Composition/Property Relationships for the Phase 2 Am-Cm Glass Variability Study

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EXECUTIVE SUMMARY

The objective of this research was to evaluate the effect of compositional uncertainties on the primary processing and product performance criteria for potential glasses to stabilize the Tank 17.1 Am-Cm solution. Given the feed composition (and its potential $\pm 40\%$ variation), the composition of the 25SrABS cullet, and the target feed loading range of 32 to 52 mass % (oxide basis), an experimental glass composition region (EGCR) for Phase 2 testing was defined. In this study, glasses were fabricated (on the laboratory-scale) and both processing and product performance properties were measured as a function of glass composition. These properties were assessed against predefined constraints to define an acceptable glass composition region (AGCR) in which all property constraints were simultaneously satisfied.

An acceptable glass composition region (AGCR) has been identified in which all processing (viscosity and liquidus temperature) and product performance (durability and recoverability) criteria as currently defined are met. The Phase 2 AGCR was only limited by the liquidus temperature constraint which restricted the AGCR to the fabrication of glasses containing < 63.5 mass % total Ln_2O_3 content (based on target compositions) or < 62.5 mass % total Ln_2O_3 content (based on measured compositions). If compositions within the AGCR are processed, the risks of process upsets are minimized and the likelihood of accepting the final glass product is increased.

Within the Phase 2 EGCR, most composition – property relationships are dependent upon the total lanthanide oxide (Ln_2O_3) content in the glass. There was no indication that the distribution of the lanthanides or the degree of minor components impact either the processing or product performance properties within the limits of the experimental design.

ACRONYMS

ADS	Analytical Development Services
AGCR	acceptable glass composition region
AIS	aluminosilicate
ARM	Approved Reference Material
ASTM	American Society for Testing and Materials
CIM	Cylindrical Induction Melter
DNFSB	Defense Nuclear Facility Safety Board
EA	Environmental Assessment
EGCR	experimental glass composition region
ICP-AES	inductively coupled plasma – atomic emission spectroscopy
NBS	National Bureau of Standards
NIST	National Institute of Standards and Technology
NMS&S	Nuclear Materials Stabilization & Storage
MPPF	Multi-Purpose Processing Facility
ORNL	Oak Ridge National Laboratory
ρ	density
PCT	product consistency test
PNNL	Pacific Northwest National Laboratory
RES	rare-earth silicate
SEM/EDS	scanning electron microscopy / energy dispersive spectroscopy
SrABS	$\text{SrO-Al}_2\text{O}_3\text{-B}_2\text{O}_3\text{-SiO}_2$
SRM	Standard Reference Material
SRTC	Savannah River Technology Center
SRTC-ML	Savannah River Technology Center – Mobile Laboratory
T_L	liquidus temperature
TTR	technical task request
η	viscosity
VFT	Vogel-Tamman-Fulcher
XRD	x-ray diffraction

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1.0 INTRODUCTION

Approximately 11,000 liters (3,600 gallons) of solution containing isotopes of americium (Am) and curium (Cm) are currently stored in F-Canyon Tank 17.1. These isotopes were recovered during plutonium-242 production campaigns in the mid- and late-1970's. The continued storage of these isotopes in a liquid solution was identified as an item of primary concern in the Defense Nuclear Facility Safety Board's (DNFSB) Recommendation 94-1 [1]. An analysis of several alternatives resulted in the recommendation to stabilize the Am-Cm solution in a high-lanthanide glass [2]. The Multi-Purpose Processing Facility (MPPF) in the F-Canyon will be used for the vitrification process. Pretreatment operations will be performed in existing canyon vessels to separate actinides and lanthanides from other impurities (primarily iron, aluminum, and sodium), reduce the solution acidity, and reduce the total volume of solution prior to the vitrification operation.

A schematic of the vitrification batch process is displayed in Figure 1. In the vitrification process, the Am-Cm feed from pretreatment is transferred to a reaction vessel. Actinide and lanthanide oxalates are precipitated from solution with oxalic acid and then washed to lower the nitric acid concentration. Oxalate precipitate is then transferred to a Pt/Rh induction melter, which is preloaded with fritted glass-making additives. The resultant mixture is then dried and heated to approximately 1450°C to produce a molten glass product in the induction heated Cylindrical Induction Melter (CIM). The glass is then poured through a drain tube into a stainless steel cylinder. The proposed baseline vitrification batch process is described in detail by Fellingner et al. [3,4], Marra et al. [5,6], Peeler et al. [7], and Vienna et al. [8].

Figure 1. Schematic of the Batch Vitrification Process.

For the vitrification campaign to be successful, a framework of knowledge sufficient to control the Am-Cm target glass composition within an acceptable processing window must be developed. Compositional control is essential to ensure that target glass compositions have properties that meet the MPPF melter processing requirements, the Oak Ridge National Laboratory (ORNL) processing capabilities for recovery of the americium and curium, and/or the product requirements for interim or long-term storage or disposal. To develop such a knowledge base, relationships between product and process properties and glass composition over the initial anticipated composition region for the MPPF vitrification process were explored by the Savannah River Technology Center (SRTC).[9] Specific composition – property relationships were identified in this initial study (Phase 1) over the compositional range of interest. These relationships were then used to define an acceptable glass composition region (AGCR) in which glasses simultaneously met both process and product performance specifications. Most Phase 1 composition – property relationships were dependent upon the total Ln_2O_3 concentration in glass.

One of the major conclusions from Phase 1 was the potential to increase the feed loadings given that the T_L constraint could be safely increased. If increased feed loadings are obtainable while satisfying the specific composition – property constraints, fewer canisters would be produced translating into a shorter processing campaign. Therefore, one of the primary objectives for Phase 2 focused on the impact of increased feed loadings on the specific process (viscosity and liquidus temperature) and product performance (durability and recoverability) constraints.

The Phase 2 glasses were fabricated, and specific processing and product performance properties were measured as a function of glass composition. These properties were assessed against predefined constraints to define an AGCR in which all property constraints were simultaneously satisfied.¹ The results of the Phase 2 composition – property relationships are described in this document. Phase 2 was developed and executed [10,11] based on the Technical Task Request (TTR) [12] as defined by the Nuclear Materials Stabilization & Storage (NMS&S) Division.

2.0 OBJECTIVE STATEMENT

The objectives of this research were two-fold:

- (1) to evaluate the effect of compositional uncertainties on the primary processing and product performance properties for potential glasses to stabilize the Tank 17.1 Am-Cm solution and
- (2) to identify the AGCR in which glasses simultaneously meet both process and product performance criteria as defined for Phase 2 [12].

¹ It should be noted that the Phase 2 processing constraint for liquidus temperature was increased 100°C to 1350°C over that used in Phase 1. This was the only constraint that differed between Phase 1 and Phase 2.

3.0 REVIEW OF PHASE 1 RESULTS

In Phase 1, the total lanthanide oxide (Ln_2O_3) concentration² in glass was systematically varied between 38 and 54 mass percent along with its composition [13]. Thirty-one glasses were fabricated and characterized in a joint SRTC and Pacific Northwest National Laboratory (PNNL) effort. The results of this study are described in detail by Peeler and colleagues [9, 14] and Vienna et al. [15, 16]. It was found that the variation in properties, such as density (ρ), liquidus temperature (T_L), and viscosity (η), could be described to first order by the variation in Ln_2O_3 concentration in glass.

To provide the technical basis from which the Phase 2 test objectives were developed, only the properties which impacted the definition of the Phase 1 AGCR will be discussed: T_L and η . The η s of Phase 1 glasses were measured as functions of temperature (T). The η - T data were then fitted to a Vogel-Tamman-Fulcher (VTF) model:

$$\ln \eta = A + \frac{B}{T - T_0} \quad (1)$$

where A , B , and T_0 are temperature independent coefficients. Equation (1) was then used to calculate a η at 1350°C (η_{1350}), which was considered the nominal melter operating temperature during the Phase 1 study. The η_{1350} values ranged from 1.24 pascal seconds (Pa·s) to 4.01 Pa·s. The effect of Ln_2O_3 concentration on $\ln[\eta_{1350}]$ is shown in Figure 2.

Of the 31 Phase 1 glasses, 10 failed the η constraint (3 – 24 Poise at 1350°C).³ All 10 glasses have viscosities exceeding the 24 Poise upper limit. For those glasses failing the viscosity constraint, total target lanthanide contents were ≤ 43.75 mass % (corresponding to ≤ 25 mass % feed loading). Based on measured Ln_2O_3 content, glasses containing at least 42 mass % total Ln_2O_3 meet the viscosity constraint. The Phase 1 viscosity data indicated that feed loadings of at least 30 mass % should be targeted in the vitrification batch process (no other properties being considered). Based on these results, a lower bound on feed loading for the development of the Phase 2 matrix was established.

With regards to liquidus temperature, two primary crystalline phases were found to precipitate from the Phase 1 glasses, an aluminosilicate (AIS) with T_L values ranging from 1164° to 1255°C and a rare-earth silicate (RES) with T_L values ranging from 1163° to 1298°C. There is a clear distinction between the primary phase fields based on total lanthanide content alone (see Figure 3). For Ln_2O_3 concentrations less than ~ 43 mass % (measured), AIS was found to be the primary phase; glasses with higher Ln_2O_3 concentrations were determined to be in the RES primary phase field. A minimum in T_L is found at approximately ~ 44 mass % Ln_2O_3 , with increasing T_L at both higher and lower Ln_2O_3 concentrations.

A weak correlation, based on low R^2 values (as shown in Figure 3), was found between T_L and Ln_2O_3 concentration for Phase 1 glasses in both primary phase fields. Within the AIS primary phase field, as Ln_2O_3 concentrations (or low loadings) increase, a gradual decrease in T_L is

² Throughout this report, the reference to lanthanide oxides (Ln_2O_3) refers to the oxides in the lanthanide (or rare earth) series (La, Ce, Pr, Nd, Sm, Eu, Gd, and Er) unless otherwise stated.

³ To convert Pa·sec to Poise multiply by 10.

observed. After transitioning into the RES primary phase field, increases in Ln_2O_3 concentration (or loading) result in increases in T_L .

Figure 2. $\ln(\eta_{1350})$ as a Function of Ln_2O_3 Concentration for Phase 1 Glasses.

Figure 3. T_L as a Function of Ln_2O_3 Concentration for Phase 1 Glasses.

(■ - Phase 1 glasses in the AIS primary phase field, ♦ - Phase 1 glasses in the RES primary phase field)

The Phase 1 AGCR was restricted based on the 1250°C liquidus constraint with 7 of the 31 Phase 1 glasses exceeding this constraint. Unlike the viscosity constraint where only low loadings caused glasses to be “unacceptable”, both high and low loaded glasses (i.e., in both primary phase fields) fail the Phase 1 T_L constraint. The Ln_2O_3 concentration alone cannot be used as the key indicator over the entire experimental glass composition region (EGCR)⁴. However, one can use the Ln_2O_3 concentration within each primary phase field. Based on the data within the AIS primary phase field, one would eliminate the fabrication of 20 mass % loaded glasses.

In the RES primary phase field, one would hope that glasses failing the 1250°C constraint would be a part of a single target loading (i.e., 40%). Unfortunately, this is not the case. Glasses deemed “unacceptable” within the RES primary phase field span feed loadings from 35 – 40 mass %. Based on the conservative T_L constraint (1250°C), a relatively large portion of the EGCR would be eliminated in the definition of the AGCR. However, if the T_L constraint were increased to 1300°C, all Phase 1 glasses would pass and the AGCR would encompass the entire Phase 1 EGCR (based solely on T_L and ignoring uncertainties associated with the measurement).

Based on the Phase 1 results an AGCR was identified in which glasses met both process and product performance criteria. Figures 4 and 5 illustrate the Phase 1 AGCR definitions based on the use of a 1250° and 1300°C T_L constraint, respectively. The operational window is expanded significantly by increasing the liquidus temperature constraint 50°C (i.e., from 1250° to 1300°C). Given that the T_L constraint could safely be increased to 1300°C, the operational window or AGCR for the Phase 1 variability study is only limited by glasses at a 20 – 25 mass% loading. Those glasses did not meet the viscosity constraint as currently defined. In other words, all glasses with feed loadings of > 25 mass % would be acceptable from both a processing and product performance perspective within the limits from which the Phase 1 matrix was developed and tested.

As previously discussed, most Phase 1 composition – property relationships are dependent upon the Ln_2O_3 concentration in the glass. There was no indication that the distribution of the lanthanides impacts either the processing or product performance properties within the limits of the experimental design.⁵ Peeler et al. [9] and Vienna et al. [15, 16] provide detailed discussions of the Phase 1 results.

Based on Phase 1 data and given that the T_L constraint could be safely increased, it was determined that increased feed loadings (higher lanthanide contents) were feasible. Therefore, Phase 2 was designed to evaluate the potential for higher feed loadings (32 – 52 mass % loading on an oxide basis or 49 – 64 mass % total Ln_2O_3) and the impact on the composition – property relationships of interest. Although higher waste loadings were evaluated in Phase 2, the matrix was designed to provide some overlap with Phase 1 as recommended by Peeler et al. [9].

⁴ The composition region as specified by the TTR [12] is referred to as the EGCR throughout this report. In short, the EGCR bounds the compositional envelope in which glasses are expected to fall based on the feed composition (and its variability) from a 2-wash scenario, the frit composition, and the target loadings.

⁵ It should be noted that the thermal reduction of $\text{Ce}^{4+} \rightarrow \text{Ce}^{3+}$ liberated O_2 may have an impact on melter processing. Vienna et al. [8] and Peeler et al. [7] provide more detailed discussions on this issue.

Figure 4. Definition of Phase 1 AGCR Based on the 1250°C T_L Constraint.
(target compositions)

Figure 5. Definition of Phase 1 AGCR Based on a 1300°C T_L Constraint.
(target compositions)

4.0 DEFINING THE PHASE 2 EXPERIMENTAL GLASS COMPOSITIONAL REGION (EGCR)

Edwards [11] provides a detailed discussion on the definition of the Phase 2 EGCR, the objectives of the “phased” approach, and the strategy for selecting glasses within the multi-dimensional composition space. As in Phase 1, three primary factors define the Phase 2 EGCR:

- (1) the composition of the Am-Cm containing feed (its average and likely variation),
- (2) the composition of the selected frit, and
- (3) the target range for the feed loading (i.e., the feed’s percentage of the glass product by mass).

The average composition of the feed has been estimated from the most recent measurement from Tank 17.1⁶ and associated material balance calculations.[17] The expected variation of each feed component for the Phase 1 design (i.e., $\pm 20\%$ of its average) did not appear to have any negative impacts on the specific Phase 1 processing or product performance properties within the design limitations. Given this knowledge, it was recommended [9] that NMS&S expand the variation of each feed component in the Phase 2 design (i.e., from ± 20 to $\pm 40\%$ of the average) to potentially expand the compositional envelope over which glasses may be produced (i.e., to demonstrate that larger uncertainties associated with pretreatment efficiencies and sampling and/or analytical error can be tolerated). Edwards [11] developed a “layered design” to evaluate both $\pm 20\%$ and $\pm 40\%$ variations of each oxide associated with the incoming Am-Cm containing feed. The nominal actinide-bearing feed material and surrogate feed material on an oxide (mass %) basis are shown in Table I.

Feed loadings in the glass are expected to fall within the interval of 32 – 52 mass % on an oxide basis [12]. The major characteristic of the actinide bearing feed (shown in Table I) is the high percentage of lanthanide oxides and actinide oxides (> 99.82 mass % of the feed). Given the high content of lanthanides and actinides, there are obviously very few “impurities” (e.g., Al_2O_3 , Fe_2O_3 , NiO , MnO , Cr_2O_3 , etc) associated with this feed stream as a result of pretreatment processes.

The concentrations of several lanthanides (Tb_2O_3 , Dy_2O_3 , Ho_2O_3 , Er_2O_3 , Tm_2O_3 , Yb_2O_3 , and Lu_2O_3) in the feed are analyzed as less than 1 mass % on an individual basis. Although the components are shown on the most recent material balance flow sheets, their concentrations may be at or below the detection limits of the analytical equipment. Assuming that these oxide components are not present in the incoming actinide-bearing stream, one can distribute their questioned contribution (a total of 2.66 mass %) over the remaining major lanthanide oxides (i.e., normalize by increasing each of the seven major Ln_2O_3 concentrations by 0.38 mass %). The Phase 1 results [9, 14] indicated that most composition – property relationships or constraints were driven by the total Ln_2O_3 concentration in glass, not the distribution of the Ln_2O_3 s.⁷ Based on these observations, the concentrations of the more prevalent Ln_2O_3 ’s were normalized so that

⁶ Rare earth analyses (La, Ce, Pr, Nd, Sm, Eu and Gd) were obtained from a cc:mail memo from M.R. Nelson to W.H. Martin dated 4/23/98. Solution density, acid content and Fe, Ni and Cr analyses were obtained from a cc:mail memo from S.L. Maxwell to R.H. Spires (TSD-ALA-98-0011) dated 2/26/98. M.M. Jerath estimated the volume of solution in Tank 17.1 to be 10,551 liters from F-Canyon operating data.

⁷ It should be noted that concentration of CeO_2 has been shown to have an impact on the processability within the CIM (i.e., thermal reduction liberating O_2 leading to a bed expansion during the conversion of the batch materials to glass). [7, 8]

the total lanthanide concentration from the feed was represented by their values alone. The surrogate feed material on which this study was based is also shown in Table I.

Table I. Average Actinide-Bearing Feed Material and Surrogate Feed Material on an Oxide (mass %) Basis.

Oxide	Actinide-Bearing Feed Material (Tank 17.3E)	Surrogate Feed Material
Lanthanide Oxides		
La ₂ O ₃	15.05	15.43
Ce ₂ O ₃	12.94	13.32
Pr ₂ O ₃	11.26	11.64
Nd ₂ O ₃	32.80	33.18
Sm ₂ O ₃	7.49	7.87
Eu ₂ O ₃	1.56	1.94
Gd ₂ O ₃	3.98	4.36
Tb ₂ O ₃	0.36	-
Dy ₂ O ₃	0.36	-
Ho ₂ O ₃	0.36	-
Er ₂ O ₃	0.35	12.08 ⁸
Tm ₂ O ₃	0.53	-
Yb ₂ O ₃	0.35	-
Lu ₂ O ₃	0.35	-
Actinide Oxides		
Am ₂ O ₃	9.70	-
Cm ₂ O ₃	2.38	-
Metallic Oxides		
Al ₂ O ₃	0.01	0.01
Fe ₂ O ₃	0.03	0.03
MnO	0.14	0.14
Total	100.00	100.00

For Phase 2, the feed loading range was primarily driven by two factors: (1) a balanced approach of increasing feed loadings (or higher total Ln₂O₃ concentrations) while minimizing potential processing risks in terms of exceeding an upper T_L constraint and (2) maintaining some degree of overlap with Phase 1 for continuity. The first issue was addressed by the use of T_L model estimates or projections (based on the Phase 1 data as shown in Figure 3) in relation to the new T_L constraint of 1350°C. The use of model predictions based on total Ln₂O₃ concentration to define upper and lower loading bounds does have its limitations. First, the Phase 2 glasses will be outside the compositional envelope on which the model was developed. Second, a linear relationship within the RES primary phase field is assumed. Based on the target feed loadings and total Ln₂O₃ concentrations for Phase 2, it is assumed that all Phase 2 glasses will be based in the RES primary phase field.

⁸ Er₂O₃ was substituted for both actinides (Am₂O₃ and Cm₂O₃) on a straight mass % basis. As with most programs involving radioactive materials, surrogates are used to expedite the development process and minimize cost and schedule impacts. The challenge is to choose a surrogate that mimics the chemical and physical response of the material properties of interest. Peeler and Reamer (WSRC-RP-97-00421) discuss the use of Er₂O₃ as an Am₂O₃ and Cm₂O₃ surrogate.

Although these two limitations exist, given the relationship between T_L and total lanthanide content for Phase 1 (see Figure 3), projections in T_L space for Phase 2 will provide some measure to avoid producing a large number of glasses with T_L in excess of 1350°C. Knowing the limitations of the T_L model, the Phase 2 design incorporated a few glasses with T_L predictions exceeding the 1350°C constraint. Edwards [11] addressed the second issue (i.e., overlap between Phase 1 and Phase 2) via the matrix design by including "replicate" glasses from the Phase 1 matrix.

The proposed frit composition for the batch vitrification process is based on a lanthanide borosilicate glass and is referred to as 25SrABS ($\text{SrO-Al}_2\text{O}_3\text{-B}_2\text{O}_3\text{-SiO}_2$). The target composition of the 25SrABS frit is given in Table II – no compositional change from Phase 1. The nomenclature or reference to 25 indicates that this frit contains 25 mass % La_2O_3 . Therefore, La_2O_3 has contributions from both the feed (~15 mass %; Table I) and the 25SrABS frit (25 mass %; Table II).

Table II: Target 25SrABS Frit Composition (mass %).

Oxide	La_2O_3	Al_2O_3	B_2O_3	SiO_2	SrO
Mass Fraction	25.00	24.87	13.54	33.68	2.91

Given the feed composition (and its potential $\pm 20\%$ and $\pm 40\%$ variation), the 25SrABS frit composition, and the target feed loading range of 32 to 52 mass % for the process, the EGCR for Phase 2 was defined.[11] Table III provides the bounding concentrations for the Phase 2 EGCR for both the inner ($\pm 20\%$ variation) and outer ($\pm 40\%$ variation) layers.

Table III. Compositional Bounds for Phase 2 EGCR Definition (mass %).

Oxide	Mass % Ranges for Feed Loadings of 32 – 52 %			
	Inner Layer ($\pm 20\%$ variation)		Outer Layer ($\pm 40\%$ variation)	
	Lower	Upper	Lower	Upper
La_2O_3	18.42	22.93	16.81	23.91
Ce_2O_3	3.41	8.31	2.56	9.70
Pr_2O_3	2.98	7.26	2.23	8.47
Nd_2O_3	8.49	20.70	6.37	24.16
Sm_2O_3	2.01	4.91	1.51	5.73
Eu_2O_3	0.05	1.21	0.37	1.41
Gd_2O_3	1.12	2.72	0.84	3.17
Er_2O_3	3.09	7.54	2.32	8.79
Al_2O_3	11.94	16.91	11.94	16.91
B_2O_3	6.50	9.21	6.50	9.21
SiO_2	16.17	22.90	16.17	22.90
SrO	1.40	1.98	1.40	1.98

The bounding composition envelope represented by Table III does not account for some trace, metallic oxides present in the material balance calculation (e.g., Al_2O_3 , Fe_2O_3 , and MnO as shown in Table I). These trace, metallic oxides are present in such small quantities (0.01, 0.03, and 0.14 mass %, respectively) in the feed they were assumed not to have a significant impact on the

properties of interest in the Phase 2 design. Although this assumption was valid in Phase 1, it will be reevaluated in Phase 2 with the insertion of five glasses using a minor component "spike" (based on a 1-wash pretreatment scenario) as discussed in the next section.

5.0 SELECTING PHASE 2 GLASS COMPOSITIONS

The strategy for selecting glass compositions for the Phase 2 EGCR has been described by Edwards [11]. Statistically, Phase 2 had three primary goals. The first was to establish the measurement procedures (and their uncertainties) that are to be used to measure the properties of interest throughout this study. The second was to assess the impact of compositional uncertainties on the primary processing and product performance properties of glasses that cover the EGCR. This second objective may be more precisely stated as the goal of answering the question; "Is there any indication that the properties of interest are unacceptable over any portion of the anticipated experimental glass composition region?"

For Phase 1, the glass composition selection process did not (and was not intended to) allow for an evaluation for discerning differences among the influences of the various components on the properties of interest. Only the influence of the total lanthanide content on these properties was explored [9]. Therefore, the third goal of Phase 2 was to investigate the influences of the total lanthanide content and of each individual lanthanide on the various properties of interest. Even though modeling the response of interest is not a primary objective of this variability study, the process used to select glasses did yield compositions that do provide the opportunity to estimate linear effects in the response(s) due to individual components in the glass.

Table IV identifies the 55 glasses selected for the Phase 2 design. The use of the AC2 nomenclature identifies this as Phase 2 of the Am-Cm variability study. As previously mentioned, Phase 2 is a "layered design" intended to evaluate both $\pm 20\%$ and $\pm 40\%$ variations of each oxide associated with the incoming Am-Cm containing feed. There are 16 unique compositions that define the inner layer (AC2-01 – AC2-16) and 14 unique compositions that define the outer layer (AC2-18 – AC2-31). It is primarily from these 30 glasses that estimations of linear effects in the response(s) due to individual components will be made. AC2-17 and AC2-32 represent the overall centroids of the inner and outer layer, respectively. Glasses (AC2-33 – AC2-41) representing feed loadings of 42 – 50 mass % (in 1% increments using the nominal feed composition) were also included in the Phase 2 design as specified by Martin [12]. AC2-42 (32 mass % loading) and AC2-43 (37 mass % loading) were added to the Phase 2 design to obtain a measure of reproducibility and to provide some consistency or overlap between phases. Five glasses (AC2-47, AC2-48, AC2-49, AC2-50, and AC2-51) are replicates of interior points (AC2-33, AC2-38, AC2-42, AC2-43, and AC2-44, respectively). AC2-45 and AC2-55 are specific glasses to address the potential impact of additional oxygen liberation from Am and Cm due to thermal reduction at high temperatures on the processability. Cerium oxide (known to reduce at higher temperatures in this system [7, 8]) was used as the surrogate for both Am and Cm oxide in these glasses. It should be noted that the true impact of this redox potential on processability can only be evaluated in the full-scale CIM. Only the impacts to the primary properties of interest in this study will be addressed. Finally, AC2-46 was added to the Phase 2 design to represent the AmCm-1A composition.⁹

⁹ The AmCm-1A composition was of extreme interest during Phase 1 which targeted a 47 mass % feed loading or 60 mass % total Ln_2O_3 concentration.

To evaluate the effect of minor metallic oxides on the primary processing and product performance properties, five additional glasses were added to the overall Phase 2 EGCR design. AC2-50 through AC2-54 are essentially replicates of AC2-33 (-47), AC2-38, AC2-42 (-48), AC2-43 (-49), and AC2-44, respectively, with the exception that these glasses have been "spiked" with maximum levels of various metallic oxides (as shown in Table V). These glasses are identified by an "*" in Table IV. The level of each minor component spike is considered an upper or bounding value that the process may receive at the highest feed loading evaluated in Phase 2 (i.e., +40% variation with a 52% feed loading based on a 1-wash scenario¹⁰). As the properties of interest are explored for this EGCR, the behavior of the spiked glasses relative to their non-spiked replicates will be investigated.

Table V. Level of Metallic Oxides "Spiked" in Select Glasses (mass %).

Oxide	Fe ₂ O ₃	NiO	Cr ₂ O ₃	CaO	Na ₂ O	K ₂ O	MnO
Mass %	0.044	0.002	0.007	0.001	0.005	0.002	0.002

Figure 6 shows the Phase 2 EGCR as defined by the 55 glasses within a compositional ternary. The three components of the ternary represent the total target La₂O₃ content (La₂O₃ contributions from both the feed and the frit), other frit, and other feed. Composition – property relationships within the EGCR (represented by the outlined "box" in Figure 6) are to be evaluated as part of this study. One of the primary goals of this study was to answer the question; "Is there any indication that the properties of interest are unacceptable with respect to the predefined criteria over any portion of this EGCR?"

¹⁰ The concentration of each minor component listed in Table I is based on a two-wash pretreatment scenario. Given that the concentration of minor components in the feed stream is related to the number of pretreatment washes (i.e., each wash reduces their concentration), allowing for and evaluating a higher concentration of minor components may allow for a reduction in the pretreatment cycle time and costs. The values shown in Table V are based on a 1-wash scenario and assume a +40% variation and 52 mass% feed loading. The concentrations of each minor component resulting from a 1-wash scenario were obtained from the TTR, Page 9 [12].

Table IV. Target Phase 2 Glass Compositions (mass fraction).

	Design	Al ₂ O ₃	B ₂ O ₃	Ce ₂ O ₃	Er ₂ O ₃	Eu ₂ O ₃	Gd ₂ O ₃	La ₂ O ₃	Nd ₂ O ₃	Pr ₂ O ₃	SiO ₂	Sm ₂ O ₃	SrO	Feed	Frit	Ln ₂ O ₃
AC2-01	IL-EV	0.1190	0.0650	0.0840	0.0760	0.0050	0.0110	0.2300	0.0840	0.0730	0.2190	0.0200	0.0140	0.353	0.417	0.583
AC2-02	IL-EV	0.1700	0.0930	0.0840	0.0300	0.0050	0.0280	0.2300	0.0920	0.0730	0.1610	0.0200	0.0140	0.332	0.438	0.562
AC2-03	IL-EV	0.1190	0.0930	0.0840	0.0300	0.0130	0.0110	0.2300	0.1900	0.0290	0.1610	0.0200	0.0200	0.377	0.393	0.607
AC2-04	IL-EV	0.1190	0.0650	0.0340	0.0300	0.0050	0.0280	0.2300	0.1850	0.0730	0.1610	0.0500	0.0200	0.365	0.405	0.635
AC2-05	IL-EV	0.1700	0.0650	0.0340	0.0300	0.0130	0.0280	0.2300	0.1020	0.0290	0.2290	0.0500	0.0200	0.286	0.484	0.516
AC2-06	IL-EV	0.1190	0.0930	0.0340	0.0760	0.0050	0.0110	0.2300	0.1780	0.0290	0.1610	0.0500	0.0140	0.383	0.387	0.613
AC2-07	IL-EV	0.1700	0.0650	0.0340	0.0760	0.0130	0.0110	0.2300	0.1090	0.0290	0.2290	0.0500	0.0140	0.292	0.478	0.522
AC2-08	IL-EV	0.1700	0.0650	0.0840	0.0300	0.0130	0.0110	0.1840	0.0840	0.0730	0.2160	0.0500	0.0200	0.345	0.471	0.529
AC2-09	IL-EV	0.1190	0.0650	0.0840	0.0760	0.0050	0.0280	0.1840	0.1330	0.0730	0.1610	0.0500	0.0140	0.457	0.359	0.641
AC2-10	IL-EV	0.1190	0.0930	0.0840	0.0760	0.0050	0.0280	0.1840	0.0840	0.0290	0.2280	0.0500	0.0200	0.356	0.460	0.540
AC2-11	IL-EV	0.1700	0.0650	0.0840	0.0300	0.0050	0.0110	0.1840	0.1970	0.0290	0.1610	0.0500	0.0140	0.406	0.410	0.590
AC2-12	IL-EV	0.1190	0.0650	0.0340	0.0300	0.0050	0.0110	0.1840	0.2070	0.0730	0.2290	0.0200	0.0200	0.383	0.433	0.567
AC2-13	IL-EV	0.1700	0.0930	0.0340	0.0300	0.0050	0.0110	0.1840	0.1070	0.0730	0.2290	0.0500	0.0140	0.310	0.506	0.494
AC2-14	IL-EV	0.1700	0.0930	0.0340	0.0760	0.0130	0.0110	0.1840	0.1450	0.0730	0.1610	0.0200	0.0200	0.372	0.444	0.556
AC2-15	IL-EV	0.1190	0.0930	0.0340	0.0300	0.0130	0.0280	0.1840	0.2070	0.0290	0.2290	0.0200	0.0140	0.361	0.455	0.545
AC2-16	IL-EV	0.1700	0.0650	0.0350	0.0760	0.0050	0.0280	0.1840	0.2070	0.0290	0.1610	0.0200	0.0200	0.400	0.416	0.584
AC2-17	IL-oc	0.1439	0.0787	0.0580	0.0524	0.0090	0.0194	0.2064	0.1361	0.0504	0.1941	0.0347	0.0170	0.360	0.434	0.566
AC2-18	OL-EV	0.1190	0.0650	0.0970	0.0230	0.0150	0.0080	0.1700	0.2420	0.0220	0.1610	0.0380	0.0200	0.299	0.461	0.539
AC2-19	OL-EV	0.1190	0.0930	0.0970	0.0880	0.0030	0.0080	0.2400	0.0630	0.0250	0.2290	0.0150	0.0200	0.299	0.461	0.539
AC2-20	OL-EV	0.1190	0.0650	0.0970	0.0230	0.0150	0.0320	0.2400	0.1340	0.0850	0.1610	0.0150	0.0140	0.401	0.359	0.641
AC2-21	OL-EV	0.1700	0.0930	0.0970	0.0230	0.0030	0.0320	0.2400	0.0810	0.0220	0.1610	0.0380	0.0200	0.316	0.444	0.556
AC2-22	OL-EV	0.1190	0.0930	0.0250	0.0230	0.0030	0.0320	0.2400	0.0630	0.0830	0.2290	0.0580	0.0200	0.299	0.461	0.539
AC2-23	OL-EV	0.1700	0.0650	0.0250	0.0230	0.0030	0.0080	0.2400	0.1850	0.0850	0.1610	0.0150	0.0200	0.344	0.416	0.584
AC2-24	OL-EV	0.1190	0.0930	0.0250	0.0340	0.0030	0.0320	0.2400	0.2420	0.0220	0.1610	0.0150	0.0140	0.373	0.387	0.613
AC2-25	OL-EV	0.1700	0.0650	0.0250	0.0880	0.0150	0.0320	0.2400	0.1040	0.0220	0.1610	0.0580	0.0200	0.344	0.416	0.584
AC2-26	OL-EV	0.1700	0.0650	0.0280	0.0880	0.0150	0.0080	0.2400	0.0630	0.0220	0.2290	0.0580	0.0140	0.282	0.478	0.522
AC2-27	OL-EV	0.1630	0.0650	0.0970	0.0230	0.0030	0.0320	0.1680	0.0630	0.0850	0.2290	0.0580	0.0140	0.361	0.471	0.529
AC2-28	OL-EV	0.1700	0.0930	0.0970	0.0810	0.0150	0.0320	0.1680	0.0630	0.0850	0.1610	0.0150	0.0200	0.388	0.444	0.556
AC2-29	OL-EV	0.1190	0.0930	0.0250	0.0880	0.0030	0.0080	0.1680	0.1780	0.0850	0.1610	0.0380	0.0140	0.445	0.387	0.613
AC2-30	OL-EV	0.1700	0.0930	0.0250	0.0230	0.0150	0.0080	0.1680	0.2180	0.0220	0.2290	0.0150	0.0140	0.326	0.506	0.494
AC2-31	OL-EV	0.1190	0.0650	0.0250	0.0880	0.0030	0.0320	0.1680	0.2140	0.0220	0.2290	0.0150	0.0200	0.399	0.433	0.567
AC2-32	OL-oc	0.1443	0.0788	0.0601	0.0546	0.0090	0.0198	0.2031	0.1298	0.0528	0.1943	0.0364	0.0170	0.363	0.434	0.566
AC2-33, -47, -50*	Interior	0.1442	0.0785	0.0559	0.0507	0.0081	0.0183	0.2098	0.1394	0.0489	0.1953	0.0331	0.0169	0.354	0.435	0.564
AC2-34	Interior	0.1418	0.0772	0.0573	0.0519	0.0083	0.0187	0.2088	0.1427	0.0501	0.1920	0.0338	0.0166	0.363	0.428	0.572
AC2-35	Interior	0.1393	0.0758	0.0586	0.0532	0.0085	0.0192	0.2079	0.1460	0.0512	0.1886	0.0346	0.0163	0.371	0.420	0.579
AC2-36	Interior	0.1368	0.0745	0.0599	0.0544	0.0087	0.0196	0.2069	0.1493	0.0524	0.1852	0.0354	0.0160	0.380	0.413	0.587
AC2-37	Interior	0.1343	0.0731	0.0613	0.0556	0.0089	0.0201	0.2060	0.1526	0.0535	0.1819	0.0362	0.0157	0.388	0.405	0.594
AC2-38, -51*	Interior	0.1318	0.0718	0.0626	0.0568	0.0091	0.0205	0.2050	0.1559	0.0547	0.1785	0.0370	0.0154	0.397	0.398	0.602
AC2-39	Interior	0.1293	0.0704	0.0639	0.0580	0.0093	0.0209	0.2041	0.1593	0.0559	0.1751	0.0378	0.0151	0.405	0.390	0.609
AC2-40	Interior	0.1268	0.0691	0.0653	0.0592	0.0095	0.0214	0.2031	0.1626	0.0570	0.1718	0.0386	0.0148	0.414	0.383	0.617
AC2-41	Interior	0.1244	0.0677	0.0666	0.0604	0.0097	0.0218	0.2022	0.1659	0.0582	0.1684	0.0394	0.0146	0.422	0.375	0.624
AC2-42, -48, -52*	Interior	0.1691	0.0921	0.0426	0.0387	0.0062	0.0140	0.2194	0.1062	0.0372	0.2290	0.0252	0.0198	0.270	0.510	0.489
AC2-43, -49, -53*	Interior	0.1567	0.0853	0.0493	0.0447	0.0072	0.0161	0.2146	0.1228	0.0431	0.2122	0.0291	0.0183	0.312	0.473	0.527
AC2-44, -54*	Interior	0.1194	0.0650	0.0693	0.0628	0.0101	0.0227	0.2002	0.1725	0.0605	0.1617	0.0409	0.0140	0.439	0.360	0.639
AC2-45	2Ce ₂ O ₃	0.1442	0.0785	0.1087	0.0507	0.0069	0.0154	0.1988	0.1155	0.0407	0.1953	0.0276	0.0169	0.366	0.435	0.564
AC2-46	AmCm 1A	0.1319	0.0718	0.0626	0.0568	0.0091	0.0205	0.2050	0.1560	0.0547	0.1785	0.0370	0.0154	0.397	0.398	0.602
AC2-55	2Ce from Nd	0.1444	0.0786	0.1120	0.0508	0.0082	0.0183	0.2100	0.0835	0.0489	0.1955	0.0331	0.0169	0.3548	0.4354	0.5648

* Design Nomenclature: IL-EV: interior layer extreme vertice; OL-EV: Outer layer extreme vertice; IL-OC: interior layer overall centroid; OL-OC: out layer overall centroid; Interior: interior points

Figure 6. Phase 2 EGCR as Defined by Target Glass Compositions (mass fraction).
♦ – outer layer extreme vertices ($\pm 40\%$); x – inner layer extreme vertices ($\pm 20\%$); y – specific compositions using average feed composition; other symbols represent overall centroids, Ce-spiked glasses, and the Am/Cm-1A glass.

6.0 PREDEFINED ACCEPTANCE CRITERIA

To ensure that the glass is both processable and meets product performance specifications, the criteria established and implemented for the Phase 2 study were utilized.[12, 13] These criteria focus on processing (liquidus temperature and viscosity) and product performance (durability and recoverability) issues and are to be used to define the AGCR based on composition – property relationships for the 55 Phase 2 glasses. That is, for a glass to be “acceptable” and fall within the AGCR, it must comply with or meet all constraints simultaneously. Each of the Phase 2 acceptance criteria is briefly discussed below.

6.1 PROCESSING CRITERIA

VISCOSITY

This constraint has been defined by a viscosity (η) range (3 – 24 Poise) at a given temperature (1350°C) based on thermal modeling and calculations of continuous and

non-continuous pour streams.¹¹ Viscosities exceeding the upper η_{1350} limit will be considered less than optimal due to the potential to result in a non-continuous pour stream (considered to be ≤ 8 kg/h).

LIQUIDUS TEMPERATURE (T_L)

Liquidus temperature is defined as the maximum temperature at which equilibrium exists between the molten glass and its primary crystalline phase.[18] If the melt temperature is above T_L , crystallization will not occur eliminating potentially negative impacts to melter processing. If the melt temperature is below T_L (or "cold" spots exist within the melter), crystallization may occur and can impact processing (e.g., crystals may plug the drain tube) and/or affect product performance (e.g., durability) if crystals are present in the final glass product. The nominal CIM operating temperatures are in the range of 1450°C. To avoid the potential negative effects of crystallization within the melter, a Phase 2 T_L criterion of 1350°C was set. This provides a conservative 100°C differential between the nominal lower melter operating temperature (1450°C) and the T_L criterion. Therefore Phase 2 glasses with T_L 's $\leq 1350^\circ\text{C}$ will be considered processable within the CIM. This is the only criterion that differs from the predefined Phase 1 constraints.¹² It should be noted that T_L measurements provide very limited insight into the kinetics of devitrification. The kinetics of devitrification for glasses spanning the Phase 2 EGCR were not evaluated as part of this task. This data could be obtained via a separate study or deduced in general from full scale CIM testing for specific processing conditions.

6.2 PRODUCT PERFORMANCE CRITERIA

RECOVERABILITY

To ensure that the product meets the current programmatic objective (i.e., recoverability of Am-Cm at ORNL), a recoverability criterion was also defined. The recoverability criterion is 98% of the total lanthanides must be recovered within 2 h using 8M nitric acid with glass ground to -35 to +60 mesh (Tyler equivalent) and heated to 110°C [12]. All Phase 2 glasses and a limited number (5) of Phase 1 glasses were tested.

DURABILITY

Durability of the final waste form can also limit the composition space over which glasses should be produced. That is, glass within a certain compositional space may be processable but may result in a non-durable product thus reducing the likelihood of acceptance (if long-term storage or disposal becomes an option). To minimize the potential "acceptance issue," durability as defined by the Product Consistency Test (PCT) (ASTM C 1285-97) [19] will also be used to define the AGCR. Acceptance will be based on a comparison of the normalized release rates of various Phase 2 glass components to those limits of the Environmental Assessment (EA) [20] (with the

¹¹ The relationship between flow rate and glass viscosity was obtained from an isothermal model of the drain tube based on the extended Bernoulli and Poiseuille equations. The viscosity required to give an 8 kg/h flow rate was obtained for a given glass density, glass pool depth (head) and drain tube diameter and length. It should be noted that the increase in nominal T_M from 1350°C (Phase 1) to 1450°C (Phase 2) has no impact on the viscosity constraint which is linked to the drain tube temperature.

¹² The Phase 1 T_L constraint (1250°C) was defined based on a nominal processing temperature (1350°C) for the Am-Cm-1 (AC1-31) glass (30 mass % feed loading). Although this glass is processable at 1350°C, the CIM is capable of much higher processing temperatures. The increase in nominal processing temperature allowed for the relaxation of the T_L constraint that was a limiting factor in the definition of the Phase 1 AGCR.

appropriate confidence limits applied). Normalized boron (B) release will be used as the key indicator of durability although the release of other components will also be tracked. Typically, Na and Li are also tracked, but the SrABS frit does not contain either Na or Li and only Na exists in the feed stream and at an extremely low concentration.

Table VI summarizes the processing and product performance criteria to be used to define the AGCR for Phase 2. Other properties have been measured and reported for the Phase 2 glasses, (e.g., homogeneity, room temperature density, high temperature density, and surface tension) however, they will not be used to define the AGCR.

Although the AGCRs defined by both the Phase 1 and Phase 2 data are discussed, the primary focus of this report is on the Phase 2 data reduction and definition of the Phase 2 AGCR. This report does not attempt to provide a detailed discussion of the data reduction and/or model development for both data sets.

Table VI. Phase 2 Composition – Property Constraints.

Property	Phase 2 Constraint
<i>Processing</i>	
Viscosity (η)	3 – 24 Poise at 1350°C
Liquidus Temperature (T_L)	$\leq 1350^\circ\text{C}$
<i>Product Performance</i>	
Durability	NL [B] < 16.695 - 2σ (EA limits) as defined by the PCT
Recoverability	98% recovery of total lanthanides under specific processing conditions

7.0 EXPERIMENTAL

The data generated for the Phase 2 variability study were accomplished via a joint effort between the SRTC and PNNL. This work was performed according to applicable DOE/RW-0333P Quality Assurance Criteria¹³ at both laboratories. Data collected and reported from PNNL were acquired under a PNNL Quality Assurance (QA) Program, SNF-70-001. A specific QA Plan Checklist for PNNL Project 30306, High Temperature Viscosity and T_L for Am-Cm Variability Study, was developed and utilized by PNNL. The QA Plan Checklist contains the QA implementing procedures; part of the PNNL Spent Fuel Nuclear Fuel QA Program was also applied to this study. Quality assurance oversight within PNNL was provided by a Quality Engineer matrixed to this work from the independent Process Quality Department. Additional surveillance was provided by the SRTC QA staff as documented in Surveillance Report 99-SUR-11-020 [21]. This section describes the experimental procedures, test equipment, and application of standards to generate the required data.

¹³ As defined by the DOE/RW-0333P Quality Assurance Program.

7.1 GLASS FABRICATION

Table IV identified the 55 Phase 2 glasses prepared for this study as well as the unique nomenclatures used (i.e., AC2 series). Each batch was prepared (to produce 450 grams of glass¹⁴) from the proper proportions of reagent grade chemicals using SRTC technical procedure "Glass Batch Preparation Procedure – GTOP-3-003".^[22] Weigh sheets were filled out as the materials were weighed.¹⁵ It should be noted that the use of reagent grade chemicals will not allow for an evaluation of certain processing issues that have been of interest in the development program (i.e., volume expansion and/or high temperature bubble formation which typically require oxalate precipitate and frit as raw material sources).^[7, 8] These issues will be evaluated in separate tests performed in the CIM pilot facility.

Once batched, these glasses were melted using a standard thermal heat treatment. In general, the raw materials were thoroughly mixed and placed into a Platinum / 5% Rhodium 600 mL crucible. The batch was subsequently placed into a high temperature furnace and the temperature was increased at ~ 4°C/minute to 1450°C. After an isothermal hold at 1450°C for 0.5 h, the crucible was removed and the glass was poured onto a clean stainless steel plate and allowed to air cool.

Based on a recommendation from the Phase 1 report [9], the melting procedure was altered or modified to minimize potential chemical composition gradients within the "as-fabricated" glasses. Compositional gradients in the pour patty may have introduced additional measurement error for some of the Phase 1 property measurements (in particular T_L as several small subsamples were obtained for the isothermal heat treatments). To minimize this potential effect, the initial pour patty was ground in a tungsten carbide (WC) mill for approximately 2 minutes. The crushed glass was subsequently transferred to its original Platinum / 5% Rhodium 600 mL crucible for a second melt at 1450°C. After an isothermal hold at 1450°C for 0.5 h, the crucible was removed and the glass was poured onto a clean stainless steel plate and allowed to air cool. It should be noted that the objective of both Phase 1 and Phase 2 was to measure specific composition – property relationships within a specific compositional envelope not to simulate melting conditions within the CIM.

Approximately 400 grams of glass was removed (poured) from the crucible while ~ 50 grams remained in the crucible along the walls. The pour patty was divided into the appropriate quantities for each property measurement. Glasses were stored in marked containers (using the unique AC2 nomenclature as defined by Edwards [11]) and either shipped to PNNL (for viscosity and liquidus temperature measurements) or retained at SRTC (for homogeneity, chemical composition, density, PCT, and recoverability measurements). As appropriate, chain-of-custody forms were used to track samples.

¹⁴ The 450 gram batch would produce enough glass from which all processing and product performance properties could be measured. The use of a single batch would minimize uncertainties associated with batch to batch variations than if smaller individual batches were produced for each property measurement. Glasses supplied to Monarch Analytical Laboratories for high temperature density measurements were batched and melted separately due to the quantity of glass required.

¹⁵ Weigh sheets can be found in the following WSRC notebooks: WSRC-NB-98-00210 and WSRC-NB-99-0004.

7.2 PROPERTY MEASUREMENTS

7.2.1 CHEMICAL COMPOSITION ANALYSIS

To confirm that the “as-fabricated” glasses corresponded to the defined target compositions (as shown in Table IV), a representative sample from each “as-fabricated” AC2 glass was submitted to the SRTC Mobile Laboratory (SRTC-ML) for chemical analysis. Edwards [23] provided an analytical plan that accompanied these samples. This plan identified the cations to be analyzed and the dissolution techniques (i.e., sodium peroxide fusion or lithium-metaborate flux) to be used. Each glass was prepared in duplicate by each of the dissolution techniques. Concentrations (as mass %) for the cations of interest were measured by Inductively Coupled Plasma – Atomic Emission Spectroscopy (ICP – AES). The analytical plan was developed in such a way as to provide the opportunity to evaluate potential sources of error. The results were evaluated to confirm that the target glass compositions were adequately met. To assess the performance of the ICP over the course of these analyses and for potential bias-correction needs, multi-element rare earth solution standards were intermittently run. The standard solutions¹⁶ were matrix matched to approximate the elemental concentrations (in ppm) in solution upon dissolution of the outer layer centroid glass (AC2-32) for both the $\text{Na}_2\text{O}_2/\text{NaOH}/\text{HCl}$ and $\text{LiBO}_2/\text{HNO}_3$ fusions.

7.2.2 HOMOGENEITY

Although visual observations for homogeneity were performed and documented¹⁷, representative samples from each “as-fabricated” glass were submitted to SRTC Analytical Development Section (ADS) for X-ray diffraction (XRD) analysis. This analysis would be used to confirm visual observations of homogeneity within a given detection limit based on the run conditions of the diffractometer. Samples from the Phase 2 test matrix were run under conditions allowing an approximate 1.0 vol% detection limit. That is, if crystals (or undissolved solids) are present at 1.0 vol% (or greater) the diffractometer will not only be able to detect these crystals but will also allow a qualitative measure (i.e., determine the type of crystal present). Otherwise, a characteristic amorphous hump indicative of a homogeneous glass product would result. Run conditions for the X-ray diffractometer were consistent with those used in Phase 1.

7.2.3 DENSITY

Room temperature density for each Phase 2 glass was measured by buoyancy (Archimedes method) and gas pycnometry. Density measurements by buoyancy in water were performed using technical procedure “Glass Density Using the Mettler AT400 Balance – GTOP-3-105”. [24] A representative glass sample (~5 gram monolithic sample) was selected from each pour patty for this measurement.

Gas pycnometry measurements were performed using technical procedure “True Particle Density Measurements – GTOP-3-108”. [25] Glass that had been ground and sieved (-200 mesh) for the PCT measurement was used for density measurement. The gas pycnometry density measurements were performed with a Quantachrome Multipycnometer using nitrogen gas, N_2 . A reference cell of known volume (V_{ref}) was filled with nitrogen and the gas pressure (P_1) was measured with a transducer. The gas was then allowed to expand into another cell of known

¹⁶ High Purity Chemicals, Charleston, SC

¹⁷ For visual observations of homogeneity refer to WSRC-NB-98-00208.

volume (V_c) that contains the ground glass powder to be measured. The pressure was again measured and the volume of the glass calculated from Equation (2):

$$V = V_c - V_{ref} \left[\left(\frac{P_1}{P_2} \right) - 1 \right] \quad (2)$$

The volume was then divided into the mass of the glass to calculate density. The manufacturer claims an experienced operator should obtain a precision of $\pm 0.3 \%$.

High temperature and annealed (room temperature) density measurements were performed on a limited number of glasses (AC2-33M, AC2-35M, AC2-37M, AC2-38M, AC2-39M, AC2-41M and AC2-44M) by Monarch Analytical Laboratories, Inc. to support thermal modeling efforts.¹⁸ These glasses spanned feed loadings of 32 – 52 mass % using the nominal feed composition. Annealed glass density was measured using ASTM C 693.[24] Prior to the measurement, samples were annealed at 650°C for 30 minutes.

Monarch also determined the molten glass density as described by Shartsis and Spinner [26]. In general, the determination of molten glass density for all seven samples was limited at the lower temperatures by viscosity and/or the formation of a surface “scum” (probable crystalline material). At the higher temperatures, Monarch reported the deposition of gas bubbles (e.g., oxygen liberated from the high temperature reduction of CeO_2) on the test bob which limited the higher temperature to which some samples could be tested and valid data reported.

Monarch also measured surface tension of these seven AC2 glasses using the “Drop-Weight” method.[27] Glass compositions did not lend themselves well to drawing test fibers by flameworking, so fibers were drawn from the melted glass after the molten density test was completed.

7.2.4 VISCOSITY

Glass η s were measured as functions of T using a spindle viscometer. The measurements were obtained in accordance with the procedure ASTM C 965, “Standard Practice for Measuring Viscosity of Glass Above the Softening Point,”[28] using PNNL procedure GDL-VIS, Rev. 1, “Standard Viscosity Measurement for Vitrified Nuclear Waste.” The η data were evaluated and fit to either single or multiple Arrhenius functions:

$$\ln \eta = E + F/T \quad (3)$$

where E and F are T-independent coefficients. Many $\ln \eta$ -1/T curves showed nonlinear behavior, which is rare in silicate glasses and was not observed in the Phase 1 study. Therefore, great care was taken in the analyses of η -T data for each glass. Any η data points obtained at temperatures below the measured T_L were not considered in the calculation due to the potential impact of crystals on η . To obtain the most useful information for these glasses, data were collected at η s below the limit for the viscometer’s current setup. Viscosity values below 0.549 Pa·s (5.49

¹⁸ These seven glasses were batched and melted separately due to the quantity of glass required. These glasses are identified with their target AC2 identifier followed by “M” to signify Monarch. Small batch-to-batch chemical variations may be expected relative to their counterpart Phase 2 glasses. The Monarch work scope was not performed under the Quality Assurance criteria of RW-0333P since these data were only to be used to support thermal modeling efforts and were not used to define the AGCR.

Poise), $\ln[\eta(\text{Pa}\cdot\text{s})] = -0.600$, were listed for information only and were not used in any calculations.[29] Finally, the $\ln\eta-1/T$ curve was evaluated for linear trends. In many cases, a single line accurately described the $\ln\eta-1/T$ behavior (the glass behaved in an Arrhenian fashion), and in other glasses (nonlinear), it did not. For the nonlinear glasses, the η_{1350} was interpolated from the measured data at T closest to and on either side of 1350°C with Equation (3). In some cases, there were insufficient data to interpolate the η_{1350} ; in these cases, the value was obtained by extrapolation of the available data or was not estimated at all if less than two data points were available. The exact steps used to determine the $\eta-T$ function and η_{1350} are described by Vienna et al. [29] for each Phase 2 glass.

To validate the glass η data, the η of a standard glass was repeatedly measured. Each measured $\eta-T$ relationship of the Standard Reference Material (SRM) for high-temperature η (SRM-710a) [30] was referred to as a run. Samples of this glass were tested at the beginning (Val-01) and end of this study (Val-03) and twice during the study (Val-01a and Val-02) for a total of four runs. The $\eta-T$ data from each run were fitted to the VTF model (Equation 1), and the within-run data variability was estimated using the uncertainties associated with these fits. The between-run variability was estimated by pooling η data from similar temperatures (within 1°C). To estimate the correct degrees of freedom, a method called the "Satterwaithe" procedure [31] was employed for each model. This procedure pools the estimates and their degrees of freedom to provide an estimate such that the uncertainties can be combined. The estimate of total variance is the combination of the between-run and within-run variances. Vienna et al. [29] provide a detailed discussion of the validation data using the SRM glass.

7.2.5 LIQUIDUS TEMPERATURE (T_L)

T_L was measured following Method B of PNNL technical procedure GDL-LQT, "Standard Test Methods for Determining the T_L of Waste Glasses and Simulated Waste Glasses," Rev. 1. A run order was not used for determining T_L for individual samples due to time constraints, but samples were grouped together in furnaces operating at a specific temperature. The final measurements used to determine T_L were confined to one of three validated furnaces to prevent differences of temperature profiles between furnaces from biasing results. Additional heat treatments (considered preliminary) in alternate furnaces have been reported elsewhere (Vienna et al. [29]); however, these measurements were not used in final T_L determination.

As glass samples were received, they were logged and analyzed by optical microscopy (OM) for crystalline material or inhomogeneities. The T_L test samples were crushed in a tungsten carbide milling chamber, sieved to capture 4.0 to 0.5 mm grains, ultrasonically washed for 2 minutes in ethanol, and dried at 90°C following the technical procedure. Each glass sample had its own platinum crucible (approximately 1.27 cm^3) and lid, which were cleaned between heat treatments. Samples were heat treated for 24 ± 2 h in calibrated and temperature-profiled furnaces.

Each glass was initially tested with three to nine preliminary heat treatments, which narrowed the temperature range in which T_L would be determined and reported. The initial preliminary heat treatments were at roughly 1200°C , and new samples were heat treated at progressively higher (or lower) temperatures in roughly 20°C to 50°C intervals until the heat-treated glass sample appeared crystal free by low magnification OM. Based on these results, the temperature difference between the lowest temperature at which samples did not form crystals (T_A) and the highest temperature at which samples did form crystals (T_C) was narrowed. Data were then collected on the samples tested near the temperature region of T_L using one of three calibrated

Del TechTM furnaces (i.e., final T_L determinations). The furnaces were profiled for temperature differences in the hot zone where samples were heat treated using certified thermocouples and calibrated thermocouple readouts.

The method was validated by heat treating SRM-773 T_L Glass from the National Institute of Standards and Technology (NIST) at the beginning, middle, and end of the test period. SRM-773 glass has a reported T_L of $988^\circ\text{C} \pm 3^\circ\text{C}$ for Method A, the trough-type platinum container test, and $991^\circ\text{C} \pm 5^\circ\text{C}$ Method B, the perforated platinum plate test.[32] A different method was used than what is described in the SRM-773 certificate. To summarize the validation tests in each furnace with SRM-773 glass, Furnace #3 had a T_L of 989°C (beginning), 988°C (mid), and 987°C (final), Furnace #8 had T_L of 988°C (beginning) and 986°C (final), and Furnace #12 had a T_L of 990°C (beginning), 989°C (mid), and 985°C (final). Furnace #8 was used mainly for preliminary tests; therefore, only two validation tests were performed during its six weeks of use for final T_L measurements.

Crystals were identified by OM (at magnifications as high as 500 $\times$), X-ray diffraction (XRD), and SEM, accompanied by energy dispersive spectroscopy (EDS), to characterize the chemical composition of analyzed samples. XRD and SEM/EDS were used for phase identification of those crystals observed by OM. Familiar phases observed by OM were not repeatedly—characterized with XRD or SEM. Some of the samples that were used for XRD and scanning electron microscopy (SEM) came from the initial heat treatments because the samples near T_L did not have sufficient crystal-number density and crystal size for useful microstructural analysis. Care was taken to ensure that the crystals analyzed matched those found at T_L .

7.2.6 DURABILITY

The Product Consistency Test (PCT) was performed on each glass to assess chemical durability using technical procedure "Nuclear Waste Glass Product Consistency Test (PCT) Method – GTOP-3-025".[19] The PCT was conducted in triplicate for each Phase 2 glass. Also included in this experimental test matrix were the Environmental Assessment (EA) glass, the Approved Reference Material (ARM-1) glass, and blanks. Samples were ground, washed, and prepared according to procedure. Fifteen (15) mL of Type I ASTM water was added to 1.5 grams of glass in stainless steel vessels. The vessels were closed, sealed, and placed into an oven at $90 \pm 2^\circ\text{C}$. Samples were left at 90°C for 7 days. The resulting solutions were sampled (filtered and acidified), labeled (according to the analytical plan), and analyzed. Edwards [33] provided an analytical plan for the SRTC-ML analysis. The overall philosophy of this plan was to provide an opportunity to assess the consistency (repeatability) of the PCT and analytical procedures in the effort to evaluate chemical durability of the Phase 2 glasses. Normalized release rates were calculated based on both target and measured compositions.

7.2.7 RECOVERABILITY

The recoverability criteria for each Phase 2 glass and five selected Phase 1 glasses (AC1-02, AC1-03, AC1-05, AC1-06, and AC1-10) were assessed by technical procedure GTOP-3-104, Rev. 1, "Recovery of Various Elements from a Waste Form." [34] In general, 0.25 g of -35 to +60 mesh (Tyler equivalent) powdered glass was placed into a clean dry 50 mL TeflonTM vessel. For each glass, five vessels were used to assess the recoverability as a function of time (0.25, 0.5, 1.0, 2.0 and 4.0 h). Ten (10) mL of 8M HNO_3 were transferred by pipette into each vessel. The vessels were then sealed and placed into an oven at 110°C . After the specified time, the vessels

were removed from the oven, allowed to cool, and the contents were transferred into 200 mL volumetric flasks. The flasks were diluted to volume with deionized water. Ten (10) mL samples of the 5 solutions for each glass formulation were removed using a sterile plastic syringe. A 0.45 μm filter disk was then attached to the syringe and the sample expelled into a plastic sample bottle. The solutions were then submitted to the SRTC-ML for analysis using the analytical plan provided by Edwards [35].

8.0 RESULTS AND DISCUSSION

8.1 CHEMICAL COMPOSITION

The measured compositions for the Phase 2 glasses, along with standards (EA, ARM-1, and the multi-element rare earth solution standard) that were included in the plan used by the SRTC-ML [23] in conducting these analyses, are provided in Appendix A. Table A.1 provides the results (raw data) for Ca, Cr, Fe, Mn, Ni, and Sr that were obtained using the lithium-metaborate dissolution method. Table A.2 provides the results (raw data) for Al, B, Ce, Er, Eu, Gd, La, Nd, Pr, Si, and Sm that were obtained using the peroxide fusion dissolution method. Table A.3 provides the results (raw data) for K and Na that were obtained using the lithium-metaborate dissolution method. The measured cation concentrations and the corresponding oxide concentrations are provided for the Phase 2 glasses and for various standards (samples of EA and ARM-1 were included for both dissolution methods and samples of the rare earth standard solution were included with the glass samples prepared using the peroxide fusion dissolution method).

Plots of the oxide measurements derived using lithium-metaborate preps (except K_2O and Na_2O) are provided in Exhibit A.1 of Appendix A, those derived using peroxide fusion in Exhibit A.2, and those for K_2O and Na_2O in Exhibit A.3. There appears to be consistency among the replicate measurements of these samples, and no obvious outliers were seen in these data. Thus, all concentration values for each oxide were averaged to determine the concentration of that oxide in a given glass. However, as noted in the tables of Appendix A, it is believed that AC2-30 and AC2-53 were inadvertently switched during the batching or melting procedure. During the screening of the data, this problem was identified via a comparison of the various rare earth oxides (target vs. measured). The values for these two glasses were identified as “fliers”. Subsequent chemical analyses were performed to verify the measured compositions of these glasses.¹⁹ Their respective data have been corrected in the tables and exhibits of Appendix A and throughout remainder of this report.

The results for the standard glasses and multi-element rare earth standard solutions for each analytical block were reviewed. Exhibit A.4 in Appendix A provides plots of the elemental concentration measurements (in wt%) by analytical block for the rare earth standard solutions. The “known” or reference concentrations for these elementals are also provided in this exhibit. The standard solution was produced to closely match the chemistry of the centroid glass (AC2-33) once dissolved. The average measured values for the standard solutions compare very favorably to their corresponding reference values. In any event, however, these values were subsequently used to bias-correct the measurements of the Phase 2 glasses for each block for each analyte acquired using peroxide fusion. The values for EA were used to bias-correct for each analyte acquired using lithium-metaborate. Comparisons among the target, measured, and bias-corrected compositions indicated that no appreciable improvement was obtained by representing the compositions of the Phase 2 glasses by the bias-corrected measurements. Therefore, in this

¹⁹ A more detailed analysis is provided in WSRC-NB-99-00004 (pp. 51 – 62).

document comparisons and analyses of the Phase 2 glass compositions are limited just to their measured and target values.

Exhibit A.5 in Appendix A provides the details of a statistical (paired) comparison of the target versus measured values for all of the glasses of this test (including EA and ARM-1) for all of the oxides as well as the sum of lanthanides and the sum of oxides. The results indicate a statistically significant difference (at a 5% significance level) between the measured and target compositions for all oxides except Ce_2O_3 , Gd_2O_3 , Nd_2O_3 , and Sm_2O_3 .

Exhibit A.6 in Appendix A provides the details of a statistical (paired) comparison of the target versus measured compositions for just the Am/Cm Phase 2 glasses for all of the oxides as well as the sum of lanthanides and the sum of oxides. The results indicate a statistically significant difference (at a 5% significance level) between the measured and target compositions for all oxides except Ce_2O_3 , Eu_2O_3 , Gd_2O_3 , Nd_2O_3 , Sm_2O_3 , and the sum of lanthanides.

Table A.4 in Appendix A provides comparisons between the target and measured compositions for each oxide of interest for each glass. The percent relative difference (% Rel Dif) between the measured and target values for each of these comparisons is also provided. In addition, the minimum, average, and maximum of the relative differences over all of the glasses are provided for each oxide in Table A.4, and this information is repeated in Table VII. It should be noted that the relative differences for CaO , Cr_2O_3 , Fe_2O_3 , K_2O , MnO , and Na_2O are large due to the extremely small quantities of these minor components in glass.

Table VII. Minimum, Average, and Maximum Percent Relative Differences
Between Target and Measured Concentrations by Oxide for the Phase 2 Glasses.

	Al_2O_3	B_2O_3	CaO	Ce_2O_3	Cr_2O_3	Er_2O_3	Eu_2O_3	Fe_2O_3	Gd_2O_3	K_2O
Min	-14.9%	-11.9%	-0.1%	-37.0%	213.2%	-9.7%	-11.0%	22.9%	-37.7%	4417.3%
Avg	3.1%	-2.0%	2592.6%	1.7%	213.2%	4.6%	3.6%	71.0%	2.1%	4417.3%
Max	15.2%	10.0%	4937.1%	14.2%	213.2%	136.0%	44.3%	93.3%	14.3%	4417.3%
	La_2O_3	MnO	Na_2O	Nd_2O_3	NiO	Pr_2O_3	SiO_2	Sm_2O_3	SrO	Total Lanthanides
Min	-15.0%	128.8%	0.4%	-15.4%	2.1%	-13.1%	-5.1%	-28.6%	-6.5%	-8.0%
Avg	1.7%	995.8%	3891.1%	-0.5%	2570.7%	9.6%	3.0%	-1.7%	2.2%	5.9%
Max	10.7%	2197.8%	6350.2%	51.5%	8187.2%	144.4%	12.7%	12.8%	13.4%	229.6%

Some additional observations regarding the target versus measured compositions are warranted. The comparisons provided in Table A.4 for AC2-21 indicate relative differences for the rare earth oxides for this glass that are consistently greater (in absolute value) than those of any of the other Phase 2 glasses. The composition of AC2-21 was remeasured but the lanthanide variation was still quite large. It should also be noted that the CeO_2 value for AC2-52 (target = 4.26 wt%) is at or below detection limit (< 0.5 wt%) which was confirmed on a second analysis. An investigation of this discrepancy led to a discovery of an error that occurred in batching (i.e., no CeO_2 was added to the batch sheet for this glass). Also, note that the measured Er_2O_3 value for ARM-1 in Table A.4 is substantially larger than the indicated target value (3.4 wt% versus 0.0 wt%). The historical composition information for ARM-1 did not include the oxide Er_2O_3 but did account for only about 98.8% of the total oxides of this glass. Thus, the assumed target value of 0.0 wt% may not be accurate, and the measured value may reflect the true concentration of this oxide in ARM-1.

Overall, the agreement between the target and measured concentrations for each of the rare earth oxides shows an improvement over that seen in Phase 1 [9]. Exhibit A.7 in Appendix A provides another comparison for these values: plots of target versus measured concentrations for all glasses for each oxide, for the sum of lanthanides and for the sum of oxides.

The sum of oxides is an important indicator of the reliability of the composition measurements for all of the study glasses, and an additional indicator for the Phase 2 glasses is the sum of lanthanides. Comparisons of these measured values to their corresponding targets are provided in Exhibits A.5 – A.7. Figure 7 provides a closer look at the sum of oxide values for the Phase 2 glasses (in the form of a histogram). A substantial portion (~22%) of these values is above 105%, a value often used as the upper bound for reliable measurements.

Figure 7. Histogram of the Sum of Measured Oxides for the Phase 2 Glasses.

Exhibit A.8 in Appendix A provides comparisons of the compositions of the duplicate glasses of Phase 2. There are five sets of duplicate glasses as indicated in Table IV. These sets were sequentially numbered 1 through 5 for the analysis in Exhibit A.8. For each oxide (even the minors) a plot of the measured concentrations is provided, and “pooled” estimates of the standard deviation and percent relative standard deviation of the repeats are calculated. Table VIII provides a summary of these relative standard deviations for the lanthanides, alumina, boron, and silica.

The values of this table (except for B_2O_3 , Ce_2O_3 , and La_2O_3) are consistently better than those seen for the repeats of Phase 1. Only the large relative standard deviation for the Ce_2O_3 is of concern, and it appears to be due to one of the repeats for group #3. The measured Ce_2O_3 value for glass AC2-55 is much different from (i.e., much lower than) the target (see Exhibit A.7 in Appendix A).

Table VIII. Summary of the Relative Standard Deviations for the Lanthanides, Al_2O_3 , B_2O_3 , and SiO_2 .

Oxide	% Relative Standard Deviation from Duplicates
Al_2O_3	3.3%
B_2O_3	5.3%
Ce_2O_3	38.0%
Er_2O_3	3.8%
Eu_2O_3	5.2%
Gd_2O_3	5.8%
La_2O_3	3.5%
Nd_2O_3	5.0%
Pr_2O_3	5.0%
SiO_2	3.4%
Sm_2O_3	4.0%

Another means of comparing the target versus measured compositions of the Phase 2 glasses is provided in Figure 8, a ternary plot in measured-space of La_2O_3 , the other feed components, and the other frit components. In this ternary, the target EGCR is outlined as in Figure 6, but the points are based on measured compositions of the Phase 2 glasses. The experimental region suggested by Figure 6 appears to be well covered by the measured region of Figure 8.

Figure 8. Phase 2 EGCR as Defined by Measured Glass Compositions (mass fraction).
♦ – outer layer extreme vertices ($\pm 40\%$); x – inner layer extreme vertices ($\pm 20\%$); y – specific compositions using average feed composition; other symbols represent overall centroids, Ce-spiked glasses, and the Am/Cm-1A glass.

Measured compositions of the seven glasses sent to Monarch for high temperature density and surface tension measurements are shown in Table IX. As previously stated, the Monarch glasses were batched and melted separately therefore slight compositional variation with their respective AC2 counterparts (as shown in Tables A.1, A.2, and A.3 in Appendix A) may exist.

Table IX. Measured Compositions of Monarch Glasses (mass %).

	AC2-33M	AC2-35M	AC2-37M	AC2-38M	AC2-39M	AC2-41M	AC2-44M
Oxide	Mass %	Mass %	Mass %	Mass %	mass %	mass %	mass %
Cr ₂ O ₃	<0.070	<0.070	<0.070	<0.070	<0.070	<0.070	<0.070
NiO	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Fe ₂ O ₃	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
MnO ₂	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
CaO	<0.010	<0.010	<0.010	<0.010	0.018	<0.010	0.021
SrO	1.54	1.56	1.52	1.50	1.41	1.38	1.36
Na ₂ O	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150
K ₂ O	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150
B ₂ O ₃	8.30	7.40	7.80	7.72	7.31	5.69	7.17
SiO ₂	21.7	19.1	19.9	18.6	18.3	15.7	16.7
Er ₂ O ₃	5.01	5.13	4.86	5.39	5.98	5.70	6.16
Gd ₂ O ₃	1.98	2.00	1.67	2.26	2.30	1.97	2.24
La ₂ O ₃	19.8	20.4	20.7	21.0	20.7	20.0	18.4
Eu ₂ O ₃	1.01	1.06	0.795	1.24	1.17	0.988	1.20
Pr ₂ O ₃	5.06	5.20	4.65	6.15	6.41	5.57	6.15
Al ₂ O ₃	13.7	14.2	12.2	13.2	13.1	12.3	11.2
CeO ₂	6.27	6.51	6.31	7.32	7.65	7.47	6.80
Nd ₂ O ₃	12.4	14.2	15.3	15.7	16.4	16.7	15.0
Sm ₂ O ₃	3.18	3.48	3.62	3.79	4.00	4.27	3.69
Total	100	100	99.2	104	105	98	96

8.2 HOMOGENEITY

Although not used to define the AGCR, "as-fabricated" Phase 2 glasses were submitted to X-ray diffraction (XRD) to confirm visual observations of homogeneity. All fifty-five Phase 2 glasses were homogeneous based on the XRD results.²⁰ The XRD patterns for AC2-42 (~49 wt% Ln₂O₃), AC2-26 (~52 wt% Ln₂O₃), AC2-15 (~55 wt% Ln₂O₃), AC2-35 (~58 wt% Ln₂O₃), AC2-39 (~61 wt% Ln₂O₃) and AC2-09 (~64 wt% Ln₂O₃) are shown in Figures 9 – 14, respectively. These glasses span the 49 – 64 wt% total Ln₂O₃ concentration evaluated in Phase 2. All six of these XRD patterns show the characteristic amorphous hump indicative of a homogeneous (non-crystalline) product. That is, if undissolved solids and/or crystallization were present in the sample, well-defined or distinct peaks would be observed which could be used to identify the crystalline phase. It should be noted that the X-ray diffractometer used in this study has a detection limit of approximately 1.0 vol% in glass. Undissolved solids and/or crystallization present below this limit remain undetected by the XRD unit.

²⁰ XRD patterns for all fifty-five Phase 2 glasses are characterized by an amorphous hump indicative of a glassy, homogeneous product within the detection limits of the x-ray diffractometer (see Appendix B). Note, the absence of well defined peaks does not provide an indication of chemical homogeneity, but simply the absence of crystalline material.

As previously noted, these glasses were produced from reagent grade oxide raw materials not the oxalate / frit mixture that will be utilized in the CIM. Different reaction pathways between the various starting materials may lead to different results although glasses within the Phase 2 EGCR have been successfully processed in the CIM resulting in homogeneous (non-crystalline) glass products. Note the absence of well-defined peaks does not provide an indication of chemical homogeneity, but simply the absence of crystalline material.

Figure 9. XRD Analysis of AC2-42 (~49 wt% Ln_2O_3).

Figure 10. XRD Analysis of AC2-26 (~52 wt% Ln_2O_3).

Figure 11. XRD Pattern of AC2-15 (~55 wt% Ln_2O_3).

Figure 12. XRD Pattern of AC2-35 (~58 wt% Ln_2O_3).

Figure 13. XRD Pattern of AC2-39 (~61 wt% Ln_2O_3).

Figure 14. XRD Pattern of AC2-09 (~64 wt% Ln_2O_3).

8.3 DENSITY

8.3.1 ROOM TEMPERATURE DENSITY

Room temperature density was determined for the Phase 2 glasses by two techniques: buoyancy and gas pycnometry. The results from both techniques are shown in Table X. Both buoyancy and gas pycnometry density values are based on individual measurements of a representative subsample.

Table X. Density of Phase 2 Glasses by Buoyancy and Gas Pycnometry.

Glass	Buoyancy (g/cm ³)	Gas Pycnometer (g/cm ³)	Glass	Buoyancy (g/cm ³)	Gas Pycnometer (g/cm ³)
AC2-01	4.2530	4.454	AC2-29	4.4529	4.608
AC2-02	4.1580	4.369	AC2-30	3.9893	4.125
AC2-03	4.3909	4.610	AC2-31	4.2320	4.292
AC2-04	4.5840	4.731	AC2-32	4.1858	4.392
AC2-05	3.9679	4.118	AC2-33	4.1829	4.419
AC2-06	4.4180	4.598	AC2-34	4.0095	4.242
AC2-07	3.9827	4.187	AC2-35	4.2688	4.306
AC2-08	4.0276	4.218	AC2-36	4.3067	4.483
AC2-09	4.6247	4.880	AC2-37	4.3528	4.572
AC2-10	4.0310	4.204	AC2-38	4.3850	4.569
AC2-11	4.3552	4.595	AC2-39	4.4278	4.632
AC2-12	4.1781	4.341	AC2-40	4.4834	4.660
AC2-13	3.8326	3.969	AC2-41	4.5150	4.705
AC2-14	4.1833	4.337	AC2-42	3.8269	4.001
AC2-15	4.0317	4.214	AC2-43	3.9964	4.162
AC2-16	4.3629	4.552	AC2-44	4.2530	4.542
AC2-17	4.1976	4.400	AC2-45	4.1863	4.335
AC2-18	4.5880	4.823	AC2-46	4.5915	4.775
AC2-19	4.0342	4.263	AC2-47	4.1925	4.351
AC2-20	4.5796	4.809	AC2-48	3.8195	3.970
AC2-21	4.1559	4.295	AC2-49	3.9980	4.218
AC2-22	4.0074	4.213	AC2-50	4.1944	4.336
AC2-23	4.3025	4.499	AC2-51	4.3852	4.455
AC2-24	4.4077	4.578	AC2-52	3.7208	3.902
AC2-25	4.3633	4.522	AC2-53	3.8180	3.998
AC2-26	4.0057	4.191	AC2-54	4.5695	4.754
AC2-27	3.9935	4.272	AC2-55	4.1754	4.331
AC2-28	4.1915	4.401			

A scatter plot of the buoyancy and gas pycnometry density data is provided in Figure 15(a). The gas pycnometry densities appear to be consistently greater than their corresponding buoyancy densities.

Figure 15(a). Buoyancy Versus Gas Pycnometry Density Measurements.

- ◆ – outer layer extreme vertices ($\pm 40\%$); x – inner layer extreme vertices ($\pm 20\%$); y – specific compositions using average feed composition; other symbols represent overall centroids, Ce-spiked glasses, and the Am/Cm-1A glass.

A statistical comparison of these data pairs is provided in Figure 15(b). The diagonal line of this figure represents perfectly equal densities from the two measurement methods. The fitted line appearing below this diagonal indicates a statistically significant difference (significance level $< 5\%$) between the measurement pairs. On average, the pycnometry density is 0.18 g/cm^3 larger than the buoyancy density.

Figure 15(b). A Statistical Test of Buoyancy Versus Gas Pycnometry Density Measurements.

- ◆ – outer layer extreme vertices ($\pm 40\%$); x – inner layer extreme vertices ($\pm 20\%$); y – specific compositions using average feed composition; other symbols represent overall centroids, Ce-spiked glasses, and the Am/Cm-1A glass.

Figures 16 and 17 show the buoyancy data as a function of total lanthanide content on both a target and measured basis. Figures 18 and 19 show the gas pycnometry data as a function of total lanthanide content on both a target and measured basis. The data indicate an excellent correlation of density with the total lanthanide content. As the total lanthanide content (or loading since the feed stream is highly lanthanide based) increases, the measured density (regardless of measurement technique) increases. This agrees well with the Phase 1 observations.[9] There appears to be more scatter in the measured data relative to the target data for both techniques.

Figure 16. Buoyancy Density Versus Target Total Ln_2O_3 Content.

◆ – outer layer extreme vertices ($\pm 40\%$); x – inner layer extreme vertices ($\pm 20\%$); y – specific compositions using average feed composition; other symbols represent overall centroids, Ce-spiked glasses, and the Am/Cm-1A glass.

Figure 17. Buoyancy Density Versus Measured Total Ln_2O_3 Content. —
◆ – outer layer extreme vertices ($\pm 40\%$); x – inner layer extreme vertices ($\pm 20\%$); y – specific compositions using average feed composition; other symbols represent overall centroids, Ce-spiked glasses, and the Am/Cm-1A glass.

Figure 18. Gas Pycnometry Density Versus Target Total Ln_2O_3 Content.
◆ – outer layer extreme vertices ($\pm 40\%$); x – inner layer extreme vertices ($\pm 20\%$); y – specific compositions using average feed composition; other symbols represent overall centroids, Ce-spiked glasses, and Am/Cm-1A (a Phase 1 glass).

Figure 19. Gas Pycnometry Density Versus Measured Total Ln_2O_3 Content.

◆ – outer layer extreme vertices ($\pm 40\%$); x – inner layer extreme vertices ($\pm 20\%$); y – specific compositions using average feed composition; other symbols represent overall centroids, Ce-spiked glasses, and Am/Cm-1A (a Phase 1 glass).

As previously stated, one of the objectives of this study was to investigate the effects due to the individual lanthanides. Figures 20 and 21 provide the results of regressions (using JMP) of these density measurements versus the individual lanthanides. For densities measured by buoyancy (Figure 20), the estimated effects for the lanthanides are very similar, and all effects are statistically significant at the 5% level. The same is true for densities measured by pycnometry (Figure 21). Thus, there is no indication of differences among the effects of the individual lanthanides on density.

Response: SRTC Density - Buoyancy (g/cm^3)

Summary of Fit

RSquare	0.866152
RSquare Adj	0.842874
Root Mean Square Error	0.090753
Mean of Response	4.213069
Observations (or Sum Wgts)	55

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	2.0183987	0.166394	12.13	<.0001
Ce ₂ O ₃	0.0377699	0.005292	7.14	<.0001
Er ₂ O ₃	0.0430736	0.006058	7.11	<.0001
Eu ₂ O ₃	0.0756425	0.034105	2.22	0.0315
Gd ₂ O ₃	0.0521115	0.015811	3.30	0.0019
La ₂ O ₃	0.0285397	0.005373	5.31	<.0001
Nd ₂ O ₃	0.0444821	0.003045	14.61	<.0001
Pr ₂ O ₃	0.0480935	0.007692	6.25	<.0001
Sm ₂ O ₃	0.0323107	0.009170	3.52	0.0010

Whole-Model Test

Residuals

* Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	2.4516924	0.306462	37.2092
Error	46	0.3788644	0.008236	Prob>F
C Total	54	2.8305569		<.0001

Figure 20. Results from JMP of a Regression of Buoyancy Density (g/cm^3) Versus Individual (measured) Lanthanide Concentrations.

◆ – outer layer extreme vertices ($\pm 40\%$); x – inner layer extreme vertices ($\pm 20\%$); y – specific compositions using average feed composition; other symbols represent overall centroids; Ce-spiked glasses, and the Am/Cm-1A glass.

Response: SRTC Density Pycnometry (g/cm^3)

Summary of Fit

RSquare	0.850618
RSquare Adj	0.824639
Root Mean Square Error	0.099218
Mean of Response	4.395964
Observations (or Sum Wgts)	55

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	2.1226416	0.181914	11.67	<.0001
Ce ₂ O ₃	0.0433014	0.005786	7.48	<.0001
Er ₂ O ₃	0.0403267	0.006623	6.09	<.0001
Eu ₂ O ₃	0.0963608	0.037286	2.58	0.0130
Gd ₂ O ₃	0.0482684	0.017285	2.79	0.0076
La ₂ O ₃	0.0301727	0.005874	5.14	<.0001
Nd ₂ O ₃	0.0443767	0.003329	13.33	<.0001
Pr ₂ O ₃	0.0508058	0.008410	6.04	<.0001
Sm ₂ O ₃	0.0332695	0.010025	3.32	0.0018

Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	2.5785415	0.322318	32.7419
Error	46	0.4528324	0.009844	Prob>F
C Total	54	3.0313739		<.0001

Figure 21. Results from JMP of a Regression of Gas Pycnometry Density (g/cm^3) Versus Individual (measured) Lanthanide Concentrations.

◆ – outer layer extreme vertices ($\pm 40\%$); x – inner layer extreme vertices ($\pm 20\%$); y – specific compositions using average feed composition; other symbols represent overall centroids, Ce-spiked glasses, and the Am/Cm-1A glass.

A review of the density measurements of the duplicate glasses for both techniques is provided in Figures 22 and 23. The first of these figures considers densities as measured by buoyancy. A pooled standard deviation (0.085 g/cm^3) was estimated across all five sets of replicates, and using the overall mean of these measurements (4.116 g/cm^3), a % relative standard deviation was determined (2.1%).

Figure 22. Density (g/cm^3) as Measured by Buoyancy for Replicates.

Using the same approach for the gas pycnometry densities results in a % relative standard deviation of 1.7% for an overall mean density of 4.293 g/cm^3 and "pooled" standard deviation of 0.073 g/cm^3 .

Figure 23. Density (g/cm^3) As Measured by Gas Pycnometry for Replicates.

8.3.2 MONARCH: HIGH TEMPERATURE AND ANNEALED DENSITY

High-temperature and annealed (room temperature) density measurements were performed on seven of the Phase 2 glasses (AC2-33M, AC2-35M, AC2-37M, AC2-38M, AC2-39M, AC2-41M and AC2-44M) by Monarch Analytical Laboratories, Inc. to support thermal modeling efforts.²¹ These seven glasses span the 32 – 52% loading range. Annealed densities, as measured by ASTM C 693 [24], are shown in Table XI and plotted in Figure 24 as a function total Ln_2O_3 content (target). Density increases can be directly attributed to increases in total lanthanide content as previously shown in Figures 16 – 19.

Table XI. Annealed Density of Select Phase 2 Glasses as Measured By Monarch Laboratories.

Glass	Total Ln_2O_3 Content (target)	Annealed Density (g/cm^3)
AC2-33M	56.4	4.194
AC2-35M	57.9	4.280
AC2-37M	59.4	4.358
AC2-38M	60.2	4.403
AC2-39M	60.9	4.444
AC2-41M	62.4	4.528
AC2-44M	63.9	4.606

Figure 24. Monarch Density Versus Target Total Ln_2O_3 Content.

²¹ These seven glasses were batched and melted separately from the Phase 2 glasses used to evaluate the primary processing and product performance properties. Since these data were only to be used to support thermal modeling efforts, this work was not performed under the Quality Assurance criteria of RW-0333P.

Tables XII – XVIII summarize the high temperature density measurements performed by Monarch Laboratories for AC2-33M, AC2-35M, AC2-37M, AC2-38M, AC2-39M, AC2-41M, and AC2-44M, respectively. In general, the determination of molten glass density for all seven glasses was limited at the lower temperatures by the formation of a scum layer (presumably crystalline). At the higher temperatures, Monarch reported the deposition of gas bubbles (e.g., oxygen liberated from the high temperature reduction of CeO_2) on the test bob limiting the higher temperatures. At higher temperatures, approaching the maximum furnace temperature (1425°C), data obtained for some samples were inconsistent with the lower temperature determinations. The disconnect or inconsistency between the low and high temperature data for select samples could not be directly attributed to either the formation of gas bubbles on the test bob or thermal currents in the glass. All seven glasses tested by Monarch were reported to be “very fluid” at the higher temperatures (see Section 8.4 for a detailed discussion of the viscosity data). At lower temperatures (1200 – 1300°C), a scum (reported by Monarch as a “probable crystalline material”) formed on the surface of all glasses tested. The formation of a crystalline scum layer is directly related to liquidus temperature (i.e., crystals are thermodynamically favorable below T_L) and provides an indication of the kinetics of devitrification in this system. When held at these temperatures for a period of time, the suspension wire to the test bob would seize; thus limiting the low temperature results.

A rigorous data reduction was not performed on the high temperature density data or surface tension data. However, the density data do indicate a reduction in high temperature density with increasing temperature. An increase in molten glass density with increased total lanthanide content (at similar temperature) also is observed. Molten glass density results as reported by Monarch [36] are briefly discussed for each glass.

AC2-33M Molten Glass Density

Monarch reported that the high temperature density data AC2-33M is suspect above ~1315°C (see Table XII). No bubbles were observed or dislodged from the test bob, but the data suggest that very small bubbles may have been present from the thermal reduction of CeO_2 . Data could not be collected below 1200°C due to the formation of a surface scum that seized the suspension wire to the test bob. As reported in a later section, T_L of AC2-33 is 1271°C.

Table XII. High Temperature Density Data for AC2-33M.

Temperature (°C)	Molten Density (g/cm^3)
1204	3.953
1230	3.947
1257	3.940
1284	3.933
1311	3.927
1339	3.925
1367	3.919
1396	3.914

AC2-35M Molten Glass Density

Table XIII summarizes the high temperature density data for AC2-35M. Observations for AC2-35M were very similar to AC2-33M for data above 1350°C and below 1200°C. Data below 1200°C could not be obtained due to the formation of a surface scum (T_L of AC2-35 = 1289°C). The data above 1335°C are suspect due to the possible influence of gas bubbles forming on the test bob.

Table XIII. High Temperature Density Data for AC2-35M.

Temperature (°C)	Molten Density (g/cm ³)
1209	4.024
1235	4.018
1288	4.006
1315	3.997
1343	3.990
1370	3.985
1398	3.979
1426	3.974

AC2-37M Molten Glass Density

The high temperature density data for AC2-37M are shown in Table XIV. Data for AC2-37M could not be collected below 1200°C due to the formation of a surface scum seizing the suspension wire (T_L of AC2-37 = 1305°C). Data above ~1375°C were not reproducible and appeared to be influenced by bubbles forming on the test bob.

Table XIV. High Temperature Density Data for AC2-37M.

Temperature (°C)	Molten Density (g/cm ³)
1204	4.112
1233	4.106
1261	4.099
1283	4.093
1316	4.084
1338	4.082
1371	4.073
1393	4.073

AC2-38M Molten Glass Density

AC2-38M data below 1200°C could not be obtained because of surface scum seizing the suspension wire to the test bob. The T_L of AC2-38 was 1308°C. High temperature data (above ~1335°C) are suspect and may have been influenced by gas bubbles forming on the test bob. The high temperature density data for AC2-38M are shown in Table XV.

Table XV. High Temperature Density Data for AC2-38M.

Temperature (°C)	Molten Density (g/cm ³)
1199	4.131
1229	4.122
1253	4.115
1308	4.099
1335	4.091
1363	4.086
1391	4.081
1421	4.075

AC2-39M Molten Glass Density

The high temperature density data for AC2-39M are shown in Table XVI. Data below 1225°C could not be obtained because the suspension wire was seized by surface scum in a very short time – indicating rapid devitrification kinetics as the total lanthanide content increases. High temperature data were collected to approximately 1425°C (furnace limitations). The influence of bubble formation on the test bob was not documented by Monarch for this specific sample. CeO₂ is present in this glass and will thermally reduce. Therefore, the high temperature results may also be suspect.

Table XVI. High Temperature Density Data for AC2-39M.

Temperature (°C)	Molten Density (g/cm ³)
1228	4.153
1257	4.146
1282	4.138
1338	4.125
1366	4.117
1375	4.115
1396	4.110
1424	4.102

AC2-41M Molten Glass Density

A surface scum was reported for AC2-41M after one hour at ~1235°C. The T_L of AC2-41 was 1324°C. Monarch indicated that the high temperature data (> 1400°C) suggest the formation of gas bubbles on the test bob. The high temperature density data for AC2-41M are shown in Table XVII.

Table XVII. High Temperature Density Data for AC2-41M.

Temperature (°C)	Molten Density (g/cm ³)
1236	4.225
1262	4.218
1289	4.210
1316	4.202
1343	4.196
1373	4.187
1401	4.180
1430	4.176

AC2-44M Molten Glass Density

The high temperature density data for AC2-44M are shown in Table XVIII. Data below ~1225°C could not be obtained because the suspension wire was seized by the formation of a surface scum. High temperature data were collected to approximately 1425°C (furnace limitations). As with AC2-39M, the influence of bubble formation on the test bob was not documented by Monarch. CeO₂ is present and therefore the high temperature data may be suspect.

Table XVIII. High Temperature Density Data for AC2-44M.

Temperature (°C)	Molten Density (g/cm ³)
1226	4.310
1253	4.302
1276	4.296
1298	4.288
1333	4.282
1359	4.271
1391	4.266
1420	4.258

8.3.3 SURFACE TENSION

Monarch also measured surface tension of these seven glasses (see Table XIX). Surface tension measurements were made using the Drop-Weight method.[27] As previously noted, the glass compositions did not lend themselves well for drawing fibers by flameworking. Therefore, the fibers were drawn from the molten glass after the high temperature density measurements were completed.

Table XIX. Surface Tension Data for Select Phase 2 Glasses.

Glass	Surface Tension (dynes/cm)
AC2-33M	357
AC2-35M	367
AC2-37M	371
AC2-38M	390
AC2-39M	395
AC2-41M	408
AC2-44M	414

8.4 VISCOSITY

The η - T relationship was measured for Phase 2 glasses using a high-temperature spindle viscometer. Generally, the data did not conform to the standard η -T relationship as described by the VTF model (Equation 1). Figure 25 compares the $\ln[\eta]$ -1/T behavior of a "typical" silicate glass (Val-01) with that of AC2-14. The $\ln[\eta]$ of AC2-14 is nearly piecewise linear with variation in 1/T. For Val-01, the variation of $\ln[\eta]$ with 1/T is nearly linear with a positive slope, which is typical of silicate glasses.

Figure 25. Comparison of $\ln[\eta]$ - $1/T$ Behavior of (a) AC2-14 and (b) Val-01.

For Phase 2 glasses with linear $\ln[\eta_{1350}] - 1/T$ relationship the η_{1350} value was estimated by a linear interpolation of $\ln[\eta_{1350}]$ vs $1/T$ for the entire data set. For the nonlinear glasses, the η_{1350} was interpolated from the measured data at T closest to and on either side of 1350°C with Equation (3). In some cases, there was insufficient data to interpolate the η_{1350} , in these cases the value was obtained by extrapolation of the available data or wasn't estimated at all if less than two data points were available. The exact steps used to determine the η - T function and η_{1350} are described by Vienna et al. [29] for each glass. This was in contrast to the VTF model (Equation 1), which was used to estimate η_{1350} values for glasses in the Phase 1 study. Table XX summarizes the linear η - T parameters (E and F in Equation 3), η_{1350} , and the method used to derive these values for the Phase 2 glasses.

Table XX. Summary of Phase 2 Viscosity Data.

Glass ID	E	F (K)	η_{1350} (Pa.s)	η_{1350} (Poise)	Comments
AC2-01	-17.449	28,908	1.44	1.44	linear
AC2-02	-20.390	32,760	0.81	8.1	nonlinear
AC2-03	-19.528	30,769	0.57	5.7	two data points
AC2-04	-	-	-	-	fewer than two data points
AC2-05	-15.642	26,669	2.20	22.0	nonlinear
AC2-06	-9.177	14,314	0.70	7.0	two data points
AC2-07	-19.963	33,688	2.21	22.1	nonlinear
AC2-08	-12.177	20,627	1.70	17.0	nonlinear
AC2-09	-18.999	30,452	0.79	7.9	linear
AC2-10	-8.973	14,981	1.29	12.9	nonlinear
AC2-11	-15.613	25,279	0.96	9.6	nonlinear
AC2-12	-4.052	7,147	1.42	14.2	nonlinear
AC2-13	-13.098	22,267	1.86	18.6	nonlinear
AC2-14	-15.750	25,380	0.89	8.9	nonlinear
AC2-15	-15.571	25,731	1.33	13.3	linear
AC2-16	-17.671	28,821	1.09	10.9	nonlinear
AC2-17	-15.154	24,804	1.14	11.4	linear
AC2-18	-	-	-	-	fewer than two data points
AC2-19	-14.837	24,619	1.39	13.9	linear
AC2-20	-	-	-	-	fewer than two data points

Glass ID	E	F (K)	η_{1350} (Pa·s)	η_{1350} (Poise)	Comments
AC2-21	-14.596	23,443	0.86	8.6	linear
AC2-22	-15.045	24,893	1.34	13.4	linear
AC2-23	-14.288	23,182	1.00	10.0	linear
AC2-24	-19.831	31,376	0.61	6.1	two data points
AC2-25	-15.537	25,492	1.18	11.8	two data points
AC2-26	-19.470	32,858	2.17	21.7	nonlinear
AC2-27	-13.273	22,608	1.93	19.3	nonlinear
AC2-28	-18.947	30,512	0.86	8.6	nonlinear
AC2-29	-16.871	26,717	0.66	6.6	linear
AC2-30	-9.360	15,680	1.35	13.5	nonlinear
AC2-31	-7.207	12,340	1.49	14.9	nonlinear
AC2-32	-19.993	32,717	1.18	11.8	nonlinear
AC2-33	-14.740	24,182	1.17	11.7	linear
AC2-34	-11.883	19,877	1.44	14.4	nonlinear
AC2-35	-15.684	25,573	1.08	10.8	two data points
AC2-36	-15.187	24,702	1.03	10.3	linear
AC2-37	-17.594	28,495	0.96	9.6	linear
AC2-38	-16.272	26,319	0.95	9.5	linear
AC2-39	-16.986	27,416	0.91	9.1	linear
AC2-40	-18.659	30,139	0.91	9.1	two data points
AC2-41	-17.554	28,261	0.87	8.7	linear
AC2-42	-11.555	19,663	1.75	17.5	nonlinear
AC2-43	-8.382	14,049	1.32	13.2	nonlinear
AC2-44	-15.956	25,803	0.94	9.4	linear
AC2-45	-14.669	23,967	1.10	11.0	linear
AC2-46	-16.753	26,832	0.80	8.0	linear
AC2-47	-14.938	24,506	1.17	11.7	linear
AC2-48	-11.809	20,058	1.73	17.3	nonlinear
AC2-49	-10.729	18,031	1.46	14.6	nonlinear
AC2-50	-14.338	23,449	1.12	11.2	linear
AC2-51	-16.473	26,651	0.95	9.5	linear
AC2-52	-18.357	31,054	2.17	21.7	nonlinear
AC2-53	-10.844	18,520	1.76	17.6	nonlinear
AC2-54	-17.617	28,349	0.86	8.6	linear
AC2-55	-15.600	25,530	1.14	11.4	nonlinear

The η_{1350} values of Phase 2 test glasses range from 5.7 Poise for AC2-03 to 22.1 Poise for AC2-07, both exterior vertex glasses. All Phase 2 glass viscosities are less than the upper 24 Poise constraint established by Martin [12] (i.e., the AGCR encompasses the entire EGCR in terms of viscosity). It should be noted that the lower η_{1350} constraint (3 Poise) was not used to limit the EGCR or define the AGCR since the detection limit of the viscometer (~5 Poise) exceeded this lower limit. In other words, a determination as to whether a particular glass met this lower η_{1350} constraint could not be made. This only had an effect on three AC2 glasses: AC2-04, AC2-18, and AC2-20 all having total Ln_2O_3 concentrations exceeding 63.5 mass %. Although η_{1350} could not be defined for these glasses, they should be processable within the CIM. This latter statement is focused solely on viscosity and assumes all other constraints are met. The viscosity constraint was primarily being driven by the establishment of a continuous pour that is based on the upper η_{1350} limit of 24 Poise. However, the non-linear η -T behavior of these glasses warrants further study.

A linear relationship between the Ln_2O_3 concentration in glass and the $\ln[\eta_{1350}]$ value was shown for Phase 1 glasses (see Figure 2). The effect of Ln_2O_3 concentration on $\ln[\eta_{1350}]$ of Phase 2 glasses is shown in Figures 26 – 27 (target and measured, respectively). A comparison shows a reasonably close match in the Ln_2O_3 effect on $\ln[\eta_{1350}]$ for Phase 1 and Phase 2 glasses, despite the fact that SiO_2 , Al_2O_3 , B_2O_3 , and SrO concentrations varied independently in Phase 2 glasses and not in Phase 1 glasses (see Figure 28). Specifically, the Ln_2O_3 partial specific $\ln[\eta_{1350}]$ for Phase 1 and Phase 2 glasses are -3.1 and -3.0 , respectively.[29] Generally, some of the Phase 1 glasses and some of the nonlinear Phase 2 glasses fell off of the linear trend.

Figure 26. Effect of Ln_2O_3 Concentration (target) on $\ln[\eta_{1350}]$ for Phase 2 Glasses

Figure 27. Effect of Ln_2O_3 Concentration (measured) on $\ln[\eta_{1350}]$ for Phase 2 Glasses.

Figure 28. Effect of Ln_2O_3 Concentration (in mass fraction) on $\ln[\eta_{1350}]$ for Phase 1 and Phase 2 Glasses.
(symbols represent: A-Phase 1 glasses, B-Linear Phase 2 glasses, and N- Nonlinear Phase 2 glasses)

As for the previous properties, one of the objectives of this study was to investigate the viscosity measurements for effects due to the individual lanthanides. Figure 29 provides the results of a regression (using JMP) of the natural logarithm of the viscosity measurements (in Poise) versus the individual (measured) lanthanides concentrations. The results indicate that Eu_2O_3 , Gd_2O_3 , and Sm_2O_3 are not statistically significant at the 5% level, the other lanthanides are, and all of the estimated effects (significant or otherwise) are comparable. Thus, there is no indication of serious differences among the effects of the individual lanthanides on viscosity.

Figure 29. Results from JMP of a Regression of the Common Logarithm of Viscosity (in Poise) Versus Individual (measured) Lanthanide Concentrations.

Isolating just the duplicate glasses (including those that were spiked with the minor components) and plotting their viscosities yields Figure 30. The “pooled” estimate of the standard deviation of these measurements is 1.3 Poise. Each of the 95% confidence intervals for the means of these five sets of repeats contains its respective spiked “duplicate” except for AC2-52 in Group 3. As discussed earlier, AC2-52 was misbatched (i.e., no CeO_2 was added). The higher measured viscosity for this particular glass is easily explained by the lower total Ln_2O_3 concentration in glass. Overall, there appears to be no significant impact on viscosities due to the minor components (at least not within the glass composition region studied here).

Figure 30. $\eta_{1350^\circ\text{C}}$ (in Poise) for Replicates.

8.5 LIQUIDUS TEMPERATURE (T_L)

The T_L s of the 55 Phase 2 glasses were between 1153°C (AC2-52) and 1405°C (AC2-04). Only two glasses had T_L s above the 1350°C limit, AC2-04 and AC2-18. Two crystal types, rare earth silicates (RESs) and aluminum oxide (Al_2O_3), were identified as the primary crystalline phases in the Phase 2 glasses using a combination of XRD, SEM/EDS, and OM. This differs from Phase 1 glasses in which rare earth silicate and aluminosilicate crystals were found and Al_2O_3 was not. The primary crystalline phase, T_L , T_A , and T_C are summarized in Table XXI. Vienna et al. [29] provide a detailed discussion of the T_L measurements for each glass, including T_L measurement data, OM and SEM micrographs, and analyses from XRD and EDS.

8.5.1 RARE EARTH SILICATE CRYSTALS

RES was the primary phase in 47 of the 55 glasses; however, four distinct morphologies of the RES were observed when identifying these crystals: needle-like (thin and straight), hair-like (thin and wavy), plate-like, and rectangular cap. Each crystal shape was analyzed using SEM. EDS

coupled to SEM showed Si, La, Nd, and O as major components and Ce, Pr, Sm, Gd, and Er as minor components in the crystals. Al is present as a minor component in some RES crystals, but not in others. Chemically, the RES crystals are the same regardless of morphology. Samples analyzed by XRD matched the crystal structure of neodymium germanium borate silicate ($\text{Nd}_3\text{BGe}_{1.08}\text{Si}_{0.92}\text{O}_{10}$). In this crystal structure, Ge could be replaced by Si and Nd could be replaced by rare earth elements to form $\text{RE}_3\text{BSi}_2\text{O}_{10}$, the crystal type that is probably present in these samples. Generally, the glasses within the RES primary phase field showed massive crystallinity (i.e., > 30 vol % RES) after a 24 h heat treatment at temperatures between 3° and 30°C below T_L . As RES crystals are difficult to redissolve once crystallized, this observation should be considered when planning for both normal and off-normal operating scenarios. Under normal operating conditions, there appears to be a great potential to plug the drain tube (which is under a thermal gradient when idling) when a highly loaded lanthanide glass is contained in the drain tube. Since the massive devitrification occurred after a 24 h heat treatment, the kinetics of devitrification are unknown (i.e., how does the degree of crystallization vary with both time and temperature). This latter statement could result in processing issues under both normal and off-normal conditions.

The RES crystals observed as needle-shaped crystals were found individually and clustered at a focal point with the needles pointing out in all directions, both found in Figure 31. The sizes of the crystals had a wide range in length from <0.1 mm to >1.0 mm and were approximately 1 μm to >10 μm thick.

Associated with the needle crystals are hair-like crystals, found within or near the needle clusters (Figure 32). These crystals are very thin (<0.5 μm) and long (>100 μm) and curved like an eyebrow. Occasionally they are observed in a coil. These crystals may be straight also, but they are so thin that they are difficult to observe by OM. However, they are very distinct when they curve or coil. SEM/EDS scans indicated a similar chemical composition for both needle and hair-like RES crystals.

Plate-like, RES crystals (Figure 33) were found in many of the samples. Unlike the plate-like RES in Phase 1, some of the plate-like crystals in Phase 2 developed unusual structures at the narrow end of the rectangular or lathe shaped crystal (Figure 34 and Figure 35). SEM/EDS analysis found no change in chemical composition of the crystals even with the unique shapes.

Table XXI. T_L and Primary Crystalline Phase for the Phase 2 Glasses.

Glass	T_L (°C)	Primary Phase	T_C (°C)	T_A (°C)	Total Ln_2O_3 Content (targeted)	Total Ln_2O_3 Content (measured)
AC2-01	1308	RES	1306	1315	58.3	60.6
AC2-02	1257	Al_2O_3	1252	1262	56.2	57.1
AC2-03	1313	RES	1312	1315	60.7	65.4
AC2-04	1405	RES	1401	1409	63.5	65.7
AC2-05	1241	RES	1240	1241	51.6	51.4
AC2-06	1309	RES	1306	1314	61.3	64.5
AC2-07	1209	RES	1204	1213	52.2	50.9
AC2-08	1242	RES	1241	1252	52.9	52.9
AC2-09	1323	RES	1320	1327	64.1	67.1
AC2-10	1255	RES	1252	1261	54.0	54.2
AC2-11	1292	Al_2O_3	1289	1295	59.0	61.9
AC2-12	1333	RES	1328	1335	56.7	59.2
AC2-13	1181	RES	1179	1185	49.4	48.1
AC2-14	1250	Al_2O_3	1246	1252	55.6	53.7
AC2-15	1279	RES	1275	1283	54.5	52.1
AC2-16	1298	Al_2O_3	1295	1299	58.4	57.9
AC2-17	1273	RES	1265	1275	56.6	55.9
AC2-18	1366	RES	1364	1374	63.5	62.7
AC2-19	1249	RES	1242	1252	53.9	56.5
AC2-20	1343	RES	1336	1349	64.1	61.5
AC2-21	1242	Al_2O_3	1240	1249	55.6	57.4
AC2-22	1284	RES	1283	1287	53.9	57.9
AC2-23	1282	Al_2O_3	1278	1284	58.4	55.9
AC2-24	1319	RES	1313	1321	61.3	63.5
AC2-25	1305	Al_2O_3	1299	1314	58.4	60.9
AC2-26	1208	RES	1204	1210	52.2	53.3
AC2-27	1242	RES	1241	1242	52.9	53.0
AC2-28	1260	Al_2O_3	1249	1264	55.6	55.9
AC2-29	1300	RES	1296	1306	61.3	64.1
AC2-30	1192	RES	1191	1197	49.4	51.1
AC2-31	1305	RES	1301	1306	56.7	58.2
AC2-32	1264	RES	1260	1265	56.6	60.4
AC2-33	1271	RES	1265	1274	56.4	54.2
AC2-34	1232	RES	1225	1235	57.2	53.6
AC2-35	1289	RES	1284	1289	57.9	55.9
AC2-36	1294	RES	1289	1295	58.7	57.1
AC2-37	1305	RES	1302	1307	59.4	59.4
AC2-38	1308	RES	1306	1312	60.2	59.9
AC2-39	1318	RES	1314	1321	60.9	62.5
AC2-40	1325	RES	1321	1328	61.7	63.3
AC2-41	1324	RES	1320	1327	62.4	61.1
AC2-42	1180	RES	1179	1191	48.9	49.0
AC2-43	1227	RES	1225	1236	52.7	52.7
AC2-44	1305	RES	1302	1307	63.9	60.4
AC2-45	1259	RES	1255	1260	56.4	57.2
AC2-46	1333	RES	1328	1335	60.2	65.9
AC2-47	1272	RES	1265	1274	56.4	57.9
AC2-48	1181	RES	1179	1185	48.9	51.4
AC2-49	1220	RES	1219	1226	52.7	52.5
AC2-50	1272	RES	1265	1274	56.4	59.6
AC2-51	1305	RES	1300	1307	60.2	59.8
AC2-52	1153	RES	1150	1158	48.9	45.0
AC2-53	1227	RES	1225	1236	52.7	51.0
AC2-54	1326	RES	1321	1328	63.9	62.1
AC2-55	1255	RES	1249	1257	56.5	59.9

* T_A is the lowest temperature at which samples did not form crystals

T_C is the highest temperature at which samples did form crystals.

Figure 31. Examples of Needle-Like RES Crystals.

Figure 32. Examples of Needle-Like, Hair-Like, and Plate-Like RES Crystals.

Figure 33. SEM Micrograph of Plate-Like RES Crystals in AC2-44 (1302°C).

Figure 34. Transmitted Light Micrograph of AC2-44 (1302°C) at 200x.

Figure 35. Transmitted Light Micrograph of AC2-41 (1313°C) at 200x.

Another unique crystal shape, observed only in the Phase 2 study, is the rectangular cap (Figure 36) found in seven samples: AC2-09 (1314°C), AC2-29 (1288°C), AC2-40 (1321°C), AC2-41 (1321°C), AC2-44 (1321°C), AC2-46 (1321°C), and AC2-54 (1321°C). The rectangular cap crystals are found floating on the surface in the middle of the sample, not near other crystal types. Many samples were thin-sectioned in an attempt to analyze this odd-shaped crystal type, but the rectangular cap was never found below the surface. AC2-46 was sent as a bulk sample, and the surface was analyzed by SEM/EDS. The EDS scan on these crystals had a similar profile to that of RES crystals with other shapes.

Figure 36. SEM Micrograph of Rectangular Cap RES Crystals on the Surface of AC2-46 (1321°C).

8.5.2 ALUMINUM OXIDE CRYSTALS

Aluminum oxide was identified as the primary phase in 8 Phase 2 glasses (see Table XXI). Two distinct Al_2O_3 crystal morphologies were found in the same glass, a plate-like crystal (see Figure 37a) and a garnet shaped crystal (Figure 37b). SEM/EDS identified high aluminum and oxygen concentrations in both crystal types (see Figures 38 – 40). No chemical difference between the two differently shaped crystals could be detected. Several samples of glasses crystallizing Al_2O_3 were analyzed by XRD, however, no conclusive results were obtained regarding structure differences.

In glasses with Al_2O_3 as the primary phase, RES formed as a secondary phase at 30°C to 40°C below T_L . In samples that were 50° to 100°C < T_L , RES crystals would be very high in both size and number density of crystals, and Al_2O_3 crystals would not be found. The Al_2O_3 crystal was never found in samples where RES was the primary phase, except when budding was observed (see Vienna et al. [29] for a description of budding). In these cases, Al_2O_3 crystals in the buds were detected by SEM/EDS.

Figure 37. Examples of Aluminum Oxide Crystals.

Figure 38. SEM Analysis of AC2-21 (1229°C).

Figure 39. SEM Micrograph of a Garnet Shaped Al_2O_3 Crystal in AC2-14 (1232°C).

Figure 40. EDS Spectrum of a Crystal in Figure 39.

8.5.3 "AS-FABRICATED" GLASSES

"As-fabricated" glasses were analyzed by OM to determine if crystalline or immiscible liquid phases existed. Three glasses, AC2-04, AC2-18, and AC2-19, were found to have RES crystals present in streaks as minor inclusions. The crystals appear very similar to those found in AC2-04 (see Figure 27). The crystal fraction was not determined but was estimated to be well less than 1 percent by PNNL. Only a few scattered crystals were found in AC2-19. All other samples appeared to be free of crystals based on OM analyses. These observations confirm visual and XRD results (see Appendix B) for 52 of the 55 Phase 2 glasses. For those three glasses in which crystallization was observed, the % crystallization estimated by PNNL is below the detection limits of the XRD (~ 1 vol%).

8.5.4 QUANTITATIVE ANALYSIS OF RES CRYSTALS BY SEM

Quantitative SEM/EDS analyses²² were performed to determine if differences in chemical composition occurred in the RES crystals. Glasses AC2-04 heat-treated at 1398°C and AC2-05 heat treated at 1223°C were chosen for the analysis since there was a large difference in TL values, 1405°C for AC2-04 and 1241°C for AC2-05. In addition, the bulk chemical composition was quite different between the two glasses. Therefore, a difference in the chemical composition of the RES crystals formed in the two glasses was expected. The RES crystals in the two glass samples were different sizes. The RES crystals found in AC2-04 were 5 to 10 times longer than those found in AC2-05, though they were both needle-shaped crystals.

The analyzed crystal compositions are listed Table XXII and glass compositions are listed in Table XXIII. On a mole-percent basis, Si was the major element in the RES crystal structure (40.5% in AC2-04 and between 43.6 to 46.4% for AC2-05). The Si concentration in glass appears to influence the RES crystal composition. As Si increased in the glass composition from 30.6 mole percent in AC2-04 glass to 37.6 mole percent in AC2-05 glass, so did its concentration in the crystal structure (again 40.5 to about 45 mole percent). Lanthanum, the element with the second highest concentration in both the crystal structure and glass, also increased from 23.65 mole percent in AC2-04 to about 26 mole percent in AC2-05. This is not intuitive since the concentration of La in the glass decreases from 18.2 mole percent in AC2-04 to 14.3 mole percent in AC2-05 (measured by EDS) and from 16.1 mole percent to 13.9 mole percent (target composition) for AC2-04 and AC2-05, respectively. Similarly, Ce concentration in the RES crystal increased while its concentration in the base glass decreased. Praseodymium and Nd followed the expected pattern of increasing in concentration in the crystal with higher concentration in the base glass. The most notable difference is in the concentration of Al in the two crystals. This evidence, however, does not suggest a different crystal type as Al is only a minor element in both spectra, and the total rare earth concentrations in both crystals are similar.

²² Analysis was performed on an elemental basis using Al₂O₃, SiO₂ (quartz), LaB₆, CeO₂, PrF₃, NdF₃, GdF₃, and ErF₃ as instrument calibration standards for their representative elements. To correct for X-ray absorbency and fluorescence, a mathematical iteration (quantitative ZAF correction method) was applied. The comparison between SEM glass-matrix composition analysis and the normalized target composition (mole percent) had an error margin of less than ±10 percent for all major elements.

Table XXII. Quantitative Analysis of Crystals in Glass
(in mole percent metals normalized to 100).

	AC2-04		AC2-05	
	Spectrum 1	Spectrum 2	Spectrum 1	Spectrum 2
Al	2.19	2.63	0.42	0.22
Si	40.41	40.62	43.67	46.37
La	23.72	23.63	26.50	25.14
Ce	2.54	2.69	3.50	3.35
Pr	6.20	6.75	3.26	3.15
Nd	20.99	21.25	12.11	11.43
Sm	not analyzed	not analyzed	5.07	4.87
Gd	1.50	0.67	2.84	2.77
Er	2.44	1.78	2.63	2.70
Total	100.00	100.00	100.00	100.00

Table XXIII. Quantitative Analysis of Glass Matrix Compared to Target Composition
(in mole percent metals normalized to 100).

	AC2-04		AC2-05	
	SEM Analysis	Normalized Target Comp	SEM Analysis	Normalized Target Comp
Al	27.76	26.64	33.21	32.90
Si	33.56	30.58	39.84	37.60
La	18.23	16.11	14.28	13.93
Ce	2.62	2.25	1.93	1.95
Pr	4.03	5.05	1.34	1.74
Nd	11.64	12.55	4.85	5.98
Sm	Not analyzed	3.27	2.07	2.83
Gd	0.74	1.76	1.07	1.52
Er	1.42	1.79	1.41	1.55
Total	100.00	100.00	100.00	100.00

8.5.5 GLASS COMPOSITION EFFECTS

A linear relationship between Ln_2O_3 concentration in glass and T_L with a primary-phase boundary was shown for Phase 1 glasses (see Figure 3). The effect of Ln_2O_3 concentration on T_L for the Phase 2 glasses is shown in Figures 41 and 42 (target versus measured Ln_2O_3 concentration, respectively). One should also note that only two glasses (AC2-04 and AC2-18) have T_L s exceeding the 1350°C constraint. Given this (and ignoring the uncertainties associated with the T_L measurement), the AGCR is only limited by those glasses with > 63.5 mass % total Ln_2O_3 (based on target compositions) or > 62.5 % mass % total Ln_2O_3 (based on measured compositions).

Figure 43 shows the effect of Ln_2O_3 concentration on T_L for both the Phase 1 and Phase 2 glasses. A comparison shows a reasonably close match in Ln_2O_3 effect on T_L for Phase 1 and Phase 2 glasses, despite the fact that SiO_2 , Al_2O_3 , B_2O_3 , and SrO concentrations varied independently in Phase 2 glasses and not in Phase 1 glasses. There is a clear primary-phase boundary between the alumino-silicate and RES fields. However, the glass compositions in the Al_2O_3 primary phase field are intermixed with those in the RES primary phase field. Further examination of compositions was required to separate the two primary-phase fields. Figure 44 shows a composition projection of Phase 1 and Phase 2 glasses in a $\text{SiO}_2 - \text{Al}_2\text{O}_3 - \text{Ln}_2\text{O}_3$ space with primary crystalline phases noted as symbols. A clear distinction between the RES and Al_2O_3 primary-phase fields can be seen by the $\text{Al}_2\text{O}_3/\text{SiO}_2$ ratio. All glasses with a ratio above 1 are in the Al_2O_3 primary phase field.

Figure 41. T_L Versus Ln_2O_3 Concentration (target, mass %) for the Phase 2 Glasses.

Figure 42. T_L Versus Ln_2O_3 Concentration (measured, mass %) for the Phase 2 Glasses.

Figure 43. T_L as a Function of Ln_2O_3 Concentration (in mass fraction) for Phase 1 and Phase 2 Glasses.

(S-Alumino-Silicate Crystals in Phase 1 Glasses, *-RES Crystals in Phase 1 Glasses, +-RES Crystals in Phase 2 glasses, and A- Al_2O_3 Crystals in Phase 2 Glasses)

Figure 44. $\text{Al}_2\text{O}_3\text{-SiO}_2\text{-Ln}_2\text{O}_3$ ternary submixture (mass%) with test glasses plotted with different symbols for each primary phase: "A"- Al_2O_3 , "S"-AlSi, and "+"-RES

Figure 45 provides the results of the investigation of the effects of the individual (measured) lanthanides on liquidus temperature. Only Eu_2O_3 is not significant at the 5% significance level, and all of the estimated effects are similar. Thus, there is no indication of substantial differences among the effects of the individual lanthanides on liquidus temperature.

Response: Liquidus Temperature (T_L) °C
Summary of Fit

RSquare	0.838186
RSquare Adj	0.810044
Root Mean Square Error	21.85874
Mean of Response	1274.727
Observations (or Sum Wgts)	55

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	803.47748	40.07753	20.05	<.0001
Ce ₂ O ₃	7.1835270	1.274744	5.64	<.0001
Er ₂ O ₃	6.2532626	1.459106	4.29	<.0001
Eu ₂ O ₃	12.127728	8.214394	1.48	0.1467
Gd ₂ O ₃	17.781934	3.808117	4.67	<.0001
La ₂ O ₃	6.6631604	1.294107	5.15	<.0001
Nd ₂ O ₃	9.7448515	0.733356	13.29	<.0001
Pr ₂ O ₃	10.102140	1.852733	5.45	<.0001
Sm ₂ O ₃	6.6793626	2.208716	3.02	0.0041

Whole-Model Test

Residuals

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	113849.89	14231.2	29.7846
Error	46	21979.02	477.8	Prob>F
C Total	54	135828.91		<.0001

Figure 45. Results of JMP Regression of Liquidus Temperature Measurements Versus Individual (measured) Lanthanide Concentrations.

- ◆ – outer layer extreme vertices ($\pm 40\%$); x – inner layer extreme vertices ($\pm 20\%$); y – specific compositions using average feed composition; other symbols represent overall centroids, Ce-spiked glasses, and the Am/Cm-1A glass.

Isolating just the duplicate glasses (including those that were spiked with the minor components) and plotting their liquidus temperature measurements leads to Figure 46. The “pooled” estimate of the standard deviation of these measurements is 10°C (even with the spiked glasses being included).

Figure 46. Liquidus Temperature (in °C) for Replicates.

8.6 DURABILITY

The extent of corrosion is usually defined as the amount of glass dissolved per unit volume of solution or the fraction of glass that has entered the solution per unit surface area. It is conveniently measured using a tracer, which is a glass component that does not participate in secondary reactions. Thus all the tracer released from the glass is found in the solution. For borosilicate glasses, boron (B) is usually chosen as the tracer because it is present in the glass in a sufficiently high concentration and is unlikely to precipitate or be absorbed from the solution.

The PCT (ASTM C-1285-94) [19] was conducted, in triplicate, for each of the Phase 2 glasses as a measure of durability (or resistance to aqueous corrosion). In addition, samples of EA glass, ARM-1 glass, and blanks were also included in this test. The solutions from these tests were submitted to the SRTC-ML for concentration measurements of B, Si, Na, Li, Al, and La. Along with the various solutions, a multi-element standard solution was run within each analytical block. Table C.1 in Appendix C shows the raw data obtained from the SRTC-ML corrected for the dilution factor (5/3).

Exhibits C.1 and C.2 provide plots of the parts per million (ppm) data presented in Table C.1 by sample (for the glass and solution samples). Exhibit C.1 includes all of the measurements from Table C.1 and Exhibit C.2 plots only the samples of the Phase 2 glasses. No problems are seen in the consistency of these results.

Exhibit C.3 provides a closer look at the measurements (for elements: Al, B, Si, and Sr) of the multi-element standard solution by analytical block. An analysis of variance (ANOVA) is conducted for each element investigating for statistically significant differences among the average of the measurements for each of these blocks. Statistically significant differences (at the 5% significance level) are seen for Al, B, and Sr but not for Si. The overall averages of the results from this exhibit are compared to the reference values for this standard solution in Exhibit C.4.

A typically expression for the leachate concentrations is as normalized elemental releases from the glass in grams of glass per liter of leachate (g/L). However, it is the common logarithm of this normalized loss (NL) that is of primary interest in modeling glass durability. This value is computed by first taking the common logarithm of each available measurement (elemental concentrations in the leachate and cation concentrations in the glass), averaging the appropriate transformed values, and then subtracting one from the difference between the averages of the transformed leachate concentrations and the transformed cation concentrations.

Tables XXIV and XXV summarize the normalized releases (NL) and the common logarithm of the normalized release (log NL) for the Phase 2 glasses, respectively.²³ Release rates of both the EA and ARM-1 glasses are also included.

²³ Normalization of the elemental losses released from the glass is usually conducted using the measured elemental concentration in the glass; these values are given in these two tables. However, the losses were also normalized using target compositions, and some results from this alternative for normalizing the elemental losses are presented in the following discussions.

Table XXIV. Normalized Release (g/L) for the Phase 2 Glasses.

Glass	Normalized Release Rate (g/L)					pH
	B	Si	Nd	Al	La	
ARM-1	0.537	0.312	0.004	0.158	0.246	10.17
EA	19.099	4.237	4.441	0.085	0.230	12.05
AC2-01	0.011	0.022	0.003	0.006	0.000	7.15
AC2-02	0.023	0.013	0.003	0.002	0.001	7.04
AC2-03	0.021	0.012	0.001	0.002	0.001	6.78
AC2-04	0.008	0.012	0.001	0.003	0.001	6.93
AC2-05	0.011	0.014	0.003	0.002	0.002	6.91
AC2-06	0.008	0.011	0.001	0.002	0.002	6.87
AC2-07	0.016	0.012	0.002	0.002	0.002	7.00
AC2-08	0.014	0.012	0.003	0.002	0.001	7.16
AC2-09	0.012	0.011	0.001	0.003	0.002	6.74
AC2-10	0.018	0.013	0.002	0.003	0.001	7.29
AC2-11	0.025	0.014	0.001	0.002	0.001	7.17
AC2-12	0.012	0.012	0.001	0.003	0.002	7.14
AC2-13	0.010	0.015	0.003	0.002	0.001	7.00
AC2-14	0.019	0.014	0.002	0.002	0.002	6.99
AC2-15	0.011	0.013	0.002	0.003	0.003	6.85
AC2-16	0.013	0.014	0.001	0.002	0.001	7.28
AC2-17	0.033	0.007	0.002	0.002	0.001	7.05
AC2-18	0.012	0.018	0.001	0.003	0.001	6.88
AC2-19	0.043	0.074	0.003	0.013	0.000	6.94
AC2-20	0.014	0.012	0.002	0.003	0.001	7.54
AC2-21	0.027	0.017	0.001	0.003	0.002	7.20
AC2-22	0.009	0.012	0.002	0.002	0.001	6.97
AC2-23	0.028	0.013	0.001	0.002	0.000	7.09
AC2-24	0.006	0.011	0.001	0.002	0.002	7.13
AC2-25	0.008	0.011	0.002	0.002	0.001	6.96
AC2-26	0.017	0.011	0.004	0.002	0.001	6.78
AC2-27	0.019	0.013	0.003	0.002	0.003	6.79
AC2-28	0.012	0.013	0.003	0.002	0.001	6.90
AC2-29	0.018	0.010	0.001	0.002	0.001	6.90
AC2-30	0.026	0.014	0.002	0.002	0.003	7.03
AC2-31	0.008	0.011	0.001	0.003	0.001	6.82
AC2-32	0.020	0.011	0.003	0.002	0.001	6.96
AC2-33	0.014	0.013	0.001	0.002	0.002	7.16
AC2-34	0.014	0.012	0.001	0.002	0.001	6.99
AC2-35	0.020	0.012	0.002	0.002	0.001	8.25
AC2-36	0.009	0.012	0.002	0.002	0.001	8.33
AC2-37	0.003	0.013	0.001	0.002	0.001	7.17
AC2-38	0.016	0.012	0.002	0.002	0.001	6.88
AC2-39	0.009	0.012	0.001	0.002	0.001	7.08
AC2-40	0.007	0.011	0.001	0.002	0.000	7.19
AC2-41	0.012	0.012	0.001	0.003	0.002	6.88
AC2-42	0.013	0.015	0.002	0.002	0.002	6.97
AC2-43	0.013	0.014	0.001	0.002	0.001	6.95
AC2-44	0.012	0.011	0.002	0.002	0.002	7.00
AC2-45	0.020	0.013	0.002	0.002	0.002	7.02
AC2-46	0.012	0.012	0.001	0.002	0.001	6.99
AC2-47	0.016	0.011	0.002	0.002	0.002	7.02
AC2-48	0.018	0.013	0.002	0.002	0.002	7.07
AC2-49	0.017	0.014	0.001	0.002	0.001	7.01
AC2-50	0.016	0.013	0.002	0.002	0.001	6.88
AC2-51	0.026	0.021	0.001	0.004	0.003	6.82
AC2-52	0.014	0.014	0.002	0.002	0.001	6.91
AC2-53	0.013	0.014	0.001	0.002	0.002	6.94
AC2-54	0.011	0.016	0.001	0.003	0.002	6.84
AC2-55	0.012	0.015	0.002	0.002	0.001	7.11

Table XXV. Common Logarithm of Normalized Release Rates (g/L).

Glass	Common Log[Normalized Release Rate (g/L)]				
	B	Si	Na	Al	La
ARM-1	-0.2700	-0.5058	-2.3979	-0.8013	-0.6091
EA	1.2810	0.6271	0.6475	-1.0706	-0.6383
AC2-01	-1.9449	-1.6504	-2.5693	-2.2167	-3.3872
AC2-02	-1.6349	-1.8773	-2.5523	-2.7298	-2.8622
AC2-03	-1.6699	-1.9061	-2.9400	-2.6057	-2.8957
AC2-04	-2.0852	-1.9334	-3.0212	-2.5896	-3.2255
AC2-05	-1.9404	-1.8476	-2.5320	-2.7291	-2.6370
AC2-06	-2.1217	-1.9781	-3.0253	-2.6026	-2.6745
AC2-07	-1.7985	-1.9138	-2.7774	-2.7451	-2.7767
AC2-08	-1.8387	-1.9225	-2.5455	-2.7270	-2.8940
AC2-09	-1.9157	-1.9436	-2.8789	-2.5972	-2.6865
AC2-10	-1.7419	-1.8878	-2.6653	-2.5797	-2.8702
AC2-11	-1.6083	-1.8506	-2.8983	-2.7498	-3.1941
AC2-12	-1.9255	-1.9343	-2.9720	-2.5965	-2.7110
AC2-13	-2.0130	-1.8290	-2.5059	-2.6388	-2.8565
AC2-14	-1.7287	-1.8546	-2.7500	-2.7429	-2.8062
AC2-15	-1.9737	-1.8802	-2.7460	-2.5728	-2.4968
AC2-16	-1.8889	-1.8452	-2.9141	-2.6327	-2.8363
AC2-17	-1.4881	-2.1647	-2.6949	-2.6629	-3.0766
AC2-18	-1.9388	-1.7426	-3.1266	-2.4649	-2.8254
AC2-19	-1.3617	-1.1303	-2.5561	-1.8962	-3.4029
AC2-20	-1.8578	-1.9039	-2.7198	-2.5732	-2.8900
AC2-21	-1.5731	-1.7632	-2.8459	-2.5585	-2.6949
AC2-22	-2.0535	-1.9279	-2.6057	-2.6203	-3.1294
AC2-23	-1.5534	-1.9006	-2.8305	-2.7328	-3.3867
AC2-24	-2.2005	-1.9511	-3.0084	-2.6081	-2.7648
AC2-25	-2.1015	-1.9672	-2.7777	-2.7595	-3.2206
AC2-26	-1.7741	-1.9771	-2.3604	-2.7566	-2.8513
AC2-27	-1.7194	-1.8885	-2.5561	-2.7160	-2.5452
AC2-28	-1.9289	-1.9018	-2.5593	-2.7313	-3.0563
AC2-29	-1.7371	-2.0042	-2.8499	-2.6121	-2.8319
AC2-30	-1.5869	-1.8665	-2.7741	-2.7642	-2.5022
AC2-31	-2.1228	-1.9514	-3.0816	-2.6006	-3.0567
AC2-32	-1.6885	-1.9443	-2.5946	-2.6926	-2.8304
AC2-33	-1.8575	-1.8737	-2.8751	-2.6632	-2.6807
AC2-34	-1.8514	-1.9150	-2.8391	-2.6249	-2.9489
AC2-35	-1.7083	-1.9151	-2.7354	-2.6469	-3.0910
AC2-36	-2.0336	-1.9348	-2.7443	-2.6475	-2.8401
AC2-37	-2.5133	-1.8950	-2.9138	-2.6335	-3.1288
AC2-38	-1.8026	-1.9209	-2.7699	-2.6217	-2.8370
AC2-39	-2.0236	-1.9252	-2.9502	-2.6276	-2.9570
AC2-40	-2.1451	-1.9453	-2.9654	-2.6231	-3.4275
AC2-41	-1.9138	-1.9220	-2.9453	-2.5982	-2.7610
AC2-42	-1.8936	-1.8375	-2.6693	-2.7431	-2.7114
AC2-43	-1.8793	-1.8590	-2.8351	-2.7059	-2.9479
AC2-44	-1.9176	-1.9476	-2.7826	-2.6340	-2.8007
AC2-45	-1.7080	-1.8905	-2.8054	-2.6872	-2.7513
AC2-46	-1.9105	-1.9238	-2.9949	-2.6094	-2.9450
AC2-47	-1.7905	-1.9561	-2.7173	-2.6770	-2.6458
AC2-48	-1.7549	-1.8878	-2.7947	-2.7624	-2.6777
AC2-49	-1.7622	-1.8507	-2.8583	-2.7027	-2.9227
AC2-50	-1.7934	-1.8918	-2.7288	-2.6918	-2.8902
AC2-51	-1.5912	-1.6698	-2.8302	-2.4159	-2.5701
AC2-52	-1.8608	-1.8558	-2.7985	-2.7295	-3.1713
AC2-53	-1.8919	-1.8648	-2.8254	-2.7125	-2.7020
AC2-54	-1.9698	-1.7864	-2.9853	-2.4860	-2.6972
AC2-55	-1.9171	-1.8326	-2.6788	-2.6778	-2.9535

Exhibit C.5 in Appendix C provides a series of plots showing the log NL's of interest versus total lanthanide content. Various combinations of target compositions and measured compositions are considered: PCT normalized using the target as well as measured compositions and each of these plotted versus both target and measured (total) lanthanide content in the glass. The relationships that are statistically significant (at the 5% significance level) out of those provided in Exhibit C.5 are summarized in Table XXVI. There is a great deal of scatter in all of the relationships in Exhibit C.5 even those of Table XXVI that are statistically significant.

Table XXVI. PCT Results Showing a Statistically Significant Linear Relationship
With the Total Ln_2O_3 Content
(Significance Level at 5%)

Log NL[Al (g/L)] (measured)	Increases with	Total Lanthanide (measured)
Log NL[Al (g/L)] (measured)	Increases with	Total Lanthanide (target)
Log NL[Nd (g/L)] (measured)	Decreases with	Total Lanthanide (measured)
Log NL[Nd (g/L)] (measured)	Decreases with	Total Lanthanide (target)
Log NL[Sr (g/L)] (measured)	Decreases with	Total Lanthanide (measured)
Log NL[Sr (g/L)] (measured)	Decreases with	Total Lanthanide (target)
Log NL[Al (g/L)] (target)	Increases with	Total Lanthanide (measured)
Log NL[Al (g/L)] (target)	Increases with	Total Lanthanide (target)
Log NL[B (g/L)] (target)	Decreases with	Total Lanthanide (target)
Log NL[Nd (g/L)] (target)	Decreases with	Total Lanthanide (measured)
Log NL[Nd (g/L)] (target)	Decreases with	Total Lanthanide (target)
Log NL[Sr (g/L)] (target)	Decreases with	Total Lanthanide (measured)
Log NL[Sr (g/L)] (target)	Decreases with	Total Lanthanide (target)

Figure 47 provides the JMP results when log NL[B (g/L)] is regressed against the individual (measured) lanthanide concentrations. Only Gd_2O_3 is statistically significant at the 5% significance level, and all of the estimated effects are comparable. Thus, there is no indication of a serious difference among the effects of the individual lanthanides on B leaching.

The durabilities of the duplicate glasses are contrasted in Exhibit C.6 of Appendix C. First, log NL plots, determined using the measured compositions of these glasses, are presented; then similar plots of the log NL values determined using the target compositions are shown.

To define the AGCR, a comparison of the normalized release rates of various glass components for the Phase 2 glasses was made to those limits of the Environmental Assessment (EA) [20] (with the appropriate confidence limits applied) as shown in Table XXVII. Normalized boron release (NL [B]) was used as the key indicator of durability as previously described.

Figure 47. Results of JMP Regression of log NL [B (g/L)]
Versus Individual (Measured) Lanthanide Concentrations.

◆ – outer layer extreme vertices ($\pm 40\%$); x – inner layer extreme vertices ($\pm 20\%$); y – specific compositions using average feed composition; other symbols represent overall centroids, Ce-spiked glasses, and the Am/Cm-1A glass.

Table XXVII. Leachate Concentrations (ppm), Normalized Release (g/L), and Log Normalized Release Rates (g/L) for the Environmental Assessment (EA) Glass.

	Leachate Concentrations [20]			
	B (ppm)	Li (ppm)	Na (ppm)	Si (ppm)
Mean	587	190	1662	893
Standard Deviation	43	14.5	112	86
	Normalized Release (NL) [20]			
	B (g/L)	Li (g/L)	Na (g/L)	Si (g/L)
Mean	16.695	9.565	13.346	3.922
Standard Deviation	1.222	0.735	0.902	0.376
	Log Normalized Release (log NL)			
	B (g/L)	Li (g/L)	Na (g/L)	Si (g/L)
	1.233	0.981	1.125	0.594

The averaged NL [B] (g/L) for the Phase 2 glasses was 0.0154 g/L and 0.0150 g/L, based on measured and target compositions, respectively. The maximum [B] release observed in Phase 2 was 0.0435 g/L from AC2-19 which is still well below the EA limit of 16.695 g/L (the historical reference value). The minimum [B] release observed in Phase 2 was 0.0031 g/L from AC2-37. Clearly, the AGCR is not limited by durability based on the results from the Phase 2 study as compared to the EA glass limits for B. All Phase 2 glasses are roughly two orders of magnitude more durable (as defined by the PCT) than the EA glass. This is in good agreement with the results observed for Phase 1.[9] The durability information from Phase 2 is summarized in Figure 48.

Figure 48. Average, Maximum and Minimum NL [B] for the Phase 2 Glasses.

8.7 RECOVERABILITY

The recovery of the lanthanides as a function of dissolution time was calculated for each glass using the recovered mass from the solution analyses (see Table D.1 in Appendix D) expressed as a percentage of the lanthanides in each formulation. The glass compositions (see Appendix A for Phase 2 compositions and Peeler et. al. [9] for selected Phase 1 compositions) were normalized prior to calculating the lanthanide recoveries. The recovery data for each glass formulation as a function of time is presented in Appendix D (see Table D.2).

Inspection of the recovery data in Appendix D shows that greater than 98% recovery of the lanthanide elements was achieved from a majority of the SrABS glass formulations in less than 2 h; however, final recoveries for 14 glasses were actually slightly less than 98% (ranging between 95 and 98%). Since the recovery of the lanthanides at each time increment was based on a single data point for most of the glass formulations, errors in the recovered lanthanide masses and total lanthanides in each glass would be reflected in the lanthanide recovery and may not be apparent. To determine if the error in the lanthanide recovery could explain the measured values which were less than 98% at 2 h, an estimate of the variance was made using a propagation of errors technique.

The percent lanthanide recovery (R_{La}) for each glass formulation was calculated using Equation (4):

$$R_{La} = 100 \frac{M_{La}}{G_{La}} = 100 \frac{V_{Solution} \sum C_i}{Wt_{La} M_{Sample}} \quad (4)$$

where the recovered mass of the lanthanide elements (M_{La}) is the product of the volume of solution ($V_{solution} = 200$ mL) and the sum of the measured lanthanides concentrations (C_i), and the total lanthanides in each glass (G_{La}) is the product of the lanthanide mass fraction (Wt_{La}) and glass sample size ($M_{Sample} \approx 0.25$ g). To calculate the variance in the lanthanide recovery, errors associated with the measurement of the solution volume and the sample size were assumed to be small compared to errors associated with the measured lanthanide concentrations and the total lanthanides in each glass, and were ignored. With this assumption, an approximate expression for the variance of the lanthanide recovery can be written as Equations (5) and (6).

$$V_{R_{La}} = \left(\frac{\partial R_{La}}{\partial M_{La}} \right)^2 V_{M_{La}} + \left(\frac{\partial R_{La}}{\partial Wt_{La}} \right)^2 V_{Wt_{La}} \quad (5)$$

$$V_{R_{La}} = \left(\frac{100}{Wt_{La} M_{Sample}} \right)^2 V_{M_{La}} + \left(-\frac{100 M_{La}}{Wt_{La}^2 M_{Sample}} \right)^2 V_{Wt_{La}} \quad (6)$$

To calculate the variance in the lanthanide recovery ($V_{R_{La}}$) using Equation (6), the variance in the recovered mass of the lanthanide elements ($V_{M_{La}}$) was initially estimated for 12 of the 60 glasses at either 0.25, 0.5, 1.0, 2.0, or 4.0 h using the analysis of 3 samples of the dissolving solution. During the glass dissolutions, multiple samples of the 12 solutions were submitted to the SRTC-ML to obtain an estimate of the variance in the measured concentrations. Any error associated

with the sample dissolution procedure would not be reflected in this variance (or the variance in the recovered masses); however, using a smaller variance in the propagation of errors is conservative since the confidence interval for the lanthanide recovery would also be smaller. An estimate of the variance in the lanthanide composition of the glasses ($\bar{V}_{WtLa}$) was calculated using the 4 measured compositions for each of the glasses. For each glass formulation, the variance of the lanthanide concentration was calculated using normalized compositions. The individual variances were then pooled to obtain the final estimate of variance. By pooling the individual estimates, an assumption was made that the variance in the lanthanide composition is not a function of the total lanthanides in the glasses.

Using the variances for the recovered lanthanide masses and the pooled variance for the lanthanide compositions, Equation (6) was used to calculate the variance in the lanthanide recovery for the 12 glasses. The 12 values were then pooled to obtain the final estimate of variance. Pooling the individual variances assumes the variance in the lanthanide recovery is not a function of dissolving time. Calculation of the pooled variance in the lanthanide recovery is summarized in Appendix D (see Table D.3).

To calculate a 95% confidence interval for the lanthanide recovery, the standard deviation in the lanthanide recovery was calculated from the pooled variance and multiplied by the appropriate value from the t-distribution. Conservatively, 24 degrees of freedom (2 from each estimate of the lanthanide recovery variance) were used to specify a value of t equal to 2.06. Multiplying this value by the pooled standard deviation (equal to $\pm 1.7\%$) results in a 95% confidence interval of $\pm 3.5\%$. Therefore, the measured values of the lanthanide recovery for the 14 glasses which were slightly less than 98% at 2 h are statistically indistinguishable from this value. All 55 Phase 2 glasses and the 5 selected Phase 1 glasses which were tested meet the recoverability criterion.

The recoverability data presented in Appendix D (see Table D.2) can be used to calculate the dissolution rate of the SrABS glasses. Rudisill et al. [36] showed that the rate of change of the mass (M) to surface area (S_A) ratio with respect to time during nitric acid dissolution was constant ($-K_R$) for a 38 wt% lanthanide borosilicate glass (see Equation (7)).

$$\frac{d\left(\frac{M}{S_A}\right)}{dt} = -K_R \quad (7)$$

This constant, equal to the negative dissolution rate, is calculated from the data using the following procedure.

Assuming the particles of glass can be approximated by spherical geometry, the mass and surface area in Equation (7) can be substituted for in terms of the particle diameter and density (ρ_g). Following integration, with the initial glass particle diameter equal to D_0 , an equation for the particle diameter (D_t) as a function of time is obtained (see Equation (8)).

$$D_t = D_0 - \frac{6K_R t}{\rho_g} \quad (8)$$

For a glass particle, the lanthanide recovery given by Equation (4) can also be defined by the ratio of the mass of glass at any time (M_t) to the initial mass (M_0) prior to dissolution (see Equation (9)).

$$R_{La} = 100 \left(1 - \frac{M_t}{M_0} \right) \quad (9)$$

Substituting for the mass in terms of the particle diameter and density yields an equation for the lanthanide recovery which is only a function of the glass particle diameter (Equation 10).

$$R_{La} = 100 \left(1 - \frac{D_t^3}{D_0^3} \right) \quad (10)$$

By substituting Equation (8) for the particle diameter, D_t , Equation (11) is obtained which can be used to calculate the glass dissolution rate from the lanthanide recovery data.

$$f(R_{La}) = \left(D_0^3 \left(1 - \frac{R_{La}}{100} \right) \right)^{\frac{1}{3}} = D_0 - \frac{6K_R t}{\rho_g} \quad (11)$$

Inspection of equation (8) shows that a plot of $f(R_{La})$ versus time is linear with a slope equal to $-6K_R/\rho_g$ and a y-intercept of D_0 . This analysis is only valid for lanthanide recovery values less than or equal to 100%; therefore, values greater than 100% (due to data scatter) used to calculate dissolution rates were rounded to a value of 100%.

As an illustration of this analysis, lanthanide recovery data from AC2-47 were used to calculate $f(R_{La})$ and plotted as a function of time in Figure 49. An initial glass particle diameter of 324 μm was used for the calculations. This value is the geometric mean of a spherical particle which passes through a 35 mesh screen (420 μm) and is retained on a 60 mesh screen (250 μm). The density of the glass (4.351 g/cm^3) measured by gas pycnometry (see Table X) was used in the dissolution rate calculation. The least squares line through the data in Figure 49 has a slope of -0.0252 cm/h which allows calculation of a dissolution rate for the AC2-47 glass equal to 0.018 $\text{g}/\text{h}\cdot\text{cm}^2$. The dissolution rates for all the Phase 2 and the selected Phase 1 glasses are presented in Appendix D (see Table D.4).

The measured dissolution rates for the SrABS glasses range from 0.007 to 0.034 $\text{g}/\text{h}\cdot\text{cm}^2$ suggesting the rate may correlate with changes in the glass composition. Figures 50 and 51 illustrate that the dissolution rate is proportional to the lanthanide oxide concentration and inversely proportional to the silicon oxide (SiO_2) concentration. The correlation with the lanthanide oxides is slightly stronger than the correlation with SiO_2 (correlation coefficient (R) of 0.67 versus 0.61). The inverse relationship of the lanthanide oxides and SiO_2 to the dissolution rate is not unexpected. The lanthanide oxides are soluble in nitric acid while SiO_2 is relatively insoluble.[37] When SiO_2 is replaced with a lanthanide in the glasses with higher (Am/Cm) loadings, the glass becomes more easy to dissolve in nitric acid. Since the glass dissolution rates were calculated based on a limited number of data points (generally 3), data scatter is quite evident in the plots (see Figures 50 and 51). The relative standard deviation of the dissolution rates (see Table D.4 in Appendix D) ranges between 0 and 35% (with an average of 12) which

could account for much of the scatter about the regression lines in Figures 50 and 51; however, other factors, such as minor component compositions and particle morphology (i.e. available surface area), certainly contribute to the ease of dissolution.

The rates given in Appendix D (see Table D.4) for the SrABS glasses can be used to calculate the expected lanthanide recovery as a function of time. Equation (8) is used to calculate the particle diameter at any time which can be substituted into Equation (10) to predict the lanthanide recovery. The recovery data and prediction curve for AC2-47 are plotted on Figure 52 to illustrate this analysis. The predictive curve defined by Equations (8) and (10) for the SrABS glasses must be shifted 5-10 minutes from the origin to account for slower dissolution rates while the nitric acid solution heats to 110°C. The spherical particle model assumes isothermal conditions during the glass dissolution. The model predictions also support the conclusion that all Phase 2 glasses and the selected Phase 1 glasses meet the recoverability criterion. All glass dissolutions are predicted to achieve at least a 98% recovery of the lanthanides elements in less than 2 h.

Elemental analyses for other components of the SrABS glasses were obtained with the lanthanide elements. The concentrations of aluminum, boron, strontium, and silicon were measured in the dissolving solutions. Elemental recoveries were calculated for these elements in the same manner as the lanthanides. In general, the recovery of aluminum, boron, and strontium tracked the results obtained for the lanthanide elements with values approaching complete recovery in approximately 2 h. For silicon, typically 2-5% of the total in the glass sample was initially soluble after 0.25 h. This value decreased over time as the dissolving proceeded and was usually less than 1% when the last sample was removed from the oven. Prior to purification of the actual Am/Cm isotopes the insoluble silicon oxide should be easily removed by filtration.

Figure 49. Calculation of the Dissolution Rate for AC2-47.

Figure 50. Correlation of Glass Dissolution Rate with Lanthanide Oxide Composition.

Figure 51. Correlation of Glass Dissolution Rate with Silicon Dioxide Concentration.

Figure 52. Predicted Lanthanide Recovery from AC2-47.

9.0 DEFINITION OF PHASE 2 AGCR

Figure 53 identifies the Phase 2 AGCR based on target compositions. Glasses within the AGCR simultaneously meet all processing and performance constraints as defined for Phase 2. It should be noted that only the T_L constraint limits the Phase 2 AGCR. Two glasses AC2-04 and AC2-18 had T_L s exceeding the 1350°C constraint. Given this (and ignoring the uncertainties associated with the T_L measurement), the AGCR is only limited by those glasses with > 63.5 mass % total Ln_2O_3 (based on target compositions). That is, Phase 2 glasses targeting between 49 and ~ 63 mass % total Ln_2O_3 content met all process and product performance specifications as defined by Martin [12].

Figure 54 shows the same compositional ternary with the Phase 2 glasses identified by their measured compositions. The AGCR is slightly reduced based on measured compositions, with Phase 2 glasses between 49 and ~ 62.5 mass % total Ln_2O_3 meeting all specifications. This slight reduction is due to measurement uncertainties associated with AC2-04 and AC2-18.

Figure 53. Definition of Phase 2 AGCR Based on Target Compositions.

Figure 54. Definition of Phase 2 AGCR Based on Measured Compositions.

10.0 CONCLUSIONS

The objective of this research was to evaluate the effect of compositional uncertainties on the primary processing and product performance criteria for potential glasses to be processed in the MPPF. Given the feed composition (and its potential $\pm 20\%$ or $\pm 40\%$ variation), the composition of 25SrABS, and the target feed loading range of 32 – 52 mass % for the process, an experimental glass composition region (EGCR) for Phase 2 testing was defined. In this study, fifty-five glasses were fabricated and both process and product performance properties were measured as a function of glass composition. These properties were assessed against predefined constraints to define an acceptable glass composition region (AGCR) in which all property constraints were simultaneously satisfied.

As a result, an AGCR has been identified in which glasses meet all processing and product performance criteria as currently defined. The operational window is only limited at Ln_2O_3 concentrations exceeding ~ 63 mass % (target) or ~ 62.5 mass % (measured) based on liquidus temperature. In other words, all glasses with total Ln_2O_3 concentrations between 49 – 62.5 (based

on the conservative measured data) would be acceptable from both a processing and product performance perspective within the limits that the study was developed.

The major observations for the Phase 2 variability study are summarized below:

CHEMICAL COMPOSITION

- (1) The target compositions for the Phase 2 glasses were adequately met. The batching and analytical processes introduced some slight discrepancies. However, these discrepancies had little to no effect on the representativeness and value of the data acquired during this study.
- (2) Multi-element standard solutions and standard glasses were introduced into the analytical process as a quality check on the Phase 2 chemical composition measurements. The measurements obtained on the standards also were used to bias-correct the measured compositions. The bias-corrected values were compared to the target and measured compositions and were deemed to have no significant impact on the evaluated results. Thus, the evaluation of composition – property relationships will be primarily based on the target and measured compositions.

HOMOGENEITY

- (3) All Phase 2 glasses were homogeneous as defined by X-ray diffraction (XRD). It should be noted that this property was not used in the definition of the Phase 2 AGCR due to the manner in which the variability study glasses were fabricated (e.g., use of oxides and carbonates instead of oxalate / cullet).

DURABILITY

- (4) The AGCR is not restricted by durability as defined by the 7-Day Product Consistency Test (PCT), ASTM C-1285-94.
- (5) PCT results indicate that the Phase 2 EGCR glasses are at least 2 orders of magnitude more durable than the Environmental Assessment (EA) glass based on normalized boron releases.

VISCOSITY

- (6) The Phase 2 AGCR is not restricted by the upper viscosity (η_{1350}) constraint of 24 Poise at 1350°C. It should be noted that the lower η_{1350} constraint (3 Poise at 1350°C) was not used to define the AGCR although three Phase 2 glasses may have viscosities below this limit. The viscosity constraint is primarily being driven by the upper limit ($\eta_{1350} = 24$ Poise) and its relation to maintaining a continuous pour stream (i.e., continuous versus drip modes). Glasses with lower viscosities should not constitute a continuous pour concern.
- (7) A majority of the Phase 2 glasses did not possess the linear Arrhenian type behavior typical of borosilicate based glasses. The viscosity versus temperature relationship of these glasses were considered to be piece wise linear. This phenomena has been linked to possible high temperature structural changes (i.e., the formation of nano-phase clusters rich in both rare earths and silica that could eventually lead to or precipitate crystallization).

LIQUIDUS TEMPERATURE

- (8) The AGCR is limited by the liquidus temperature constraint with 2 of the 55 Phase 2 glass T_L 's exceeding 1350°C. AC2-04 and AC2-18 had measured T_L 's of 1405° and 1366°C, respectively. This observation restricts the AGCR to the fabrication of glasses containing < 63.5 mass % total Ln_2O_3 content (based on target compositions) or < 62.5 mass % total Ln_2O_3 content (based on measured compositions).
- (9) Within the Phase 2 EGCR, two primary phase fields were observed: a rare earth silicate (RES) phase and mullite (Al_2O_3). The aluminosilicate (AIS) phase observed in Phase 1 at $\leq$

~42.5 mass % total Ln_2O_3 content (on an measured basis) was not observed in Phase 2. It should be noted that the design of the Phase 2 matrix had a lower total Ln_2O_3 concentration limit of 49 mass % therefore the AIS primary was not expected based on Phase 1 results.

- (10) A clear distinction continues to exist between the RES and AIS primary phase fields in terms of total lanthanide content for both Phase 1 and Phase 2 glasses. However, the use of total Ln_2O_3 concentration does not provide a demarcation of the Al_2O_3 primary phase field.
- (11) Projecting the Phase 1 and Phase 2 glass compositions into a SiO_2 - Al_2O_3 - Ln_2O_3 submixture clearly differentiates the three primary phase fields.
- (12) Although 84 of the 86 Phase 1 and Phase 2 glasses meet the 1350°C T_L specification, this measurement does not provide any insight into the kinetics of devitrification which has been a technical issue for processing (i.e., plugging the drain tube).

RECOVERABILITY

- (13) All 55 Phase 2 glasses and the 5 selected Phase 1 glasses which were tested met the recoverability criterion (dissolution of 98% of the lanthanide elements in less than 2 h); therefore, no limitations are placed on the AGCR as a result of these tests.
- (14) Dissolution of the SrABS glasses was described by a spherical particle model based on the observation that the rate of change of the mass to surface area ratio of lanthanide-containing glasses during nitric acid dissolution is constant. Calculation of the dissolution rates for the 60 glasses using the recoverability data showed the rate is proportional to the lanthanide oxide concentration and inversely proportional to the SiO_2 concentration in the glass. When SiO_2 is replaced with a lanthanide element at higher (Am/Cm) loadings, the glass becomes more easily dissolved in nitric acid due to the solubility of the lanthanide oxides compared to SiO_2 .

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Appendix A – Chemical Composition Data for the Phase 2 Glasses

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Appendix A

WSRC-TR-99-00393

Table A.1: Measured Compositions (Using Lithium-metaborate Dissolution Method)

Revision 0

(concentrations are expressed as weight percents)

Block	Sequence	Glass ID	Lab ID	Ca	Cr	Fe	Mn	Ni	Sr	Ca	Cr	Fe	Mn	Ni	Sr
1-1	1	EA	elm111	0.803	<0.030	6.32	1.05	0.445	0.044	1.124	0.022	9.036	1.356	0.566	0.052
1-1	2	AC2-32	f20lm11	0.014	<0.030	<0.020	<0.010	<0.060	1.480	0.020	0.022	0.014	0.006	0.038	1.750
1-1	3	AC2-18	f25lm11	0.022	<0.030	<0.020	<0.010	<0.060	1.730	0.031	0.022	0.014	0.006	0.038	2.046
1-1	4	AC2-32	f20lm21	0.02	<0.030	<0.020	<0.010	<0.060	1.440	0.028	0.022	0.014	0.006	0.038	1.703
1-1	5	AC2-05	f40lm21	0.017	<0.030	0.028	<0.010	<0.060	1.680	0.024	0.022	0.040	0.006	0.038	1.987
1-1	6	AC2-23	f05lm11	0.014	<0.030	<0.020	<0.010	<0.060	1.730	0.020	0.022	0.014	0.006	0.038	2.046
1-1	7	AC2-25	f45lm11	0.013	<0.030	<0.020	<0.010	<0.060	1.670	0.018	0.022	0.014	0.006	0.038	1.975
1-1	8	AC2-29	f50lm21	0.011	<0.030	<0.020	<0.010	<0.060	1.220	0.015	0.022	0.014	0.006	0.038	1.443
1-1	9	AC2-54	f56lm11	0.018	<0.030	0.057	<0.010	<0.060	1.200	0.025	0.022	0.081	0.006	0.038	1.419
1-1	10	AC2-18	f25lm21	0.02	<0.030	<0.020	<0.010	<0.060	1.780	0.028	0.022	0.014	0.006	0.038	2.105
1-1	11	AC2-47	f10lm21	0.015	<0.030	<0.020	<0.010	<0.060	1.450	0.021	0.022	0.014	0.006	0.038	1.715
1-1	12	AC2-24	f15lm21	0.015	<0.030	<0.020	<0.010	<0.060	1.160	0.021	0.022	0.014	0.006	0.038	1.372
1-1	13	AC2-33	f35lm11	0.013	<0.030	<0.020	<0.010	<0.060	1.480	0.018	0.022	0.014	0.006	0.038	1.750
1-1	14	EA	elm112	0.796	<0.030	6.06	1.03	0.431	0.043	1.114	0.022	8.664	1.330	0.548	0.051
1-1	15	AC2-33	f35lm21	0.012	<0.030	<0.020	<0.010	<0.060	1.430	0.017	0.022	0.014	0.006	0.038	1.691
1-1	16	AC2-24	f15lm11	0.013	<0.030	<0.020	<0.010	<0.060	1.190	0.018	0.022	0.014	0.006	0.038	1.407
1-1	17	AC2-25	f45lm21	0.015	<0.030	0.032	<0.010	<0.060	1.660	0.021	0.022	0.046	0.006	0.038	1.963
1-1	18	AC2-23	f05lm21	0.016	<0.030	<0.020	<0.010	<0.060	1.650	0.022	0.022	0.014	0.006	0.038	1.951
1-1	19	AC2-29	f50lm11	0.014	<0.030	0.023	<0.010	<0.060	1.170	0.020	0.022	0.033	0.006	0.038	1.384
1-1	20	AC2-31	f55lm11	0.012	<0.030	0.016	<0.010	<0.060	1.690	0.017	0.022	0.023	0.006	0.038	1.999
1-1	21	AC2-43	f30lm21	0.014	<0.030	0.012	<0.010	<0.060	1.530	0.020	0.022	0.017	0.006	0.038	1.809
1-1	22	AC2-05	f40lm11	0.018	<0.030	0.023	<0.010	<0.060	1.710	0.025	0.022	0.033	0.006	0.038	2.022
1-1	23	AC2-31	f55lm21	0.014	<0.030	0.026	<0.010	<0.060	1.730	0.020	0.022	0.037	0.006	0.038	2.046
1-1	24	AC2-47	f10lm11	0.027	<0.030	0.021	<0.010	<0.060	1.470	0.038	0.022	0.030	0.006	0.038	1.738
1-1	25	AC2-54	f56lm21	0.018	<0.030	0.046	<0.010	<0.060	1.240	0.025	0.022	0.066	0.006	0.038	1.466
1-1	26	AC2-43	f30lm11	0.015	<0.030	0.017	<0.010	<0.060	1.640	0.021	0.022	0.024	0.006	0.038	1.939
1-1	27	EA	elm113	0.818	<0.030	6.42	1.08	0.438	0.044	1.145	0.022	9.179	1.394	0.557	0.052
1-2	1	EA	elm121	0.83	<0.030	6.58	1.06	0.454	0.028	1.161	0.022	9.407	1.369	0.578	0.033

The as-reported values for AC2-30 and AC2-53 are shaded to indicate that these measurements are believed to be switched.

They are relabeled accordingly elsewhere in this report.

< implies less than detection limit.

Appendix A

WSRC-TR-99-00393

Table A.1: Measured Compositions (Using Lithium-metaborate Dissolution Method)
(concentrations are expressed as weight percents)

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Block	Sequence	Glass ID	Lab ID	Ca	Cr	Fe	Mn	Ni	Sr	Ca	Cr	Fe	Mn	Ni	Sr
1-2	2	AC2-43	f30lm12	0.025	<0.030	<0.020	<0.010	<0.060	1.640	0.035	0.022	0.014	0.006	0.038	1.939
1-2	3	AC2-31	f55lm12	0.024	<0.030	<0.020	<0.010	<0.060	1.780	0.034	0.022	0.014	0.006	0.038	2.105
1-2	4	AC2-29	f50lm12	0.016	<0.030	0.035	<0.010	<0.060	1.180	0.022	0.022	0.050	0.006	0.038	1.395
1-2	5	AC2-43	f30lm22	0.26	<0.030	<0.020	<0.010	<0.060	1.570	0.364	0.022	0.014	0.006	0.038	1.857
1-2	6	AC2-32	f20lm12	0.029	<0.030	0.021	<0.010	<0.060	1.500	0.041	0.022	0.030	0.006	0.038	1.774
1-2	7	AC2-33	f35lm12	0.025	<0.030	0.031	<0.010	<0.060	1.490	0.035	0.022	0.044	0.006	0.038	1.762
1-2	8	AC2-47	f10lm12	0.04	<0.030	0.028	<0.010	<0.060	1.550	0.056	0.022	0.040	0.006	0.038	1.833
1-2	9	AC2-05	f40lm12	0.029	<0.030	0.03	<0.010	<0.060	1.790	0.041	0.022	0.043	0.006	0.038	2.117
1-2	10	AC2-25	f45lm22	0.025	<0.030	0.033	<0.010	<0.060	1.720	0.035	0.022	0.047	0.006	0.038	2.034
1-2	11	AC2-31	f55lm22	0.026	<0.030	0.032	<0.010	<0.060	1.820	0.036	0.022	0.046	0.006	0.038	2.152
1-2	12	AC2-05	f40lm22	0.03	<0.030	0.052	<0.010	<0.060	1.730	0.042	0.022	0.074	0.006	0.038	2.046
1-2	13	AC2-29	f50lm22	0.022	<0.030	0.03	<0.010	<0.060	1.250	0.031	0.022	0.043	0.006	0.038	1.478
1-2	14	EA	elm122	0.849	<0.030	6.67	1.08	0.436	0.028	1.188	0.022	9.536	1.394	0.555	0.033
1-2	15	AC2-24	f15lm22	0.026	<0.030	<0.020	<0.010	<0.060	1.270	0.036	0.022	0.014	0.006	0.038	1.502
1-2	16	AC2-24	f15lm12	0.025	<0.030	<0.020	<0.010	<0.060	1.250	0.035	0.022	0.014	0.006	0.038	1.478
1-2	17	AC2-33	f35lm22	0.027	<0.030	0.021	<0.010	<0.060	1.470	0.038	0.022	0.030	0.006	0.038	1.738
1-2	18	AC2-23	f05lm22	0.027	<0.030	<0.020	<0.010	<0.060	1.800	0.038	0.022	0.014	0.006	0.038	2.129
1-2	19	AC2-18	f25lm22	0.031	<0.030	<0.020	<0.010	<0.060	1.900	0.043	0.022	0.014	0.006	0.038	2.247
1-2	20	AC2-54	f56lm22	0.029	<0.030	0.051	<0.010	<0.060	1.190	0.041	0.022	0.073	0.006	0.038	1.407
1-2	21	AC2-54	f56lm12	0.026	<0.030	0.058	<0.010	<0.060	1.200	0.036	0.022	0.083	0.006	0.038	1.419
1-2	22	AC2-47	f10lm22	0.027	<0.030	<0.020	<0.010	<0.060	1.470	0.038	0.022	0.014	0.006	0.038	1.738
1-2	23	AC2-23	f05lm12	0.024	<0.030	<0.020	<0.010	<0.060	1.750	0.034	0.022	0.014	0.006	0.038	2.070
1-2	24	AC2-18	f25lm12	0.034	<0.030	0.026	<0.010	<0.060	1.750	0.048	0.022	0.037	0.006	0.038	2.070
1-2	25	AC2-25	f45lm12	0.024	<0.030	<0.020	<0.010	<0.060	1.760	0.034	0.022	0.014	0.006	0.038	2.081
1-2	26	AC2-32	f20lm22	0.034	<0.030	0.055	<0.010	<0.060	1.470	0.048	0.022	0.079	0.006	0.038	1.738
1-2	27	EA	elm123	0.83	<0.030	6.59	1.05	0.444	0.028	1.161	0.022	9.422	1.356	0.565	0.033
2-1	1	EA	elm211	0.835	<0.030	6.54	1.07	0.439	0.044	1.168	0.022	9.350	1.382	0.559	0.052
2-1	2	AC2-44	f44lm11	0.018	<0.030	<0.020	0.014	<0.060	1.300	0.025	0.022	0.014	0.018	0.038	1.537
2-1	3	AC2-48	f34lm11	0.016	<0.030	<0.020	0.013	<0.060	1.700	0.022	0.022	0.014	0.017	0.038	2.010

The as-reported values for AC2-30 and AC2-53 are shaded to indicate that these measurements are believed to be switched.

They are relabeled accordingly elsewhere in this report.

< implies less than detection limit.

Appendix A

Table A.1: Measured Compositions (Using Lithium-metaborate Dissolution Method)
(concentrations are expressed as weight percents)

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Revision 0

Block	Sequence	Glass ID	Lab ID	Ca	Cr	Fe	Mn	Ni	Sr	Ca	Cr	Fe	Mn	Ni	Sr
2-1	4	AC2-14	f19lm11	0.025	<0.030	<0.020	0.014	<0.060	1.730	0.035	0.022	0.014	0.018	0.038	2.046
2-1	5	AC2-51	f09lm21	0.018	<0.030	0.046	0.015	<0.060	1.320	0.025	0.022	0.066	0.019	0.038	1.561
2-1	6	AC2-03	f04lm21	0.024	<0.030	<0.020	0.014	<0.060	1.710	0.034	0.022	0.014	0.018	0.038	2.022
2-1	7	AC2-44	f44lm21	0.021	<0.030	0.022	0.015	<0.060	1.310	0.029	0.022	0.031	0.019	0.038	1.549
2-1	8	AC2-01	f39lm11	0.023	<0.030	0.036	0.014	<0.060	1.200	0.032	0.022	0.051	0.018	0.038	1.419
2-1	9	AC2-52	f24lm11	0.016	<0.030	0.04	0.016	<0.060	1.760	0.022	0.022	0.057	0.021	0.038	2.081
2-1	10	AC2-38	f49lm11	0.019	<0.030	<0.020	0.014	<0.060	1.390	0.027	0.022	0.014	0.018	0.038	1.644
2-1	11	AC2-20	f14lm21	0.024	<0.030	<0.020	0.014	<0.060	1.210	0.034	0.022	0.014	0.018	0.038	1.431
2-1	12	AC2-38	f49lm21	0.018	<0.030	<0.020	0.014	<0.060	1.350	0.025	0.022	0.014	0.018	0.038	1.597
2-1	13	EA	elm212	0.859	<0.030	6.58	1.06	0.44	0.044	1.202	0.022	9.407	1.369	0.560	0.052
2-1	14	AC2-52	f24lm21	0.018	<0.030	0.059	0.016	<0.060	1.790	0.025	0.022	0.084	0.021	0.038	2.117
2-1	15	AC2-19	f29lm21	0.019	<0.030	<0.020	0.014	<0.060	1.740	0.027	0.022	0.014	0.018	0.038	2.058
2-1	16	AC2-15	f54lm11	0.021	<0.030	0.02	0.015	<0.060	1.190	0.029	0.022	0.029	0.019	0.038	1.407
2-1	17	AC2-20	f14lm11	0.021	<0.030	<0.020	0.014	<0.060	1.170	0.029	0.022	0.014	0.018	0.038	1.384
2-1	18	AC2-19	f29lm11	0.026	<0.030	<0.020	0.014	<0.060	1.830	0.036	0.022	0.014	0.018	0.038	2.164
2-1	19	AC2-48	f34lm21	0.017	<0.030	0.02	0.014	<0.060	1.690	0.024	0.022	0.029	0.018	0.038	1.999
2-1	20	AC2-51	f09lm11	0.022	<0.030	0.043	0.015	<0.060	1.320	0.031	0.022	0.061	0.019	0.038	1.561
2-1	21	AC2-01	f39lm21	0.02	<0.030	0.037	0.014	<0.060	1.190	0.028	0.022	0.053	0.018	0.038	1.407
2-1	22	AC2-14	f19lm21	0.021	<0.030	0.022	0.014	<0.060	1.730	0.029	0.022	0.031	0.018	0.038	2.046
2-1	23	AC2-03	f04lm11	0.024	<0.030	<0.020	0.014	<0.060	1.700	0.034	0.022	0.014	0.018	0.038	2.010
2-1	24	AC2-15	f54lm21	0.014	<0.030	0.03	0.015	<0.060	1.240	0.020	0.022	0.043	0.019	0.038	1.466
2-1	25	EA	elm213	0.829	<0.030	6.49	1.05	0.434	0.043	1.160	0.022	9.279	1.356	0.552	0.051
2-2	1	EA	elm221	0.892	<0.030	6.61	1.07	0.459	0.044	1.248	0.022	9.450	1.382	0.584	0.052
2-2	2	AC2-38	f49lm12	0.024	<0.030	0.031	0.013	<0.060	1.330	0.034	0.022	0.044	0.017	0.038	1.573
2-2	3	AC2-14	f19lm22	0.024	<0.030	0.037	0.014	<0.060	1.750	0.034	0.022	0.053	0.018	0.038	2.070
2-2	4	AC2-48	f34lm22	0.02	<0.030	0.058	0.014	<0.060	1.730	0.028	0.022	0.083	0.018	0.038	2.046
2-2	5	AC2-14	f19lm12	0.031	<0.030	0.03	0.014	<0.060	1.730	0.043	0.022	0.043	0.018	0.038	2.046
2-2	6	AC2-19	f29lm12	0.033	<0.030	0.03	0.014	<0.060	1.800	0.046	0.022	0.043	0.018	0.038	2.129
2-2	7	AC2-15	f54lm12	0.028	<0.030	0.039	0.014	<0.060	1.240	0.039	0.022	0.056	0.018	0.038	1.466

The as-reported values for AC2-30 and AC2-53 are shaded to indicate that these measurements are believed to be switched.

They are relabeled accordingly elsewhere in this report.

< implies less than detection limit.

Appendix A

WSRC-TR-99-00393

Table A.1: Measured Compositions (Using Lithium-metaborate Dissolution Method)
(concentrations are expressed as weight percents)

Revision 0

Block	Sequence	Glass ID	Lab ID	Ca	Cr	Fe	Mn	Ni	Sr	Ca	Cr	Fe	Mn	Ni	Sr
2-2	8	AC2-20	f14lm22	0.027	<0.030	0.031	0.013	<0.060	1.240	0.038	0.022	0.044	0.017	0.038	1.466
2-2	9	AC2-51	f09lm12	0.028	<0.030	0.064	0.015	<0.060	1.340	0.039	0.022	0.092	0.019	0.038	1.585
2-2	10	AC2-01	f39lm22	0.048	<0.030	0.048	0.014	<0.060	1.230	0.067	0.022	0.069	0.018	0.038	1.455
2-2	11	AC2-03	f04lm12	0.029	<0.030	0.023	0.013	<0.060	1.760	0.041	0.022	0.033	0.017	0.038	2.081
2-2	12	AC2-44	f44lm12	0.023	<0.030	0.039	0.014	<0.060	1.360	0.032	0.022	0.056	0.018	0.038	1.608
2-2	13	EA	elm222	0.839	<0.030	6.7	1.09	0.468	0.045	1.174	0.022	9.579	1.407	0.596	0.053
2-2	14	AC2-03	f04lm22	0.029	<0.030	0.022	0.014	0.431	1.760	0.041	0.022	0.031	0.018	0.548	2.081
2-2	15	AC2-20	f14lm12	0.026	<0.030	0.023	0.013	<0.060	1.190	0.036	0.022	0.033	0.017	0.038	1.407
2-2	16	AC2-52	f24lm12	0.023	<0.030	0.06	0.015	<0.060	1.810	0.032	0.022	0.086	0.019	0.038	2.141
2-2	17	AC2-52	f24lm22	0.021	<0.030	0.079	0.016	<0.060	1.760	0.029	0.022	0.113	0.021	0.038	2.081
2-2	18	AC2-44	f44lm22	0.028	<0.030	0.036	0.014	<0.060	1.400	0.039	0.022	0.051	0.018	0.038	1.656
2-2	19	AC2-01	f39lm12	0.029	<0.030	0.054	0.014	<0.060	1.220	0.041	0.022	0.077	0.018	0.038	1.443
2-2	20	AC2-51	f09lm22	0.023	<0.030	0.067	0.015	<0.060	1.310	0.032	0.022	0.096	0.019	0.038	1.549
2-2	21	AC2-38	f49lm22	0.023	<0.030	0.042	0.014	<0.060	1.320	0.032	0.022	0.060	0.018	0.038	1.561
2-2	22	AC2-48	f34lm12	0.022	<0.030	0.032	0.013	<0.060	1.740	0.031	0.022	0.046	0.017	0.038	2.058
2-2	23	AC2-15	f54lm22	0.02	<0.030	0.052	0.014	<0.060	1.170	0.028	0.022	0.074	0.018	0.038	1.384
2-2	24	AC2-19	f29lm22	0.025	<0.030	0.025	0.014	<0.060	1.760	0.035	0.022	0.036	0.018	0.038	2.081
2-2	25	EA	elm223	0.846	<0.030	6.52	1.09	0.458	0.045	1.184	0.022	9.322	1.407	0.583	0.053
3-1	1	EA	elm311	0.829	<0.030	6.12	1.04	0.503	<0.010	1.160	0.022	8.750	1.343	0.640	0.006
3-1	2	AC2-46	f28lm21	0.012	<0.030	<0.020	<0.010	<0.060	1.200	0.017	0.022	0.014	0.006	0.038	1.419
3-1	3	AC2-53	f53lm21	<0.010	<0.030	<0.020	<0.010	<0.060	1.170	0.007	0.022	0.014	0.006	0.038	1.384
3-1	4	AC2-26	f38lm21	<0.010	<0.030	<0.020	<0.010	<0.060	1.210	0.007	0.022	0.014	0.006	0.038	1.431
3-1	5	AC2-27	f48lm11	0.015	<0.030	0.021	<0.010	<0.060	1.180	0.021	0.022	0.030	0.006	0.038	1.395
3-1	6	AC2-27	f48lm21	0.017	<0.030	<0.020	<0.010	<0.060	1.210	0.024	0.022	0.014	0.006	0.038	1.431
3-1	7	AC2-06	f18lm21	0.013	<0.030	<0.020	<0.010	<0.060	1.220	0.018	0.022	0.014	0.006	0.038	1.443
3-1	8	AC2-07	f43lm21	0.016	<0.030	0.022	<0.010	<0.060	1.230	0.022	0.022	0.031	0.006	0.038	1.455
3-1	9	AC2-10	f03lm21	0.019	<0.030	<0.020	<0.010	<0.060	1.750	0.027	0.022	0.014	0.006	0.038	2.070
3-1	10	AC2-08	f08lm21	0.024	<0.030	0.024	<0.010	<0.060	1.790	0.034	0.022	0.034	0.006	0.038	2.117
3-1	11	AC2-53	f53lm11	0.016	<0.030	<0.020	<0.010	<0.060	1.200	0.022	0.022	0.014	0.006	0.038	1.419

The as-reported values for AC2-30 and AC2-53 are shaded to indicate that these measurements are believed to be switched.

They are relabeled accordingly elsewhere in this report.

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Appendix A

Table A.1: Measured Compositions (Using Lithium-metaborate Dissolution Method)
(concentrations are expressed as weight percents)

WSRC-TR-99-00393

Revision 0

Block	Sequence	Glass ID	Lab ID	Ca	Cr	Fe	Mn	Ni	Sr	Ca	Cr	Fe	Mn	Ni	Sr
3-1	12	ARM	f13lm21	1.63	<0.030	0.024	0.01	<0.060	0.411	2.281	0.022	0.034	0.013	0.038	0.486
3-1	13	EA	elm312	0.817	<0.030	6.24	1.06	0.513	<0.010	1.143	0.022	8.921	1.369	0.653	0.006
3-1	14	ARM	f13lm11	1.68	<0.030	<0.020	<0.010	0.431	0.419	2.351	0.022	0.014	0.006	0.548	0.496
3-1	15	AC2-46	f28lm11	0.013	<0.030	0.034	<0.010	<0.060	1.220	0.018	0.022	0.049	0.006	0.038	1.443
3-1	16	AC2-10	f03lm11	0.022	<0.030	0.02	<0.010	<0.060	1.720	0.031	0.022	0.029	0.006	0.038	2.034
3-1	17	AC2-13	f33lm21	0.017	<0.030	0.043	<0.010	<0.060	1.220	0.024	0.022	0.061	0.006	0.038	1.443
3-1	18	AC2-06	f18lm11	0.016	<0.030	<0.020	<0.010	<0.060	1.180	0.022	0.022	0.014	0.006	0.038	1.395
3-1	19	AC2-55	f23lm11	0.014	<0.030	<0.020	<0.010	<0.060	1.410	0.020	0.022	0.014	0.006	0.038	1.667
3-1	20	AC2-08	f08lm11	0.022	<0.030	0.032	<0.010	<0.060	1.670	0.031	0.022	0.046	0.006	0.038	1.975
3-1	21	AC2-13	f33lm11	0.02	<0.030	0.043	<0.010	<0.060	1.210	0.028	0.022	0.061	0.006	0.038	1.431
3-1	22	AC2-07	f43lm11	0.018	<0.030	<0.020	<0.010	<0.060	1.250	0.025	0.022	0.014	0.006	0.038	1.478
3-1	23	AC2-55	f23lm21	0.013	<0.030	<0.020	<0.010	<0.060	1.450	0.018	0.022	0.014	0.006	0.038	1.715
3-1	24	AC2-26	f38lm11	0.012	<0.030	0.098	<0.010	<0.060	1.220	0.017	0.022	0.140	0.006	0.038	1.443
3-1	25	EA	elm313	0.826	<0.030	6.27	1.05	0.474	<0.010	1.156	0.022	8.964	1.356	0.603	0.006
3-2	1	EA	elm321	0.826	<0.030	6.15	1.06	0.494	<0.010	1.156	0.022	8.793	1.369	0.629	0.006
3-2	2	AC2-08	f08lm12	0.036	<0.030	0.02	0.011	<0.060	1.730	0.050	0.022	0.029	0.014	0.038	2.046
3-2	3	AC2-27	f48lm22	0.029	<0.030	<0.020	0.011	<0.060	1.220	0.041	0.022	0.014	0.014	0.038	1.443
3-2	4	AC2-13	f33lm22	0.029	<0.030	0.031	0.011	<0.060	1.210	0.041	0.022	0.044	0.014	0.038	1.431
3-2	5	AC2-55	f23lm12	0.028	<0.030	<0.020	0.011	<0.060	1.490	0.039	0.022	0.014	0.014	0.038	1.762
3-2	6	AC2-10	f03lm22	0.033	<0.030	<0.020	0.011	<0.060	1.820	0.046	0.022	0.014	0.014	0.038	2.152
3-2	7	AC2-13	f33lm12	0.038	<0.030	0.046	0.012	<0.060	1.220	0.053	0.022	0.066	0.015	0.038	1.443
3-2	8	ARM	f13lm22	1.67	<0.030	0.024	0.017	<0.060	0.424	2.337	0.022	0.034	0.022	0.038	0.501
3-2	9	AC2-27	f48lm12	0.03	<0.030	0.025	0.011	<0.060	1.270	0.042	0.022	0.036	0.014	0.038	1.502
3-2	10	AC2-26	f38lm12	0.024	<0.030	0.07	0.011	<0.060	1.240	0.034	0.022	0.100	0.014	0.038	1.466
3-2	11	AC2-46	f28lm12	0.026	<0.030	0.032	0.011	<0.060	1.230	0.036	0.022	0.046	0.014	0.038	1.455
3-2	12	AC2-08	f08lm22	0.038	<0.030	0.024	0.011	<0.060	1.710	0.053	0.022	0.034	0.014	0.038	2.022
3-2	13	EA	elm322	0.834	<0.030	6.28	1.06	0.496	<0.010	1.167	0.022	8.979	1.369	0.631	0.006
3-2	14	AC2-07	f43lm22	0.029	<0.030	0.024	0.011	<0.060	1.210	0.041	0.022	0.034	0.014	0.038	1.431
3-2	15	AC2-53	f53lm12	0.03	<0.030	0.02	0.011	<0.060	1.180	0.042	0.022	0.029	0.014	0.038	1.395

The as-reported values for AC2-30 and AC2-53 are shaded to indicate that these measurements are believed to be switched.

They are relabeled accordingly elsewhere in this report.

< implies less than detection limit.

Appendix A

Table A.1: Measured Compositions (Using Lithium-metaborate Dissolution Method)
(concentrations are expressed as weight percents)

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Block	Sequence	Glass ID	Lab ID	Ca	Cr	Fe	Mn	Ni	Sr	Ca	Cr	Fe	Mn	Ni	Sr
3-2	16	ARM	f13lm12	1.64	<0.030	0.035	0.017	<0.060	0.410	2.295	0.022	0.050	0.022	0.038	0.485
3-2	17	AC2-07	f43lm12	0.031	<0.030	<0.020	0.011	<0.060	1.210	0.043	0.022	0.014	0.014	0.038	1.431
3-2	18	AC2-10	f03lm12	0.035	<0.030	0.021	0.011	<0.060	1.700	0.049	0.022	0.030	0.014	0.038	2.010
3-2	19	AC2-06	f18lm12	0.03	<0.030	<0.020	0.011	<0.060	1.210	0.042	0.022	0.014	0.014	0.038	1.431
3-2	20	AC2-55	f23lm22	0.027	<0.030	<0.020	0.01	<0.060	1.450	0.038	0.022	0.014	0.013	0.038	1.715
3-2	21	AC2-53	f53lm22	0.024	<0.030	0.023	0.011	<0.060	1.250	0.034	0.022	0.033	0.014	0.038	1.478
3-2	22	AC2-06	f18lm22	0.032	<0.030	<0.020	0.011	<0.060	1.200	0.045	0.022	0.014	0.014	0.038	1.419
3-2	23	AC2-26	f38lm22	0.024	<0.030	0.02	0.011	<0.060	1.240	0.034	0.022	0.029	0.014	0.038	1.466
3-2	24	AC2-46	f28lm22	0.025	<0.030	0.024	0.01	<0.060	1.220	0.035	0.022	0.034	0.013	0.038	1.443
3-2	25	EA	elm323	0.514	<0.030	6.45	1.07	0.498	<0.010	0.719	0.022	9.222	1.382	0.634	0.006
4-1	1	EA	elm411	0.835	<0.030	6.38	1.04	0.497	<0.010	1.168	0.022	9.121	1.343	0.632	0.006
4-1	2	AC2-50	f02lm21	0.034	<0.030	0.057	0.007	<0.060	1.500	0.048	0.022	0.081	0.009	0.038	1.774
4-1	3	AC2-36	f22lm11	0.027	<0.030	0.022	0.005	<0.060	1.380	0.038	0.022	0.031	0.006	0.038	1.632
4-1	4	AC2-37	f17lm21	0.026	<0.030	0.02	0.005	<0.060	1.450	0.036	0.022	0.029	0.006	0.038	1.715
4-1	5	AC2-40	f12lm11	0.026	<0.030	0.031	0.005	<0.060	1.220	0.036	0.022	0.044	0.006	0.038	1.443
4-1	6	AC2-37	f17lm11	0.026	<0.030	0.026	0.005	<0.060	1.340	0.036	0.022	0.037	0.006	0.038	1.585
4-1	7	AC2-17	f32lm11	0.024	<0.030	0.024	0.005	<0.060	1.440	0.034	0.022	0.034	0.006	0.038	1.703
4-1	8	AC2-28	f07lm11	0.035	<0.030	0.036	0.006	<0.060	1.690	0.049	0.022	0.051	0.008	0.038	1.999
4-1	9	AC2-34	f52lm11	0.026	<0.030	0.024	0.005	<0.060	1.560	0.036	0.022	0.034	0.006	0.038	1.845
4-1	10	AC2-30	f27lm11	0.027	<0.030	0.063	0.008	<0.060	1.540	0.038	0.022	0.090	0.010	0.038	1.821
4-1	11	AC2-28	f07lm21	0.028	<0.030	0.025	0.005	<0.060	1.680	0.039	0.022	0.036	0.006	0.038	1.987
4-1	12	AC2-11	f37lm11	0.031	<0.030	0.039	0.006	<0.060	1.180	0.043	0.022	0.056	0.008	0.038	1.395
4-1	13	EA	elm412	0.77	<0.030	6.26	1.01	<0.060	<0.010	1.077	0.022	8.950	1.304	0.038	0.006
4-1	14	AC2-50	f02lm11	0.031	<0.030	0.057	0.007	0.431	1.410	0.043	0.022	0.081	0.009	0.548	1.667
4-1	15	AC2-39	f42lm11	0.029	<0.030	0.028	0.006	<0.060	1.280	0.041	0.022	0.040	0.008	0.038	1.514
4-1	16	AC2-11	f37lm21	0.031	<0.030	0.04	0.007	<0.060	1.190	0.043	0.022	0.057	0.009	0.038	1.407
4-1	17	AC2-39	f42lm21	0.03	<0.030	0.035	0.006	<0.060	1.240	0.042	0.022	0.050	0.008	0.038	1.466
4-1	18	AC2-34	f52lm21	0.025	<0.030	0.025	0.005	<0.060	1.560	0.035	0.022	0.036	0.006	0.038	1.845
4-1	19	AC2-40	f12lm21	0.027	<0.030	0.017	0.005	<0.060	1.240	0.038	0.022	0.024	0.006	0.038	1.466

The as-reported values for AC2-30 and AC2-53 are shaded to indicate that these measurements are believed to be switched.

They are relabeled accordingly elsewhere in this report.

< implies less than detection limit.

Appendix A

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Table A.1: Measured Compositions (Using Lithium-metaborate Dissolution Method)

Revision 0

(concentrations are expressed as weight percents)

Block	Sequence	Glass ID	Lab ID	Ca	Cr	Fe	Mn	Ni	Sr	Ca	Cr	Fe	Mn	Ni	Sr
4-1	20	AC2-30	f27lm21	0.029	<0.030	0.061	0.007	<0.060	1.560	0.041	0.022	0.087	0.009	0.038	1.845
4-1	21	AC2-17	f32lm21	0.026	<0.030	0.022	0.005	<0.060	1.500	0.036	0.022	0.031	0.006	0.038	1.774
4-1	22	AC2-12	f47lm21	0.029	<0.030	0.046	0.005	<0.060	1.690	0.041	0.022	0.066	0.006	0.038	1.999
4-1	23	AC2-36	f22lm21	0.024	<0.030	0.029	0.005	<0.060	1.410	0.034	0.022	0.041	0.006	0.038	1.667
4-1	24	AC2-12	f47lm11	0.024	<0.030	0.028	0.005	<0.060	1.720	0.034	0.022	0.040	0.006	0.038	2.034
4-1	25	EA	elm413	0.803	<0.030	6.48	1.05	0.489	<0.010	1.124	0.022	9.264	1.356	0.622	0.006
4-2	1	EA	elm421	0.832	<0.030	6.34	1.03	0.498	<0.010	1.164	0.022	9.064	1.330	0.634	0.006
4-2	2	AC2-40	f12lm12	0.034	<0.030	<0.020	<0.001	<0.060	1.190	0.048	0.022	0.014	0.001	0.038	1.407
4-2	3	AC2-30	f27lm22	0.036	<0.030	0.052	<0.001	<0.060	1.530	0.050	0.022	0.074	0.001	0.038	1.809
4-2	4	AC2-28	f07lm22	0.034	<0.030	<0.020	<0.001	<0.060	1.680	0.048	0.022	0.014	0.001	0.038	1.987
4-2	5	AC2-39	f42lm22	0.036	<0.030	0.023	<0.001	<0.060	1.250	0.050	0.022	0.033	0.001	0.038	1.478
4-2	6	AC2-11	f37lm12	0.037	<0.030	0.025	<0.001	<0.060	1.200	0.052	0.022	0.036	0.001	0.038	1.419
4-2	7	AC2-37	f17lm12	0.033	<0.030	<0.020	<0.001	<0.060	1.270	0.046	0.022	0.014	0.001	0.038	1.502
4-2	8	AC2-36	f22lm12	0.052	<0.030	<0.020	<0.001	<0.060	1.370	0.073	0.022	0.014	0.001	0.038	1.620
4-2	9	AC2-34	f52lm12	0.033	<0.030	<0.020	<0.001	<0.060	1.510	0.046	0.022	0.014	0.001	0.038	1.786
4-2	10	AC2-11	f37lm22	0.037	<0.030	0.027	<0.001	<0.060	1.140	0.052	0.022	0.039	0.001	0.038	1.348
4-2	11	AC2-12	f47lm12	0.031	<0.030	<0.020	<0.001	<0.060	1.680	0.043	0.022	0.014	0.001	0.038	1.987
4-2	12	AC2-17	f32lm12	0.03	<0.030	<0.020	<0.001	<0.060	1.410	0.042	0.022	0.014	0.001	0.038	1.667
4-2	13	EA	elm422	0.795	<0.030	5.87	1.02	0.475	<0.010	1.112	0.022	8.392	1.317	0.604	0.006
4-2	14	AC2-30	f27lm12	0.037	<0.030	0.054	<0.001	<0.060	1.520	0.052	0.022	0.077	0.001	0.038	1.798
4-2	15	AC2-50	f02lm12	0.039	<0.030	0.052	<0.001	<0.060	1.410	0.055	0.022	0.074	0.001	0.038	1.667
4-2	16	AC2-50	f02lm22	0.04	<0.030	0.046	<0.001	<0.060	1.450	0.056	0.022	0.066	0.001	0.038	1.715
4-2	17	AC2-40	f12lm22	0.034	<0.030	<0.020	<0.001	<0.060	1.240	0.048	0.022	0.014	0.001	0.038	1.466
4-2	18	AC2-34	f52lm22	0.033	<0.030	<0.020	<0.001	<0.060	1.580	0.046	0.022	0.014	0.001	0.038	1.869
4-2	19	AC2-36	f22lm22	0.031	<0.030	<0.020	<0.001	<0.060	1.370	0.043	0.022	0.014	0.001	0.038	1.620
4-2	20	AC2-17	f32lm22	0.032	<0.030	<0.020	<0.001	<0.060	1.450	0.045	0.022	0.014	0.001	0.038	1.715
4-2	21	AC2-12	f47lm22	0.035	<0.030	0.03	<0.001	<0.060	1.660	0.049	0.022	0.043	0.001	0.038	1.963
4-2	22	AC2-28	f07lm12	0.038	<0.030	0.032	<0.001	<0.060	1.680	0.053	0.022	0.046	0.001	0.038	1.987
4-2	23	AC2-39	f42lm12	0.037	<0.030	<0.020	<0.001	<0.060	1.280	0.052	0.022	0.014	0.001	0.038	1.514

The as-reported values for AC2-30 and AC2-53 are shaded to indicate that these measurements are believed to be switched.

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< implies less than detection limit.

Appendix A

WSRC-TR-99-00393

Table A.1: Measured Compositions (Using Lithium-metaborate Dissolution Method)
(concentrations are expressed as weight percents)

Revision 0

Block	Sequence	Glass ID	Lab ID	Ca	Cr	Fe	Mn	Ni	Sr	Ca	Cr	Fe	Mn	Ni	Sr
4-2	24	AC2-37	f17lm22	0.033	<0.030	<0.020	<0.001	<0.060	1.380	0.046	0.022	0.014	0.001	0.038	1.632
4-2	25	EA	elm423	0.813	<0.030	6.04	1.02	0.491	<0.010	1.138	0.022	8.635	1.317	0.625	0.006
5-1	1	EA	elm511	0.811	<0.030	6.26	1.03	0.496	<0.010	1.135	0.022	8.950	1.330	0.631	0.006
5-1	2	AC2-49	f41lm21	0.014	<0.030	<0.020	<0.001	<0.060	1.640	0.020	0.022	0.014	0.001	0.038	1.939
5-1	3	AC2-45	f06lm21	0.019	<0.030	<0.020	<0.001	<0.060	1.460	0.027	0.022	0.014	0.001	0.038	1.727
5-1	4	AC2-42	f21lm11	0.019	<0.030	<0.020	<0.001	<0.060	1.760	0.027	0.022	0.014	0.001	0.038	2.081
5-1	5	AC2-22	f31lm21	0.012	<0.030	<0.020	<0.001	<0.060	1.800	0.017	0.022	0.014	0.001	0.038	2.129
5-1	6	AC2-02	f01lm11	0.03	<0.030	<0.020	<0.001	<0.060	1.210	0.042	0.022	0.014	0.001	0.038	1.431
5-1	7	AC2-49	f41lm11	0.021	<0.030	<0.020	<0.001	<0.060	1.570	0.029	0.022	0.014	0.001	0.038	1.857
5-1	8	AC2-41	f11lm21	0.013	<0.030	<0.020	<0.001	<0.060	1.280	0.018	0.022	0.014	0.001	0.038	1.514
5-1	9	AC2-45	f06lm11	0.024	<0.030	<0.020	<0.001	<0.060	1.430	0.034	0.022	0.014	0.001	0.038	1.691
5-1	10	AC2-09	f26lm11	0.025	<0.030	<0.020	<0.001	<0.060	1.220	0.035	0.022	0.014	0.001	0.038	1.443
5-1	11	AC2-02	f01lm21	0.024	<0.030	<0.020	<0.001	<0.060	1.220	0.034	0.022	0.014	0.001	0.038	1.443
5-1	12	AC2-42	f21lm21	0.013	<0.030	<0.020	<0.001	<0.060	1.730	0.018	0.022	0.014	0.001	0.038	2.046
5-1	13	EA	elm512	0.794	<0.030	6.51	1.05	0.49	<0.010	1.111	0.022	9.307	1.356	0.624	0.006
5-1	14	AC2-21	f51lm21	0.016	<0.030	<0.020	<0.001	<0.060	1.670	0.022	0.022	0.014	0.001	0.038	1.975
5-1	15	AC2-16	f16lm21	0.014	<0.030	<0.020	<0.001	<0.060	1.790	0.020	0.022	0.014	0.001	0.038	2.117
5-1	16	AC2-16	f16lm11	0.015	<0.030	<0.020	<0.001	<0.060	1.720	0.021	0.022	0.014	0.001	0.038	2.034
5-1	17	AC2-35	f46lm21	0.014	<0.030	<0.020	<0.001	<0.060	1.420	0.020	0.022	0.014	0.001	0.038	1.679
5-1	18	AC2-04	f36lm21	0.02	<0.030	<0.020	<0.001	<0.060	1.770	0.028	0.022	0.014	0.001	0.038	2.093
5-1	19	AC2-21	f51lm11	0.011	<0.030	<0.020	<0.001	<0.060	1.770	0.015	0.022	0.014	0.001	0.038	2.093
5-1	20	AC2-09	f26lm21	0.018	<0.030	<0.020	<0.001	<0.060	1.250	0.025	0.022	0.014	0.001	0.038	1.478
5-1	21	AC2-04	f36lm21	0.01	<0.030	<0.020	<0.001	<0.060	1.720	0.014	0.022	0.014	0.001	0.038	2.034
5-1	22	AC2-41	f11lm11	0.02	<0.030	<0.020	<0.001	<0.060	1.290	0.028	0.022	0.014	0.001	0.038	1.526
5-1	23	AC2-35	f46lm11	0.018	<0.030	<0.020	<0.001	<0.060	1.400	0.025	0.022	0.014	0.001	0.038	1.656
5-1	24	AC2-22	f31lm11	0.02	<0.030	<0.020	<0.001	<0.060	1.280	0.028	0.022	0.014	0.001	0.038	1.514
5-1	25	EA	elm513	0.82	<0.030	6.26	1.05	0.485	<0.010	1.147	0.022	8.950	1.356	0.617	0.006
5-2	1	EA	elm521	0.826	<0.030	6.27	1.06	0.481	<0.010	1.156	0.022	8.964	1.369	0.612	0.006
5-2	2	AC2-42	f21lm22	0.011	<0.030	0.028	<0.010	<0.060	1.690	0.015	0.022	0.040	0.006	0.038	1.999

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Appendix A

WSRC-TR-99-00393

Table A.1: Measured Compositions (Using Lithium-metaborate Dissolution Method)
(concentrations are expressed as weight percents)

Revision 0

Block	Sequence	Glass ID	Lab ID	Ca	Cr	Fe	Mn	Ni	Sr	Ca	Cr	Fe	Mn	Ni	Sr
5-2	3	AC2-35	f46lm22	0.013	<0.030	0.033	<0.010	<0.060	1.400	0.018	0.022	0.047	0.006	0.038	1.656
5-2	4	AC2-09	f26lm22	0.017	<0.030	0.028	<0.010	<0.060	1.210	0.024	0.022	0.040	0.006	0.038	1.431
5-2	5	AC2-22	f31lm12	<0.010	<0.030	0.027	<0.010	<0.060	1.740	0.007	0.022	0.039	0.006	0.038	2.058
5-2	6	AC2-41	f11lm22	0.012	<0.030	0.023	<0.010	<0.060	1.210	0.017	0.022	0.033	0.006	0.038	1.431
5-2	7	AC2-16	f16lm22	0.014	<0.030	0.035	<0.010	<0.060	1.760	0.020	0.022	0.050	0.006	0.038	2.081
5-2	8	AC2-21	f51lm22	0.016	<0.030	0.048	<0.010	<0.060	1.630	0.022	0.022	0.069	0.006	0.038	1.928
5-2	9	AC2-35	f46lm12	0.016	<0.030	0.034	<0.010	<0.060	1.390	0.022	0.022	0.049	0.006	0.038	1.644
5-2	10	AC2-09	f26lm12	0.024	<0.030	0.04	<0.010	<0.060	1.180	0.034	0.022	0.057	0.006	0.038	1.395
5-2	11	AC2-45	f06lm12	0.024	<0.030	0.034	<0.010	<0.060	1.440	0.034	0.022	0.049	0.006	0.038	1.703
5-2	12	AC2-04	f36lm12	0.018	<0.030	0.124	<0.010	<0.060	1.700	0.025	0.022	0.177	0.006	0.038	2.010
5-2	13	EA	elm522	0.808	<0.030	6.01	1.04	0.479	<0.010	1.131	0.022	8.592	1.343	0.610	0.006
5-2	14	AC2-45	f06lm22	0.018	<0.030	0.023	<0.010	0.431	1.410	0.025	0.022	0.033	0.006	0.548	1.667
5-2	15	AC2-04	f36lm22	<0.010	<0.030	0.024	<0.010	<0.060	1.670	0.007	0.022	0.034	0.006	0.038	1.975
5-2	16	AC2-02	f01lm12	0.033	<0.030	0.034	<0.010	<0.060	1.190	0.046	0.022	0.049	0.006	0.038	1.407
5-2	17	AC2-02	f01lm22	0.03	<0.030	0.033	<0.010	<0.060	1.170	0.042	0.022	0.047	0.006	0.038	1.384
5-2	18	AC2-16	f16lm12	0.014	<0.030	0.024	<0.010	<0.060	1.660	0.020	0.022	0.034	0.006	0.038	1.963
5-2	19	AC2-21	f51lm12	0.01	<0.030	0.03	<0.010	<0.060	1.740	0.014	0.022	0.043	0.006	0.038	2.058
5-2	20	AC2-42	f21lm12	0.019	<0.030	0.027	<0.010	<0.060	1.680	0.027	0.022	0.039	0.006	0.038	1.987
5-2	21	AC2-49	f41lm22	0.013	<0.030	0.026	<0.010	<0.060	1.530	0.018	0.022	0.037	0.006	0.038	1.809
5-2	22	AC2-41	f11lm12	0.015	<0.030	0.031	<0.010	<0.060	1.240	0.021	0.022	0.044	0.006	0.038	1.466
5-2	23	AC2-49	f41lm12	0.022	<0.030	0.04	<0.010	<0.060	1.490	0.031	0.022	0.057	0.006	0.038	1.762
5-2	24	AC2-22	f31lm22	0.013	<0.030	0.032	<0.010	<0.060	1.700	0.018	0.022	0.046	0.006	0.038	2.010
5-2	25	EA	elm523	0.4	<0.030	6.1	0.997	0.479	<0.010	0.560	0.022	8.721	1.287	0.610	0.006

The as-reported values for AC2-30 and AC2-53 are shaded to indicate that these measurements are believed to be switched. They are relabeled accordingly elsewhere in this report.
< implies less than detection limit.

Table A.2: Measured Compositions (Using Peroxide Fusion Dissolution Method)
(concentrations are expressed as weight percents)

Block	Sequence	Glass ID	Lab ID	Al	B	Ce	Er	Eu	Gd	La	Nd	Pr	Si	Sm
1-1	1	EA	epf111	1.9	3.53	<0.100	0.483	<0.100	<0.100	0.364	<0.100	<0.100	21.4	<0.100
1-1	2	AC2-08	f08pf11	8.7	1.89	7	2.48	1.02	0.945	15.4	7.03	6.06	9.53	4.15
1-1	3	AC2-51	f09pf11	6.74	2.07	5.28	4.73	0.742	1.72	17.4	13.1	4.51	7.75	3.06
1-1	4	restd	res111	10.4	2.84	5.36	4.02	1.01	2.12	21	10.3	4.34	9.96	3.08
1-1	5	AC2-18	f25pf21	6.35	1.82	8.25	1.99	1.27	0.71	14.9	20	2.74	7.27	5.18
1-1	6	AC2-52	f24pf21	9.38	2.7	0.098	3.51	0.549	1.27	20.1	9.56	2.88	10.7	2.3
1-1	7	AC2-52	f24pf11	9.35	2.85	0.133	3.54	0.566	1.25	19.8	9.29	2.93	10.9	2.17
1-1	8	EA	epf112	2.03	3.5	<0.100	0.488	<0.100	<0.100	0.378	<0.100	<0.100	22.4	<0.100
1-1	9	AC2-51	f09pf21	6.73	2.17	5.49	4.9	0.75	1.82	17.5	12.9	4.56	8.12	3.11
1-1	10	AC2-18	f25pf11	6.15	1.8	8.36	2.04	1.3	0.709	14.5	19.1	2.8	7.22	4.98
1-1	11	AC2-05	f40pf11	8.86	1.81	3.01	2.62	1.06	2.46	19.1	8.43	2.48	10	4.1
1-1	12	restd	res112	9.76	2.85	4.99	4.01	0.961	2.01	20.1	9.17	4.06	9.34	2.91
1-1	13	AC2-05	f40pf21	9.32	2.01	3.28	2.99	1.13	2.64	21.1	9.33	2.82	10.5	4.34
1-1	14	AC2-49	f41pf11	7.85	2.51	4.18	3.86	0.599	1.35	18.7	10.5	3.68	9.18	2.41
1-1	15	AC2-54	p56pf21	6.57	1.9	5.72	5.18	0.839	1.98	17.1	14	4.99	7.05	3.45
1-1	16	AC2-08	f08pf21	8.69	1.82	7.22	2.61	1.06	0.953	15.8	6.86	6.13	9.48	4.31
1-1	17	EA	epf113	1.89	3.39	<0.100	0.469	<0.100	<0.100	0.387	<0.100	<0.100	21.7	<0.100
1-2	1	EA	epf121	1.91	3.47	<0.100	0.443	<0.100	<0.100	0.411	<0.100	<0.100	21.3	<0.100
1-2	2	AC2-49	f41pf21	8.88	2.7	4.57	3.88	0.675	1.5	17.2	10.4	3.71	10.1	2.49
1-2	3	AC2-54	f56pf11	7.26	2.04	6.28	5.53	0.916	2.14	17.1	14.5	5.09	8.1	3.56
1-2	4	AC2-18	f25pf22	6.16	1.9	8.01	1.74	1.32	0.824	13.6	20.5	2.78	7.48	4.53
1-2	5	AC2-05	f40pf12	9.17	2.05	2.65	2.49	1.17	2.45	18.5	8.6	2.47	11.1	4.02
1-2	6	AC2-51	f09pf22	7.07	2.28	5.43	5.22	0.788	1.94	16.4	12.9	5.09	8.89	3.06
1-2	7	AC2-49	f41pf22	8.58	2.73	4.9	3.81	0.681	1.54	17	11.2	4.14	10.5	2.38
1-2	8	restd	res121	9	2.99	4.44	3.54	0.938	1.91	17.3	9.96	3.7	9.76	2.63
1-2	9	AC2-05	f40pf22	8.38	1.72	2.99	2.24	1.01	2.48	19.3	8.64	2.51	10.4	3.72
1-2	10	AC2-54	f56pf22	6.78	2.01	5.96	5.57	0.898	2.05	15.8	14.5	5.61	7.94	3.15
1-2	11	AC2-54	f56pf12	5.78	1.98	5.54	5	0.865	1.76	15.9	15	4.3	7.72	2.87
1-2	12	EA	epf122	1.78	3.58	<0.100	0.401	<0.100	<0.100	0.367	<0.100	<0.100	22.8	<0.100
1-2	13	AC2-52	f24pf12	8.43	2.8	0.38	3.64	0.555	1.36	17.3	9.37	2.88	10.5	1.83
1-2	14	AC2-49	f41pf12	8.31	2.44	4.76	3.54	0.601	1.46	16.6	11.2	3.88	9.6	2.56
1-2	15	AC2-52	f24pf22	8.6	2.9	0.23	3.39	0.576	1.26	17.3	9.51	2.75	11.4	2.04
1-2	16	restd	res122	8.32	3.05	4.65	3.6	0.878	2.11	17.9	10.4	3.4	9.96	2.56
1-2	17	AC2-51	f09pf12	7.44	2.09	5.72	4.76	0.914	1.93	17.4	13.7	5.26	8.82	3.11
1-2	18	AC2-18	f25pf12	6.16	1.93	7.58	1.83	1.29	0.874	13.5	20.7	2.62	7.81	4.33
1-2	19	AC2-08	f08pf22	8.92	2.11	6.79	2.87	1.17	1.2	15.5	7.6	6.32	12.1	4.06
1-2	20	AC2-08	f08pf12	9.25	2.29	8.01	2.87	1.18	1.22	15.4	7.52	6.21	12.5	4.16
1-2	21	EA	epf123	1.73	3.39	<0.100	0.443	<0.100	<0.100	0.341	<0.100	<0.100	22.6	<0.100
2-1	1	EA	epf211	1.97	3.33	<0.100	0.442	<0.100	<0.100	0.351	<0.100	<0.100	21.6	<0.100
2-1	2	AC2-28	f07pf11	9.34	2.72	8.47	7.12	1.24	2.8	14.3	5.55	7.54	7.14	1.31
2-1	3	AC2-01	f39pf21	6.54	1.91	7.75	6.62	0.389	0.938	19.9	7.51	6.5	10.1	1.66
2-1	4	AC2-31	f55pf11	6.4	1.96	2.12	7.55	0.241	2.72	14.4	17.8	2.06	10.5	1.21
2-1	5	AC2-28	f07pf21	9.43	2.82	8.66	7.1	1.27	2.79	14.4	5.42	7.62	7.81	1.21
2-1	6	restd	res211	10.5	3.04	5.24	4.02	1.01	1.98	20.6	10	4.27	9.73	2.92
2-1	7	AC2-09	f26pf11	6.54	1.88	7.43	6.61	1.1	2.47	16.5	10.9	6.43	7.48	4.13
2-1	8	AC2-39	f42pf21	7.16	2.11	5.6	4.97	0.772	1.79	17.3	13.2	4.96	7.85	3.11
2-1	9	AC2-55	f23pf11	7.96	2.39	9.98	4.56	0.67	1.58	18.6	7.16	5.04	9.12	2.91
2-1	10	EA	epf212	1.99	3.48	<0.100	0.465	<0.100	<0.100	0.461	<0.100	<0.100	22.8	<0.100

The as-reported values for AC2-30 and AC2-53 are shaded to indicate that these measurements are believed to be switched.

They are relabeled accordingly elsewhere in this report.

< implies less than detection limit.

Table A.2: Measured Compositions (Using Peroxide Fusion Dissolution Method)
(concentrations are expressed as weight percents)

Block	Sequence	Glass ID	Lab ID	Al	B	Ce	Er	Eu	Gd	La	Nd	Pr	Si	Sm
2-1	11	AC2-01	f39pf11	6.55	2	7.74	7.03	0.405	0.986	20.2	7.58	6.68	10.3	1.68
2-1	12	AC2-47	f10pf11	8.11	2.38	5.16	4.71	0.695	1.59	18.8	12	4.48	9.09	2.93
2-1	13	AC2-47	f10pf21	8.11	2.37	5.1	4.62	0.697	1.7	18.7	11.9	4.54	9.18	3.03
2-1	14	restd	res212	10.2	3.07	5.1	4.08	1.01	2.1	20.8	10.1	4.37	9.58	2.96
2-1	15	AC2-39	f42pf11	7.16	2.13	5.94	5.32	0.817	1.8	18.3	14	5.16	8.18	3.46
2-1	16	AC2-09	f26pf21	6.97	2.08	8.05	7.22	1.14	2.56	17.6	12	6.92	7.87	4.48
2-1	17	AC2-55	f23pf21	7.97	2.47	10.6	4.58	0.689	1.65	19	7.34	5.37	9.05	3.07
2-1	18	AC2-31	f55pf21	6.96	2.07	2.33	8.24	0.275	3	15.9	19.5	2.23	11.4	1.32
2-1	19	EA	epf213	2	3.62	<0.100	0.498	<0.100	<0.100	0.376	<0.100	<0.100	23	<0.100
2-2	1	EA	epf221	1.94	3.63	<0.100	0.568	<0.100	<0.100	0.35	<0.100	<0.100	22.6	<0.100
2-2	2	AC2-09	f26pf22	6.42	1.95	7.52	6.84	1.1	2.52	16.3	11.1	6.68	7.85	4.56
2-2	3	AC2-39	f42pf22	6.88	2.14	5.58	5.2	0.803	1.88	18.4	13.1	5.14	8.5	3.26
2-2	4	AC2-01	f39pf22	6.56	2.01	7.56	6.92	0.438	1.08	20.5	7.36	6.89	10.9	1.83
2-2	5	AC2-47	f10pf22	7.99	2.35	5.12	4.38	0.717	1.77	19	12.1	4.61	9.84	3.06
2-2	6	restd	res221	10.4	3.07	5.35	3.94	1.04	2.16	21.1	10.5	4.22	10.1	3.14
2-2	7	AC2-01	f39pf12	6.38	1.86	7.2	6.56	0.434	1.1	20.7	7.21	6.64	10.7	1.75
2-2	8	AC2-31	f55pf22	6.48	1.94	2.27	7.94	0.281	2.82	14.9	18.1	2.05	11.2	1.38
2-2	9	AC2-28	f07pf12	8.68	2.79	8.17	7.1	1.27	2.94	14.3	5.24	7.13	7.59	1.27
2-2	10	EA	epf222	1.88	3.25	<0.100	0.551	<0.100	<0.100	0.42	<0.100	<0.100	21.2	<0.100
2-2	11	AC2-28	f07pf22	8.46	2.69	8.06	6.94	1.24	2.94	14.4	5.54	7.39	7.59	1.32
2-2	12	AC2-47	f10pf12	7.48	2.12	4.82	4.22	0.683	1.64	17.4	11	4.46	8.72	2.85
2-2	13	AC2-55	f23pf12	8.15	2.44	9.58	4.65	0.743	1.79	19.7	7.14	5.25	9.98	3.13
2-2	14	restd	res222	10.4	3.04	5.28	4.06	1.04	2.23	21.8	9.93	4.45	10.4	3.15
2-2	15	AC2-39	f42pf12	7.08	2.18	5.82	5.26	0.848	1.95	18.5	13.2	5.37	8.7	3.6
2-2	16	AC2-55	f23pf22	7.67	2.5	9.7	4.55	0.707	1.74	18.6	7	5.2	9.41	2.92
2-2	17	AC2-31	f55pf12	6.74	1.99	2.22	8.22	0.278	2.84	15.4	17	2.09	11	1.38
2-2	18	AC2-09	f26pf12	6.44	2.07	7.62	6.68	1.2	2.65	16.9	11.4	7.12	7.76	4.59
2-2	19	EA	epf223	1.9	3.61	<0.100	0.552	<0.100	<0.100	0.323	<0.100	<0.100	23.1	<0.100
3-1	1	EA	epf311	1.95	3.53	<0.100	0.519	<0.100	<0.100	0.331	<0.100	<0.100	22.2	<0.100
3-1	2	AC2-41	f11pf11	6.55	2.04	5.76	5.27	0.822	1.8	17.8	13.3	5.23	7.69	3.24
3-1	3	AC2-30	f27pf21	8.32	2.56	4.13	3.74	0.644	1.29	16.9	9.78	3.64	9.62	2.45
3-1	4	AC2-15	f54pf11	5.31	2.73	2.68	2.51	1.08	2.29	14.4	16.3	2.44	10.1	1.65
3-1	5	AC2-26	f38pf11	8.75	1.19	2.36	7.5	1.22	0.591	19.2	4.84	1.97	10.7	4.63
3-1	6	restd	res311	9.57	2.95	4.63	3.87	0.972	1.9	19.3	8.99	3.98	9.47	2.78
3-1	7	AC2-36	f22pf21	7.4	2.3	4.92	4.66	0.717	1.58	16.9	11.8	4.29	8.58	2.9
3-1	8	AC2-07	f43pf21	9.29	1.86	2.82	6.56	1.08	0.895	18.6	8.62	2.52	10.8	1.66
3-1	9	AC2-07	f43pf11	9.28	1.95	2.71	6.41	1.1	0.866	16.8	9.09	2.59	10.8	1.7
3-1	10	EA	epf312	2.07	3.48	<0.100	0.503	<0.100	<0.100	0.295	<0.100	<0.100	22.9	<0.100
3-1	11	AC2-45	f06pf11	7.51	2.35	8.32	4.08	0.53	1.23	15.9	8.77	4.07	8.99	2.16
3-1	12	AC2-45	f06pf21	8.29	2.39	9.25	4.3	0.591	1.36	17.1	9.71	4.17	9.52	2.63
3-1	13	AC2-26	f38pf21	9.74	1.89	2.51	7.81	1.37	0.66	21	5.16	2.09	11.3	4.91
3-1	14	restd	res312	10.7	3.08	4.89	4.15	1.06	2.03	19.7	9.18	4.14	9.86	2.93
3-1	15	AC2-41	f11pf21	6.02	1.97	4.55	5.22	0.807	1.77	16.1	11.4	4.42	7.39	2.86
3-1	16	AC2-30	f27pf11	8.01	2.14	3.64	3.22	0.57	1.1	16.1	8.96	3.26	8.28	1.95
3-1	17	AC2-15	f54pf11	6.04	2.7	2.56	2.58	1.04	2.41	14.7	13.6	2.27	10.3	1.54
3-1	18	AC2-36	f22pf11	7.09	2.29	4.65	4.63	0.693	1.58	16.1	11.7	4.33	8.11	2.56
3-1	19	EA	epf313	1.8	2.97	<0.100	0.46	<0.100	<0.100	0.266	<0.100	<0.100	20.4	<0.100
3-2	1	EA	epf321	2.08	3.53	<0.100	0.52	<0.100	<0.100	0.344	<0.100	<0.100	24.2	<0.100

The as-reported values for AC2-30 and AC2-53 are shaded to indicate that these measurements are believed to be switched.

They are relabeled accordingly elsewhere in this report.

< implies less than detection limit.

Table A.2: Measured Compositions (Using Peroxide Fusion Dissolution Method)
(concentrations are expressed as weight percents)

Revision 0

Block	Sequence	Glass ID	Lab ID	Al	B	Ce	Er	Eu	Gd	La	Nd	Pr	Si	Sm
3-2	2	AC2-45	f06pf22	8.52	2.47	10	4.63	0.579	1.4	17.7	9.88	4.45	10	2.54
3-2	3	AC2-26	f38pf22	9.77	2.02	2.52	7.81	1.25	0.715	22.1	5.74	2.15	11.8	5.2
3-2	4	AC2-26	f38pf12	9.8	2.01	2.74	7.91	1.26	0.728	22	5.71	2.32	11.6	5.02
3-2	5	AC2-30	f27pf12	8.92	2.69	4.35	4.03	0.612	1.4	18.6	10.4	3.94	11.1	2.47
3-2	6	restd	re321	11.2	3.23	5.16	4.07	1.02	2.02	20.9	10.2	4.41	10.7	3.12
3-2	7	AC2-45	f06pf12	8.12	2.42	9.65	4.73	0.544	1.38	17.6	9.97	4.53	10.1	2.37
3-2	8	AC2-30	f27pf22	9.14	2.84	4.47	4.34	0.625	1.46	19.3	11	4.02	10.9	2.52
3-2	9	AC2-41	f11pf12	6.72	2.13	5.74	5.41	0.806	1.92	18.2	14.2	5.28	8.01	3.5
3-2	10	EA	epf322	2.04	3.66	<0.100	0.545	<0.100	<0.100	0.282	<0.100	<0.100	24.4	<0.100
3-2	11	AC2-07	f43pf22	9.46	1.92	2.83	6.87	1.02	0.959	19.8	9.71	2.61	11.4	1.63
3-2	12	AC2-15	f54pf22	6.55	3.01	3.01	2.69	1.07	2.46	16.1	17.1	2.62	12	1.77
3-2	13	AC2-15	f54pf12	7.03	3.03	3.05	2.64	1.12	2.55	16.1	17.9	2.59	11.3	1.72
3-2	14	restd	re322	10.9	3.2	5.25	4.29	0.982	2.12	21.2	10	4.42	11.2	3.09
3-2	15	AC2-36	f22pf22	7.79	2.31	5.45	4.87	0.7	1.69	17.6	12.6	4.74	9.38	3.25
3-2	16	AC2-41	f11pf22	7.14	2.26	5.91	5.6	0.797	1.94	17.3	14	5.09	8.17	3.41
3-2	17	AC2-07	f43pf12	9.04	2.02	2.97	7.03	1.07	0.943	20.4	8.52	2.63	11.9	1.82
3-2	18	AC2-36	f22pf12	7.33	2.45	5.24	5.11	0.693	1.71	18.3	12.4	4.61	9.46	2.97
3-2	19	EA	epf323	1.98	3.37	<0.100	0.505	<0.100	<0.100	0.362	<0.100	<0.100	23.1	<0.100
4-1	1	EA	epf411	2.15	3.73	<0.100	0.502	<0.100	<0.100	0.391	<0.100	<0.100	24.1	<0.100
4-1	2	AC2-40	f12pf21	7.43	2.15	5.49	5.32	0.87	1.83	17.6	13.6	5.54	8.58	3.55
4-1	3	AC2-40	f12pf11	6.68	1.93	5.47	5.04	0.798	1.81	17	13.7	5.04	8.3	3.09
4-1	4	AC2-23	f05pf11	9.86	1.92	2.15	2.08	0.283	0.589	19.9	15	6.26	7.78	1.34
4-1	5	AC2-42	f21pf11	9.37	2.68	3.76	3.47	0.515	1.1	18.4	8.45	3.2	11	2.2
4-1	6	restd	re411	10.6	2.97	5.04	4.45	1.01	2.03	20.7	9.76	4.28	10.2	3.2
4-1	7	AC2-42	f21pf21	9.55	2.78	3.8	3.54	0.528	1.22	18.8	9.16	3.38	11.7	2.41
4-1	8	AC2-44	f44pf11	7.38	2.25	5.52	5.21	0.816	1.76	17.7	12.7	4.86	8.73	3.43
4-1	9	AC2-23	f05pf21	8.5	1.77	2.03	1.83	0.267	0.555	19.4	13.5	5.98	7.57	1.2
4-1	10	EA	epf412	<0.100	1.61	<0.100	0.15	<0.100	<0.100	<0.100	<0.100	0.151	12	<0.100
4-1	11	AC2-11	f37pf11	9.42	2.17	7.51	2.84	0.46	0.977	16.6	17.1	3.47	8.54	4.72
4-1	12	AC2-53	f53pf21	9.96	3.05	2.25	2.05	1.35	0.601	15.7	19	2.16	11.6	1.5
4-1	13	AC2-11	f37pf21	9.56	1.99	7.52	2.77	0.459	0.953	16.7	17.2	3.4	8.2	4.84
4-1	14	restd	res412	11.1	3.29	5.15	4.4	1.06	2.05	21	10.3	4.56	11	3.21
4-1	15	AC2-53	f53pf11	10.2	3.1	2.36	2.14	1.4	0.627	15	19.1	2.1	11.7	1.57
4-1	16	AC2-46	f28pf21	7.01	2.07	6.28	6.08	0.968	2.1	17.3	15.3	5.54	8.17	3.9
4-1	17	AC2-46	f28pf21	6.87	2.02	5.98	5.75	0.71	1.97	17.7	14.1	5.54	8.14	3.61
4-1	18	AC2-44	f44pf21	7.21	2.13	5.37	5.16	0.809	1.71	16.6	12.3	4.99	8.72	3.33
4-1	19	EA	epf413	1.96	3.45	0.14	0.465	<0.100	<0.100	0.368	<0.100	<0.100	23.1	<0.100
4-2	1	EA	epf421	1.97	3.59	<0.100	0.533	<0.100	<0.100	0.368	<0.100	<0.100	22.8	<0.100
4-2	2	AC2-42	f21pf12	9.27	2.76	3.63	3.57	0.564	1.17	19.5	8.84	3.37	10.7	2.13
4-2	3	AC2-53	f53pf12	9.15	2.79	2.09	2.04	1.31	0.598	14.3	18.2	1.97	10.6	1.22
4-2	4	AC2-23	f05pf22	8.74	1.92	2.17	2.11	0.3	0.634	21	15.4	6.49	7.31	1.23
4-2	5	AC2-11	f37pf12	9.07	1.92	7.13	2.68	0.464	0.913	16.2	17	3.27	7.72	4.48
4-2	6	restd	re421	10.2	2.98	5.17	4.08	1.05	2.01	20.4	10.2	4.25	9.63	3.08
4-2	7	AC2-44	f44pf22	6.95	2.2	5.5	5.1	0.835	1.72	18.1	13.3	4.97	8.28	3.19
4-2	8	AC2-44	f44pf12	7.16	2.14	5.38	5.16	0.818	1.78	18	13.1	4.78	8.33	3.2
4-2	9	AC2-42	f21pf22	8.71	2.68	3.45	3.39	0.546	1.13	18.5	8.98	3.28	10.2	2.08
4-2	10	EA	epf422	1.937	3.55	<0.100	0.576	<0.100	<0.100	0.385	<0.100	<0.100	22.6	<0.100
4-2	11	AC2-46	f28pf22	6.48	2.03	5.95	5.73	0.883	1.9	17.5	15	5.55	7.48	3.45

The as-reported values for AC2-30 and AC2-53 are shaded to indicate that these measurements are believed to be switched.

They are relabeled accordingly elsewhere in this report.

< implies less than detection limit.

Table A.2: Measured Compositions (Using Peroxide Fusion Dissolution Method)
(concentrations are expressed as weight percents)

Block	Sequence	Glass ID	Lab ID	Al	B	Ce	Er	Eu	Gd	La	Nd	Pr	Si	Sm
4-2	12	AC2-53	f53pf22	9.43	3.01	2.19	2.2	1.39	0.676	15.4	19.1	2.21	11.1	1.33
4-2	13	AC2-40	f12pf12	6.89	2.12	5.61	5.65	0.885	1.91	18.5	14.2	5.41	8.09	3.5
4-2	14	restd	res422	10.2	3.23	5.13	4.45	1.06	2.11	21.4	10.5	4.36	10.4	3.09
4-2	15	AC2-23	f05pf12	8.93	2	2.21	2.17	0.305	0.674	20.9	15.6	6.52	7.83	1.33
4-2	16	AC2-46	f28pf12	6.76	2.02	6.13	5.83	0.925	2.02	18.3	14.9	5.7	7.89	3.44
4-2	17	AC2-40	f12pf22	6.99	2.18	5.72	5.69	0.875	1.88	18.9	13.9	5.35	8.7	3.46
4-2	18	AC2-11	f37pf22	9.42	1.86	7.51	2.75	0.485	0.955	16.6	16.4	3.43	7.87	4.46
4-2	19	EA	epf423	1.99	3.62	<0.100	0.603	<0.100	<0.100	0.384	<0.100	<0.100	23.8	<0.100
5-1	1	EA	epf511	2.04	3.48	<0.100	0.522	<0.100	<0.100	0.348	<0.100	<0.100	23.4	<0.100
5-1	2	AC2-19	f29pf11	6.78	2.53	8.56	7.7	0.217	0.808	20.5	5.28	3.12	11.2	1.32
5-1	3	ARM	f13pf11	3.18	3.3	1.09	2.57	<0.100	<0.100	<0.100	5.65	0.249	19.4	0.123
5-1	4	AC2-04	f36pf11	6.41	1.73	2.97	2.68	0.436	2.62	21.5	15.8	5.93	8.02	4.49
5-1	5	AC2-25	f45pf21	9.75	1.82	2.32	7.93	1.33	3.13	22.9	9.03	2.31	8.09	5.36
5-1	6	restd	res511	10.3	2.77	5.13	4.15	1.05	2.19	22.2	9.98	4.49	10.5	3.1
5-1	7	AC2-34	f52pf21	8.8	2.44	4.66	4.21	0.675	1.61	19.2	10.8	4.19	10.2	2.64
5-1	8	AC2-04	f36pf21	6.71	1.73	3.24	2.88	0.458	2.85	22.7	16.8	6.25	8.14	4.66
5-1	9	AC2-34	f52pf11	8.91	2.19	4.72	4.09	0.652	1.64	19.3	10.8	4.26	10.5	2.66
5-1	10	EA	epf512	2.09	3.19	0.162	0.56	<0.100	<0.100	0.4	<0.100	<0.100	24.6	0.177
5-1	11	AC2-03	f04pf11	6.97	2.58	8.31	2.86	1.19	1.13	22.2	17.3	3.53	8.58	1.83
5-1	12	ARM	f13pf21	3.38	3.93	1.32	3.45	<0.100	<0.100	<0.100	5.37	0.253	25.1	0.12
5-1	13	AC2-03	f04pf21	7.12	2.47	8.13	2.88	1.21	1.15	23.6	17.1	3.64	8.34	1.95
5-1	14	restd	res512	10.9	2.81	5.68	4.37	1.07	2.27	22.8	10.1	4.7	10.9	3.5
5-1	15	AC2-25	f45pf11	10.3	1.76	2.6	8.95	1.44	3.21	23.2	9.56	2.31	8.52	5.44
5-1	16	AC2-32	f20pf21	8.46	2.46	5.96	5.14	0.816	1.99	19.8	11.7	5.09	11.1	3.48
5-1	17	AC2-19	f29pf21	7.15	2.43	9.29	8.23	0.225	0.84	22.3	5.65	3.5	11.7	1.49
5-1	18	AC2-32	f20pf11	8.82	2.19	6.33	5.46	0.834	2.13	21	12.1	5.15	10.1	3.28
5-1	19	EA	epf513	2.13	3.26	<0.100	0.58	<0.100	<0.100	0.415	<0.100	<0.100	24.9	<0.100
5-2	1	EA	epf521	2.03	3.6	<0.100	0.607	<0.100	<0.100	0.378	<0.100	<0.100	23.1	<0.100
5-2	2	ARM	f13pf12	3.3	3.72	1.17	2.82	<0.100	<0.100	0.061	5.02	<0.100	19.7	<0.100
5-2	3	AC2-19	f29pf22	6.33	2.93	8.74	7.68	0.24	0.745	20.2	5.23	3.02	10.7	0.784
5-2	4	AC2-04	f36pf12	6.49	1.96	3.06	2.72	0.475	2.51	20.7	15.1	5.96	7.82	2.85
5-2	5	AC2-32	f20pf12	8.09	2.65	5.64	5.11	0.791	1.8	18.9	10.6	4.85	9.44	2.05
5-2	6	restd	res521	9.98	3.01	4.99	3.98	0.993	2.03	19.8	9.64	4.07	9.85	3.03
5-2	7	ARM	f13pf22	3.5	4.03	1.19	2.97	<0.100	<0.100	0.078	4.67	<0.100	22.4	<0.100
5-2	8	AC2-19	f29pf12	6.56	2.8	8.67	7.73	0.24	0.78	21.3	5.43	3.15	10.8	0.946
5-2	9	AC2-25	f45pf12	9.25	2.07	2.15	7.82	1.26	2.78	20.8	8.81	2.02	7.94	4.81
5-2	10	EA	epf522	1.98	3.44	<0.100	0.595	<0.100	<0.100	0.38	<0.100	<0.100	22.5	<0.100
5-2	11	AC2-03	f04pf22	6.51	2.83	8.02	2.7	1.13	1.05	20.4	16.6	3.21	7.97	1.18
5-2	12	AC2-34	f52pf12	8.56	2.51	4.44	4.04	0.648	1.48	18	9.99	3.89	9.97	1.57
5-2	13	AC2-04	f36pf22	6.3	1.88	3.1	2.67	0.421	2.43	21.9	15.3	5.76	7.37	3.89
5-2	14	restd	res522	9.92	2.82	4.93	3.82	0.979	2.02	20	9.7	4.07	9.88	3
5-2	15	AC2-34	f52pf22	8.3	2.37	4.53	4.05	0.618	1.5	17.7	9.83	3.81	9.4	1.45
5-2	16	AC2-03	f04pf12	6.29	2.61	7.55	2.73	1.08	1.02	19.6	15.2	3.05	7.61	1.3
5-2	17	AC2-32	f20pf22	7.48	2.36	5.09	4.73	0.717	1.76	17	10.3	4.37	8.76	3.26
5-2	18	AC2-25	f45pf22	9.02	1.93	2.15	7.5	1.25	2.71	20.3	8.56	1.87	7.41	3.53
5-2	19	EA	epf523	1.89	3.22	<0.100	0.589	<0.100	<0.100	0.373	<0.100	<0.100	22.5	<0.100
6-1	1	EA	epf611	1.94	3.41	<0.100	0.52	<0.100	<0.100	0.315	<0.100	<0.100	21.4	<0.100
6-1	2	AC2-21	f51pf21	9.19	2.77	8.46	2.1	0.269	2.82	21	7.02	2.85	7.46	4.94

The as-reported values for AC2-30 and AC2-53 are shaded to indicate that these measurements are believed to be switched.

They are relabeled accordingly elsewhere in this report.

< implies less than detection limit.

Table A.2: Measured Compositions (Using Peroxide Fusion Dissolution Method)
(concentrations are expressed as weight percents)

Revision 0

Block	Sequence	Glass ID	Lab ID	Al	B	Ce	Er	Eu	Gd	La	Nd	Pr	Si	Sm
6-1	3	AC2-10	f03pf11	6.34	2.74	7.07	6.67	0.441	2.39	16.1	7.36	3.17	10.6	4.37
6-1	4	AC2-33	f35pf21	7.81	2.34	4.71	4.38	0.709	1.63	17.7	11.8	4.17	8.81	2.84
6-1	5	AC2-10	f03pf21	6.47	2.69	6.98	6.76	0.437	2.44	15.8	7.15	3.25	10.4	4.16
6-1	6	restd	res611	10.1	2.84	4.82	4.02	0.979	1.99	20.4	9.74	4	10.1	2.99
6-1	7	AC2-43	f30pf21	8.32	2.45	4.12	3.84	0.607	1.35	18	9.94	3.57	9.61	2.34
6-1	8	AC2-43	f30pf11	8.3	2.4	4.01	3.82	0.615	1.34	18.1	10.4	3.52	9.51	2.36
6-1	9	AC2-21	f51pf11	6.47	2.73	2.12	7.79	0.299	0.673	14.3	14.5	6.42	7.51	4.92
6-1	10	EA	epf612	2.05	3.28	<0.100	0.525	<0.100	<0.100	0.307	<0.100	<0.100	22.3	<0.100
6-1	11	AC2-35	f46pf21	7.54	2.24	4.73	4.84	0.759	1.66	17.2	12.2	4.02	8.99	2.83
6-1	12	AC2-35	f46pf11	7.07	2.03	4.57	4.4	0.701	1.53	16.7	11.6	4.06	8.44	2.81
6-1	13	AC2-20	f14pf21	6.61	1.7	7.79	1.87	1.21	2.62	19.6	11	6.97	7.41	1.17
6-1	14	restd	res612	10.1	2.76	4.69	3.95	1.02	1.91	19.7	9.42	3.96	9.58	2.66
6-1	15	AC2-14	f19pf21	8.81	2.38	2.67	6.47	1.06	0.858	14.7	11.9	5.39	7.02	1.45
6-1	16	AC2-20	f14pf11	6.08	1.66	7.49	1.92	1.2	2.62	19	11	6.9	6.97	1.17
6-1	17	AC2-14	f19pf11	8.97	2.46	2.77	6.12	1.05	0.866	14.5	11.7	5.33	7.17	1.55
6-1	18	AC2-33	f35pf11	7.27	1.97	4.29	4.08	0.634	1.46	15.6	10.8	3.96	8.37	2.47
6-1	19	EA	epf613	1.88	3.08	<0.100	0.454	<0.100	<0.100	0.276	<0.100	<0.100	20.2	<0.100
6-2	1	EA	epf621	2.06	3.57	<0.100	0.513	<0.100	<0.100	0.35	<0.100	<0.100	23.6	<0.100
6-2	2	AC2-20	f14pf22	6.02	1.89	7.76	2.03	1.2	2.82	19.6	10.8	7.19	7.58	1.22
6-2	3	AC2-35	f46pf21	7.31	2.16	4.72	4.26	0.66	1.6	17.2	10.7	4.33	8.54	3.07
6-2	4	AC2-21	f51pf22	9.04	2.82	8.11	1.93	0.24	2.77	19.5	6.36	2.79	7.58	4.65
6-2	5	AC2-10	f03pf22	6.22	2.7	7.18	6.22	0.399	2.4	15.5	6.23	3.22	10.9	4.28
6-2	6	restd	res621	9.91	3.11	4.8	3.87	0.971	1.96	20.2	9.4	4.19	10.3	3.03
6-2	7	AC2-21	f51pf12	5.94	2.56	2.18	7.17	0.295	0.659	14.8	14.2	6.32	7.08	4.53
6-2	8	AC2-33	f35pf22	7.81	2.34	4.76	4.27	0.673	1.57	17.6	11.3	4.24	9.27	2.87
6-2	9	AC2-20	f14pf12	6.24	1.89	7.81	1.92	1.22	2.76	20.5	11.5	7.38	7.56	1.24
6-2	10	EA	epf622	2.12	3.48	<0.100	0.516	<0.100	<0.100	0.403	<0.100	<0.100	23	<0.100
6-2	11	AC2-33	f35pf12	7.81	2.56	4.69	4.22	0.704	1.65	17.9	11.1	4.11	9.91	3.02
6-2	12	AC2-43	f30pf22	8.72	2.7	4.38	3.94	0.615	1.39	18.8	10.3	3.86	10.3	2.59
6-2	13	AC2-14	f19pf22	9.48	2.86	3.03	6.32	1.12	0.958	15.4	12	5.88	7.41	1.84
6-2	14	restd	res622	10.2	3.04	5.35	4.17	0.952	2	20.4	10.1	4.55	9.82	3.28
6-2	15	AC2-10	f03pf12	6.3	2.91	7.25	6.48	0.392	2.32	15.1	7.02	3.09	10.8	4.42
6-2	16	AC2-35	f46pf22	7.65	2.36	5.23	4.56	0.721	1.72	18.3	12.5	4.52	8.94	3.09
6-2	17	AC2-43	f30pf12	8.53	2.76	4.52	4.06	0.629	1.49	19.1	10.4	3.93	10.3	2.71
6-2	18	AC2-14	f19pf12	9.62	2.92	3.15	6.71	1.14	0.984	15.9	13.3	6.25	8.02	1.88
6-2	19	EA	epf623	2.2	3.79	<0.100	0.534	<0.100	<0.100	0.395	<0.100	<0.100	24	<0.100
7-1	1	EA	epf711	2.13	3.72	<0.100	0.59	<0.100	<0.100	0.394	<0.100	<0.100	23.4	<0.100
7-1	2	AC2-48	f34pf21	9.79	3.04	3.94	3.42	0.564	1.2	18.4	8.94	3.39	11.3	2.15
7-1	3	AC2-50	f02pf11	8.23	2.63	5.26	5.12	0.762	1.86	18.8	12.2	4.5	10.5	2.97
7-1	4	AC2-24	f15pf21	6.54	2.93	2.11	3.17	0.322	2.8	20.5	20.4	2.2	7.82	1.25
7-1	5	AC2-06	f18pf11	6.74	3.14	3.09	7.35	0.472	1.02	20.3	14.5	2.77	8.03	4.51
7-1	6	restd	res711	10.7	3.34	5.39	4.35	1.08	2.18	20.4	10.2	4.4	10.5	3.04
7-1	7	AC2-48	f34pf11	9.55	3.18	4.06	3.61	0.559	1.3	19.6	9.14	3.32	11.7	2.24
7-1	8	AC2-50	f02pf21	8.54	2.7	5.39	4.78	0.77	1.74	20.2	12.5	4.75	10.1	3.1
7-1	9	AC2-12	f47pf11	7.09	2.18	3.49	3.5	0.55	1.14	18.4	19.8	6.3	12.9	1.75
7-1	10	EA	epf712	2.2	4.04	<0.100	0.649	<0.100	<0.100	0.448	<0.100	<0.100	25.2	<0.100
7-1	11	AC2-12	f47pf21	6.53	2.13	3.05	3.11	0.478	1.04	16.9	16.3	5.6	11.8	1.66
7-1	12	AC2-22	f31pf11	7.09	3.05	2.54	2.07	1.39	3	21.8	6.02	6.58	11.6	5.6

The as-reported values for AC2-30 and AC2-53 are shaded to indicate that these measurements are believed to be switched.

They are relabeled accordingly elsewhere in this report.

< implies less than detection limit.

Block	Sequence	Glass ID	Lab ID	Al	B	Ce	Er	Eu	Gd	La	Nd	Pr	Si	Sm
7-1	13	AC2-24	f15pf11	6.9	3.24	2.45	3.34	0.365	3.23	22.9	20.7	2.24	8.32	1.33
7-1	14	restd	res712	10.9	3.33	5.27	4.33	1.03	2.16	20.3	9.8	4.28	10.8	2.93
7-1	15	AC2-22	f31pf21	6.79	3.05	2.42	2.21	1.37	3	20.6	5.78	6.65	11.8	4.96
7-1	16	AC2-29	f50pf21	6.76	3.16	2.39	8.03	0.322	0.769	15.4	15.5	7.02	8.22	4.83
7-1	17	AC2-29	f50pf11	6.3	2.9	2.3	7.68	0.306	0.688	14.6	14	6.4	7.54	4.6
7-1	18	AC2-06	f18pf21	6.63	3.05	3.4	6.89	0.475	0.976	19.6	16	2.7	8.28	4.84
7-1	19	EA	epf713	2.18	3.91	<0.100	0.641	<0.100	<0.100	0.433	<0.100	<0.100	25.7	<0.100
7-2	1	EA	epf721	2.07	3.66	<0.100	0.68	<0.100	<0.100	0.438	<0.100	<0.100	23.9	<0.100
7-2	2	AC2-50	f02pf12	8.4	2.57	5.1	4.65	0.803	1.66	18	12.4	4.57	9.89	2.92
7-2	3	AC2-48	f34pf12	9.93	3.12	3.9	3.78	0.658	1.35	21.3	10.2	3.73	11.1	2.91
7-2	4	AC2-22	f31pf22	7.26	3.08	2.43	2.47	1.51	3	22.8	6.2	7.38	11.9	5.91
7-2	5	AC2-29	f50pf22	7.85	3.74	2.74	10.2	0.474	0.956	18.2	18.5	8.57	9.3	3.9
7-2	6	restd	res721	11.5	3.69	5.9	4.95	1.3	2.44	23.5	11.3	5.33	11.5	3.51
7-2	7	AC2-06	f18pf12	7.29	3.3	3.31	8.68	0.617	1.2	22.6	16.7	3.19	8.73	4.9
7-2	8	AC2-06	f18pf22	6.04	2.68	2.78	6.53	0.552	1.04	18.2	16.4	2.59	6.92	3.16
7-2	9	AC2-12	f47pf22	6.47	2.17	2.89	3.05	0.565	1.06	16.6	18.6	5.99	11.2	1.97
7-2	10	EA	epf722	2.41	4.22	<0.100	0.765	<0.100	<0.100	0.504	<0.100	<0.100	25.8	<0.100
7-2	11	AC2-24	f15pf12	6.85	3.11	2.29	3.27	0.404	2.93	22	21.2	2.19	8.23	1.48
7-2	12	AC2-48	f34pf22	9.31	2.95	3.54	3.57	0.647	1.26	18.6	9.12	3.47	10.6	2.33
7-2	13	AC2-22	f31pf12	6.67	3.12	2.36	2.33	1.45	3.09	22.3	6.2	7.03	11.6	6.02
7-2	14	restd	res722	10.9	3.26	5.33	4.67	1.18	2.26	22	10	4.63	10.6	3.18
7-2	15	AC2-24	f15pf22	6.75	2.89	2.28	3.21	0.404	2.8	20.8	19.6	2.12	7.58	1.39
7-2	16	AC2-12	f47pf12	6.24	2.04	2.91	3.02	0.544	1.02	15.7	18.1	5.97	10.8	1.68
7-2	17	AC2-50	f02pf22	7.62	2.44	4.72	4.73	0.793	1.61	18.1	12.2	4.47	9.28	3.12
7-2	18	AC2-29	f50pf12	6.38	2.91	2.12	7.73	0.384	0.726	14.4	14.8	6.88	7.62	4.71
7-2	19	EA	epf723	1.85	3.36	<0.100	0.662	<0.100	<0.100	0.107	<0.100	<0.100	22.4	<0.100
8-1	1	EA	epf811	1.9	3.28	<0.100	0.461	<0.100	<0.100	0.297	<0.100	<0.100	21.2	<0.100
8-1	2	AC2-38	f49pf21	6.8	2.15	5.11	4.97	0.731	1.74	17.9	12.1	4.75	8.15	2.93
8-1	3	AC2-27	f48pf21	8.73	1.88	8.31	2.03	0.259	2.84	14.8	5.06	7.27	11	5
8-1	4	AC2-16	f16pf21	8.94	2	2.92	6.77	0.456	2.4	15.9	16.5	2.66	7.62	1.45
8-1	5	AC2-17	f32pf21	7.54	2.43	4.99	4.44	0.769	1.68	17.5	10.7	4.46	9.33	2.72
8-1	6	restd	res811	9.83	3.1	5	3.87	0.979	1.97	20.4	9	4.16	9.94	2.87
8-1	7	AC2-38	f49pf11	6.79	2.18	5.42	4.81	0.79	1.7	17.7	11.9	4.77	8.45	3.1
8-1	8	AC2-37	f17pf21	7.05	2.16	5.05	4.85	0.737	1.75	17.9	11.4	4.56	8.42	2.95
8-1	9	AC2-16	f16pf11	8.95	1.88	2.93	6.51	0.457	2.32	15.4	15.8	2.54	7.52	1.58
8-1	10	EA	epf812	1.92	3.44	<0.100	0.493	<0.100	<0.100	0.31	<0.100	<0.100	22.5	<0.100
8-1	11	AC2-27	f48pf11	8.63	1.89	8.09	1.92	0.247	2.82	14.2	5.12	7.1	11	4.7
8-1	12	AC2-17	f32pf11	7.47	2.37	4.82	4.43	0.735	1.7	17.4	10.1	4.43	9.05	2.82
8-1	13	AC2-37	f17pf11	7.09	2.22	5.24	4.85	0.756	1.77	17.6	11.6	4.53	8.46	2.92
8-1	14	restd	res812	9.59	2.96	4.9	3.84	0.995	1.99	20.2	8.78	4.14	9.82	2.92
8-1	15	AC2-13	f33pf11	8.78	2.7	2.93	2.55	0.411	0.961	15.9	8.18	5.7	10.6	3.97
8-1	16	AC2-02	f01pf11	8.93	2.92	7.28	2.62	0.425	2.54	20.4	7.29	6.26	7.91	1.6
8-1	17	AC2-13	f33pf21	8.81	2.82	2.96	2.58	0.417	0.963	16	8.29	5.48	10.6	3.9
8-1	18	AC2-02	f01pf21	8.56	2.8	6.85	2.44	0.4	2.55	20.2	6.83	6.4	7.64	1.5
8-1	19	EA	epf813	1.84	3.43	<0.100	0.497	<0.100	<0.100	0.329	<0.100	<0.100	23	<0.100
8-2	1	EA	epf821	2.01	3.66	<0.100	0.534	<0.100	<0.100	0.46	<0.100	<0.100	22.6	<0.100
8-2	2	AC2-13	f33pf12	9.13	2.79	2.84	2.83	0.501	1	15.7	9.3	5.77	11	4.42
8-2	3	AC2-17	f32pf12	7.84	2.45	4.91	4.73	0.843	1.77	17.4	11.6	4.39	9.4	3.1

The as-reported values for AC2-30 and AC2-53 are shaded to indicate that these measurements are believed to be switched.

They are relabeled accordingly elsewhere in this report.

< implies less than detection limit.

Table A.2: Measured Compositions (Using Peroxide Fusion Dissolution Method)
(concentrations are expressed as weight percents)

Block	Sequence	Glass ID	Lab ID	Al	B	Ce	Er	Eu	Gd	La	Nd	Pr	Si	Sm
8-2	4	AC2-16	f16pf22	8.9	1.92	2.96	6.78	0.509	2.38	16	17.8	2.72	7.47	1.64
8-2	5	AC2-27	f48pf12	8.71	2.02	8.13	2.04	0.321	2.9	14.4	5.61	7.38	11	4.73
8-2	6	restd	res821	10	2.98	4.79	4.14	1.05	2.05	20.4	9.64	4.16	9.85	3.07
8-2	7	AC2-13	f33pf22	8.97	2.84	2.75	2.66	0.49	1.01	15.6	9.23	5.63	10.9	4
8-2	8	AC2-02	f01pf22	9.29	2.83	7.32	2.75	0.499	2.65	20.8	8.33	6.65	7.82	1.81
8-2	9	AC2-16	f16pf12	9.62	2	3	7.33	0.535	2.59	15.9	17.7	2.81	7.71	1.73
8-2	10	EA	epf822	2.07	3.72	<0.100	0.507	<0.100	<0.100	0.471	<0.100	<0.100	23	<0.100
8-2	11	AC2-02	f01pf12	9.01	2.91	7.42	2.87	0.493	2.51	19.4	8.38	6.51	7.76	1.72
8-2	12	AC2-27	f48pf22	8.6	1.96	8.07	2.08	0.314	3.01	14.7	5.8	7.5	10.9	4.94
8-2	13	AC2-38	f49pf22	7.16	2.22	5.35	5.04	0.848	1.84	17.3	13.6	4.88	8.39	3.24
8-2	14	restd	res822	10.2	3.11	4.75	4.15	1.06	2.09	19.9	9.55	4.24	10	2.86
8-2	15	AC2-17	f32pf22	7.83	2.49	5.06	4.84	0.851	1.71	17.8	11.7	4.42	9.53	3.01
8-2	16	AC2-38	f49pf12	7.15	2.2	5.32	5.38	0.868	1.77	17.8	13.6	4.88	8.52	3.25
8-2	17	AC2-37	f17pf22	7.28	2.34	5.23	5.1	0.851	1.86	18.4	13.3	4.76	8.91	3.24
8-2	18	AC2-37	f17pf12	7.25	2.36	5.35	5.33	0.826	1.88	18.1	12.9	4.9	8.98	3.12
8-2	19	EA	epf823	2.06	3.6	<0.100	0.542	<0.100	<0.100	0.472	<0.100	<0.100	23.5	<0.100

The as-reported values for AC2-30 and AC2-53 are shaded to indicate that these measurements are believed to be switched.

They are relabeled accordingly elsewhere in this report.

< implies less than detection limit.

(concentrations are expressed as weight percents)

Block	Sequence	Glass ID	Lab ID	Al ₂ O ₃	B ₂ O ₃	Ce ₂ O ₃	Er ₂ O ₃	Eu ₂ O ₃	Gd ₂ O ₃	La ₂ O ₃	Nd ₂ O ₃	Pr ₂ O ₃	SiO ₂	Sm ₂ O ₃
2-1	10	EA	epf212	3.760	11.205	0.059	0.532	0.058	0.058	0.541	0.058	0.059	48.776	0.058
2-1	11	AC2-01	f39pf11	12.376	6.440	9.066	8.039	0.469	1.136	23.691	8.841	7.818	22.035	1.948
2-1	12	AC2-47	f10pf11	15.324	7.663	6.044	5.386	0.805	1.833	22.049	13.997	5.243	19.446	3.398
2-1	13	AC2-47	f10pf21	15.324	7.631	5.974	5.283	0.807	1.959	21.931	13.880	5.313	19.639	3.514
2-1	14	restd	res212	19.273	9.885	5.974	4.665	1.169	2.420	24.394	11.781	5.114	20.494	3.432
2-1	15	AC2-39	f42pf11	13.529	6.858	6.958	6.083	0.946	2.075	21.462	16.330	6.039	17.499	4.012
2-1	16	AC2-09	f26pf21	13.170	6.697	9.429	8.256	1.320	2.951	20.641	13.997	8.098	16.836	5.195
2-1	17	AC2-55	f23pf21	15.059	7.953	12.416	5.237	0.798	1.902	22.283	8.561	6.285	19.361	3.560
2-1	18	AC2-31	f55pf21	13.151	6.665	2.729	9.422	0.318	3.458	18.648	22.745	2.610	24.388	1.531
2-1	19	EA	epf213	3.779	11.656	0.059	0.569	0.058	0.058	0.441	0.058	0.059	49.204	0.058
2-2	1	EA	epf221	3.666	11.688	0.059	0.650	0.058	0.058	0.410	0.058	0.059	48.348	0.058
2-2	2	AC2-09	f26pf22	12.131	6.279	8.808	7.822	1.274	2.905	19.117	12.947	7.818	16.794	5.288
2-2	3	AC2-39	f42pf22	13.000	6.891	6.536	5.946	0.930	2.167	21.580	15.280	6.015	18.184	3.780
2-2	4	AC2-01	f39pf22	12.395	6.472	8.855	7.913	0.507	1.245	24.042	8.585	8.063	23.318	2.122
2-2	5	AC2-47	f10pf22	15.097	7.567	5.997	5.009	0.830	2.040	22.283	14.113	5.395	21.051	3.548
2-2	6	restd	res221	19.651	9.885	6.266	4.505	1.204	2.490	24.746	12.247	4.939	21.607	3.641
2-2	7	AC2-01	f39pf12	12.055	5.989	8.433	7.501	0.503	1.268	24.277	8.410	7.771	22.891	2.029
2-2	8	AC2-31	f55pf22	12.244	6.247	2.659	9.079	0.325	3.250	17.475	21.112	2.399	23.960	1.600
2-2	9	AC2-28	f07pf12	16.401	8.984	9.570	8.119	1.471	3.389	16.771	6.112	8.344	16.237	1.473
2-2	10	EA	epf222	3.552	10.465	0.059	0.630	0.058	0.058	0.493	0.058	0.059	45.353	0.058
2-2	11	AC2-28	f07pf22	15.985	8.662	9.441	7.936	1.436	3.389	16.888	6.462	8.649	16.237	1.531
2-2	12	AC2-47	f10pf12	14.133	6.826	5.646	4.826	0.791	1.890	20.407	12.830	5.220	18.655	3.305
2-2	13	AC2-55	f23pf12	15.399	7.857	11.221	5.317	0.860	2.063	23.104	8.328	6.144	21.350	3.630
2-2	14	restd	res222	19.651	9.788	6.184	4.643	1.204	2.570	25.567	11.582	5.208	22.249	3.653
2-2	15	AC2-39	f42pf12	13.378	7.019	6.817	6.015	0.982	2.248	21.697	15.396	6.285	18.612	4.175
2-2	16	AC2-55	f23pf22	14.492	8.050	11.362	5.203	0.819	2.006	21.814	8.165	6.086	20.131	3.386
2-2	17	AC2-31	f55pf12	12.735	6.408	2.600	9.400	0.322	3.273	18.061	19.829	2.446	23.532	1.600
2-2	18	AC2-09	f26pf12	12.168	6.665	8.925	7.639	1.389	3.054	19.820	13.297	8.333	16.601	5.323
2-2	19	EA	epf223	3.590	11.624	0.059	0.631	0.058	0.058	0.379	0.058	0.059	49.418	0.058
3-1	1	EA	epf311	3.685	11.366	0.059	0.593	0.058	0.058	0.388	0.058	0.059	47.492	0.058
3-1	2	AC2-41	f11pf11	12.376	6.569	6.747	6.026	0.952	2.075	20.876	15.513	6.121	16.451	3.757
3-1	3	AC2-30	f27pf21	15.721	8.243	4.837	4.277	0.746	1.487	19.820	11.407	4.260	20.580	2.841
3-1	4	AC2-15	f54pf11	10.033	8.790	3.139	2.870	1.251	2.639	16.888	19.012	2.856	21.607	1.913
3-1	5	AC2-26	f38pf11	16.533	3.832	2.764	8.576	1.413	0.681	22.518	5.645	2.305	22.891	5.369
3-1	6	restd	res311	18.083	9.499	5.423	4.425	1.125	2.190	22.635	10.486	4.658	20.259	3.224
3-1	7	AC2-36	f22pf21	13.982	7.406	5.763	5.329	0.830	1.821	19.820	13.764	5.021	18.355	3.363
3-1	8	AC2-07	f43pf21	17.553	5.989	3.303	7.501	1.251	1.032	21.814	10.054	2.949	23.104	1.925
3-1	9	AC2-07	f43pf11	17.535	6.279	3.174	7.330	1.274	0.998	19.703	10.603	3.031	23.104	1.971
3-1	10	EA	epf312	3.911	11.205	0.059	0.575	0.058	0.058	0.346	0.058	0.059	48.990	0.058
3-1	11	AC2-45	f06pf11	14.190	7.567	9.745	4.665	0.614	1.418	18.648	10.229	4.763	19.232	2.505
3-1	12	AC2-45	f06pf21	15.664	7.696	10.835	4.917	0.684	1.568	20.055	11.326	4.880	20.366	3.050
3-1	13	AC2-26	f38pf21	18.404	6.086	2.940	8.931	1.586	0.761	24.629	6.019	2.446	24.174	5.694
3-1	14	restd	res312	20.218	9.917	5.728	4.746	1.227	2.340	23.104	10.708	4.845	21.093	3.398
3-1	15	AC2-41	f11pf21	11.375	6.343	5.329	5.969	0.934	2.040	18.882	13.297	5.173	15.809	3.316
3-1	16	AC2-30	f27pf11	15.135	6.891	4.264	3.682	0.660	1.268	18.882	10.451	3.815	17.713	2.261
3-1	17	AC2-15	f54pf11	11.413	8.694	2.999	2.950	1.204	2.778	17.240	15.863	2.657	22.035	1.786
3-1	18	AC2-36	f22pf11	13.397	7.374	5.447	5.294	0.802	1.821	18.882	13.647	5.067	17.350	2.969
3-1	19	EA	epf313	3.401	9.563	0.059	0.526	0.058	0.058	0.312	0.058	0.059	43.642	0.058

The as-reported values for AC2-30 and AC2-53 are shaded to indicate that these measurements are believed to be switched.

They are relabeled accordingly elsewhere in this report.

< implies less than detection limit.

Table A.2: Measured Compositions (Using Peroxide Fusion Dissolution Method)
(concentrations are expressed as weight percents)

Revision 0

Block	Sequence	Glass ID	Lab ID	Al ₂ O ₃	B ₂ O ₃	Ce ₂ O ₃	Er ₂ O ₃	Eu ₂ O ₃	Gd ₂ O ₃	La ₂ O ₃	Nd ₂ O ₃	Pr ₂ O ₃	SiO ₂	Sm ₂ O ₃
3-2	1	EA	epf321	3.930	11.366	0.059	0.595	0.058	0.058	0.403	0.058	0.059	51.771	0.058
3-2	2	AC2-45	f06pf22	16.099	7.953	11.713	5.294	0.670	1.614	20.759	11.524	5.208	21.393	2.945
3-2	3	AC2-26	f38pf22	18.460	6.504	2.952	8.931	1.447	0.824	25.919	6.695	2.516	25.244	6.030
3-2	4	AC2-26	f38pf12	18.517	6.472	3.209	9.045	1.459	0.839	25.802	6.660	2.715	24.816	5.821
3-2	5	AC2-30	f27pf12	16.854	8.662	5.095	4.608	0.709	1.614	21.814	12.131	4.611	23.746	2.864
3-2	6	restd	re321	21.162	10.400	6.044	4.654	1.181	2.328	24.512	11.897	5.161	22.891	3.618
3-2	7	AC2-45	f06pf12	15.343	7.792	11.303	5.409	0.630	1.591	20.641	11.629	5.301	21.607	2.748
3-2	8	AC2-30	f27pf22	17.270	9.145	5.236	4.963	0.724	1.683	22.635	12.830	4.705	23.318	2.922
3-2	9	AC2-41	f11pf12	12.697	6.858	6.723	6.186	0.933	2.213	21.345	16.563	6.179	17.136	4.059
3-2	10	EA	epf322	3.855	11.785	0.059	0.623	0.058	0.058	0.331	0.058	0.059	52.199	0.058
3-2	11	AC2-07	f43pf22	17.875	6.182	3.315	7.856	1.181	1.105	23.221	11.326	3.054	24.388	1.890
3-2	12	AC2-15	f54pf22	12.376	9.692	3.526	3.076	1.239	2.835	18.882	19.945	3.066	25.672	2.052
3-2	13	AC2-15	f54pf12	13.283	9.756	3.572	3.019	1.297	2.939	18.882	20.879	3.031	24.174	1.995
3-2	14	restd	re322	20.596	10.304	6.149	4.906	1.137	2.444	24.863	11.664	5.173	23.960	3.583
3-2	15	AC2-36	f22pf22	14.719	7.438	6.384	5.569	0.811	1.948	20.641	14.697	5.547	20.067	3.769
3-2	16	AC2-41	f11pf22	13.491	7.277	6.922	6.404	0.923	2.236	20.289	16.330	5.957	17.478	3.954
3-2	17	AC2-07	f43pf12	17.081	6.504	3.479	8.039	1.239	1.087	23.925	9.938	3.078	25.458	2.110
3-2	18	AC2-36	f22pf12	13.850	7.889	6.138	5.843	0.802	1.971	21.462	14.463	5.395	20.238	3.444
3-2	19	EA	epf323	3.741	10.851	0.059	0.577	0.058	0.058	0.425	0.058	0.059	49.418	0.058
4-1	1	EA	epf411	4.062	12.010	0.059	0.574	0.058	0.058	0.459	0.058	0.059	51.557	0.058
4-1	2	AC2-40	f12pf21	14.039	6.923	6.430	6.083	1.007	2.109	20.641	15.863	6.483	18.355	4.117
4-1	3	AC2-40	f12pf11	12.622	6.214	6.407	5.763	0.924	2.086	19.938	15.980	5.898	17.756	3.583
4-1	4	AC2-23	f05pf11	18.630	6.182	2.518	2.378	0.328	0.679	23.339	17.496	7.326	16.644	1.554
4-1	5	AC2-42	f21pf11	17.705	8.629	4.404	3.968	0.596	1.268	21.580	9.856	3.745	23.532	2.551
4-1	6	restd	re411	20.029	9.563	5.903	5.089	1.169	2.340	24.277	11.384	5.009	21.821	3.711
4-1	7	AC2-42	f21pf21	18.045	8.951	4.451	4.048	0.611	1.406	22.049	10.684	3.956	25.030	2.795
4-1	8	AC2-44	f44pf11	13.945	7.245	6.466	5.958	0.945	2.029	20.759	14.813	5.688	18.676	3.977
4-1	9	AC2-23	f05pf21	16.061	5.699	2.378	2.093	0.309	0.640	22.752	15.746	6.998	16.195	1.392
4-1	10	EA	epf412	0.094	5.184	0.059	0.172	0.058	0.058	0.059	0.058	0.177	25.672	0.058
4-1	11	AC2-11	f37pf11	17.799	6.987	8.796	3.248	0.533	1.126	19.468	19.945	4.061	18.270	5.473
4-1	12	AC2-53	f53pf21	18.819	9.821	2.635	2.344	1.563	0.693	18.413	22.162	2.528	24.816	1.739
4-1	13	AC2-11	f37pf21	18.064	6.408	8.808	3.167	0.531	1.098	19.586	20.062	3.979	17.542	5.612
4-1	14	restd	res412	20.973	10.593	6.032	5.031	1.227	2.363	24.629	12.014	5.337	23.532	3.722
4-1	15	AC2-53	f53pf11	19.273	9.982	2.764	2.447	1.621	0.723	17.592	22.278	2.458	25.030	1.821
4-1	16	AC2-46	f28pf21	13.245	6.665	7.356	6.952	1.121	2.420	20.289	17.846	6.483	17.478	4.522
4-1	17	AC2-46	f28pf21	12.981	6.504	7.004	6.575	0.822	2.271	20.759	16.446	6.483	17.414	4.186
4-1	18	AC2-44	f44pf21	13.623	6.858	6.290	5.900	0.937	1.971	19.468	14.347	5.840	18.655	3.861
4-1	19	EA	epf413	3.703	11.109	0.164	0.532	0.058	0.058	0.432	0.058	0.059	49.418	0.058
4-2	1	EA	epf421	3.722	11.559	0.059	0.609	0.058	0.058	0.432	0.058	0.059	48.776	0.058
4-2	2	AC2-42	f21pf12	17.516	8.887	4.252	4.082	0.653	1.349	22.870	10.311	3.944	22.891	2.470
4-2	3	AC2-53	f53pf12	17.289	8.984	2.448	2.333	1.517	0.689	16.771	21.228	2.305	22.677	1.415
4-2	4	AC2-23	f05pf22	16.514	6.182	2.542	2.413	0.347	0.731	24.629	17.963	7.595	15.638	1.426
4-2	5	AC2-11	f37pf12	17.138	6.182	8.351	3.065	0.537	1.052	18.999	19.829	3.827	16.515	5.195
4-2	6	restd	re421	19.273	9.595	6.056	4.665	1.216	2.317	23.925	11.897	4.974	20.601	3.572
4-2	7	AC2-44	f44pf22	13.132	7.084	6.442	5.832	0.967	1.982	21.228	15.513	5.816	17.713	3.699
4-2	8	AC2-44	f44pf12	13.529	6.891	6.302	5.900	0.947	2.052	21.110	15.280	5.594	17.820	3.711
4-2	9	AC2-42	f21pf22	16.458	8.629	4.041	3.876	0.632	1.302	21.697	10.474	3.839	21.821	2.412
4-2	10	EA	epf422	3.660	11.431	0.059	0.659	0.058	0.058	0.452	0.058	0.059	48.348	0.058

The as-reported values for AC2-30 and AC2-53 are shaded to indicate that these measurements are believed to be switched.

They are relabeled accordingly elsewhere in this report.

< implies less than detection limit.

Table A.2: Measured Compositions (Using Peroxide Fusion Dissolution Method)
(concentrations are expressed as weight percents)

Block	Sequence	Glass ID	Lab ID	Al ₂ O ₃	B ₂ O ₃	Ce ₂ O ₃	Er ₂ O ₃	Eu ₂ O ₃	Gd ₂ O ₃	La ₂ O ₃	Nd ₂ O ₃	Pr ₂ O ₃	SiO ₂	Sm ₂ O ₃
4-2	11	AC2-46	f28pf22	12.244	6.536	6.969	6.552	1.022	2.190	20.524	17.496	6.495	16.002	4.001
4-2	12	AC2-53	f53pf22	17.818	9.692	2.565	2.516	1.609	0.779	18.061	22.278	2.586	23.746	1.542
4-2	13	AC2-40	f12pf12	13.019	6.826	6.571	6.461	1.025	2.201	21.697	16.563	6.331	17.307	4.059
4-2	14	restd	res422	19.273	10.400	6.009	5.089	1.227	2.432	25.098	12.247	5.103	22.249	3.583
4-2	15	AC2-23	f05pf12	16.873	6.440	2.589	2.481	0.353	0.777	24.512	18.196	7.630	16.751	1.542
4-2	16	AC2-46	f28pf12	12.773	6.504	7.180	6.667	1.071	2.328	21.462	17.379	6.671	16.879	3.989
4-2	17	AC2-40	f12pf22	13.208	7.019	6.700	6.507	1.013	2.167	22.166	16.213	6.261	18.612	4.012
4-2	18	AC2-11	f37pf22	17.799	5.989	8.796	3.145	0.562	1.101	19.468	19.129	4.014	16.836	5.172
4-2	19	EA	epf423	3.760	11.656	0.059	0.690	0.058	0.058	0.450	0.058	0.059	50.915	0.058
5-1	1	EA	epf511	3.855	11.205	0.059	0.597	0.058	0.058	0.408	0.058	0.059	50.060	0.058
5-1	2	AC2-19	f29pf11	12.811	8.146	10.026	8.805	0.251	0.931	24.042	6.159	3.651	23.960	1.531
5-1	3	ARM	f13pf11	6.009	10.626	1.277	2.939	0.058	0.058	0.059	6.590	0.291	41.502	0.143
5-1	4	AC2-04	f36pf11	12.112	5.570	3.479	3.065	0.505	3.020	25.215	18.429	6.940	17.157	5.207
5-1	5	AC2-25	f45pf21	18.423	5.860	2.717	9.068	1.540	3.608	26.857	10.533	2.703	17.307	6.215
5-1	6	restd	res511	19.462	8.919	6.009	4.746	1.216	2.524	26.036	11.641	5.255	22.463	3.595
5-1	7	AC2-34	f52pf21	16.628	7.857	5.458	4.814	0.782	1.856	22.518	12.597	4.904	21.821	3.061
5-1	8	AC2-04	f36pf21	12.679	5.570	3.795	3.293	0.530	3.285	26.623	19.596	7.314	17.414	5.404
5-1	9	AC2-34	f52pf11	16.835	7.052	5.529	4.677	0.755	1.890	22.635	12.597	4.985	22.463	3.085
5-1	10	EA	epf512	3.949	10.271	0.190	0.640	0.058	0.058	0.469	0.058	0.059	52.627	0.205
5-1	11	AC2-03	f04pf11	13.170	8.307	9.734	3.270	1.378	1.302	26.036	20.179	4.131	18.355	2.122
5-1	12	ARM	f13pf21	6.387	12.654	1.546	3.945	0.058	0.058	0.059	6.264	0.296	53.696	0.139
5-1	13	AC2-03	f04pf21	13.453	7.953	9.523	3.293	1.401	1.325	27.678	19.945	4.260	17.842	2.261
5-1	14	restd	res512	20.596	9.048	6.653	4.997	1.239	2.616	26.740	11.781	5.500	23.318	4.059
5-1	15	AC2-25	f45pf11	19.462	5.667	3.045	10.234	1.667	3.700	27.209	11.151	2.703	18.227	6.308
5-1	16	AC2-32	f20pf21	15.985	7.921	6.981	5.878	0.945	2.294	23.221	13.647	5.957	23.746	4.035
5-1	17	AC2-19	f29pf21	13.510	7.824	10.881	9.411	0.261	0.968	26.153	6.590	4.096	25.030	1.728
5-1	18	AC2-32	f20pf11	16.665	7.052	7.414	6.244	0.966	2.455	24.629	14.113	6.027	21.607	3.803
5-1	19	EA	epf513	4.025	10.497	0.059	0.663	0.058	0.058	0.487	0.058	0.059	53.269	0.058
5-2	1	EA	epf521	3.836	11.592	0.059	0.694	0.058	0.058	0.443	0.058	0.059	49.418	0.058
5-2	2	ARM	f13pf12	6.235	11.978	1.370	3.225	0.058	0.058	0.072	5.855	0.059	42.144	0.058
5-2	3	AC2-19	f29pf22	11.961	9.434	10.237	8.782	0.278	0.859	23.691	6.100	3.534	22.891	0.909
5-2	4	AC2-04	f36pf12	12.263	6.311	3.584	3.110	0.550	2.893	24.277	17.613	6.975	16.729	3.305
5-2	5	AC2-32	f20pf12	15.286	8.533	6.606	5.843	0.916	2.075	22.166	12.364	5.676	20.195	2.377
5-2	6	restd	res521	18.857	9.692	5.845	4.551	1.150	2.340	23.221	11.244	4.763	21.072	3.514
5-2	7	ARM	f13pf22	6.613	12.976	1.394	3.396	0.058	0.058	0.091	5.447	0.059	47.920	0.058
5-2	8	AC2-19	f29pf12	12.395	9.016	10.155	8.839	0.278	0.899	24.981	6.334	3.686	23.104	1.097
5-2	9	AC2-25	f45pf12	17.478	6.665	2.518	8.942	1.459	3.204	24.394	10.276	2.364	16.986	5.578
5-2	10	EA	epf522	3.741	11.076	0.059	0.680	0.058	0.058	0.446	0.058	0.059	48.134	0.058
5-2	11	AC2-03	f04pf22	12.301	9.112	9.394	3.087	1.308	1.210	23.925	19.362	3.757	17.050	1.368
5-2	12	AC2-34	f52pf12	16.174	8.082	5.201	4.620	0.750	1.706	21.110	11.652	4.552	21.329	1.821
5-2	13	AC2-04	f36pf22	11.904	6.053	3.631	3.053	0.487	2.801	25.684	17.846	6.741	15.767	4.511
5-2	14	restd	res522	18.744	9.080	5.775	4.368	1.134	2.328	23.456	11.314	4.763	21.136	3.479
5-2	15	AC2-34	f52pf22	15.683	7.631	5.306	4.631	0.716	1.729	20.759	11.466	4.459	20.109	1.681
5-2	16	AC2-03	f04pf12	11.885	8.404	8.843	3.122	1.251	1.176	22.987	17.729	3.569	16.280	1.507
5-2	17	AC2-32	f20pf22	14.133	7.599	5.962	5.409	0.830	2.029	19.938	12.014	5.114	18.740	3.780
5-2	18	AC2-25	f45pf22	17.043	6.214	2.518	8.576	1.447	3.124	23.808	9.984	2.188	15.852	4.093
5-2	19	EA	epf523	3.571	10.368	0.059	0.674	0.058	0.058	0.437	0.058	0.059	48.134	0.058
6-1	1	EA	epf611	3.666	10.980	0.059	0.595	0.058	0.058	0.369	0.058	0.059	45.781	0.058

The as-reported values for AC2-30 and AC2-53 are shaded to indicate that these measurements are believed to be switched.

They are relabeled accordingly elsewhere in this report.

< implies less than detection limit.

Table A.2: Measured Compositions (Using Peroxide Fusion Dissolution Method)
(concentrations are expressed as weight percents)

Block	Sequence	Glass ID	Lab ID	Al ₂ O ₃	B ₂ O ₃	Ce ₂ O ₃	Er ₂ O ₃	Eu ₂ O ₃	Gd ₂ O ₃	La ₂ O ₃	Nd ₂ O ₃	Pr ₂ O ₃	SiO ₂	Sm ₂ O ₃
6-1	2	AC2-21	f51pf21	17.365	8.919	9.909	2.401	0.311	3.250	24.629	8.188	3.335	15.959	5.728
6-1	3	AC2-10	f03pf11	11.979	8.823	8.281	7.627	0.511	2.755	18.882	8.585	3.710	22.677	5.067
6-1	4	AC2-33	f35pf21	14.757	7.535	5.517	5.009	0.821	1.879	20.759	13.764	4.880	18.847	3.293
6-1	5	AC2-10	f03pf21	12.225	8.662	8.176	7.730	0.506	2.812	18.530	8.340	3.803	22.249	4.824
6-1	6	restd	res611	19.084	9.145	5.646	4.597	1.134	2.294	23.925	11.361	4.681	21.607	3.467
6-1	7	AC2-43	f30pf21	15.721	7.889	4.826	4.391	0.703	1.556	21.110	11.594	4.178	20.559	2.713
6-1	8	AC2-43	f30pf11	15.683	7.728	4.697	4.368	0.712	1.544	21.228	12.131	4.119	20.345	2.737
6-1	9	AC2-21	f51pf11	12.225	8.790	2.483	8.908	0.346	0.776	16.771	16.913	7.513	16.066	5.705
6-1	10	EA	epf612	3.873	10.561	0.059	0.600	0.058	0.058	0.360	0.058	0.059	47.706	0.058
6-1	11	AC2-35	f46pf21	14.247	7.213	5.540	5.535	0.879	1.913	20.172	14.230	4.705	19.232	3.282
6-1	12	AC2-35	f46pf11	13.359	6.536	5.353	5.031	0.812	1.763	19.586	13.530	4.751	18.056	3.258
6-1	13	AC2-20	f14pf21	12.490	5.474	9.124	2.138	1.401	3.020	22.987	12.830	8.157	15.852	1.357
6-1	14	restd	res612	19.084	8.887	5.493	4.517	1.181	2.201	23.104	10.987	4.634	20.494	3.085
6-1	15	AC2-14	f19pf21	16.646	7.663	3.127	7.398	1.227	0.989	17.240	13.880	6.308	15.018	1.681
6-1	16	AC2-20	f14pf11	11.488	5.345	8.773	2.196	1.389	3.020	22.283	12.830	8.075	14.911	1.357
6-1	17	AC2-14	f19pf11	16.949	7.921	3.245	6.998	1.216	0.998	17.006	13.647	6.238	15.339	1.797
6-1	18	AC2-33	f35pf11	13.737	6.343	5.025	4.665	0.734	1.683	18.296	12.597	4.634	17.906	2.864
6-1	19	EA	epf613	3.552	9.917	0.059	0.519	0.058	0.058	0.324	0.058	0.059	43.214	0.058
6-2	1	EA	epf621	3.892	11.495	0.059	0.587	0.058	0.058	0.410	0.058	0.059	50.487	0.058
6-2	2	AC2-20	f14pf22	11.375	6.086	9.089	2.321	1.389	3.250	22.987	12.597	8.414	16.216	1.415
6-2	3	AC2-35	f46pf21	13.812	6.955	5.529	4.871	0.764	1.844	20.172	12.480	5.067	18.270	3.560
6-2	4	AC2-21	f51pf22	17.081	9.080	9.499	2.207	0.278	3.193	22.870	7.418	3.265	16.216	5.392
6-2	5	AC2-10	f03pf22	11.753	8.694	8.410	7.113	0.462	2.766	18.178	7.267	3.768	23.318	4.963
6-2	6	restd	res621	18.725	10.014	5.622	4.425	1.124	2.259	23.691	10.964	4.904	22.035	3.514
6-2	7	AC2-21	f51pf12	11.224	8.243	2.553	8.199	0.342	0.760	17.357	16.563	7.396	15.146	5.253
6-2	8	AC2-33	f35pf22	14.757	7.535	5.575	4.883	0.779	1.810	20.641	13.180	4.962	19.831	3.328
6-2	9	AC2-20	f14pf12	11.790	6.086	9.148	2.196	1.413	3.181	24.042	13.414	8.637	16.173	1.438
6-2	10	EA	epf622	4.006	11.205	0.059	0.590	0.058	0.058	0.473	0.058	0.059	49.204	0.058
6-2	11	AC2-33	f35pf12	14.757	8.243	5.493	4.826	0.815	1.902	20.993	12.947	4.810	21.200	3.502
6-2	12	AC2-43	f30pf22	16.476	8.694	5.130	4.505	0.712	1.602	22.049	12.014	4.517	22.035	3.003
6-2	13	AC2-14	f19pf22	17.912	9.209	3.549	7.227	1.297	1.104	18.061	13.997	6.881	15.852	2.134
6-2	14	restd	res622	19.273	9.788	6.266	4.768	1.102	2.305	23.925	11.781	5.325	21.008	3.803
6-2	15	AC2-10	f03pf12	11.904	9.370	8.492	7.410	0.454	2.674	17.709	8.188	3.616	23.104	5.125
6-2	16	AC2-35	f46pf22	14.455	7.599	6.126	5.214	0.835	1.982	21.462	14.580	5.290	19.125	3.583
6-2	17	AC2-43	f30pf12	16.117	8.887	5.294	4.643	0.728	1.717	22.400	12.131	4.599	22.035	3.143
6-2	18	AC2-14	f19pf12	18.177	9.402	3.690	7.673	1.320	1.134	18.648	15.513	7.314	17.157	2.180
6-2	19	EA	epf623	4.157	12.203	0.059	0.611	0.058	0.058	0.463	0.058	0.059	51.343	0.058
7-1	1	EA	epf711	4.025	11.978	0.059	0.675	0.058	0.058	0.462	0.058	0.059	50.060	0.058
7-1	2	AC2-48	f34pf21	18.498	9.788	4.615	3.911	0.653	1.383	21.580	10.428	3.967	24.174	2.493
7-1	3	AC2-50	f02pf11	15.551	8.468	6.161	5.855	0.882	2.144	22.049	14.230	5.266	22.463	3.444
7-1	4	AC2-24	f15pf21	12.357	9.434	2.471	3.625	0.373	3.227	24.042	23.795	2.575	16.729	1.450
7-1	5	AC2-06	f18pf11	12.735	10.110	3.619	8.405	0.547	1.176	23.808	16.913	3.242	17.179	5.230
7-1	6	restd	res711	20.218	10.754	6.313	4.974	1.251	2.513	23.925	11.897	5.149	22.463	3.525
7-1	7	AC2-48	f34pf11	18.045	10.239	4.755	4.128	0.647	1.498	22.987	10.661	3.885	25.030	2.598
7-1	8	AC2-50	f02pf21	16.136	8.694	6.313	5.466	0.892	2.006	23.691	14.580	5.559	21.607	3.595
7-1	9	AC2-12	f47pf11	13.397	7.019	4.088	4.002	0.637	1.314	21.580	23.095	7.373	27.597	2.029
7-1	10	EA	epf712	4.157	13.008	0.059	0.742	0.058	0.058	0.525	0.058	0.059	53.910	0.058
7-1	11	AC2-12	f47pf21	12.338	6.858	3.572	3.556	0.553	1.199	19.820	19.012	6.554	25.244	1.925

The as-reported values for AC2-30 and AC2-53 are shaded to indicate that these measurements are believed to be switched.

They are relabeled accordingly elsewhere in this report.

< implies less than detection limit.

Table A.3: K and Na Measurements (Using Lithium-metaborate Dissolution Method)

Revision 0

(concentrations are expressed as weight percents)

Block	Sequence	Glass ID	Lab ID	K	Na	K ₂ O	Na ₂ O	Block	Sequence	Glass ID	Lab ID	K	Na	K ₂ O	Na ₂ O
1-1	1	EA	epf111	<0.150	12.7	0.090	17.120	1-2	1	EA	elm121	<0.150	12.5	0.090	16.850
1-1	2	AC2-25	f45lm21	<0.150	0.184	0.090	0.248	1-2	2	AC2-29	f50lm12	<0.150	0.204	0.090	0.275
1-1	3	AC2-32	f20lm21	<0.150	0.152	0.090	0.205	1-2	3	AC2-32	f20lm22	<0.150	0.169	0.090	0.228
1-1	4	AC2-43	f30lm21	<0.150	0.132	0.090	0.178	1-2	4	AC2-29	f50lm22	<0.150	0.226	0.090	0.305
1-1	5	AC2-31	f55lm11	<0.150	0.182	0.090	0.245	1-2	5	AC2-54	f56lm22	<0.150	0.202	0.090	0.272
1-1	6	AC2-47	f10lm11	<0.150	0.17	0.090	0.229	1-2	6	AC2-33	f35lm12	<0.150	0.162	0.090	0.218
1-1	7	AC2-24	f15lm11	<0.150	0.173	0.090	0.233	1-2	7	AC2-18	f25lm22	<0.150	0.183	0.090	0.247
1-1	8	AC2-25	f45lm11	<0.150	0.171	0.090	0.231	1-2	8	AC2-05	f40lm22	<0.150	0.207	0.090	0.279
1-1	9	AC2-18	f25lm11	<0.150	0.164	0.090	0.221	1-2	9	AC2-25	f45lm12	<0.150	0.177	0.090	0.239
1-1	10	AC2-05	f40lm21	<0.150	0.194	0.090	0.262	1-2	10	AC2-23	f05lm22	<0.150	0.162	0.090	0.218
1-1	11	AC2-05	f40lm11	<0.150	0.202	0.090	0.272	1-2	11	AC2-54	f56lm12	<0.150	0.185	0.090	0.249
1-1	12	AC2-33	f35lm11	<0.150	0.157	0.090	0.212	1-2	12	AC2-24	f15lm12	<0.150	0.186	0.090	0.251
1-1	13	AC2-32	f20lm11	<0.150	0.165	0.090	0.222	1-2	13	AC2-31	f55lm12	<0.150	0.191	0.090	0.257
1-1	14	EA	elm112	<0.150	12.4	0.090	16.715	1-2	14	EA	elm122	<0.150	12.9	0.090	17.389
1-1	15	AC2-33	f35lm21	<0.150	0.197	0.090	0.266	1-2	15	AC2-47	f10lm22	<0.150	0.163	0.090	0.220
1-1	16	AC2-29	f50lm21	<0.150	0.219	0.090	0.295	1-2	16	AC2-43	f30lm22	<0.150	0.153	0.090	0.206
1-1	17	AC2-18	f25lm21	<0.150	0.169	0.090	0.228	1-2	17	AC2-47	f10lm12	<0.150	0.183	0.090	0.247
1-1	18	AC2-29	f50lm11	<0.150	0.182	0.090	0.245	1-2	18	AC2-18	f25lm12	<0.150	0.176	0.090	0.237
1-1	19	AC2-54	f56lm21	<0.150	0.195	0.090	0.263	1-2	19	AC2-33	f35lm22	<0.150	0.21	0.090	0.283
1-1	20	AC2-23	f05lm11	<0.150	0.148	0.090	0.200	1-2	20	AC2-32	f20lm12	<0.150	0.173	0.090	0.233
1-1	21	AC2-47	f10lm21	<0.150	0.148	0.090	0.200	1-2	21	AC2-43	f30lm12	<0.150	0.167	0.090	0.225
1-1	22	AC2-23	f05lm21	<0.150	0.151	0.090	0.204	1-2	22	AC2-24	f15lm22	<0.150	0.185	0.090	0.249
1-1	23	AC2-24	f15lm21	<0.150	0.182	0.090	0.245	1-2	23	AC2-31	f55lm22	<0.150	0.236	0.090	0.318
1-1	24	AC2-43	f30lm11	<0.150	0.152	0.090	0.205	1-2	24	AC2-25	f45lm22	<0.150	0.203	0.090	0.274
1-1	25	AC2-31	f55lm21	<0.150	0.216	0.090	0.291	1-2	25	AC2-23	f05lm12	<0.150	0.165	0.090	0.222
1-1	26	AC2-54	f56lm11	<0.150	0.19	0.090	0.256	1-2	26	AC2-05	f40lm12	<0.150	0.21	0.090	0.283
1-1	27	EA	elm113	<0.150	12.2	0.090	16.446	1-2	27	EA	elm123	<0.150	12.7	0.090	17.120
2-1	1	EA	elm211	<0.150	12.9	0.090	17.389	2-2	1	EA	elm221	<0.150	12.2	0.090	16.446
2-1	2	AC2-52	f24lm21	<0.150	0.16	0.090	0.216	2-2	2	AC2-20	f14lm12	<0.150	0.187	0.090	0.252
2-1	3	AC2-51	f09lm11	<0.150	0.187	0.090	0.252	2-2	3	AC2-48	f34lm22	<0.150	0.119	0.090	0.160
2-1	4	AC2-51	f09lm21	<0.150	0.322	0.090	0.434	2-2	4	AC2-38	f49lm12	<0.150	0.146	0.090	0.197
2-1	5	AC2-19	f29lm11	<0.150	0.14	0.090	0.189	2-2	5	AC2-19	f29lm22	<0.150	0.123	0.090	0.166

Table A.3: K and Na Measurements (Using Lithium-metaborate Dissolution Method)

Revision 0

(concentrations are expressed as weight percents)

Block	Sequence	Glass ID	Lab ID	K	Na	K ₂ O	Na ₂ O	Block	Sequence	Glass ID	Lab ID	K	Na	K ₂ O	Na ₂ O
2-1	6	AC2-15	f54lm21	<0.150	0.212	0.090	0.286	2-2	6	AC2-15	f54lm22	<0.150	0.181	0.090	0.244
2-1	7	AC2-19	f29lm11	<0.150	0.144	0.090	0.194	2-2	7	AC2-01	f39lm12	<0.150	0.178	0.090	0.240
2-1	8	AC2-38	f49lm21	<0.150	0.179	0.090	0.241	2-2	8	AC2-19	f29lm12	<0.150	0.118	0.090	0.159
2-1	9	AC2-15	f54lm11	<0.150	0.208	0.090	0.280	2-2	9	AC2-52	f24lm22	<0.150	0.14	0.090	0.189
2-1	10	AC2-01	f39lm21	<0.150	0.176	0.090	0.237	2-2	10	AC2-14	f19lm22	<0.150	0.183	0.090	0.247
2-1	11	AC2-14	f19lm11	<0.150	0.206	0.090	0.278	2-2	11	AC2-48	f34lm12	<0.150	0.139	0.090	0.187
2-1	12	AC2-03	f04lm21	<0.150	0.182	0.090	0.245	2-2	12	AC2-44	f44lm22	<0.150	0.168	0.090	0.226
2-1	13	EA	elm212	<0.150	12.6	0.090	16.985	2-2	13	EA	elm222	<0.150	12.3	0.090	16.580
2-1	14	AC2-52	f24lm11	<0.150	0.186	0.090	0.251	2-2	14	AC2-52	f24lm12	<0.150	0.162	0.090	0.218
2-1	15	AC2-38	f49lm11	<0.150	0.184	0.090	0.248	2-2	15	AC2-20	f14lm22	<0.150	0.162	0.090	0.218
2-1	16	AC2-14	f19lm21	<0.150	0.2	0.090	0.270	2-2	16	AC2-15	f54lm12	<0.150	0.174	0.090	0.235
2-1	17	AC2-48	f34lm11	<0.150	0.171	0.090	0.231	2-2	17	AC2-44	f44lm12	<0.150	0.175	0.090	0.236
2-1	18	AC2-44	f44lm21	<0.150	0.209	0.090	0.282	2-2	18	AC2-01	f39lm22	<0.150	0.142	0.090	0.191
2-1	19	AC2-44	f44lm11	<0.150	0.209	0.090	0.282	2-2	19	AC2-14	f19lm12	<0.150	0.175	0.090	0.236
2-1	20	AC2-48	f34lm21	<0.150	0.156	0.090	0.210	2-2	20	AC2-38	f49lm22	<0.150	0.158	0.090	0.213
2-1	21	AC2-20	f14lm21	<0.150	0.178	0.090	0.240	2-2	21	AC2-51	f09lm22	<0.150	0.286	0.090	0.386
2-1	22	AC2-03	f04lm11	<0.150	0.182	0.090	0.245	2-2	22	AC2-51	f09lm12	<0.150	0.162	0.090	0.218
2-1	23	AC2-01	f39lm11	<0.150	0.206	0.090	0.278	2-2	23	AC2-03	f04lm22	<0.150	0.152	0.090	0.205
2-1	24	AC2-20	f14lm11	<0.150	0.204	0.090	0.275	2-2	24	AC2-03	f04lm12	<0.150	0.166	0.090	0.224
2-1	25	EA	elm213	<0.150	12.8	0.090	17.254	2-2	25	EA	elm223	<0.150	12.4	0.090	16.715
3-1	1	EA	elm311	<0.150	12.4	0.090	16.715	3-2	1	EA	elm321	<0.150	12.9	0.090	17.389
3-1	2	AC2-08	f08lm21	<0.150	0.224	0.090	0.302	3-2	2	ARM	f13lm22	<0.150	7.54	0.090	10.164
3-1	3	AC2-46	f28lm11	<0.150	0.181	0.090	0.244	3-2	3	AC2-06	f18lm12	<0.150	0.232	0.090	0.313
3-1	4	AC2-13	f33lm21	<0.150	0.138	0.090	0.186	3-2	4	AC2-53	f53lm22	<0.150	0.307	0.090	0.414
3-1	5	AC2-53	f53lm11	<0.150	0.187	0.090	0.252	3-2	5	AC2-55	f23lm22	<0.150	0.207	0.090	0.279
3-1	6	AC2-10	f03lm21	<0.150	0.21	0.090	0.283	3-2	6	AC2-08	f08lm12	<0.150	0.253	0.090	0.341
3-1	7	AC2-46	f28lm21	<0.150	0.189	0.090	0.255	3-2	7	AC2-26	f38lm12	<0.150	0.212	0.090	0.286
3-1	8	AC2-07	f43lm11	<0.150	0.213	0.090	0.287	3-2	8	AC2-46	f28lm12	<0.150	0.242	0.090	0.326
3-1	9	AC2-06	f18lm11	<0.150	0.212	0.090	0.286	3-2	9	AC2-06	f18lm22	<0.150	0.284	0.090	0.383
3-1	10	AC2-27	f48lm11	<0.150	0.214	0.090	0.288	3-2	10	AC2-53	f53lm12	<0.150	0.255	0.090	0.344
3-1	11	ARM	f13lm21	<0.150	7.24	0.090	9.760	3-2	11	AC2-10	f03lm12	<0.150	0.274	0.090	0.369
3-1	12	AC2-07	f43lm21	<0.150	0.217	0.090	0.293	3-2	12	AC2-27	f48lm12	<0.150	0.273	0.090	0.368

Table A.3: K and Na Measurements (Using Lithium-metaborate Dissolution Method)
(concentrations are expressed as weight percents)

Block	Sequence	Glass ID	Lab ID	K	Na	K ₂ O	Na ₂ O	Block	Sequence	Glass ID	Lab ID	K	Na	K ₂ O	Na ₂ O
3-1	13	EA	elm312	<0.150	12.4	0.090	16.715	3-2	13	EA	elm322	<0.150	13	0.090	17.524
3-1	14	AC2-10	f031m11	<0.150	0.231	0.090	0.311	3-2	14	AC2-13	f331m22	<0.150	0.145	0.090	0.195
3-1	15	AC2-08	f081m11	<0.150	0.235	0.090	0.317	3-2	15	AC2-08	f081m22	<0.150	0.301	0.090	0.406
3-1	16	AC2-26	f381m21	<0.150	0.232	0.090	0.313	3-2	16	AC2-07	f431m22	<0.150	0.293	0.090	0.395
3-1	17	ARM	f131m11	<0.150	7.18	0.090	9.679	3-2	17	AC2-27	f481m22	<0.150	0.279	0.090	0.376
3-1	18	AC2-26	f381m11	<0.150	0.193	0.090	0.260	3-2	18	AC2-10	f031m22	<0.150	0.281	0.090	0.379
3-1	19	AC2-55	f231m21	<0.150	0.189	0.090	0.255	3-2	19	AC2-55	f231m12	<0.150	0.271	0.090	0.365
3-1	20	AC2-27	f481m21	<0.150	0.195	0.090	0.263	3-2	20	AC2-26	f381m22	<0.150	0.284	0.090	0.383
3-1	21	AC2-13	f331m11	<0.150	0.156	0.090	0.210	3-2	21	AC2-46	f281m22	<0.150	0.276	0.090	0.372
3-1	22	AC2-55	f231m11	<0.150	0.205	0.090	0.276	3-2	22	ARM	f131m12	<0.150	7.45	0.090	10.043
3-1	23	AC2-06	f181m21	<0.150	0.246	0.090	0.332	3-2	23	AC2-07	f431m12	<0.150	0.295	0.090	0.398
3-1	24	AC2-53	f531m21	<0.150	0.278	0.090	0.375	3-2	24	AC2-13	f331m12	<0.150	0.149	0.090	0.201
3-1	25	EA	elm313	<0.150	11.5	0.090	15.502	3-2	25	EA	elm323	<0.150	12.6	0.090	16.985
4-1	1	EA	elm411	<0.150	12.3	0.090	16.580	4-2	1	EA	elm421	<0.150	12.9	0.090	17.389
4-1	2	AC2-11	f371m11	<0.150	0.267	0.090	0.360	4-2	2	AC2-34	f521m12	<0.150	0.725	0.090	0.977
4-1	3	AC2-50	f021m21	<0.150	0.242	0.090	0.326	4-2	3	AC2-28	f071m12	<0.150	0.159	0.090	0.214
4-1	4	AC2-12	f471m21	<0.150	0.291	0.090	0.392	4-2	4	AC2-36	f221m22	<0.150	0.144	0.090	0.194
4-1	5	AC2-40	f121m11	<0.150	0.242	0.090	0.326	4-2	5	AC2-11	f371m12	<0.150	0.182	0.090	0.245
4-1	6	AC2-11	f371m21	<0.150	0.264	0.090	0.356	4-2	6	AC2-12	f471m12	<0.150	0.182	0.090	0.245
4-1	7	AC2-36	f221m21	<0.150	0.228	0.090	0.307	4-2	7	AC2-37	f171m12	<0.150	0.142	0.090	0.191
4-1	8	AC2-17	f321m11	<0.150	0.23	0.090	0.310	4-2	8	AC2-37	f171m22	<0.150	0.153	0.090	0.206
4-1	9	AC2-36	f221m11	<0.150	0.254	0.090	0.342	4-2	9	AC2-36	f221m12	<0.150	0.143	0.090	0.193
4-1	10	AC2-40	f121m21	<0.150	0.251	0.090	0.338	4-2	10	AC2-11	f371m22	<0.150	0.159	0.090	0.214
4-1	11	AC2-50	f021m11	<0.150	0.265	0.090	0.357	4-2	11	AC2-17	f321m22	<0.150	0.13	0.090	0.175
4-1	12	AC2-34	f521m11	<0.150	0.766	0.090	1.033	4-2	12	AC2-30	f271m12	<0.150	0.191	0.090	0.257
4-1	13	EA	elm412	<0.150	12.3	0.090	16.580	4-2	13	EA	elm422	<0.150	12.8	0.090	17.254
4-1	14	AC2-30	f271m21	<0.150	0.292	0.090	0.394	4-2	14	AC2-34	f521m22	<0.150	0.181	0.090	0.244
4-1	15	AC2-39	f421m21	<0.150	0.326	0.090	0.439	4-2	15	AC2-30	f271m22	<0.150	0.154	0.090	0.208
4-1	16	AC2-34	f521m21	<0.150	0.27	0.090	0.364	4-2	16	AC2-28	f071m22	<0.150	0.152	0.090	0.205
4-1	17	AC2-37	f171m21	<0.150	0.282	0.090	0.380	4-2	17	AC2-39	f421m22	<0.150	0.202	0.090	0.272
4-1	18	AC2-28	f071m21	<0.150	0.27	0.090	0.364	4-2	18	AC2-40	f121m12	<0.150	0.14	0.090	0.189
4-1	19	AC2-39	f421m11	<0.150	0.269	0.090	0.363	4-2	19	AC2-39	f421m22	<0.150	0.136	0.090	0.183

Block	Sequence	Glass ID	Lab ID	K	Na	K ₂ O	Na ₂ O	Block	Sequence	Glass ID	Lab ID	K	Na	K ₂ O	Na ₂ O
4-1	20	AC2-30	f27lm11	<0.150	0.312	0.090	0.421	4-2	20	AC2-12	f47lm22	<0.150	0.183	0.090	0.247
4-1	21	AC2-28	f07lm11	<0.150	0.274	0.090	0.369	4-2	21	AC2-50	f02lm12	<0.150	0.145	0.090	0.195
4-1	22	AC2-17	f32lm21	<0.150	0.267	0.090	0.360	4-2	22	AC2-17	f32lm12	<0.150	0.123	0.090	0.166
4-1	23	AC2-12	f47lm11	<0.150	0.311	0.090	0.419	4-2	23	AC2-50	f02lm22	<0.150	0.137	0.090	0.185
4-1	24	AC2-37	f17lm11	<0.150	0.287	0.090	0.387	4-2	24	AC2-40	f12lm22	<0.150	0.124	0.090	0.167
4-1	25	EA	elm413	<0.150	12.6	0.090	16.985	4-2	25	EA	elm423	<0.150	12.8	0.090	17.254
5-1	1	EA	elm511	<0.150	12.5	0.090	16.850	5-2	1	EA	elm521	<0.150	12.4	0.090	16.715
5-1	2	AC2-41	f11lm21	<0.150	0.157	0.090	0.212	5-2	2	AC2-49	f41lm22	<0.150	0.168	0.090	0.226
5-1	3	AC2-49	f41lm21	<0.150	0.164	0.090	0.221	5-2	3	AC2-21	f51lm22	<0.150	0.152	0.090	0.205
5-1	4	AC2-45	f06lm11	<0.150	0.144	0.090	0.194	5-2	4	AC2-16	f16lm12	<0.150	0.168	0.090	0.226
5-1	5	AC2-35	f46lm11	<0.150	0.182	0.090	0.245	5-2	5	AC2-21	f51lm12	<0.150	0.19	0.090	0.256
5-1	6	AC2-22	f31lm21	<0.150	0.136	0.090	0.183	5-2	6	AC2-22	f31lm22	<0.150	0.129	0.090	0.174
5-1	7	AC2-16	f16lm11	<0.150	0.182	0.090	0.245	5-2	7	AC2-45	f06lm12	<0.150	0.141	0.090	0.190
5-1	8	AC2-42	f21lm11	<0.150	0.144	0.090	0.194	5-2	8	AC2-41	f11lm12	<0.150	0.153	0.090	0.206
5-1	9	AC2-09	f26lm21	<0.150	0.178	0.090	0.240	5-2	9	AC2-02	f01lm22	<0.150	0.164	0.090	0.221
5-1	10	AC2-49	f41lm11	<0.150	0.206	0.090	0.278	5-2	10	AC2-09	f26lm22	<0.150	0.166	0.090	0.224
5-1	11	AC2-04	f36lm11	<0.150	0.161	0.090	0.217	5-2	11	AC2-35	f46lm22	<0.150	0.168	0.090	0.226
5-1	12	AC2-04	f36lm21	<0.150	0.159	0.090	0.214	5-2	12	AC2-49	f41lm12	<0.150	0.193	0.090	0.260
5-1	13	EA	elm512	<0.150	12.3	0.090	16.580	5-2	13	EA	elm522	<0.150	12.6	0.090	16.985
5-1	14	AC2-16	f16lm21	<0.150	0.183	0.090	0.247	5-2	14	AC2-35	f46lm12	<0.150	0.16	0.090	0.216
5-1	15	AC2-45	f06lm21	<0.150	0.154	0.090	0.208	5-2	15	AC2-42	f21lm12	<0.150	0.127	0.090	0.171
5-1	16	AC2-21	f51lm21	<0.150	0.158	0.090	0.213	5-2	16	AC2-45	f06lm22	<0.150	0.134	0.090	0.181
5-1	17	AC2-21	f51lm11	<0.150	0.208	0.090	0.280	5-2	17	AC2-04	f36lm22	<0.150	0.139	0.090	0.187
5-1	18	AC2-02	f01lm11	<0.150	0.188	0.090	0.253	5-2	18	AC2-16	f16lm22	<0.150	0.151	0.090	0.204
5-1	19	AC2-35	f46lm21	<0.150	0.189	0.090	0.255	5-2	19	AC2-04	f36lm12	<0.150	0.142	0.090	0.191
5-1	20	AC2-22	f31lm11	<0.150	0.147	0.090	0.198	5-2	20	AC2-02	f01lm12	<0.150	0.159	0.090	0.214
5-1	21	AC2-42	f21lm21	<0.150	0.727	0.090	0.980	5-2	21	AC2-09	f26lm12	<0.150	0.187	0.090	0.252
5-1	22	AC2-02	f01lm21	<0.150	0.192	0.090	0.259	5-2	22	AC2-41	f11lm22	<0.150	0.148	0.090	0.200
5-1	23	AC2-09	f26lm11	<0.150	0.216	0.090	0.291	5-2	23	AC2-22	f31lm12	<0.150	0.118	0.090	0.159
5-1	24	AC2-41	f11lm11	<0.150	0.18	0.090	0.243	5-2	24	AC2-42	f21lm22	<0.150	0.481	0.090	0.648
5-1	25	EA	elm513	<0.150	12.4	0.090	16.715	5-2	25	EA	elm523	<0.150	12	0.090	16.176

Table A.4: Comparison of Target Versus Measured Oxide Concentration
(concentrations are expressed as weight percents)

Short Glass ID	Al ₂ O ₃			B ₂ O ₃			CaO		
	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff
0 (EA)	3.700	3.698	0.0%	11.300	11.183	-1.0%	1.120	1.118	-0.1%
1	11.900	12.296	3.3%	6.500	6.263	-3.7%	0.000	0.042	
2	17.000	16.906	-0.6%	9.300	9.225	-0.8%	0.000	0.041	
3	11.900	12.702	6.7%	9.300	8.444	-9.2%	0.000	0.037	
4	11.900	12.239	2.9%	6.500	5.876	-9.6%	0.000	0.019	
5	17.000	16.878	-0.7%	6.500	6.110	-6.0%	0.000	0.033	
6	11.900	12.612	6.0%	9.300	9.797	5.3%	0.000	0.032	
7	17.000	17.511	3.0%	6.500	6.239	-4.0%	0.000	0.033	
8	17.000	16.798	-1.2%	6.500	6.528	0.4%	0.000	0.042	
9	11.900	12.457	4.7%	6.500	6.424	-1.2%	0.000	0.029	
10	11.900	11.965	0.5%	9.300	8.887	-4.4%	0.000	0.038	
11	17.000	17.700	4.1%	6.500	6.392	-1.7%	0.000	0.048	
12	11.900	12.438	4.5%	6.500	6.858	5.5%	0.000	0.042	
13	17.000	16.859	-0.8%	9.300	8.975	-3.5%	0.000	0.036	
14	17.000	17.421	2.5%	9.300	8.549	-8.1%	0.000	0.035	
15	11.900	11.776	-1.0%	9.300	9.233	-0.7%	0.000	0.029	
16	17.000	17.199	1.2%	6.500	6.279	-3.4%	0.000	0.020	
17	14.390	14.492	0.7%	7.870	7.840	-0.4%	0.000	0.039	
18	11.900	11.724	-1.5%	6.500	5.997	-7.7%	0.000	0.037	
19	11.900	12.669	6.5%	9.300	8.605	-7.5%	0.000	0.036	
20	11.900	11.786	-1.0%	6.500	5.748	-11.6%	0.000	0.034	
21	17.000	14.474	-14.9%	9.300	8.758	-5.8%	0.000	0.019	
22	11.900	13.137	10.4%	9.300	9.901	6.5%	0.000	0.017	
23	17.000	17.020	0.1%	6.500	6.126	-5.8%	0.000	0.028	
24	11.900	12.773	7.3%	9.300	9.797	5.3%	0.000	0.028	
25	17.000	18.101	6.5%	6.500	6.102	-6.1%	0.000	0.027	
26	17.000	17.979	5.8%	6.500	5.723	-11.9%	0.000	0.023	
27	16.300	16.377	0.5%	6.500	6.239	-4.0%	0.000	0.032	
28	17.000	16.963	-0.2%	9.300	8.871	-4.6%	0.000	0.047	
29	11.900	12.891	8.3%	9.300	10.231	10.0%	0.000	0.022	
30	17.000	18.300	7.6%	9.300	9.619	3.4%	0.000	0.026	
31	11.900	12.556	5.5%	6.500	6.408	-1.4%	0.000	0.027	
32	14.430	15.518	7.5%	7.880	7.776	-1.3%	0.000	0.034	
33	14.420	14.502	0.6%	7.850	7.414	-5.6%	0.000	0.027	
34	14.180	16.330	15.2%	7.720	7.655	-0.8%	0.000	0.041	
35	13.930	13.968	0.3%	7.580	7.076	-6.7%	0.000	0.021	
36	13.680	13.987	2.2%	7.450	7.527	1.0%	0.000	0.047	
37	13.430	13.543	0.8%	7.310	7.309	0.0%	0.000	0.041	
38	13.180	13.179	0.0%	7.180	7.044	-1.9%	0.000	0.029	
39	12.930	13.359	3.3%	7.040	6.891	-2.1%	0.000	0.046	
40	12.680	13.222	4.3%	6.910	6.746	-2.4%	0.000	0.042	
41	12.440	12.485	0.4%	6.770	6.762	-0.1%	0.000	0.021	
42	16.910	17.431	3.1%	9.210	8.774	-4.7%	0.000	0.022	
43	15.670	15.999	2.1%	8.530	8.299	-2.7%	0.000	0.110	
44	11.940	13.557	13.5%	6.500	7.019	8.0%	0.000	0.031	
45	14.420	15.324	6.3%	7.850	7.752	-1.2%	0.000	0.030	

Table A.4: Comparison of Target Versus Measured Oxide Concentrations
(concentrations are expressed as weight percents)

Revision 0

Short Glass ID	Al ₂ O ₃			B ₂ O ₃			CaO		
	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff
46	13.190	12.811	-2.9%	7.180	6.552	-8.7%	0.000	0.027	
47	14.420	14.970	3.8%	7.850	7.422	-5.5%	0.000	0.038	
48	16.910	18.224	7.8%	9.210	9.893	7.4%	0.000	0.026	
49	15.670	15.881	1.3%	8.530	8.356	-2.0%	0.000	0.024	
50	14.420	15.489	7.4%	7.850	8.323	6.0%	0.001	0.050	4937.1%
51	13.180	13.217	0.3%	7.180	6.931	-3.5%	0.001	0.032	3083.2%
52	16.910	16.892	-0.1%	9.210	9.056	-1.7%	0.001	0.027	2628.4%
53	15.670	16.245	3.7%	8.530	8.235	-3.5%	0.001	0.045	4412.4%
54	11.940	12.466	4.4%	6.500	6.383	-1.8%	0.001	0.032	3083.2%
55	14.440	14.998	3.9%	7.860	7.889	0.4%	0.000	0.029	
100 (ARM)	5.590	6.311	12.9%	11.300	12.059	6.7%	2.230	2.316	3.8%
Min			-14.9%			-11.9%			-0.1%
Avg			3.1%			-2.0%			2592.6%
Max			15.2%			10.0%			4937.1%

Table A.4: Comparison of Target Versus Measured Oxide Concentration
(concentrations are expressed as weight percents)

Short Glass ID	Ce ₂ O ₃			Cr ₂ O ₃			Er ₂ O ₃		
	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff
0 (EA)	0.000	0.063		0.000	0.022		0.000	0.601	
1	8.400	8.858	5.5%	0.000	0.022		7.600	7.756	2.0%
2	8.400	8.454	0.6%	0.000	0.022		3.000	3.053	1.8%
3	8.400	9.373	11.6%	0.000	0.022		3.000	3.193	6.4%
4	3.400	3.622	6.5%	0.000	0.022		3.000	3.130	4.3%
5	3.400	3.493	2.7%	0.000	0.022		3.000	2.956	-1.5%
6	3.400	3.684	8.3%	0.000	0.022		7.600	8.419	10.8%
7	3.400	3.318	-2.4%	0.000	0.022		7.600	7.681	1.1%
8	8.400	8.498	1.2%	0.000	0.022		3.000	3.096	3.2%
9	8.400	8.966	6.7%	0.000	0.022		7.600	7.819	2.9%
10	8.400	8.340	-0.7%	0.000	0.022		7.600	7.470	-1.7%
11	8.400	8.688	3.4%	0.000	0.022		3.000	3.156	5.2%
12	3.400	3.613	6.3%	0.000	0.022		3.300	3.625	9.8%
13	3.400	3.362	-1.1%	0.000	0.022		3.000	3.036	1.2%
14	3.400	3.403	0.1%	0.000	0.022		7.600	7.324	-3.6%
15	3.400	3.309	-2.7%	0.000	0.022		3.000	2.979	-0.7%
16	3.500	3.458	-1.2%	0.000	0.022		7.600	7.830	3.0%
17	5.800	5.792	-0.1%	0.000	0.022		5.240	5.272	0.6%
18	9.700	9.429	-2.8%	0.000	0.022		2.300	2.173	-5.5%
19	9.700	10.325	6.4%	0.000	0.022		8.800	8.959	1.8%
20	9.700	9.034	-6.9%	0.000	0.022		2.300	2.213	-3.8%
21	9.700	6.111	-37.0%	0.000	0.022		2.300	5.429	136.0%
22	2.500	2.855	14.2%	0.000	0.022		2.300	2.596	12.9%
23	2.500	2.507	0.3%	0.000	0.022		2.300	2.341	1.8%
24	2.500	2.673	6.9%	0.000	0.022		3.400	3.714	9.2%
25	2.500	2.700	8.0%	0.000	0.022		8.800	9.205	4.6%
26	2.800	2.966	5.9%	0.000	0.022		8.800	8.871	0.8%
27	9.700	9.546	-1.6%	0.000	0.022		2.300	2.307	0.3%
28	9.700	9.769	0.7%	0.000	0.022		8.100	8.079	-0.3%
29	2.500	2.796	11.9%	0.000	0.022		8.800	9.617	9.3%
30	2.500	2.603	4.1%	0.000	0.022		2.300	2.410	4.8%
31	2.500	2.618		0.000	0.022		8.800	9.134	3.8%
32	6.010	6.741		0.000	0.022		5.460	5.843	7.0%
33	5.590	5.403		0.000	0.022		5.070	4.846	-4.4%
34	5.730	5.373		0.000	0.022		5.190	4.685	-9.7%
35	5.860	5.637		0.000	0.022		5.320	5.163	-3.0%
36	5.990	5.933		0.000	0.022		5.440	5.509	1.3%
37	6.130	6.111		0.000	0.022		5.560	5.755	3.5%
38	6.260	6.208		0.000	0.022		5.680	5.775	1.7%
39	6.390	6.717		0.000	0.022		5.800	5.932	2.3%
40	6.530	6.527		0.000	0.022		5.920	6.203	4.8%
41	6.660	6.430		0.000	0.022		6.040	6.146	1.8%
42	4.260	4.287		0.000	0.022		3.870	3.994	3.2%
43	4.930	4.987		0.000	0.022		4.470	4.477	0.2%
44	6.930	6.375		0.000	0.022		6.280	5.898	-6.1%
45	10.870	10.899		0.000	0.022		5.070	5.071	0.0%

Table A.4: Comparison of Target Versus Measured Oxide Concentrations
(concentrations are expressed as weight percents)

Revision 0

Short Glass ID	Ce ₂ O ₃			Cr ₂ O ₃			Er ₂ O ₃		
	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff
46	6.260	7.127		0.000	0.022		5.680	6.687	17.7%
47	5.590	5.915		0.000	0.022		5.070	5.126	1.1%
48	4.260	4.521		0.000	0.022		3.870	4.111	6.2%
49	4.930	5.391		0.000	0.022		4.470	4.314	-3.5%
50	5.590	5.994		0.007	0.022	213.2%	5.070	5.512	8.7%
51	6.260	6.419		0.007	0.022	213.2%	5.680	5.606	-1.3%
52	4.260	0.246		0.007	0.022	213.2%	3.870	4.025	4.0%
53	4.930	4.858		0.007	0.022	213.2%	4.470	4.382	-2.0%
54	6.930	6.881		0.007	0.022	213.2%	6.280	6.083	-3.1%
55	11.200	11.672		0.000	0.022		5.080	5.243	3.2%
100 (ARM)	1.440	1.397	-3.0%	0.000	0.022		0.000	3.376	
Min			-37.0%			213.2%			-9.7%
Avg			1.7%			213.2%			4.6%
Max			14.2%			213.2%			136.0%

Table A.4: Comparison of Target Versus Measured Oxide Concentrations
(concentrations are expressed as weight percents)

Revision 0

Short Glass ID	Eu ₂ O ₃			Fe ₂ O ₃			Gd ₂ O ₃		
	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff
0 (EA)	0.000	0.058		7.380	9.072	22.9%	0.000	0.058	
1	0.500	0.482	-3.5%	0.000	0.063		1.100	1.183	7.5%
2	0.500	0.526	5.2%	0.000	0.031		2.800	2.954	5.5%
3	1.300	1.334	2.7%	0.000	0.023		1.100	1.253	14.0%
4	0.500	0.518	3.6%	0.000	0.060		2.800	3.000	7.1%
5	1.300	1.265	-2.7%	0.000	0.048		2.800	2.890	3.2%
6	0.500	0.613	22.5%	0.000	0.014		1.100	1.221	11.0%
7	1.300	1.236	-4.9%	0.000	0.024		1.100	1.055	-4.0%
8	1.300	1.282	-1.4%	0.000	0.036		1.100	1.244	13.1%
9	1.300	1.314	1.1%	0.000	0.031		2.800	2.939	5.0%
10	0.500	0.483	-3.4%	0.000	0.022		2.800	2.752	-1.7%
11	0.500	0.541	8.1%	0.000	0.047		1.100	1.094	-0.5%
12	0.500	0.619	23.7%	0.000	0.041		1.100	1.228	11.6%
13	0.500	0.527	5.3%	0.000	0.058		1.100	1.134	3.1%
14	1.300	1.265	-2.7%	0.000	0.035		1.100	1.056	-4.0%
15	1.300	1.248	-4.0%	0.000	0.050		2.800	2.798	-0.1%
16	0.500	0.567	13.3%	0.000	0.028		2.800	2.792	-0.3%
17	0.900	0.926	2.9%	0.000	0.024		1.940	1.977	1.9%
18	1.500	1.499	0.0%	0.000	0.020		0.800	0.898	12.3%
19	0.300	0.267	-11.0%	0.000	0.027		0.800	0.914	14.3%
20	1.500	1.398	-6.8%	0.000	0.026		3.200	3.118	-2.6%
21	0.300	0.319	6.4%	0.000	0.035		3.200	1.995	-37.7%
22	1.500	1.656	10.4%	0.000	0.028		3.200	3.484	8.9%
23	0.300	0.334	11.4%	0.000	0.014		0.800	0.707	-11.7%
24	0.300	0.433	44.3%	0.000	0.014		3.200	3.389	5.9%
25	1.500	1.528	1.9%	0.000	0.030		3.200	3.409	6.5%
26	1.500	1.476	-1.6%	0.000	0.071		0.800	0.776	-3.0%
27	0.300	0.330	10.1%	0.000	0.024		3.200	3.334	4.2%
28	1.500	1.453	-3.1%	0.000	0.037		3.200	3.305	3.3%
29	0.300	0.430	43.4%	0.000	0.035		0.800	0.905	13.1%
30	1.500	1.578	5.2%	0.000	0.023		0.800	0.721	-9.9%
31	0.300	0.311	3.7%	0.000	0.030		3.200	3.279	2.5%
32	0.900	0.914	1.6%	0.000	0.034		1.980	2.213	11.8%
33	0.810	0.787	-2.8%	0.000	0.026		1.830	1.818	-0.6%
34	0.830	0.751	-9.6%	0.000	0.025		1.870	1.795	-4.0%
35	0.850	0.822	-3.2%	0.000	0.031		1.920	1.876	-2.3%
36	0.870	0.811	-6.7%	0.000	0.025		1.960	1.890	-3.6%
37	0.890	0.918	3.1%	0.000	0.024		2.010	2.092	4.1%
38	0.910	0.937	3.0%	0.000	0.033		2.050	2.031	-0.9%
39	0.930	0.938	0.8%	0.000	0.034		2.090	2.138	2.3%
40	0.950	0.992	4.5%	0.000	0.024		2.140	2.141	0.0%
41	0.970	0.936	-3.5%	0.000	0.026		2.180	2.141	-1.8%
42	0.620	0.623	0.5%	0.000	0.027		1.400	1.331	-4.9%
43	0.720	0.714	-0.9%	0.000	0.018		1.610	1.605	-0.3%
44	1.010	0.949	-6.0%	0.000	0.038		2.270	2.008	-11.5%

Table A.4: Comparison of Target Versus Measured Oxide Concentrations
(concentrations are expressed as weight percents)

Revision 0

Short Glass ID	Eu ₂ O ₃			Fe ₂ O ₃			Gd ₂ O ₃		
	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff
45	0.690	0.650	-5.9%	0.000	0.028		1.540	1.547	0.5%
46	0.910	1.009	10.9%	0.000	0.036		2.050	2.302	12.3%
47	0.810	0.808	-0.2%	0.000	0.025		1.830	1.931	5.5%
48	0.620	0.703	13.4%	0.000	0.043		1.400	1.472	5.2%
49	0.720	0.740	2.8%	0.000	0.031		1.610	1.686	4.7%
50	0.810	0.905	11.8%	0.044	0.076	72.2%	1.830	1.980	8.2%
51	0.910	0.925	1.6%	0.044	0.079	78.7%	2.050	2.135	4.2%
52	0.620	0.650	4.9%	0.044	0.085	93.3%	1.400	1.481	5.8%
53	0.720	0.710	-1.5%	0.044	0.082	86.8%	1.610	1.513	-6.0%
54	1.010	1.018	0.8%	0.044	0.076	72.2%	2.270	2.285	0.7%
55	0.820	0.813	-0.8%	0.000	0.014		1.830	1.948	6.4%
100	0.000	0.058		0.000	0.033		0.000	0.058	
(ARM)									
Min			-11.0%			22.9%			-37.7%
Avg			3.6%			71.0%			2.1%
Max			44.3%			93.3%			14.3%

Table A.4: Comparison of Target Versus Measured Oxide Concentrations
(concentrations are expressed as weight percents)

Revision 0

Short Glass ID	K ₂ O			La ₂ O ₃			MnO		
	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff
0 (EA)	0.000	0.090		0.420	0.424	1.0%	1.340	3.065	128.8%
1	0.000	0.090		23.000	23.837	3.6%	0.000	0.041	
2	0.000	0.090		23.000	23.691	3.0%	0.000	0.008	
3	0.000	0.090		23.000	25.157	9.4%	0.000	0.040	
4	0.000	0.090		23.000	25.450	10.7%	0.000	0.008	
5	0.000	0.090		23.000	22.870	-0.6%	0.000	0.015	
6	0.000	0.090		23.000	23.661	2.9%	0.000	0.023	
7	0.000	0.090		23.000	22.166	-3.6%	0.000	0.023	
8	0.000	0.090		18.400	18.208	-1.0%	0.000	0.023	
9	0.000	0.090		18.400	19.732	7.2%	0.000	0.008	
10	0.000	0.090		18.400	18.325	-0.4%	0.000	0.023	
11	0.000	0.090		18.400	19.381	5.3%	0.000	0.010	
12	0.000	0.090		18.400	19.820	7.7%	0.000	0.008	
13	0.000	0.090		18.400	18.530	0.7%	0.000	0.024	
14	0.000	0.090		18.400	17.739	-3.6%	0.000	0.041	
15	0.000	0.090		18.400	17.973	-2.3%	0.000	0.042	
16	0.000	0.090		18.400	18.530	0.7%	0.000	0.008	
17	0.000	0.090		20.640	20.553	-0.4%	0.000	0.008	
18	0.000	0.090		17.000	16.566	-2.6%	0.000	0.015	
19	0.000	0.090		24.000	24.717	3.0%	0.000	0.041	
20	0.000	0.090		24.000	23.075	-3.9%	0.000	0.039	
21	0.000	0.090		24.000	20.407	-15.0%	0.000	0.008	
22	0.000	0.090		24.000	25.655	6.9%	0.000	0.008	
23	0.000	0.090		24.000	23.808	-0.8%	0.000	0.015	
24	0.000	0.090		24.000	25.274	5.3%	0.000	0.015	
25	0.000	0.090		24.000	25.567	6.5%	0.000	0.015	
26	0.000	0.090		24.000	24.717	3.0%	0.000	0.023	
27	0.000	0.090		16.800	17.035	1.4%	0.000	0.023	
28	0.000	0.090		16.800	16.830	0.2%	0.000	0.009	
29	0.000	0.090		16.800	18.354	9.3%	0.000	0.015	
30	0.000	0.090		16.800	17.709	5.4%	0.000	0.023	
31	0.000	0.090		16.800	17.768	5.8%	0.000	0.015	
32	0.000	0.090		20.310	22.488	10.7%	0.000	0.015	
33	0.000	0.090		20.980	20.172	-3.9%	0.000	0.015	
34	0.000	0.090		20.880	21.755	4.2%	0.000	0.008	
35	0.000	0.090		20.790	20.348	-2.1%	0.000	0.008	
36	0.000	0.090		20.690	20.201	-2.4%	0.000	0.008	
37	0.000	0.090		20.600	21.110	2.5%	0.000	0.008	
38	0.000	0.090		20.500	20.729	1.1%	0.000	0.040	
39	0.000	0.090		20.410	21.257	4.1%	0.000	0.009	
40	0.000	0.090		20.310	21.110	3.9%	0.000	0.008	
41	0.000	0.090		20.220	20.348	0.6%	0.000	0.008	
42	0.000	0.090		21.940	22.049	0.5%	0.000	0.008	
43	0.000	0.090		21.460	21.697	1.1%	0.000	0.015	
44	0.000	0.090		20.020	20.641	3.1%	0.000	0.042	
45	0.000	0.090		19.880	20.026	0.7%	0.000	0.008	

Table A.4: Comparison of Target Versus Measured Oxide Concentrations
(concentrations are expressed as weight percents)

Revision 0

Short Glass ID	K ₂ O			La ₂ O ₃			MnO		
	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff
46	0.000	0.090		20.500	20.759	1.3%	0.000	0.023	
47	0.000	0.090		20.980	21.667	3.3%	0.000	0.015	
48	0.000	0.090		21.940	22.840	4.1%	0.000	0.039	
49	0.000	0.090		21.460	20.377	-5.0%	0.000	0.008	
50	0.002	0.090	4417.3%	20.980	22.019	5.0%	0.002	0.011	447.1%
51	0.002	0.090	4417.3%	20.500	20.143	-1.7%	0.002	0.044	2088.4%
52	0.002	0.090	4417.3%	21.940	21.843	-0.4%	0.002	0.046	2197.8%
53	0.002	0.090	4417.3%	21.460	20.788	-3.1%	0.002	0.012	483.6%
54	0.002	0.090	4417.3%	20.020	19.322	-3.5%	0.002	0.015	629.5%
55	0.000	0.090		21.000	22.254	6.0%	0.000	0.023	
100	0.000	0.090		0.000	0.070		0.000	0.036	
(ARM)									
Min			4417.3%			-15.0%			128.8%
Avg			4417.3%			1.7%			995.8%
Max			4417.3%			10.7%			2197.8%

Table A.4: Comparison of Target Versus Measured Oxide Concentrations
(concentrations are expressed as weight percents)

Revision 0

Short Glass ID	Na ₂ O			Nd ₂ O ₃			NiO		
	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff
0 (EA)	16.800	16.863	0.4%	0.000	0.058		0.570	0.582	2.1%
1	0.000	0.237		8.400	8.649	3.0%	0.000	0.038	
2	0.000	0.237		9.200	8.990	-2.3%	0.000	0.038	
3	0.000	0.230		19.000	19.304	1.6%	0.000	0.166	
4	0.000	0.203		18.500	18.371	-0.7%	0.000	0.038	
5	0.000	0.274		10.200	10.206	0.1%	0.000	0.038	
6	0.000	0.328		17.800	18.546	4.2%	0.000	0.038	
7	0.000	0.343		10.900	10.480	-3.9%	0.000	0.038	
8	0.000	0.341		8.400	8.459	0.7%	0.000	0.038	
9	0.000	0.252		13.300	13.239	-0.5%	0.000	0.038	
10	0.000	0.336		8.400	8.095	-3.6%	0.000	0.038	
11	0.000	0.294		19.700	19.741	0.2%	0.000	0.038	
12	0.000	0.326		20.700	21.228	2.6%	0.000	0.038	
13	0.000	0.198		10.700	10.206	-4.6%	0.000	0.038	
14	0.000	0.257		14.500	14.259	-1.7%	0.000	0.038	
15	0.000	0.261		20.700	18.925	-8.6%	0.000	0.038	
16	0.000	0.231		20.700	19.770	-4.5%	0.000	0.038	
17	0.000	0.253		13.610	12.860	-5.5%	0.000	0.038	
18	0.000	0.233		24.200	23.415	-3.2%	0.000	0.038	
19	0.000	0.177		6.300	6.296	-0.1%	0.000	0.038	
20	0.000	0.246		13.400	12.918	-3.6%	0.000	0.038	
21	0.000	0.239		8.100	12.271	51.5%	0.000	0.038	
22	0.000	0.179		6.300	7.057	12.0%	0.000	0.038	
23	0.000	0.211		18.500	17.350	-6.2%	0.000	0.038	
24	0.000	0.245		24.200	23.882	-1.3%	0.000	0.038	
25	0.000	0.248		10.400	10.486	0.8%	0.000	0.038	
26	0.000	0.310		6.300	6.255	-0.7%	0.000	0.038	
27	0.000	0.324		6.300	6.296	-0.1%	0.000	0.038	
28	0.000	0.288		6.300	6.342	0.7%	0.000	0.038	
29	0.000	0.280		17.800	18.312	2.9%	0.000	0.038	
30	0.000	0.346		21.800	21.987	0.9%	0.000	0.038	
31	0.000	0.278		21.400	21.112	-1.3%	0.000	0.038	
32	0.000	0.222		12.980	13.035	0.4%	0.000	0.038	
33	0.000	0.245		13.940	13.122	-5.9%	0.000	0.038	
34	0.000	0.654		14.270	12.078	-15.4%	0.000	0.038	
35	0.000	0.236		14.600	13.705	-6.1%	0.000	0.038	
36	0.000	0.259		14.930	14.143	-5.3%	0.000	0.038	
37	0.000	0.291		15.260	14.347	-6.0%	0.000	0.038	
38	0.000	0.225		15.590	14.930	-4.2%	0.000	0.038	
39	0.000	0.314		15.930	15.601	-2.1%	0.000	0.038	
40	0.000	0.255		16.260	16.155	-0.6%	0.000	0.038	
41	0.000	0.215		16.590	15.426	-7.0%	0.000	0.038	
42	0.000	0.498		10.620	10.331	-2.7%	0.000	0.038	
43	0.000	0.204		12.280	11.967	-2.5%	0.000	0.038	
44	0.000	0.256		17.250	14.988	-13.1%	0.000	0.038	
45	0.000	0.193		11.550	11.177	-3.2%	0.000	0.166	

Table A.4: Comparison of Target Versus Measured Oxide Concentrations
(concentrations are expressed as weight percents)

Revision 0

Short Glass ID	Na ₂ O			Nd ₂ O ₃			NiO		
	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff
46	0.000	0.299		15.600	17.292	10.8%	0.000	0.038	
47	0.000	0.224		13.940	13.705	-1.7%	0.000	0.038	
48	0.000	0.197		10.620	10.906	2.7%	0.000	0.038	
49	0.000	0.246		12.280	12.626	2.8%	0.000	0.038	
50	0.005	0.266	5217.9%	13.940	14.376	3.1%	0.002	0.166	8187.2%
51	0.005	0.323	6350.2%	15.590	15.338	-1.6%	0.002	0.038	1808.8%
52	0.005	0.218	4267.5%	10.620	11.002	3.6%	0.002	0.038	1808.8%
53	0.005	0.320	6296.3%	12.280	11.705	-4.7%	0.002	0.038	1808.8%
54	0.005	0.260	5103.3%	17.250	16.913	-2.0%	0.002	0.038	1808.8%
55	0.000	0.294		8.350	8.351	0.0%	0.000	0.038	
100	9.670	9.911	2.5%	5.960	6.039	1.3%	0.000	0.166	
(ARM)									
Min			0.4%			-15.4%			2.1%
Avg			3891.1%			-0.5%			2570.7%
Max			6350.2%			51.5%			8187.2%

Table A.4: Comparison of Target Versus Measured Oxide Concentrations
(concentrations are expressed as weight percents)

Revision 0

Short Glass ID	Pr ₂ O ₃			SiO ₂			Sm ₂ O ₃		
	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff
0 (EA)	0.000	0.061		48.730	48.571	-0.3%	0.000	0.061	
1	7.300	7.815	7.1%	21.900	22.463	2.6%	2.000	2.006	0.3%
2	7.300	7.554	3.5%	16.100	16.649	3.4%	2.000	1.922	-3.9%
3	2.900	3.929	35.5%	16.100	17.382	8.0%	2.000	1.815	-9.3%
4	7.300	6.993	-4.2%	16.100	16.767	4.1%	5.000	4.607	-7.9%
5	2.900	3.008	3.7%	22.900	22.463	-1.9%	5.000	4.691	-6.2%
6	2.900	3.291	13.5%	16.100	17.093	6.2%	5.000	5.047	0.9%
7	2.900	3.028	4.4%	22.900	24.014	4.9%	2.000	1.974	-1.3%
8	7.300	7.232	-0.9%	21.600	23.324	8.0%	5.000	4.836	-3.3%
9	7.300	7.943	8.8%	16.100	16.558	2.8%	5.000	5.149	3.0%
10	2.900	3.724	28.4%	22.800	22.837	0.2%	5.000	4.995	-0.1%
11	2.900	3.970	36.9%	16.100	17.291	7.4%	5.000	5.363	7.3%
12	7.300	6.981	-4.4%	22.900	24.976	9.1%	2.000	2.047	2.3%
13	7.300	6.606	-9.5%	22.900	23.051	0.7%	5.000	4.722	-5.6%
14	7.300	6.685	-8.4%	16.100	15.842	-1.6%	2.000	1.948	-2.6%
15	2.900	2.902	0.1%	22.900	23.372	2.1%	2.000	1.937	-3.2%
16	2.900	3.139	8.3%	16.100	16.216	0.7%	2.000	1.855	-7.2%
17	5.040	5.179	2.7%	19.410	19.954	2.8%	3.470	3.377	-2.7%
18	2.200	3.201	45.5%	16.100	15.927	-1.1%	5.800	5.514	-4.9%
19	2.500	3.742	49.7%	22.900	23.746	3.7%	1.500	1.316	-12.3%
20	8.500	8.321	-2.1%	16.100	15.788	-1.9%	1.500	1.392	-7.2%
21	2.200	5.378	144.4%	16.100	15.847	-1.6%	5.800	5.520	-4.8%
22	8.300	8.087	-2.6%	22.900	25.083	9.5%	5.800	6.520	12.4%
23	8.500	7.388	-13.1%	16.100	16.307	1.3%	1.500	1.478	-1.4%
24	2.200	2.560	16.4%	16.100	17.088	6.1%	1.500	1.580	5.3%
25	2.200	2.490	13.2%	16.100	17.093	6.2%	5.800	5.549	-4.3%
26	2.200	2.496	13.4%	22.900	24.281	6.0%	5.800	5.728	-1.2%
27	8.500	8.558	0.7%	22.900	23.479	2.5%	5.800	5.615	-3.2%
28	8.500	8.684	2.2%	16.100	16.114	0.1%	1.500	1.481	-1.2%
29	8.500	8.447	-0.6%	16.100	17.478	8.6%	5.800	5.230	-9.8%
30	2.200	2.469	12.2%	22.900	24.067	5.1%	1.500	1.629	8.6%
31	2.200	2.466	12.1%	22.900	23.586	3.0%	1.500	1.534	2.2%
32	5.280	5.694	7.8%	19.430	21.072	8.5%	3.640	3.499	-3.9%
33	4.890	4.822	-1.4%	19.530	19.446	-0.4%	3.310	3.247	-1.9%
34	5.010	4.725	-5.7%	19.200	21.430	11.6%	3.380	2.412	-28.6%
35	5.120	4.953	-3.3%	18.860	18.671	-1.0%	3.460	3.421	-1.1%
36	5.240	5.258	0.3%	18.520	19.002	2.6%	3.540	3.386	-4.3%
37	5.350	5.486	2.5%	18.190	18.596	2.2%	3.620	3.545	-2.1%
38	5.470	5.641	3.1%	17.850	17.922	0.4%	3.700	3.630	-1.9%
39	5.590	6.036	8.0%	17.510	17.772	1.5%	3.780	3.893	3.0%
40	5.700	6.244	9.5%	17.180	18.008	4.8%	3.860	3.943	2.1%
41	5.820	5.857	0.6%	16.840	16.719	-0.7%	3.940	3.772	-4.3%
42	3.720	3.871	4.1%	22.900	23.318	1.8%	2.520	2.557	1.5%
43	4.310	4.354	1.0%	21.220	21.243	0.1%	2.910	2.899	-0.4%
44	6.050	5.734	-5.2%	16.170	18.216	12.7%	4.090	3.812	-6.8%
45	4.070	5.038	23.8%	19.530	20.650	5.7%	2.760	2.812	1.9%

Table A.4: Comparison of Target Versus Measured Oxide Concentrations
(concentrations are expressed as weight percents)

Revision 0

Short Glass ID	Pr ₂ O ₃			SiO ₂			Sm ₂ O ₃		
	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff	Target	Meas	% Rel Diff
46	5.470	6.533	19.4%	17.850	16.943	-5.1%	3.700	4.175	12.8%
47	4.890	5.293	8.2%	19.530	19.698	0.9%	3.310	3.441	4.0%
48	3.720	4.070	9.4%	22.900	23.907	4.4%	2.520	2.792	10.8%
49	4.310	4.509	4.6%	21.220	21.061	-0.7%	2.910	2.853	-2.0%
50	4.890	5.351	9.4%	19.530	21.270	8.9%	3.310	3.511	6.1%
51	5.470	5.682	3.9%	17.850	17.959	0.6%	3.700	3.577	-3.3%
52	3.720	3.347	-10.0%	22.900	23.265	1.6%	2.520	2.418	-4.1%
53	4.310	4.348	0.9%	21.220	21.340	0.6%	2.910	2.722	-6.5%
54	6.050	5.849	-3.3%	16.170	16.478	1.9%	4.090	3.777	-7.6%
55	4.890	6.103	24.8%	19.550	20.088	2.8%	3.310	3.487	5.4%
100	0.000	0.176		46.500	46.316	-0.4%	0.000	0.099	
(ARM)									
Min			-13.1%			-5.1%			-28.6%
Avg			9.6%			3.0%			-1.7%
Max			144.4%			12.7%			12.8%

Table A.4: Comparison of Target Versus Measured Oxide Concentrations
(concentrations are expressed as weight percents)

Revision 0

Short Glass ID	SrO			Sum of Oxides		Total Lanthanides		
	Target	Meas	% Rel Diff	Target	Meas	Target	Meas	% Rel Diff.
0 (EA)	0.000	0.022		91.36	95.67	0.420	1.384	229.6%
1	1.400	1.431	2.2%	100.00	103.57	58.300	60.585	3.9%
2	1.400	1.416	1.2%	100.00	101.81	56.200	57.143	1.7%
3	2.000	2.049	2.4%	100.00	106.54	60.700	65.359	7.7%
4	2.000	2.028	1.4%	100.00	103.04	63.500	65.690	3.4%
5	2.000	2.043	2.1%	100.00	99.39	51.600	51.378	-0.4%
6	1.400	1.422	1.6%	100.00	105.95	61.300	64.482	5.2%
7	1.400	1.449	3.5%	100.00	100.72	52.200	50.939	-2.4%
8	2.000	2.040	2.0%	100.00	102.14	52.900	52.855	-0.1%
9	1.400	1.437	2.6%	100.00	104.45	64.100	67.101	4.7%
10	2.000	2.067	3.3%	100.00	100.51	54.000	54.184	0.3%
11	1.400	1.393	-0.5%	100.00	105.26	59.000	61.935	5.0%
12	2.000	1.996	-0.2%	100.00	106.00	56.700	59.161	4.3%
13	1.400	1.437	2.6%	100.00	98.91	49.400	48.123	-2.6%
14	2.000	2.052	2.6%	100.00	98.06	55.600	53.679	-3.5%
15	1.400	1.431	2.2%	100.00	98.42	54.500	52.070	-4.5%
16	2.000	2.049	2.4%	100.00	100.12	58.400	57.942	-0.8%
17	1.700	1.715	0.9%	100.01	100.41	56.640	55.935	-1.2%
18	2.000	2.117	5.8%	100.00	98.92	63.500	62.695	-1.3%
19	2.000	2.108	5.4%	100.00	104.10	53.900	56.536	4.9%
20	1.400	1.422	1.6%	100.00	96.71	64.100	61.467	-4.1%
21	2.000	2.013	0.7%	100.00	98.97	55.600	57.428	3.3%
22	2.000	1.928	-3.6%	100.00	108.34	53.900	57.909	7.4%
23	2.000	2.049	2.4%	100.00	97.83	58.400	55.913	-4.3%
24	1.400	1.440	2.8%	100.00	105.05	61.300	63.504	3.6%
25	2.000	2.013	0.7%	100.00	104.71	58.400	60.934	4.3%
26	1.400	1.452	3.7%	100.00	103.30	52.200	53.285	2.1%
27	1.400	1.443	3.1%	100.00	101.11	52.900	53.021	0.2%
28	2.000	1.990	-0.5%	100.00	100.41	55.600	55.943	0.6%
29	1.400	1.425	1.8%	100.00	106.62	61.300	64.091	4.6%
30	1.400	1.419	1.4%	100.00	105.08	49.400	51.106	3.5%
31	2.000	2.075	3.8%	100.00	103.35	56.700	58.222	2.7%
32	1.700	1.741	2.4%	100.00	106.99	56.560	60.427	6.8%
33	1.690	1.735	2.7%	99.91	97.78	56.420	54.216	-3.9%
34	1.660	1.836	10.6%	99.92	101.71	57.160	53.575	-6.3%
35	1.630	1.659	1.8%	99.92	97.75	57.920	55.925	-3.4%
36	1.600	1.635	2.2%	99.91	99.77	58.660	57.131	-2.6%
37	1.570	1.608	2.4%	99.92	100.93	59.420	59.364	-0.1%
38	1.540	1.594	3.5%	99.91	100.10	60.160	59.881	-0.5%
39	1.510	1.493	-1.1%	99.91	102.58	60.920	62.512	2.6%
40	1.480	1.446	-2.3%	99.92	103.22	61.670	63.315	2.7%
41	1.460	1.484	1.7%	99.93	98.93	62.420	61.056	-2.2%
42	1.980	2.028	2.4%	99.95	101.30	48.950	49.043	0.2%
43	1.830	1.886	3.1%	99.94	100.62	52.690	52.699	0.0%
44	1.400	1.588	13.4%	99.91	101.30	63.900	60.406	-5.5%
45	1.690	1.697	0.4%	99.92	103.18	56.430	57.220	1.4%

Table A.4: Comparison of Target Versus Measured Oxide Concentrations
(concentrations are expressed as weight percents)

Revision 0

Short Glass ID	SrO			Sum of Oxides		Total Lanthanides		
	Target	Meas	% Rel Diff	Target	Meas	Target	Meas	% Rel Diff.
46	1.540	1.440	-6.5%	99.93	104.16	60.170	65.884	9.5%
47	1.690	1.756	3.9%	99.91	102.18	56.420	57.886	2.6%
48	1.980	2.028	2.4%	99.95	105.92	48.950	51.415	5.0%
49	1.830	1.842	0.7%	99.94	100.10	52.690	52.495	-0.4%
50	1.690	1.706	0.9%	99.97	107.12	56.420	59.648	5.7%
51	1.540	1.564	1.6%	99.97	100.12	60.160	59.825	-0.6%
52	1.980	2.105	6.3%	100.01	96.86	48.950	45.013	-8.0%
53	1.830	1.818	-0.6%	100.00	99.27	52.690	51.025	-3.2%
54	1.400	1.428	2.0%	99.97	99.42	63.900	62.129	-2.8%
55	1.690	1.715	1.5%	100.02	105.07	56.480	59.872	6.0%
100	0.450	0.492	9.3%	83.14	89.02	7.400	11.273	52.3%
(ARM)								
Min			-6.5%					-8.0%
Avg			2.2%					5.9%
Max			13.4%					229.6%

CaO By Glass #

Cr₂O₃ By Glass #

Fe₂O₃ By Glass #

MnO By Glass #

NiO By Glass

SrO By Glass

Al₂O₃ By Glass #

B₂O₃ By Glass #

Ce₂O₃ By Glass #

Er₂O₃ By Glass #

Eu₂O₃ By Glass #

Gd₂O₃ By Glass #

La_2O_3 By Glass #

Nd_2O_3 By Glass #

Pr₂O₃ By Glass

SiO₂ By Glass

Sm₂O₃ By Glass #

K_2O By Glass

Na_2O By Glass

**Oneway Anova
Summary of Fit**

RSquare	0.859589
RSquare Adj	0.727954
Root Mean Square Error	0.33186
Mean of Response	10.265
Observations (or Sum Wgts)	32

Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	15	10.787500	0.719167	6.5301
Error	16	1.762100	0.110131	Prob>F
C Total	31	12.549600	0.404826	0.0003

Means for Oneway Anova			
Level	Number	Mean	Std Error
1-1	2	10.0800	0.23466
1-2	2	8.6600	0.23466
2-1	2	10.3500	0.23466
2-2	2	10.4000	0.23466
3-1	2	10.1350	0.23466
3-2	2	11.0500	0.23466
4-1	2	10.8500	0.23466
4-2	2	10.2000	0.23466
5-1	2	10.6000	0.23466
5-2	2	9.9500	0.23466
6-1	2	10.1000	0.23466
6-2	2	10.0550	0.23466
7-1	2	10.8000	0.23466
7-2	2	11.2000	0.23466
8-1	2	9.7100	0.23466
8-2	2	10.1000	0.23466

Std Error uses a pooled estimate of error variance

**Oneway Anova
Summary of Fit**

RSquare	0.810786
RSquare Adj	0.633399
Root Mean Square Error	0.119726
Mean of Response	3.056563
Observations (or Sum Wgts)	32

Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	15	0.9827719	0.065518	4.5707
Error	16	0.2293500	0.014334	Prob>F
C Total	31	1.2121219	0.039101	0.0022

Means for Oneway Anova			
Level	Number	Mean	Std Error
1-1	2	2.84500	0.08466
1-2	2	3.02000	0.08466
2-1	2	3.05500	0.08466
2-2	2	3.05500	0.08466
3-1	2	3.01500	0.08466
3-2	2	3.21500	0.08466
4-1	2	3.13000	0.08466
4-2	2	3.10500	0.08466
5-1	2	2.79000	0.08466
5-2	2	2.91500	0.08466
6-1	2	2.80000	0.08466
6-2	2	3.07500	0.08466
7-1	2	3.33500	0.08466
7-2	2	3.47500	0.08466
8-1	2	3.03000	0.08466
8-2	2	3.04500	0.08466

Std Error uses a pooled estimate of error variance

**Oneway Anova
Summary of Fit**

RSquare	0.786257
RSquare Adj	0.585873
Root Mean Square Error	0.199319
Mean of Response	5.079687
Observations (or Sum Wgts)	32

Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	15	2.3382469	0.155883	3.9237
Error	16	0.6356500	0.039728	Prob>F
C Total	31	2.9738969	0.095932	0.0050

Means for Oneway Anova			
Level	Number	Mean	Std Error
1-1	2	5.17500	0.14094
1-2	2	4.54500	0.14094
2-1	2	5.17000	0.14094
2-2	2	5.31500	0.14094
3-1	2	4.76000	0.14094
3-2	2	5.20500	0.14094
4-1	2	5.09500	0.14094
4-2	2	5.15000	0.14094
5-1	2	5.40500	0.14094
5-2	2	4.96000	0.14094
6-1	2	4.75500	0.14094
6-2	2	5.07500	0.14094
7-1	2	5.33000	0.14094
7-2	2	5.61500	0.14094
8-1	2	4.95000	0.14094
8-2	2	4.77000	0.14094

Std Error uses a pooled estimate of error variance

**Oneway Anova
Summary of Fit**

RSquare	0.89583
RSquare Adj	0.79817
Root Mean Square Error	0.129494
Mean of Response	4.114375
Observations (or Sum Wgts)	32

Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	15	2.3072875	0.153819	9.1730
Error	16	0.2683000	0.016769	Prob>F
C Total	31	2.5755875	0.083083	<.0001

Means for Oneway Anova			
Level	Number	Mean	Std Error
1-1	2	4.01500	0.09157
1-2	2	3.57000	0.09157
2-1	2	4.05000	0.09157
2-2	2	4.00000	0.09157
3-1	2	4.01000	0.09157
3-2	2	4.18000	0.09157
4-1	2	4.42500	0.09157
4-2	2	4.26500	0.09157
5-1	2	4.26000	0.09157
5-2	2	3.90000	0.09157
6-1	2	3.98500	0.09157
6-2	2	4.02000	0.09157
7-1	2	4.34000	0.09157
7-2	2	4.81000	0.09157
8-1	2	3.85500	0.09157
8-2	2	4.14500	0.09157

Std Error uses a pooled estimate of error variance

Eu By Block—Reference Value is 1 wt %

Oneway Anova Summary of Fit

RSquare	0.887409
RSquare Adj	0.781856
Root Mean Square Error	0.034316
Mean of Response	1.024656
Observations (or Sum Wgts)	32

Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	15	0.14850372	0.009900	8.4072
Error	16	0.01884150	0.001178	Prob>F
C Total	31	0.16734522	0.005398	<.0001

Means for Oneway Anova			
Level	Number	Mean	Std Error
1-1	2	0.98550	0.02427
1-2	2	0.90800	0.02427
2-1	2	1.01000	0.02427
2-2	2	1.04000	0.02427
3-1	2	1.01600	0.02427
3-2	2	1.00100	0.02427
4-1	2	1.03500	0.02427
4-2	2	1.05500	0.02427
5-1	2	1.06000	0.02427
5-2	2	0.98600	0.02427
6-1	2	0.99950	0.02427
6-2	2	0.96150	0.02427
7-1	2	1.05500	0.02427
7-2	2	1.24000	0.02427
8-1	2	0.98700	0.02427
8-2	2	1.05500	0.02427

Std Error uses a pooled estimate of error variance

**Oneway Anova
Summary of Fit**

RSquare	0.818724
RSquare Adj	0.648778
Root Mean Square Error	0.070267
Mean of Response	2.075
Observations (or Sum Wgts)	32

Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	15	0.35680000	0.023787	4.8176
Error	16	0.07900000	0.004937	Prob>F
C Total	31	0.43580000	0.014058	0.0017

Means for Oneway Anova			
Level	Number	Mean	Std Error
1-1	2	2.06500	0.04969
1-2	2	2.01000	0.04969
2-1	2	2.04000	0.04969
2-2	2	2.19500	0.04969
3-1	2	1.96500	0.04969
3-2	2	2.07000	0.04969
4-1	2	2.04000	0.04969
4-2	2	2.06000	0.04969
5-1	2	2.23000	0.04969
5-2	2	2.02500	0.04969
6-1	2	1.95000	0.04969
6-2	2	1.98000	0.04969
7-1	2	2.17000	0.04969
7-2	2	2.35000	0.04969
8-1	2	1.98000	0.04969
8-2	2	2.07000	0.04969

Std Error uses a pooled estimate of error variance

**Oneway Anova
Summary of Fit**

RSquare	0.927133
RSquare Adj	0.858819
Root Mean Square Error	0.451387
Mean of Response	20.55625
Observations (or Sum Wgts)	32

Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	15	41.478750	2.76525	13.5718
Error	16	3.260000	0.20375	Prob>F
C Total	31	44.738750	1.44319	<.0001

Means for Oneway Anova			
Level	Number	Mean	Std Error
1-1	2	20.5500	0.31918
1-2	2	17.6000	0.31918
2-1	2	20.7000	0.31918
2-2	2	21.4500	0.31918
3-1	2	19.5000	0.31918
3-2	2	21.0500	0.31918
4-1	2	20.8500	0.31918
4-2	2	20.9000	0.31918
5-1	2	22.5000	0.31918
5-2	2	19.9000	0.31918
6-1	2	20.0500	0.31918
6-2	2	20.3000	0.31918
7-1	2	20.3500	0.31918
7-2	2	22.7500	0.31918
8-1	2	20.3000	0.31918
8-2	2	20.1500	0.31918

Std Error uses a pooled estimate of error variance

**Oneway Anova
Summary of Fit**

RSquare	0.716462
RSquare Adj	0.450645
Root Mean Square Error	0.386491
Mean of Response	9.87
Observations (or Sum Wgts)	32

Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	15	6.0392000	0.402613	2.6953
Error	16	2.3900000	0.149375	Prob>F
C Total	31	8.4292000	0.271910	0.0289

Means for Oneway Anova			
Level	Number	Mean	Std Error
1-1	2	9.7350	0.27329
1-2	2	10.1800	0.27329
2-1	2	10.0500	0.27329
2-2	2	10.2150	0.27329
3-1	2	9.0850	0.27329
3-2	2	10.1000	0.27329
4-1	2	10.0300	0.27329
4-2	2	10.3500	0.27329
5-1	2	10.0400	0.27329
5-2	2	9.6700	0.27329
6-1	2	9.5800	0.27329
6-2	2	9.7500	0.27329
7-1	2	10.0000	0.27329
7-2	2	10.6500	0.27329
8-1	2	8.8900	0.27329
8-2	2	9.5950	0.27329

Std Error uses a pooled estimate of error variance

Oneway Anova**Summary of Fit**

RSquare	0.84289
RSquare Adj	0.695599
Root Mean Square Error	0.179757
Mean of Response	4.268125
Observations (or Sum Wgts)	32

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	15	2.7736875	0.184913	5.7226
Error	16	0.5170000	0.032312	Prob>F
C Total	31	3.2906875	0.106151	0.0006

Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	2	4.20000	0.12711
1-2	2	3.55000	0.12711
2-1	2	4.32000	0.12711
2-2	2	4.33500	0.12711
3-1	2	4.06000	0.12711
3-2	2	4.41500	0.12711
4-1	2	4.42000	0.12711
4-2	2	4.30500	0.12711
5-1	2	4.59500	0.12711
5-2	2	4.07000	0.12711
6-1	2	3.98000	0.12711
6-2	2	4.37000	0.12711
7-1	2	4.34000	0.12711
7-2	2	4.98000	0.12711
8-1	2	4.15000	0.12711
8-2	2	4.20000	0.12711

Std Error uses a pooled estimate of error variance

**Oneway Anova
Summary of Fit**

RSquare	0.780594
RSquare Adj	0.574901
Root Mean Square Error	0.343261
Mean of Response	10.16344
Observations (or Sum Wgts)	32

Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	15	6.7072719	0.447151	3.7949
Error	16	1.8852500	0.117828	Prob>F
C Total	31	8.5925219	0.277178	0.0059

Means for Oneway Anova			
Level	Number	Mean	Std Error
1-1	2	9.6500	0.24272
1-2	2	9.8600	0.24272
2-1	2	9.6550	0.24272
2-2	2	10.2500	0.24272
3-1	2	9.6650	0.24272
3-2	2	10.9500	0.24272
4-1	2	10.6000	0.24272
4-2	2	10.0150	0.24272
5-1	2	10.7000	0.24272
5-2	2	9.8650	0.24272
6-1	2	9.8400	0.24272
6-2	2	10.0600	0.24272
7-1	2	10.6500	0.24272
7-2	2	11.0500	0.24272
8-1	2	9.8800	0.24272
8-2	2	9.9250	0.24272

Std Error uses a pooled estimate of error variance

**Oneway Anova
Summary of Fit**

RSquare	0.793145
RSquare Adj	0.599218
Root Mean Square Error	0.132169
Mean of Response	3.025625
Observations (or Sum Wgts)	32

Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	15	1.0716875	0.071446	4.0899
Error	16	0.2795000	0.017469	Prob>F
C Total	31	1.3511875	0.043587	0.0040

Means for Oneway Anova			
Level	Number	Mean	Std Error
1-1	2	2.99500	0.09346
1-2	2	2.59500	0.09346
2-1	2	2.94000	0.09346
2-2	2	3.14500	0.09346
3-1	2	2.85500	0.09346
3-2	2	3.10500	0.09346
4-1	2	3.20500	0.09346
4-2	2	3.08500	0.09346
5-1	2	3.30000	0.09346
5-2	2	3.01500	0.09346
6-1	2	2.82500	0.09346
6-2	2	3.15500	0.09346
7-1	2	2.98500	0.09346
7-2	2	3.34500	0.09346
8-1	2	2.89500	0.09346
8-2	2	2.96500	0.09346

Std Error uses a pooled estimate of error variance

≡ Paired t-Test

Paired t-Test

Target (wt%) - Measured (wt%)

Mean Difference	-0.40587	Prob > t	<.0001
Std Error	0.085468	Prob > t	1.0000
t-Ratio	-4.7488	Prob < t	<.0001
DF	56

≡ Paired t-Test

Paired t-Test

Target (wt%) - Measured (wt%)

Mean Difference	0.140035	Prob > t	0.0110
Std Error	0.053218	Prob > t	0.0055
t-Ratio	2.631354	Prob < t	0.9945
DF	56		

Appendix A

Exhibit A.5: Paired Comparisons By Oxide Using All Test Glasses

WSRC-TR-99-00393
Revision 0

≡ Paired t-Test

Paired t-Test

Target (wt%) - Measured (wt%)			
Mean Difference	-0.03422	Prob > t	<.0001
Std Error	0.002064	Prob > t	1.0000
t-Ratio	-16.577	Prob < t	<.0001
DF	56

≡ Paired t-Test

Paired t-Test

Target (wt%) - Measured (wt%)			
Mean Difference	0.02304	Prob > t	0.8262
Std Error	0.104414	Prob > t	0.4131
t-Ratio	0.220663	Prob < t	0.5869
DF	56

≡ Paired t-Test

Paired t-Test

Target (wt%) - Measured (wt%)			
Mean Difference	-0.23076	Prob > t	0.0087
Std Error	0.084889	Prob > t	0.9956
t-Ratio	-2.71844	Prob < t	0.0044
DF	56

≡ Paired t-Test

Paired t-Test

Target (wt%) - Measured (wt%)			
Mean Difference	-0.01575	Prob > t	0.0354
Std Error	0.007309	Prob > t	0.9823
t-Ratio	-2.15541	Prob < t	0.0177
DF	56

Paired t-Test

Target (wt%) - Measured (wt%)			
Mean Difference	-0.03271	Prob > t	<.0001
Std Error	0.001652	Prob > t	1.0000
t-Ratio	-19.8029	Prob < t	<.0001
DF	56

Paired t-Test

Target (wt%) - Measured (wt%)			
Mean Difference	-0.02996	Prob > t	0.2518
Std Error	0.025872	Prob > t	0.8741
t-Ratio	-1.1579	Prob < t	0.1259
DF	56		

La₂O₃
Measured (wt%) By Target (wt%)

≡ Paired t-Test

Paired t-Test

Target (wt%) - Measured (wt%)

Mean Difference	-0.33532	Prob > t	0.0119
Std Error	0.129	Prob > t	0.9940
t-Ratio	-2.59936	Prob < t	0.0060
DF	56		

Na₂O
Measured (wt%) By Target (wt%)

≡ Paired t-Test

Paired t-Test

Target (wt%) - Measured (wt%)

Mean Difference	-0.26663	Prob > t	<.0001
Std Error	0.010556	Prob > t	1.0000
t-Ratio	-25.2598	Prob < t	<.0001
DF	56

Paired t-Test

Target (wt%) - Measured (wt%)	
Mean Difference	0.173125
Std Error	0.117648
t-Ratio	1.471553
DF	56

Prob > t	0.1467
Prob > t	0.0734
Prob < t	0.9266

Paired t-Test

Target (wt%) - Measured (wt%)	
Mean Difference	-0.25646
Std Error	0.080968
t-Ratio	-3.16743
DF	56

Prob > t	0.0025
Prob > t	0.9988
Prob < t	0.0012

≡ Paired t-Test

Paired t-Test

Target (wt%) - Measured (wt%)

Mean Difference	-0.57904	Prob > t	<.0001
Std Error	0.095674	Prob > t	1.0000
t-Ratio	-6.05225	Prob < t	<.0001
DF	56

≡ Paired t-Test

Paired t-Test

Target (wt%) - Measured (wt%)

Mean Difference	0.056892	Prob > t	0.0810
Std Error	0.032017	Prob > t	0.0405
t-Ratio	1.776931	Prob < t	0.9595
DF	56		

Appendix A

Exhibit A.5: Paired Comparisons By Oxide Using All Test Glasses

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≡ Paired t-Test

Paired t-Test

Target (wt%) - Measured (wt%)			
Mean Difference	-0.03567	Prob > t	<.0001
Std Error	0.006115	Prob > t	1.0000
t-Ratio	-5.83249	Prob < t	<.0001
DF	56

≡ Paired t-Test

Paired t-Test

Target (wt%) - Measured (wt%)			
Mean Difference	-0.6152	Prob > t	0.0436
Std Error	0.298001	Prob > t	0.9782
t-Ratio	-2.06441	Prob < t	0.0218
DF	56		

Sum of Oxides
Measured (wt%) By Target (wt%)

≡ Paired t-Test

Paired t-Test

Target (wt%) - Measured (wt%)

Mean Difference	-2.065	Prob > t <.0001
Std Error	0.394912	Prob > t 1.0000
t-Ratio	-5.22903	Prob < t <.0001
DF	56

Paired t-Test

Paired t-Test

Target (wt%) - Measured (wt%)			
Mean Difference	-0.40755	Prob > t	<.0001
Std Error	0.088099	Prob > t	1.0000
t-Ratio	-4.62612	Prob < t	<.0001
DF	54

Paired t-Test

Paired t-Test

Target (wt%) - Measured (wt%)			
Mean Difference	0.156794	Prob > t	0.0043
Std Error	0.052599	Prob > t	0.0022
t-Ratio	2.980953	Prob < t	0.9978
DF	54

Paired t-Test

Paired t-Test

Target (wt%) - Measured (wt%)			
Mean Difference	0.024247	Prob > t	0.8236
Std Error	0.108233	Prob > t	0.4118
t-Ratio	0.224021	Prob < t	0.5882
DF	54

Paired t-Test

Paired t-Test

Target (wt%) - Measured (wt%)			
Mean Difference	-0.16685	Prob > t	0.0138
Std Error	0.065512	Prob > t	0.9931
t-Ratio	-2.54683	Prob < t	0.0069
DF	54		

Appendix A

Exhibit A.6: Paired Comparisons By Oxide Using Only Am/Cm Phase 2 Glasses

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≡ Paired t-Test

Paired t-Test

Target (wt%) - Measured (wt%)			
Mean Difference	-0.01422	Prob > t	0.0631
Std Error	0.007495	Prob > t	0.9684
t-Ratio	-1.89747	Prob < t	0.0316
DF	54

≡ Paired t-Test

Paired t-Test

Target (wt%) - Measured (wt%)			
Mean Difference	-0.02895	Prob > t	0.2850
Std Error	0.026811	Prob > t	0.8575
t-Ratio	-1.0798	Prob < t	0.1425
DF	54		

La₂O₃
Measured (wt%) By Target (wt%)

Paired t-Test

Target (wt%) - Measured (wt%)

Mean Difference	-0.34616	Prob > t	0.0122
Std Error	0.1335	Prob > t	0.9939
t-Ratio	-2.59298	Prob < t	0.0061
DF	54		

Nd₂O₃
Measured (wt%) By Target (wt%)

Paired t-Test

Target (wt%) - Measured (wt%)

Mean Difference	0.181918	Prob > t	0.1411
Std Error	0.121798	Prob > t	0.0705
t-Ratio	1.493605	Prob < t	0.9295
DF	54

Paired t-Test

Paired t-Test

Target (wt%) - Measured (wt%)			
Mean Difference	-0.26148	Prob > t	0.0029
Std Error	0.083847	Prob > t	0.9985
t-Ratio	-3.11848	Prob < t	0.0015
DF	54

Paired t-Test

Paired t-Test

Target (wt%) - Measured (wt%)			
Mean Difference	-0.60634	Prob > t	<.0001
Std Error	0.097183	Prob > t	1.0000
t-Ratio	-6.23918	Prob < t	<.0001
DF	54		

Appendix A

Exhibit A.6: Paired Comparisons By Oxide Using Only Am/Cm Phase 2 Glasses

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Paired t-Test

Target (wt%) - Measured (wt%)

Mean Difference	0.061879	Prob > t	0.0661
Std Error	0.03299	Prob > t	0.0331
t-Ratio	1.875681	Prob < t	0.9669
DF	54

Paired t-Test

Target (wt%) - Measured (wt%)

Mean Difference	-0.03579	Prob > t	<.0001
Std Error	0.006334	Prob > t	1.0000
t-Ratio	-5.65089	Prob < t	<.0001
DF	54		

**Sum of Lanthanides
Measured (wt%) By Target (wt%)**

Paired t-Test

Target (wt%) - Measured (wt%)

Mean Difference	-0.54961	Prob > t	0.0752
Std Error	0.302899	Prob > t	0.9624
t-Ratio	-1.81451	Prob < t	0.0376
DF	54		

**Sum of Oxides
Measured (wt%) By Target (wt%)**

Paired t-Test

Target (wt%) - Measured (wt%)

Mean Difference	-1.9547	Prob > t	<.0001
Std Error	0.400968	Prob > t	1.0000
t-Ratio	-4.87495	Prob < t	<.0001
DF	54		

Al_2O_3

B_2O_3

CaO

Ce₂O₃

Cr₂O₃

Er₂O₃

Appendix A

WSRC-TR-99-00393
Revision 0

Exhibit A.7: Target Versus Measured Compositions by Glass by Oxide

Gd₂O₃

K₂O

Na_2O

Nd_2O_3

Exhibit A.7: Target Versus Measured Compositions by Glass by Oxide

NiO

Pr₂O₃

Appendix A

Exhibit A.7: Target Versus Measured Compositions by Glass by Oxide

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Revision 0

SiO_2

Sm_2O_3

SrO

Sum of Lanthanides

Repeatability Standard Deviation 0.50631
Overall Mean of Response 15.23482
Repeatability—% Relative Std Dev 3.3%

Repeatability Standard Deviation 0.424268
Overall Mean of Response 7.934577
Repeatability—% Relative Std Dev 5.3%

Repeatability Standard Deviation 0.023081
 Overall Mean of Response 0.038047
 Repeatability—% Relative Std Dev 60.7%

Repeatability Standard Deviation 0.466565
 Overall Mean of Response 1.227999
 Repeatability—% Relative Std Dev 38.0%

Repeatability Standard Deviation 0
 Overall Mean of Response 0.021924
 Repeatability—% Relative Std Dev —All values at detection limit.

Repeatability Standard Deviation 0.185721
 Overall Mean of Response 4.934422
 Repeatability—% Relative Std Dev 3.8%

Repeatability Standard Deviation 0.042217
 Overall Mean of Response 0.805342
 Repeatability—% Relative Std Dev 5.2%

Repeatability Standard Deviation 0.030796
 Overall Mean of Response 0.049022
 Repeatability—% Relative Std Dev 62.8%

Repeatability Standard Deviation 0.103954
Overall Mean of Response 1.79052
Repeatability—% Relative Std Dev 5.8%

Repeatability Standard Deviation 0
Overall Mean of Response 0.090345
Repeatability—% Relative Std Dev —All values at detection limit.

Repeatability Standard Deviation 0.744335
 Overall Mean of Response 21.09912
 Repeatability—% Relative Std Dev 3.5%

Repeatability Standard Deviation 0.012366
 Overall Mean of Response 0.023679
 Repeatability—% Relative Std Dev 52.2%

Repeatability Standard Deviation 0.092961
 Overall Mean of Response 0.267837
 Repeatability—% Relative Std Dev 34.7%

Repeatability Standard Deviation 0.655406
 Overall Mean of Response 13.22384
 Repeatability—% Relative Std Dev 5.0%

Repeatability Standard Deviation 0.036826
 Overall Mean of Response 0.047988
 Repeatability—% Relative Std Dev 76.7%

Repeatability Standard Deviation 0.242715
 Overall Mean of Response 4.83604
 Repeatability—% Relative Std Dev 5.0%

Repeatability Standard Deviation 0.68545
Overall Mean of Response 20.39411
Repeatability—% Relative Std Dev 3.4%

Repeatability Standard Deviation 0.126304
Overall Mean of Response 3.171952
Repeatability—% Relative Std Dev 4.0%

Repeatability Standard Deviation 0.050966
 Overall Mean of Response 1.775265
 Repeatability—% Relative Std Dev 2.9%

Repeatability Standard Deviation 3.306779
 Overall Mean of Response 100.93
 Repeatability—% Relative Std Dev 3.3%

Repeatability Standard Deviation 0.68545
Overall Mean of Response 20.39411
Repeatability—% Relative Std Dev 3.4%

Repeatability Standard Deviation 0.126304
Overall Mean of Response 3.171952
Repeatability—% Relative Std Dev 4.0%

Repeatability Standard Deviation 0.050966
 Overall Mean of Response 1.775265
 Repeatability—% Relative Std Dev 2.9%

Repeatability Standard Deviation 3.306779
 Overall Mean of Response 100.93
 Repeatability—% Relative Std Dev 3.3%

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Appendix B – Homogeneity as Defined by X-Ray Diffraction Analysis
For the Phase 2 Glasses

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Figure B.1. XRD Analysis of AC2-01.

Figure B.2. XRD Analysis of AC2-02.

Figure B.3. XRD Analysis of AC2-03.

Figure B.4. XRD Analysis of AC2-04.

Figure B.5. XRD Analysis of AC2-05.

Figure B.6. XRD Analysis of AC2-06.

Figure B.7. XRD Analysis of AC2-07.

Figure B.8. XRD Analysis of AC2-08.

Figure B.9. XRD Analysis of AC2-09.

Figure B.10. XRD Analysis of AC2-10.

Figure B.11. XRD Analysis of AC2-11.

Figure B.12. XRD Analysis of AC2-12.

Figure B.13. XRD Analysis of AC2-13.

Figure B.14. XRD Analysis of AC2-14.

Figure B.15. XRD Analysis of AC2-15.

Figure B.16. XRD Analysis of AC2-16.

Figure B.17. XRD Analysis of AC2-17.

Figure B.18. XRD Analysis of AC2-18.

Figure B.19. XRD Analysis of AC2-19.

Figure B.20. XRD Analysis of AC2-20.

Figure B.21. XRD Analysis of AC2-21.

Figure B.22. XRD Analysis of AC2-22.

Figure B.23. XRD Analysis of AC2-23.

Figure B.24. XRD Analysis of AC2-24.

Figure B.25. XRD Analysis of AC2-25.

Figure B.26. XRD Analysis of AC2-26.

Figure B.27. XRD Analysis of AC2-27.

Figure B.28. XRD Analysis of AC2-28.

Figure B.29. XRD Analysis of AC2-29.

Figure B.30. XRD Analysis of AC2-30.
(* Although labeled on XRD plot as AC2-53, plot is actually
AC2-30 due to an inadvertent sample switch)

Figure B.29. XRD Analysis of AC2-29.

Figure B.30. XRD Analysis of AC2-30.
(* Although labeled on XRD plot as AC2-53, plot is actually
AC2-30 due to an inadvertent sample switch)

Figure B.31. XRD Analysis of AC2-31.

Figure B.32. XRD Analysis of AC2-32.

Figure B.33. XRD Analysis of AC2-33.

Figure B.34. XRD Analysis of AC2-34.

Figure B.35. XRD Analysis of AC2-35.

Figure B.36. XRD Analysis of AC2-36.

Figure B.37. XRD Analysis of AC2-37.

Figure B.38. XRD Analysis of AC2-38.

Figure B.39. XRD Analysis of AC2-39.

Figure B.40. XRD Analysis of AC2-40.

Figure B.41. XRD Analysis of AC2-41.

Figure B.42. XRD Analysis of AC2-42.

Figure B.43. XRD Analysis of AC2-43.

Figure B.44. XRD Analysis of AC2-44.

Figure B.45. XRD Analysis of AC2-45.

Figure B.46. XRD Analysis of AC2-46.

Figure B.47. XRD Analysis of AC2-47.

Figure B.48. XRD Analysis of AC2-48.

Figure B.49. XRD Analysis of AC2-49.

Figure B.50. XRD Analysis of AC2-50.

Figure B.51. XRD Analysis of AC2-51.

Figure B.52. XRD Analysis of AC2-52.

Figure B.53. XRD Analysis of AC2-53.
(*Although labeled on XRD plot as AC2-30, plot is actually
AC2-53 due to an inadvertent sample switch)

Figure B.54. XRD Analysis of AC2-54.

Figure B.54. XRD Analysis of AC2-55.

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Appendix C – PCT Raw Data and Analysis

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Appendix C

Table C.1: Measured Concentrations in PCT Leachate Solutions
(corrected for dilution factor and blanks)

WSRC-TR-99-00393

Revision 0

Block	Sequence	Glass ID	Glass #	Lab ID	Values are in Parts Per Million (ppm)							Values have been adjusted for dilution factor of 1.6667.						
					Al	B	Er	La	Nd	Si	Sr	Al (ppm)	B (ppm)	Er (ppm)	La (ppm)	Nd (ppm)	Si (ppm)	Sr (ppm)
1	1	std	0	stdb1-1	4.08	21.4	<0.100	<0.100	<0.180	51.9	<0.010	4.080	21.400	0.050	0.050	0.090	51.900	0.005
1	2	AC2-34	34	j088	<0.200	0.5	<0.100	0.18	<0.180	0.796	0.145	0.167	0.833	0.083	0.300	0.150	1.327	0.242
1	3	AC2-22	22	j035	<0.200	0.294	<0.100	0.185	<0.180	0.788	0.143	0.167	0.490	0.083	0.308	0.150	1.313	0.238
1	4	AC2-41	41	j058	<0.200	<0.180	<0.100	0.183	<0.180	0.543	0.088	0.167	0.150	0.083	0.305	0.150	0.905	0.147
1	5	AC2-01	1	j025	0.265	0.287	<0.100	<0.100	0.213	1.72	0.074	0.442	0.478	0.083	0.083	0.355	2.867	0.123
1	6	AC2-16	16	j036	<0.200	<0.180	<0.100	0.377	0.235	0.694	0.145	0.167	0.150	0.083	0.628	0.392	1.157	0.242
1	7	B	999	j052	<0.200	<0.180	<0.100	<0.100	<0.180	<0.180	<0.010	0.167	0.150	0.083	0.083	0.150	0.150	0.008
1	8	AC2-10	10	j076	<0.200	0.22	<0.100	0.216	<0.180	0.775	0.164	0.167	0.367	0.083	0.360	0.150	1.292	0.273
1	9	AC2-40	40	j038	<0.200	<0.180	<0.100	0.263	<0.180	0.565	0.091	0.167	0.150	0.083	0.438	0.150	0.942	0.152
1	10	AC2-43	43	j029	<0.200	<0.180	<0.100	0.232	<0.180	0.753	0.149	0.167	0.150	0.083	0.387	0.150	1.255	0.248
1	11	AC2-46	46	j010	<0.200	<0.180	<0.100	0.139	<0.180	0.54	0.087	0.167	0.150	0.083	0.232	0.150	0.900	0.145
1	12	std	0	stdb1-2	3.94	20.9	<0.100	<0.100	<0.180	51.1	<0.010	3.940	20.900	0.050	0.050	0.090	51.100	0.005
1	13	AC2-07	7	j102	<0.200	0.312	<0.100	0.288	<0.180	0.789	0.094	0.167	0.520	0.083	0.480	0.150	1.315	0.157
1	14	AC2-28	28	j054	<0.200	0.296	<0.100	0.173	<0.180	0.535	0.177	0.167	0.493	0.083	0.288	0.150	0.892	0.295
1	15	AC2-31	31	j171	<0.200	<0.180	<0.100	0.203	<0.180	0.7	0.113	0.167	0.150	0.083	0.338	0.150	1.167	0.188
1	16	AC2-52	52	j163	<0.200	0.26	<0.100	0.171	<0.180	0.854	0.171	0.167	0.433	0.083	0.285	0.150	1.423	0.285
1	17	AC2-25	25	j135	<0.200	<0.180	<0.100	<0.100	<0.180	0.517	0.133	0.167	0.150	0.083	0.083	0.150	0.862	0.222
1	18	AC2-19	19	j141	0.434	0.708	<0.100	<0.100	<0.180	4.65	0.108	0.723	1.180	0.083	0.083	0.150	7.750	0.180
1	19	AC2-49	49	j016	<0.200	0.215	<0.100	0.226	<0.180	0.774	0.159	0.167	0.358	0.083	0.377	0.150	1.290	0.265
1	20	AC2-37	37	j095	<0.200	<0.180	<0.100	0.207	<0.180	0.624	0.106	0.167	0.150	0.083	0.345	0.150	1.040	0.177
1	21	AC2-55	55	j154	<0.200	0.23	<0.100	0.266	<0.180	0.861	0.188	0.167	0.383	0.083	0.443	0.150	1.435	0.313
1	22	AC2-04	4	j071	<0.200	<0.180	<0.100	0.186	<0.180	0.588	0.118	0.167	0.150	0.083	0.310	0.150	0.980	0.197
1	23	std	0	stdb1-3	3.9	21.4	<0.100	<0.100	<0.180	50.5	<0.010	3.900	21.400	0.050	0.050	0.090	50.500	0.005
2	1	std	0	stdb2-1	3.96	20.6	<0.100	<0.100	<0.180	51.3	<0.010	3.960	20.600	0.050	0.050	0.090	51.300	0.005
2	2	AC2-49	49	j021	<0.200	0.369	<0.100	0.171	<0.180	0.93	0.249	0.167	0.615	0.083	0.285	0.150	1.550	0.415
2	3	AC2-36	36	j037	<0.200	<0.180	<0.100	<0.100	<0.180	0.543	0.163	0.167	0.150	0.083	0.083	0.150	0.905	0.272
2	4	AC2-30	30	j051	<0.200	<0.180	<0.100	0.115	<0.180	0.736	0.227	0.167	0.150	0.083	0.192	0.150	1.227	0.378
2	5	AC2-55	55	j062	<0.200	<0.180	<0.100	0.153	<0.180	0.825	0.239	0.167	0.150	0.083	0.255	0.150	1.375	0.398
2	6	AC2-37	37	j055	<0.200	<0.180	<0.100	<0.100	<0.180	0.765	0.195	0.167	0.150	0.083	0.083	0.150	1.275	0.325
2	7	AC2-42	42	j043	<0.200	<0.180	<0.100	0.229	<0.180	0.943	0.28	0.167	0.150	0.083	0.382	0.150	1.572	0.467

< implies a value less than the detection limit; these values were set to half the detection limit

The as-reported PCT values for AC2-30 and AC2-53 are shaded. These PCT values are switched elsewhere in this report.

Appendix C

Table C.1: Measured Concentrations in PCT Leachate Solutions
(corrected for dilution factor and blanks)

WSRC-TR-99-00393

Revision 0

Block	Sequence	Glass ID	Glass #	Lab ID	Values are in Parts Per Million (ppm)							Values have been adjusted for dilution factor of 1.6667.						
					Al	B	Er	La	Nd	Si	Sr	Al (ppm)	B (ppm)	Er (ppm)	La (ppm)	Nd (ppm)	Si (ppm)	Sr (ppm)
2	8	AC2-19	19	j074	0.599	0.68	<0.100	<0.100	<0.180	5.37	0.17	0.998	1.133	0.083	0.083	0.150	8.950	0.283
2	9	AC2-31	31	j064	<0.200	<0.180	<0.100	<0.100	<0.180	0.737	0.188	0.167	0.150	0.083	0.083	0.150	1.228	0.313
2	10	AC2-24	24	j048	<0.200	<0.180	<0.100	0.159	<0.180	0.506	0.132	0.167	0.150	0.083	0.265	0.150	0.843	0.220
2	11	AC2-05	5	j006	<0.200	<0.180	<0.100	0.214	<0.180	0.873	0.245	0.167	0.150	0.083	0.357	0.150	1.455	0.408
2	12	std	0	stdb2-2	3.89	20.5	<0.100	<0.100	<0.180	49.1	0.044	3.890	20.500	0.050	0.050	0.090	49.100	0.044
2	13	AC2-10	10	j084	<0.200	0.25	<0.100	0.187	<0.180	0.893	0.234	0.167	0.417	0.083	0.312	0.150	1.488	0.390
2	14	B	999	j077	<0.200	<0.180	<0.100	<0.100	<0.180	<0.180	0.05	0.167	0.150	0.083	0.083	0.150	0.150	0.083
2	15	AC2-52	52	j053	<0.200	0.204	<0.100	<0.100	<0.180	1	0.266	0.167	0.340	0.083	0.083	0.150	1.667	0.443
2	16	AC2-31	31	j044	<0.200	<0.180	<0.100	<0.100	<0.180	0.785	0.205	0.167	0.150	0.083	0.083	0.150	1.308	0.342
2	17	AC2-13	13	j020	0.186	<0.180	<0.100	0.287	0.196	1.05	0.213	0.310	0.150	0.083	0.478	0.327	1.750	0.355
2	18	AC2-34	34	j001	<0.200	<0.180	<0.100	0.218	<0.180	0.696	0.212	0.167	0.150	0.083	0.363	0.150	1.160	0.353
2	19	AC2-04	4	j061	<0.200	<0.180	<0.100	<0.100	<0.180	0.567	0.191	0.167	0.150	0.083	0.083	0.150	0.945	0.318
2	20	AC2-28	28	j026	<0.200	<0.180	<0.100	<0.100	<0.180	0.605	0.259	0.167	0.150	0.083	0.083	0.150	1.008	0.432
2	21	AC2-07	7	j174	<0.200	<0.180	<0.100	0.119	<0.180	0.845	0.176	0.167	0.150	0.083	0.198	0.150	1.408	0.293
2	22	AC2-22	22	j023	<0.200	<0.180	<0.100	0.1	<0.180	0.831	0.227	0.167	0.150	0.083	0.167	0.150	1.385	0.378
2	23	std	0	stdb2-3	3.91	21.2	<0.100	<0.100	<0.180	50.2	0.044	3.910	21.200	0.050	0.050	0.090	50.200	0.044
3	1	std	0	stdb3-1	3.98	20.3	<0.100	<0.100	<0.180	51.9	<0.010	3.980	20.300	0.050	0.050	0.090	51.900	0.005
3	2	AC2-16	16	j140	<0.200	0.426	<0.100	<0.100	<0.180	0.594	0.105	0.167	0.710	0.083	0.083	0.150	0.990	0.175
3	3	AC2-07	7	j086	<0.200	0.225	<0.100	0.199	<0.180	0.831	0.065	0.167	0.375	0.083	0.332	0.150	1.385	0.108
3	4	AC2-49	49	j028	<0.200	0.246	<0.100	<0.100	<0.180	0.803	0.102	0.167	0.410	0.083	0.083	0.150	1.338	0.170
3	5	AC2-28	28	j113	<0.200	0.277	<0.100	<0.100	<0.180	0.562	0.138	0.167	0.462	0.083	0.083	0.150	0.937	0.230
3	6	AC2-55	55	j072	<0.200	0.272	<0.100	<0.100	<0.180	0.8	0.133	0.167	0.453	0.083	0.083	0.150	1.333	0.222
3	7	AC2-40	40	j101	<0.200	<0.180	<0.100	<0.100	<0.180	0.535	0.06	0.167	0.150	0.083	0.008	0.150	0.892	0.100
3	8	AC2-19	19	j162	0.513	0.704	<0.100	<0.100	<0.180	4.81	0.062	0.855	1.173	0.083	0.083	0.150	8.017	0.103
3	9	AC2-52	52	j009	<0.200	0.237	<0.100	<0.100	<0.180	0.881	0.129	0.167	0.395	0.083	0.083	0.150	1.468	0.215
3	10	AC2-22	22	j105	<0.200	0.164	<0.100	<0.100	<0.180	0.875	0.104	0.167	0.273	0.083	0.083	0.150	1.458	0.173
3	11	AC2-40	40	j164	<0.200	<0.180	<0.100	<0.100	<0.180	0.622	0.064	0.167	0.150	0.083	0.083	0.150	1.037	0.107
3	12	std	0	stdb3-2	3.89	20.7	<0.100	<0.100	<0.180	49.5	<0.010	3.890	20.700	0.050	0.050	0.090	49.500	0.005
3	13	AC2-10	10	j089	<0.200	0.491	<0.100	<0.100	<0.180	0.824	<0.010	0.167	0.818	0.083	0.083	0.150	1.373	0.008
3	14	B	999	j161	<0.200	<0.180	<0.100	<0.100	<0.180	<0.180	<0.010	0.167	0.150	0.083	0.083	0.150	0.150	0.008

Appendix C

Table C.1: Measured Concentrations in PCT Leachate Solutions
(corrected for dilution factor and blanks)

WSRC-TR-99-00393

Revision 0

Block	Sequence	Glass ID	Glass #	Lab ID	Values are in Parts Per Million (ppm)							Values have been adjusted for dilution factor of 1.6667.						
					Al	B	Er	La	Nd	Si	Sr	Al (ppm)	B (ppm)	Er (ppm)	La (ppm)	Nd (ppm)	Si (ppm)	Sr (ppm)
3	15	AC2-37	37	j118	<0.200	<0.180	<0.100	<0.100	<0.180	0.614	0.069	0.167	0.015	0.083	0.083	0.150	1.023	0.115
3	16	AC2-46	46	j142	<0.200	<0.180	<0.100	<0.100	<0.180	0.523	0.046	0.167	0.150	0.083	0.083	0.150	0.872	0.077
3	17	AC2-34	34	j045	0.186	0.18	<0.100	<0.100	<0.180	0.705	0.088	0.310	0.300	0.083	0.083	0.150	1.175	0.147
3	18	AC2-43	43	j150	<0.200	0.195	<0.100	<0.100	<0.180	0.722	0.11	0.167	0.325	0.083	0.083	0.150	1.203	0.183
3	19	AC2-01	1	j173	0.206	<0.180	<0.100	<0.100	<0.180	1.17	0.063	0.343	0.150	0.083	0.083	0.150	1.950	0.105
3	20	AC2-25	25	j083	<0.200	<0.180	<0.100	<0.100	<0.180	0.518	0.118	0.167	0.150	0.083	0.083	0.150	0.863	0.197
3	21	AC2-13	13	j110	<0.200	0.221	<0.100	<0.100	<0.180	0.89	0.09	0.167	0.368	0.083	0.083	0.150	1.483	0.150
3	22	AC2-04	4	j130	<0.200	<0.180	<0.100	<0.100	<0.180	0.494	0.071	0.167	0.150	0.083	0.083	0.150	0.823	0.118
3	23	std	0	stdb3-3	4.07	19.9	<0.100	<0.100	<0.180	50	<0.010	4.070	19.900	0.050	0.050	0.090	50.000	0.005
4	1	std	0	stdb4-1	3.94	22.4	<0.100	<0.100	<0.180	52	<0.010	3.940	22.400	0.050	0.050	0.090	52.000	0.005
4	2	AC2-02	2	j121	<0.200	0.509	<0.100	0.173	<0.180	0.643	0.097	0.167	0.848	0.083	0.288	0.150	1.072	0.162
4	3	AC2-11	11	j066	<0.200	0.255	<0.100	<0.100	<0.180	0.577	0.077	0.167	0.425	0.083	0.083	0.150	0.962	0.128
4	4	EA	102	j156	<0.200	39.4	<0.100	<0.100	<0.180	55.3	<0.010	1.667	656.680	0.833	0.833	1.500	921.685	0.083
4	5	AC2-26	26	j042	<0.200	0.713	<0.100	0.118	<0.180	0.771	0.046	0.167	1.188	0.083	0.197	0.150	1.285	0.077
4	6	AC2-20	20	j097	<0.200	0.405	<0.100	0.169	<0.180	0.595	0.051	0.167	0.675	0.083	0.282	0.150	0.992	0.085
4	7	AC2-32	32	j126	<0.200	0.394	<0.100	0.123	0.188	0.684	0.084	0.167	0.657	0.083	0.205	0.313	1.140	0.140
4	8	AC2-53	53	j138	<0.200	0.416	<0.100	0.414	0.246	0.98	0.073	0.167	0.693	0.083	0.690	0.410	1.633	0.122
4	9	AC2-38	38	j013	<0.200	0.245	<0.100	0.139	<0.180	0.566	0.037	0.167	0.408	0.083	0.232	0.150	0.943	0.062
4	10	AC2-29	29	j152	<0.200	0.261	<0.100	0.126	<0.180	0.511	0.027	0.167	0.435	0.083	0.210	0.150	0.852	0.045
4	11	AC2-17	17	j165	<0.200	0.337	<0.100	<0.100	<0.180	0.089	0.125	0.167	0.562	0.083	0.083	0.150	0.148	0.208
4	12	std	0	stdb4-2	3.86	21.1	<0.100	<0.100	<0.180	52.4	<0.010	3.860	21.100	0.050	0.050	0.090	52.400	0.005
4	13	AC2-47	47	j040	<0.200	0.411	<0.100	0.242	<0.180	0.629	0.049	0.167	0.685	0.083	0.403	0.150	1.048	0.082
4	14	AC2-50	50	j019	<0.200	0.364	<0.100	0.122	<0.180	0.725	0.09	0.167	0.607	0.083	0.203	0.150	1.208	0.150
4	15	AC2-05	5	j022	<0.200	0.275	<0.100	0.183	<0.180	0.865	0.122	0.167	0.458	0.083	0.305	0.150	1.442	0.203
4	16	AC2-44	44	j122	<0.200	0.235	<0.100	0.162	<0.180	0.633	0.049	0.167	0.392	0.083	0.270	0.150	1.055	0.082
4	17	AC2-14	14	j144	<0.200	0.336	<0.100	0.106	<0.180	0.574	0.122	0.167	0.560	0.083	0.177	0.150	0.957	0.203
4	18	AC2-35	35	j116	<0.200	0.255	<0.100	0.102	<0.180	0.605	0.057	0.167	0.425	0.083	0.170	0.150	1.008	0.095
4	19	AC2-08	8	j031	<0.200	0.23	<0.100	<0.100	<0.180	0.756	0.117	0.167	0.383	0.083	0.083	0.150	1.260	0.195
4	20	AC2-23	23	j132	<0.200	0.216	<0.100	<0.100	<0.180	0.612	0.09	0.167	0.360	0.083	0.083	0.150	1.020	0.150
4	21	AC2-41	41	j047	<0.200	0.18	<0.100	0.156	<0.180	0.546	0.041	0.167	0.300	0.083	0.260	0.150	0.910	0.068

Appendix C

Table C.1: Measured Concentrations in PCT Leachate Solutions
(corrected for dilution factor and blanks)

WSRC-TR-99-00393

Revision 0

Block	Sequence	Glass ID	Glass #	Lab ID	Values are in Parts Per Million (ppm)							Values have been adjusted for dilution factor of 1.6667.						
					Al	B	Er	La	Nd	Si	Sr	Al (ppm)	B (ppm)	Er (ppm)	La (ppm)	Nd (ppm)	Si (ppm)	Sr (ppm)
4	22	std	0	stdb4-3	3.69	22.2	<0.100	<0.100	<0.180	52.8	<0.010	3.690	22.200	0.050	0.050	0.090	52.800	0.005
5	1	std	0	stdb5-1	3.93	20.8	<0.100	<0.100	<0.180	52.7	<0.010	3.930	20.800	0.050	0.050	0.090	52.700	0.005
5	2	AC2-32	32	j145	<0.200	0.369	<0.100	0.227	<0.180	0.629	0.152	0.167	0.615	0.083	0.378	0.150	1.048	0.253
5	3	AC2-44	44	j067	<0.200	<0.180	<0.100	0.192	<0.180	0.506	0.117	0.167	0.150	0.083	0.320	0.150	0.843	0.195
5	4	AC2-11	11	j090	<0.200	0.196	<0.100	0.102	<0.180	0.59	0.167	0.167	0.327	0.083	0.170	0.150	0.983	0.278
5	5	EA	102	j085	<0.200	40	<0.100	<0.100	<0.180	61.3	<0.010	1.667	666.680	0.833	0.833	1.500	1021.687	0.083
5	6	AC2-53	53	j131	<0.200	0.864	<0.100	0.236	<0.180	0.873	0.151	0.167	1.440	0.083	0.393	0.150	1.455	0.252
5	7	AC2-38	38	j030	<0.200	0.401	<0.100	0.202	<0.180	0.622	0.138	0.167	0.668	0.083	0.337	0.150	1.037	0.230
5	8	AC2-17	17	j172	<0.200	0.361	<0.100	0.133	<0.180	0.719	0.184	0.167	0.602	0.083	0.222	0.150	1.198	0.307
5	9	AC2-41	41	j091	<0.200	0.224	<0.100	0.206	<0.180	0.596	0.124	0.167	0.373	0.083	0.343	0.150	0.993	0.207
5	10	AC2-23	23	j166	<0.200	0.187	<0.100	<0.100	<0.180	0.5	0.164	0.167	0.312	0.083	0.083	0.150	0.833	0.273
5	11	AC2-14	14	j160	<0.200	0.276	<0.100	0.167	<0.180	0.58	0.208	0.167	0.460	0.083	0.278	0.150	0.967	0.347
5	12	std	0	stdb5-2	4.01	20.6	<0.100	<0.100	<0.180	51.9	<0.010	4.010	20.600	0.050	0.050	0.090	51.900	0.005
5	13	AC2-29	29	j099	<0.200	0.376	<0.100	0.132	<0.180	0.433	0.107	0.167	0.627	0.083	0.220	0.150	0.722	0.178
5	14	AC2-08	8	j060	<0.200	0.265	<0.100	0.176	<0.180	0.75	0.212	0.167	0.442	0.083	0.293	0.150	1.250	0.353
5	15	AC2-26	26	j136	<0.200	<0.180	<0.100	0.176	<0.180	0.605	0.112	0.167	0.150	0.083	0.293	0.150	1.008	0.187
5	16	AC2-35	35	j139	<0.200	0.196	<0.100	0.118	<0.180	0.569	0.138	0.167	0.327	0.083	0.197	0.150	0.948	0.230
5	17	AC2-47	47	j063	<0.200	<0.180	<0.100	0.279	<0.180	0.598	0.15	0.167	0.150	0.083	0.465	0.150	0.997	0.250
5	18	AC2-02	2	j120	<0.200	0.352	<0.100	0.112	<0.180	0.597	0.179	0.167	0.587	0.083	0.187	0.150	0.995	0.298
5	19	AC2-20	20	j125	<0.200	<0.180	<0.100	0.136	<0.180	0.442	0.126	0.167	0.150	0.083	0.227	0.150	0.737	0.210
5	20	AC2-50	50	j170	<0.200	0.189	<0.100	0.184	<0.180	0.708	0.192	0.167	0.315	0.083	0.307	0.150	1.180	0.320
5	21	AC2-01	1	j106	0.244	<0.180	<0.100	<0.100	<0.180	1.39	0.129	0.407	0.150	0.083	0.083	0.150	2.317	0.215
5	22	std	0	stdb5-3	4.01	20.7	<0.100	<0.100	<0.180	50.6	<0.010	4.010	20.700	0.050	0.050	0.090	50.600	0.005
6	1	std	0	stdb6-1	4.02	20.8	<0.100	<0.100	0.271	51.6	0.047	4.020	20.800	0.050	0.050	0.271	51.600	0.047
6	2	EA	102	j056	<0.200	40	<0.100	<0.100	0.292	56.7	0.046	1.667	666.680	0.833	0.833	4.867	945.019	0.767
6	3	AC2-23	23	j104	<0.200	0.805	<0.100	<0.100	0.283	0.621	0.197	0.167	1.342	0.083	0.083	0.472	1.035	0.328
6	4	AC2-29	29	j108	<0.200	0.434	<0.100	0.159	0.291	0.517	0.14	0.167	0.723	0.083	0.265	0.485	0.862	0.233
6	5	AC2-47	47	j027	<0.200	0.304	<0.100	0.233	0.305	0.607	0.168	0.167	0.507	0.083	0.388	0.508	1.012	0.280
6	6	AC2-17	17	j149	<0.200	0.88	<0.100	0.103	0.294	0.878	0.224	0.167	1.467	0.083	0.172	0.490	1.463	0.373
6	7	AC2-44	44	j103	<0.200	0.187	<0.100	0.15	0.254	0.598	0.147	0.167	0.312	0.083	0.250	0.423	0.997	0.245

Appendix C

Table C.1: Measured Concentrations in PCT Leachate Solutions
(corrected for dilution factor and blanks)

WSRC-TR-99-00393

Revision 0

Block	Sequence	Glass ID	Glass #	Lab ID	Values are in Parts Per Million (ppm)							Values have been adjusted for dilution factor of 1.6667.						
					Al	B	Er	La	Nd	Si	Sr	Al (ppm)	B (ppm)	Er (ppm)	La (ppm)	Nd (ppm)	Si (ppm)	Sr (ppm)
6	8	AC2-14	14	j115	<0.200	0.284	<0.100	0.161	0.274	0.719	0.227	0.167	0.473	0.083	0.268	0.457	1.198	0.378
6	9	AC2-05	5	j109	<0.200	<0.180	<0.100	0.502	0.453	0.949	0.245	0.167	0.150	0.083	0.837	0.755	1.582	0.408
6	10	AC2-32	32	j012	<0.200	0.18	<0.100	0.176	0.293	0.705	0.195	0.167	0.300	0.083	0.293	0.488	1.175	0.325
6	11	std	0	stdb6-2	4.09	21.2	<0.100	<0.100	0.237	51.2	0.044	4.090	21.200	0.050	0.050	0.237	51.200	0.044
6	12	AC2-11	11	j068	<0.200	0.506	<0.100	<0.100	0.261	0.94	0.171	0.167	0.843	0.083	0.083	0.435	1.567	0.285
6	13	AC2-02	2	j087	<0.200	0.353	<0.100	0.238	0.269	0.619	0.203	0.167	0.588	0.083	0.397	0.448	1.032	0.338
6	14	AC2-35	35	j169	<0.200	0.344	<0.100	<0.100	0.269	0.75	0.166	0.167	0.573	0.083	0.083	0.448	1.250	0.277
6	15	AC2-53	53	j050	<0.200	0.278	<0.100	0.237	0.311	0.904	0.181	0.167	0.463	0.083	0.395	0.518	1.507	0.302
6	16	AC2-50	50	j124	<0.200	0.226	<0.100	0.136	0.325	0.873	0.205	0.167	0.377	0.083	0.227	0.542	1.455	0.342
6	17	AC2-38	38	j123	<0.200	<0.180	<0.100	0.131	0.274	0.623	0.181	0.167	0.150	0.083	0.218	0.457	1.038	0.302
6	18	AC2-13	13	j158	<0.200	0.215	<0.100	0.16	0.249	0.942	0.173	0.167	0.358	0.083	0.267	0.415	1.570	0.288
6	19	AC2-20	20	j094	<0.200	<0.180	<0.100	0.153	0.251	0.641	0.178	0.167	0.150	0.083	0.255	0.418	1.068	0.297
6	20	AC2-08	8	j093	<0.200	<0.180	<0.100	0.191	0.235	0.843	0.244	0.167	0.150	0.083	0.318	0.392	1.405	0.407
6	21	AC2-26	26	j073	<0.200	<0.180	<0.100	0.272	0.341	0.793	0.158	0.167	0.150	0.083	0.453	0.568	1.322	0.263
6	22	std	0	stdb6-3	3.92	21.1	<0.100	<0.100	0.251	53.4	0.044	3.920	21.100	0.050	0.050	0.251	53.400	0.044
7	1	std	0	stdb7-1	3.96	21.7	<0.100	0.125	<0.180	51	0.061	3.960	21.700	0.050	0.125	0.090	51.000	0.061
7	2	AC2-46	46	j137	<0.200	0.417	<0.100	0.252	<0.180	0.643	0.153	0.167	0.695	0.083	0.420	0.150	1.072	0.255
7	3	AC2-21	21	j147	<0.200	0.443	<0.100	0.26	<0.180	0.686	0.293	0.167	0.738	0.083	0.433	0.150	1.143	0.488
7	4	AC2-24	24	j133	<0.200	0.188	<0.100	0.371	0.216	0.517	0.141	0.167	0.313	0.083	0.618	0.360	0.862	0.235
7	5	AC2-15	15	j032	<0.200	0.18	<0.100	0.316	0.214	0.818	0.154	0.167	0.300	0.083	0.527	0.357	1.363	0.257
7	6	AC2-12	12	j069	<0.200	<0.180	<0.100	0.187	0.195	0.724	0.191	0.167	0.150	0.083	0.312	0.325	1.207	0.318
7	7	AC2-03	3	j014	<0.200	0.26	<0.100	0.201	0.183	0.627	0.25	0.167	0.433	0.083	0.335	0.305	1.045	0.417
7	8	AC2-45	45	j079	<0.200	0.256	<0.100	0.251	<0.180	0.755	0.246	0.167	0.427	0.083	0.418	0.150	1.258	0.410
7	9	AC2-54	54	j098	<0.200	<0.180	<0.100	0.15	<0.180	0.779	0.197	0.167	0.150	0.083	0.250	0.150	1.298	0.328
7	10	ARM	101	j112	3.05	10.8	<0.100	0.115	0.204	38.2	0.067	5.083	18.000	0.083	0.192	0.340	63.668	0.112
7	11	std	0	stdb7-2	3.98	21	<0.100	0.119	<0.180	52.4	0.058	3.980	21.000	0.050	0.119	0.090	52.400	0.058
7	12	AC2-27	27	j024	<0.200	0.441	<0.100	0.368	<0.180	0.884	0.203	0.167	0.735	0.083	0.613	0.150	1.473	0.338
7	13	AC2-42	42	j057	<0.200	0.375	<0.100	0.331	0.182	0.852	0.259	0.167	0.625	0.083	0.552	0.303	1.420	0.432
7	14	AC2-33	33	j146	<0.200	0.257	<0.100	0.249	<0.180	0.744	0.217	0.167	0.428	0.083	0.415	0.150	1.240	0.362
7	15	AC2-48	48	j153	<0.200	0.268	<0.100	0.276	<0.180	0.805	0.249	0.167	0.447	0.083	0.460	0.150	1.342	0.415

Appendix C

Table C.1: Measured Concentrations in PCT Leachate Solutions
(corrected for dilution factor and blanks)

WSRC-TR-99-00393

Revision 0

Block	Sequence	Glass ID	Glass #	Lab ID	Values are in Parts Per Million (ppm)							Values have been adjusted for dilution factor of 1.6667.						
					Al	B	Er	La	Nd	Si	Sr	Al (ppm)	B (ppm)	Er (ppm)	La (ppm)	Nd (ppm)	Si (ppm)	Sr (ppm)
7	16	AC2-09	9	j015	<0.200	<0.180	<0.100	0.24	<0.180	0.509	0.156	0.167	0.150	0.083	0.400	0.150	0.848	0.260
7	17	AC2-51	51	j111	<0.200	<0.180	<0.100	0.291	0.196	0.736	0.166	0.167	0.150	0.083	0.485	0.327	1.227	0.277
7	18	AC2-25	25	j151	<0.200	<0.180	<0.100	0.195	<0.180	0.516	0.211	0.167	0.150	0.083	0.325	0.150	0.860	0.352
7	19	AC2-06	6	j117	<0.200	<0.180	<0.100	0.247	<0.180	0.488	0.149	0.167	0.150	0.083	0.412	0.150	0.813	0.248
7	20	AC2-39	39	j070	<0.200	<0.180	<0.100	0.129	<0.180	0.616	0.167	0.167	0.150	0.083	0.215	0.150	1.027	0.278
7	21	AC2-18	18	j011	<0.200	<0.180	<0.100	0.139	<0.180	0.747	0.151	0.167	0.150	0.083	0.232	0.150	1.245	0.252
7	22	std	0	stdb7-3	3.94	20	<0.100	0.127	0.183	52.1	0.053	3.940	20.000	0.050	0.127	0.183	52.100	0.053
8	1	std	0	stdb8-1	4.12	22.5	<0.100	0.124	<0.180	53.4	<0.010	4.120	22.500	0.050	0.124	0.090	53.400	0.005
8	2	AC2-12	12	j033	<0.200	0.431	<0.100	0.24	<0.180	0.866	0.164	0.167	0.718	0.083	0.400	0.150	1.443	0.273
8	3	AC2-15	15	j082	<0.200	0.377	0.147	0.43	0.277	0.899	0.134	0.167	0.628	0.245	0.717	0.462	1.498	0.223
8	4	AC2-21	21	j129	<0.200	0.502	<0.100	0.207	<0.180	0.699	0.257	0.167	0.837	0.083	0.345	0.150	1.165	0.428
8	5	AC2-33	33	j039	<0.200	0.305	<0.100	0.252	<0.180	0.705	0.172	0.167	0.508	0.083	0.420	0.150	1.175	0.287
8	6	AC2-36	36	j003	<0.200	0.27	0.169	0.466	0.278	0.651	0.143	0.167	0.450	0.282	0.777	0.463	1.085	0.238
8	7	AC2-39	39	j059	<0.200	0.222	<0.100	0.11	<0.180	0.529	0.117	0.167	0.370	0.083	0.183	0.150	0.882	0.195
8	8	AC2-48	48	j114	<0.200	0.357	<0.100	0.255	<0.180	0.859	0.218	0.167	0.595	0.083	0.425	0.150	1.432	0.363
8	9	AC2-03	3	j157	<0.200	0.336	0.103	0.2	<0.180	0.487	0.204	0.167	0.560	0.172	0.333	0.150	0.812	0.340
8	10	AC2-54	54	j018	<0.200	0.256	0.101	0.175	<0.180	0.592	0.154	0.167	0.427	0.168	0.292	0.150	0.987	0.257
8	11	std	0	stdb8-2	3.95	21	<0.100	0.128	<0.180	52.6	<0.010	3.950	21.000	0.050	0.128	0.090	52.600	0.005
8	12	AC2-43	43	j143	<0.200	0.485	<0.100	0.169	<0.180	1.03	0.133	0.167	0.808	0.083	0.282	0.150	1.717	0.222
8	13	AC2-16	16	j148	0.206	<0.180	<0.100	0.14	<0.180	0.665	0.115	0.343	0.150	0.083	0.233	0.150	1.108	0.192
8	14	AC2-51	51	j004	<0.200	0.748	<0.100	0.283	<0.180	0.588	0.126	0.167	1.247	0.083	0.472	0.150	0.980	0.210
8	15	AC2-09	9	j078	<0.200	0.379	0.103	0.256	<0.180	0.456	0.112	0.167	0.632	0.172	0.427	0.150	0.760	0.187
8	16	AC2-06	6	j041	<0.200	0.324	<0.100	0.251	<0.180	0.415	0.097	0.167	0.540	0.083	0.418	0.150	0.692	0.162
8	17	AC2-45	45	j002	<0.200	0.406	<0.100	0.204	<0.180	0.652	0.194	0.167	0.677	0.083	0.340	0.150	1.087	0.323
8	18	AC2-18	18	j080	0.208	0.263	<0.100	0.117	<0.180	1.04	0.127	0.347	0.438	0.083	0.195	0.150	1.733	0.212
8	19	AC2-27	27	j159	<0.200	0.275	<0.100	0.291	<0.180	0.752	0.164	0.167	0.458	0.083	0.485	0.150	1.253	0.273
8	20	AC2-30	30	j007	<0.200	0.331	<0.100	0.329	<0.180	0.842	0.208	0.167	0.552	0.083	0.548	0.150	1.403	0.347
8	21	ARM	101	j008	3.4	12.8	0.105	0.12	<0.180	42.5	0.019	5.667	21.334	0.175	0.200	0.150	70.835	0.032
8	22	std	0	stdb8-3	4.04	21.7	<0.100	0.128	<0.180	50.7	<0.010	4.040	21.700	0.050	0.128	0.090	50.700	0.005
9	1	std	0	stdb9-1	4.05	21.2	<0.100	<0.100	<0.180	51	<0.010	4.050	21.200	0.050	0.050	0.090	51.000	0.005

Appendix C

Table C.1: Measured Concentrations in PCT Leachate Solutions
(corrected for dilution factor and blanks)

WSRC-TR-99-00393

Revision 0

Block	Sequence	Glass ID	Glass #	Lab ID	Values are in Parts Per Million (ppm)							Values have been adjusted for dilution factor of 1.6667.						
					Al	B	Er	La	Nd	Si	Sr	Al (ppm)	B (ppm)	Er (ppm)	La (ppm)	Nd (ppm)	Si (ppm)	Sr (ppm)
9	2	AC2-06	6	j119	<0.200	<0.180	<0.100	0.271	<0.180	0.633	0.049	0.167	0.150	0.083	0.452	0.150	1.055	0.082
9	3	AC2-45	45	j049	<0.200	0.218	<0.100	0.117	<0.180	0.841	0.152	0.167	0.363	0.083	0.195	0.150	1.402	0.253
9	4	AC2-42	42	j046	<0.200	0.27	<0.100	0.139	<0.180	1.07	0.17	0.167	0.450	0.083	0.232	0.150	1.783	0.283
9	5	AC2-33	33	j155	<0.200	<0.180	<0.100	0.159	<0.180	0.74	0.105	0.167	0.150	0.083	0.265	0.150	1.233	0.175
9	6	AC2-51	51	j100	0.418	0.539	0.192	0.259	<0.180	2.89	0.08	0.697	0.898	0.320	0.432	0.150	4.817	0.133
9	7	AC2-27	27	j075	<0.200	<0.180	<0.100	0.143	<0.180	0.928	0.108	0.167	0.150	0.083	0.238	0.150	1.547	0.180
9	8	AC2-36	36	j134	<0.200	<0.180	<0.100	0.143	<0.180	0.672	0.071	0.167	0.150	0.083	0.238	0.150	1.120	0.118
9	9	AC2-12	12	j034	<0.200	<0.180	<0.100	0.171	<0.180	0.863	0.097	0.167	0.150	0.083	0.285	0.150	1.438	0.162
9	10	AC2-54	54	j128	0.216	<0.180	<0.100	0.298	<0.180	0.936	0.105	0.360	0.150	0.083	0.497	0.150	1.560	0.175
9	11	std	0	stdb9-2	3.92	21.9	<0.100	<0.100	<0.180	52	<0.010	3.920	21.900	0.050	0.050	0.090	52.000	0.005
9	12	AC2-03	3	j005	<0.200	0.436	<0.100	0.109	<0.180	0.726	0.17	0.167	0.727	0.083	0.182	0.150	1.210	0.283
9	13	AC2-24	24	j168	<0.200	<0.180	<0.100	0.186	<0.180	0.59	0.029	0.167	0.150	0.083	0.310	0.150	0.983	0.048
9	14	AC2-15	15	j065	<0.200	<0.180	<0.100	0.185	<0.180	0.876	0.046	0.167	0.150	0.083	0.308	0.150	1.460	0.077
9	15	ARM	101	j107	3.06	12.7	<0.100	<0.100	<0.180	41.2	<0.010	5.100	21.167	0.083	0.083	0.150	68.668	0.008
9	16	AC2-48	48	j092	<0.200	0.356	<0.100	0.21	<0.180	0.946	0.139	0.167	0.593	0.083	0.350	0.150	1.577	0.232
9	17	AC2-30	30	j081	<0.200	0.256	<0.100	0.249	<0.180	0.88	0.147	0.167	0.427	0.083	0.415	0.150	1.467	0.245
9	18	AC2-39	39	j167	<0.200	<0.180	<0.100	0.122	<0.180	0.637	0.053	0.167	0.150	0.083	0.203	0.150	1.062	0.088
9	19	AC2-18	18	j127	<0.200	<0.180	<0.100	0.125	<0.180	0.679	0.08	0.167	0.150	0.083	0.208	0.150	1.132	0.133
9	20	AC2-21	21	j096	0.205	0.373	<0.100	0.174	<0.180	0.94	0.247	0.342	0.622	0.083	0.290	0.150	1.567	0.412
9	21	AC2-09	9	j017	<0.200	<0.180	<0.100	0.146	<0.180	0.637	0.045	0.167	0.150	0.083	0.243	0.150	1.062	0.075
9	22	std	0	stdb9-3	3.99	21.4	<0.100	<0.100	<0.180	50	<0.010	3.990	21.400	0.050	0.050	0.090	50.000	0.005

Appendix C

Exhibit C.1: PCT Leachate Concentrations Plotted by Glass Number
(0 – Solution Standard; 101 – ARM; 102- EA; 999 – blank)

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Al (ppm) By Glass #

B (ppm) By Glass #

Er (ppm) By Glass #

La (ppm) By Glass #

Appendix C
Exhibit C.1: PCT Leachate Concentrations Plotted by Glass Number
(0 – Solution Standard; 101 – ARM; 102- EA; 999 – blank)

Nd (ppm) By Glass #

Si (ppm) By Glass #

Appendix C

Exhibit C.1: PCT Leachate Concentrations Plotted by Glass Number
(0 – Solution Standard; 101 – ARM; 102- EA; 999 – blank)

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Sr (ppm) By Glass #

Appendix C
Exhibit C.2: PCT Leachate Concentrations Plotted for Phase 2 Glasses Only

Al (ppm) By Glass #

B (ppm) By Glass #

Exhibit C.2: PCT Leachate Concentrations Plotted for Phase 2 Glasses Only

Revision 0

Er (ppm) By Glass #

La (ppm) By Glass #

Appendix C
Exhibit C.2: PCT Leachate Concentrations Plotted for Phase 2 Glasses Only

Nd (ppm) By Glass #

Si (ppm) By Glass #

Appendix C
Exhibit C.2: PCT Leachate Concentrations Plotted for Phase 2 Glasses Only

Sr (ppm) By Glass #

**Oneway Anova
Summary of Fit**

RSquare	0.433491
RSquare Adj	0.181709
Root Mean Square Error	0.078834
Mean of Response	3.964444
Observations (or Sum Wgts)	27

Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	0.08560000	0.010700	1.7217
Error	18	0.11186667	0.006215	Prob>F
C Total	26	0.19746667	0.007595	0.1611

Means for Oneway Anova			
Level	Number	Mean	Std Error
1	3	3.97333	0.04551
2	3	3.92000	0.04551
3	3	3.98000	0.04551
4	3	3.83000	0.04551
5	3	3.98333	0.04551
6	3	4.01000	0.04551
7	3	3.96000	0.04551
8	3	4.03667	0.04551
9	3	3.98667	0.04551

Std Error uses a pooled estimate of error variance

**Oneway Anova
Summary of Fit**

RSquare	0.580539
RSquare Adj	0.394111
Root Mean Square Error	0.511353
Mean of Response	21.11852
Observations (or Sum Wgts)	27

Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	6.514074	0.814259	3.1140
Error	18	4.706667	0.261481	Prob>F
C Total	26	11.220741	0.431567	0.0216

Means for Oneway Anova			
Level	Number	Mean	Std Error
1	3	21.2333	0.29523
2	3	20.7667	0.29523
3	3	20.3000	0.29523
4	3	21.9000	0.29523
5	3	20.7000	0.29523
6	3	21.0333	0.29523
7	3	20.9000	0.29523
8	3	21.7333	0.29523
9	3	21.5000	0.29523

Std Error uses a pooled estimate of error variance

**Oneway Anova
Summary of Fit**

RSquare	0.439802
RSquare Adj	0.190825
Root Mean Square Error	1.02361
Mean of Response	51.45556
Observations (or Sum Wgts)	27

Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	14.806667	1.85083	1.7664
Error	18	18.860000	1.04778	Prob>F
C Total	26	33.666667	1.29487	0.1505

Means for Oneway Anova			
Level	Number	Mean	Std Error
1	3	51.1667	0.59098
2	3	50.2000	0.59098
3	3	50.4667	0.59098
4	3	52.4000	0.59098
5	3	51.7333	0.59098
6	3	52.0667	0.59098
7	3	51.8333	0.59098
8	3	52.2333	0.59098
9	3	51.0000	0.59098

Std Error uses a pooled estimate of error variance

**Oneway Anova
Summary of Fit**

RSquare	0.907898
RSquare Adj	0.866964
Root Mean Square Error	0.007647
Mean of Response	0.018148
Observations (or Sum Wgts)	27

Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	0.01037674	0.001297	22.1795
Error	18	0.00105267	0.000058	Prob>F
C Total	26	0.01142941	0.000440	<.0001

Means for Oneway Anova			
Level	Number	Mean	Std Error
1	3	0.005000	0.00442
2	3	0.031000	0.00442
3	3	0.005000	0.00442
4	3	0.005000	0.00442
5	3	0.005000	0.00442
6	3	0.045000	0.00442
7	3	0.057333	0.00442
8	3	0.005000	0.00442
9	3	0.005000	0.00442

Std Error uses a pooled estimate of error variance

Results of Standard Solution Measurements

Block	N Rows	Al (ppm)	B (ppm)	Si (ppm)
1	3	3.9733	21.233	51.167
2	3	3.92	20.767	50.2
3	3	3.98	20.3	50.467
4	3	3.83	21.9	52.4
5	3	3.9833	20.7	51.733
6	3	4.01	21.033	52.067
7	3	3.96	20.9	51.833
8	3	4.0367	21.733	52.233
9	3	3.9867	21.5	51
Avg		3.964	21.119	51.456
Ref Value		4	20	50
% Diff		-0.9%	5.6%	2.9%

log NL[Al] (g/L) mc By Repeat Group

Repeatability Standard Deviation 0.064
Overall Mean of Response -2.657

log NL[Er] (g/L) mc By Repeat Group

Repeatability Standard Deviation 0.058
Overall Mean of Response -2.687

log NL[B] (g/L) mc By Repeat Group

Repeatability Standard Deviation 0.077
Overall Mean of Response -1.828

log NL[La] (g/L) mc By Repeat Group

Repeatability Standard Deviation 0.182
Overall Mean of Response -2.789

log NL[Nd] (g/L) mc By Repeat Group

Repeatability Standard Deviation 0.078
 Overall Mean of Response -2.805

log NL[Sr] (g/L) mc By Repeat Group

Repeatability Standard Deviation 0.098
 Overall Mean of Response -1.788

log NL[Si] (g/L) mc By Repeat Group

Repeatability Standard Deviation 0.079
 Overall Mean of Response -1.862

log NL[Al] (g/L) tc By Repeat Group

Repeatability Standard Deviation 0.059
 Overall Mean of Response -2.642

log NL[B] (g/L) tc By Repeat Group

Repeatability Standard Deviation 0.089
Overall Mean of Response -1.832

log NL[La] (g/L) tc By Repeat Group

Repeatability Standard Deviation 0.180
Overall Mean of Response -2.789

log NL[Er] (g/L) tc By Repeat Group

Repeatability Standard Deviation 0.055
Overall Mean of Response -2.685

log NL[Nd] (g/L) tc By Repeat Group

Repeatability Standard Deviation 0.072
Overall Mean of Response -2.815

log NL[Si] (g/L) tc By Repeat Group

Repeatability Standard Deviation 0.075
 Overall Mean of Response -1.851

log NL[Sr] (g/L) tc By Repeat Group

Repeatability Standard Deviation 0.098
 Overall Mean of Response -1.788

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Appendix D – Lanthanide Recovery from Phase 2 and Selected Phase 1 Glasses

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Appendix D
Table D.1 Elemental Analysis of Dissolved SrABS Glasses

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Revision 0

AC2-01													
Time	Sample Mass	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	(g)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2509	39.7	14.5	12.4	14.4	3.58	0.823	1.91	13.5	12.9	5.11	2.33	3.82
0.50	0.2508	127	46.8	41.8	45.7	10.6	2.70	6.09	43.9	40.4	13.3	7.59	2.80
1.00	0.2507	241	89.0	78.8	89.8	20.6	5.59	11.9	85.3	81.9	25.0	14.8	1.17
2.00	0.2501	247	94.5	80.0	88.4	20.8	5.30	12.4	86.6	79.4	26.8	15.3	0.539
4.00	0.2507	253	92.5	82.0	90.2	20.9	5.52	12.1	89.1	84.0	25.6	15.1	0.678

AC2-02													
Time	Sample Mass	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	(g)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2502	32.5	11.6	9.87	12.6	2.78	0.698	3.96	4.38	14.4	5.49	1.98	3.07
0.50	0.2502	125	45.8	39.0	49.3	10.9	2.78	16.0	16.6	58.1	18.3	7.44	2.07
0.50	(1)	117	16.8	15.8	50.3	24.2	6.56	14.2	15.4	54.9	12.3	10.1	2.92
0.50	(1)	122	17.3	15.0	49.8	24.0	6.53	14.6	15.9	53.2	12.7	10.3	3.00
1.00	0.2507	244	91.2	77.1	98.7	21.4	5.41	31.2	33.6	111	36.4	14.6	1.20
2.00	0.2502	250	89.8	78.2	103	21.6	5.57	31.8	34.8	115	37.5	15.4	0.796
4.00	0.2504	246	92.8	79.7	102	23.2	5.60	31.4	34.5	116	37.1	15.1	0.738

(1) Duplicate Analysis of 0.50 hr Sample

AC2-03													
Time	Sample Mass	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	(g)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2504	34.4	12.3	5.64	29.0	2.94	1.88	1.71	4.62	11.2	5.36	3.02	3.24
0.50	0.2508	124	46.0	20.8	101	11.0	7.10	6.23	17.0	41.7	18.3	10.8	2.54
1.00	0.2510	238	89.3	40.6	197	21.2	13.8	12.3	33.3	83.4	36.2	21.6	1.07
2.00	0.2510	236	89.1	41.0	201	21.2	13.6	12.2	33.2	82.1	35.9	21.1	0.840
4.00	0.2507	248	89.4	41.4	208	21.1	14.0	12.3	34.1	82.9	37.4	20.7	0.871

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Table D.1 Elemental Analysis of Dissolved SrABS Glasses

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AC2-04													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2509	47.1	7.07	13.6	35.4	10.0	1.02	5.74	6.25	15.5	5.78	4.22	2.93
0.50	0.2509	173	24.6	51.9	136	37.3	4.03	20.9	23.4	57.0	19.6	15.3	2.05
1.00	0.2507	235	34.8	71.1	194	52.0	5.49	29.6	32.1	81.1	28.8	21.4	0.747
2.00	0.2507	235	35.0	72.3	192	53.5	5.55	30.0	32.5	81.9	28.1	21.2	0.710
4.00	0.2507	234	35.3	70.7	192	52.8	5.54	30.0	33.7	82.4	27.4	21.5	0.679
AC2-05													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2505	30.4	4.38	3.85	12.1	6.28	1.56	3.56	3.99	13.1	3.87	2.42	4.53
0.50	0.2506	116	17.1	15.3	48.0	24.4	6.48	14.0	15.5	54.3	11.4	10.1	2.23
1.00	0.2506	250	36.3	32.1	107	51.6	14.2	29.4	32.5	112	25.8	21.7	1.28
2.00	0.2504	256	35.4	33.1	109	52.6	14.4	30.3	35.3	118	27.3	21.3	0.799
4.00	0.2504	255	37.0	32.4	102	51.6	14.0	30.0	34.6	119	25.8	21.2	0.778
AC2-06													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2502	46.8	6.75	6.45	34.5	9.76	0.986	2.23	16.1	15.4	7.85	2.77	3.04
0.50	0.2510	159	24.0	22.2	117	34.3	3.52	7.80	54.7	52.6	25.3	10.1	2.09
1.00	0.2505	234	35.3	33.5	181	50.6	5.15	11.8	83.7	78.2	36.3	14.5	0.853
2.00	0.2505	238	36.2	33.9	180	52.3	5.31	11.8	82.8	80.5	36.3	14.7	0.581
4.00	0.2506	236	35.9	34.0	176	50.6	5.27	11.8	84.6	79.8	36.0	14.6	0.531

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Table D.1 Elemental Analysis of Dissolved SrABS Glasses

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AC2-07													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2510	34.1	5.09	4.52	15.3	3.05	2.00	1.81	12.2	15.3	4.31	2.12	3.90
0.50	0.2504	108	16.0	14.2	49.6	8.92	6.17	5.72	36.5	50.6	12.6	6.72	2.77
1.00	0.2510	222	34.7	30.4	102	19.6	13.0	12.5	80.7	111	26.6	14.5	1.16
2.00	0.2509	245	36.5	32.6	109	20.6	14.0	13.1	87.0	117	28.7	14.9	0.567
4.00	0.2506	240	36.2	32.2	108	20.2	14.4	12.6	84.1	112	27.8	14.7	0.661

AC2-08													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2509	25.7	11.8	9.72	11.5	7.09	1.75	1.67	4.23	14.2	3.94	2.87	5.05
0.50	0.2507	90.0	42.0	35.5	40.8	24.4	6.34	5.66	15.1	50.7	12.1	9.55	2.75
1.00	0.2506	182	84.2	71.4	83.7	50.7	12.4	11.3	31.6	103	22.8	19.4	1.27
2.00	0.2508	195	87.1	75.3	86.6	55.7	13.6	12.1	32.8	110	24.6	19.8	1.14
4.00	0.2508	192	90.1	75.2	87.0	54.0	13.5	12.0	33.8	109	24.0	20.1	0.733

AC2-09													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2510	31.7	14.5	12.9	20.2	8.33	2.20	5.02	13.2	12.6	4.77	2.48	2.83
0.50	0.2510	121	54.7	47.4	78.8	31.4	8.34	18.4	50.5	48.4	16.5	9.06	2.47
1.00	0.2508	200	91.4	77.3	128	52.6	13.5	30.3	83.6	80.7	27.3	15.1	1.19
2.00	0.2504	199	89.8	79.1	133	53.7	14.0	31.0	82.4	81.1	25.8	15.3	0.863
4.00	0.2506	202	88.6	80.5	134	54.0	14.0	30.9	84.6	80.0	27.6	15.4	0.080

Table D.1 Elemental Analysis of Dissolved SrABS Glasses

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AC2-11													
Time (hr)	Sample	La (µg/mL)	Ce (µg/mL)	Pr (µg/mL)	Nd (µg/mL)	Sm (µg/mL)	Eu (µg/mL)	Gd (µg/mL)	Er (µg/mL)	Al (µg/mL)	B (µg/mL)	Sr (µg/mL)	Si (µg/mL)
	Mass (g)												
0.25	0.2505	28.3	13.5	5.76	29.4	7.79	0.728	1.72	4.86	16.9	3.86	2.18	2.60
0.50	0.2505	98.4	47.5	21.1	107	27.7	2.85	6.24	18.5	62.4	13.9	7.96	2.59
1.00	0.2508	180	85.1	37.7	196	49.7	5.36	11.8	33.5	111	24.8	14.0	0.958
2.00	0.2510	190	89.5	41.1	201	51.5	5.46	12.4	33.9	116	25.2	14.8	0.556
2.00	(1)	190	88.2	41.4	210	53.8	5.56	12.0	33.7	111	25.3	14.8	0.754
2.00	(1)	198	90.2	38.6	189	54.0	5.6	13.2	33.6	112	28.1	15.3	0.846
4.00	0.2505	183	86.9	38.9	197	52.8	5.45	11.6	36.2	117	25.1	14.9	0.646

(1) Duplicate Analysis of 2.00 hr Sample

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Table D.1 Elemental Analysis of Dissolved SrABS Glasses

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AC2-12													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2507	36.1	6.65	13.4	39.5	3.94	0.978	2.20	6.90	15.3	5.19	4.05	6.21
0.50	0.2507	106	19.4	40.8	118	11.3	2.98	6.74	20.7	47.0	14.1	12.5	2.91
1.00	0.2505	173	32.3	64.6	199	19.7	5.01	10.7	34.4	77.6	22.6	20.1	1.09
2.00	0.2509	189	34.3	68.1	206	19.8	5.55	11.7	36.3	81.6	24.7	21.0	0.751
4.00	0.2508	187	34.4	69.1	215	20.5	5.54	12.1	37.4	83.5	24.7	20.6	0.735

AC2-13													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2505	23.0	4.26	8.64	13.6	6.19	0.603	1.36	4.01	13.4	4.97	1.78	4.30
0.50	0.2505	78.8	14.1	29.3	46.2	20.8	2.17	4.84	13.8	46.0	15.0	6.00	2.35
1.00	0.2508	163	29.9	62.1	100	44.8	4.62	10.2	28.1	95.4	31.6	12.8	1.28
1.00	(1)	168	30.5	62.9	101	44.0	4.52	10.4	28.4	99.4	31.2	12.8	1.75
1.00	(1)	169	30.2	64.4	102	45.2	4.50	10.2	28.5	99.4	31.7	12.6	1.91
2.00	0.2507	188	35.3	74.4	119	51.6	5.30	11.9	33.1	114	35.9	15.1	0.857
4.00	0.2505	189	35.7	74.2	119	50.9	5.50	11.7	32.1	114	34.3	15.0	0.825

(1) Duplicate Analysis of 1.00 hr Sample

AC2-14													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2510	21.2	4.11	7.95	16.8	2.37	1.61	1.43	9.35	12.6	4.31	2.57	2.89
0.50	0.2508	85.1	15.1	29.9	61.0	8.72	5.99	5.45	37.2	46.9	17.4	9.31	3.59
1.00	0.2507	194	35.3	69.1	144	19.7	14.0	12.9	85.4	111	39.2	20.5	1.32
2.00	0.2507	195	35.0	67.6	144	20.9	13.7	12.9	86.0	111	38.6	20.9	0.984
4.00	0.2509	194	36.3	72.5	147	20.6	14.2	12.8	85.7	116	40.0	21.6	1.09

Table D.1 Elemental Analysis of Dissolved SrABS Glasses

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AC2-16													
Time (hr)	Sample	La (µg/mL)	Ce (µg/mL)	Pr (µg/mL)	Nd (µg/mL)	Sm (µg/mL)	Eu (µg/mL)	Gd (µg/mL)	Er (µg/mL)	Al (µg/mL)	B (µg/mL)	Sr (µg/mL)	Si (µg/mL)
	Mass (g)												
0.25	0.2508	22.0	3.94	3.7	22.5	2.31	0.688	3.69	9.52	12.5	3.68	2.52	3.86
0.25	(1)	27.0	4.96	4.49	29.4	3.10	0.720	4.12	11.4	15.1	3.87	2.85	6.00
0.25	(1)	26.4	5.09	4.42	29.4	2.99	0.711	4.16	11.3	14.8	3.50	2.91	5.94
0.50	0.2510	82.1	15.8	14.1	87.4	8.78	2.45	13.8	36.1	48.0	12.3	9.11	2.83
1.00	0.2506	188	35.5	32.2	210	20.2	5.48	31.2	82.8	115	26.5	20.0	1.29
2.00	0.2505	196	35.9	31.9	204	20.3	5.80	32.5	86.0	118	29.0	20.7	1.17
4.00	0.2510	193	36.5	32.3	211	20.3	5.72	32.0	86.3	114	28.3	21.2	0.962

(1) Duplicate Analysis of 0.25 hr Sample

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Table D.1 Elemental Analysis of Dissolved SrABS Glasses

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AC2-17													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2507	104	29.3	26.7	70.5	18.0	4.72	10.2	28.4	45.6	14.7	8.74	2.98
0.50	0.2509	119	33.0	30.2	76.4	19.7	5.18	11.7	32.0	50.3	17.7	9.96	2.37
1.00	0.2506	214	62.0	55.3	142	36.2	9.60	21.0	58.2	93.6	31.4	17.5	1.31
2.00	0.2509	222	61.1	55.1	143	37.0	9.72	20.8	58.3	93.6	31.0	17.9	0.678
4.00	0.2506	221	62.8	55.7	144	37.3	9.80	21.7	62.2	93.9	32.7	18.3	0.586

AC2-18													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2505	38.4	22.1	8.64	52.6	13.3	3.59	2.09	5.63	17.0	6.05	4.78	3.41
0.50	0.2505	110	62.4	24.2	147	38.7	9.99	5.85	14.9	47.3	16.8	13.4	2.54
1.00	0.2507	178	109	39.2	253	60.8	17.0	9.83	24.9	80.9	25.5	21.8	0.518
2.00	0.2506	174	106	39.4	245	61.1	16.5	9.71	25.5	79.4	27.1	21.1	0.478
4.00	0.2510	180	105	39.7	245	60.8	16.7	9.70	24.8	80.7	26.3	21.1	0.506

AC2-19													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2507	34.1	13.7	4.93	8.22	2.12	0.419	1.28	12.4	10.2	5.81	2.85	3.74
0.50	0.2507	128	50.8	19.0	31.6	ND	1.68	4.72	48.9	39.9	20.7	10.9	2.26
1.00	0.2502	271	98.3	35.6	61.7	15.3	3.25	8.90	92.1	78.1	36.2	20.9	1.21
2.00	0.2510	262	102	37.5	64.0	16.5	3.26	9.30	94.4	80.5	38.2	20.9	0.973
4.00	0.2512	287	103	38.4	61.2	16.2	3.28	9.28	95.5	82.1	39.0	20.8	1.00

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Table D.1 Elemental Analysis of Dissolved SrABS Glasses

AC2-20												
Time (hr)	Sample Mass (g)	La ($\mu\text{g/mL}$)	Ce ($\mu\text{g/mL}$)	Pr ($\mu\text{g/mL}$)	Nd ($\mu\text{g/mL}$)	Sm ($\mu\text{g/mL}$)	Eu ($\mu\text{g/mL}$)	Gd ($\mu\text{g/mL}$)	Er ($\mu\text{g/mL}$)	Al ($\mu\text{g/mL}$)	B ($\mu\text{g/mL}$)	Si ($\mu\text{g/mL}$)
0.25	0.2505	190	76.7	67.1	101	11.4	12.0	27.4	19.2	59.6	20.6	2.79
0.50	0.2505	194	79.3	66.3	104	11.4	12.0	28.3	18.9	59.3	20.9	2.32
1.00	0.2509	252	106	90.0	135	14.9	16.1	37.4	25.2	81.1	28.3	1.49
2.00	0.2509	256	106	90.9	138	15.3	15.9	37.4	25.2	82.0	26.6	0.985
4.00	0.2508	263	105	88.0	140	14.9	16.3	37.1	26.0	80.6	27.7	0.552
AC2-21												
Time (hr)	Sample Mass (g)	La ($\mu\text{g/mL}$)	Ce ($\mu\text{g/mL}$)	Pr ($\mu\text{g/mL}$)	Nd ($\mu\text{g/mL}$)	Sm ($\mu\text{g/mL}$)	Eu ($\mu\text{g/mL}$)	Gd ($\mu\text{g/mL}$)	Er ($\mu\text{g/mL}$)	Al ($\mu\text{g/mL}$)	B ($\mu\text{g/mL}$)	Si ($\mu\text{g/mL}$)
0.25	0.2504	40.1	17.1	6.26	13.3	9.75	0.503	5.85	4.06	17.5	6.97	2.93
0.50	0.2508	144	63.7	22.3	48.5	35.8	1.93	21.0	14.9	66.8	21.4	2.06
1.00	0.2507	256	109	37.7	86.2	60.9	3.45	38.4	26.6	118	36.4	1.18
2.00	0.2506	251	112	37.7	85.1	61.1	3.44	38.7	26.6	115	37.0	0.687
4.00	0.2509	258	111	38.3	87.5	59.7	3.23	38.0	25.8	116	37.0	0.566
AC2-22												
Time (hr)	Sample Mass (g)	La ($\mu\text{g/mL}$)	Ce ($\mu\text{g/mL}$)	Pr ($\mu\text{g/mL}$)	Nd ($\mu\text{g/mL}$)	Sm ($\mu\text{g/mL}$)	Eu ($\mu\text{g/mL}$)	Gd ($\mu\text{g/mL}$)	Er ($\mu\text{g/mL}$)	Al ($\mu\text{g/mL}$)	B ($\mu\text{g/mL}$)	Si ($\mu\text{g/mL}$)
0.25	0.2509	36.9	3.81	11.1	10.6	8.96	2.30	5.30	3.89	12.0	5.40	4.11
0.50	0.2509	124	13.5	36.6	35.0	28.9	7.64	17.6	12.2	38.5	17.7	2.28
1.00	0.2505	238	26.1	68.8	66.1	54.0	15.0	33.5	22.9	75.0	32.1	1.29
2.00	0.2507	244	27.0	75.0	70.0	59.4	16.6	36.2	26.6	79.0	38.1	0.750
4.00	0.2508	256	27.1	77.5	70.9	58.6	16.2	35.9	26.0	81.8	37.6	0.745

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Table D.1 Elemental Analysis of Dissolved SrABS Glasses

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AC2-23													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2514	39.5	4.20	12.4	30.0	2.43	0.550	1.45	4.19	18.1	4.85	3.36	3.60
0.50	0.2510	143	14.6	41.9	104	8.68	1.94	4.96	14.6	62.4	16.6	11.5	3.79
1.00	0.2508	254	24.7	76.1	189	14.7	3.41	9.00	25.2	112	26.7	20.5	0.687
2.00	0.2512	250	25.1	79.1	178	15.2	3.54	9.18	26.5	109	28.6	20.7	0.771
4.00	0.2505	249	25.3	76.6	191	15.6	3.59	9.19	26.4	114	28.3	21.4	0.750

AC2-24													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2510	40.0	4.11	3.75	39.5	2.53	0.531	5.53	5.85	12.1	5.75	2.37	3.14
0.50	0.2510	130	13.7	13.1	130	8.36	1.87	17.8	20.3	41.4	19.1	7.59	2.59
1.00	0.2505	249	25.7	23.6	253	16.1	3.56	33.6	37.1	80.0	35.3	14.1	1.08
2.00	0.2505	252	25.4	24.2	248	16.2	3.58	34.6	38.1	79.4	35.3	14.9	0.867
4.00	0.2509	257	25.3	24.2	247	16.1	3.41	34.2	37.0	77.5	34.9	14.1	0.718

AC2-25													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2505	41.7	4.42	4.15	17.0	10.3	2.50	5.63	16.3	18.8	5.06	3.51	4.80
0.50	0.2504	125	12.4	12.5	51.2	31.0	7.51	17.0	48.8	54.1	13.1	10.3	2.89
1.00	0.2509	254	26.3	26.4	107	63.6	15.5	34.3	94.8	115	26.1	21.0	1.18
2.00	0.2507	255	27.2	27.3	105	63.2	15.7	33.9	98.1	115	26.5	20.8	1.00
4.00	0.2505	250	25.6	25.6	105	62.2	15.7	34.0	97.9	114	26.8	21.1	1.24

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Table D.1 Elemental Analysis of Dissolved SrABS Glasses

AC2-26														
Time (hr)	Sample Mass (g)	La ($\mu\text{g/mL}$)	Ce ($\mu\text{g/mL}$)	Pr ($\mu\text{g/mL}$)	Nd ($\mu\text{g/mL}$)	Sm ($\mu\text{g/mL}$)	Eu ($\mu\text{g/mL}$)	Gd ($\mu\text{g/mL}$)	Er ($\mu\text{g/mL}$)	Al ($\mu\text{g/mL}$)	B ($\mu\text{g/mL}$)	Sr ($\mu\text{g/mL}$)	Si ($\mu\text{g/mL}$)	
0.25	0.2506	38.9	4.50	3.99	9.84	9.57	2.44	1.33	14.2	16.5	3.85	2.33	4.00	
0.50	0.2505	111	12.8	11.4	29.3	27.0	6.94	3.85	42.4	48.6	10.9	6.67	4.31	
1.00	0.2508	235	28.8	24.9	62.0	58.4	15.1	8.18	93.6	108	24.4	13.7	1.34	
2.00	0.2510	247	29.7	25.8	67.5	64.9	15.8	8.64	97.4	108	24.7	14.7	1.15	
4.00	0.2508	255	29.5	26.3	65.9	63.5	15.9	8.62	98.3	110	25.1	14.7	1.30	
AC2-27														
Time (hr)	Sample Mass (g)	La ($\mu\text{g/mL}$)	Ce ($\mu\text{g/mL}$)	Pr ($\mu\text{g/mL}$)	Nd ($\mu\text{g/mL}$)	Sm ($\mu\text{g/mL}$)	Eu ($\mu\text{g/mL}$)	Gd ($\mu\text{g/mL}$)	Er ($\mu\text{g/mL}$)	Al ($\mu\text{g/mL}$)	B ($\mu\text{g/mL}$)	Sr ($\mu\text{g/mL}$)	Si ($\mu\text{g/mL}$)	
0.25	0.2504	26.6	15.5	13.7	9.90	8.93	0.37	5.07	3.60	16.7	4.74	2.19	4.07	
0.50	0.2507	86.4	49.1	44.0	32.2	29.1	1.49	16.5	12.1	52.9	13.0	7.37	2.44	
1.00	0.2504	170	99.4	84.2	63.2	57.1	3.06	32.3	23.3	106	24.7	14.1	0.848	
2.00	0.2508	179	104	88.4	66.9	59.9	3.23	34.3	25.7	110	27.8	15.5	0.531	
4.00	0.2510	180	100	91.6	67.2	60.8	3.17	34.0	25.0	111	28.3	15.5	0.648	
AC2-28														
Time (hr)	Sample Mass (g)	La ($\mu\text{g/mL}$)	Ce ($\mu\text{g/mL}$)	Pr ($\mu\text{g/mL}$)	Nd ($\mu\text{g/mL}$)	Sm ($\mu\text{g/mL}$)	Eu ($\mu\text{g/mL}$)	Gd ($\mu\text{g/mL}$)	Er ($\mu\text{g/mL}$)	Al ($\mu\text{g/mL}$)	B ($\mu\text{g/mL}$)	Sr ($\mu\text{g/mL}$)	Si ($\mu\text{g/mL}$)	
0.25	0.2506	86.3	50.6	43.0	31.0	7.37	7.70	17.8	43.8	54.3	18.8	10.5	3.27	
0.50	0.2505	85.9	49.9	42.5	30.5	7.28	7.64	18.1	42.1	53.6	19.7	10.2	3.51	
1.00	0.2506	165	99.5	87.6	62.3	14.9	15.3	36.1	89.1	108	37.6	19.6	1.36	
2.00	0.2504	180	104	90.0	64.0	15.2	16.2	38.2	91.7	114	40.2	20.8	0.845	
4.00	0.2507	179	104	90.3	64.0	15.4	15.8	37.8	91.1	112	38.1	20.7	0.598	

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AC2-30													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	(µg/mL)	(µg/mL)	(µg/mL)	(µg/mL)	(µg/mL)	(µg/mL)	(µg/mL)	(µg/mL)	(µg/mL)	(µg/mL)	(µg/mL)	(µg/mL)
0.25	0.2507	28.9	6.96	6.14	16.3	3.98	0.920	2.11	6.35	13.5	5.26	2.40	3.65
0.50	0.2504	112	26.3	23.8	62.3	15.3	3.74	8.72	24.9	52.4	17.0	9.65	2.95
0.50	(1)	115	27.1	24.3	66.5	16.8	4.07	8.74	25.9	53.2	17.4	10.1	4.43
0.50	(1)	115	26.9	23.2	65.4	15.4	3.86	9.12	25.9	54.2	17.1	9.97	4.48
1.00	0.2503	217	51.2	46.4	116	29.4	7.31	16.8	46.7	102	31.7	18.8	1.41
2.00	0.2507	224	52.0	48.9	123	31.3	7.62	17.8	50.1	104	33.0	19.5	0.994
4.00	0.2507	220	52.5	48.3	122	30.8	7.39	17.1	49.1	109	33.8	19.3	1.18

(1) Duplicate Analysis of 0.50 hr Sample

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Table D.1 Elemental Analysis of Dissolved SrABS Glasses

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AC2-31													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2506	22.8	3.35	3.45	28.0	2.12	0.498	4.70	12.6	10.4	3.56	2.83	4.00
0.50	0.2509	80.1	11.6	11.5	89.8	6.95	1.64	15.4	42.8	35.5	13.1	9.48	2.74
1.00	0.2504	161	24.2	23.2	192	14.3	3.26	31.4	86.7	73.5	24.1	19.0	1.56
2.00	0.2506	172	25.6	26.0	216	16.0	3.67	34.3	93.2	81.7	26.6	20.8	1.02
4.00	0.2504	172	25.7	25.5	212	16.0	3.52	34.0	97.1	80.5	27.3	20.9	0.906

AC2-32													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2506	45.8	13.6	12.0	28.2	7.89	1.94	4.49	12.4	20.4	7.77	3.96	5.13
0.50	0.2509	116	34.7	31.4	73.4	20.9	5.32	11.3	31.5	53.1	18.2	10.0	4.95
1.00	0.2506	204	62.4	56.3	131	37.4	9.76	20.7	57.8	96.7	33.0	18.1	1.06
2.00	0.2504	211	64.3	57.3	134	37.7	9.76	20.5	58.0	100	33.5	18.4	0.695
4.00	0.2504	213	64.5	56.5	137	37.9	9.62	21.0	58.8	98.3	33.5	18.7	0.74

AC2-33													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2509	32.7	8.80	7.49	21.1	5.07	1.22	2.88	8.06	13.5	4.84	2.67	3.55
0.50	0.2506	113	30.0	26.5	73.1	18.1	4.29	9.88	28.7	47.6	15.4	8.84	2.07
1.00	0.2510	213	56.4	49.8	141	33.1	8.14	18.7	53.1	90.8	29.0	16.8	1.13
2.00	0.2509	220	58.4	51.2	149	35.2	8.62	20.0	57.4	93.0	29.6	17.1	0.924
4.00	0.2504	224	58.4	52.3	148	34.8	8.58	19.5	57.6	92.4	30.4	17.4	0.712

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AC2-34													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2507	33.5	7.78	7.14	17.6	4.20	1.01	2.52	7.29	15.1	5.75	2.72	3.87
0.50	0.2507	118	29.0	25.5	63.9	15.6	4.09	9.16	27.0	53.9	17.4	10.2	2.03
1.00	0.2504	224	52.7	50.2	120	29.4	7.92	17.8	50.8	106	32.6	19.6	0.886
2.00	0.2503	239	54.0	49.8	127	29.7	8.17	18.0	52.8	105	33.8	19.7	0.832
4.00	0.2506	226	57.0	50.2	131	29.7	8.68	18.4	51.6	110	33.3	19.5	0.735

AC2-35													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2507	92.2	26.2	23.1	63.8	15.6	3.84	8.65	24.8	37.4	12.8	7.28	3.29
0.50	0.2506	99.2	27.2	25.2	67.1	16.5	4.16	9.19	26.9	39.6	14.2	7.79	3.70
0.50	(1)	103	28.6	25.9	65.6	17.1	4.24	9.96	27.1	43.3	15.3	8.42	6.89
0.50	(1)	101	28.1	24.2	68.7	16.9	4.05	9.48	27.3	41.9	13.7	7.91	5.91
1.00	0.2508	197	58.4	50.2	142	33.2	8.16	18.9	55.9	82.5	27.5	15.6	1.44
2.00	0.2506	227	63.6	57.5	155	36.6	9.59	21.2	62.0	93.8	31.2	18.3	0.885
4.00	0.2507	222	64.1	55.2	154	37.5	9.17	20.3	59.6	90.3	31.0	17.3	0.46
(1) Duplicate Analysis of 0.50 hr Sample													

AC2-36													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2510	31.1	9.74	8.44	22.2	5.28	1.36	3.16	8.75	13.4	5.68	2.60	3.81
0.50	0.2505	103	30.2	27.3	77.1	17.5	4.53	10.7	28.9	43.4	13.5	8.20	3.30
1.00	0.2509	215	67.2	58.8	166	36.7	9.49	22.9	61.9	93.7	28.8	17.8	1.45
2.00	0.2505	212	65.7	58.3	161	37.3	9.63	22.8	62.9	93.7	28.8	16.7	0.634
4.00	0.2509	223	67.4	57.5	166	36.6	9.40	22.8	62.5	98.7	32.7	17.3	0.674

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Table D.1 Elemental Analysis of Dissolved SrABS Glasses

AC2-37												
Time (hr)	Sample Mass (g)	La ($\mu\text{g/mL}$)	Ce ($\mu\text{g/mL}$)	Pr ($\mu\text{g/mL}$)	Nd ($\mu\text{g/mL}$)	Sm ($\mu\text{g/mL}$)	Eu ($\mu\text{g/mL}$)	Gd ($\mu\text{g/mL}$)	Er ($\mu\text{g/mL}$)	Al ($\mu\text{g/mL}$)	B ($\mu\text{g/mL}$)	Si ($\mu\text{g/mL}$)
0.25	0.2509	36.2	11.1	9.66	25.8	6.10	1.62	3.69	10.3	14.5	5.40	3.32
0.50	0.2506	104	31.4	27.4	75.7	17.8	4.49	10.5	29.6	43.2	14.5	3.13
1.00	0.2510	204	61.7	55.8	152	35.4	9.13	21.8	59.4	88.1	28.8	0.822
2.00	0.2505	208	64.6	56.6	154	36.9	9.28	21.8	60.1	86.8	30.7	0.744
4.00	0.2509	210	63.4	56.5	160	36.6	9.33	21.5	60.5	89.5	29.4	0.780
AC2-38												
Time (hr)	Sample Mass (g)	La ($\mu\text{g/mL}$)	Ce ($\mu\text{g/mL}$)	Pr ($\mu\text{g/mL}$)	Nd ($\mu\text{g/mL}$)	Sm ($\mu\text{g/mL}$)	Eu ($\mu\text{g/mL}$)	Gd ($\mu\text{g/mL}$)	Er ($\mu\text{g/mL}$)	Al ($\mu\text{g/mL}$)	B ($\mu\text{g/mL}$)	Si ($\mu\text{g/mL}$)
0.25	0.2507	39.7	11.9	10.9	28.3	6.84	1.69	4.05	11.1	15.5	5.91	3.81
0.50	0.2512	127	38.9	36.2	93.7	22.7	5.77	14.1	37.0	52.2	18.3	2.33
1.00	0.2507	222	65.5	61.2	163	39.1	9.81	23.8	62.9	86.6	29.8	0.580
2.00	0.2507	219	67.8	61.0	162	37.7	9.98	22.7	61.7	86.3	29.4	0.368
4.00	0.2504	218	66.2	63.2	159	39.4	9.91	22.7	63.2	87.6	29.3	0.440
AC2-39												
Time (hr)	Sample Mass (g)	La ($\mu\text{g/mL}$)	Ce ($\mu\text{g/mL}$)	Pr ($\mu\text{g/mL}$)	Nd ($\mu\text{g/mL}$)	Sm ($\mu\text{g/mL}$)	Eu ($\mu\text{g/mL}$)	Gd ($\mu\text{g/mL}$)	Er ($\mu\text{g/mL}$)	Al ($\mu\text{g/mL}$)	B ($\mu\text{g/mL}$)	Si ($\mu\text{g/mL}$)
0.25	0.2506	32.9	10.8	9.56	25.2	6.27	1.58	3.34	10.1	14.1	4.48	4.13
0.50	0.2509	117	35.9	32.6	89.5	21.9	5.51	11.8	35.5	48.9	15.8	2.66
1.00	0.2503	198	65.3	57.7	159	36.0	9.76	21.1	62.2	86.2	27.6	1.02
2.00	0.2509	203	65.8	60.1	164	39.0	10.1	21.1	64.4	89.9	28.6	0.809
4.00	0.2508	206	69.1	59.9	164	38.4	10.2	21.8	66.4	92.2	28.0	0.752

Appendix D
Table D.1 Elemental Analysis of Dissolved SrABS Glasses

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AC2-40													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2503	34.4	11.4	10.2	26.5	6.52	1.66	3.64	10.6	13.0	4.77	2.60	3.77
0.50	0.2505	135	44.6	40.2	105	27.1	6.59	14.1	43.3	54.6	17.1	10.1	2.21
1.00	0.2502	213	71.7	62.5	171	40.6	10.3	23.7	67.9	84.4	26.6	15.5	0.978
2.00	0.2506	205	70.0	62.6	171	42.2	10.5	23.4	64.5	83.2	26.7	15.4	0.558
4.00	0.2509	219	71.0	64.0	168	43.2	10.8	24.2	69.0	86.3	27.0	15.9	0.536

AC2-41													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2509	48.5	16.0	14.2	39.6	9.64	2.21	5.49	15.3	18.4	6.00	3.56	3.23
0.50	0.2506	134	43.8	39.3	111	27.7	6.51	15.5	43.9	52.9	16.5	9.82	2.26
1.00	0.2504	211	70.4	60.9	175	43.2	10.3	23.9	68.7	81.0	25.9	14.8	0.863
2.00	0.2506	211	70.8	63.0	171	43.3	10.4	23.7	68.7	83.3	25.6	15.2	0.596
4.00	0.2507	208	69.6	63.9	178	43.7	10.2	23.8	67.9	81.8	26.1	15.4	0.703
4.00	(1)	216	72.3	65.2	168	41.7	10.4	24.6	66.5	84.7	29.2	16.2	0.791
4.00	(1)	215	70.3	64.7	164	42.5	10.3	23.8	67.8	84.8	30.5	16.1	0.621

(1) Duplicate Analysis of 0.50 hr Sample

AC2-42													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2507	34.9	6.98	5.90	16.6	3.98	1.06	2.39	6.49	17.4	6.41	3.34	5.00
0.50	0.2503	108	20.3	18.1	48.2	12.1	3.15	7.18	19.6	52.3	18.0	9.79	1.78
1.00	0.2504	231	41.0	37.8	98.5	23.4	6.25	14.4	38.1	104	35.4	19.2	0.859
2.00	0.2506	271	44.4	39.3	107	26.2	6.83	15.5	41.3	113	37.0	21.1	0.967
4.00	0.2508	258	44.7	39.2	112	27.3	6.76	15.5	41.8	114	38.3	21.0	0.829

Appendix D
Table D.1 Elemental Analysis of Dissolved SrABS Glasses

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AC2-43													
Time (hr)	Sample Mass (g)	La ($\mu\text{g/mL}$)	Ce ($\mu\text{g/mL}$)	Pr ($\mu\text{g/mL}$)	Nd ($\mu\text{g/mL}$)	Sm ($\mu\text{g/mL}$)	Eu ($\mu\text{g/mL}$)	Gd ($\mu\text{g/mL}$)	Er ($\mu\text{g/mL}$)	Al ($\mu\text{g/mL}$)	B ($\mu\text{g/mL}$)	Sr ($\mu\text{g/mL}$)	Si ($\mu\text{g/mL}$)
0.25	0.2513	34.5	8.11	7.28	20.1	5.02	1.18	2.64	7.34	16.0	5.86	2.96	4.09
0.50	0.2517	116	26.8	23.4	64.0	16.0	4.01	9.23	25.7	52.9	17.5	9.90	2.17
1.00	0.2506	225	52.5	46.1	126	31.5	7.90	17.3	48.3	102	32.9	18.9	0.864
2.00	0.2508	234	53.2	47.2	130	33.2	8.04	17.9	51.1	108	34.5	18.9	0.739
4.00	0.2512	223	52.7	47.0	129	31.8	7.84	18.5	51.2	106	33.9	18.9	0.655

AC2-44													
Time (hr)	Sample Mass (g)	La ($\mu\text{g/mL}$)	Ce ($\mu\text{g/mL}$)	Pr ($\mu\text{g/mL}$)	Nd ($\mu\text{g/mL}$)	Sm ($\mu\text{g/mL}$)	Eu ($\mu\text{g/mL}$)	Gd ($\mu\text{g/mL}$)	Er ($\mu\text{g/mL}$)	Al ($\mu\text{g/mL}$)	B ($\mu\text{g/mL}$)	Sr ($\mu\text{g/mL}$)	Si ($\mu\text{g/mL}$)
0.25	0.2505	27.9	8.24	7.88	19.5	4.70	1.24	2.85	7.81	10.7	4.38	1.95	3.44
0.50	0.2503	109	33.8	31.8	83.0	19.0	4.96	12.0	31.7	43.5	14.2	8.15	2.29
1.00	0.2506	209	67.0	61.2	163	37.9	9.70	23.3	62.6	92.3	29.0	16.3	1.08
2.00	0.2508	227	68.5	61.6	163	40.7	10.1	23.5	64.7	87.7	29.1	16.7	0.641
4.00	0.2506	216	68.9	61.4	167	38.5	10.1	23.7	60.2	89.3	30.2	16.9	0.632

AC2-45													
Time (hr)	Sample Mass (g)	La ($\mu\text{g/mL}$)	Ce ($\mu\text{g/mL}$)	Pr ($\mu\text{g/mL}$)	Nd ($\mu\text{g/mL}$)	Sm ($\mu\text{g/mL}$)	Eu ($\mu\text{g/mL}$)	Gd ($\mu\text{g/mL}$)	Er ($\mu\text{g/mL}$)	Al ($\mu\text{g/mL}$)	B ($\mu\text{g/mL}$)	Sr ($\mu\text{g/mL}$)	Si ($\mu\text{g/mL}$)
0.25	0.2506	39.3	21.1	10.0	21.7	5.46	1.38	3.08	10.2	17.2	6.19	3.30	4.93
0.50	0.2509	115	63.8	29.8	66.2	16.7	4.06	9.15	31.1	51.0	17.5	9.85	3.35
1.00	0.2503	209	112	52.9	118	30.0	7.22	16.5	55.5	93.1	30.4	17.3	1.25
2.00	0.2504	203	117	54.5	122	30.4	7.68	16.3	56.8	94.6	30.1	17.7	1.18
4.00	0.2504	206	118	55.6	122	30.5	7.45	16.8	54.3	95.2	30.2	17.6	1.30

AC2-46													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)
0.25	0.2513	40.2	13.9	12.7	33.8	8.16	2.04	4.48	12.9	14.9	5.15	2.82	3.17
0.50	0.2515	127	46.8	41.8	113	28.0	6.89	15.2	44.3	49.0	16.0	9.64	1.69
1.00	0.2506	210	74.6	65.3	181	44.6	11.2	24.5	71.0	81.0	25.6	14.9	0.83
2.00	0.2507	206	76.3	65.7	177	44.1	11.0	24.6	72.5	79.5	26.1	14.6	0.751
4.00	0.2510	205	74.4	63.9	176	42.8	11.0	23.4	72.8	79.7	25.8	14.4	0.665

AC2-47													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)
0.25	0.2504	49.7	12.9	12.0	33.0	7.70	1.89	4.44	12.7	21.2	7.11	4.10	4.11
0.50	0.2504	137	37.0	33.0	90.1	22.0	5.58	12.4	35.8	60.5	18.9	11.2	2.38
1.00	0.2503	215	58.3	51.2	143	34.4	8.32	19.2	55.3	91.7	28.0	17.1	1.08
2.00	0.2504	218	60.3	52.8	148	34.7	8.72	20.2	56.8	93.2	30.0	17.7	0.584
4.00	0.2503	220	57.6	52.9	145	35.0	8.72	20.0	57.7	93.1	30.2	17.9	0.781

AC2-48													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)	(μg/mL)
0.25	0.2506	38.5	7.44	6.92	19.0	4.56	1.07	2.44	6.86	18.1	6.78	3.46	4.13
0.50	0.2508	97.9	19.1	18.4	49.9	11.5	2.81	6.47	18.2	50.2	16.6	9.04	3.82
1.00	0.2510	217	40.4	38.9	105	24.2	5.98	14.3	39.3	106	34.6	19.5	1.26
2.00	0.2504	216	43.3	39.3	111	25.6	6.45	14.5	42.1	109	35.3	20.4	0.856
4.00	0.2504	225	45.0	40.8	113	26.8	6.77	15.0	43.0	116	35.1	21.0	0.799

Appendix D
Table D.1 Elemental Analysis of Dissolved SrABS Glasses

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AC2-49													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2504	42.2	9.55	8.90	24.4	5.82	1.46	3.29	9.58	18.7	6.81	3.59	4.50
0.50	0.2509	129	29.2	26.4	72.0	17.5	4.29	9.84	27.3	56.4	18.4	10.8	2.58
1.00	0.2506	225	52.0	47.0	132	31.7	7.93	17.5	48.9	102	32.3	19.3	1.33
2.00	0.2507	229	51.7	48.0	134	31.5	7.80	18.3	49.7	106	33.7	19.4	1.22
4.00	0.2506	222	54.4	47.3	128	32.0	7.74	17.4	49.5	101	32.9	18.7	1.28
AC2-50													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2509	27.4	7.09	6.26	17.1	4.26	1.06	2.34	6.57	11.0	4.34	2.19	3.69
0.50	0.2505	34.6	9.20	8.40	22.2	5.36	1.36	3.11	9.15	14.0	5.37	2.88	3.55
1.00	0.2504	155	42.9	37.4	100	24.3	6.03	13.9	38.8	64.7	21.3	12.6	3.11
2.00	0.2509	229	61.6	55.4	150	36.7	8.79	20.2	59.3	96.7	30.9	17.9	0.961
4.00	0.2506	223	60.0	54.7	146	35.8	8.67	19.4	57.4	92.9	32.1	17.6	0.439
AC2-51													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2510	29.5	8.95	7.88	22.2	5.26	1.28	3.00	8.47	11.7	4.52	2.32	3.44
0.50	0.2504	105	32.0	28.4	76.2	19.3	4.52	10.4	29.8	41.4	14.6	8.42	1.99
1.00	0.2508	219	66.8	57.7	155	38.8	9.31	21.0	62.4	83.8	27.2	17.2	0.929
2.00	0.2505	212	65.5	57.4	161	37.7	9.42	22.6	62.9	84.1	28.1	17.1	0.403
4.00	0.2504	220	66.6	57.2	157	38.3	9.52	21.5	62.6	85.5	28.7	16.8	0.432

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Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2502	28.8	0.311	4.35	14.1	3.33	0.812	1.96	5.52	14.1	5.79	2.55	3.14
0.50	0.2508	90.5	0.180	12.9	42.5	10.4	2.58	6.16	17.1	42.5	15.3	8.18	2.33
1.00	0.2508	221	0.399	31.4	103	25.1	6.29	14.6	41.2	105	36.5	19.7	1.03
2.00	0.2504	252	0.383	35.0	112	28.1	7.01	16.5	47.7	117	41.6	21.5	0.842
4.00	0.2507	243	0.494	33.9	114	29.1	7.09	16.8	47.1	113	41.4	21.8	0.806

AC2-53													
Time (hr)	Sample	La (µg/mL)	Ce (µg/mL)	Pr (µg/mL)	Nd (µg/mL)	Sm (µg/mL)	Eu (µg/mL)	Gd (µg/mL)	Er (µg/mL)	Al (µg/mL)	B (µg/mL)	Sr (µg/mL)	Si (µg/mL)
	Mass (g)												
0.25	0.2505	30.5	4.39	4.29	38.3	2.65	2.72	1.52	4.49	18.9	6.36	2.59	4.54
0.50	0.2506	84.2	12.4	11.7	108	7.22	7.72	4.31	12.3	53.8	17.7	7.30	2.08
1.00	0.2506	156	22.6	22.1	195	14.6	14.3	7.92	23.4	99.9	32.8	13.7	1.02
2.00	0.2506	176	25.2	24.2	222	15.0	15.8	8.52	24.7	111	36.4	14.7	0.793
4.00	0.2507	175	26.5	24.6	232	15.5	15.8	8.69	26.1	116	37.1	14.9	0.851

AC2-54													
Time (hr)	Sample	La (μg/mL)	Ce (μg/mL)	Pr (μg/mL)	Nd (μg/mL)	Sm (μg/mL)	Eu (μg/mL)	Gd (μg/mL)	Er (μg/mL)	Al (μg/mL)	B (μg/mL)	Sr (μg/mL)	Si (μg/mL)
	Mass (g)												
0.25	0.2512	33.9	11.6	10.3	28.6	7.18	1.76	3.94	10.9	13.6	4.42	2.42	3.18
0.50	0.2510	98.3	34.3	30.8	82.6	21.7	5.31	11.8	32.6	40.7	12.3	7.04	2.31
1.00	0.2516	209	74.8	65.9	184	47.2	11.1	25.6	71.3	87.1	26.8	14.6	0.860
1.00	(1)	213	76.3	65.6	185	45.7	11.2	25.8	71.0	91.1	27.4	15.3	1.02
1.00	(1)	230	73.9	63.6	172	43.3	11.2	25.4	70.9	88.3	27.7	15.3	1.14
2.00	0.2510	210	74.8	66.4	174	43.3	11.3	25.3	71.0	88.9	26.8	14.6	0.682
4.00	0.2510	217	76.1	68.2	178	45.5	11.2	25.8	67.1	88.5	26.7	15.1	0.662

(1) Duplicate Analysis of 1.00 hr Sample

Appendix D
Table D.1 Elemental Analysis of Dissolved SrABS Glasses

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AC2-55													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2503	43.6	23.0	11.7	16.3	6.70	1.70	4.00	10.7	18.9	6.98	3.46	3.86
0.50	0.2512	122	64.0	32.2	46.1	19.3	4.83	11.1	29.6	53.7	17.1	9.75	1.88
1.00	0.2507	252	118	57.9	84.9	34.0	8.53	20.3	52.6	97.5	32.5	17.6	0.929
2.00	0.2512	254	116	59.5	82.1	35.3	8.96	20.6	56.7	97.6	32.6	18.0	0.773
4.00	0.2505	258	117	58.9	83.8	34.5	9.12	20.9	54.3	101	34.4	18.2	0.776

AC1-02													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2507	23.4	3.09	2.75	5.32	1.28	0.39	0.751	3.02	11.9	4.40	2.38	1.84
0.50	0.2503	94.4	12.5	11.3	20.7	5.00	1.58	2.94	12.9	48.5	16.3	9.42	2.17
1.00	0.2505	212	27.9	25.3	45.8	11.4	3.46	6.54	27.1	111	33.7	20.7	1.31
2.00	0.2505	248	32.7	29.4	54.2	12.8	4.08	7.61	32.1	130	41.6	25.4	1.10
4.00	0.2503	232	32.4	28.5	55.1	12.3	4.01	7.49	31.1	128	41.0	23.6	0.905

AC1-03													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2506	18.3	2.61	2.28	5.38	1.17	0.308	0.617	2.49	9.63	3.94	2.11	1.47
0.50	0.2508	85.9	11.7	10.4	23.6	4.52	1.45	2.75	11.0	43.2	15.3	9.28	1.62
1.00	0.2508	198	29.5	25.7	58.4	10.7	3.46	6.57	28.2	109	39.0	22.3	1.12
2.00	0.2504	234	33.8	30.6	68.5	12.5	4.20	7.40	32.8	132	44.7	26.9	0.752
4.00	0.2509	235	33.4	29.4	65.8	12.2	4.10	7.35	31.7	128	43.1	26.1	0.625

Appendix D
Table D.1 Elemental Analysis of Dissolved SrABS Glasses

WSRC-TR-99-00393
Revision 0

AC1-05													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2505	33.9	6.07	4.01	13.6	1.87	0.751	1.79	5.39	17.8	6.93	3.57	3.98
0.50	0.2506	102	18.0	11.8	42.8	5.50	2.16	5.34	16.0	54.8	19.5	10.6	1.98
1.00	0.2509	191	35.3	22.3	79.6	10.3	4.14	9.65	28.9	102	34.2	18.7	1.13
2.00	0.2505	232	40.6	26.6	93.1	12.2	4.84	11.6	36.7	124	43.7	22.6	0.589
4.00	0.2509	236	41.5	27.4	97.8	12.0	4.92	11.7	37.6	127	43.8	23.5	0.751
4.00	(1)	242	41.2	28.6	96.7	12.1	5.09	12.1	37.2	129	45.0	23.4	0.917
4.00	(1)	234	43.1	28.3	99.1	13.0	4.98	11.4	38.4	125	38.8	23.3	0.756
(1) Duplicate Analysis of 4.00 hr Sample													

AC1-06													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2505	32.7	3.83	4.60	9.15	1.67	0.609	1.70	4.56	15.8	5.82	3.11	2.68
0.50	0.2508	110	13.2	15.8	32.2	6.22	2.21	5.82	16.2	56.2	18.7	11.0	2.05
1.00	0.2507	216	26.7	33.1	64.6	11.3	4.36	11.6	31.7	109	36.2	20.6	1.27
2.00	0.2507	238	29.8	36.0	71.8	11.2	4.90	12.6	35.8	123	39.6	24.2	0.916
4.00	0.2504	248	29.5	36.7	74.3	11.3	4.97	12.6	36.8	126	39.5	24.4	0.753

AC1-10													
Time	Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Er	Al	B	Sr	Si
(hr)	Mass	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)	($\mu\text{g/mL}$)
0.25	0.2509	41.8	7.10	6.43	18.6	5.22	0.927	2.52	6.92	19.0	7.00	3.70	4.38
0.50	0.2505	103	18.1	16.4	46.8	14.2	2.46	6.40	17.8	48.1	15.2	9.69	2.21
1.00	0.2508	206	38.7	33.1	98.7	27.2	5.14	13.1	36.6	102	32.3	19.2	1.28
2.00	0.2507	228	40.3	36.2	109	28.0	5.79	14.5	40.5	111	34.7	21.3	0.817
4.00	0.2506	239	40.5	37.8	109	29.3	5.72	14.4	39.3	112	35.5	20.8	0.854

AC2-01		AC2-02		AC2-03	
Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)
0.25	16.0	0.25	13.0	0.25	14.1
0.50	51.6	0.50	46.1	0.50	50.6
1.00	99.0	1.00	100.0	1.00	97.9
2.00	101.3	2.00	102.3	2.00	98.2
4.00	102.7	4.00	102.2	4.00	101.5

AC2-04		AC2-05		AC2-06	
Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)
0.25	18.4	0.25	11.9	0.25	18.9
0.50	68.8	0.50	46.3	0.50	64.5
1.00	95.5	1.00	99.6	1.00	97.1
2.00	95.8	2.00	102.1	2.00	97.9
4.00	95.5	4.00	100.3	4.00	96.9

AC2-07		AC2-08		AC2-09	
Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)
0.25	14.3	0.25	13.2	0.25	15.6
0.50	45.1	0.50	46.8	0.50	59.3
1.00	94.5	1.00	94.9	1.00	97.9
2.00	102.5	2.00	100.4	2.00	98.8
4.00	100.7	4.00	100.3	4.00	99.7

AC2-10		AC2-11		AC2-12	
Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)
0.25	13.5	0.25	14.6	0.25	18.3
0.50	36.7	0.50	52.2	0.50	54.4
1.00	85.3	1.00	94.8	1.00	89.9
2.00	101.3	2.00	99.3	2.00	95.1
4.00	100.3	4.00	96.9	4.00	96.9

AC2-13		AC2-14		AC2-15	
Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)
0.25	11.8	0.25	11.0	0.25	14.3
0.50	40.2	0.50	42.2	0.50	48.7
1.00	85.9	1.00	97.6	1.00	91.9
2.00	99.2	2.00	97.7	2.00	99.0
4.00	99.2	4.00	99.0	4.00	100.4

AC2-16		AC2-17		AC2-18	
Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)
0.25	12.7	0.25	48.7	0.25	21.5
0.50	41.8	0.50	54.6	0.50	60.8
1.00	97.2	1.00	100.0	1.00	101.6
2.00	98.4	2.00	101.3	2.00	99.6
4.00	99.0	4.00	102.7	4.00	100.0

AC2-19		AC2-20		AC2-21	
Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)
0.25	13.2	0.25	74.1	0.25	15.6
0.50	48.8	0.50	75.4	0.50	56.4
1.00	100.6	1.00	99.1	1.00	99.1
2.00	100.8	2.00	100.3	2.00	98.7
4.00	104.9	4.00	101.2	4.00	99.6

AC2-22		AC2-23		AC2-24	
Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)
0.25	14.4	0.25	15.4	0.25	15.7
0.50	47.9	0.50	54.4	0.50	51.5
1.00	91.4	1.00	97.2	1.00	98.9
2.00	96.6	2.00	95.4	2.00	99.0
4.00	98.9	4.00	97.4	4.00	99.1

AC2-25		AC2-26		AC2-27	
Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)
0.25	16.3	0.25	15.3	0.25	14.9
0.50	48.8	0.50	44.1	0.50	48.1
1.00	99.2	1.00	94.7	1.00	94.7
2.00	99.8	2.00	100.2	2.00	99.7
4.00	98.4	4.00	101.4	4.00	99.6

AC2-28		AC2-29		AC2-30	
Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)
0.25	48.0	0.25	15.2	0.25	17.0
0.50	47.4	0.50	47.8	0.50	47.5
1.00	95.1	1.00	96.5	1.00	87.3
2.00	100.1	2.00	98.4	2.00	98.0
4.00	99.7	4.00	98.4	4.00	100.4

Table D.2 Lanthanide (La) Recovery from SrABS Glasses

Rev. 0

AC2-31		AC2-32		AC2-33	
Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)
0.25	12.8	0.25	20.8	0.25	14.6
0.50	42.8	0.50	53.4	0.50	51.0
1.00	88.5	1.00	95.5	1.00	96.1
2.00	96.8	2.00	97.7	2.00	100.6
4.00	96.7	4.00	98.7	4.00	101.4

AC2-34		AC2-35		AC2-36	
Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)
0.25	14.3	0.25	42.0	0.25	14.6
0.50	51.6	0.50	45.4	0.50	48.7
1.00	97.7	1.00	91.6	1.00	103.5
2.00	102.4	2.00	102.9	2.00	102.4
4.00	101.2	4.00	101.1	4.00	104.7

AC2-37		AC2-38		AC2-39	
Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)
0.25	16.5	0.25	17.8	0.25	15.2
0.50	47.6	0.50	58.2	0.50	53.3
1.00	94.7	1.00	100.6	1.00	93.1
2.00	96.8	2.00	99.8	2.00	95.8
4.00	97.7	4.00	99.9	4.00	97.0

AC2-40		AC2-41		AC2-42	
Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)
0.25	15.9	0.25	22.7	0.25	15.1
0.50	63.1	0.50	63.6	0.50	45.6
1.00	100.4	1.00	100.1	1.00	94.4
2.00	98.5	2.00	99.8	2.00	106.1
4.00	101.4	4.00	99.9	4.00	104.8

AC2-43		AC2-44		AC2-45	
Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)
0.25	15.3	0.25	12.5	0.25	18.8
0.50	50.5	0.50	50.9	0.50	56.3
1.00	98.6	1.00	98.9	1.00	101.1
2.00	102.1	2.00	102.7	2.00	102.1
4.00	99.5	4.00	100.9	4.00	102.6

AC2-46		AC2-47		AC2-48	
Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)
0.25	18.8	0.25	22.1	0.25	16.7
0.50	62.0	0.50	61.3	0.50	43.0
1.00	100.4	1.00	96.2	1.00	92.9
2.00	99.6	2.00	98.6	2.00	95.7
4.00	98.3	4.00	98.2	4.00	99.0

AC2-49		AC2-50		AC2-51	
Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)
0.25	18.7	0.25	12.0	0.25	13.5
0.50	56.0	0.50	15.6	0.50	47.6
1.00	99.8	1.00	70.0	1.00	98.1
2.00	101.2	2.00	103.7	2.00	97.9
4.00	99.1	4.00	101.1	4.00	98.6

AC2-52		AC2-53		AC2-54	
Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)
0.25	11.9	0.25	13.0	0.25	16.1
0.50	36.5	0.50	51.4	0.50	47.2
1.00	88.6	1.00	96.3	1.00	102.5
2.00	100.0	2.00	100.5	2.00	100.5
4.00	98.5	4.00	99.1	4.00	102.4

AC2-55		AC1-02		AC1-03	
Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)
0.25	19.3	0.25	9.3	0.25	7.6
0.50	53.7	0.50	37.6	0.50	34.6
1.00	102.7	1.00	83.7	1.00	82.4
2.00	103.3	2.00	98.0	2.00	97.0
4.00	104.1	4.00	93.9	4.00	95.7

AC1-05		AC1-06		AC1-10	
Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)	Time (hr)	La Recovery (%)
0.25	14.4	0.25	12.8	0.25	17.6
0.50	43.6	0.50	43.7	0.50	44.4
1.00	81.6	1.00	86.6	1.00	90.3
2.00	98.1	2.00	95.5	2.00	98.9
4.00	101.0	4.00	98.6	4.00	101.5

Glass ID	Time	Sample Mass	Recovered Mass	Variance of Recovered Mass	Lanthanide Composition	Lanthanide Recovery	Variance of Lanthanide Recovery
	(h)	(g)	(g)	(g ²)	(Wt Fraction)	(%)	(% ²)
AC2-02	0.50	0.2502	5.54×10^{-2}	2.45×10^{-5}	0.481	46.1	17.1
AC2-10	0.25	0.2502	1.56×10^{-2}	5.59×10^{-7}	0.463	13.5	0.4
AC2-11	2.00	0.2510	1.25×10^{-1}	1.72×10^{-6}	0.504	99.3	1.6
AC2-13	1.00	0.2508	8.98×10^{-2}	1.30×10^{-6}	0.417	85.9	1.8
AC2-15	0.25	0.2510	1.62×10^{-2}	1.38×10^{-6}	0.454	14.3	1.1
AC2-16	0.25	0.2508	1.59×10^{-2}	3.63×10^{-6}	0.497	12.7	2.3
AC2-29	2.00	0.2506	1.27×10^{-1}	7.40×10^{-6}	0.516	98.4	4.9
AC2-35	0.50	0.2506	5.58×10^{-2}	1.34×10^{-6}	0.491	45.4	1.0
AC2-41	4.00	0.2507	1.33×10^{-1}	3.87×10^{-7}	0.529	99.9	0.7
AC2-53	0.50	0.2504	5.67×10^{-2}	5.65×10^{-7}	0.441	51.4	0.7
AC2-54	1.00	0.2516	1.38×10^{-1}	2.33×10^{-7}	0.536	102.5	0.6
AC1-05	4.00	0.2509	9.44×10^{-2}	3.70×10^{-7}	0.373	101.0	1.4
Pooled Lanthanide Composition Variance					1.39×10^{-5}	$V_{\text{pooled}} = 2.8$	

Glass ID	Dissolution Rate	Dissolution Rate Standard Deviation	Relative Standard Deviation
	(g/h-cm ²)	(g/h-cm ²)	(%)
AC2-01	0.024	0.003	12
AC2-02	0.031	0.006	20
AC2-03	0.023	0.002	10
AC2-04	0.019	0.002	12
AC2-05	0.025	0.004	16
AC2-06	0.021	0.001	3
AC2-07	0.018	0.002	11
AC2-08	0.018	0.002	10
AC2-09	0.024	0.001	3
AC2-10	0.013	0.002	12
AC2-11	0.019	0.001	4
AC2-12	0.015	0.000 ₄	2
AC2-13	0.013	0.001	7
AC2-14	0.022	0.003	15
AC2-15	0.016	0.001	4
AC2-16	0.022	0.004	16
AC2-17	0.025	0.007	30
AC2-18	0.033	0.005	14
AC2-19	0.030	0.006	19
AC2-20	0.016	0.005	32
AC2-21	0.023	0.002	9
AC2-22	0.016	0.001	5
AC2-23	0.021	0.001	4
AC2-24	0.024	0.003	12
AC2-25	0.025	0.004	15
AC2-26	0.018	0.002	12
AC2-27	0.018	0.002	9
AC2-28	0.015	0.005	35
AC2-29	0.021	0.002	11
AC2-30	0.013	0.000 ₄	3
AC2-31	0.015	0.001	7
AC2-32	0.017	0.002	12
AC2-33	0.020	0.001	7
AC2-34	0.021	0.002	9
AC2-35	0.013	0.004	33
AC2-36	0.032	0.006	19
AC2-37	0.019	0.002	10
AC2-38	0.032	0.004	14
AC2-39	0.018	0.000 ₂	1
AC2-40	0.032	0.003	10
AC2-41	0.032	0.004	12
AC2-42	0.017	0.002	11

Glass ID	Dissolution Rate	Dissolution Rate Standard Deviation	Relative Standard Deviation
	(g/h·cm ²)	(g/h·cm ²)	(%)
AC2-43	0.022	0.003	12
AC2-44	0.024	0.003	12
AC2-45	0.030	0.005	16
AC2-46	0.033	0.004	12
AC2-47	0.018	0.000 ₁	0.4
AC2-48	0.015	0.002	14
AC2-49	0.025	0.003	13
AC2-50	0.013	0.001	11
AC2-51	0.022	0.003	13
AC2-52	0.011	0.001	8
AC2-53	0.019	0.001	7
AC2-54	0.034	0.007	20
AC2-55	0.030	0.005	18
AC1-02	0.008	0.001	14
AC1-03	0.007	0.001	15
AC1-05	0.008	0.001	10
AC1-06	0.011	0.001	5
AC1-10	0.009	0.002	19

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