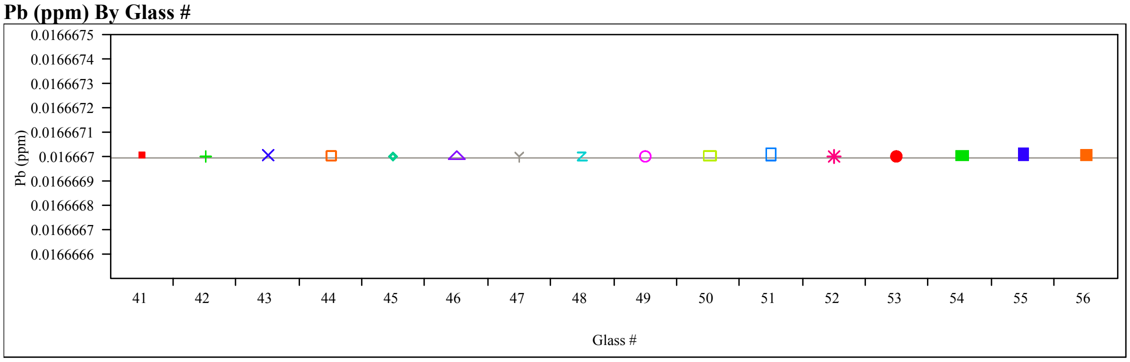
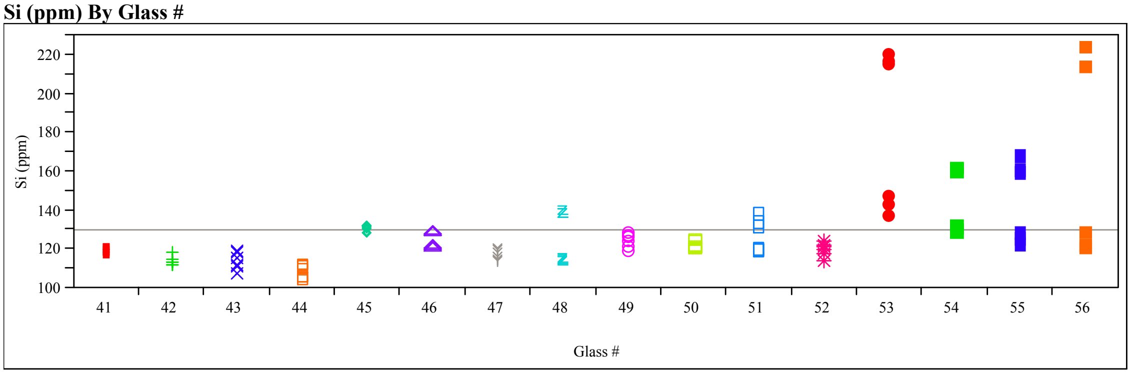
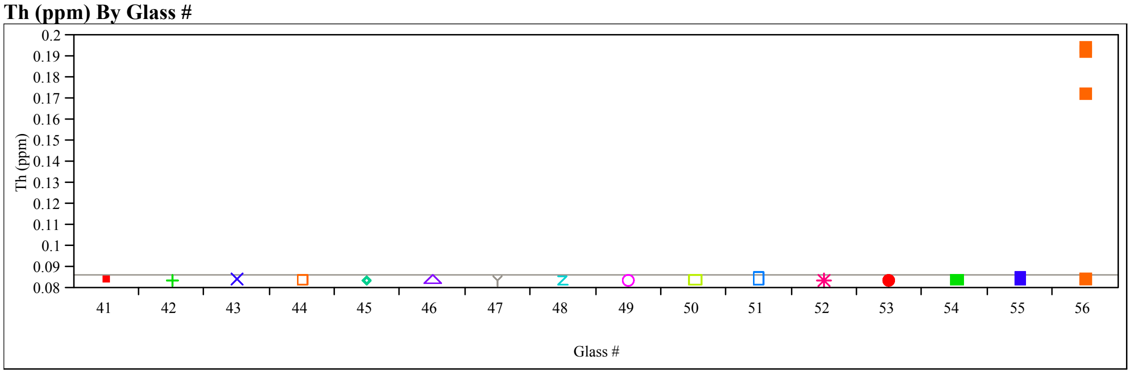


Exhibit E5. Laboratory PCT Measurements by Glass Number for Study Glasses (continued)

Si (ppm) By Glass #



Th (ppm) By Glass #



U (ppm) By Glass #

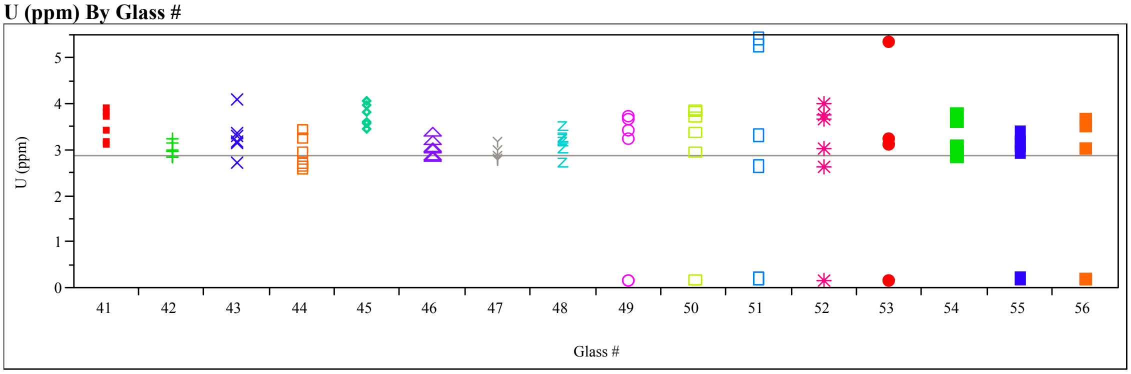


Exhibit E6. Correlations and Scatter Plots of Normalized PCTs Over All Compositional Views and Heat Treatments

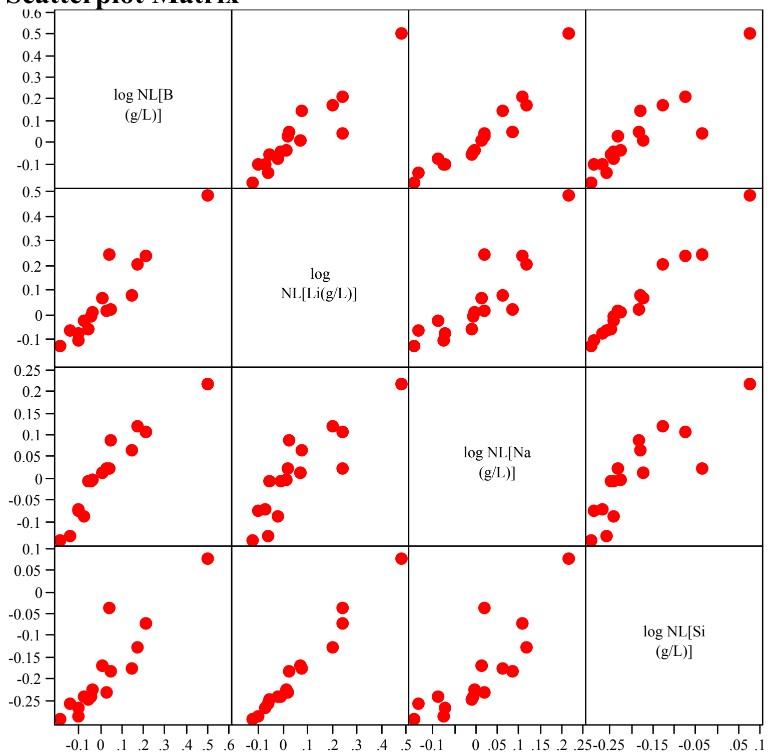
Comp View/Heat Treatment=Measured bc-ccc

Multivariate

Correlations

	log NL[B (g/L)]	log NL[Li(g/L)]	log NL[Na (g/L)]	log NL[Si (g/L)]
log NL[B (g/L)]	1.0000	0.9357	0.9432	0.9013
log NL[Li(g/L)]	0.9357	1.0000	0.8632	0.9877
log NL[Na (g/L)]	0.9432	0.8632	1.0000	0.8348
log NL[Si (g/L)]	0.9013	0.9877	0.8348	1.0000

Scatterplot Matrix



Comp View/Heat Treatment=Measured bc-quenched

Multivariate

Correlations

	log NL[B (g/L)]	log NL[Li(g/L)]	log NL[Na (g/L)]	log NL[Si (g/L)]
log NL[B (g/L)]	1.0000	0.7638	0.9181	0.8431
log NL[Li(g/L)]	0.7638	1.0000	0.6183	0.9287
log NL[Na (g/L)]	0.9181	0.6183	1.0000	0.7764
log NL[Si (g/L)]	0.8431	0.9287	0.7764	1.0000

Scatterplot Matrix

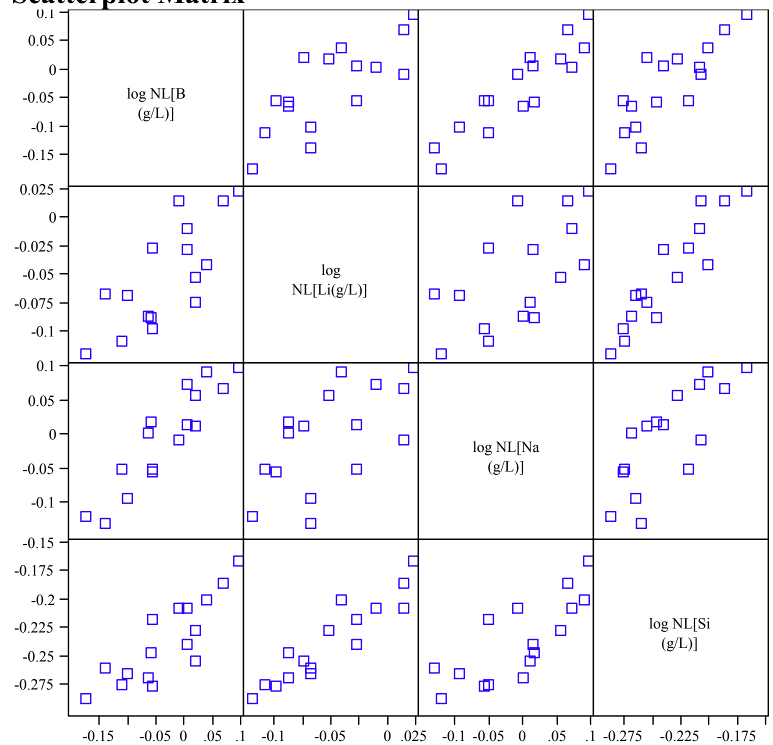
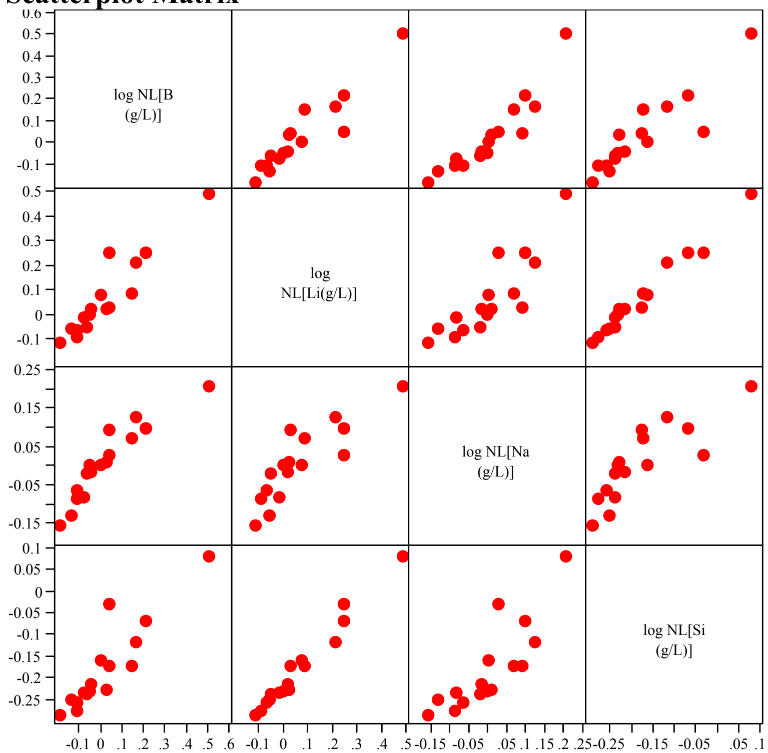


Exhibit E6. Correlations and Scatter Plots of Normalized PCTs Over All Compositional Views and Heat Treatments (continued)

Comp View/Heat Treatment=Measured-ccc
Multivariate
Correlations

	log NL[B (g/L)]	log NL[Li(g/L)]	log NL[Na (g/L)]	log NL[Si (g/L)]
log NL[B (g/L)]	1.0000	0.9384	0.9285	0.9049
log NL[Li(g/L)]	0.9384	1.0000	0.8623	0.9876
log NL[Na (g/L)]	0.9285	0.8623	1.0000	0.8397
log NL[Si (g/L)]	0.9049	0.9876	0.8397	1.0000

Scatterplot Matrix



Comp View/Heat Treatment=Measured-quenched
Multivariate
Correlations

	log NL[B (g/L)]	log NL[Li(g/L)]	log NL[Na (g/L)]	log NL[Si (g/L)]
log NL[B (g/L)]	1.0000	0.7708	0.8743	0.8491
log NL[Li(g/L)]	0.7708	1.0000	0.6077	0.9269
log NL[Na (g/L)]	0.8743	0.6077	1.0000	0.7856
log NL[Si (g/L)]	0.8491	0.9269	0.7856	1.0000

Scatterplot Matrix

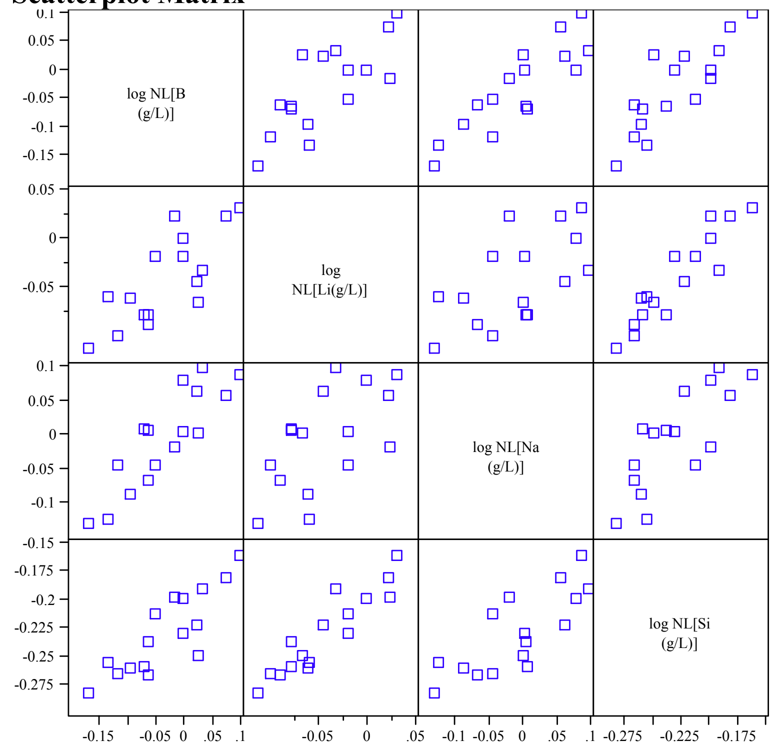
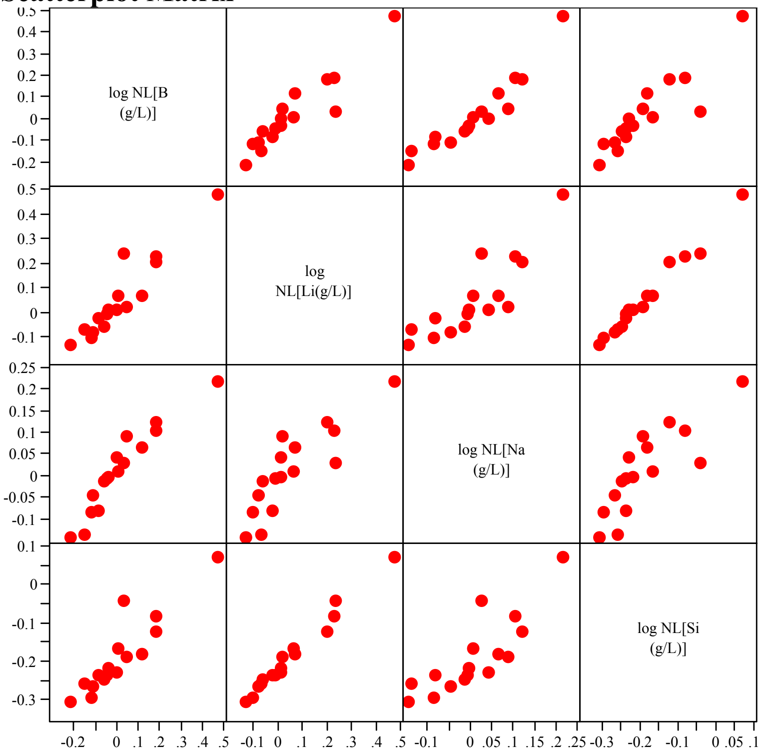


Exhibit E6. Correlations and Scatter Plots of Normalized PCTs Over All Compositional Views and Heat Treatments (continued)

Comp View/Heat Treatment=target-ccc
Multivariate
Correlations

	log NL[B (g/L)]	log NL[Li(g/L)]	log NL[Na (g/L)]	log NL[Si (g/L)]
log NL[B (g/L)]	1.0000	0.9382	0.9459	0.9062
log NL[Li(g/L)]	0.9382	1.0000	0.8582	0.9903
log NL[Na (g/L)]	0.9459	0.8582	1.0000	0.8320
log NL[Si (g/L)]	0.9062	0.9903	0.8320	1.0000

Scatterplot Matrix



Comp View/Heat Treatment=target-quenched
Multivariate
Correlations

	log NL[B (g/L)]	log NL[Li(g/L)]	log NL[Na (g/L)]	log NL[Si (g/L)]
log NL[B (g/L)]	1.0000	0.7872	0.9162	0.8679
log NL[Li(g/L)]	0.7872	1.0000	0.5860	0.9460
log NL[Na (g/L)]	0.9162	0.5860	1.0000	0.7607
log NL[Si (g/L)]	0.8679	0.9460	0.7607	1.0000

Scatterplot Matrix

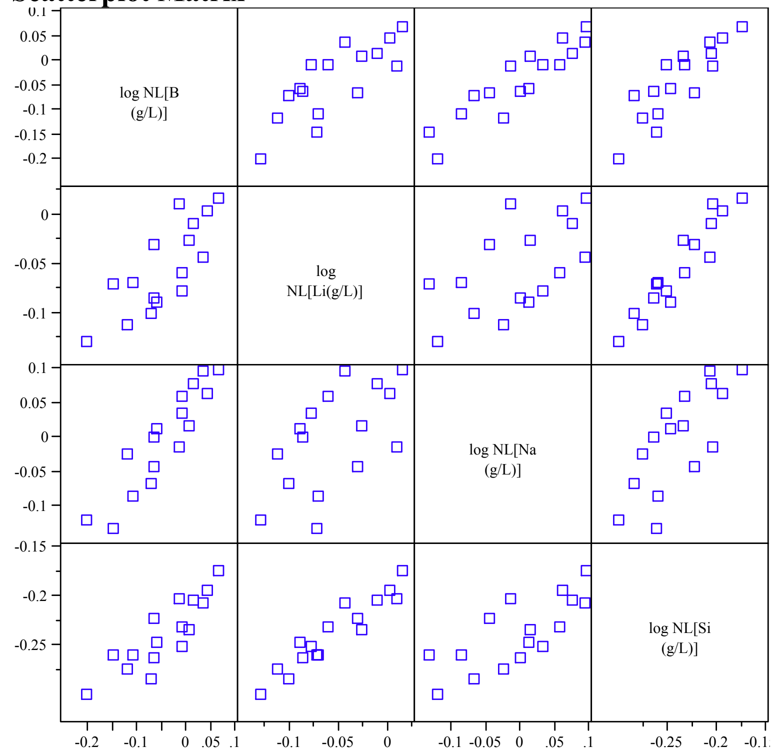
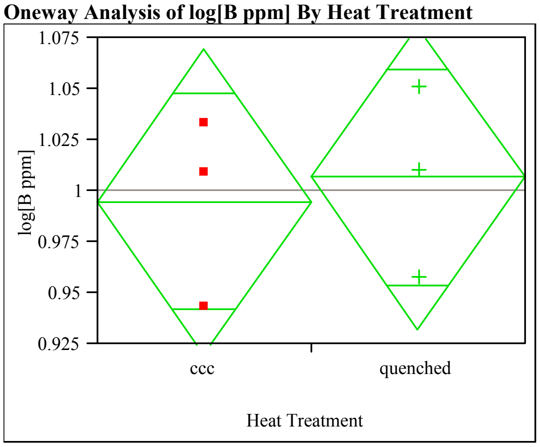


Exhibit E7. Effects of Heat Treatment on PCT ppm-Response of Study Glasses

Glass ID=NEPH3-41

Oneway Analysis of log[B ppm] By Heat Treatment



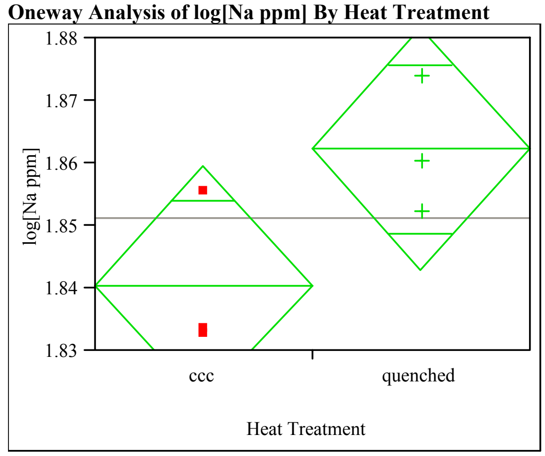
t Test

ccc-quenched

Assuming equal variances

Difference	-0.01198	t Ratio	-0.31508
Std Err Dif	0.03802	DF	4
Upper CL Dif	0.09357	Prob > |t|	0.7685
Lower CL Dif	-0.11753	Prob > t	0.6158
Confidence	0.95	Prob < t	0.3842

Oneway Analysis of log[Na ppm] By Heat Treatment



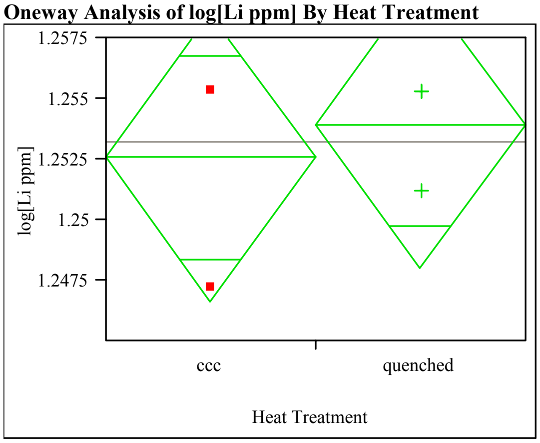
t Test

ccc-quenched

Assuming equal variances

Difference	-0.02177	t Ratio	-2.2242
Std Err Dif	0.00979	DF	4
Upper CL Dif	0.00541	Prob > |t|	0.0902
Lower CL Dif	-0.04895	Prob > t	0.9549
Confidence	0.95	Prob < t	0.0451

Oneway Analysis of log[Li ppm] By Heat Treatment



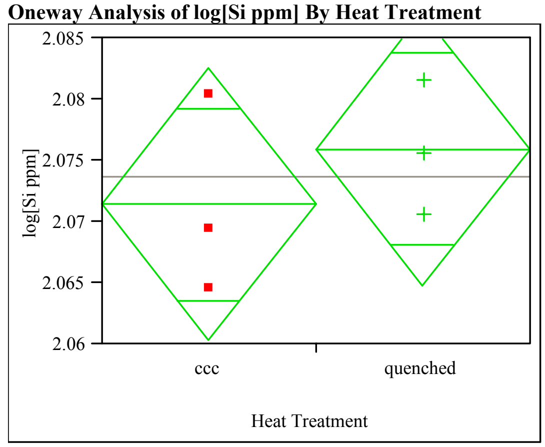
t Test

ccc-quenched

Assuming equal variances

Difference	-0.00136	t Ratio	-0.44972
Std Err Dif	0.00302	DF	4
Upper CL Dif	0.00703	Prob > |t|	0.6762
Lower CL Dif	-0.00975	Prob > t	0.6619
Confidence	0.95	Prob < t	0.3381

Oneway Analysis of log[Si ppm] By Heat Treatment



t Test

ccc-quenched

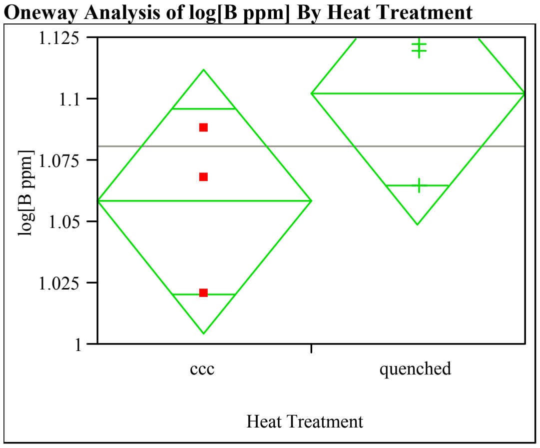
Assuming equal variances

Difference	-0.00451	t Ratio	-0.79506
Std Err Dif	0.00567	DF	4
Upper CL Dif	0.01123	Prob > |t|	0.4711
Lower CL Dif	-0.02025	Prob > t	0.7645
Confidence	0.95	Prob < t	0.2355

Exhibit E7. Effects of Heat Treatment on PCT ppm-Response of Study Glasses (continued)

Glass ID=NEPH3-42

Oneway Analysis of log[B ppm] By Heat Treatment



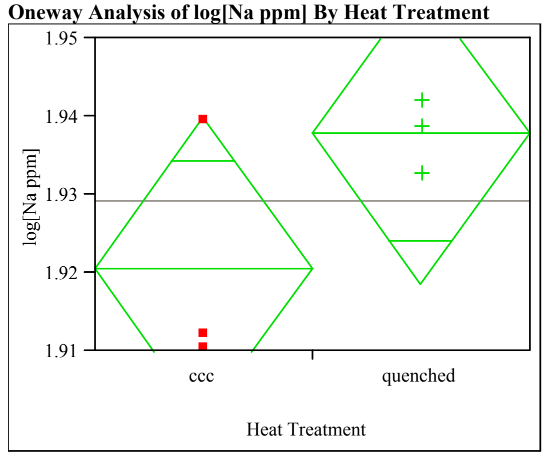
t Test

ccc-quenched

Assuming equal variances

Difference	-0.04409	t Ratio	-1.61201
Std Err Dif	0.02735	DF	4
Upper CL Dif	0.03185	Prob > |t|	0.1823
Lower CL Dif	-0.12002	Prob > t	0.9089
Confidence	0.95	Prob < t	0.0911

Oneway Analysis of log[Na ppm] By Heat Treatment



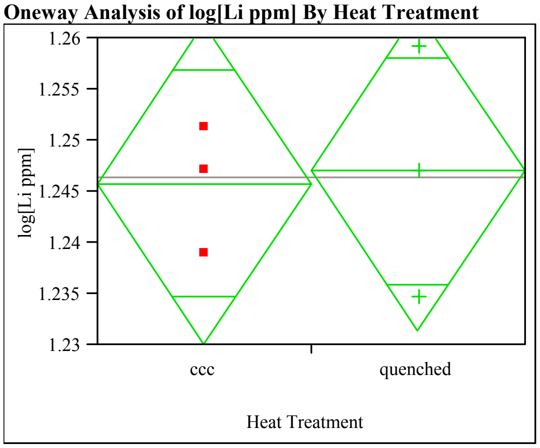
t Test

ccc-quenched

Assuming equal variances

Difference	-0.01722	t Ratio	-1.75004
Std Err Dif	0.00984	DF	4
Upper CL Dif	0.01010	Prob > |t|	0.1550
Lower CL Dif	-0.04455	Prob > t	0.9225
Confidence	0.95	Prob < t	0.0775

Oneway Analysis of log[Li ppm] By Heat Treatment



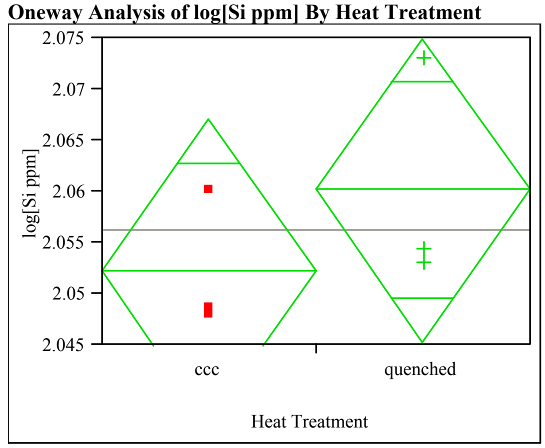
t Test

ccc-quenched

Assuming equal variances

Difference	-0.00128	t Ratio	-0.16079
Std Err Dif	0.00797	DF	4
Upper CL Dif	0.02086	Prob > |t|	0.8801
Lower CL Dif	-0.02342	Prob > t	0.5600
Confidence	0.95	Prob < t	0.4400

Oneway Analysis of log[Si ppm] By Heat Treatment



t Test

ccc-quenched

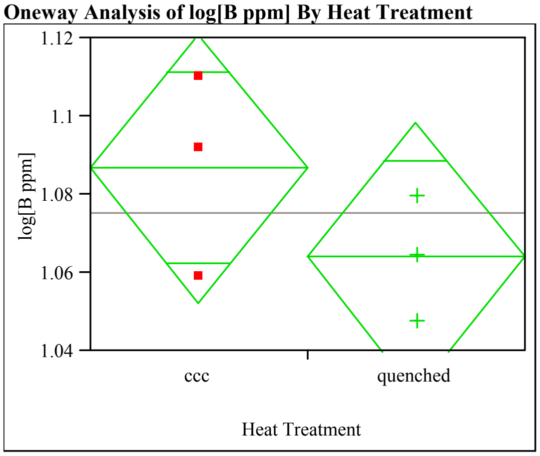
Assuming equal variances

Difference	-0.00799	t Ratio	-1.05445
Std Err Dif	0.00758	DF	4
Upper CL Dif	0.01305	Prob > |t|	0.3512
Lower CL Dif	-0.02904	Prob > t	0.8244
Confidence	0.95	Prob < t	0.1756

Exhibit E7. Effects of Heat Treatment on PCT ppm-Response of Study Glasses (continued)

Glass ID=NEPH3-43

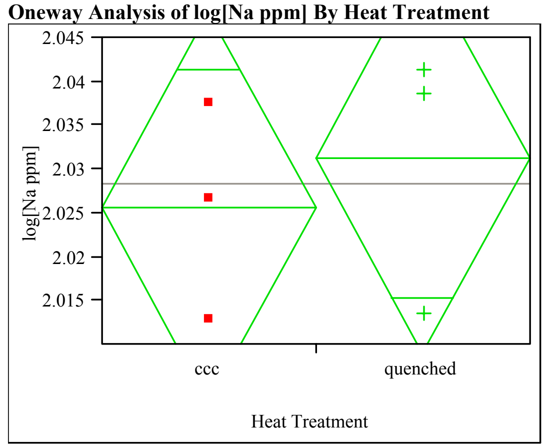
Oneway Analysis of log[B ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.02278	t Ratio	1.295567
Std Err Dif	0.01758	DF	4
Upper CL Dif	0.07159	Prob > |t|	0.2648
Lower CL Dif	-0.02604	Prob > t	0.1324
Confidence	0.95	Prob < t	0.8676

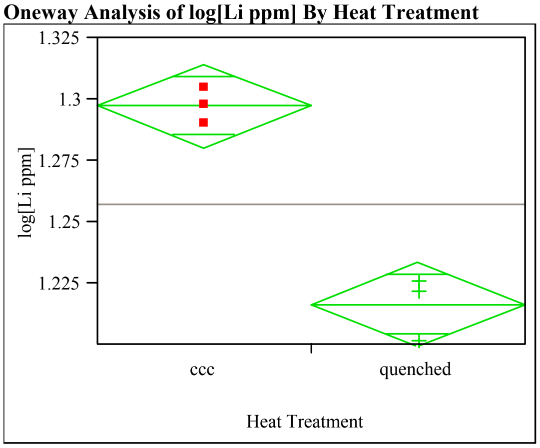
Oneway Analysis of log[Na ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	-0.00558	t Ratio	-0.49077
Std Err Dif	0.01138	DF	4
Upper CL Dif	0.02601	Prob > |t|	0.6493
Lower CL Dif	-0.03717	Prob > t	0.6754
Confidence	0.95	Prob < t	0.3246

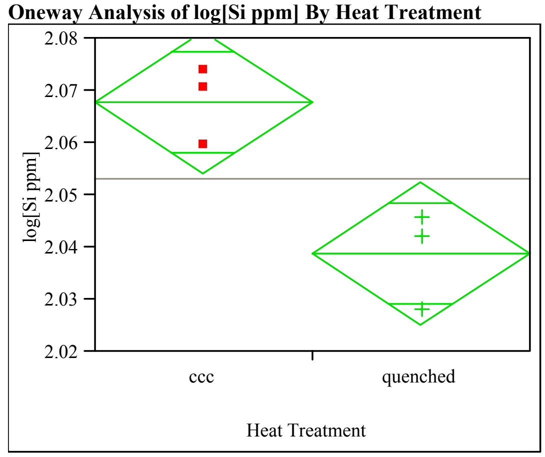
Oneway Analysis of log[Li ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.080731	t Ratio	9.393163
Std Err Dif	0.008595	DF	4
Upper CL Dif	0.104594	Prob > |t|	0.0007
Lower CL Dif	0.056869	Prob > t	0.0004
Confidence	0.95	Prob < t	0.9996

Oneway Analysis of log[Si ppm] By Heat Treatment



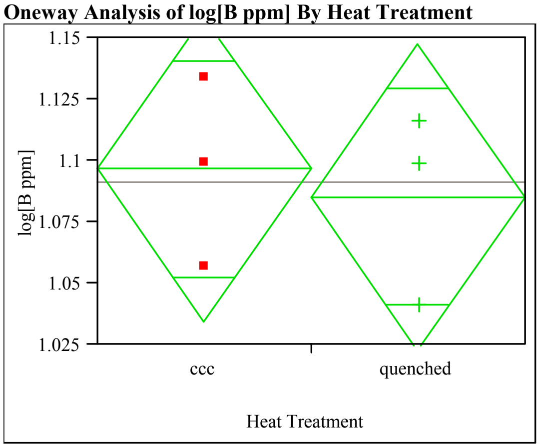
t Test
ccc-quenched
Assuming equal variances

Difference	0.029252	t Ratio	4.199821
Std Err Dif	0.006965	DF	4
Upper CL Dif	0.048590	Prob > |t|	0.0137
Lower CL Dif	0.009914	Prob > t	0.0068
Confidence	0.95	Prob < t	0.9932

Exhibit E7. Effects of Heat Treatment on PCT ppm-Response of Study Glasses (continued)

Glass ID=NEPH3-44

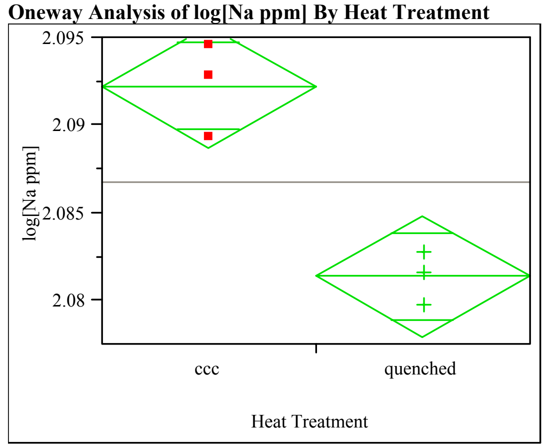
Oneway Analysis of log[B ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.01115	t Ratio	0.352564
Std Err Dif	0.03164	DF	4
Upper CL Dif	0.09899	Prob > |t|	0.7422
Lower CL Dif	-0.07669	Prob > t	0.3711
Confidence	0.95	Prob < t	0.6289

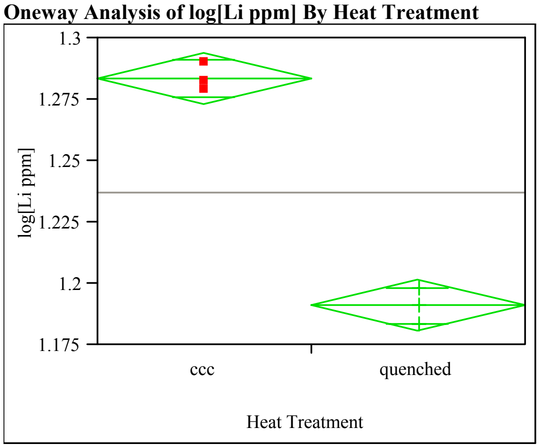
Oneway Analysis of log[Na ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.010862	t Ratio	6.106634
Std Err Dif	0.001779	DF	4
Upper CL Dif	0.015800	Prob > |t|	0.0036
Lower CL Dif	0.005923	Prob > t	0.0018
Confidence	0.95	Prob < t	0.9982

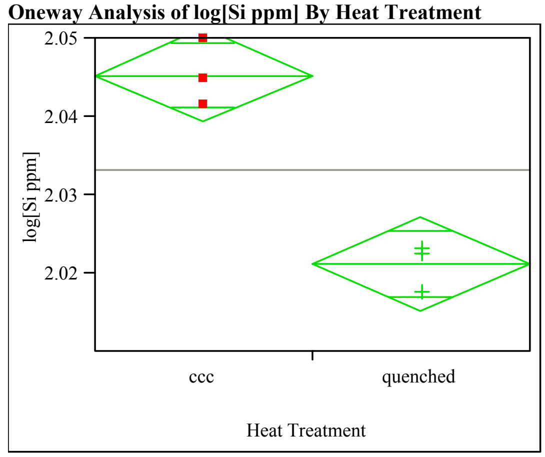
Oneway Analysis of log[Li ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.092709	t Ratio	17.39502
Std Err Dif	0.005330	DF	4
Upper CL Dif	0.107506	Prob > |t|	<.0001
Lower CL Dif	0.077912	Prob > t	<.0001
Confidence	0.95	Prob < t	1.0000

Oneway Analysis of log[Si ppm] By Heat Treatment



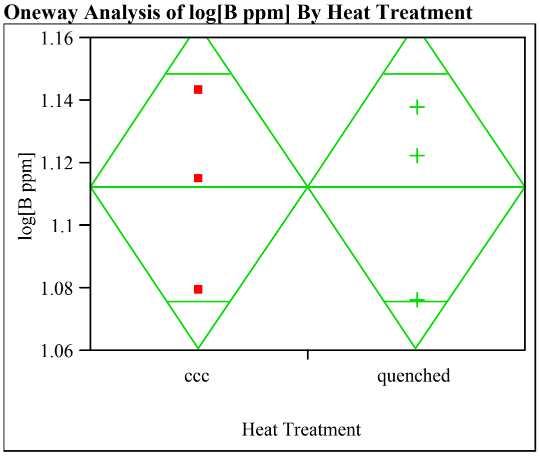
t Test
ccc-quenched
Assuming equal variances

Difference	0.024127	t Ratio	7.996557
Std Err Dif	0.003017	DF	4
Upper CL Dif	0.032503	Prob > |t|	0.0013
Lower CL Dif	0.015750	Prob > t	0.0007
Confidence	0.95	Prob < t	0.9993

Exhibit E7. Effects of Heat Treatment on PCT ppm-Response of Study Glasses (continued)

Glass ID=NEPH3-45

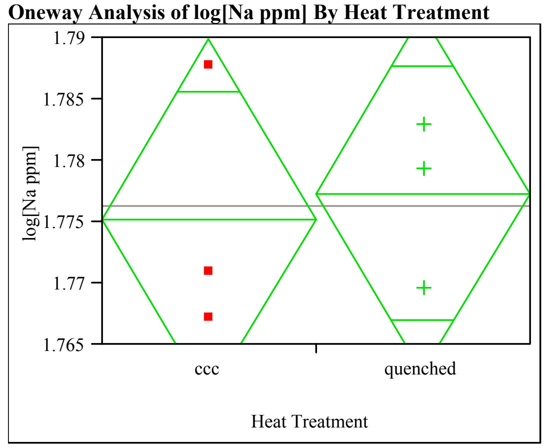
Oneway Analysis of log[B ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.000007	t Ratio	0.000286
Std Err Dif	0.02622	DF	4
Upper CL Dif	0.07282	Prob > |t|	0.9998
Lower CL Dif	-0.07280	Prob > t	0.4999
Confidence	0.95	Prob < t	0.5001

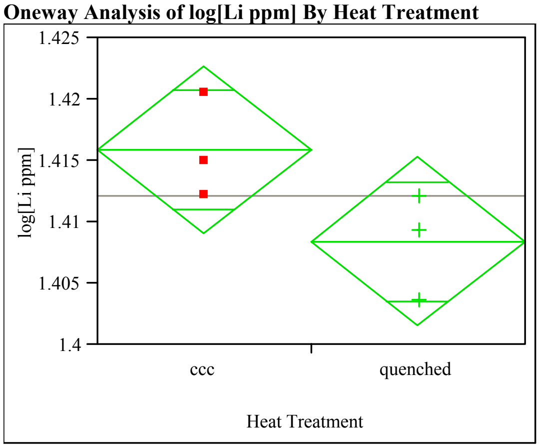
Oneway Analysis of log[Na ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	-0.00208	t Ratio	-0.27776
Std Err Dif	0.00747	DF	4
Upper CL Dif	0.01867	Prob > |t|	0.7950
Lower CL Dif	-0.02282	Prob > t	0.6025
Confidence	0.95	Prob < t	0.3975

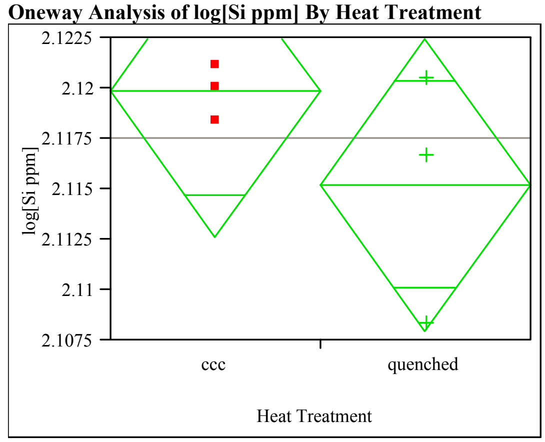
Oneway Analysis of log[Li ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.00747	t Ratio	2.137898
Std Err Dif	0.00350	DF	4
Upper CL Dif	0.01718	Prob > |t|	0.0993
Lower CL Dif	-0.00223	Prob > t	0.0497
Confidence	0.95	Prob < t	0.9503

Oneway Analysis of log[Si ppm] By Heat Treatment



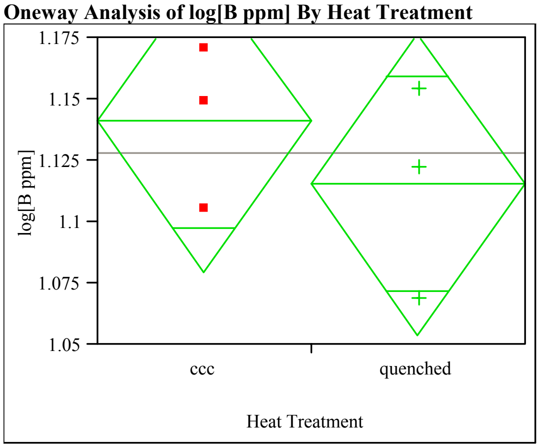
t Test
ccc-quenched
Assuming equal variances

Difference	0.00463	t Ratio	1.251875
Std Err Dif	0.00370	DF	4
Upper CL Dif	0.01490	Prob > |t|	0.2788
Lower CL Dif	-0.00564	Prob > t	0.1394
Confidence	0.95	Prob < t	0.8606

Exhibit E7. Effects of Heat Treatment on PCT ppm-Response of Study Glasses (continued)

Glass ID=NEPH3-46

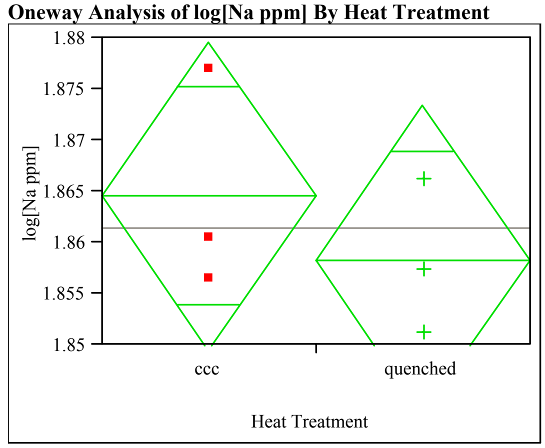
Oneway Analysis of log[B ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.02581	t Ratio	0.821072
Std Err Dif	0.03144	DF	4
Upper CL Dif	0.11310	Prob > |t|	0.4577
Lower CL Dif	-0.06148	Prob > t	0.2289
Confidence	0.95	Prob < t	0.7711

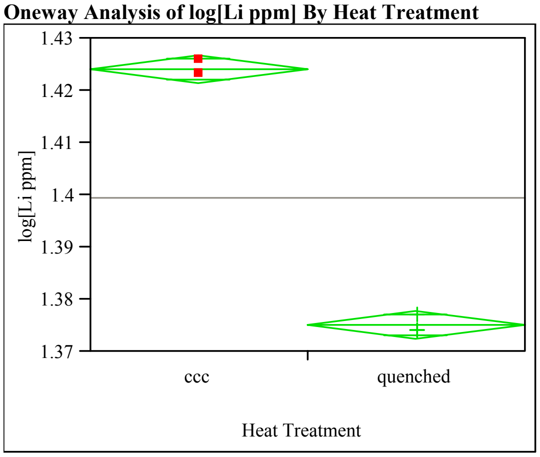
Oneway Analysis of log[Na ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.00626	t Ratio	0.814247
Std Err Dif	0.00769	DF	4
Upper CL Dif	0.02760	Prob > |t|	0.4612
Lower CL Dif	-0.01508	Prob > t	0.2306
Confidence	0.95	Prob < t	0.7694

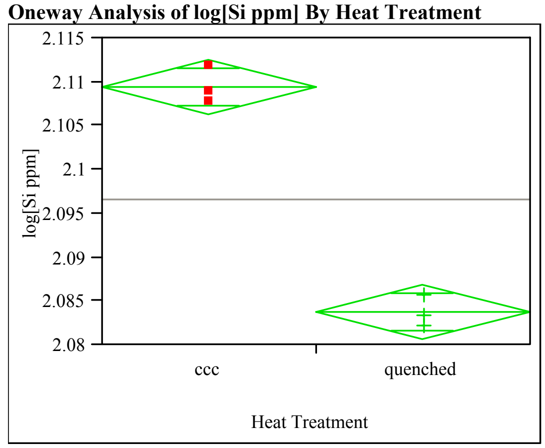
Oneway Analysis of log[Li ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.049001	t Ratio	35.96934
Std Err Dif	0.001362	DF	4
Upper CL Dif	0.052783	Prob > |t|	<.0001
Lower CL Dif	0.045218	Prob > t	<.0001
Confidence	0.95	Prob < t	1.0000

Oneway Analysis of log[Si ppm] By Heat Treatment



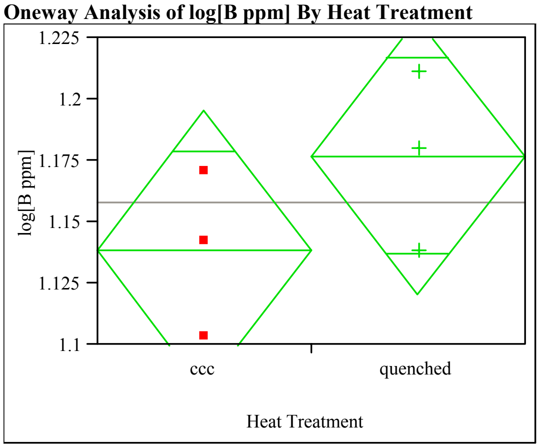
t Test
ccc-quenched
Assuming equal variances

Difference	0.025684	t Ratio	16.32364
Std Err Dif	0.001573	DF	4
Upper CL Dif	0.030053	Prob > |t|	<.0001
Lower CL Dif	0.021316	Prob > t	<.0001
Confidence	0.95	Prob < t	1.0000

Exhibit E7. Effects of Heat Treatment on PCT ppm-Response of Study Glasses (continued)

Glass ID=NEPH3-47

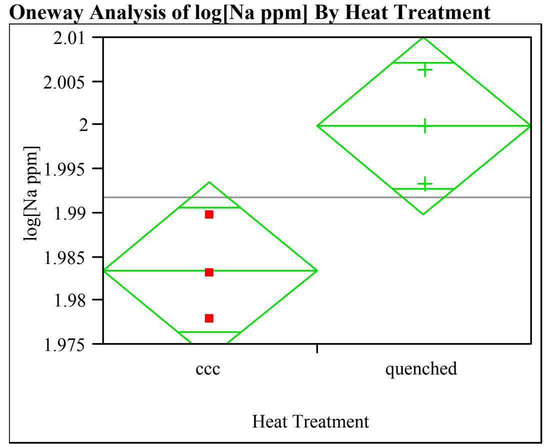
Oneway Analysis of log[B ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	-0.03818	t Ratio	-1.32691
Std Err Dif	0.02878	DF	4
Upper CL Dif	0.04171	Prob > |t|	0.2552
Lower CL Dif	-0.11808	Prob > t	0.8724
Confidence	0.95	Prob < t	0.1276

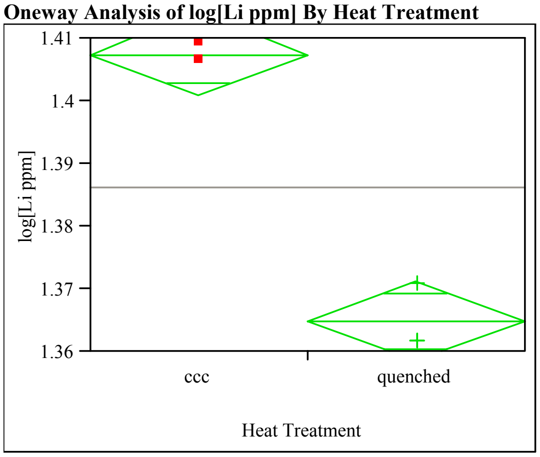
Oneway Analysis of log[Na ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	-0.01647	t Ratio	-3.21447
Std Err Dif	0.00512	DF	4
Upper CL Dif	-0.00224	Prob > |t|	0.0325
Lower CL Dif	-0.03069	Prob > t	0.9838
Confidence	0.95	Prob < t	0.0162

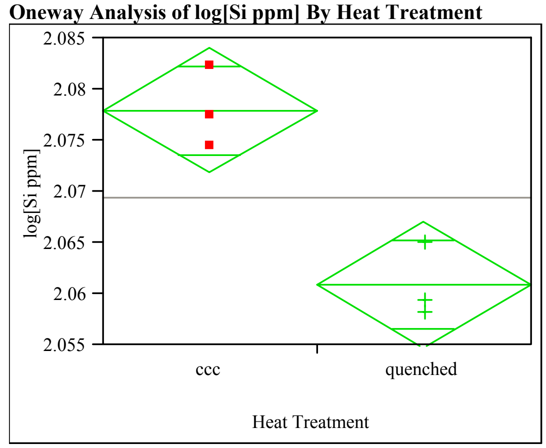
Oneway Analysis of log[Li ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.042642	t Ratio	13.10835
Std Err Dif	0.003253	DF	4
Upper CL Dif	0.051674	Prob > |t|	0.0002
Lower CL Dif	0.033610	Prob > t	<.0001
Confidence	0.95	Prob < t	0.9999

Oneway Analysis of log[Si ppm] By Heat Treatment



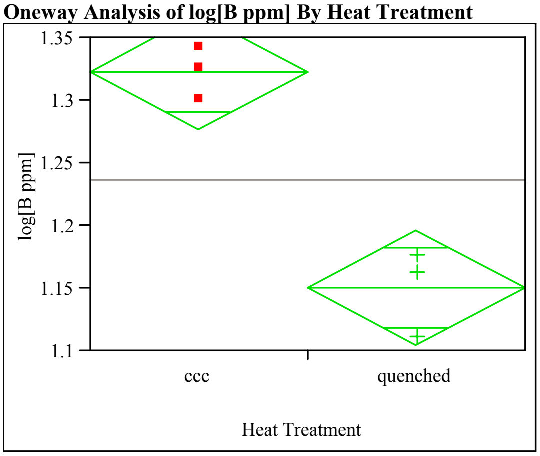
t Test
ccc-quenched
Assuming equal variances

Difference	0.017064	t Ratio	5.466503
Std Err Dif	0.003122	DF	4
Upper CL Dif	0.025731	Prob > |t|	0.0054
Lower CL Dif	0.008397	Prob > t	0.0027
Confidence	0.95	Prob < t	0.9973

Exhibit E7. Effects of Heat Treatment on PCT ppm-Response of Study Glasses (continued)

Glass ID=NEPH3-48

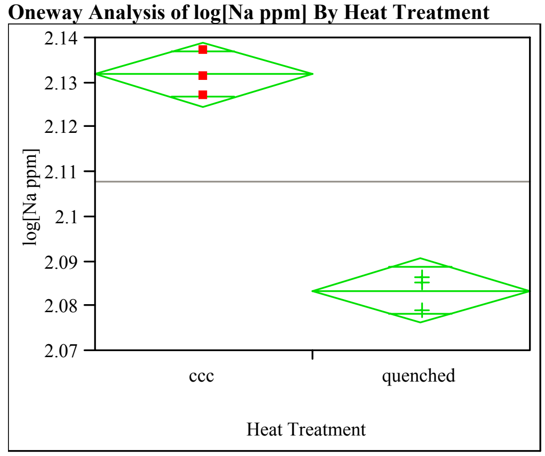
Oneway Analysis of log[B ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.172145	t Ratio	7.44033
Std Err Dif	0.023137	DF	4
Upper CL Dif	0.236383	Prob > |t|	0.0017
Lower CL Dif	0.107907	Prob > t	0.0009
Confidence	0.95	Prob < t	0.9991

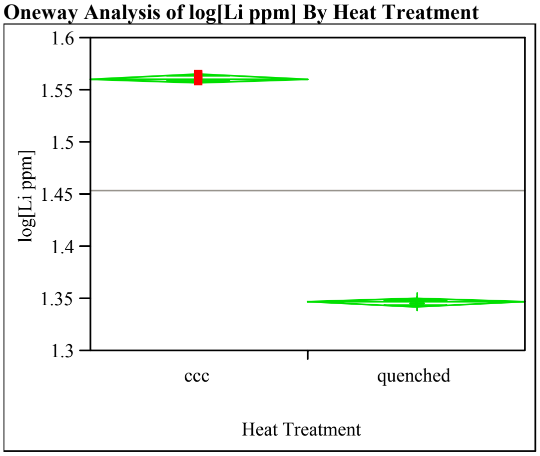
Oneway Analysis of log[Na ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.048348	t Ratio	13.122
Std Err Dif	0.003685	DF	4
Upper CL Dif	0.058578	Prob > |t|	0.0002
Lower CL Dif	0.038119	Prob > t	<.0001
Confidence	0.95	Prob < t	0.9999

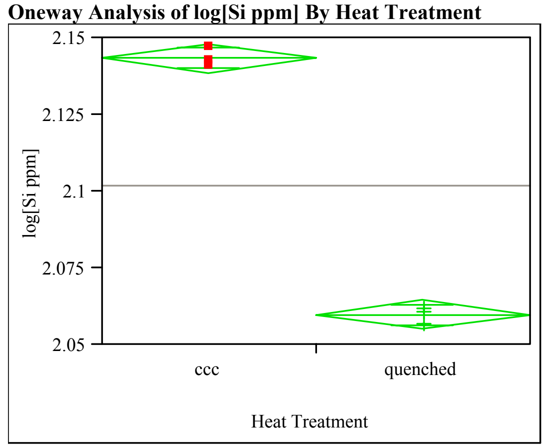
Oneway Analysis of log[Li ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.214839	t Ratio	104.2037
Std Err Dif	0.002062	DF	4
Upper CL Dif	0.220564	Prob > |t|	<.0001
Lower CL Dif	0.209115	Prob > t	<.0001
Confidence	0.95	Prob < t	1.0000

Oneway Analysis of log[Si ppm] By Heat Treatment



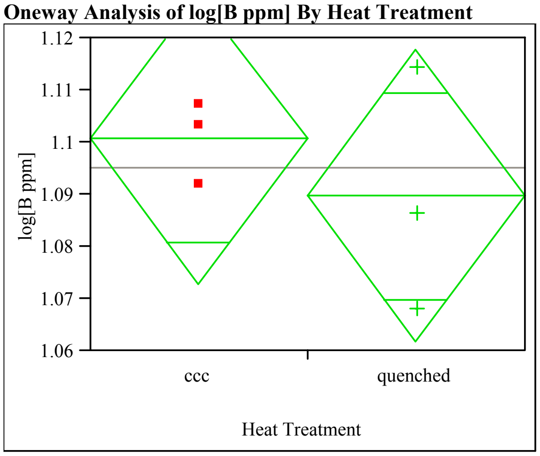
t Test
ccc-quenched
Assuming equal variances

Difference	0.083675	t Ratio	34.71592
Std Err Dif	0.002410	DF	4
Upper CL Dif	0.090367	Prob > |t|	<.0001
Lower CL Dif	0.076983	Prob > t	<.0001
Confidence	0.95	Prob < t	1.0000

Exhibit E7. Effects of Heat Treatment on PCT ppm-Response of Study Glasses (continued)

Glass ID=NEPH3-49

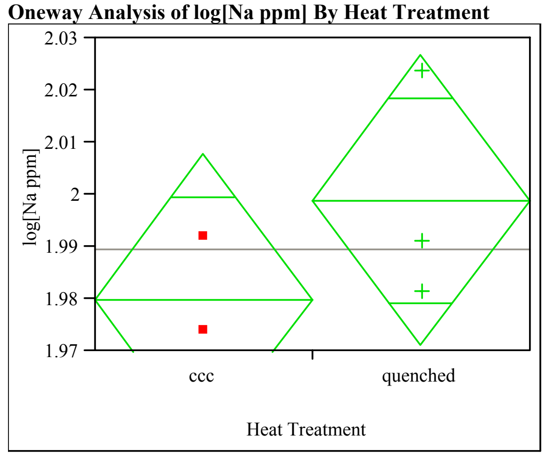
Oneway Analysis of log[B ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.01102	t Ratio	0.77311
Std Err Dif	0.01426	DF	4
Upper CL Dif	0.05060	Prob > |t|	0.4826
Lower CL Dif	-0.02856	Prob > t	0.2413
Confidence	0.95	Prob < t	0.7587

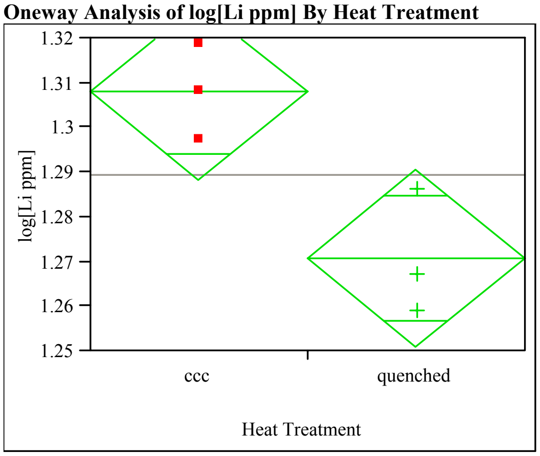
Oneway Analysis of log[Na ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	-0.01897	t Ratio	-1.33856
Std Err Dif	0.01417	DF	4
Upper CL Dif	0.02038	Prob > |t|	0.2517
Lower CL Dif	-0.05833	Prob > t	0.8741
Confidence	0.95	Prob < t	0.1259

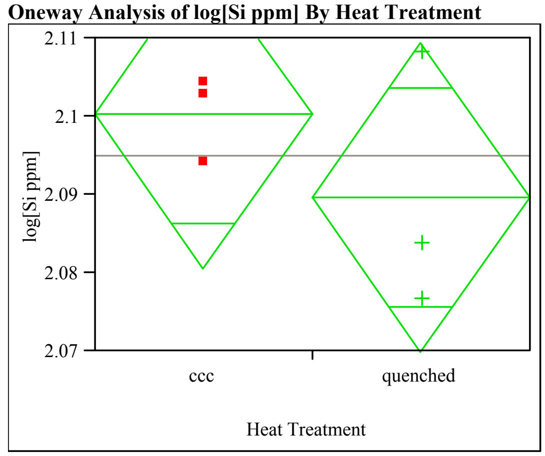
Oneway Analysis of log[Li ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.037203	t Ratio	3.675848
Std Err Dif	0.010121	DF	4
Upper CL Dif	0.065303	Prob > |t|	0.0213
Lower CL Dif	0.009103	Prob > t	0.0106
Confidence	0.95	Prob < t	0.9894

Oneway Analysis of log[Si ppm] By Heat Treatment



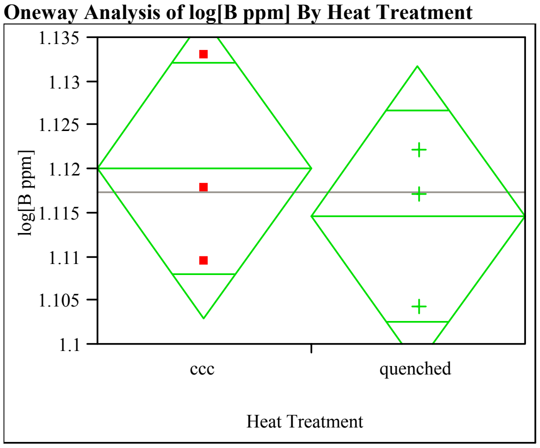
t Test
ccc-quenched
Assuming equal variances

Difference	0.01065	t Ratio	1.057116
Std Err Dif	0.01008	DF	4
Upper CL Dif	0.03863	Prob > |t|	0.3501
Lower CL Dif	-0.01733	Prob > t	0.1750
Confidence	0.95	Prob < t	0.8250

Exhibit E7. Effects of Heat Treatment on PCT ppm-Response of Study Glasses (continued)

Glass ID=NEPH3-50

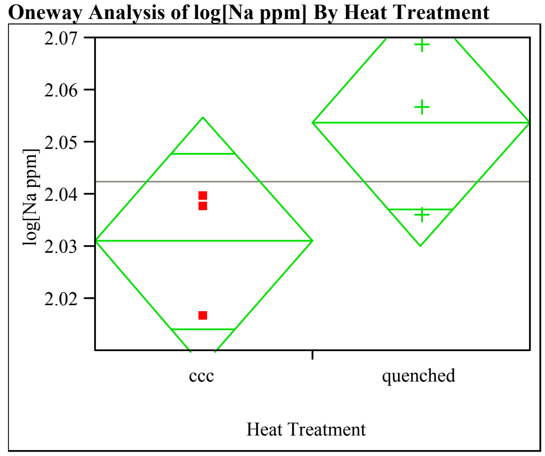
Oneway Analysis of log[B ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.00548	t Ratio	0.629419
Std Err Dif	0.00870	DF	4
Upper CL Dif	0.02964	Prob > |t|	0.5632
Lower CL Dif	-0.01869	Prob > t	0.2816
Confidence	0.95	Prob < t	0.7184

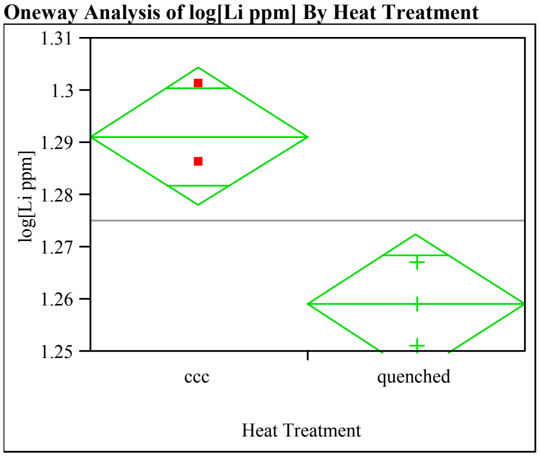
Oneway Analysis of log[Na ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	-0.02288	t Ratio	-1.89407
Std Err Dif	0.01208	DF	4
Upper CL Dif	0.01066	Prob > |t|	0.1311
Lower CL Dif	-0.05641	Prob > t	0.9344
Confidence	0.95	Prob < t	0.0656

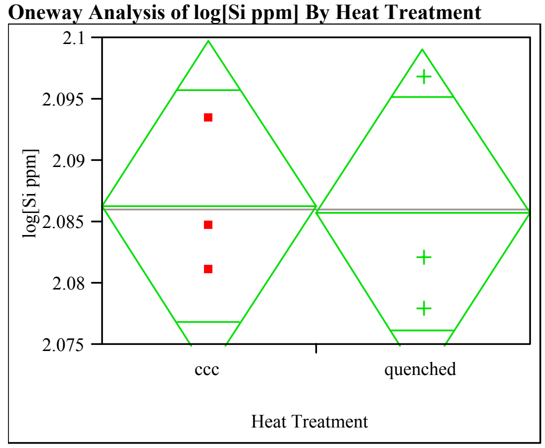
Oneway Analysis of log[Li ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.031988	t Ratio	4.75487
Std Err Dif	0.006727	DF	4
Upper CL Dif	0.050666	Prob > |t|	0.0089
Lower CL Dif	0.013310	Prob > t	0.0045
Confidence	0.95	Prob < t	0.9955

Oneway Analysis of log[Si ppm] By Heat Treatment



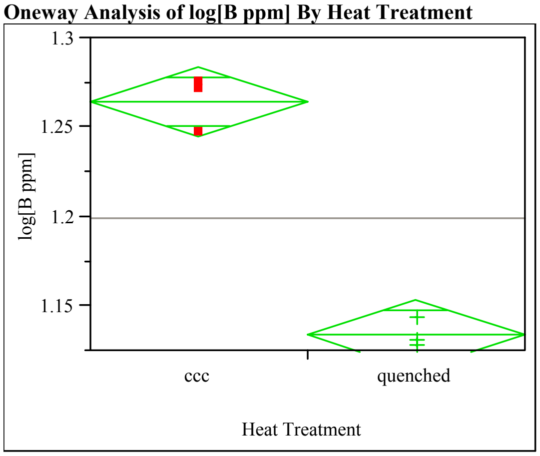
t Test
ccc-quenched
Assuming equal variances

Difference	0.00064	t Ratio	0.093507
Std Err Dif	0.00683	DF	4
Upper CL Dif	0.01959	Prob > |t|	0.9300
Lower CL Dif	-0.01832	Prob > t	0.4650
Confidence	0.95	Prob < t	0.5350

Exhibit E7. Effects of Heat Treatment on PCT ppm-Response of Study Glasses (continued)

Glass ID=NEPH3-51

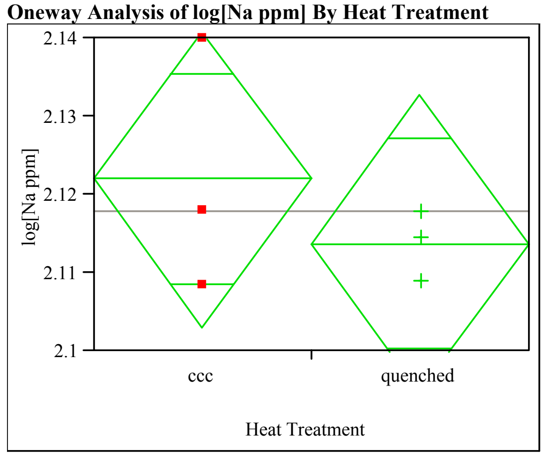
Oneway Analysis of log[B ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.129834	t Ratio	13.08715
Std Err Dif	0.009921	DF	4
Upper CL Dif	0.157378	Prob > |t|	0.0002
Lower CL Dif	0.102290	Prob > t	<.0001
Confidence	0.95	Prob < t	0.9999

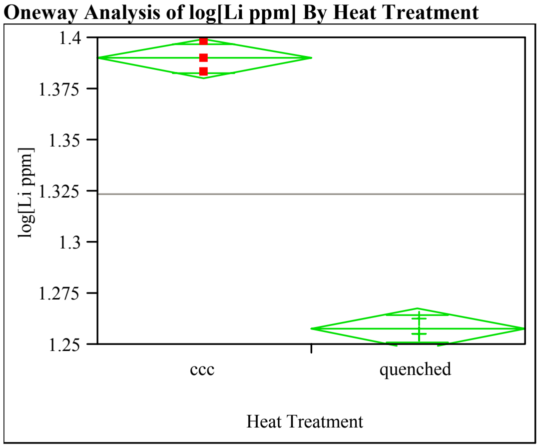
Oneway Analysis of log[Na ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.00827	t Ratio	0.852906
Std Err Dif	0.00970	DF	4
Upper CL Dif	0.03520	Prob > |t|	0.4418
Lower CL Dif	-0.01866	Prob > t	0.2209
Confidence	0.95	Prob < t	0.7791

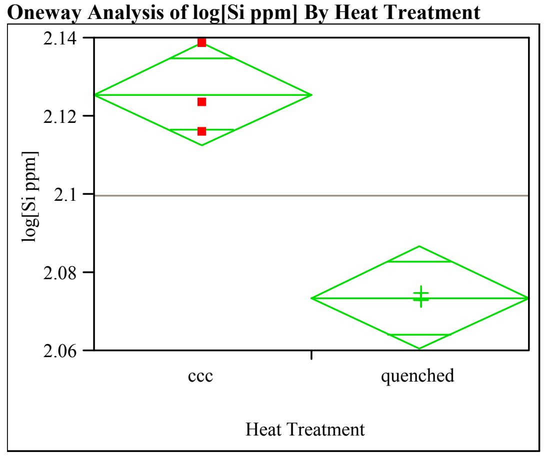
Oneway Analysis of log[Li ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.132179	t Ratio	26.25671
Std Err Dif	0.005034	DF	4
Upper CL Dif	0.146156	Prob > |t|	<.0001
Lower CL Dif	0.118202	Prob > t	<.0001
Confidence	0.95	Prob < t	1.0000

Oneway Analysis of log[Si ppm] By Heat Treatment



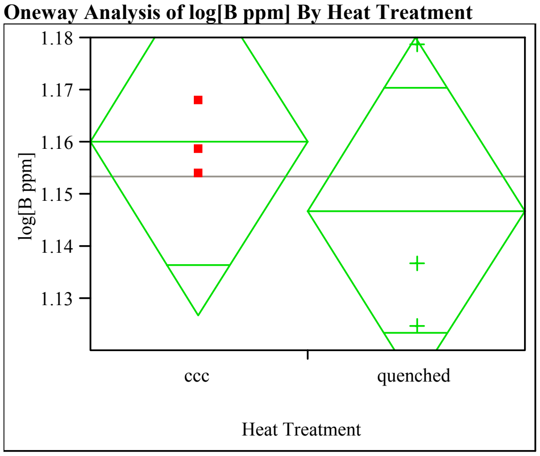
t Test
ccc-quenched
Assuming equal variances

Difference	0.052023	t Ratio	7.775508
Std Err Dif	0.006691	DF	4
Upper CL Dif	0.070599	Prob > |t|	0.0015
Lower CL Dif	0.033447	Prob > t	0.0007
Confidence	0.95	Prob < t	0.9993

Exhibit E7. Effects of Heat Treatment on PCT ppm-Response of Study Glasses (continued)

Glass ID=NEPH3-52

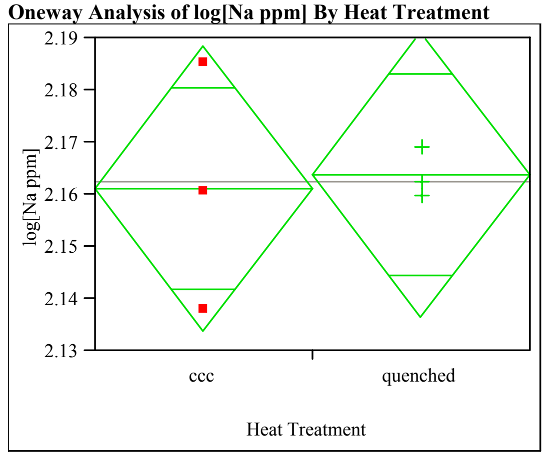
Oneway Analysis of log[B ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.01312	t Ratio	0.775441
Std Err Dif	0.01692	DF	4
Upper CL Dif	0.06008	Prob > |t|	0.4814
Lower CL Dif	-0.03385	Prob > t	0.2407
Confidence	0.95	Prob < t	0.7593

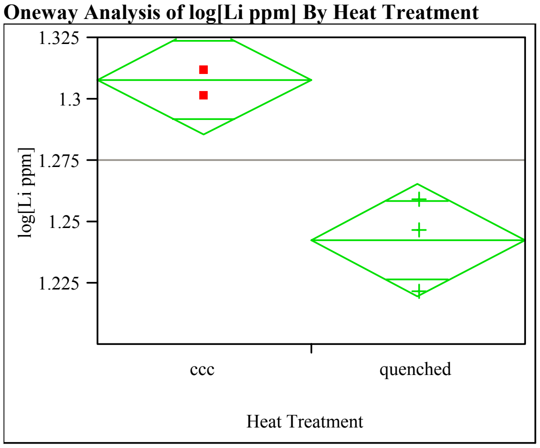
Oneway Analysis of log[Na ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	-0.00274	t Ratio	-0.1958
Std Err Dif	0.01397	DF	4
Upper CL Dif	0.03606	Prob > |t|	0.8543
Lower CL Dif	-0.04153	Prob > t	0.5728
Confidence	0.95	Prob < t	0.4272

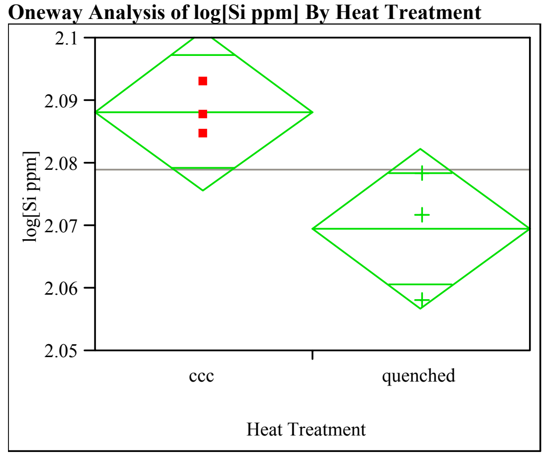
Oneway Analysis of log[Li ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.065420	t Ratio	5.644337
Std Err Dif	0.011590	DF	4
Upper CL Dif	0.097600	Prob > |t|	0.0049
Lower CL Dif	0.033240	Prob > t	0.0024
Confidence	0.95	Prob < t	0.9976

Oneway Analysis of log[Si ppm] By Heat Treatment



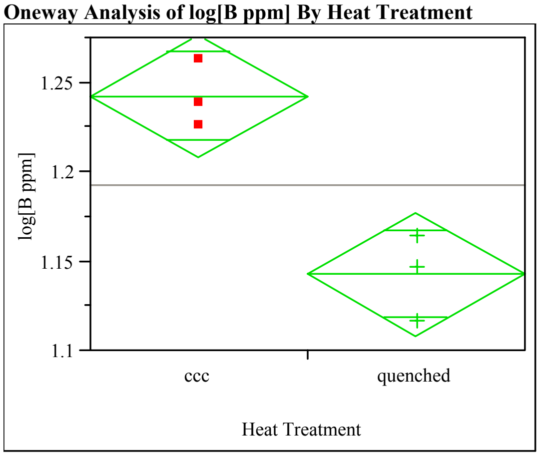
t Test
ccc-quenched
Assuming equal variances

Difference	0.018775	t Ratio	2.900557
Std Err Dif	0.006473	DF	4
Upper CL Dif	0.036747	Prob > |t|	0.0441
Lower CL Dif	0.000803	Prob > t	0.0220
Confidence	0.95	Prob < t	0.9780

Exhibit E7. Effects of Heat Treatment on PCT ppm-Response of Study Glasses (continued)

Glass ID=NEPH3-53

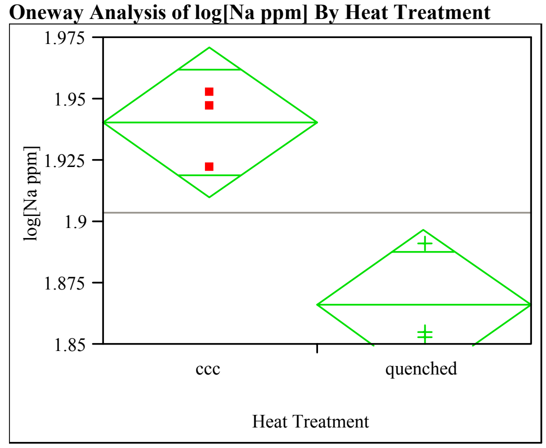
Oneway Analysis of log[B ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.099671	t Ratio	5.651291
Std Err Dif	0.017637	DF	4
Upper CL Dif	0.148639	Prob > |t|	0.0048
Lower CL Dif	0.050703	Prob > t	0.0024
Confidence	0.95	Prob < t	0.9976

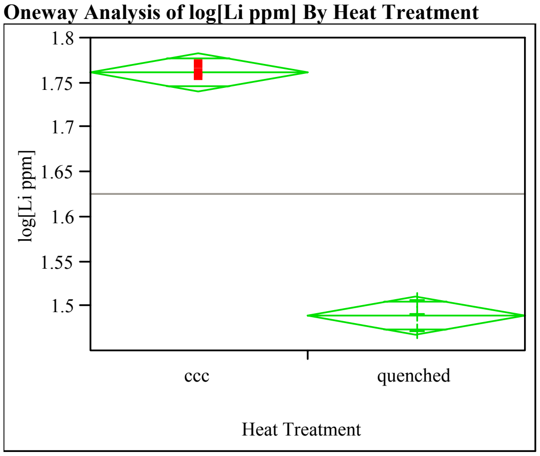
Oneway Analysis of log[Na ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.073828	t Ratio	4.74838
Std Err Dif	0.015548	DF	4
Upper CL Dif	0.116997	Prob > |t|	0.0090
Lower CL Dif	0.030660	Prob > t	0.0045
Confidence	0.95	Prob < t	0.9955

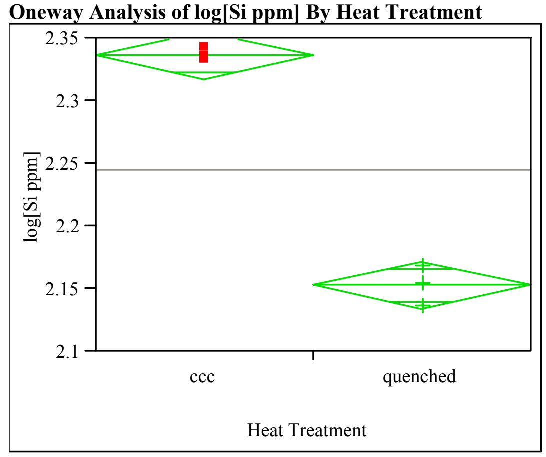
Oneway Analysis of log[Li ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.271796	t Ratio	24.88768
Std Err Dif	0.010921	DF	4
Upper CL Dif	0.302117	Prob > |t|	<.0001
Lower CL Dif	0.241474	Prob > t	<.0001
Confidence	0.95	Prob < t	1.0000

Oneway Analysis of log[Si ppm] By Heat Treatment



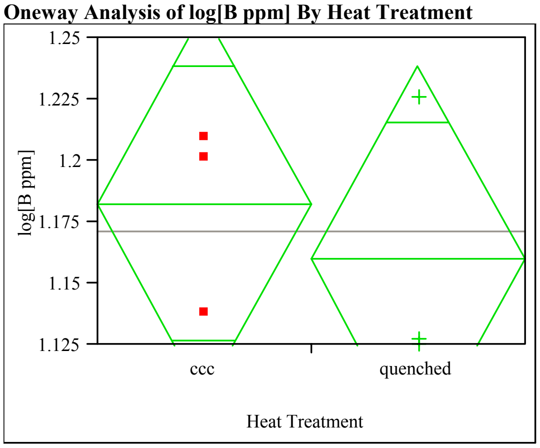
t Test
ccc-quenched
Assuming equal variances

Difference	0.183946	t Ratio	18.87241
Std Err Dif	0.009747	DF	4
Upper CL Dif	0.211007	Prob > |t|	<.0001
Lower CL Dif	0.156884	Prob > t	<.0001
Confidence	0.95	Prob < t	1.0000

Exhibit E7. Effects of Heat Treatment on PCT ppm-Response of Study Glasses (continued)

Glass ID=NEPH3-54

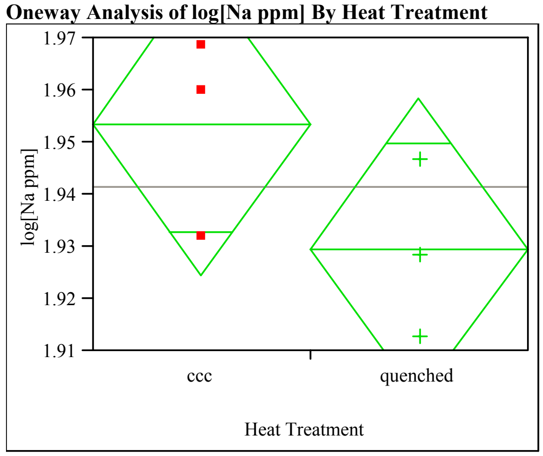
Oneway Analysis of log[B ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.02283	t Ratio	0.568886
Std Err Dif	0.04013	DF	4
Upper CL Dif	0.13425	Prob > |t|	0.5999
Lower CL Dif	-0.08859	Prob > t	0.2999
Confidence	0.95	Prob < t	0.7001

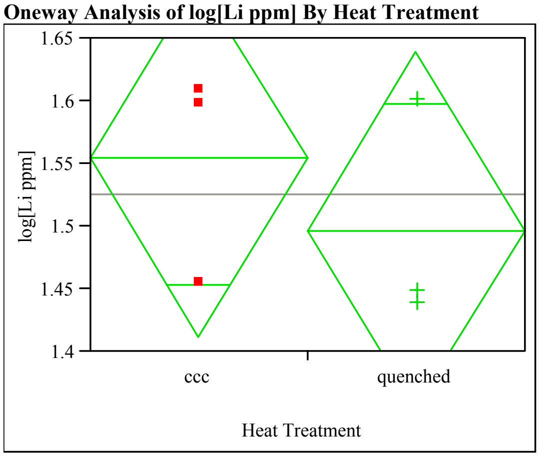
Oneway Analysis of log[Na ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.02395	t Ratio	1.621974
Std Err Dif	0.01476	DF	4
Upper CL Dif	0.06494	Prob > |t|	0.1801
Lower CL Dif	-0.01705	Prob > t	0.0901
Confidence	0.95	Prob < t	0.9099

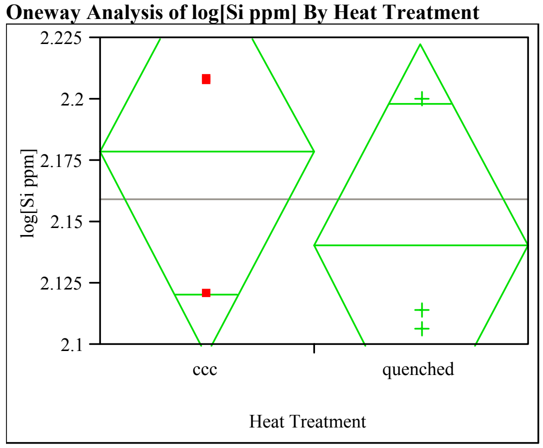
Oneway Analysis of log[Li ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.05713	t Ratio	0.789008
Std Err Dif	0.07240	DF	4
Upper CL Dif	0.25815	Prob > |t|	0.4742
Lower CL Dif	-0.14390	Prob > t	0.2371
Confidence	0.95	Prob < t	0.7629

Oneway Analysis of log[Si ppm] By Heat Treatment



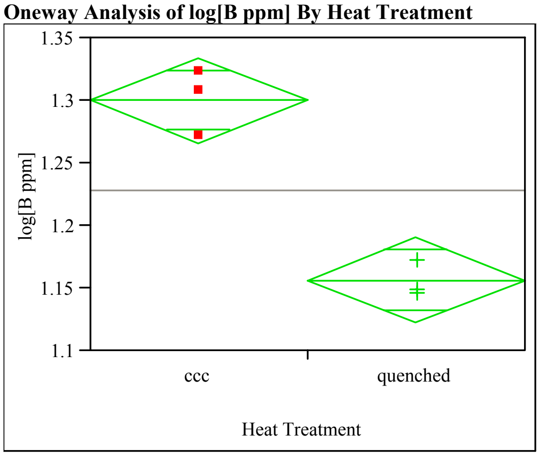
t Test
ccc-quenched
Assuming equal variances

Difference	0.03832	t Ratio	0.915343
Std Err Dif	0.04186	DF	4
Upper CL Dif	0.15454	Prob > |t|	0.4118
Lower CL Dif	-0.07791	Prob > t	0.2059
Confidence	0.95	Prob < t	0.7941

Exhibit E7. Effects of Heat Treatment on PCT ppm-Response of Study Glasses (continued)

Glass ID=NEPH3-55

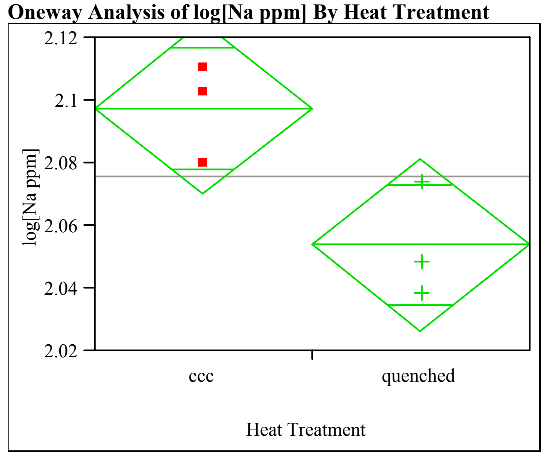
Oneway Analysis of log[B ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.143805	t Ratio	8.282353
Std Err Dif	0.017363	DF	4
Upper CL Dif	0.192012	Prob > |t|	0.0012
Lower CL Dif	0.095598	Prob > t	0.0006
Confidence	0.95	Prob < t	0.9994

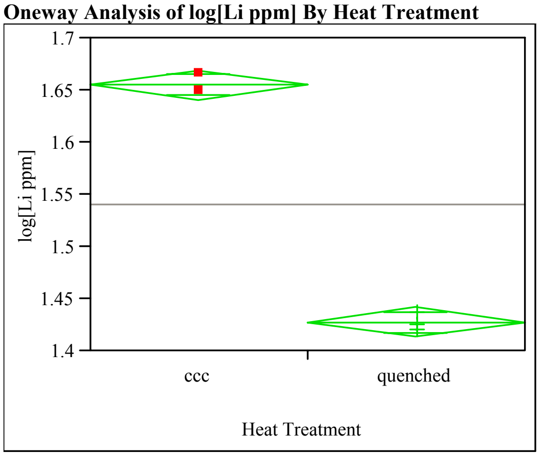
Oneway Analysis of log[Na ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.043607	t Ratio	3.119276
Std Err Dif	0.013980	DF	4
Upper CL Dif	0.082422	Prob > |t|	0.0356
Lower CL Dif	0.004793	Prob > t	0.0178
Confidence	0.95	Prob < t	0.9822

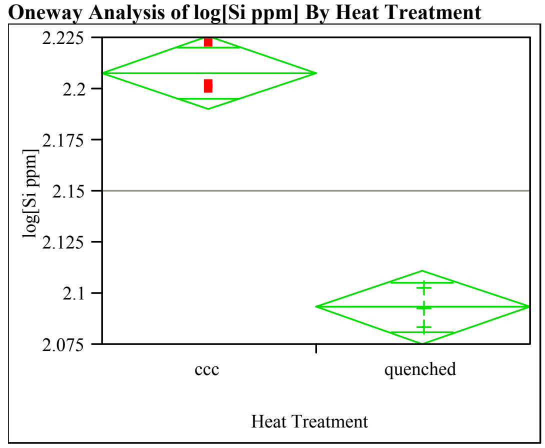
Oneway Analysis of log[Li ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.227564	t Ratio	31.95058
Std Err Dif	0.007122	DF	4
Upper CL Dif	0.247339	Prob > |t|	<.0001
Lower CL Dif	0.207790	Prob > t	<.0001
Confidence	0.95	Prob < t	1.0000

Oneway Analysis of log[Si ppm] By Heat Treatment



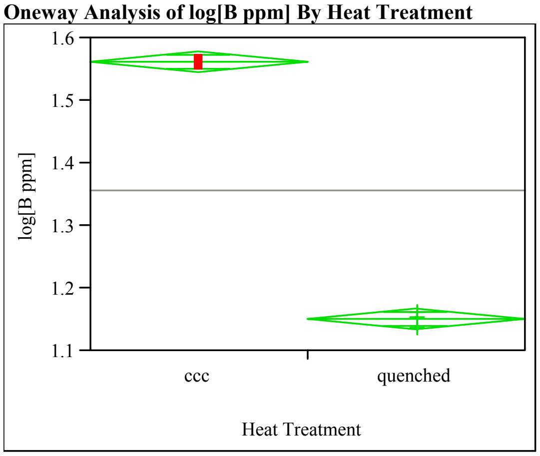
t Test
ccc-quenched
Assuming equal variances

Difference	0.114559	t Ratio	12.79553
Std Err Dif	0.008953	DF	4
Upper CL Dif	0.139417	Prob > |t|	0.0002
Lower CL Dif	0.089701	Prob > t	0.0001
Confidence	0.95	Prob < t	0.9999

Exhibit E7. Effects of Heat Treatment on PCT ppm-Response of Study Glasses (continued)

Glass ID=NEPH3-56

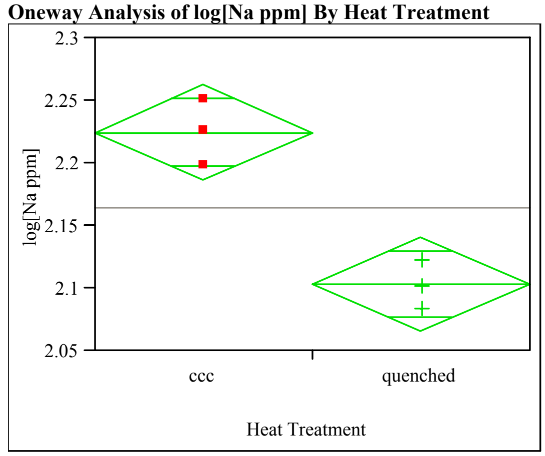
Oneway Analysis of log[B ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.409778	t Ratio	49.45317
Std Err Dif	0.008286	DF	4
Upper CL Dif	0.432784	Prob > |t|	<.0001
Lower CL Dif	0.386772	Prob > t	<.0001
Confidence	0.95	Prob < t	1.0000

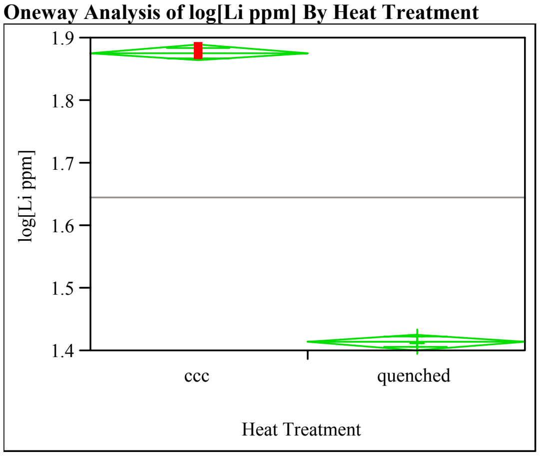
Oneway Analysis of log[Na ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.121570	t Ratio	6.33415
Std Err Dif	0.019193	DF	4
Upper CL Dif	0.174857	Prob > |t|	0.0032
Lower CL Dif	0.068282	Prob > t	0.0016
Confidence	0.95	Prob < t	0.9984

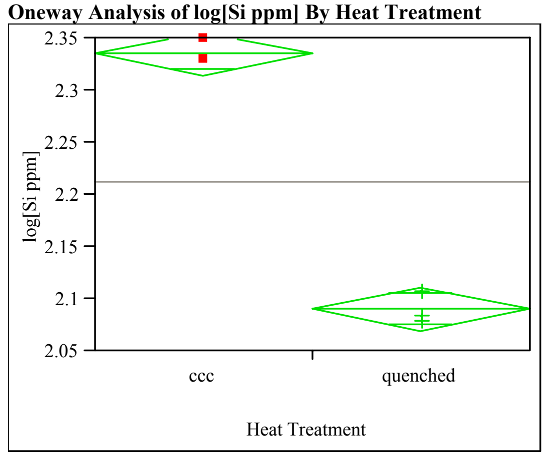
Oneway Analysis of log[Li ppm] By Heat Treatment



t Test
ccc-quenched
Assuming equal variances

Difference	0.463292	t Ratio	77.75813
Std Err Dif	0.005958	DF	4
Upper CL Dif	0.479835	Prob > |t|	<.0001
Lower CL Dif	0.446750	Prob > t	<.0001
Confidence	0.95	Prob < t	1.0000

Oneway Analysis of log[Si ppm] By Heat Treatment



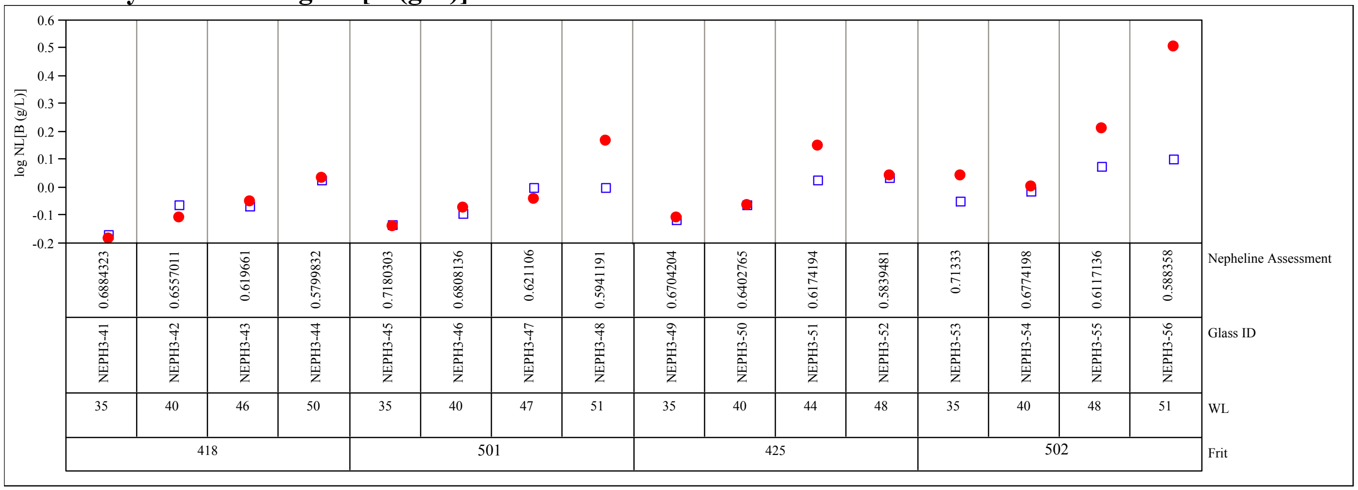
t Test
ccc-quenched
Assuming equal variances

Difference	0.245366	t Ratio	22.7109
Std Err Dif	0.010804	DF	4
Upper CL Dif	0.275362	Prob > |t|	<.0001
Lower CL Dif	0.215369	Prob > t	<.0001
Confidence	0.95	Prob < t	1.0000

Exhibit E8. Effects of Heat Treatment for Study Glasses by Compositional View

Comp View=Measured

Variability Chart for log NL[B (g/L)]



Variability Chart for log NL[Li(g/L)]

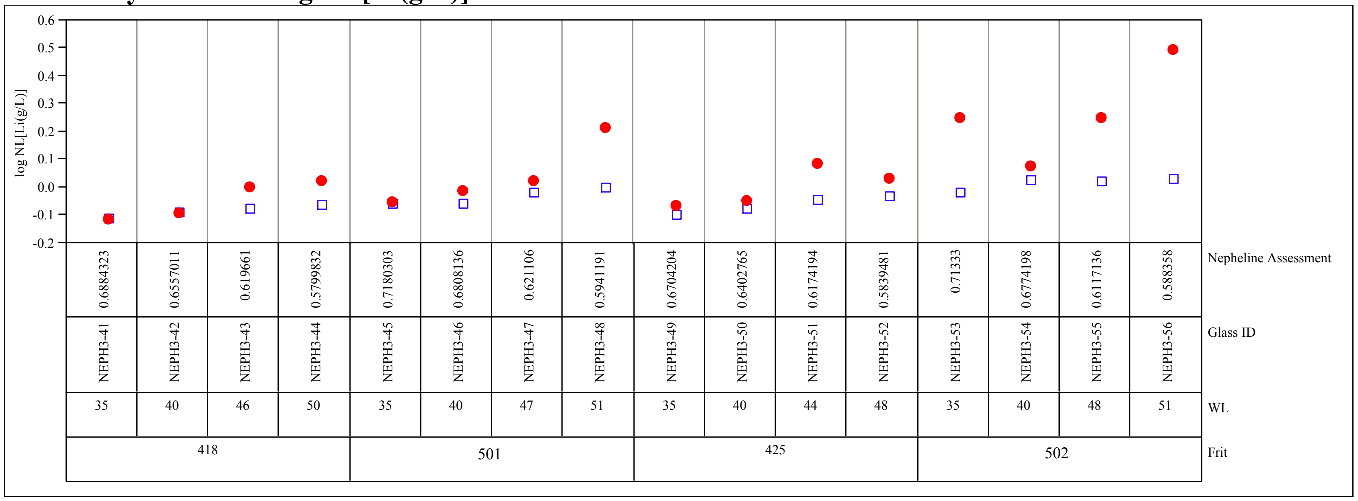
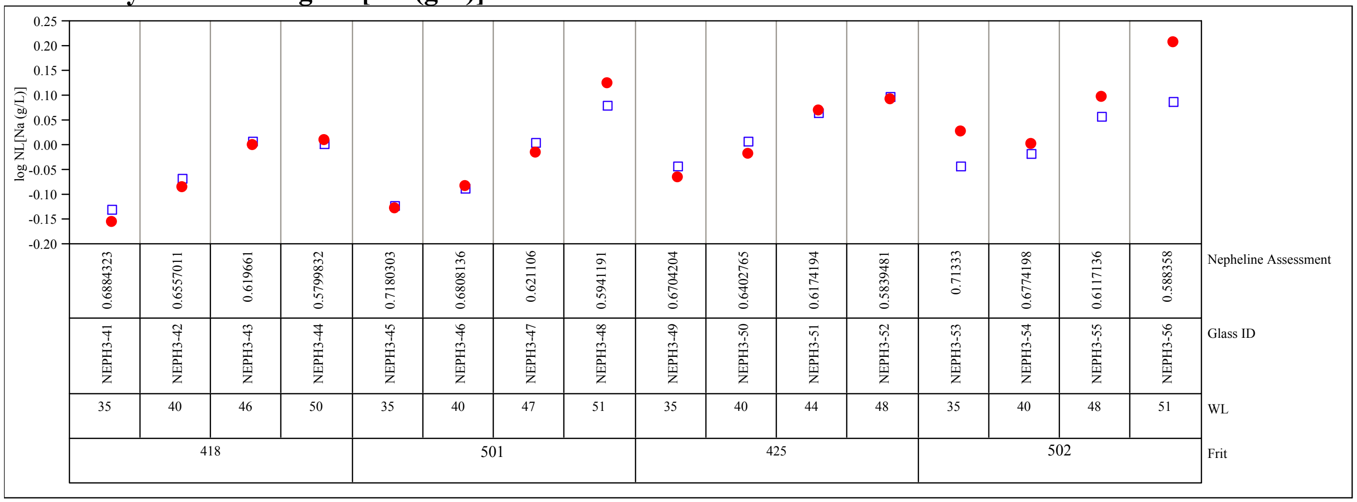


Exhibit E8. Effects of Heat Treatment for Study Glasses by Compositional View (continued)

Variability Chart for log NL[Na (g/L)]



Variability Chart for log NL[Si (g/L)]

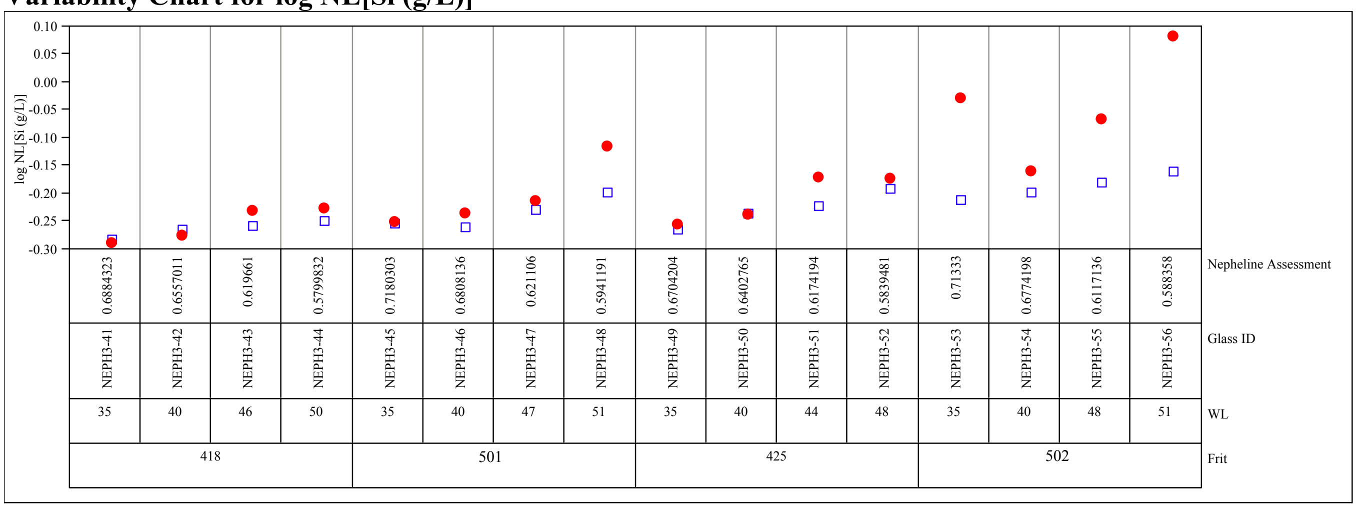
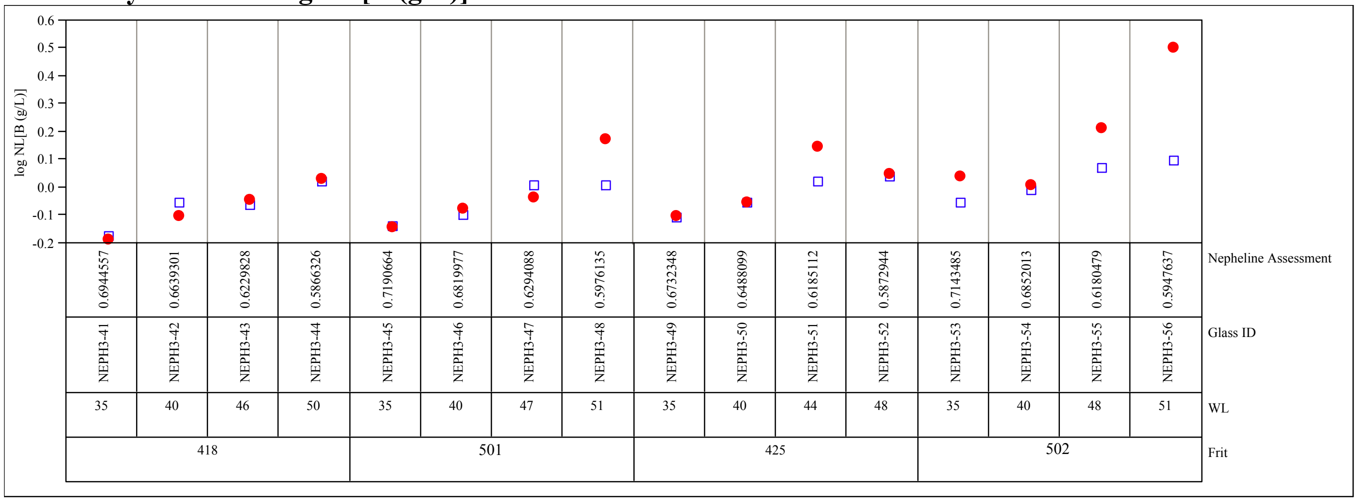


Exhibit E8. Effects of Heat Treatment for Study Glasses by Compositional View (continued)

Comp View=Measured bc

Variability Chart for log NL[B (g/L)]



Variability Chart for log NL[Li(g/L)]

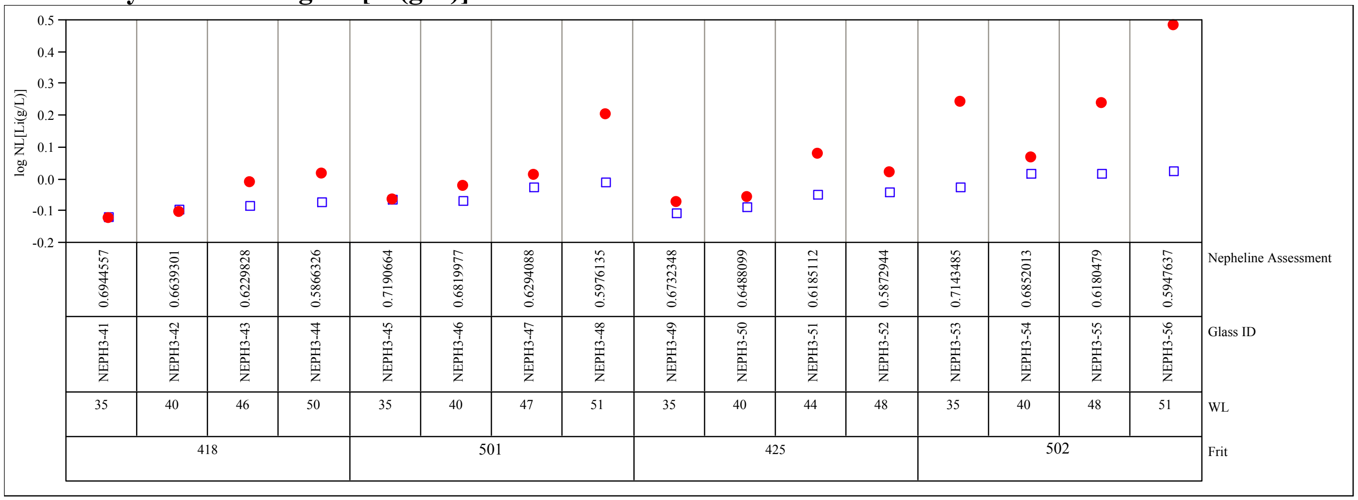
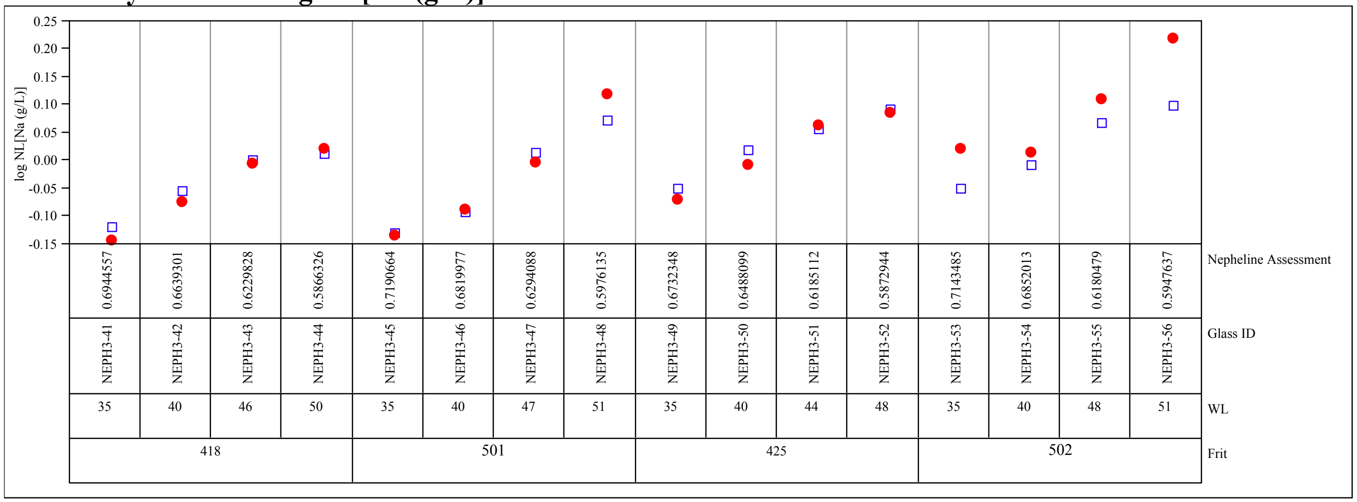


Exhibit E8. Effects of Heat Treatment for Study Glasses by Compositional View (continued)

Variability Chart for log NL[Na (g/L)]



Variability Chart for log NL[Si (g/L)]

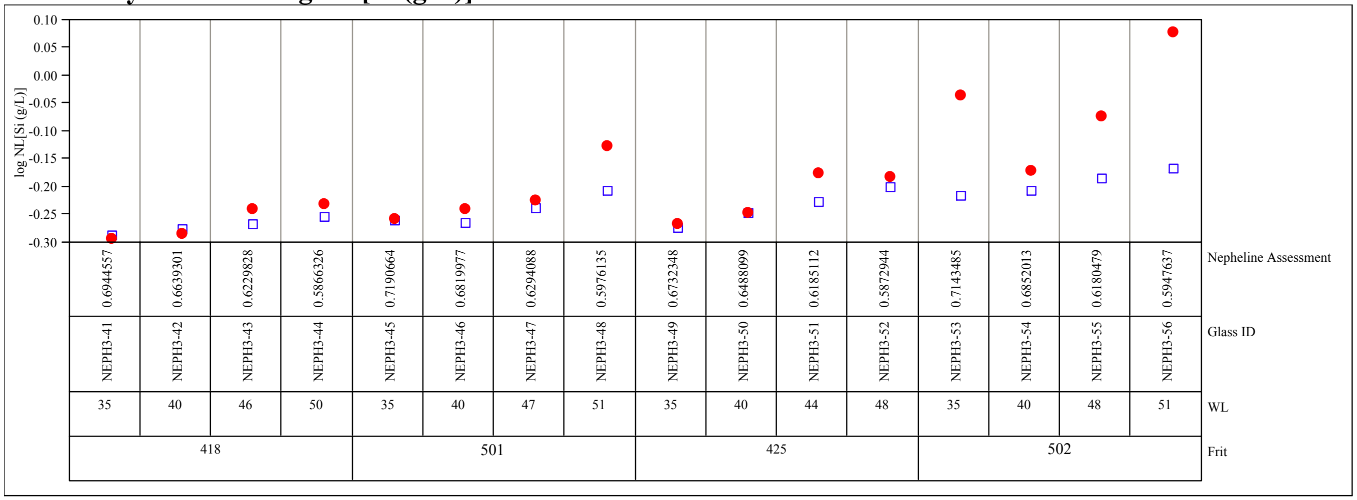
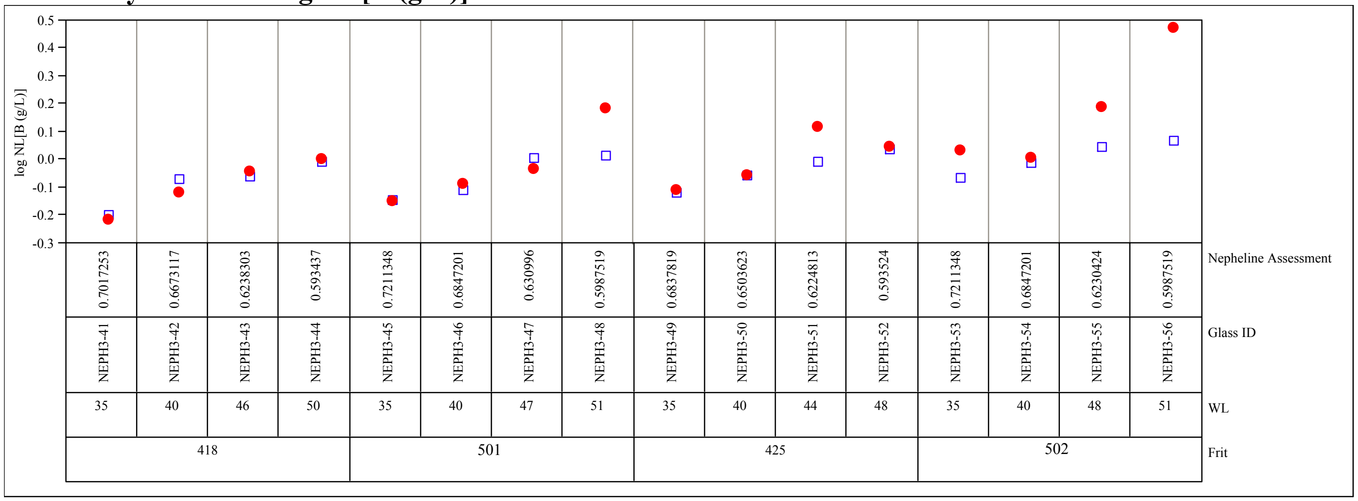


Exhibit E8. Effects of Heat Treatment for Study Glasses by Compositional View (continued)

Comp View=target

Variability Chart for log NL[B (g/L)]



Variability Chart for log NL[Li(g/L)]

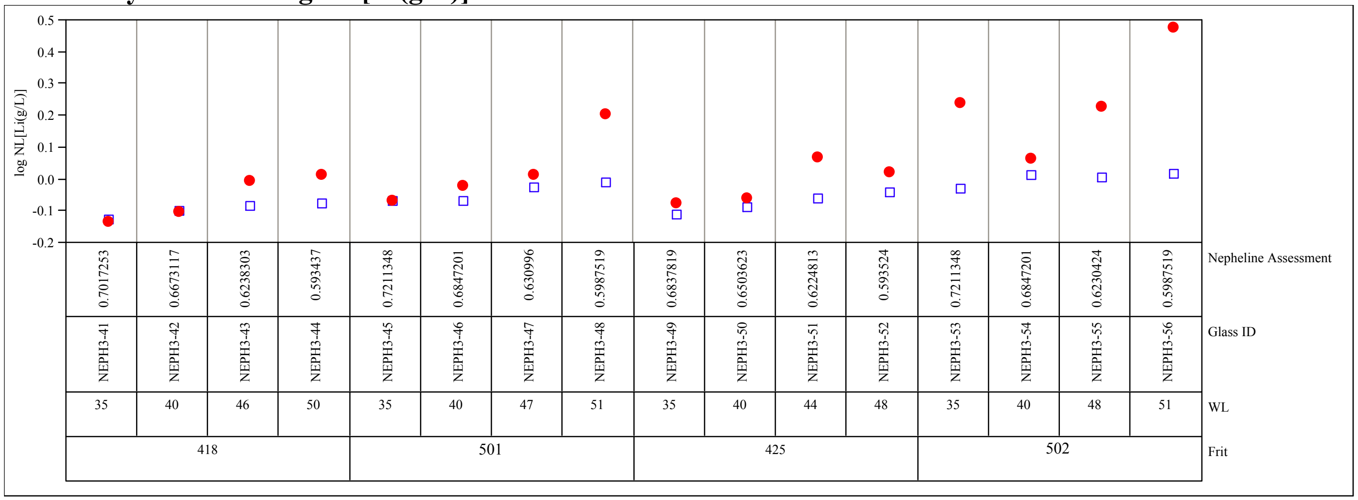
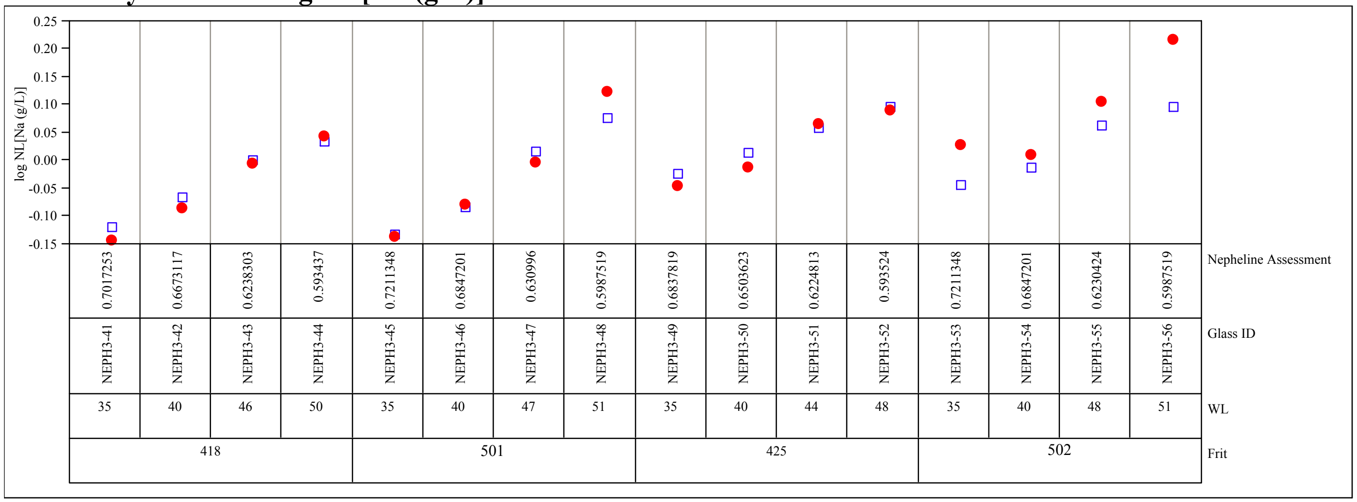


Exhibit E8. Effects of Heat Treatment for Study Glasses by Compositional View (continued)

Variability Chart for log NL[Na (g/L)]



Variability Chart for log NL[Si (g/L)]

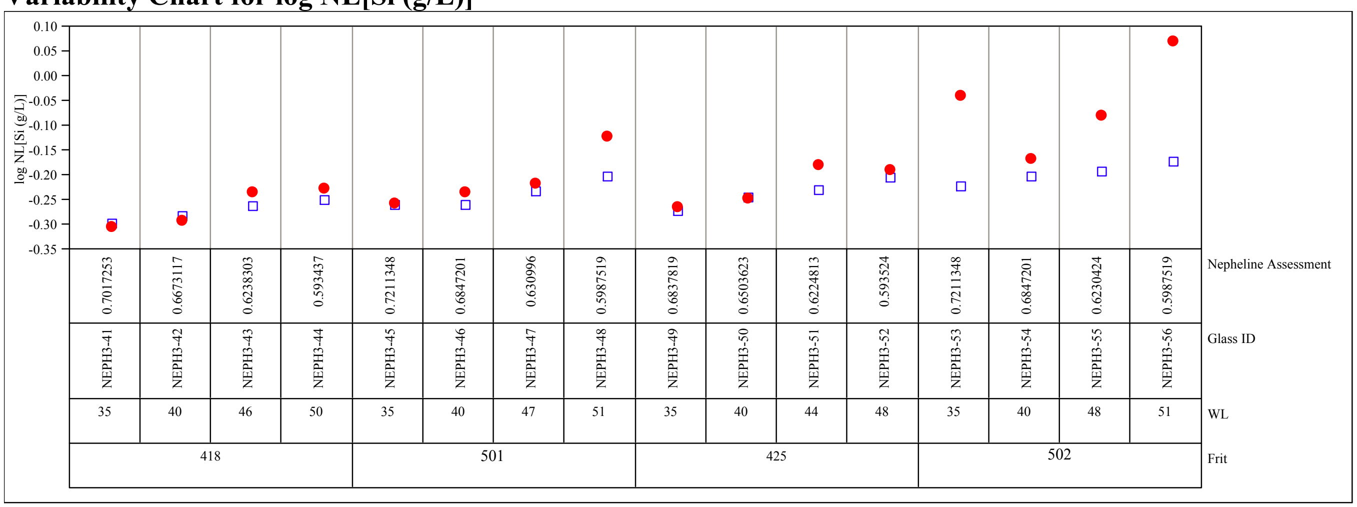
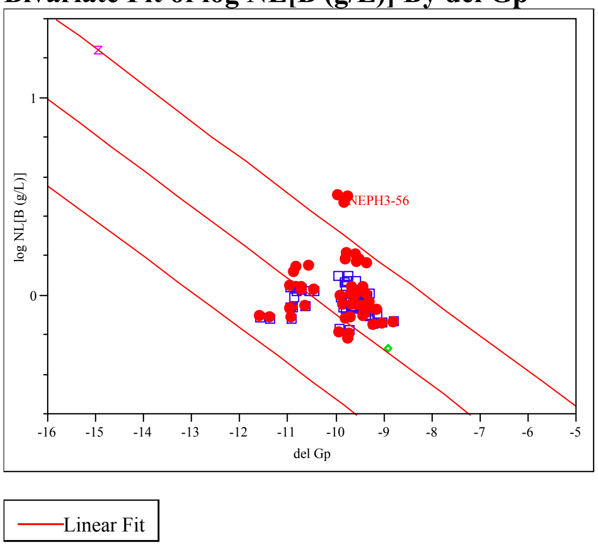
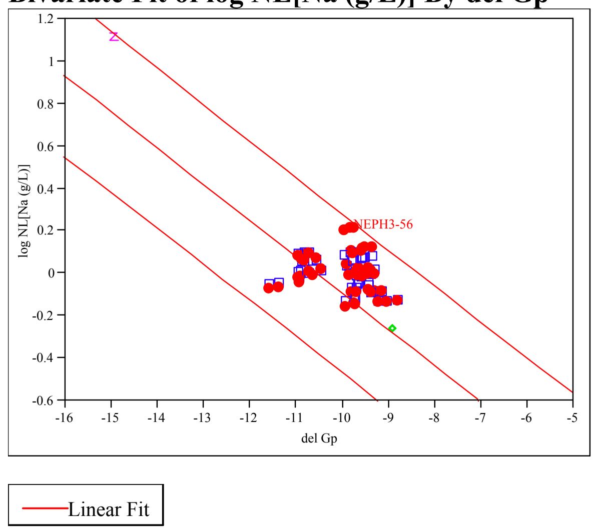


Exhibit E9. del Gp (ΔG_p) Predictions versus Common Logarithm Normalized Leachate (log NL[.]) for B, Li, Na, and Si Over All Compositional Views and Heat Treatments

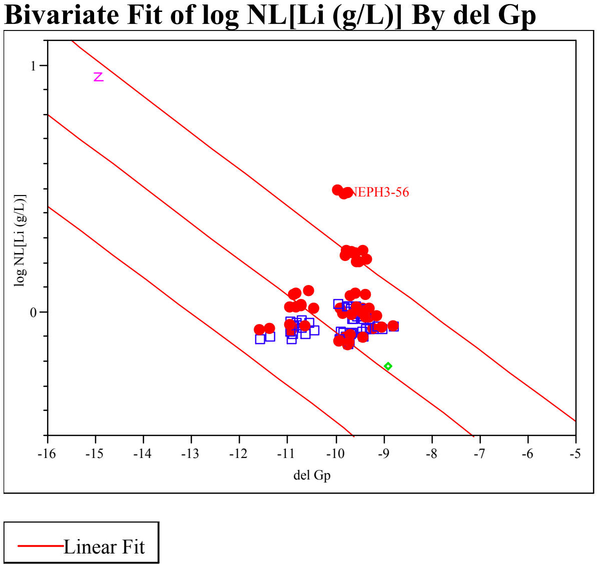
Bivariate Fit of log NL[B (g/L)] By del Gp



Bivariate Fit of log NL[Na (g/L)] By del Gp



Bivariate Fit of log NL[Li (g/L)] By del Gp



Bivariate Fit of log NL[Si (g/L)] By del Gp

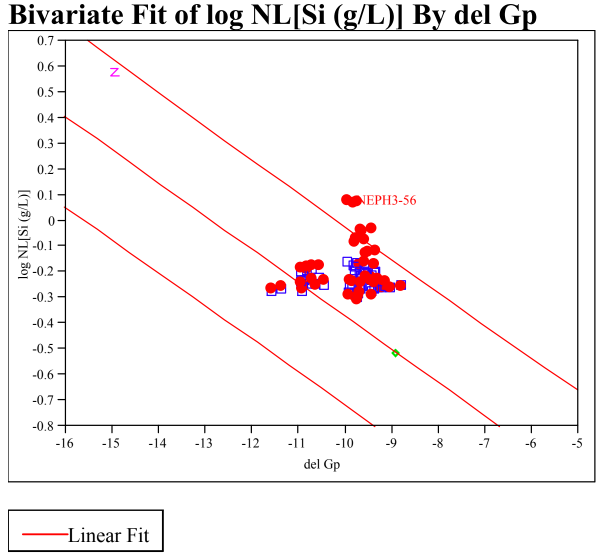
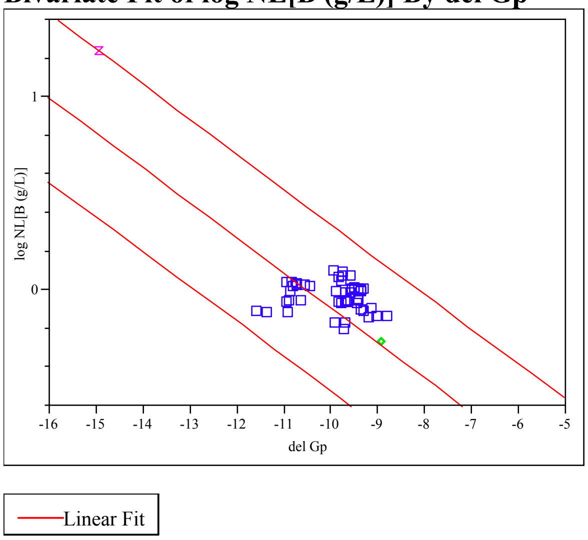
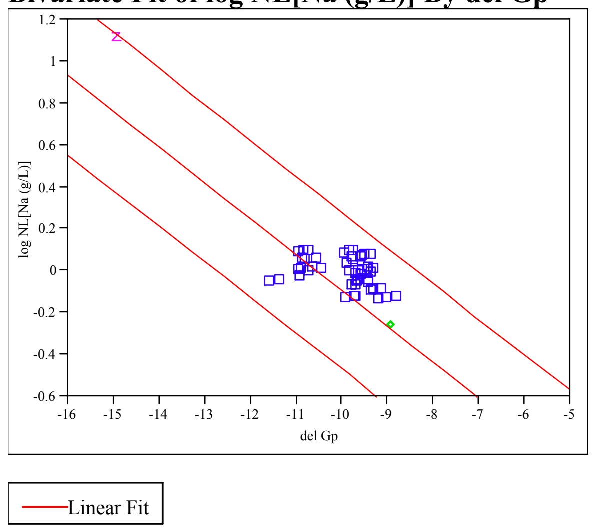


Exhibit E10. del Gp (ΔG_p) Predictions versus Common Logarithm Normalized Leachate (log NL[.]) for B, Li, Na, and Si Over All Compositional Views for Quenched Glasses

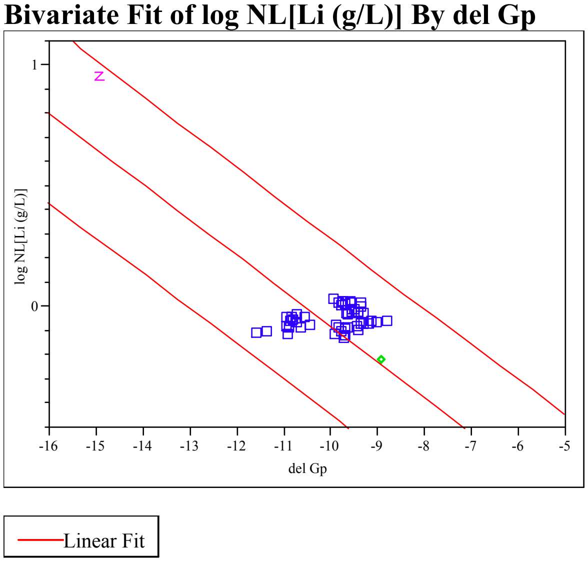
Bivariate Fit of log NL[B (g/L)] By del Gp



Bivariate Fit of log NL[Na (g/L)] By del Gp



Bivariate Fit of log NL[Li (g/L)] By del Gp



Bivariate Fit of log NL[Si (g/L)] By del Gp

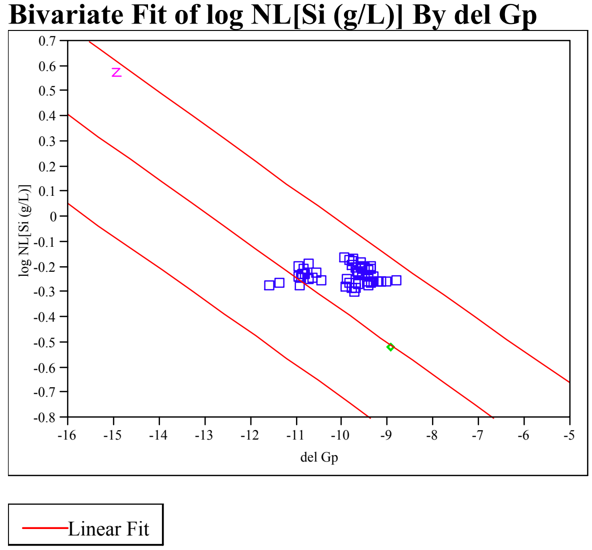
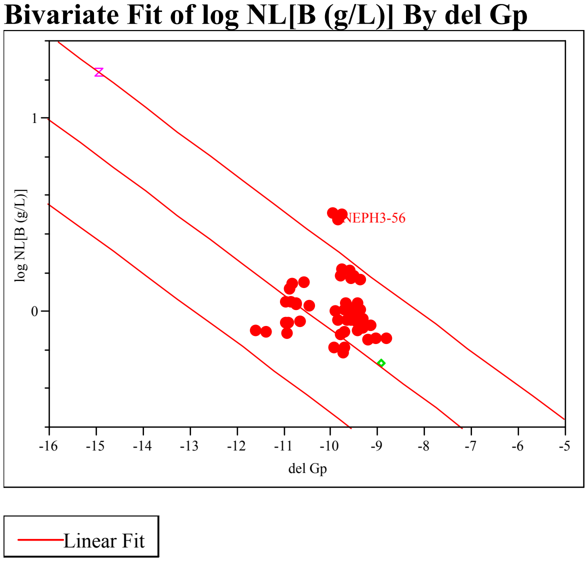
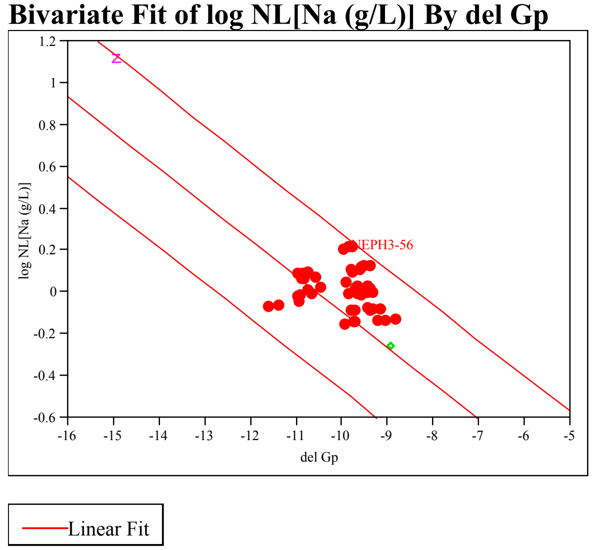


Exhibit E11. del Gp (ΔG_p) Predictions versus Common Logarithm Normalized Leachate (log NL[.]) for B, Li, Na, and Si Over All Compositional Views for ccc Glasses

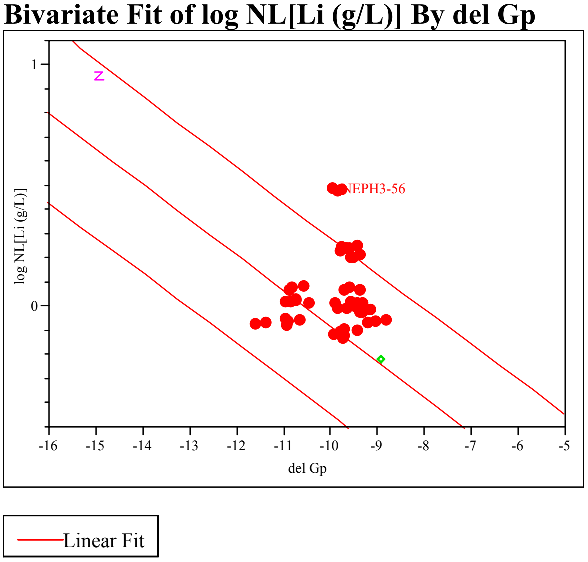
Bivariate Fit of log NL[B (g/L)] By del Gp



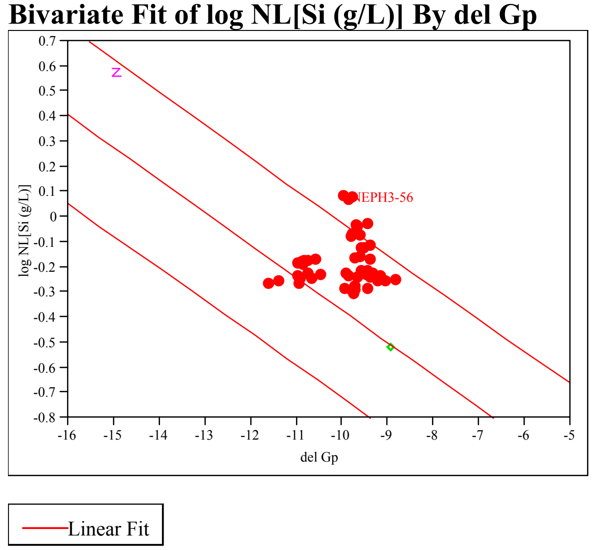
Bivariate Fit of log NL[Na (g/L)] By del Gp



Bivariate Fit of log NL[Li (g/L)] By del Gp



Bivariate Fit of log NL[Si (g/L)] By del Gp



Distribution:

J.E. Marra, SRNL
R.E. Edwards, SRNL
D.A. Crowley, 999-W
S.L. Marra, 773-A
T.B. Calloway, 999-W
D.B. Burns, 786-5A
G.T. Chandler, 773-A
N.E. Bibler, SRNL
C.M. Jantzen, SRNL
J.R. Harbour, 773-42A
G.G. Wicks, SRNL
R.C. Tuckfield, 773-42A
D.K. Peeler, 999-W
T.B. Edwards, 773-42A
K.M. Fox, 773-A
C.C. Herman, 773-42A
A.S. Choi, 999-W
M.E. Smith, 999-W
M.E. Stone, 999-W
D.H. Miller, 999-W
M.J. Barnes, 999-W
M.S. Miller, 704-S
J.E. Occhipinti, 704-S
T.M. Jones, 999-W
R.M. Hoeppel, 704-27S
B.A. Davis, 704-27S
P.M. Patel, 704-27S
J.F. Iaukea, 704-30S
J.W. Ray, 704-S
M.A. Rios-Armstrong, 766-H
J.M. Gillam, 766-H
H.B. Shah, 766-H