ORP-61889
Revision 0

Impacts of Process and Prediction Uncertainties on Projected Hanford Waste Glass Amount

EWG-RPT-015, Rev 0.0 (PNNL-26996)

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Office of River Protection

P.O. Box 450
Richland, Washington 99352

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Date Published
February 2018

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APPROVED
By Erin C Meegan at 8:03 am, Mar 08, 2018

Release Approval　　　Date

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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Abstract

Analyses were performed to evaluate the impacts of using the advanced glass models, constraints (Vienna et al. 2016), and uncertainty descriptions on projected Hanford glass mass. The maximum allowable waste oxide loading (WOL) was estimated for waste compositions while simultaneously satisfying all applicable glass property and composition constraints with sufficient confidence. Different components of prediction and composition/process uncertainties were systematically included in the calculations to evaluate their impacts on glass mass. The analyses estimated the production of 23,360 MT of immobilized high-level waste (IHLW) glass when no uncertainties were taken into account. Accounting for prediction and composition/process uncertainties resulted in 5.01 relative percent increase in estimated glass mass of 24,531 MT. Roughly equal impacts were found for prediction uncertainties (2.58 RPD) and composition/process uncertainties (2.43 RPD). The immobilized low-activity waste (ILAW) mass was predicted to be 282,350 MT without uncertainty and with waste loading “line” rules in place. Accounting for prediction and composition/process uncertainties resulted in only 0.08 relative percent increase in estimated glass mass of 282,562 MT. Without application of line rules the glass mass decreases by 10.6 relative percent (252,490 MT) for the case with no uncertainties. Addition of prediction uncertainties increases glass mass by 1.32 relative percent and the addition of composition/process uncertainties increase glass mass by an additional 7.73 relative percent (9.06 relative percent increase combined). The glass mass estimate without line rules (275,359 MT) was 2.55 relative percent lower than that with the line rules (282,562 MT), after accounting for all applicable uncertainties.

Quality Assurance

This task was performed under the U.S. Department of Energy (DOE) Office of River Protection (ORP) Inter-Entity Work Order # M0ORV00020 and under Pacific Northwest National Laboratory's (PNNL's) Nuclear Quality Assurance Program (NQAP). The NQAP uses ASME NQA-1-2012, Quality Assurance Requirements for Nuclear Facility Applications as its consensus standard and NQA-1-2012 Subpart 4.2.1 as the basis for its graded approach to quality. The information in this report was produced under a grading of Basic Research.

Acknowledgments

The authors gratefully acknowledge the financial support provided by the U.S. Department of Energy Waste Treatment and Immobilization Plant Project.

The authors also thank the following people for their technical review and consultations on the work leading to this report:

- Michael Schweiger (PNNL) for peer review of the document
- Jeremy Belsher (WRPS) for supplying the waste feed vectors used in the calculation

These calculations were based on the *Preliminary ILAW Formulation Algorithm* and the *Preliminary IHLW Formulation Algorithm* developed by the Bechtel National, Inc (BNI) as part of the WTP project. We are thankful to BNI for use of these algorithms.

The authors thank Hans Brandal for quality assurance support and Veronica Perez for records management.

Acronyms and Abbreviations

BNI	Bechtel National, Inc.
CI	confidence interval
c_{Sp}	equilibrium concentration of spinel in the melt
CRV	concentrate receipt vessel
DOE	U.S. Department of Energy
DWPF	defense waste processing facility
DWPF-EA	defense waste processing facility environmental assessment
EMF	effluent management facility
ETF	effluent treatment facility
GFC	glass forming chemical
HBV	HLW blend vessel
HLW	high-level waste
IHLW	immobilized high-level waste
ILAW	immobilized low-activity waste
LAW	low-activity waste
LAWPS	low-activity waste pretreatment system
MFPV	melter feed preparation vessel
MFV	melter feed vessel
MT	metric ton
NP	nepheline
ORP	Office of River Protection
PCT	Product Consistency Test
PT	pretreatment facility
RMSE	root mean squared error
RPD	relative percentage difference
SCI	simultaneous confidence interval
$T_{2\%}$	temperature at two volume percent crystals in equilibrium with the melt
T_L	liquidus temperature
TOE	total online efficiency
VHT	Vapor Hydration Test
WOL	waste oxide loading
WRPS	Washington River Protection Solutions
WTP	Hanford Tank Waste Treatment and Immobilization Plant
η_{1150}	melt viscosity at the processing temperature

Contents

Figures

Tables

1.0 Background

The U.S. Department of Energy (DOE) Office of River Protection (ORP) is responsible for the safe retrieval, treatment, and disposal of this waste. For this scope ORP is contracting Bechtel National, Inc. (BNI) to design, construct, and commission the world's largest radioactive waste treatment plant: the Hanford Tank Waste Treatment and Immobilization Plant (WTP) - (DOE 2000). The plant will separate the tank waste into high-level waste (HLW) and low-activity waste (LAW) fractions through filtration, cesium ion exchange, and precipitation. Each fraction will be vitrified in separate facilities into borosilicate waste glass.

Waste glass data and property-composition models were developed for the commissioning of the WTP (Piepel et al. 2007; Piepel et al. 2008). These models with uncertainty descriptions and plant operating strategies and current estimated process data were used to develop glass formulation algorithms to be used in plant operation (Kim and Vienna 2012; Vienna and Kim 2014). The current WTP glass property models, constraints, and algorithms were intended to be used in plant commissioning and represent modest waste loading and relatively conservative constraints. Application of prediction and process uncertainties was found to have a negligible impact on the amount of glass to be produced at Hanford while using the conservative models (Nelson 2010; Nelson et al. 2007).

Since their development significant advancements in glass formulation and property modeling has been made (Muller et al. 2012; Vienna et al. 2013; Russell et al. 2017; Kim et al. 2008; Muller et al. 2010; Matlack et al. 2005a; Matlack et al. 2005b; Matlack et al. 2006a, b; Matlack et al. 2007; Matlack et al. 2009; Matlack et al. 2010c; Matlack et al. 2010a; Matlack et al. 2010b). These data were compiled and incorporated into sets of constraints and glass property models which are aimed at estimating the amount of glass that would be produced at Hanford upon successfully completion of the on-going studies (Vienna et al. 2016). As this latter set of models and constraints are intended to maximize waste loading in glass they are necessarily far less conservative than those intended for plant commissioning. It stands to reason that application of prediction and process/composition uncertainties would have a larger impact on the projected amount of glass produced during the Hanford mission than for the commissioning models and constraints.

The objective of this study is to quantify the expected changes in glass amount for the entire Hanford mission by applying these new models and constraints along with the anticipated prediction and process/composition uncertainties. The process is described that determined how the glass masses were obtained and the results from each type of calculation is summarized.

2.0 Waste Treatment Process Summary

A detailed description of the assumed waste treatment process is given elsewhere (Deng et al. 2016). This section summarizes the key aspects of that process that impacts the formulation of glass with its associated uncertainties. A schematic of the LAW and HLW vitrification process is shown in Figure 1. A feed preparation or pretreatment process will deliver waste to the vitrification plants. In the case used in this report, LAW feed is prepared for the first ten years of operation in a LAW Pretreatment System (LAWPS) with recycle streams from an Effluent Treatment Facility (ETF), not shown in Figure 1, and blended in the LAW Concentrate Receipt Vessel (CRV). After 10 years of operation the LAW feed is blended with recycle streams in the Pretreatment Facility (PT). The HLW feed including pretreated sludge and Cs ion exchange eluate are delivered to the HLW Melter Feed Preparation Vessel (MFPV) from the PT HLW Blend Vessel (HBV). The final glass formulations and ultimate WOL are determined for each batch of waste from samples taken from the HLW MFPV and the LAW CRV and analyzed.

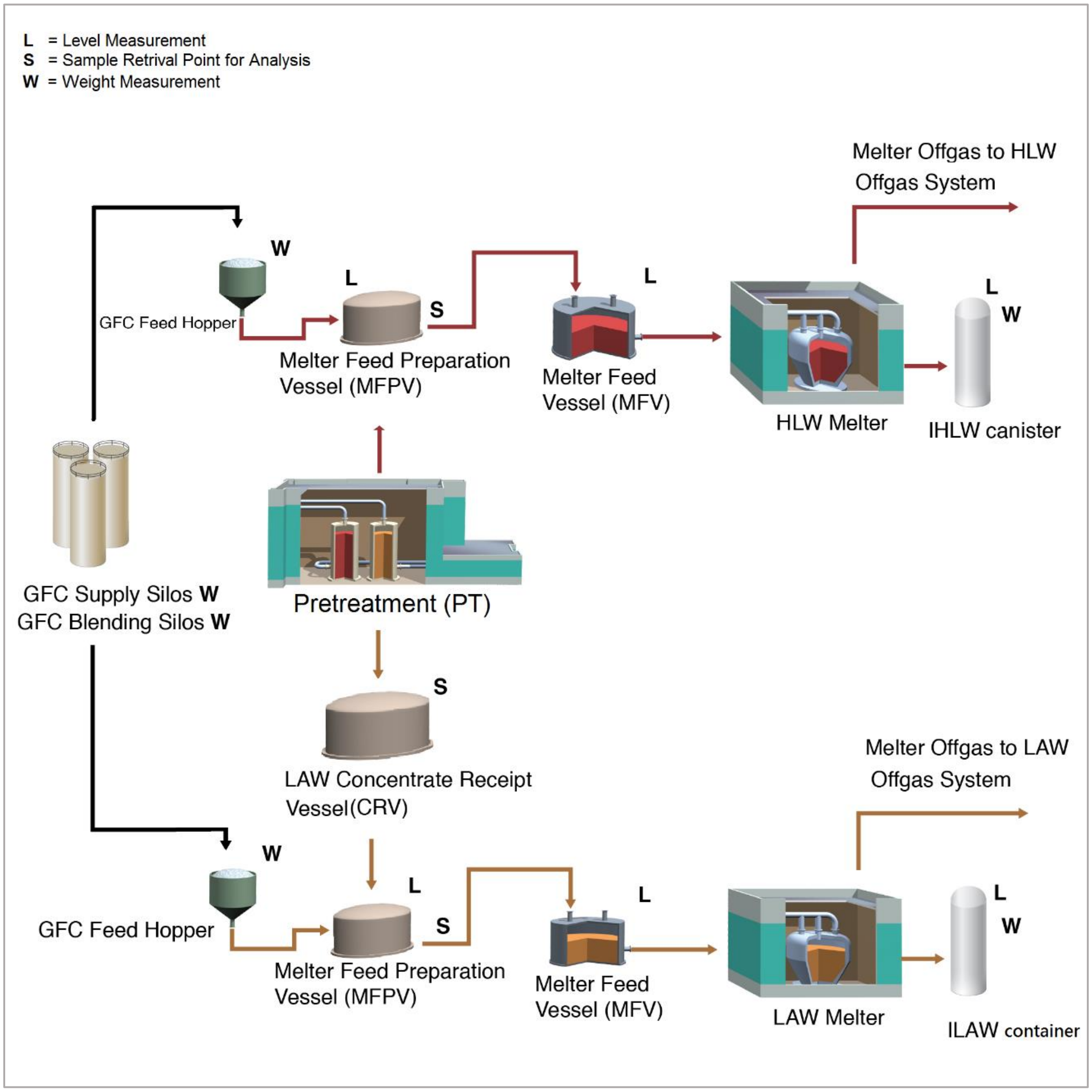


Figure 1. Schematic of the LAW and HLW vitrification process.

In the baseline flowsheet, the HLW vitrification plant will receive pretreated HLW from PT in the MFPV. The vessel content level will be measured before (heel level) and after (waste+heel level) waste addition to calculate the volume of waste and melter feed heel in each batch. The contents of the vessel will then be mixed, sampled, and analyzed for chemical and radiochemical concentrations. The current baseline is to analyze four samples of waste+heel for each MFPV batch. Based on the analyzed composition of waste+heel, glasses will be formulated to ensure the batch will meet all processing and product quality constraints with sufficient confidence. The associated mix of glass forming chemicals (GFC's) will be weighed, blended, and transferred into the MFPV. The level of slurry in the MFPV will be measured to determine melter feed volume and samples (nominally up to eight samples) will be taken and analyzed for chemical composition. The composition and associated predicted properties from this latter set of analyses will be used to qualify the glass to be produced and generate data for glass production records.[1] The melter feed will then be transferred as a batch to the melter feed vessel (MFV) where it will be continuously fed into the melter. The volumes of melter feed in both the MFPV and MFV will be measured before and after waste transfer to determine volume of melter feed in that batch.

The LAW vitrification plant will receive pretreated LAW from either LAWPS + effluent management facility (EMF) or PT in the CRV. The vessel content level will be measured after waste addition to estimate the volume of waste in each CRV batch. The contents of the vessel will then be mixed, sampled, and analyzed for chemical and radiochemical concentrations. The current baseline is to analyze three samples of waste for each CRV batch. Based on the analyzed composition, glasses will be formulated to ensure the melter feed batch will meet all processing and product quality constraints with sufficient confidence. The calculated volume of LAW for each MFPV batch from the CRV will be transferred into the MFPV. The mass of each glass forming chemicals (GFC's) to achieve the target glass composition will be weighed, blended, and transferred into the MFPV. The level of slurry in the MFPV will be measured to determine melter feed volume and a sample will be taken and analyzed for chemical composition as a process control measure to confirm the appropriate melter feed was prepared. The composition and associated predicted properties from analyses of waste in the CRV, the measured mass of each GFC, and the volume of waste transferred from the CRV to the MFPV will be used to produce and generate data for glass production records.

[1] Reporting of radionuclide concentrations will be based on measurement of radionuclide concentrations in the waste+heel samples.

3.0 Glass Constraints and Property Models

Estimates of maximum WOL were determined in this study by numerically optimizing glass compositions for each waste composition while simultaneously satisfying a number of property and composition constraints, the process/composition constraints described in Section 3.1 for HLW and Section 3.2 for LAW. The melter feed should be both processable and yield an adequate product, i.e., the resultant glass should have properties within acceptable ranges. Properties of the target glass are predicted using glass-composition property models; which are valid over fixed composition ranges defined by model validity constraints. The models and constraint sets used in this study are those described by Vienna (2016) and are briefly described in the following subsections.

3.1 HLW Constraints and Property Models

Table 1 summarizes the HLW glass property/composition constraints used in glass optimization with bulleted descriptions and explanations for each constraint below the table. Also reported are glass component concentration limits (Table 2) for model validity, chromium tolerance, and phosphate tolerance.

Table 1. Summary of HLW Melt and Glass Constraints

Property/Composition Constraint	Limit
PCT Responses	ln[PCT-B, Na, Li, g/m^2] ≤ 1.386[(a)]
Nepheline	$p \le 0.3$ (probability)
Spinel	$T_{2\%} \le 950°C$
Zirconium-containing phases	T_L-Zr $\le 1050°C$ if $g_{ZrO_2} > 0.04$ (mass fraction)
Viscosity at 1150°C	$0.693 \le \ln(\eta_{1150}, \text{Pa·s}) \le 2.079$[(b)]
P_2O_5 and CaO concentrations	$w_{P_2O_5} \times w_{CaO} \le 6.5$ $(wt\%)^2$
Salt, SO_3 concentration	$w_{SO_3} \le w_{SO_3}^{Limit}$ (wt%)
Eskolaite formation	$g_{Cr_2O_3} \le 0.03$ (mass fraction)
B_2O_3 and SiO_2 concentrations	$g_{SiO_2} + g_{B_2O_3} \ge 0.32$ (mass fraction)

(a) This corresponds to PCT-B, -Na, -Li ≤ 4 g/m^2.
(b) This corresponds to $2 \le \eta_{1150} \le 8$ Pa·s.

1. The normalized PCT responses of boron, sodium, and lithium of HLW glasses must be below those of the Defense Waste Processing Facility Environmental Assessment (DWPF-EA) glass (Jantzen et al. 1993) with sufficient confidence (DOE 1996). The WTP Wasteform Qualification Report uses a 95% confidence level (Nelson 2010). A conservative value of 4 g/m^2 was used in this study. Although this value is conservative (48% to 60% of the limit) it has previously been shown to not be impactful on WOL.

2. The formation of nepheline on slow-cooled glass has been previously shown to strongly impact the chemical durability of glass and the ability to predict PCT responses (Kim et al. 1995). A predicted probability of 30% nepheline precipitation by the current submixture model (Vienna et al. 2017) was found to represent roughly 95% confidence that nepheline would not form in waste glasses as described in detail in (Vienna et al. 2016).
3. The accumulation of spinel in the melter may disrupt processing and/or reduce melter life (Matyas et al. 2012). Vienna et al. (2016) used an ad-hoc yet conservative limit of 2 vol% spinel at equilibrium with the melt at 950°C.
4. Some waste types, rich in ZrO_2 (> 4 wt%), are prone to precipitation of zirconia containing phases which may disrupt processing and/or reduce melter life (Crum et al. 1997). A T_L limit of 1050°C is used in this study. The model reported in (Vienna et al. 2016) for T_L-Zr was modified slightly to avoid a jump in predicted response at g_{ZrO_2} = 0.04 as described at the end of this subsection.
5. The viscosity of glass melts must be maintained near 5 Pa·s for smooth processing. The $2 < \eta_{1150} < 8$ limit was used for this study.
6. Glasses high in phosphate may form non-durable secondary phases, increase corrosivity of metal melter components, and form difficult to melt phases in the melter cold-cap. An ad-hoc constraint of calcium oxide times phosphorous oxide < 6.5 $wt\%^2$ was developed to avoid the many deleterious effects of high phosphate glasses (Vienna 2008).
7. Sulfate salt accumulation in the melter may increase melter materials corrosion and increase volatility (Vienna et al. 2014). A sulfate solubility model was used to avoid compositions prone to salt accumulation in HLW melter feeds.
8. Some waste types, rich in Cr_2O_3 (> 3 wt%) are prone to eskolaite precipitation and/or molten chromate salt accumulation. An ad-hoc 3 wt% constraint was used to avoid those compositions.
9. Glasses low in the two primary solvents or glass formers – SiO_2 and B_2O_3 – may not make a processable glass. An ad-hoc limit of 32 wt% of combined formers was used, based on preliminary test data.

The models used to predict these properties are generally of the form:

$$t(P) = \sum_{i=1}^{q} a_i g_i + \text{ Selected}\left\{\sum_{i=1}^{q} a_{ii} g_i^2 + \sum_{i=1}^{q-1}\sum_{j=i+1}^{q} a_{ij} g_i g_j\right\} \quad (1)$$

where, $t(P)$ is the transformed property, a_i are the ith component coefficient, a_{ii} are the ith cross ith and ith cross jth component interaction coefficients, and g_i and g_j are the mass fractions of component i and j. Exceptions to this model form are: 1) PCT models which also contain $g^3_{Al_2O_3}$, and $g^4_{Al_2O_3}$ terms and 2) nepheline formation probability which is a polynomial of normalized component concentrations. Model details and coefficients are given by Vienna et al. (2016). In addition to the property constraints, the model validity constraints for glass component concentrations, shown in Table 2 are used.

Table 2. HLW Glass Component Concentration Constraints, in Mass Fractions

Component	Min	Max
Al_2O_3	0.0190	0.3000
B_2O_3	0.0400	0.2200
Bi_2O_3	0	0.0700
CaO	0	0.1000
CdO	0	0.0150
Cr_2O_3	0	0.0300
F	0	0.0250
Fe_2O_3	0	0.2000
K_2O	0	0.0600
Li_2O	0	0.0600
MgO	0	0.0600
MnO	0	0.0800
Na_2O	0.0410	0.2400
NiO	0	0.0300
P_2O_5	0	0.0450
SiO_2	0.2200	0.5300
SrO	0	0.1010
ThO_2	0	0.0600
TiO_2	0	0.0500
UO_3	0	0.0630
ZnO	0	0.0400
ZrO_2	0	0.1350

Application of the constraints and models from Vienna et al. 2016 resulted in significant challenges to converge on optimal solutions using standard optimization routines (e.g., Microsoft Excel™ solver, Frontline Analytical Solver, the solver built-in to Gensym G2). Two changes were implemented in calculations described in this report to improve stability and enable optimal solutions using standard optimization routines.

1. The model reported in (Vienna et al. 2016) for T_L-Zr was modified slightly to avoid a jump in predicted response at $g_{ZrO_2} = 0.04$. A sigmoidal function that approaches 0 at $g_{ZrO_2} < 0.04$ and approaches predicted T_L-Zr at $g_{ZrO_2} > 0.04$ was added: $T_L - Zr = \dfrac{\sum T_i g_i}{1+e^{-1000(g_{ZrO_2}-0.039)}}$. This addition has no practical implications to meeting the constraint while allowing for successful numerical optimization of glass compositions near $g_{ZrO_2} = 0.04$.
2. Additives used were limited to silica, borax, sodium carbonate, lithium carbonate, zincite, wollastonite, V_2O_5, kyanite, and hematite. Compared to the recommended additives of: Al_2O_3, B_2O_3, CaO, Li_2O, MgO, Na_2O, SiO_2, V_2O_5, ZnO, and ZrO_2. Effectively, MgO and ZrO_2 were excluded.

3.2 LAW Constraints and Property Models

Table 3 summarizes the LAW glass property/composition constraints used in glass optimization. A set of waste loading rules were used during some of the calculations as an ad-hoc method of limiting loading of waste in glass (Muller et al. 2010). Whether the loading rules where applied or not, each waste glass met a set of property constraints: sulfate solubility; baddeleyite (ZrO_2) and cassiterite (SnO_2) precipitation; durability including alkali to ZrO_2+CaO+SnO_2 ratio, PCT response, and vapor hydration test (VHT) response; η_{1150}; and refractory corrosion. A description and explanation of each of the property constraints are itemized below Table 3. In Table 4 glass component concentration constraints are identified.

Table 3. Summary of LAW Melt and Glass Constraints

Waste Loading Rules	Limit
Alkali content	$w_{Na_2O} + 0.66 w_{K_2O} \le 24\,\text{wt\%}$
Alkali and sulfur content	$w_{Na_2O} + 0.66 w_{K_2O} \le 33.94 - 11.69 w_{SO_3}$, wt%
Sulfur content	$w_{SO_3} \le 1.5\,\text{wt\%}$
Halide content	$g_{SO_3} \le 0.01825 - 0.4936 \times \left(1.761 g_{Cl} + 2.971 g_{Cr_2O_3} - 0.1608 g_{P_2O_5}\right)$
Property	**Limit**
Salt, SO_3 concentration	$w_{SO_3} \le w_{SO_3}^{Limit}$
Combined zirconia, tin, and alumina constraint	$g_{ZrO_2} + g_{SnO_2} + g_{Al_2O_3} \le 0.17$
Alkali minus sum of zirconia, tin, and lime constraint	$g_{Na_2O} + 0.66 g_{K_2O} + 2.07 g_{Li_2O} - g_{ZrO_2} - g_{SnO_2} - g_{CaO} \le 0.15$
PCT response	ln[PCT NL, g/L] ≤ 1.386
VHT response	ln[VHT D, μm] ≤ 6.116
Viscosity at 1150°C	0.693≤ ln[η_{1150}, Pa·s] ≤ 2.079
K-3 neck corrosion at 1208°C	ln[k_{1208}, in] ≤ -3.2189

1. Sulfate salt accumulation in the melter may increase melter materials corrosion and increase volatility (Vienna et al. 2014). A sulfate solubility model was used to avoid compositions prone to salt accumulation in LAW melter feeds.
2. Some glass formulations, rich in combined ZrO_2, SnO_2, and Al_2O_3 are prone to precipitation of baddeleyite (ZrO_2) or cassiterite (SnO_2) which may disrupt processing and/or reduce melter life. An ad-hoc empirical rule constraining the combine concentrations of those oxides reduces the likelihood of their precipitation.
3. LAW glasses are particularly prone to relatively poor chemical durability due to high alkali content. Above some threshold in alkali content the durability test responses of glasses become very high and change in a non-linear fashion. ZrO_2, SnO_2, and CaO generally increase the alkali concentration where the durability becomes highly non-linear. An empirical, ad-hoc, concentration constraint is used to 1) help reduce the likelihood of non-durable glasses and 2) improve the ability of PCT and VHT models to better predict responses.
4. The normalized PCT responses of boron, sodium, and silicon of LAW glasses must be below 4 g/L (DOE 2000).
5. The VHT response of LAW glasses must be below 50 g/m^2/d (DOE 2000).
6. The viscosity of glass melts must be maintained near 5 Pa·s for smooth processing. The $2 < \eta_{1150} < 8$ limit was used for this study.

7. Glasses rich in alkali are prone to excessive refractory corrosion. K-3 corrosion > 0.04 inches per year at the melt line was suggested as an appropriate limit to avoid excessive corrosion (Muller et al. 2015).

The models used to predict these properties are generally of the form shown in Eqn 1. Model details and coefficients are given by Vienna et al. (2016). In addition to the property constraints, the model validity constraints for glass components are used (Table 4).

Table 4. LAW Glass Component Concentration Constraints, in Mass Fractions

Component	Min	Max
Al_2O_3	0.0553	0.1370
B_2O_3	0.0600	0.1370
CaO	0	0.1060
Cl	0	0.0117
Cr_2O_3	0	0.0100
Fe_2O_3	0	0.0997
K_2O	0	0.0589
Li_2O	0	0.0503
MgO	0	0.0350
Na_2O	0.0248	0.2600
P_2O_5	0	0.0340
SiO_2	0.2983	0.5020
SnO_2	0	0.0501
TiO_2	0	0.0341
V_2O_5	0	0.0401
ZnO	0	0.0540
ZrO_2	0	0.0675

4.0 Uncertainty Estimates

As stated earlier, glass compositions are optimized for each waste to maximize WOL while simultaneously satisfying a number of property and composition constraints. Both glass composition and glass property predictions are uncertain and in practical applications variation in estimated glass composition, along with uncertainties in glass property predictions, are combined to ensure that the final glass will meet constraints with sufficient confidence. Figure 2 shows a schematic diagram of the glass formulation method applied to Hanford HLW. The ternary diagram on the left is meant to represent the multidimensional composition region made up by a particular waste batch at the top of the diagram; the concentrations of each of the ten potential glass forming additives are expressed across the bottom. The property constraints (calculated using glass property models) limit the portion of composition region within which glass can be formulated as shown by the solid black lines for different properties. Model prediction uncertainties further narrow the composition space within which glass can be formulated as shown by the dotted black lines. A glass can be formulated anywhere within the region defined by the property limits with associated uncertainties. The composition of the glass isn't precisely known. So, various sources of composition uncertainties must be accounted for as shown by the tan circle. The final glass formulation region is the region surrounded by the dotted lines (representing property limits with prediction uncertainty) that an uncertain composition (represented by the tan circle and defined in schematic on right side of Figure 2) can fit.

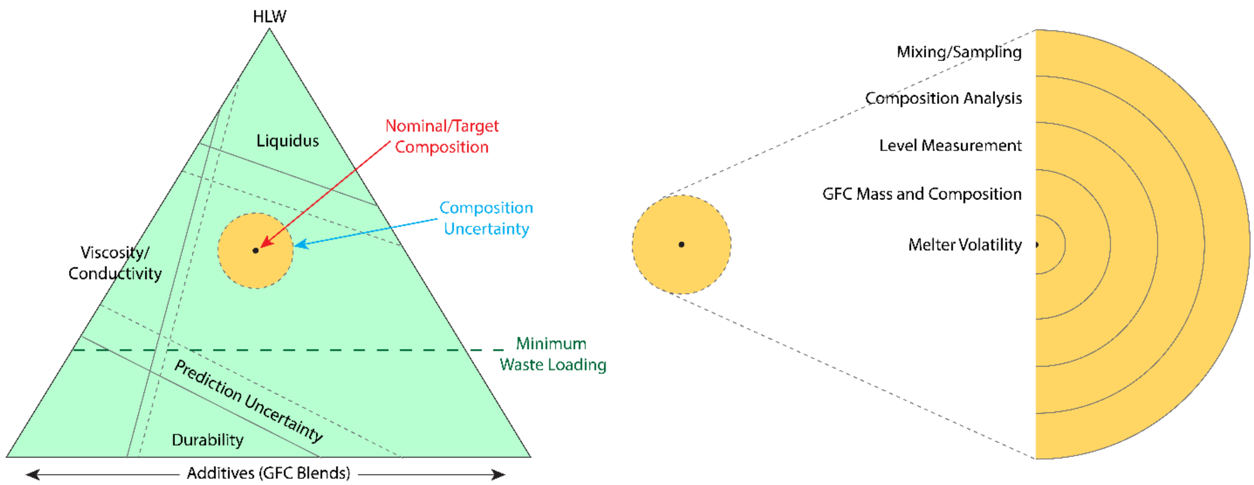


Figure 2. Schematic Representation of the Hanford HLW Glass Processing Envelope, from Vienna (2014).

The constraints used thus expressed as lower- and upper- combined confidence intervals:

$$L_\alpha^L \le t(P_\alpha) - U_\alpha^{pred} - U_\alpha^{comp} \text{ and } L_\alpha^U \ge t(P_\alpha) + U_\alpha^{pred} + U_\alpha^{comp} \quad (2)$$

where L_α^L and L_α^U are the lower and upper limits on transformed property α [$t(P_\alpha)$], U_α^{Pred} is the uncertainty in prediction of $t(P_\alpha)$, and U_α^{Comp} is the expression of composition uncertainty expressed in units of $t(P_\alpha)$. The values of uncertainty scale with the level of confidence obtained. The following subsection describes the calculation of these uncertainty values.

4.1 Model Prediction Uncertainties

Most of the property models used in this study are of the form of partial quadratic models of a transformed property (Eqn 1). Prediction uncertainty can be expressed as a confidence interval (CI) as in Eqn 3 or a simultaneous confidence interval (SCI), Eqn 4:

$$U_{CI}^{pred} = t_{1-\alpha(n-p)}\sqrt{s^2\mathbf{x}^T\left(\mathbf{X}^T\mathbf{X}\right)^{-1}\mathbf{x}} \tag{3}$$

$$U_{SCI}^{pred} = \sqrt{ps^2F_{1-\alpha(\mathrm{p,\ n\text{-}p})}\mathbf{x}^T\left(\mathbf{X}^T\mathbf{X}\right)^{-1}\mathbf{x}} \tag{4}$$

where:
- n = number of data in the model
- s = root mean squared error (RMSE) of model
- F = 1-α quantile of an F-distribution
- t = 1-α quantile of a t-distribution
- α = the confidence level
- p = number of model parameters (terms)
- **x** = glass composition vector represented in model terms
- **X** = matrix of glass compositions used in fitting the model

Generally SCI's are used when you need a given confidence that all batches will meet the limit while CI's are used when you need confidence that the single batch will meet the limit. The variance covariance matrix (**Ω**), tables listed in Table 5 and 0, combines the terms of these equations into a single matrix:

$$\mathbf{\Omega} = s^2\left(\mathbf{X}^T\mathbf{X}\right)^{-1} \tag{5}$$

Table 5 lists the property models used in formulation optimization and the uncertainty expressions assumed along with the Appendix A table for each associated variance covariance matrix.

Table 5. Summary of Predicted Properties and Associated Uncertainty Expressions

Property, units	$t(P)$	Confidence	Ω
HLW PCT normalized boron release, g/m^2	$\ln(r_B)$	95% SCI	Table A.1
HLW PCT normalized sodium release, g/m^2	$\ln(r_{Na})$	95% SCI	Table A.2
HLW PCT normalized lithium release, g/m^2	$\ln(r_{Li})$	95% SCI	Table A.3
HLW T_L of Zr containing phases, °C	T_L	90% CI	Table A.4
HLW $T_{2\%}$ of spinel, °C	$T_{2\%}$	90% CI	Table A.5
HLW nepheline probability, distance above the cutoff in SiO_2+xB_2O_3 direction	Norm mass fract	95% boot-strap	boot-strap trials in A.6
HLW viscosity at 1150°C, Pa·s	$\ln(\eta_{1150})$	90% CI	Table A.7
HLW sulfate solubility, wt%	w_{SO3}	90% CI	Table A.8
LAW PCT normalized concentration, g/L	ln(NC)	90% SCI	Table A.9
LAW VHT alteration depth, µm	ln(d)	90% SCI	Table A.10
LAW K-3 neck corrosion, in	ln(k)	90% CI	Table A.11
LAW sulfate solubility, wt%	w_{SO3}	90% CI	Table A.12
LAW viscosity at 1150°C, Pa·s	$\ln(\eta_{1150})$	90% CI	Table A.13

One key exception to the typical uncertainty quantification method is the nepheline probability model. The mathematical form of this model is different than Eqn (1):

$$P = -\frac{bC + 2bB - \sqrt{3}C}{2\left(A + B + C\right)} - \frac{c\left(2B + C\right)^2}{4\left(A + B + C\right)^2} - a \qquad (6)$$

where A, B, C are normalized weighted combinations of component concentrations in the glass (Vienna et al. 2017). A boot strapping method was used to estimate the uncertainty in this models prediction. This boot strapping method, described in detail in (Vienna et al. 2016), was aimed at obtaining a 95% confidence in model predictions.

4.2 Process/Composition Uncertainties

The glass composition is estimated using a mass balance for each MFPV batch (see MFPV in Figure 1) and will be defined in Subsections 4.2.1 and 4.2.2. As shown in the right half of Figure 2 there are several uncertainty parameters which impact this mass balance. Due to the non-linear nature of the mass balance equation, there is not an analytical solution to the uncertainty value. Therefore, a Monte-Carlo approach was taken to estimate compositions uncertainties (Kim and Vienna 2012; Vienna and Kim 2014). Monte Carlo simulations are a class of computational methods that rely on repeated random sampling to model the probability of different outcomes in processes that cannot easily be predicted due to the presence of uncertain variables. Monte Carlo methods use probability distribution for modelling random variables. Different types of probability distributions are used to describe the uncertain variable, such as normal, triangular, and PERT. Then many iterations, or simulations, are run using numerical computations that will generate different outcomes (compositions and predicted properties in this case) and their probability of occurrence. In other words, the Monte Carlo method provides a probabilistic estimate of the uncertainty in glass composition and associated predicted properties. Although a very similar approach is taken to define the composition uncertainties in LAW and HLW glasses, the details of the mass balance equation require slightly different treatment.

4.2.1 HLW Process/Composition Uncertainties

The HLW mass balance is given by:

$$g_i = \frac{\left[c_i^{HLW} V^{HLW} f_i + \sum_{k=1}^{n^{GFCs}} g_{ik}^{\substack{oxide \\ inGFC}} M_k^{\substack{GFC\,in \\ MFPV}} \right] v_i}{\sum_{i=1}^{n\,oxides} \left[c_i^{HLW} V^{HLW} f_i + \sum_{k=1}^{n^{GFCs}} g_{ik}^{\substack{oxide \\ inGFC}} M_k^{\substack{GFC\,in \\ MFPV}} \right] v_i} \tag{7}$$

where:

g_i = mass fraction of i[th] oxide in glass (g/g)

c_i^{HLW} = Concentration of the i[th] component measured in samples from the MFPV prior to addition of GFCs (g/mL)

V^{HLW} = Volume of waste in the HLW MFPV batch (L)

f_i = A conversion factor from element mg to oxide kg (kg/mg)

$g_{ik}^{\substack{oxide \\ inGFC}}$ = Mass fraction of the i[th] oxide in the k[th] GFC (g/g)

$M_k^{\substack{GFC\,in \\ MFPV}}$ = Mass of the k[th] GFC in the MFPV batch (kg)

n^{GFCs} = Number of GFC's added to the MFPV batch

v_i = Fraction of i[th] oxide retained in the glass (g/g)

The values: c_i^{HLW}, V^{HLW}, $g_{ik}^{\substack{oxide \\ inGFC}}$, $M_k^{\substack{GFC\,in \\ MFPV}}$, and v_i are each uncertain and each is given a probability distribution. The uncertainty on waste component concentration is estimated as a normal distribution centered on the average measured values (in this study the nominal value for the waste composition) and a standard deviation (s_i^{cHLW}) is given by:

$$s_i^{cHLW} = \frac{\sqrt{\left(c_i^{HLW} RSD_i^{Analysis}\right)^2 + \left(c_i^{HLW} RSD_i^{mix/samp}\right)^2}}{\sqrt{n^{samps}}} \tag{8}$$

where $RSD_i^{Analysis}$ and $RSD_i^{mix/samp}$ are the relative standard deviations for analysis of analyte i and mixing and sampling, and n^{samps} is the number of MFPV samples analyzed for analyte i. The analytical RSD's were derived from Dodd and Kaiser (2006) and are listed in Appendix B. The mixing and sampling RSD is 3.58% based on (Piepel et al. 2013).

Specific components and their levels of uncertainty are described below which are necessary for the computation of Eqn 7:

The MFPV volume will be obtained from the radar level measurement before and after waste addition. The standard deviation (s^V) for waste volume is calculated from error propagation of two volume measurements as described in Appendix J of Vienna and Kim (2014). A normal probability distribution is assumed centered on the nominal volume with an s^V of 125 L.

The composition of GFC's are uncertain with near normal distributions of major components and skewed distributions of impurity concentrations (centered near zero with long positive tails). A PERT (or Beta) distribution was used to estimate the probability distribution of all GFC compositions (see Appendix L of Vienna and Kim 2014). Appendix C lists the minimum, maximum, and most likely concentration of components in each GFC (based on values reported in Table A-4 of Vienna and Kim 2014).

The mass of each GFC is determined by measurements of multiple (3) load cells on each weigh hopper in the Glass Former Storage Facility. A normal probability distribution centered on the nominal weight with a standard deviation (s^{GFCM}) of 0.260 kg was used based on the results reported in Appendix K of Vienna and Kim 2014.

The natural log of melter decontamination factor – $\ln\left[\frac{1}{1-\nu_i}\right]$ was found to be near normal in distribution (Nelson 2013). However to avoid the non-physical option of greater $\nu_i > 1$, a PERT distribution in $\ln\left[\frac{1}{1-\nu_i}\right]$ with minimum, maximum, and most likely values are reported in Appendix D, based on the values reported by Nelson (2013).

The mass balance equation with parameter probability distributions was used in a Monte Carlo routine to generate 10,000 realizations of the target glass composition. The Microsoft Excel™ add-in RiskAmp™, version 4.90, was used to perform the calculations. For each glass composition realization, each of the properties and composition constraints listed in Section 3.1 were calculated. The half-width of each property distribution for the associated confidence level listed in Table 5 (95% confidence for PCT and nepheline formation, 90% confidence for all other properties) was as U_{α}^{Comp}.

$$U_{comp}^{prop} = Q_{CL\%}^{prop} - Q_{50\%}^{prop} \text{ or } Q_{50\%}^{prop} - Q_{100-CL\%}^{prop} \tag{9}$$

where U_{comp}^{prop} = composition uncertainty for "*prop*", i.e., uncertainty in predicted "*prop*" due to glass composition uncertainty (in property model units)

$Q_{CL\%}^{prop}$ = CL% [=100(1−α)] percentile of the distribution of 10,000 property values

$Q_{50\%}^{prop}$ = median predicted property value or CL% = 50% percentile of the distribution of 10,000 property values

Figure 3 shows an example of the probability distribution calculated by this method.

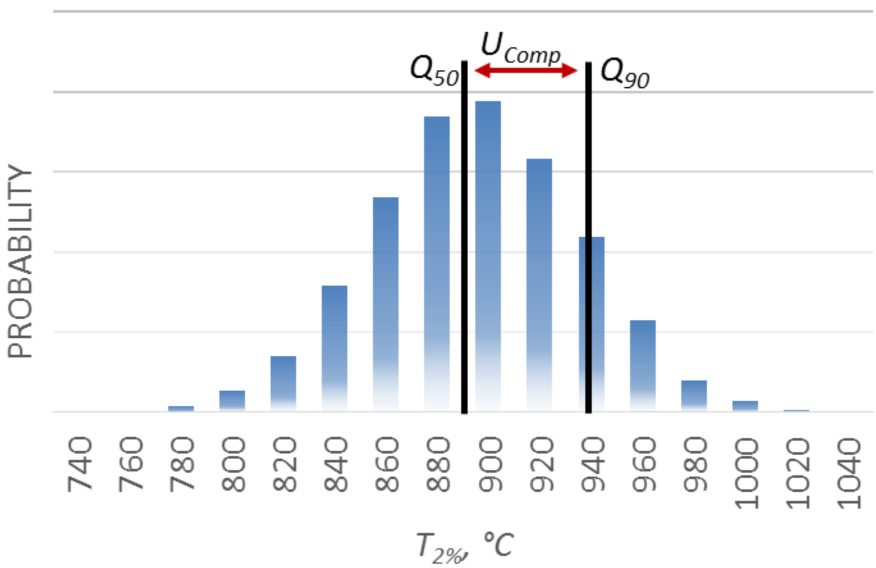


Figure 3. Example Histogram of Predicted $T_{2\%}$ Values from a 10,000 Run Monte Carlo Calculation.

This process mimic's nearly exactly the Step 2 calculation used in Vienna and Kim 2014. The primary difference being the inclusion of MFPV heel (melter feed) was included in their calculation, but, not included in this study. This had the effect of slightly decreasing the calculated uncertainty in c_i^{HLW} in this study compared to that shown previously. To adjust for the decrease, the assumed number of MFPV samples was decreased. The initial calculations where performed with four MFPV samples (the nominal for plant operation). Calculations were then repeated assuming a single MFPV sample. The real impact of uncertainty is expected to lie between these two estimates. The values for both are reported in Section 6.4. Comparisons are drawn based on the average of the results from 1 and 4 samples.

4.2.2 LAW Process/Composition Uncertainties

The process for estimating U_α^{Comp} for LAW glass compositions follows very nearly the same as that for HLW (described in Section 4.2.1) with a few differences. The mass balance for each batch depends on volume and composition of waste in the CRV which is transferred to the MFPV instead of analysis of waste in the MFPV (see Figure 1). The LAW mass balance is given by:

$$g_i = \frac{\left[c_i^{LAW} V^{LAW} f_i + \sum_{k=1}^{n^{GFCs}} g_{ik}^{\substack{oxide \\ inGFC}} M_k^{\substack{GFC\,in \\ MFPV}} \right] \nu_i}{\sum_{i=1}^{n\,oxides} \left[c_i^{LAW} V^{LAW} f_i + \sum_{k=1}^{n^{GFCs}} g_{ik}^{\substack{oxide \\ inGFC}} M_k^{\substack{GFC\,in \\ MFPV}} \right] \nu_i} \tag{10}$$

where:

$g_i =$ mass fraction of i[th] oxide in glass (g/g)

$c_i^{LAW} =$ Concentration of the i[th] component measured in samples from the CRV prior to transfer to the MFPV (g/mL)

$V^{LAW} =$ Volume of LAW transferred in a batch to the MFPV (L)

$f_i =$ A conversion factor from element mg to oxide kg (kg/mg)

$g_{ik}^{\substack{oxide\\inGFC}} =$ Mass fraction of the i[th] oxide in the k[th] GFC (g/g)

$M_k^{\substack{GFCin\\MFPV}} =$ Mass of the k[th] GFC in the MFPV batch (kg)

$n^{GFCs} =$ Number of GFC's added to the MFPV batch

$v_i =$ Fraction of i[th] oxide retained in the glass (g/g)

The values: c_i^{LAW}, V^{LAW}, $g_{ik}^{\substack{oxide\\inGFC}}$, $M_k^{\substack{GFCin\\MFPV}}$, and v_i are each uncertain and each is given a probability distribution. The uncertainty on waste component concentration is estimated as a normal distribution centered on the average measured values (in this study the nominal value for the waste composition) and a standard deviation (s_i^{cLAW}) is given by:

$$s_i^{cLAW} = \frac{\sqrt{\left(c_i^{LAW} RSD_i^{Analysis}\right)^2 + \left(c_i^{LAW} RSD_i^{mix/samp}\right)^2}}{\sqrt{n^{samps}}} \tag{11}$$

where $RSD_i^{Analysis}$ and $RSD_i^{mix/samp}$ are the relative standard deviations for analysis of analyte i and mixing and sampling, and n^{samps} is the number of CRV samples analyzed for analyte i. The analytical RSD's were derived from Dodd and Kaiser (2005) and are listed in Appendix B. The mixing and sampling RSD is 1.47% based on Petkus (2012). The n^{samps} for LAW is 3 per the sampling and analysis plan (Arakali and Johnson 2013).

Specific components and their levels of uncertainty are described below which are necessary for the computation of Eqn 10:
The LAW volume transferred from the CRV to the MFPV will be obtained from the radar level measurement before and after waste transfer from each vessel. The standard deviation (s^V) for waste volume is calculated from error propagation of four volume measurements as described in Appendix D of Kim and Vienna (2012). A normal probability distribution is assumed centered on the nominal volume with an s^V of 447.2 L.

The composition of GFC's are uncertain with near normal distributions of major components and skewed distributions of impurity concentrations (centered near zero with long positive tails). A PERT (or Beta) distribution was used to estimate the probability distribution of all GFC compositions. Appendix C lists the minimum, maximum, and most likely concentration of components in each GFC (based on values reported in Table A-4 of Kim and Vienna 2012).

The mass of each GFC is determined by measurements of multiple (3) load cells on each weigh hopper in the Glass Former Storage Facility. A normal probability distribution centered on the nominal weight with a standard deviation (s^{GFCM}) of 0.1039 kg for major components (>41.6 kg per batch) and 0.0520 kg for minor components (<41.6 kg per batch) was used based on the results reported in Appendix E of Kim and Vienna 2012.

The natural log of melter decontamination factor – $\ln\left[\frac{1}{1-v_i}\right]$ was found to be near normal in distribution (Petkus and Vienna 2012). However to avoid the non-physical option of greater $v_i > 1$, a PERT distribution in $\ln\left[\frac{1}{1-v_i}\right]$ with minimum, maximum, and most likely values reported in Appendix D, based on the values reported by Petkus and Vienna (2012).

The mass balance equation with parameter probability distributions was used in a Monte Carlo routine to generate 10,000 realizations of the target glass composition. The Microsoft Excel™ add-in RiskAmp™, version 4.90, was used to perform the calculations. For each glass composition realization, each of the properties and composition limits listed in Section 3.2 were calculated. The half-width of each property distribution for the associated confidence level (shown in Table 5) was as U_{α}^{Comp}. This process is exactly the Step 1 calculation used in Kim and Vienna 2012.

4.3 Estimation of Individual Uncertainty Impacts on Glass

The impact of individual sources of uncertainty were estimated by systematically removing individual and combined sources of uncertainty and repeating the glass optimization to determine the resulting WOL and associated glass mass. The first three cases to be evaluated were:

1) no uncertainties
2) prediction uncertainties only (no composition/process uncertainties)
3) prediction plus composition/process uncertainties.

Then the prediction uncertainties for individual properties were removed one-at-a-time (e.g., $U_{T_{2\%}}^{Pred}=0$, $U_{VHT}^{Pred}=0$, $U_{nepheline}^{Pred}=0$, …) until most of the glass mass increase caused by application of prediction uncertainties only was accounted for.

5.0 Waste Feeds

The waste feed estimate used for this study is from the *River Protection Project System Plan* revision 8 (SP8) (DOE 2017) which is required to estimate the impacts of the glass property models and constraints and associated uncertainties on glass to be produced at Hanford[1]. The base line case (Case #1) waste feed batches were used in this study. According to this case, 4008 batches of HLW are to be delivered from PT to HLW while 28,458 batches of LAW are planned to be delivered to supplemental LAW vitrification facilities, initially from a combined input of LAWPS (roughly 10 years) then from PT. Internal recycles of off gas scrub solution from ETF (first 10 years roughly) and LAWPS are included in the LAW feed estimates. The major component concentrations in waste are shown vs batch number in Figure 4 and Figure 5 for HLW and LAW, respectively.

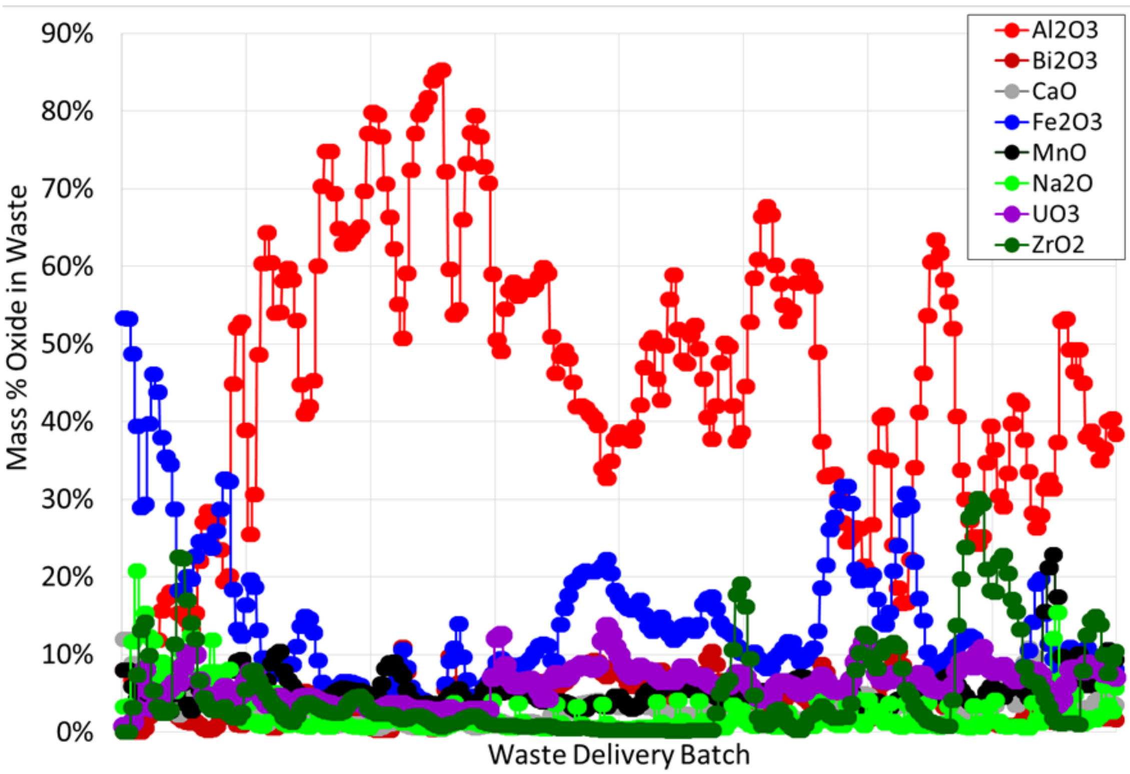


Figure 4. Plot of Major HLW Component Concentrations vs Batch Number (~4000 batches)

[1] The SP8 case 1 represents one of the current River Protection Project baseline flowsheets. The previous baseline flowsheet was documented in revision 6 of that report (SP6) case 1.

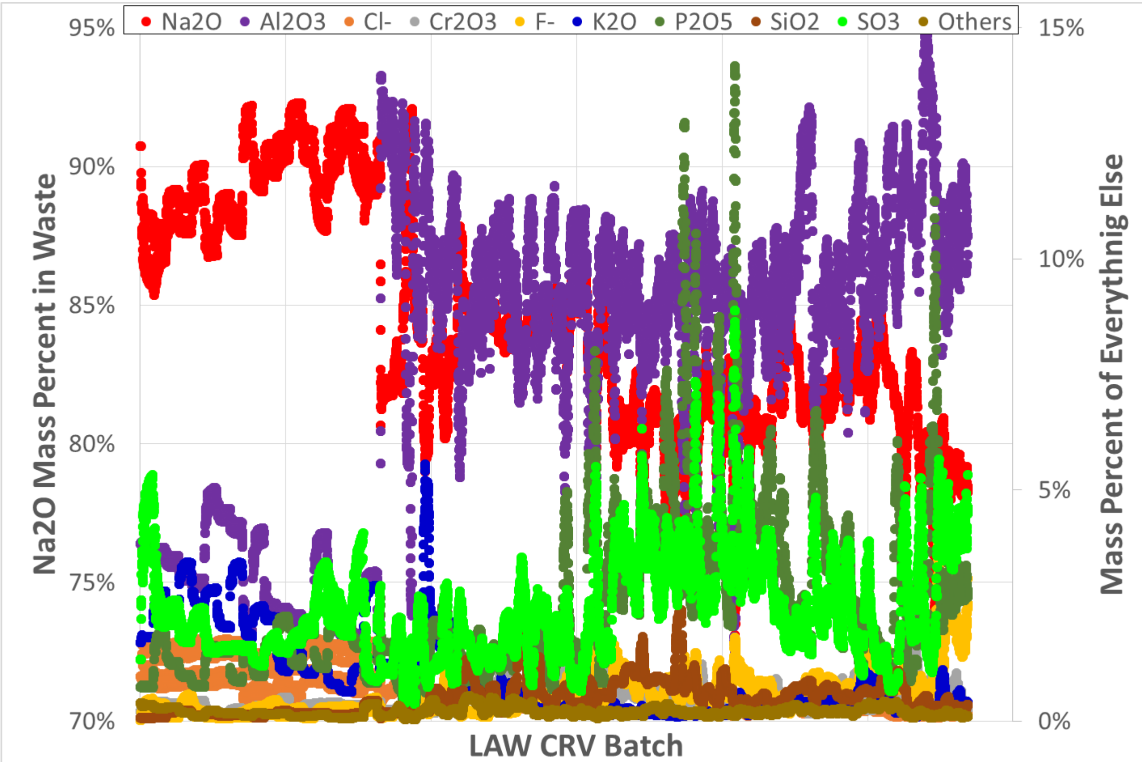


Figure 5. Plot of Major LAW Component Concentrations vs Batch Number (~28,500)

As the number of batches for both HLW and LAW exceed the amount that could be practically used in the calculations performed in this study, cluster analysis was used to group wastes of like composition into clusters. The mass weighted average composition of each cluster was then used to estimate the WOL (and associated glass mass) represented by each cluster. Hierarchical clustering was performed using JMP® statistical software (version 13.2.1, SAS Institute, Inc., Cary, NC).

For HLW waste batches clustering was performed on the mass fractions of the following 12 waste components: Al_2O_3, Bi_2O_3, Cr_2O_3, Fe_2O_3, MnO, Na_2O, NiO, P_2O_5, SO_3, ThO_2, UO_3, and ZrO_2. The number of clusters was varied from 15 to 50 and the resulting mean composition distance[2] was calculated (shown in Figure 6). Several plateaus around clusters 15, 18, 24, 30 and 34 are apparent in this analysis. Analyses of parallel plots of clusters at each of the plateaus suggested that 30 clusters would represent a good balance between few enough clusters for practical calculation and sufficient number of clusters to well represent the waste. The parallel plots for the 30 HLW cluster case is shown in Figure 7.

[2] Mean distance between each glass composition and the cluster center point.

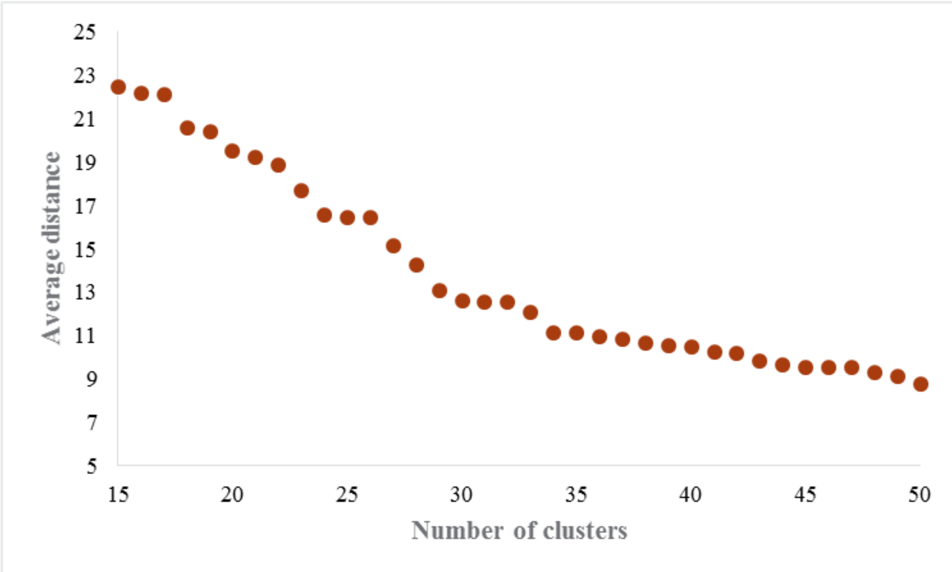
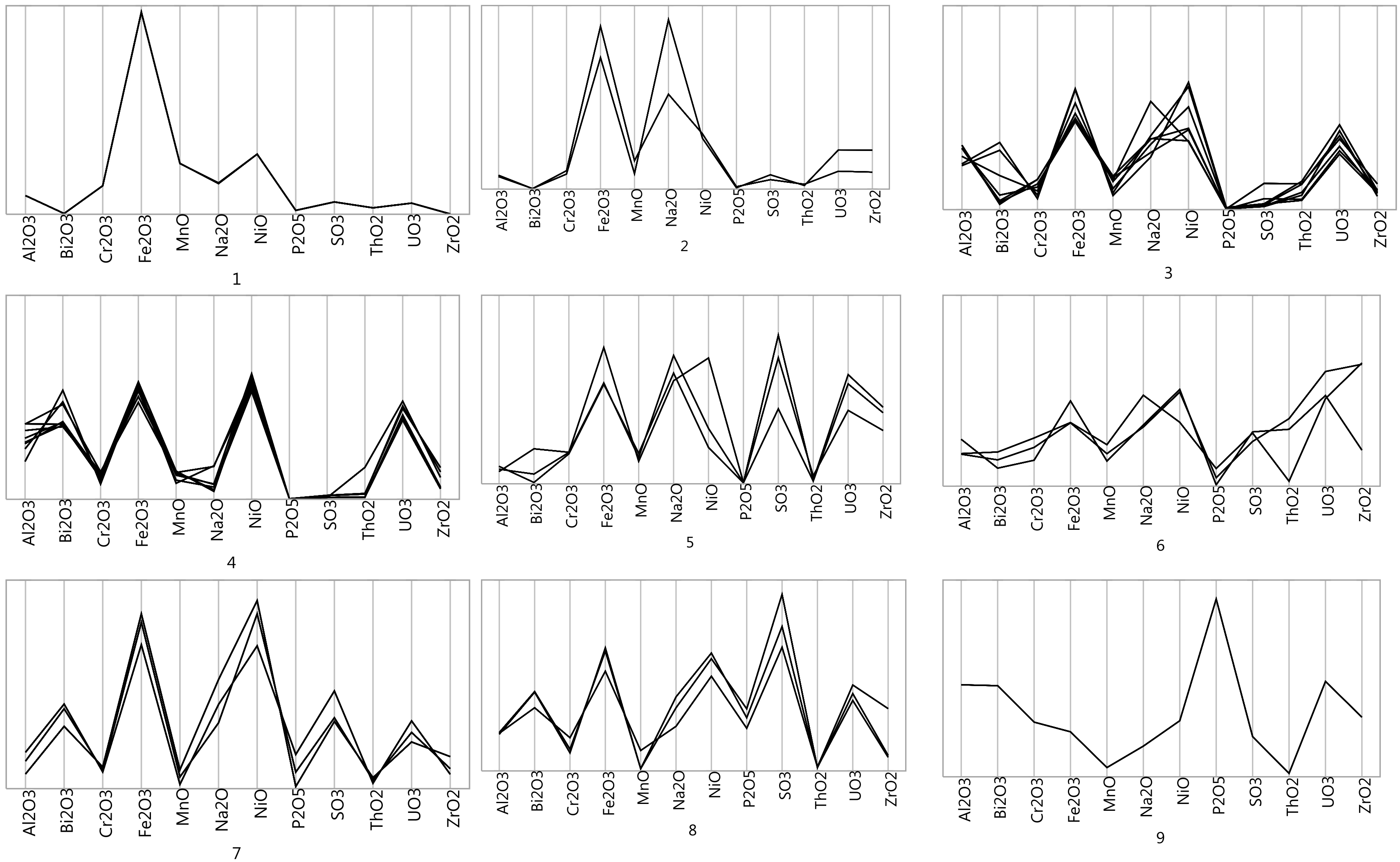
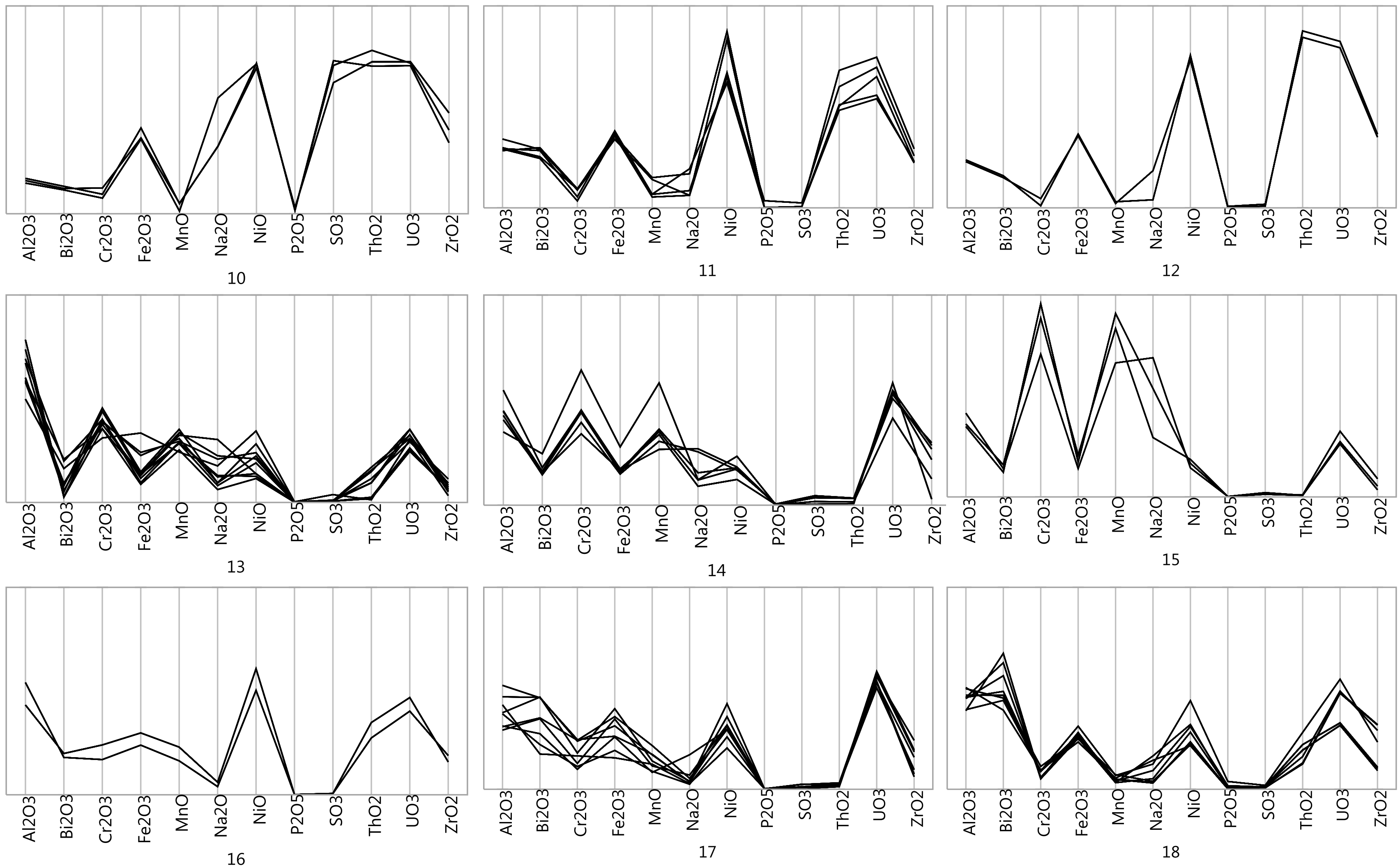


Figure 6. Average Distance versus Number of HLW Clusters from Hierarchical Cluster Analysis.


Al2O3
Bi2O3
Cr2O3
Fe2O3
MnO
Na2O
NiO
P2O5
SO3
ThO2
UO3
ZrO2
1
2
3
4
5
6
7
8
9


Al2O3
Bi2O3
Cr2O3
Fe2O3
MnO
Na2O
NiO
P2O5
SO3
ThO2
UO3
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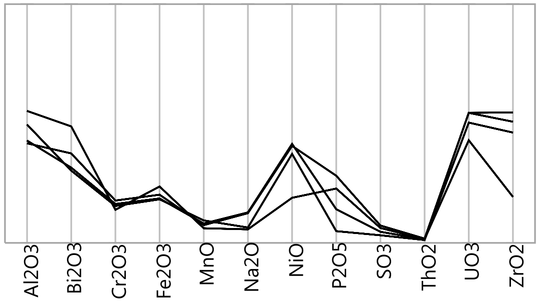
14
15
16
17
18



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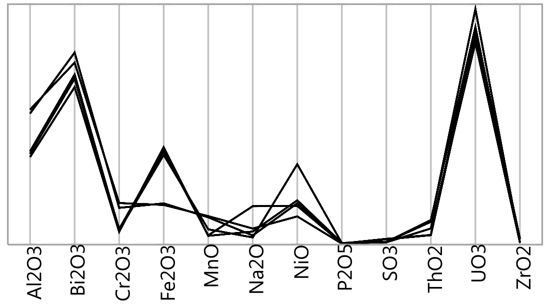

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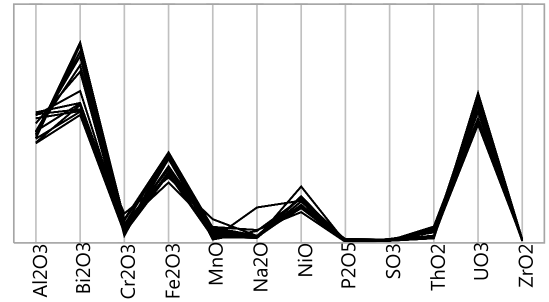

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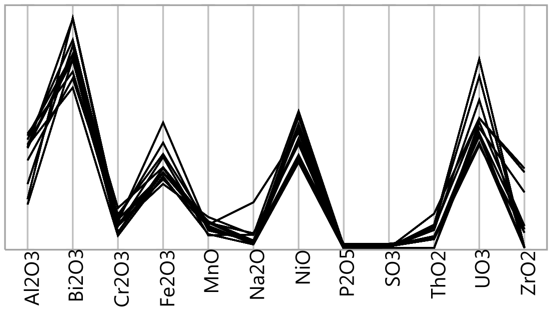

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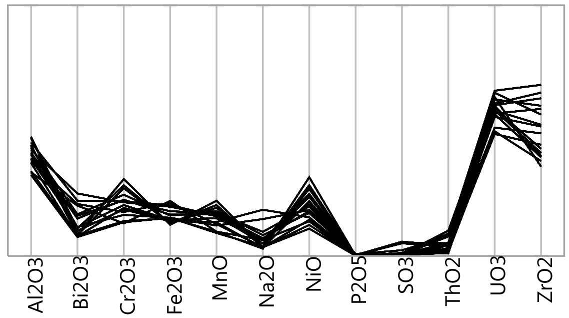

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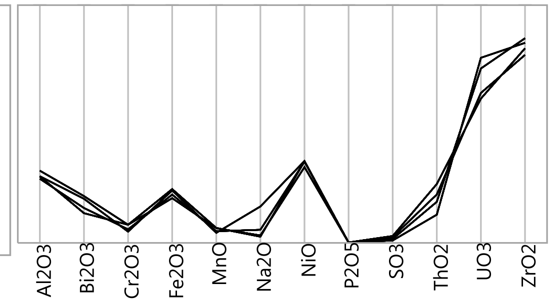

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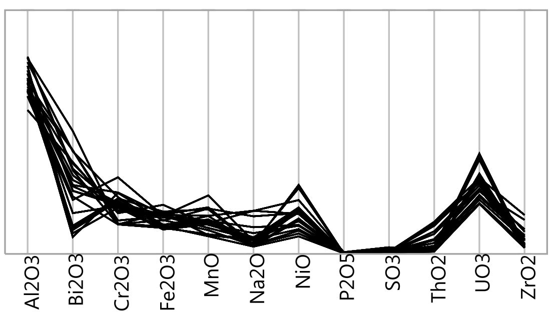

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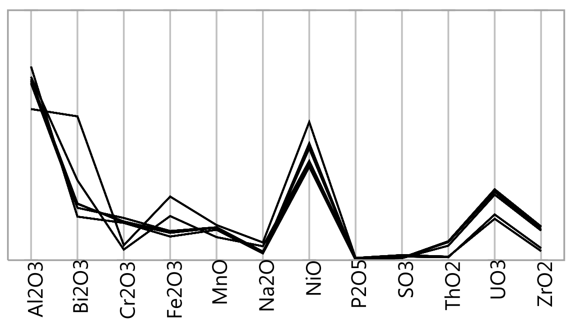

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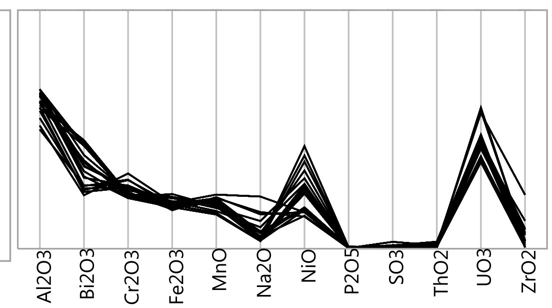

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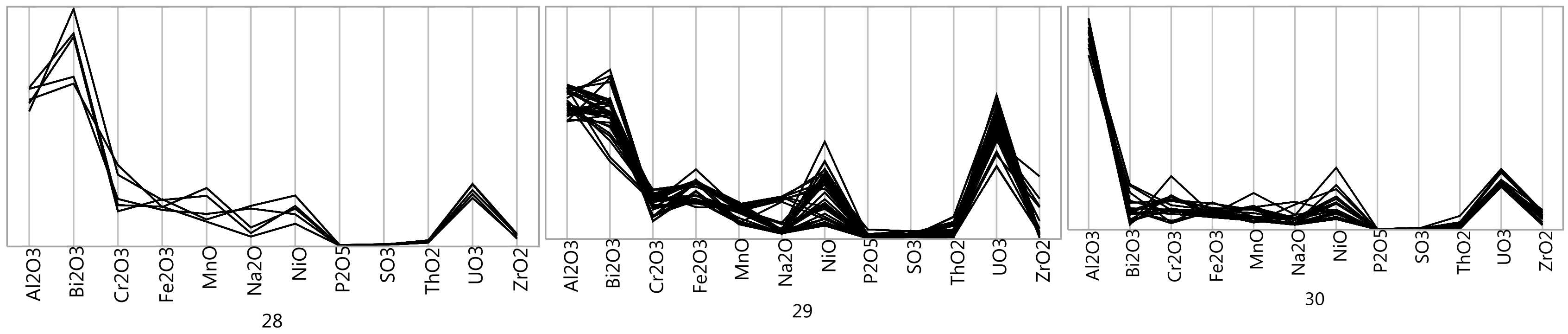


Figure 7. Parallel Plots of 30 HLW Composition Clusters

For LAW waste batches clustering was performed on the mass fractions of the following 8 waste components: Al_2O_3, Cl^-, Cr_2O_3, F^-, K_2O, Na_2O, P_2O_5, and SO_3. The number of clusters was varied from 15 to 50 and the resulting mean composition distance[1] was calculated (shown in Figure 8). Several plateaus around clusters 25, 36, 42 and 47 are apparent in this analysis. Analyses of parallel plots of clusters at each of the plateaus suggested that 36 clusters would represent a good balance between few enough clusters for practical calculation and sufficient number of clusters to well represent the waste. The parallel plots for the 36 LAW cluster case is shown in Figure 9.

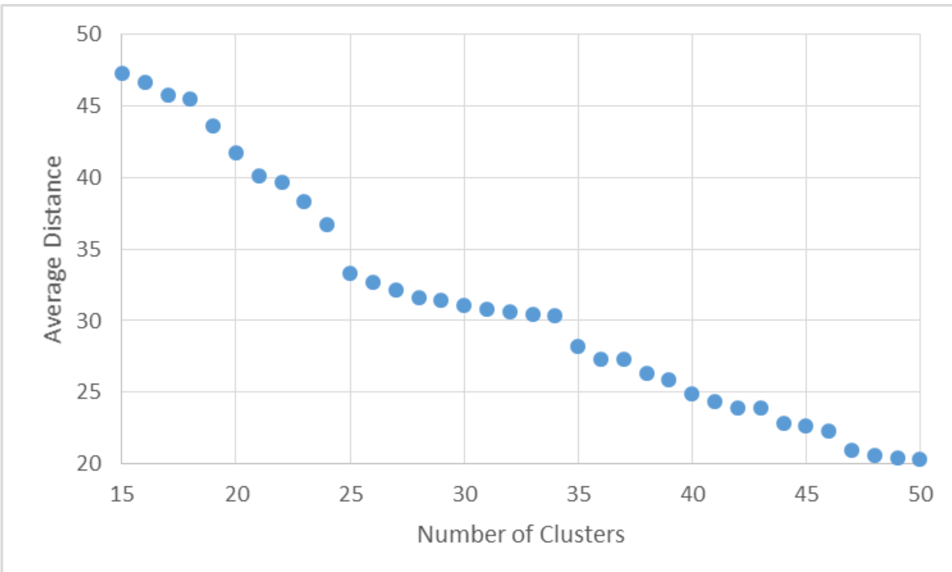
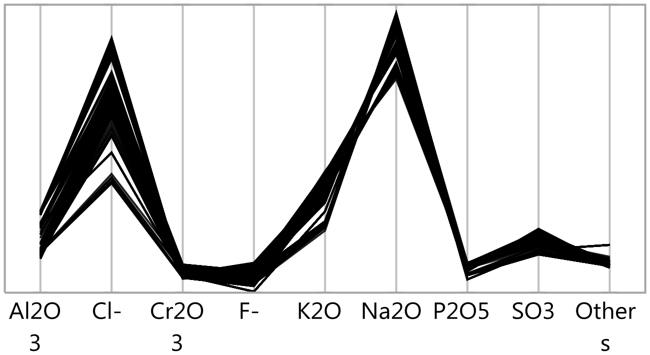


Figure 8. Average Distance versus Number of LAW Clusters from Hierarchical Cluster Analysis.

Attachment 1 lists the batch compositions and cluster number assignment for each batch of HLW and LAW feed. Also listed are the masses (of calcined oxide) and average composition of each cluster.

[1] Mean distance between each glass composition in the cluster to the cluster center point.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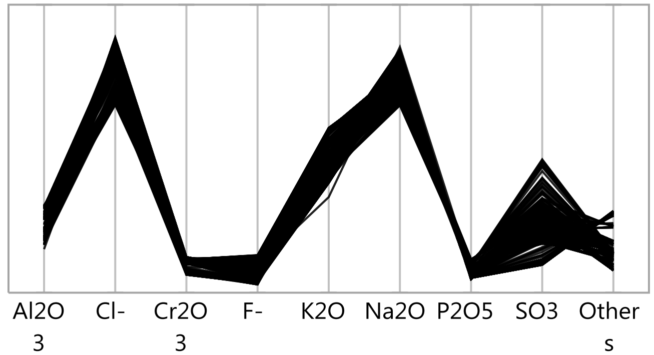
Cl-
Cr2O3
F-
K2O
Na2O
P2O5
SO3
Others

1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Cr2O3
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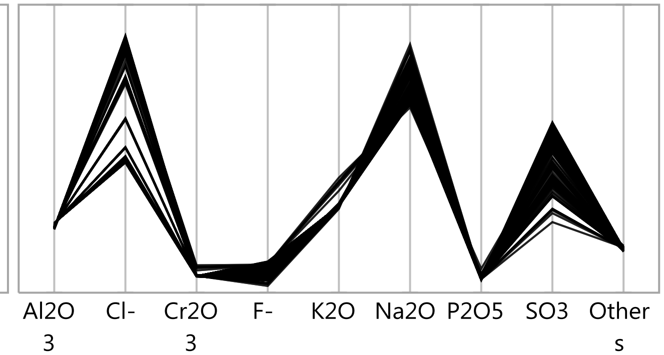
K2O
Na2O
P2O5
SO3
Others

2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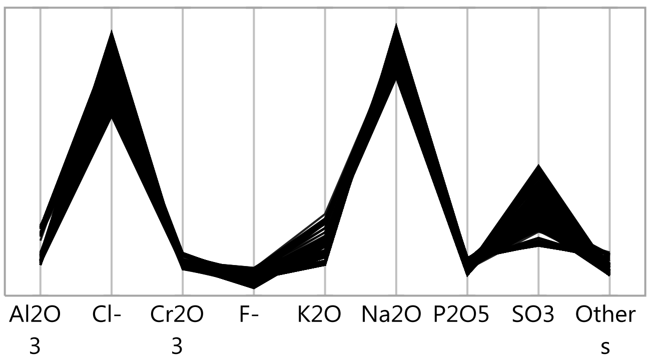
Cl-
Cr2O3
F-
K2O
Na2O
P2O5
SO3
Others

3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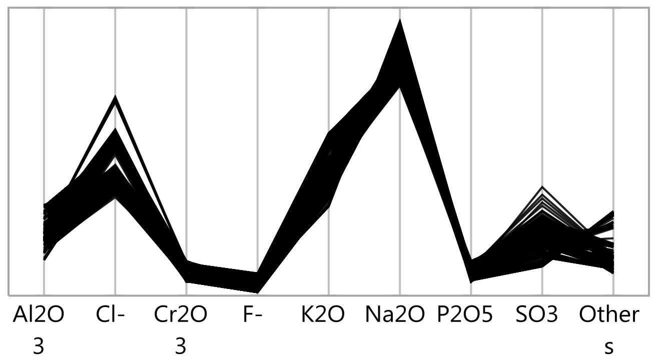
Cl-
Cr2O3
F-
K2O
Na2O
P2O5
SO3
Others

4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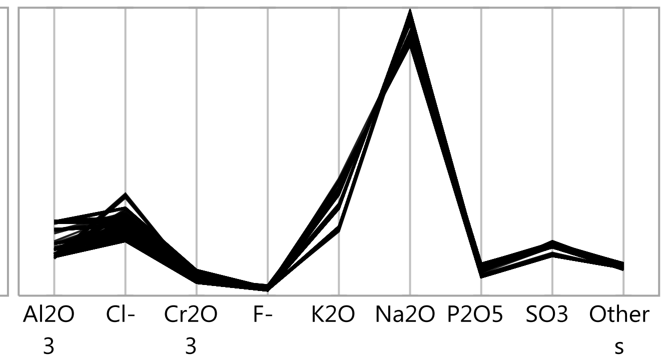
Cl-
Cr2O3
F-
K2O
Na2O
P2O5
SO3
Others

5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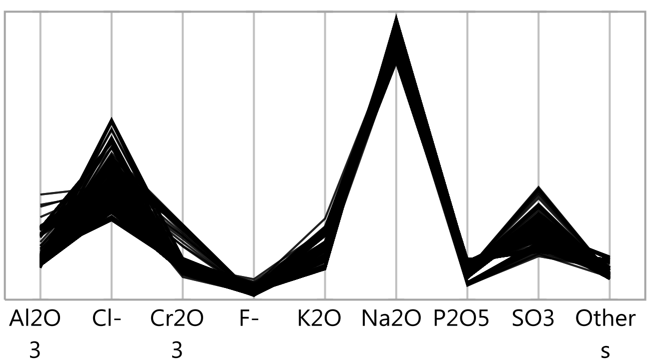
Cl-
Cr2O3
F-
K2O
Na2O
P2O5
SO3
Others

6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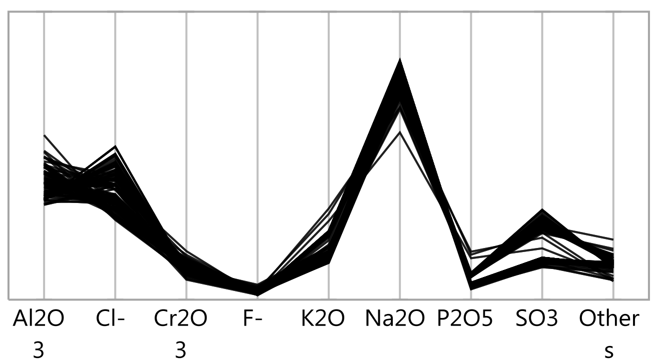
Cl-
Cr2O3
F-
K2O
Na2O
P2O5
SO3
Others

7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Cr2O3
F-
K2O
Na2O
P2O5
SO3
Others

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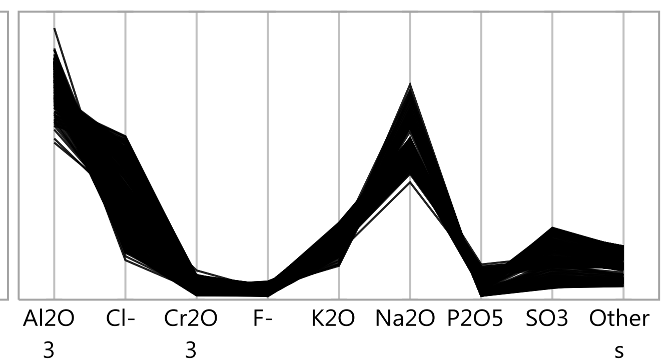
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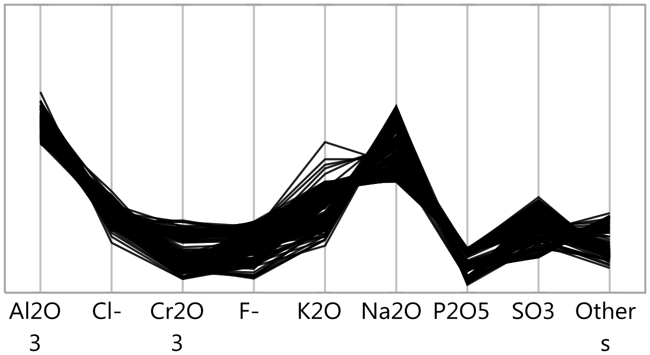
SO3
Others

9



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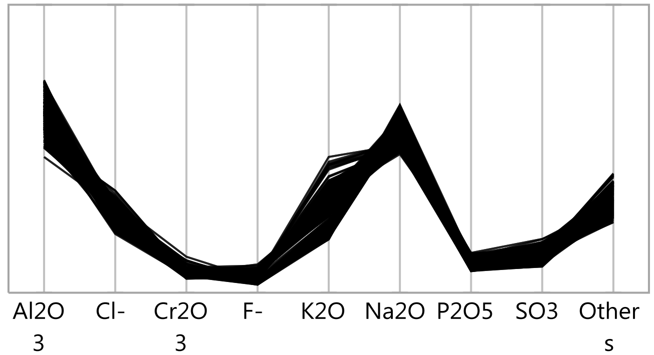

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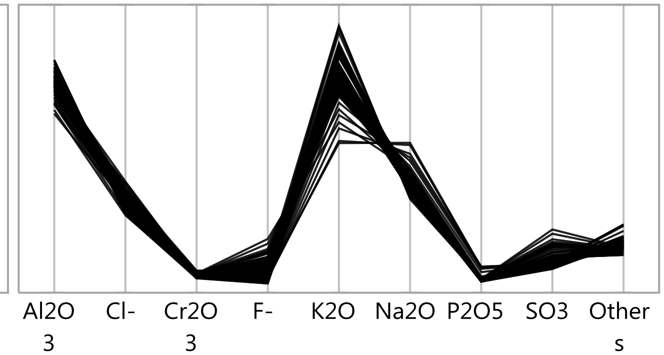

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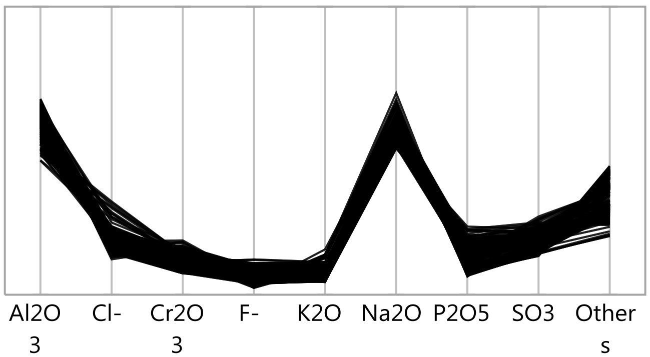

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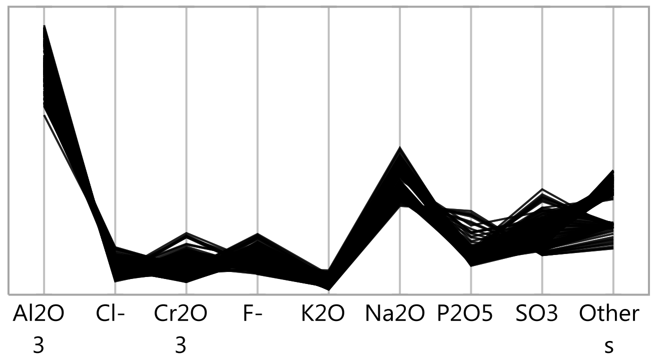

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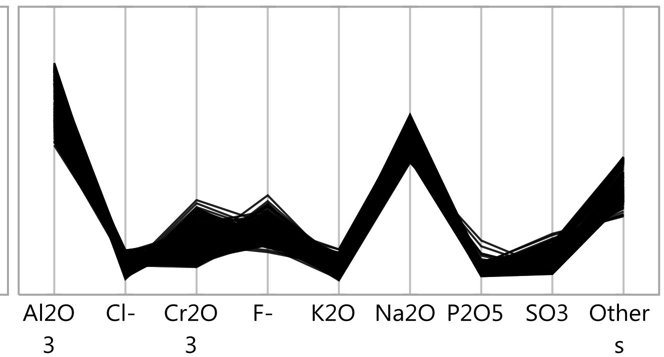

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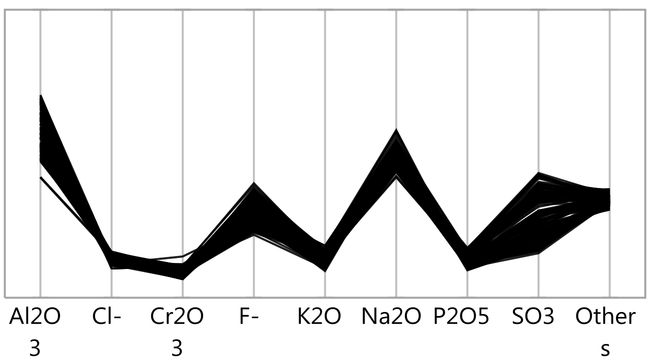

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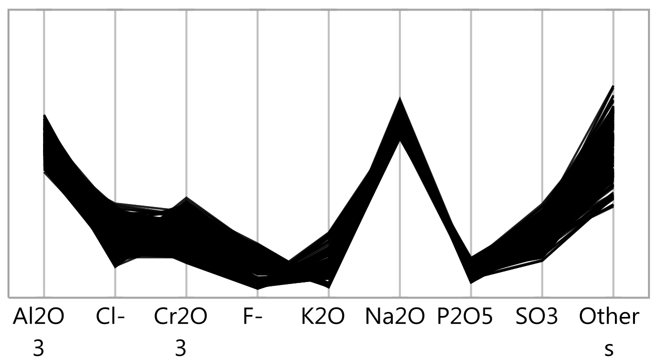

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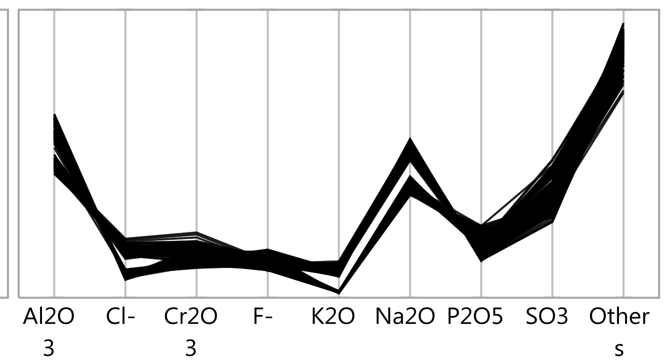

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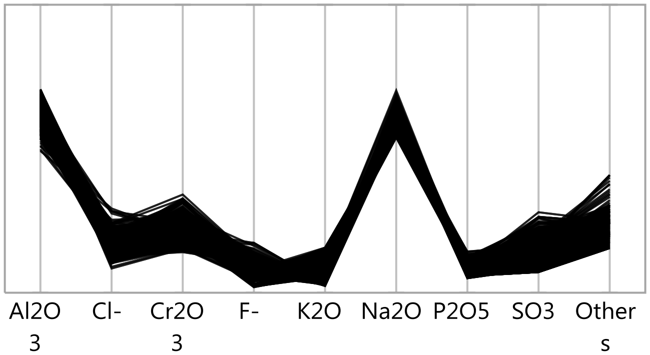

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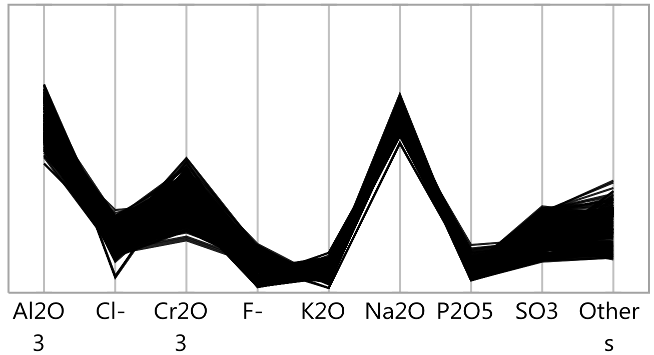

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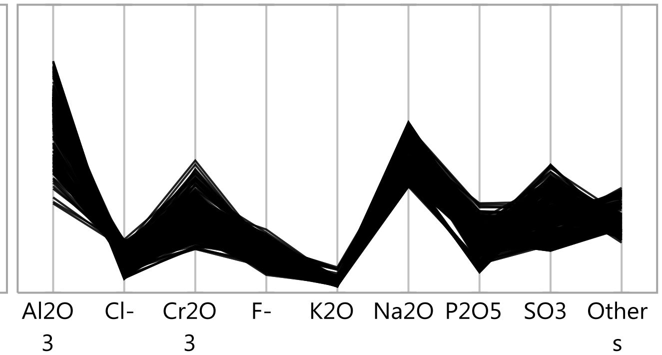

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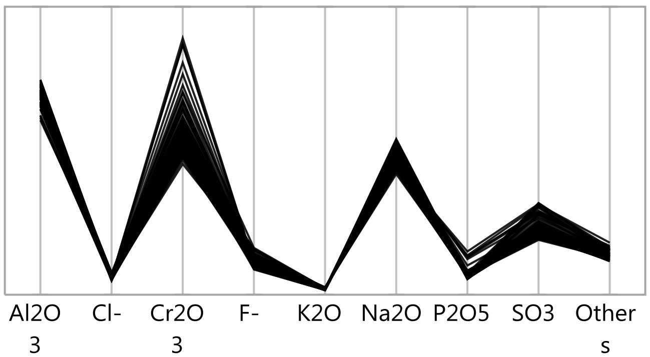

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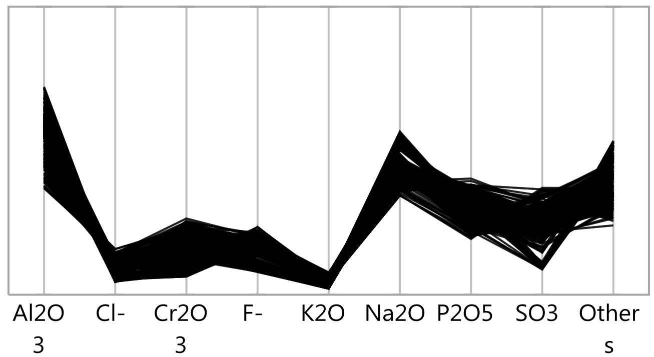

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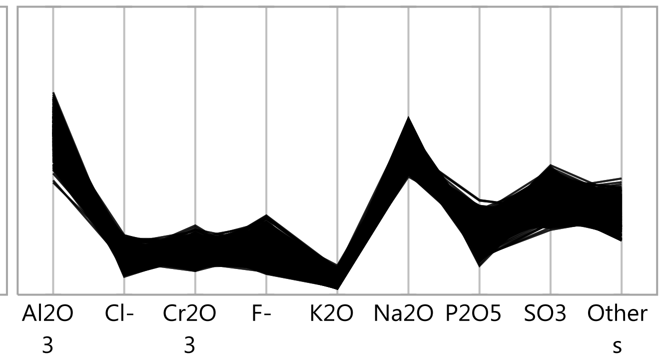

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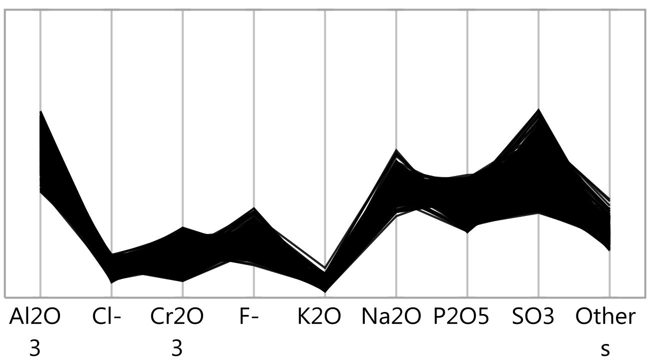

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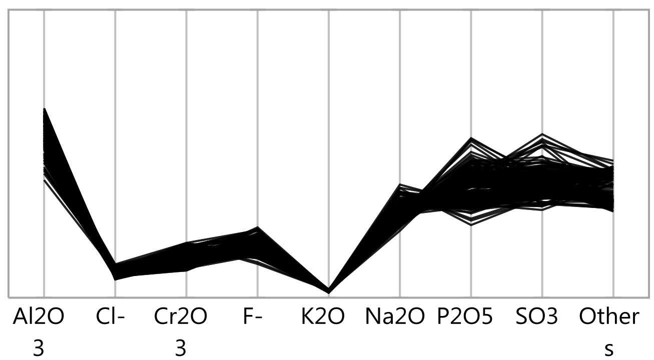

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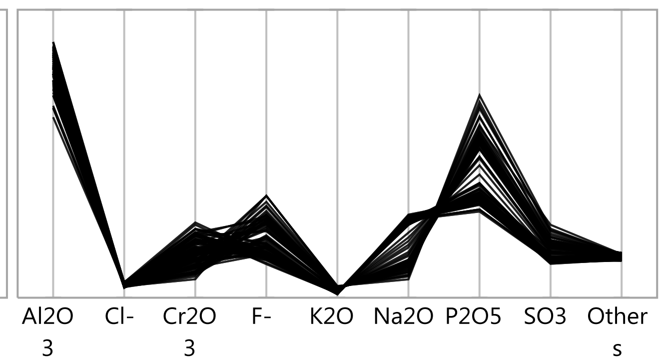

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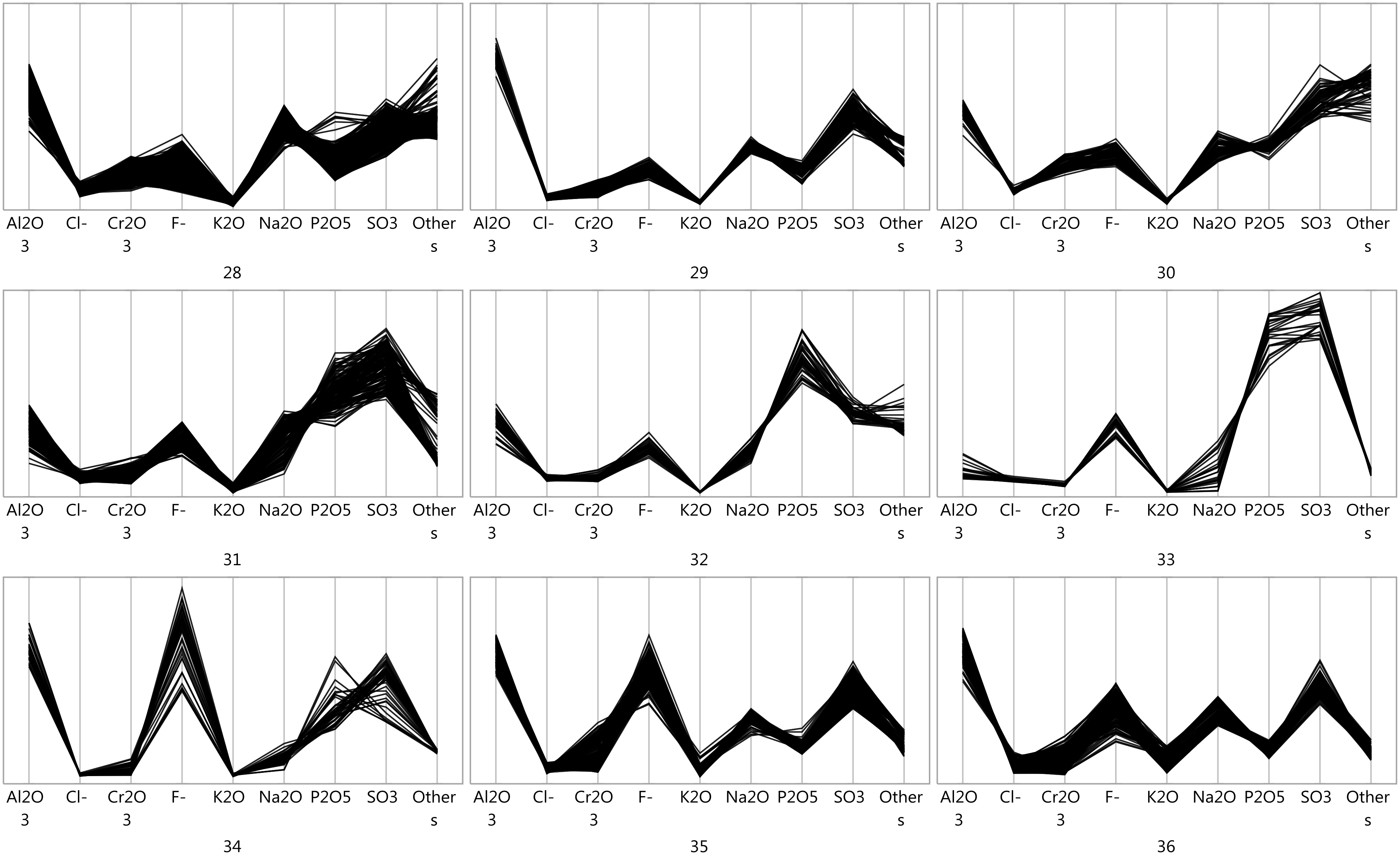

Figure 9. Parallel Coordinate Plots for 36 LAW Clusters.

6.0 HLW Calculation Results and Discussion

A series of calculations were performed to maximize the WOL for each HLW composition while simultaneously satisfying all of the HLW constraints listed in Section 3.1. If one of the property/composition constraints (Table 1) limits the WOL, the additive composition is adjusted to increase the loading until one or more additional constraints are met. Therefore, the WOL is limited by more than one constraint, unless a single component concentration constraint, typically, a model validity constraint (Table 2) for waste components (e.g., Fe_2O_3, MnO, or Al_2O_3) is encountered. Some glasses with WOL limited by property/composition constraints may also be limited by a model validity constraint (Table 2) for additive components (e.g., B_2O_3, Na_2O, or Li_2O).

Calculations were performed without any uncertainties for the 30 HLW feed composition clusters and described in Section 6.1. The impact of prediction uncertainties are discussed in Sections 6.2 and 6.3. Finally, the impacts of various composition/process uncertainties are discussed in Sections 6.4 and 6.5.

6.1 No Uncertainties

The maximum WOL for each of the 30 waste clusters was determined and reported in Table 6. Using the constraints and models reported by Vienna et al. (2016), 23,360 MT of HLW glass would be produced (7735 canisters, assuming 3.02 MT of glass per canister). The glass is most limited by viscosity, $T_{2\%}$, and nepheline with a lower fraction limited by single component (Al, Fe and Mn) constraints (12 wt%) (Figure 10). For comparison, 100% of the *River Protection Project System Plan* revision 6 wastes were limited by single component constraints using the WTP baseline models and constraints (Certa et al. 2011).

Table 6. Waste Mass, Maximum WOL, Glass Mass, and Limiting Factors for each of 30 HLW Clusters with No Uncertainties

Cluster	Waste oxides, kg	WOL, wt%	Glass, MT	Limits(a)
1	102,015	37.4	272.5	Max Fe
2	93,314	45.1	206.8	Max Fe
3	304,764	49.6	614.5	T2,Vis,NP
4	340,138	45.0	756.1	T2,Vis,NP
5	118,988	52.1	228.2	T2,Vis,B
6	130,884	49.6	263.7	T2,Vis,NP
7	129,640	44.7	290.1	T2,Vis,Na
8	135,350	49.1	275.6	T2,Vis,NP
9	40,217	42.8	94.0	TZr,Vis,NP
10	137,773	54.1	254.7	T2,Vis,NP
11	229,181	49.3	464.7	T2,Vis,NP
12	96,641	52.0	185.7	T2,Vis,NP
13	414,412	42.4	977.3	T2,Vis,B
14	226,581	48.3	469.5	T2,Vis

Cluster	Waste oxides, kg	WOL, wt%	Glass, MT	Limits(a)
15	102,370	39.0	262.4	Max Mn
16	89,071	43.9	203.1	T2,Visc,B
17	334,869	50.8	659.1	T2,Vis
18	376,435	50.5	746.1	T2,Vis
19	178,911	40.1	446.5	TZr,Vis,NP,B
20	228,853	48.8	469.3	T2,Vis
21	710,511	47.7	1,489.9	T2,Vis,B
22	546,626	47.6	1,148.9	T2,Vis,NP
23	709,324	42.3	1,677.2	TZr,Vis,NP
24	196,576	42.0	467.9	T2,Vis,NP
25	979,245	43.5	2,251.2	T2,NP,B
26	276,233	41.8	660.3	T2,Vis
27	784,370	43.7	1,793.9	T2,Vis,B
28	220,037	44.2	497.3	T2,Vis,B
29	1,388,456	46.0	3,020.4	T2,Vis
30	841,474	38.0	2,213.7	Max Al
Sum(b)	10,463,259	44.8	23,360	

(a) limiting factors include: Max Fe (g_{Fe2O3}= 20wt%), T2 ($T_{2\%}$=950°C), Vis (η_{1150} = 2 or 8 Pa·s), NP (nepheline probability = 30%), TZr (T_L-Zr = 1050°C), Max Mn (g_{MnO} = 8 wt%), Max Al (g_{Al2O3} = 30 wt%). B (model validity, g_{B2O3} = 4 - 22 wt%), Na (model validity, g_{Na2O} = 4.1 - 24 wt%).
(b) sum for waste oxide mass and glass mass, weighted average for WOL.

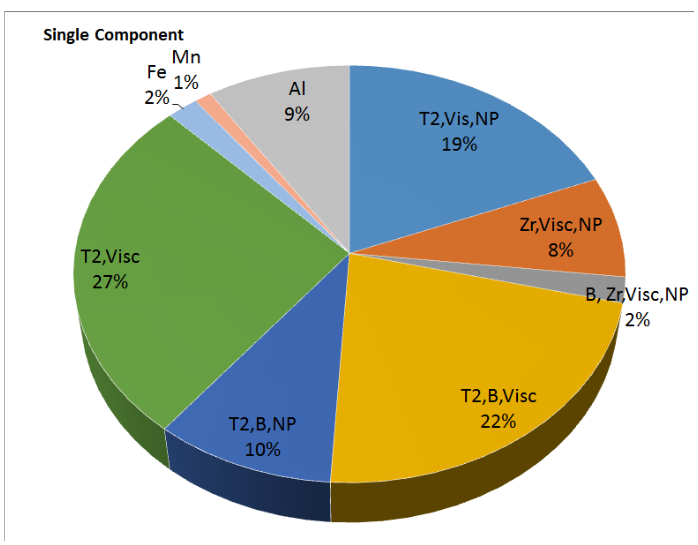

Figure 10. Waste Loading Limiting Factors (Glass Mass Basis) for HLW Glasses.

6.2 Prediction Uncertainties Only

The waste estimates were performed using the prediction uncertainties (as described in Section 4.1). The results are summarized in Table 7. The total glass mass produced is 23,963 MT, 2.58 relative percent higher than the case without any uncertainties. Generally, the waste loading limiting factors were the same as in the no uncertainty case. Exceptions include:

- Clusters 9 was limited by TZr, viscosity and nepheline with no uncertainty, with prediction uncertainties there are limitations by TZr, viscosity, nepheline and boron;
- Clusters 14, 18, 20 and 29 were limited by T2 and viscosity without uncertainty, with prediction uncertainties there are limitations by T2, viscosity and boron;
- Clusters 13 and 27 were limited by T2, boron and viscosity with no uncertainty, with prediction uncertainties there are limitations by T2 and viscosity only;
- Cluster 17 was limited by T2 and viscosity without uncertainty, is limited by T2, viscosity and nepheline with prediction uncertainties;
- Cluster 26 was limited by T2 and viscosity with no uncertainty, is limited by T2, viscosity and nepheline with prediction uncertainties.

Table 7. Waste Mass, Maximum WOL, Glass Mass, and Limiting Factors for 30 HLW Clusters with Prediction Uncertainties

Cluster	Waste oxides, kg	WOL, wt%	Glass, MT	Limits(a)
1	102,015	37.4	272.5	Max Fe
2	93,314	45.1	206.8	Max Fe
3	304,764	48.6	626.9	T2,Vis,NP
4	340,138	44.1	770.7	T2,Vis,NP
5	118,988	51.0	233.2	T2,Vis,B
6	130,884	48.4	270.3	T2,Vis,NP
7	129,640	43.7	296.8	T2,Vis,Na
8	135,350	48.2	280.5	T2,Vis,NP
9	40,217	40.7	98.9	TZr,Vis,NP,B
10	137,773	52.9	260.6	T2,Vis,NP
11	229,181	48.2	475.7	T2,Vis,NP
12	96,641	51.0	189.5	T2,Vis,NP
13	414,412	41.3	1,003.8	T2,Vis
14	226,581	46.9	483.2	T2,Vis,B
15	102,370	39.0	262.4	Max Mn
16	89,071	42.7	208.6	T2,Visc,B
17	334,869	49.8	672.8	T2,Vis,NP
18	376,435	49.3	763.8	T2,Vis,B
19	178,911	37.6	475.3	TZr,Vis,NP,B
20	228,853	47.7	480.0	T2,Vis,B
21	710,511	46.6	1,525.9	T2,Vis,B
22	546,626	46.4	1,177.7	T2,Vis,NP
23	709,324	39.8	1,783.8	TZr,Vis,NP

Cluster	Waste oxides, kg	WOL, wt%	Glass, MT	Limits(a)
24	196,576	40.2	489.4	T2,Vis,NP
25	979,245	42.3	2,314.5	T2,NP,B
26	276,233	40.7	679.2	T2,Vis,NP
27	784,370	42.7	1,838.5	T2,Vis
28	220,037	43.0	511.5	T2,Vis,B
29	1,388,456	44.8	3,096.6	T2,Vis,B
30	841,474	38.0	2,213.8	Max Al
Sum(b)	10,463,259	43.7	23,963.2	

(a) limiting factors include: Max Fe (g_{Fe2O3}= 20wt%), T2 ($T_{2\%}$=950°C), Vis (η_{1150} = 2 or 8 Pa·s), NP (nepheline probability = 30%), TZr (T_L-Zr = 1050°C), Max Mn (g_{MnO} = 8 wt%), Max Al (g_{Al2O3} = 30 wt%). B (model validity, g_{B2O3} = 4 - 22 wt%), Na (model validity, g_{Na2O} = 4.1 - 24 wt%).
(b) sum for waste oxide mass and glass mass, weighted average for WOL.

6.3 Evaluation of Individual Property Prediction Uncertainties

With a roughly 2.58 relative percent increase in predicted HLW glass mass due to the application of prediction uncertainties, a study was performed to determine which prediction uncertainties had the most significant impact on glass mass. Table 8 shows the glass masses resulting from excluding individual prediction uncertainties one-at-a-time while all other prediction uncertainties were applied. Excluding the $T_{2\%}$ prediction uncertainties had the strongest effect with RPD of -1.67% followed by -0.36% for T_L-Zr, -0.30% for nepheline, and -0.13% for viscosity.

Table 8. HLW Glass Masses Generated by Individually Excluding Prediction Uncertainties for Various Properties

Cluster	No Uncertainties	Prediction Uncertainties all properties	Prediction Uncertainties No η	Prediction Uncertainties No $T_{2\%}$	Prediction Uncertainties No NP	Prediction Uncertainties No T_L-Zr
1	272.5	272.5	272.5	272.5	272.5	272.5
2	206.8	206.8	206.8	206.8	206.8	206.8
3	614.5	626.9	625.9	617.1	625.2	626.9
4	756.1	770.7	769.5	759.4	768.7	770.7
5	228.2	233.2	232.4	229.1	233.2	233.2
6	263.7	270.3	269.8	265.1	269.2	270.3
7	290.1	296.8	296.2	290.7	296.8	296.8
8	275.6	280.5	280.0	277.2	279.4	280.5
9	94.0	98.9	98.8	98.9	97.2	96.0
10	254.7	260.6	260.0	256.3	259.4	260.6
11	464.7	475.7	474.7	466.0	474.6	475.7
12	185.7	189.5	189.1	186.3	189.0	189.5
13	977.3	1,003.8	1,002.4	978.8	1,003.8	1,003.8
14	469.5	483.2	482.4	470.1	483.2	483.2

Cluster	No Uncertainties	Prediction Uncertainties all properties	Prediction Uncertainties No η	Prediction Uncertainties No $T_{2\%}$	Prediction Uncertainties No NP	Prediction Uncertainties No T_L-Zr
15	262.4	262.4	262.4	262.4	262.4	262.4
16	203.1	208.6	208.3	203.4	208.6	208.6
17	659.1	672.8	672.0	659.7	672.7	672.7
18	746.1	763.8	762.8	746.9	763.8	763.8
19	446.5	475.3	474.5	475.3	463.5	458.1
20	469.3	480.0	479.1	469.9	480.0	480.0
21	1,489.9	1,525.9	1,523.7	1,492.2	1,525.9	1,525.9
22	1,148.9	1,177.7	1,175.8	1,150.3	1,177.1	1,177.7
23	1,677.2	1,783.8	1,777.4	1,783.8	1,746.0	1,716.8
24	467.9	489.4	488.6	484.1	488.0	489.4
25	2,251.2	2,314.5	2,314.5	2,264.0	2,303.8	2,314.5
26	660.3	679.2	678.8	663.2	679.1	679.2
27	1,793.9	1,838.5	1,836.0	1,796.7	1,838.5	1,838.5
28	497.3	511.5	510.9	498.1	511.5	511.5
29	3,020.4	3,096.6	3,092.3	3,025.1	3,096.6	3,096.6
30	2,213.7	2,213.8	2,213.8	2,213.7	2,213.8	2,213.8
Sum	23,360	23,963	23,931	23,563	23,890	23,876

6.4 Prediction and Composition/Process Uncertainties

The HLW waste estimates were performed using both prediction uncertainties (as described in Section 4.1) and composition/process uncertainties (as described in Section 4.2.1). The results are summarized in Table 9. The total glass masses produced are 24,703 MT and 24,359 MT for combined uncertainties if one or four MFPV samples are analyzed, respectively. The average glass mass (used for comparisons later in the report) is 24,531 MT. The average is 5.01 relative percent higher than the no uncertainty case and therefore composition uncertainties account for 2.43 relative percent increase in glass mass (the remaining 2.58% from prediction uncertainties). Generally, the waste loading limiting factors were the same as in the no uncertainty case. Exceptions include:

- Cluster 9 limited by TZr, viscosity and nepheline with no uncertainty and limited by TZr, viscosity, nepheline and boron with prediction and composition uncertainties;
- Cluster 13 limited by T2, boron and viscosity with no uncertainty and limited only by T2 and viscosity with prediction and composition/process uncertainties;
- Cluster 17 limited by T2 and viscosity with no uncertainty and limited by T2, viscosity and nepheline with prediction and composition/process uncertainties;
- Cluster 18 limited by T2 and viscosity with no uncertainty and limited by T2, viscosity and boron with prediction and composition/process uncertainties;
- Cluster 25 limited by T2, boron and nepheline with no uncertainty and limited by the same properties with 4 MFPV samplings with prediction and composition/process uncertainties and by T2, viscosity and nepheline with one sampling with prediction and composition/process uncertainties.

Table 9. Glass Mass and Limiting Factors for 30 HLW Clusters with Prediction and Composition/Process Uncertainties

Cluster	Waste oxides, kg	One MFPV Sample WOL, wt%	One MFPV Sample Glass, MT	Four MFPV Samples WOL, wt%	Four MFPV Samples Glass, MT	Limits(a)
1	102,015	37.4	272.6	37.4	272.5	Max Fe
2	93,314	45.1	206.9	45.1	206.9	Max Fe
3	304,764	47.1	647.0	47.8	637.9	T2,Vis,NP
4	340,138	42.8	795.3	43.4	783.8	T2,Vis,NP
5	118,988	49.1	242.2	50.0	237.9	T2,Vis,B
6	130,884	47.1	278.0	47.7	274.4	T2,Vis,NP
7	129,640	41.9	309.3	42.7	303.3	T2,Vis,Na
8	135,350	46.7	289.6	47.4	285.4	T2,Vis,NP
9	40,217	39.2	102.5	39.8	101.1	TZr,Vis,NP,B
10	137,773	51.4	268.0	52.1	264.5	T2,Vis,NP
11	229,181	46.8	489.5	47.4	483.1	T2,Vis,NP
12	96,641	49.6	194.7	50.2	192.3	T2,Vis,NP
13	414,412	39.8	1,040.6	40.5	1,023.7	T2,Vis
14	226,581	45.4	499.6	46.1	492.0	T2,Vis,B
15	102,370	39.0	262.6	39.0	262.5	Max Mn
16	89,071	41.3	215.6	41.9	212.4	T2,Visc,B
17	334,869	48.3	693.5	49.0	683.8	T2,Vis,NP
18	376,435	47.8	788.3	48.4	777.0	T2,Vis,B
19	178,911	36.2	493.8	36.8	485.8	TZr,Vis,NP,B
20	228,853	46.1	496.3	46.8	488.7	T2,Vis
21	710,511	45.0	1,578.6	45.7	1,554.2	T2,Vis,B
22	546,626	45.0	1,215.6	45.6	1,198.4	T2,Vis,NP
23	709,324	38.2	1,857.3	38.9	1,823.4	TZr,Vis,NP
24	196,576	38.9	505.7	39.5	498.0	T2,Vis,NP
25	979,245	40.9	2,393.3	41.6	2,355.6	T2,Vis,NP (1 sample) T2,NP,B (4 samples)
26	276,233	39.2	704.9	39.9	692.9	T2,Vis
27	784,370	41.2	1,905.7	41.8	1,875.3	T2,Vis,B
28	220,037	41.5	530.0	42.2	521.6	T2,Vis,B
29	1,388,456	43.2	3,211.8	44.0	3,156.3	T2,Vis,B
30	841,474	38.0	2,214.0	38.0	2,213.9	Max Al
Sum	10,463,259	42.4	24,702.8	43.0	24,358.6	

(a) limiting factors include: Max Fe (g_{Fe2O3}= 20wt%), T2 ($T_{2\%}$=950°C), Vis (η_{1150} = 2 or 8 Pa·s), NP (nepheline probability = 30%), TZr (T_L-Zr = 1050°C), Max Mn (g_{MnO} = 8 wt%), Max Al (g_{Al2O3} = 30 wt%). B (model validity, g_{B2O3} = 4 - 22 wt%), Na (model validity, g_{Na2O} = 4.1 - 24 wt%).

6.5 Evaluation of Individual Sources of Composition/Process Uncertainty

With a roughly 2.43 relative percent increase in predicted HLW glass mass due to the application of composition/process uncertainties, a study was performed to determine which components of composition uncertainties had the most significant impact on glass mass. Table 10 shows the glass masses resulting from excluding individual composition uncertainties, one-at-a-time, while all other composition uncertainty components were applied. Excluding the analytical uncertainties had the strongest effect by decreasing the total glass mass by 1.31% followed by 0.1% for mixing and sampling uncertainty. The individual effects of remaining four composition uncertainty components were not calculated for all clusters because their effects calculated for selected clusters were negligible, all less than 0.1%.

Table 10. HLW Glass Masses Generated by Individually Excluding Prediction Uncertainties for Various Properties, kg

Cluster	No uncertainties	Prediction uncertainties for all properties	Full Prediction & Composition Uncertainties(a)	Prediction & Composition Uncertainties without Analytical Uncertainty(a)	Prediction & Composition Uncertainties without Mixing and Sampling Uncertainty(a)
1	272.5	272.5	272.6	272.6	272.6
2	206.8	206.8	206.9	206.9	206.9
3	614.5	626.9	642.4	634.4	641.6
4	756.1	770.7	789.5	779.6	788.1
5	228.2	233.2	240.1	236.3	239.7
6	263.7	270.3	276.2	273.5	275.7
7	290.1	296.8	306.3	300.5	306.0
8	275.6	280.5	287.5	283.8	286.9
9	94.0	98.9	101.8	100.7	101.5
10	254.7	260.6	266.3	263.8	265.6
11	464.7	475.7	486.3	481.1	485.6
12	185.7	189.5	193.5	191.8	193.2
13	977.3	1,003.8	1,032.1	1,015.3	1,031.6
14	469.5	483.2	495.8	489.1	495.1
15	262.4	262.4	262.5	262.6	262.6
16	203.1	208.6	214.0	211.1	213.7
17	659.1	672.8	688.6	680.3	687.8
18	746.1	763.8	782.6	772.1	782.0
19	446.5	475.3	489.8	481.8	489.2
20	469.3	480.0	492.5	485.3	492.2
21	1,489.9	1,525.9	1,566.4	1,542.5	1,565.1
22	1,148.9	1,177.7	1,207.0	1,190.8	1,205.9
23	1,677.2	1,783.8	1,840.3	1,809.9	1,838.9

Cluster	No uncertainties	Prediction uncertainties for all properties	Full Prediction & Composition Uncertainties(a)	Prediction & Composition Uncertainties without Analytical Uncertainty(a)	Prediction & Composition Uncertainties without Mixing and Sampling Uncertainty(a)
24	467.9	489.4	501.9	494.5	501.3
25	2,251.2	2,314.5	2,374.4	2,338.5	2,371.7
26	660.3	679.2	698.9	687.0	698.3
27	1,793.9	1,838.5	1,890.5	1,859.5	1,888.5
28	497.3	511.5	525.8	517.3	525.2
29	3,020.4	3,096.6	3,184.1	3,132.6	3,180.2
30	2,213.7	2,213.8	2,214.0	2,214.0	2,214.0
Sum	23,360	23,963	24,531	24,209	24,507

(a) Glass Mass reported are the average of the masses produced with one and four MFPV samples.

7.0 LAW Calculation Results and Discussion

Calculations were performed using the 36 LAW feed composition clusters. Initially, calculations were performed using the waste loading line rules with and without uncertainties (Section 7.1). Then the calculations were performed without the waste loading line rules (Section 7.2). The impact of various prediction uncertainties are discussed in Section 7.2.3. Finally, the impacts of various composition/process uncertainties are discussed in Section 7.2.5.

7.1 LAW Glass Mass with Waste Loading ('Line') Rules

A series of waste loading line rules were developed in Vienna et al. (2016) to simply estimate the likely WOL of LAW glass during production without recourse to a detailed set of constraints, property models, and uncertainty descriptions. These rules are primarily used to constrain total alkali and SO_3 in glass as shown in Figure 11. In addition to the three blue lines in this figure (new proposed waste loading rules), there is also a combined chlorine, chromium, and phosphorous rule with equations listed in Table 3. The initial question to answer is if the loadings estimated by the line rules can be obtained by glasses for estimated Hanford wastes while still meeting all the property constraints with sufficient confidence. This subsection aims to answer that question.

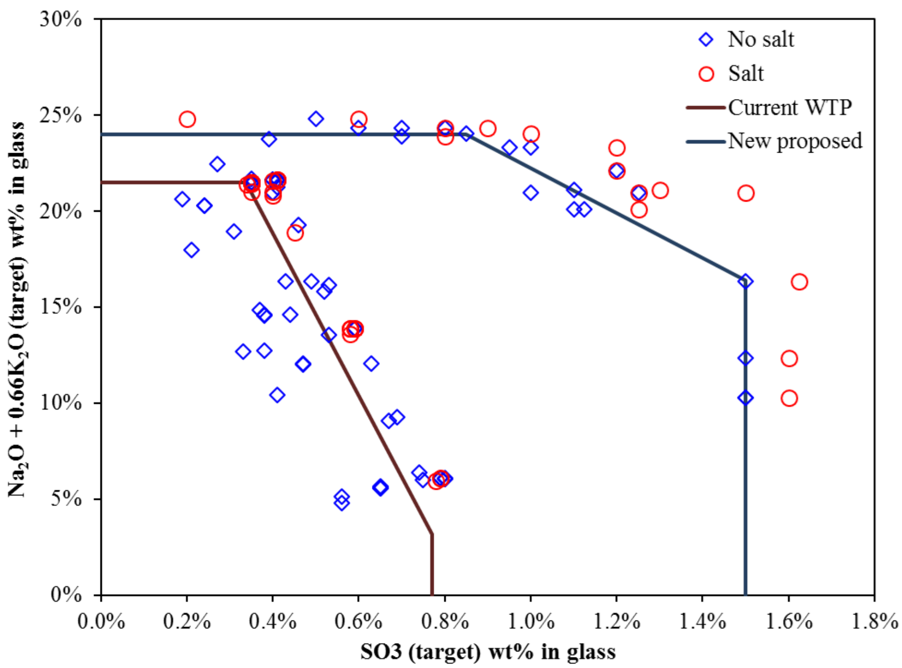

Figure 11. Comparison of the WTP Baseline and Proposed New Waste Loading Line Rules for Normalized Alkali and Sulfur Content. (Vienna et al. (2016)).

The maximum WOL for each of the 36 waste clusters was determined and reported in Table 11. Using the constraints and models reported by Vienna et al. (2016), 282,350 MT of LAW glass would be produced (51,243 containers, assuming 5.51 MT of glass per container). The glass is more limited by the alkali constraint (68%) than by the alkali plus sulfur constraint (32%), sometimes including halide constraints (28%) – see Figure 12.

Table 11. Waste Mass, Maximum WOL, Glass Mass, and Limiting Factors for each of 36 LAW Clusters with Line Rules

Cluster	Waste oxides, MT	No Uncertainty WOL, wt%	No Uncertainty Glass, MT	Pred + Comp Uncertainty WOL, wt%	Pred + Comp Uncertainty Glass, MT	Limits[(a)]
1	2,295	26.2	8,749	26.2	8,751	NaK
2	2,334	26.5	8,806	26.5	8,813	NaK
3	1,244	26.9	4,632	26.5	4,690	NaK+H
4	2,257	26.9	8,399	26.8	8,408	NaK+H
5	484	23.4	2,067	23.4	2,067	NaKS+H
6	2,021	26.9	7,525	26.8	7,531	NaK
7	492	27.4	1,798	27.4	1,800	NaK
8	3,669	26.1	14,083	26.0	14,093	NaK
9	1,920	26.5	7,258	26.4	7,282	NaK+H
10	5,375	28.4	18,924	28.4	18,930	NaK
11	5,812	28.2	20,636	28.1	20,650	NaK
12	4,898	28.3	17,286	28.3	17,295	NaK
13	2,345	28.6	8,205	28.6	8,214	NaK
14	1,025	28.9	3,548	28.9	3,551	NaK
15	4,719	28.7	16,417	28.7	16,420	NaKS
16	2,450	28.6	8,552	28.6	8,558	NaK
17	3,775	29.0	13,033	28.9	13,043	NaK
18	1,085	29.1	3,723	29.1	3,725	NaK
19	2,643	29.1	9,080	29.1	9,082	NaK
20	2,253	29.8	7,566	29.8	7,572	NaK
21	558	29.0	1,927	28.9	1,927	NaK
22	2,398	29.0	8,275	29.0	8,276	NaKS
23	2,584	27.6	9,376	27.6	9,376	NaKS+H
24	4,992	29.6	16,893	29.5	16,908	NaK
25	4,622	27.1	17,051	27.1	17,052	NaKS+H
26	1,547	27.3	5,661	27.3	5,661	NaKS+H
27	1,481	26.2	5,649	26.2	5,649	NaKS+H
28	681	28.5	2,392	28.5	2,392	NaKS
29	1,536	26.5	5,796	26.5	5,797	NaKS+H
30	2,214	26.4	8,390	26.4	8,391	NaKS+H
31	463	30.9	1,497	30.9	1,498	NaK
32	404	32.0	1,261	31.8	1,271	NaK
33	358	26.6	1,346	26.6	1,346	NaKS+H
34	500	23.9	2,091	23.9	2,091	NaKS+H
35	919	24.0	3,836	24.0	3,836	NaKS
36	112	18.1	619	18.1	619	SO_3
Sum[(b)]	78,465	27.8	282,350	27.8	282,562	

Cluster	Waste oxides, MT	No Uncertainty WOL, wt%	Glass, MT	Pred + Comp Uncertainty WOL, wt%	Glass, MT	Limits(a)
(a) NaK = Na_2O+K_2O Line Rule, NaKS = Na_2O+K_2O+SO_3 Line Rule, SO_3 = SO_3 Line Rule, +H includes also Halide Line Rule. The limits reported in this table are applicable to both uncertainty cases: No Uncertainty and Prediction plus Composition Uncertainties. (b) Sum for waste oxide and glass masses, weighted average for WOL						

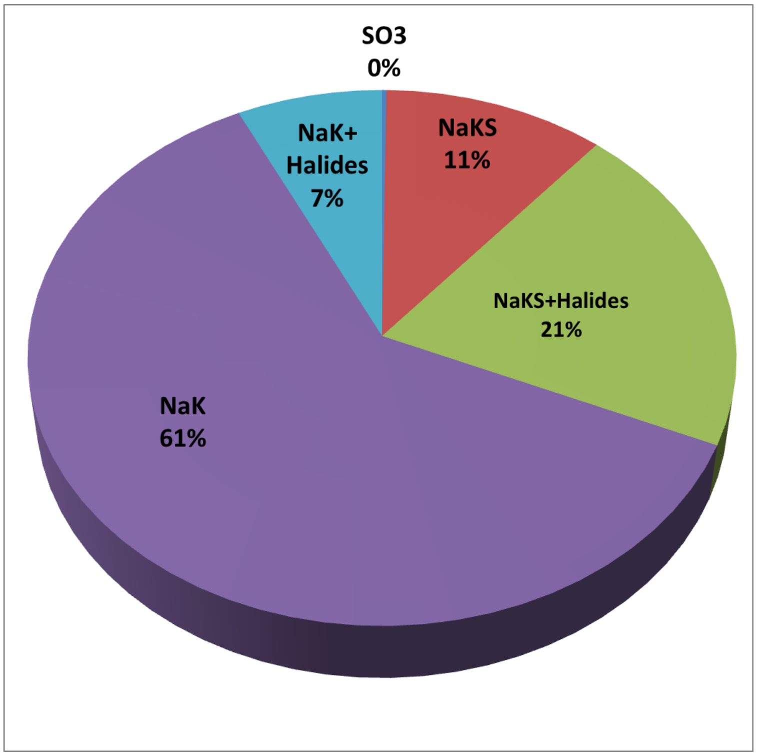

Figure 12. Distribution of LAW Glass Mass Limited by Various Line Rules.

The total glass mass increases only slightly when prediction and composition/process uncertainties are applied – no more than 1.25 relative percent increase for any individual cluster with an average of 0.08% relative difference as a weighted average across all clusters. Therefore, the application of waste loading line rules do serve the initial purpose.

7.2 LAW Glass Mass without Waste Loading ('Line') Rules

The waste loading line rules were found in Section 7.1 to be sufficiently conservative to account for various uncertainties in LAW WOL. The next related question to answer is "how conservative are the line rules?" The following sub-sections seeks to answer that question. A series of calculations were performed to maximize the WOL for each LAW composition while simultaneously satisfying all of the LAW constraints listed in Section 3.2. If one of the property/composition constraints (Table 3) limits the WOL, the additive composition is adjusted to increase the loading until one or more additional constraints are met. Therefore, the WOL is limited by more than one constraint. Unlike HLW glasses there are no LAW glasses limited by single component concentration constraints but all LAW glasses were also limited by one or more model validity constraints (Table 4).

7.2.1 No Uncertainties

Reported in Table 12 are the maximum WOL for each of the 36 waste clusters which was determined with the line rules suppressed. These calculations resulted in an estimate of 252,490 MT of LAW glass to be produced (45,824 containers, assuming 5.51 MT of glass per container). This is 10.58 relative percent lower than the estimates made when line rules are applied. The glass is most limited by K-3 corrosion, viscosity and Alkali + Zr + Sn +Ca (58%) (Figure 13).

Table 12. Waste Mass, Maximum WOL, Glass Mass, and Limiting Factors for each of 36 LAW Clusters with No Uncertainties and No Line Rules

Cluster	Waste oxides, MT	WOL, wt%	Glass, MT	Limits(a)
1	2,295	28.9	7,946	Al,B,Na,Zr,K3,Visc,(Alk+Zr+Sn+Ca)
2	2,334	29.3	7,973	Al,B,Na,Zr,K3,Visc,(Alk+Zr+Sn+Ca)
3	1,244	29.4	4,238	Al,B,Na,Zr,K3,Visc,(Alk+Zr+Sn+Ca),wSO3
4	2,257	29.7	7,597	Al,B,Na,Zr,K3,Visc,(Zr+Sn+Al),(Alk+Zr+Sn+Ca),wSO3
5	484	27.9	1,734	V,VHT,K3,Visc,wSO3,(Zr+Sn+Al)
6	2,021	29.6	6,838	Al,B,Na,Zr,K3,Visc,(Alk+Zr+Sn+Ca)
7	492	29.9	1,649	Al,B,Na,Zr,K3,Visc,(Alk+Zr+Sn+Ca)
8	3,669	28.5	12,893	Al,B,Na,Zr,K3,Visc,(Alk+Zr+Sn+Ca)
9	1,920	28.8	6,656	Al,B,Na,Zr,K3,Visc,(Alk+Zr+Sn+Ca),wSO3
10	5,375	31.0	17,362	Al,B,Na,Zr,K3,Visc,(Alk+Zr+Sn+Ca)
11	5,812	30.6	18,972	Al,B,Na,Zr,K3,Visc,(Alk+Zr+Sn+Ca)
12	4,898	30.8	15,906	Al,B,Na,Zr,K3,Visc,(Alk+Zr+Sn+Ca)
13	2,345	31.1	7,553	Al,B,Na,Ti,Zr,K3,Visc,(Alk+Zr+Sn+Ca),wSO3
14	1,025	31.3	3,270	Al,B,Na,Zr,K3,Visc,(Alk+Zr+Sn+Ca)
15	4,719	31.6	14,919	Al,B,Na,Zr,K3,Visc,(Alk+Zr+Sn+Ca),wSO3
16	2,450	31.5	7,782	Al,B,Na,Zr,K3,Visc,(Alk+Zr+Sn+Ca)
17	3,775	31.5	11,989	Al,B,Na,Zr,K3,Visc,(Alk+Zr+Sn+Ca)
18	1,085	31.5	3,439	B,Cr,Zr,K3,Visc,(Zr+Sn+Al),(Alk+Zr+Sn+Ca)
19	2,643	31.7	8,324	Al,B,Na,Zr,K3,Visc,(Alk+Zr+Sn+Ca)
20	2,253	32.3	6,972	Al,B,Na,Zr,K3,Visc,(Alk+Zr+Sn+Ca)
21	558	32.5	1,715	Al,B,Na,Zr,K3,Visc,(Alk+Zr+Sn+Ca)
22	2,398	32.2	7,452	Al,B,Na,Zr,K3,wSO3,(Alk+Zr+Sn+Ca)
23	2,584	32.4	7,988	Al,B,Na,Zr,K3,wSO3,(Alk+Zr+Sn+Ca)
24	4,992	32.1	15,567	Al,B,Na,Zr,K3,Visc,(Alk+Zr+Sn+Ca)
25	4,622	32.2	14,353	Al,B,Na,Zr,K3,wSO3,(Alk+Zr+Sn+Ca)
26	1,547	32.5	4,763	Al,B,Na,Zr,K3,wSO3,(Alk+Zr+Sn+Ca)
27	1,481	33.2	4,461	B,Na,V,Zr,VHT,K3,wSO3
28	681	33.0	2,062	Al,B,Na,Zr,K3,wSO3,(Alk+Zr+Sn+Ca)
29	1,536	32.9	4,676	Cr,V,Zr,VHT,K3,wSO3,(Zr+Sn+Al)
30	2,214	32.7	6,774	Cr,V,Zr,VHT,K3,wSO3,(Zr+Sn+Al)

Cluster	Waste oxides, MT	WOL, wt%	Glass, MT	Limits(a)
31	463	33.5	1,381	Al,B,Na,Zr,K3,Visc,(Alk+Zr+Sn+Ca)
32	404	34.8	1,162	Al,B,Na,Zr,K3,Visc,(Alk+Zr+Sn+Ca)
33	358	33.8	1,058	Si,V,VHT,K3,Visc,wSO3,(Zr+Sn+Al)
34	500	30.5	1,640	Al,B,V,Zr,PCT,VHT,K3,Visc,wSO3
35	919	30.9	2,977	Al,Ca,V,VHT,K3,Visc,wSO3
36	112	25.0	449	Al,B,P,PCT,Visc,wSO3,(Alk-Zr-Sn-Ca)
Sum(b)	78,465	31.1	252,490	

(a) Limiting factors include: Al, B, Ca, Cr, Na, P, Si, Ti, V, and Zr represent model validity constraints for correspond oxide components given in Table 4. (Alk-Zr-Sn-Ca) = $g_{Na_2O} + 0.66 g_{K_2O} + 2.07 g_{Li_2O} - g_{ZrO_2} - g_{SnO_2} - g_{CaO} \leq 0.15$, K3 = K-3 neck corrosion at 1208°C ln[k_{1208}, in] ≤ -3.2189, PCT = ln[PCT *NL,* g/L] ≤ 1.386, VHT = ln[VHT *D*, µm] ≤ 6.116, Visc = 0.693 ≤ ln [η_{1150}, Pa•s] ≤ 2.079, wSO3 = SO_3 salt concentration $w_{SO_3} \leq w_{SO_3}^{Limit}$, (Zr+Sn+Al) = $g_{ZrO_2} + g_{SnO_2} + g_{Al_2O_3} \leq 0.17$.

(b) Sum for waste oxide and glass masses, weighted average for WOL

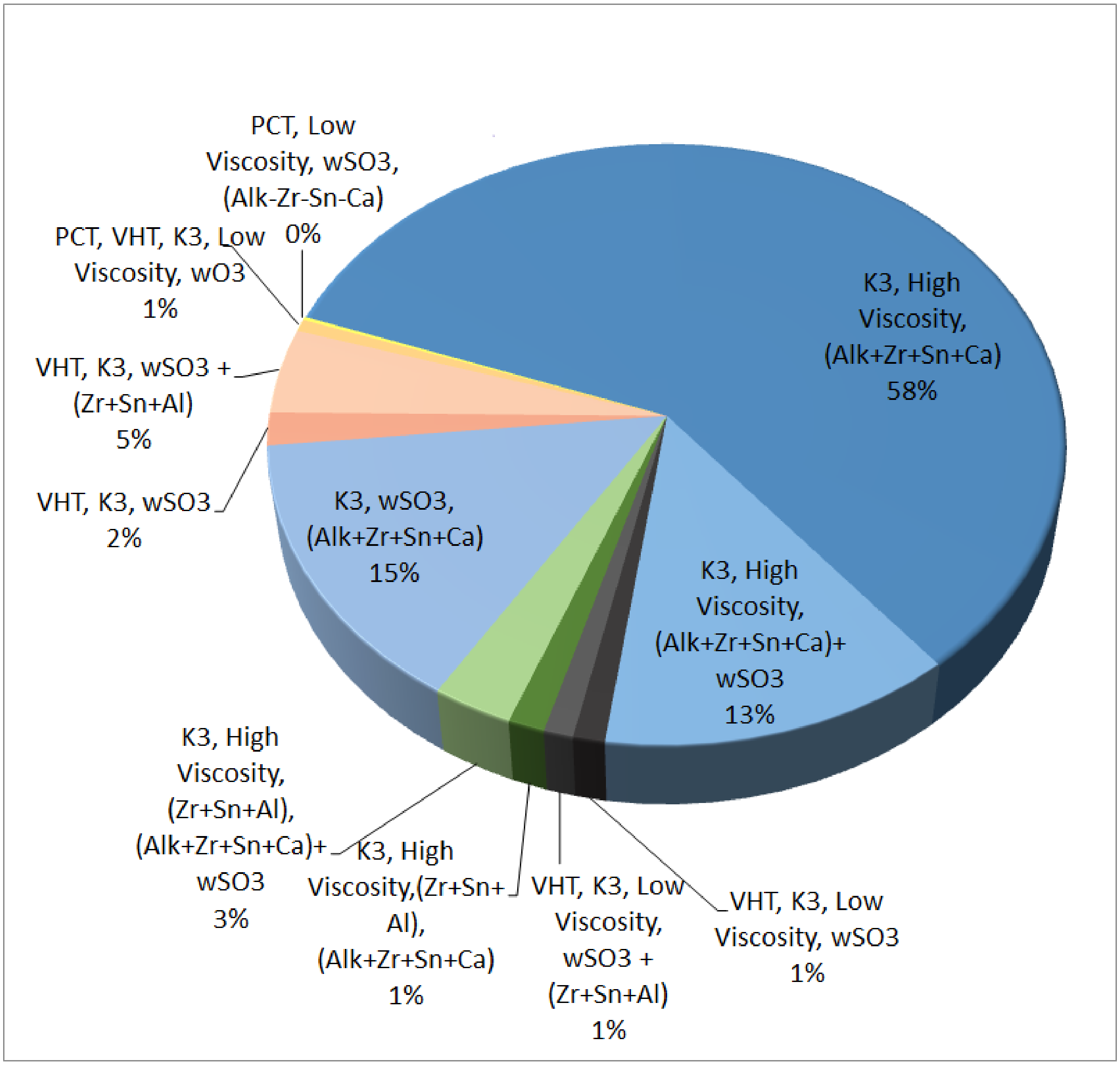

Figure 13. Waste Loading Limiting Factors for LAW Glasses without Line Rules.

7.2.2 Prediction Uncertainties Only

The waste estimates were performed using the prediction uncertainties (as described in Section 4.1) and without the waste loading line rules. The results are summarized in Table 13. The total glass mass produced is 255,833 MT, 1.32 relative percent higher than the case without any uncertainties. The waste loading limiting factors are reported in Table 13.

Table 13. Waste Mass, Maximum WOL, Glass Mass, and Limiting Factors for 36 LAW Clusters with Prediction Uncertainties without Line Rules

Cluster	Waste oxides, kg	WOL, wt%	Glass, MT	Limits(a)
1	2,295	28.8	7,959	Al,B,Cr,Zr,VHT,K3,Visc,(Zr+Sn+Al)
2	2,334	29.0	8,050	Al,B,Cr,Zr,VHT,K3,Visc,(Zr+Sn+Al)
3	1,244	28.9	4,304	B,Cr,Zr,VHT,K3,Visc,wSO3,(Zr+Sn+Al)
4	2,257	29.2	7,741	B,Cr,Zr,VHT,K3,Visc,(Zr+Sn+Al)
5	484	26.5	1,825	V,VHT,K3,wSO3
6	2,021	29.5	6,862	Al,B,Cr,Zr,VHT,K3,Visc,(Zr+Sn+Al)
7	492	29.9	1,649	Al,B,Cr,Na,Zr,VHT,K3,Visc,(Zr+Sn+Al)
8	3,669	28.4	12,896	Al,B,Na,Zr,VHT,K3,Visc,(Zr+Sn+Al)
9	1,920	28.7	6,695	B,Cr,Zr,VHT,K3,Visc,(Zr+Sn+Al)
10	5,375	31.0	17,365	Al,B,Na,Zr,VHT,K3,Visc,(Zr+Sn+Al)
11	5,812	30.6	18,974	Al,B,Na,Zr,VHT,K3,Visc,(Zr+Sn+Al)
12	4,898	30.8	15,907	Al,B,Na,Zr,VHT,K3,Visc,(Zr+Sn+Al)
13	2,345	31.0	7,567	B,Cr,Zr,VHT,K3,Visc,(Zr+Sn+Al)
14	1,025	31.3	3,271	Al,B,Cr,Na,Zr,VHT,K3,Visc,(Zr+Sn+Al)
15	4,719	31.3	15,068	B,Cr,Zr,VHT,K3,Visc,wSO3,(Zr+Sn+Al)
16	2,450	31.5	7,787	Al,B,Cr,Zr,VHT, K3,Visc,(Zr+Sn+Al)
17	3,775	31.5	11,992	Al,B,Na,Zr,VHT,K3,Visc,(Zr+Sn+Al)
18	1,085	31.5	3,444	B,Cr,V,Zr,VHT,K3,Visc,(Zr+Sn+Al)
19	2,643	31.7	8,326	Al,B,Na,Zr,VHT,K3,Visc,(Zr+Sn+Al)
20	2,253	32.3	6,974	Al,B,Na,Zr,VHT,K3,Visc,(Zr+Sn+Al)
21	558	31.8	1,756	Al,B,Cr,Zr,VHT,K3,Visc,(Zr+Sn+Al)
22	2,398	31.8	7,547	B,Cr,Zr,VHT,K3,wSO3,(Zr+Sn+Al)
23	2,584	31.5	8,213	B,Cr,V,Zr,VHT,K3,wSO3,(Zr+Sn+Al)
24	4,992	32.1	15,573	Al,B,Cr,Na,Zr,VHT,K3,Visc,(Zr+Sn+Al)
25	4,622	31.2	14,819	B,V,Zr,VHT,K3,wSO3
26	1,547	31.5	4,909	B,V,Zr,VHT,K3,wSO3
27	1,481	30.9	4,793	V,VHT,K3,wSO3
28	681	32.4	2,103	B,Cr,V,Zr,VHT,K3,wSO3,(Zr+Sn+Al)
29	1,536	30.7	5,010	Al,V,VHT,K3,wSO3
30	2,214	30.7	7,215	V,VHT,K3,wSO3
31	463	33.5	1,382	Al,B,Na,Zr,VHT,K3,Visc,(Zr+Sn+Al)
32	404	34.7	1,165	Al,B,Cr,Zr,VHT,K3,Visc,(Zr+Sn+Al)
33	358	31.4	1,141	V,VHT,K3,wSO3
34	500	28.3	1,767	V,VHT,K3,wSO3
35	919	28.4	3,237	V,VHT,K3,wSO3
36	112	20.5	547	Al,B,Ca,V,VHT,Visc, wSO3
Sum(b)	78,465	30.7	255,833	

Cluster	Waste oxides, kg	WOL, wt%	Glass, MT	Limits(a)

(a) Limiting factors include: Al, B, Ca, Cr, Na, P, Si, V, and Zr represent model validity constraints for correspond oxide components given in Table 4. (Alk-Zr-Sn-Ca) = $g_{Na_2O}+0.66g_{K_2O}+2.07g_{Li_2O}-g_{ZrO_2}-g_{SnO_2}-g_{CaO}\leq 0.15$, K3 = K-3 neck corrosion at 1208°C ln[k_{1208}, in] $\leq$ -3.2189, PCT = ln[PCT *NL,* g/L] ≤ 1.386, VHT = ln[VHT *D*, μm] $\leq$ 6.116, Visc = 0.693 ≤ ln [η_{1150}, Pa•s] ≤ 2.079, wSO3 = SO_3 salt concentration $w_{SO_3}\leq w_{SO_3}^{Limit}$, (Zr+Sn+Al) = $g_{ZrO_2}+g_{SnO_2}+g_{Al_2O_3}\leq 0.17$.
(b) Sum for waste oxide and glass masses, weighted average for WOL

7.2.3 Evaluation of Individual Property Prediction Uncertainties

An analysis was performed to determine the role of prediction uncertainties for individual properties on the amount of glass produced. Table 14 summarizes the glass masses resulting from systematic elimination of prediction uncertainties for different properties. The most influential property was VHT with -0.81% (RPD after removing prediction uncertainty for VHT) followed by K3 -0.61%, w_{SO3} -0.28%, and least influential was viscosity with -0.03%. Analysis was not performed for PCT because PCT was not a limiting property for any cluster when prediction uncertainties were applied as shown in Table 13.

Table 14. LAW Glass Mass (MT) for Various Different Property Prediction Uncertainty Cases

Cluster	No uncertainties	Prediction uncertainties for all properties	Prediction uncertainties for all but VHT	Prediction uncertainties for all but K3	Prediction uncertainties for all but w_{SO3}	Prediction uncertainties for all but Viscosity
1	7,946	7,959	7,946	7,947	7,959	7,955
2	7,973	8,050	7,974	7,999	8,050	8,045
3	4,238	4,304	4,240	4,257	4,297	4,304
4	7,597	7,741	7,599	7,680	7,741	7,734
5	1,734	1,825	1,803	1,783	1,805	1,825
6	6,838	6,862	6,838	6,839	6,862	6,858
7	1,649	1,649	1,649	1,649	1,649	1,649
8	12,893	12,896	12,894	12,894	12,896	12,896
9	6,656	6,695	6,658	6,658	6,695	6,688
10	17,362	17,365	17,362	17,362	17,365	17,365
11	18,972	18,974	18,972	18,972	18,974	18,974
12	15,906	15,907	15,906	15,906	15,907	15,906
13	7,553	7,567	7,555	7,555	7,567	7,560
14	3,270	3,271	3,270	3,270	3,271	3,271
15	14,919	15,068	14,925	14,925	15,044	15,068
16	7,782	7,787	7,783	7,783	7,787	7,785
17	11,989	11,992	11,990	11,990	11,992	11,991
18	3,439	3,444	3,439	3,441	3,444	3,442
19	8,324	8,326	8,325	8,325	8,326	8,325

20	6,972	6,974	6,973	6,973	6,974	6,974
21	1,715	1,756	1,716	1,747	1,756	1,755
22	7,452	7,547	7,456	7,465	7,533	7,547
23	7,988	8,213	8,015	8,089	8,167	8,213
24	15,567	15,573	15,570	15,569	15,573	15,572
25	14,353	14,819	14,433	14,582	14,709	14,819
26	4,763	4,909	4,771	4,833	4,877	4,909
27	4,461	4,793	4,684	4,690	4,708	4,793
28	2,062	2,103	2,063	2,074	2,097	2,103
29	4,676	5,010	4,891	4,876	4,911	4,978
30	6,774	7,215	7,086	7,070	7,118	7,215
31	1,381	1,382	1,382	1,381	1,382	1,382
32	1,162	1,165	1,162	1,162	1,165	1,164
33	1,058	1,141	1,117	1,113	1,120	1,141
34	1,640	1,767	1,719	1,721	1,730	1,767
35	2,977	3,237	3,130	3,143	3,150	3,237
36	449	547	462	547	512	547
Sum	252,490	255,833	253,760	254,268	255,112	255,757

7.2.4 Prediction and Composition/Process Uncertainties

The waste estimates were performed using both prediction uncertainties (as described in Section 4.1) and composition/process uncertainties (as described in Section 4.2). The results are summarized in Table 15. The total glass masses produced is 275,359 MT for combined uncertainties, 9.06 relative percent higher than the no uncertainty case and therefore composition uncertainties account for 7.73 relative percent additional increase in glass mass (the remaining 1.32% from prediction uncertainties). The glass mass is 2.48 relative percent below that estimated with the line rules. The waste loading limiting factors are reported in Table 15.

Table 15. Waste Mass, Maximum WOL, Glass Mass, and Limiting Factors for 36 LAW Clusters with Prediction and Composition/Process Uncertainties without Line Rules

Cluster	Waste oxides, MT	WOL, wt%	Glass, MT	Limits
1	2,295	26.4	8,683	Al,B,Cr, Zr,VHT, K3,Visc,(Zr+Sn+Al)
2	2,334	26.9	8,688	Al,B,Cr,V,Zr,VHT,K3,Visc,(Zr+Sn+Al)
3	1,244	26.6	4,668	B,Cr,V,Zr,VHT,K3,Visc,(Zr+Sn+Al)
4	2,257	27.0	8,372	Al,B,Cr,V,Zr,VHT,K3,Visc,(Zr+Sn+Al)
5	484	24.9	1,944	V,VHT,K3,wSO3
6	2,021	27.3	7,411	Al,B,Cr,V,Zr,VHT,K3,Visc,(Zr+Sn+Al)
7	492	27.6	1,781	Al,B,Cr,V,Zr,VHT,K3,Visc,(Zr+Sn+Al)
8	3,669	26.5	13,859	Al,B,Cr,Zr,VHT,K3,Visc,(Zr+Sn+Al)
9	1,920	26.5	7,257	B,CrV,Zr,VHT,K3,Visc,(Zr+Sn+Al)

Cluster	Waste oxides, MT	WOL, wt%	Glass, MT	Limits
10	5,375	28.8	18,660	Al,B,CrV,Zr,VHT,K3,Visc,(Zr+Sn+Al)
11	5,812	28.6	20,356	Al,B,Cr,V,Zr,VHT,K3,Visc,(Zr+Sn+Al)
12	4,898	28.8	16,981	Al,B,Cr,Zr,VHT,K3,Visc,(Zr+Sn+Al)
13	2,345	28.5	8,225	Al,B,Cr,V,Zr,VHT,K3,Visc,(Zr+Sn+Al)
14	1,025	29.0	3,536	Al,B,Cr,V,Zr,VHT,K3,Visc,(Zr+Sn+Al)
15	4,719	28.9	16,326	B,Cr,V,Zr,VHT,K3,Visc,(Zr+Sn+Al)
16	2,450	28.8	8,513	Al,B,Cr,Zr,VHT,K3,Visc,(Zr+Sn+Al)
17	3,775	29.2	12,919	Al,B,Cr,V,Zr,VHT,K3,Visc,(Zr+Sn+Al)
18	1,085	29.4	3,689	Al,B,Cr,V,Zr,VHT,K3,Visc,(Zr+Sn+Al)
19	2,643	29.7	8,907	Al,B,Cr,Zr,VHT,K3,Visc,(Zr+Sn+Al)
20	2,253	30.1	7,491	Al,B,Cr,V,Zr,VHT,K3,Visc,(Zr+Sn+Al)
21	558	29.2	1,911	Al,B,Cr,Zr,VHT,K3,Visc,(Zr+Sn+Al)
22	2,398	29.4	8,165	B,Cr,V,Zr,VHT,K3,Visc,(Zr+Sn+Al)
23	2,584	29.3	8,821	Cr,V,Zr,VHT,K3,Visc,(Zr+Sn+Al),wSO3
24	4,992	29.7	16,833	Al,B,Cr,V,Zr,VHT,K3,Visc,(Zr+Sn+Al)
25	4,622	29.1	15,865	Cr,V,Zr,VHT,K3,Visc,(Zr+Sn+Al),wSO3
26	1,547	29.4	5,259	B,Cr,V,Zr,VHT,K3,Visc,(Zr+Sn+Al),wSO3
27	1,481	28.9	5,115	V,VHT,K3,wSO3
28	681	30.1	2,257	B,Cr,V,Zr,VHT,K3,Visc,(Zr+Sn+Al),wSO3
29	1,536	28.7	5,355	Al,V,VHT,K3,Visc,wSO3
30	2,214	28.7	7,711	V,VHT,K3,wSO3
31	463	31.5	1,466	Al,B,Cr,Zr,VHT,K3,Visc,(Zr+Sn+Al)
32	404	32.2	1,254	Al,B,Cr,Zr,VHT,K3,Visc,(Zr+Sn+Al)
33	358	29.5	1,216	V,VHT,K3,wSO3
34	500	26.6	1,875	V,VHT,K3,wSO3
35	919	26.8	3,426	V,VHT,K3,wSO3
36	112	20.0	561	Al,B,Ca,V,VHT,Visc,wSO3
Sum(b)	78,465	28.5	275,359	

(a) Limiting factors include: Al, B, Ca, Cr, Na, P, Si, V, and Zr represent model validity constraints for correspond oxide components given in Table 4. (Alk-Zr-Sn-Ca) = $g_{Na_2O} + 0.66 g_{K_2O} + 2.07 g_{Li_2O} - g_{ZrO_2} - g_{SnO_2} - g_{CaO} \leq 0.15$, K3 = K-3 neck corrosion at 1208°C ln[k_{1208}, in] ≤ -3.2189, PCT = ln[PCT *NL,* g/L] ≤ 1.386, VHT = ln[VHT *D*, μm] ≤ 6.116, Visc = 0.693 ≤ ln [η_{1150}, Pa•s] ≤ 2.079, wSO3 = SO_3 salt concentration $w_{SO_3} \leq w_{SO_3}^{Limit}$, (Zr+Sn+Al) = $g_{ZrO_2} + g_{SnO_2} + g_{Al_2O_3} \leq 0.17$.

(b) Sum for waste oxide and glass masses, weighted average for WOL

7.2.5 Evaluation of Individual Sources of Composition/Process Uncertainty

An analysis was performed to determine the role of individual sources of composition uncertainties on the amount of glass produced. Table 16 summarizes the glass masses resulting from systematic elimination of sources of composition uncertainties. Excluding the analytical uncertainties had the strongest effect by decreasing the total glass mass by 3.19% followed by 1.62% for volume transfer uncertainty. The individual effects of remaining four composition uncertainty components were not calculated for all clusters because their effects calculated for selected clusters were negligible.

Table 16. LAW Glass Mass (MT) for Full Prediction and Composition Uncertainty Compared to Cases with Analytical and Mixing and Sampling Uncertainties Removed

Cluster	No uncertainties	Prediction uncertainties for all properties	Full Prediction & Composition Uncertainties	Prediction & Composition Uncertainties without Analytical Uncertainty	Prediction & Composition Uncertainties without Volume Transfer Uncertainty
1	7,946	7,959	8,683	8,312	8,540
2	7,973	8,050	8,688	8,423	8,554
3	4,238	4,304	4,668	4,503	4,576
4	7,597	7,741	8,372	8,104	8,229
5	1,734	1,825	1,944	1,892	1,922
6	6,838	6,862	7,411	7,174	7,289
7	1,649	1,649	1,781	1,725	1,750
8	12,893	12,896	13,859	13,422	13,643
9	6,656	6,695	7,257	7,023	7,128
10	17,362	17,365	18,660	18,086	18,344
11	18,972	18,974	20,356	19,715	20,035
12	15,906	15,907	16,981	16,432	16,685
13	7,553	7,567	8,225	7,947	8,056
14	3,270	3,271	3,536	3,423	3,472
15	14,919	15,068	16,326	15,775	16,021
16	7,782	7,787	8,513	8,209	8,355
17	11,989	11,992	12,919	12,474	12,681
18	3,439	3,444	3,689	3,575	3,636
19	8,324	8,326	8,907	8,628	8,751
20	6,972	6,974	7,491	7,256	7,381
21	1,715	1,756	1,911	1,835	1,878
22	7,452	7,547	8,165	7,890	8,023
23	7,988	8,213	8,821	8,546	8,684
24	15,567	15,573	16,833	16,275	16,568
25	14,353	14,819	15,865	15,415	15,660
26	4,763	4,909	5,259	5,102	5,180
27	4,461	4,793	5,115	4,967	5,058
28	2,062	2,103	2,257	2,187	2,220
29	4,676	5,010	5,355	5,200	5,287
30	6,774	7,215	7,711	7,491	7,613
31	1,381	1,382	1,466	1,424	1,448

Cluster	No uncertainties	Prediction uncertainties for all properties	Full Prediction & Composition Uncertainties	Prediction & Composition Uncertainties without Analytical Uncertainty	Prediction & Composition Uncertainties without Volume Transfer Uncertainty
32	1,162	1,165	1,254	1,215	1,234
33	1,058	1,141	1,216	1,182	1,202
34	1,640	1,767	1,875	1,832	1,855
35	2,977	3,237	3,426	3,350	3,388
36	449	547	561	557	558
Sum	252,490	255,833	275,359	266,566	270,903

7.2.6 Without VHT Constraint

As most of the glasses were limited by the VHT constraint a calculation was performed to evaluate the impacts of the VHT constraint on glass mass. For full prediction and composition/process uncertainties, 275,359 MT of LAW glass is estimated. Table 17 summarizes the calculations made on LAW glasses. Removing only the VHT constraint (while keeping all other constraints with both prediction and composition uncertainties) results is an estimated 260,281 MT of LAW glass– a 5.48 relative percent reduction in glass mass. This reduction in mass translates to roughly 3 years of operation assuming 30 MT/d at 70% total online efficiency (TOE). As the correlation between VHT response and glass source-term in IDF is tenuous at best, there appears to be a significant schedule and cost driver to reevaluate this contract constraint.

Table 17. Glass Mass (MT) Projected for the Full Mission for Each of the 12 Evaluated Cases

Case	Line Rules	Prediction Uncertainties	Composition Uncertainties	Full Mission, MT
1	Y	None	None	282,350
2	Y	All	All	282,562
3	N	None	None	252,490
4	N	All	None	255,833
5	N	All but VHT	None	253,760
6	N	All but K3	None	254,268
7	N	All but w_{SO3}	None	255,112
8	N	All but η	None	255,757
9	N	All	All	275,359
10	N	All	All but analytical	266,566
11	N	All	All but volume transfer	270,903
12(a)	N	All but VHT	All but VHT	260,281
(a) Case 12 excludes VHT as a constraint				

7.2.7 Evaluation of Glass Mass for Initial Phase of LAW Processing

In the first roughly 10 years of processing, the LAW vitrification facility will be fed by the LAWPS with recycles coming from the EMF. This waste is distinct in composition as seen in Figure 5 with the very high sodium content compared to all other wastes. Estimates of the uncertainty impacts for these specific clusters are useful to evaluating processing during the initial stages of plant operation. They also give an indication of the impacts of the PT process on LAW performance by difference. Evaluation of the waste feeds identified eight clusters (1-6, 8, and 9) to make up this initial time period. Table 18 summarizes the results of the 12 cases evaluated and described in Sections 7.1 and 7.2 for the full mission and also for the eight clusters of waste to be processed in the initial phase of deployment (roughly 10 years of processing). Results from the initial phase shows the same general trend as the full mission. That is the relative differences in glass masses between cases are generally the same for the initial phase and for the full mission.

Table 18. Glass Mass (MT) Projected for the Initial Phase of Processing and Full Mission for Each of the 12 Evaluated Cases

Case	Line Rules	Prediction Uncertainties	Composition Uncertainties	Initial Phase, MT	Full Mission, MT
1	Y	None	None	61,520	282,350
2	Y	All	All	61,633	282,562
3	N	None	None	55,875	252,490
4	N	All	None	56,332	255,833
5	N	All but VHT	None	55,953	253,760
6	N	All but K3	None	56,057	254,268
7	N	All but w_{SO3}	None	56,306	255,112
8	N	All but η	None	56,304	255,757
9	N	All	All	60,882	275,359
10	N	All	All but analytical	58,854	266,566
11	N	All	All but volume transfer	59,880	270,903
12(a)	N	All but VHT	All but VHT	58,014	260,281
(a) Case 12 excludes VHT as a constraint					

8.0 Summary and Conclusions

Analyses were performed to evaluate the impacts of using the advanced glass models, constraints (Vienna et al. 2016), and uncertainty descriptions on projected Hanford glass mass. Waste feed vectors supporting the SP8 (DOE 2017) were used as a basis for Hanford LAW and HLW compositions to be vitrified. The large number of waste batches (4008 for HLW and 28,458 for LAW) would not allow detailed calculations for each individual batch. Cluster analysis was performed to group the 4008 HLW batches into 30 clusters and the 28,458 LAW batches into 36 clusters, each of like composition. The maximum allowable WOL was estimated for each cluster while simultaneously satisfying all applicable glass property and composition constraints with sufficient confidence. Different components of prediction and composition/process uncertainties were systematically excluded in the calculations to evaluate their impacts on glass mass. The results of these calculations are described in the subsections below for HLW and LAW.

8.1 High-Level Waste

Applying the advanced glass models and constraints to the SP8 estimate of Hanford HLW generated 23,360 MT of HLW glass (7,735 canisters, assuming 3.02 MT of glass per canister) without use of uncertainty estimates. The WOL of glass is most limited by viscosity, $T_{2\%}$, and nepheline with a small fraction limited by single component (Al, Fe and Mn) constraints (12 wt%) as shown in Figure 14. Accounting for prediction and composition/process uncertainties resulted in 5.01 relative percent increase in estimated glass mass: 24,531 MT (8,123 canisters). Roughly equal impacts were found for prediction uncertainties (2.58 RPD) and composition/process uncertainties (2.43 RPD). The prediction uncertainties with the largest impact are: $T_{2\%}$> T_L-Zr>nepheline> viscosity. The composition/process uncertainties with the largest impact are: analytical>mixing and sampling>all others.

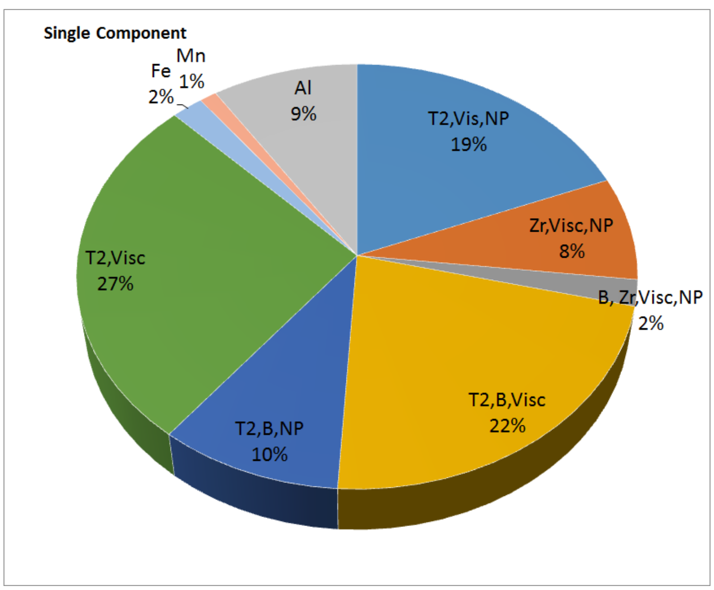

Figure 14. Waste Loading Limiting Factors (Glass Mass Basis) for HLW Glasses.

8.2 Low-Activity Waste

Applying the advanced glass models and constraints reported by Vienna et al. (2016) to the SP8 estimate of Hanford LAW generated 282,350 MT of LAW glass (51,243 containers, assuming 5.51 MT of glass container) without use of uncertainty estimates. The WOL of glass for all wastes were determined by the waste loading line rules (Figure 11). The glass is more limited by the alkali constraint (68%) than by the alkali plus sulfur constraint (32%), sometimes including halide constraints (28%). Accounting for prediction and composition/process uncertainties resulted in 0.08 relative percent increase in estimated glass mass: 282,562 MT (51,282 containers). The line rules were developed to simply estimate the likely WOL of LAW glass during production without recourse to a detailed set of constraints, property models, and uncertainty descriptions. The result that glass mass did not increase after application of all applicable uncertainties shows that the line rules successfully limited the loading as intended. However, they may be too conservative and unnecessarily limit WOL. Calculations were therefore performed without the line rules to determine the maximum WOL both with and without applicable uncertainties.

Table 19 summarizes the LAW glass mass estimates for a series of cases with different sources of uncertainty accounted for (see Section 7.0 for detailed explanation of each case). Without application of line rules the glass mass decreases by 10.6 relative percent (252,490 MT) for the case with no uncertainties. Addition of prediction uncertainties increases glass mass by 1.32 relative percent and the addition of composition/process uncertainties increase glass mass by an additional 7.73 relative percent (9.06 relative percent increase combined). The glass mass estimate without line rules (275,359 MT) was 2.55 relative percent lower than that with the line rules (282,562 MT), after accounting for all applicable uncertainties. These comparisons are shown in Table 20.

Table 19. LAW Glass Mass Estimates for Cases Including Various Uncertainty Terms

Case	Line Rules	Prediction Uncertainties	Composition Uncertainties	Glass Mass, MT	Containers
1	Y	None	None	282,350	51,243
2	Y	All	All	282,562	51,282
3	N	None	None	252,490	45,824
4	N	All	None	255,833	46,431
5	N	All but VHT	None	253,760	40,054
6	N	All but K3	None	254,268	46,147
7	N	All but w_{SO3}	None	255,112	46,300
8	N	All but η	None	255,757	46,417
9	N	All	All	275,359	49,974
10	N	All	All but analytical	266,566	48,379
11	N	All	All but volume transfer	270,903	49,166
12(a)	N	All but VHT	All but VHT	260,281	47,238
(a) Case 12 excludes VHT as a constraint.					

Table 20. Summary of Impacts of Line Rules and Uncertainties on LAW Glass Mass and Containers (a)

	No Uncertainty	Property Prediction Uncertainties Only	Property Prediction + Composition Uncertainties
With Line Rules ON			
Mass (MTG) **Containers** **RPD**	282,350 51,243	282,358 51,245 (0%)	282,562 51,282 (+0.1%)
With Line Rules OFF			
Mass (MTG) **Containers** **RPD**	252,490 45,824 [-11%]	255,833 46,431 (+1%)[-9%]	275,359 49,974 (+9%)[-3%]
(a) change in parentheses is relative to no uncertainty cases (e.g., left), change in square brackets is relative to the line rules cases (e.g., up)			

9.0 References

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Appendix A

Table A.1. Variance covariance matrix for HLW PCT-B

Term	Al_2O_3	B_2O_3	Fe_2O_3	Li_2O	MgO	Na_2O	SiO_2	TiO_2	ZnO	ZrO_2	CaO	P_2O_5	SO_3	UO_3	Others	(Al_2O_3)^2	(Al_2O_3)^3	(Al_2O_3)^4
Al_2O_3	9.203	-0.113	-0.284	-0.111	-0.095	-0.270	-0.245	-0.174	-1.459	0.364	-0.009	-0.497	-0.834	-0.409	-0.258	-109.681	460.920	-632.078
B_2O_3	-0.113	0.132	0.005	0.016	-0.049	0.008	-0.019	0.015	-0.033	-0.055	-0.006	-0.108	0.197	0.091	-0.012	1.371	-8.118	13.665
Fe_2O_3	-0.284	0.005	0.119	-0.027	-0.042	-0.015	-0.001	-0.090	-0.040	0.042	-0.004	-0.023	0.212	-0.037	-0.027	3.232	-12.304	15.482
Li_2O	-0.111	0.016	-0.027	0.795	-0.024	0.080	-0.077	0.010	0.156	-0.045	0.106	0.126	-0.404	-0.163	0.017	1.058	-6.552	10.638
MgO	-0.095	-0.049	-0.042	-0.024	2.374	-0.022	-0.026	0.417	0.809	0.110	-0.101	-0.458	0.708	0.155	-0.075	1.953	-6.123	4.062
Na_2O	-0.270	0.008	-0.015	0.080	-0.022	0.124	-0.022	0.007	0.033	-0.036	0.000	0.040	-0.027	-0.018	0.035	2.539	-10.287	14.174
SiO_2	-0.245	-0.019	-0.001	-0.077	-0.026	-0.022	0.030	-0.016	0.041	-0.012	-0.018	0.053	0.049	-0.004	-0.006	2.853	-11.185	14.607
TiO_2	-0.174	0.015	-0.090	0.010	0.417	0.007	-0.016	1.949	0.632	0.072	0.035	0.014	-0.618	0.353	-0.106	3.160	-14.728	20.597
ZnO	-1.459	-0.033	-0.040	0.156	0.809	0.033	0.041	0.632	6.980	-0.617	0.180	0.366	1.840	0.270	-0.316	15.841	-60.122	75.188
ZrO_2	0.364	-0.055	0.042	-0.045	0.110	-0.036	-0.012	0.072	-0.617	0.610	-0.048	-0.200	-0.229	0.059	-0.085	-3.575	15.532	-22.673
CaO	-0.009	-0.006	-0.004	0.106	-0.101	0.000	-0.018	0.035	0.180	-0.048	0.537	-0.110	-0.210	0.051	0.021	-0.461	3.032	-5.895
P_2O_5	-0.497	-0.108	-0.023	0.126	-0.458	0.040	0.053	0.014	0.366	-0.200	-0.110	5.066	0.574	-0.010	-0.296	5.550	-30.000	50.390
SO_3	-0.834	0.197	0.212	-0.404	0.708	-0.027	0.049	-0.618	1.840	-0.229	-0.210	0.574	44.957	-0.577	-0.762	-13.251	111.718	-205.065
UO_3	-0.409	0.091	-0.037	-0.163	0.155	-0.018	-0.004	0.353	0.270	0.059	0.051	-0.010	-0.577	0.959	-0.012	5.056	-20.777	27.378
Others	-0.258	-0.012	-0.027	0.017	-0.075	0.035	-0.006	-0.106	-0.316	-0.085	0.021	-0.296	-0.762	-0.012	0.274	3.041	-12.885	17.967
(Al_2O_3)^2	-109.681	1.371	3.232	1.058	1.953	2.539	2.853	3.160	15.841	-3.575	-0.461	5.550	-13.251	5.056	3.041	1379.785	-6022.753	8487.915
(Al_2O_3)^3	460.920	-8.118	-12.304	-6.552	-6.123	-10.287	-11.185	-14.728	-60.122	15.532	3.032	-30.000	111.718	-20.777	-12.885	-6022.753	27206.367	-39386.450
(Al_2O_3)^4	-632.078	13.665	15.482	10.638	4.062	14.174	14.607	20.597	75.188	-22.673	-5.895	50.390	-205.065	27.378	17.967	8487.915	-39386.450	58302.720

Table A.2. Variance covariance matrix for HLW PCT-Na

Term	Al_2O_3	B_2O_3	Fe_2O_3	Li_2O	MgO	Na_2O	SiO_2	TiO_2	ZnO	ZrO_2	CaO	P_2O_5	SO_3	UO_3	Others	(Al_2O_3)^2	(Al_2O_3)^3	(Al_2O_3)^4
Al_2O_3	7.049	-0.088	-0.219	-0.093	-0.081	-0.213	-0.184	-0.136	-1.134	0.291	-0.009	-0.380	-0.667	-0.315	-0.203	-83.939	352.587	-483.369
B_2O_3	-0.088	0.100	0.004	0.013	-0.037	0.006	-0.015	0.011	-0.024	-0.043	-0.004	-0.082	0.151	0.070	-0.009	1.061	-6.249	10.492
Fe_2O_3	-0.219	0.004	0.091	-0.020	-0.032	-0.011	-0.001	-0.068	-0.029	0.031	-0.003	-0.017	0.164	-0.028	-0.020	2.489	-9.473	11.921
Li_2O	-0.093	0.013	-0.020	0.608	-0.016	0.063	-0.059	0.008	0.124	-0.038	0.082	0.096	-0.301	-0.123	0.014	0.894	-5.324	8.525
MgO	-0.081	-0.037	-0.032	-0.016	1.811	-0.015	-0.020	0.319	0.622	0.081	-0.076	-0.348	0.546	0.119	-0.055	1.569	-4.971	3.482
Na_2O	-0.213	0.006	-0.011	0.063	-0.015	0.095	-0.017	0.006	0.029	-0.030	0.001	0.031	-0.015	-0.013	0.028	2.001	-8.088	11.117
SiO_2	-0.184	-0.015	-0.001	-0.059	-0.020	-0.017	0.023	-0.013	0.030	-0.009	-0.014	0.040	0.036	-0.003	-0.005	2.152	-8.440	11.027
TiO_2	-0.136	0.011	-0.068	0.008	0.319	0.006	-0.013	1.485	0.484	0.054	0.027	0.011	-0.468	0.269	-0.080	2.440	-11.343	15.846
ZnO	-1.134	-0.024	-0.029	0.124	0.622	0.029	0.030	0.484	5.332	-0.479	0.139	0.280	1.421	0.207	-0.237	12.293	-46.653	58.353
ZrO_2	0.291	-0.043	0.031	-0.038	0.081	-0.030	-0.009	0.054	-0.479	0.470	-0.037	-0.153	-0.186	0.044	-0.067	-2.862	12.358	-17.937
CaO	-0.009	-0.004	-0.003	0.082	-0.076	0.001	-0.014	0.027	0.139	-0.037	0.410	-0.084	-0.158	0.039	0.017	-0.331	2.236	-4.400
P_2O_5	-0.380	-0.082	-0.017	0.096	-0.348	0.031	0.040	0.011	0.280	-0.153	-0.084	3.860	0.439	-0.007	-0.225	4.244	-22.916	38.467
SO_3	-0.667	0.151	0.164	-0.301	0.546	-0.015	0.036	-0.468	1.421	-0.186	-0.158	0.439	34.282	-0.437	-0.575	-9.785	83.944	-154.758
UO_3	-0.315	0.070	-0.028	-0.123	0.119	-0.013	-0.003	0.269	0.207	0.044	0.039	-0.007	-0.437	0.731	-0.009	3.885	-15.956	21.019
Others	-0.203	-0.009	-0.020	0.014	-0.055	0.028	-0.005	-0.080	-0.237	-0.067	0.017	-0.225	-0.575	-0.009	0.210	2.382	-10.062	13.999
(Al_2O_3)^2	-83.939	1.061	2.489	0.894	1.569	2.001	2.152	2.440	12.293	-2.862	-0.331	4.244	-9.785	3.885	2.382	1054.954	-4602.750	6484.726
(Al_2O_3)^3	352.587	-6.249	-9.473	-5.324	-4.971	-8.088	-8.440	-11.343	-46.653	12.358	2.236	-22.916	83.944	-15.956	-10.062	-4602.750	20781.754	-30076.171
(Al_2O_3)^4	-483.369	10.492	11.921	8.525	3.482	11.117	11.027	15.846	58.353	-17.937	-4.400	38.467	-154.758	21.019	13.999	6484.726	-30076.171	44506.919

Table A.3. Variance covariance matrix for HLW PCT-Li

Term	Al_2O_3	B_2O_3	Fe_2O_3	Li_2O	MgO	Na_2O	SiO_2	TiO_2	ZnO	ZrO_2	CaO	P_2O_5	SO_3	UO_3	Others	(Al_2O_3)^2	(Al_2O_3)^3	(Al_2O_3)^4
Al_2O_3	7.098	-0.077	-0.232	-0.078	-0.072	-0.196	-0.191	-0.112	-0.986	0.262	0.057	-0.385	-0.453	-0.299	-0.200	-85.124	358.041	-490.306
B_2O_3	-0.077	0.111	0.008	0.030	-0.043	0.004	-0.019	0.011	-0.044	-0.041	-0.010	-0.104	0.154	0.075	-0.008	0.941	-5.976	10.366
Fe_2O_3	-0.232	0.008	0.102	-0.001	-0.042	-0.017	-0.003	-0.075	-0.075	0.038	-0.018	-0.026	0.178	-0.029	-0.019	2.613	-9.830	12.218
Li_2O	-0.078	0.030	-0.001	0.874	-0.029	0.040	-0.083	0.032	0.096	-0.021	0.024	0.162	-0.202	-0.124	0.017	0.413	-3.920	7.535
MgO	-0.072	-0.043	-0.042	-0.029	2.023	-0.018	-0.022	0.390	0.961	0.092	-0.063	-0.261	0.980	0.149	-0.078	1.308	-2.761	-1.029
Na_2O	-0.196	0.004	-0.017	0.040	-0.018	0.102	-0.016	0.003	0.021	-0.030	-0.001	0.021	-0.054	-0.014	0.030	1.853	-7.594	10.564
SiO_2	-0.191	-0.019	-0.003	-0.083	-0.022	-0.016	0.026	-0.015	0.034	-0.011	-0.009	0.042	0.014	-0.006	-0.006	2.283	-8.965	11.674
TiO_2	-0.112	0.011	-0.075	0.032	0.390	0.003	-0.015	1.476	0.646	0.055	0.037	0.035	-0.319	0.274	-0.090	2.084	-9.719	13.435
ZnO	-0.986	-0.044	-0.075	0.096	0.961	0.021	0.034	0.646	6.503	-0.490	0.231	0.352	2.519	0.222	-0.344	10.202	-36.838	43.623
ZrO_2	0.262	-0.041	0.038	-0.021	0.092	-0.030	-0.011	0.055	-0.490	0.463	-0.037	-0.156	-0.170	0.046	-0.060	-2.584	11.485	-17.096
CaO	0.057	-0.010	-0.018	0.024	-0.063	-0.001	-0.009	0.037	0.231	-0.037	0.497	-0.114	-0.135	0.043	0.008	-1.017	5.007	-8.235
P_2O_5	-0.385	-0.104	-0.026	0.162	-0.261	0.021	0.042	0.035	0.352	-0.156	-0.114	4.173	0.424	-0.023	-0.248	4.536	-25.465	43.392
SO_3	-0.453	0.154	0.178	-0.202	0.980	-0.054	0.014	-0.319	2.519	-0.170	-0.135	0.424	35.222	-0.409	-0.646	-13.188	101.530	-182.219
UO_3	-0.299	0.075	-0.029	-0.124	0.149	-0.014	-0.006	0.274	0.222	0.046	0.043	-0.023	-0.409	0.727	-0.006	3.705	-15.159	19.809
Others	-0.200	-0.008	-0.019	0.017	-0.078	0.030	-0.006	-0.090	-0.344	-0.060	0.008	-0.248	-0.646	-0.006	0.220	2.347	-9.831	13.595
(Al_2O_3)^2	-85.124	0.941	2.613	0.413	1.308	1.853	2.283	2.084	10.202	-2.584	-1.017	4.536	-13.188	3.705	2.347	1077.438	-4706.340	6621.798
(Al_2O_3)^3	358.041	-5.976	-9.830	-3.920	-2.761	-7.594	-8.965	-9.719	-36.838	11.485	5.007	-25.465	101.530	-15.159	-9.831	-4706.340	21282.228	-30765.789
(Al_2O_3)^4	-490.306	10.366	12.218	7.535	-1.029	10.564	11.674	13.435	43.623	-17.096	-8.235	43.392	-182.219	19.809	13.595	6621.798	-30765.789	45480.242

Table A.4. Variance covariance matrix for HLW TL-ZR

Term	Al_2O_3	B_2O_3	Ln_2O_3	Li_2O	Na_2O	SrO	ZrO_2	Others
Al_2O_3	36866.261	-5799.889	44567.343	-26798.297	-13555.884	-36355.717	17890.969	-363.724
B_2O_3	-5799.889	9277.831	-19508.584	2450.367	7865.096	-23166.554	-6514.831	-1173.851
Ln_2O_3	44567.343	-19508.584	224350.880	-29383.636	-26904.436	60874.755	42864.823	-3878.191
Li_2O	-26798.297	2450.367	-29383.636	58010.595	16883.040	102908.803	-32737.169	-369.637
Na_2O	-13555.884	7865.096	-26904.436	16883.040	26584.493	6667.999	-16736.785	-2897.094
SrO	-36355.717	-23166.554	60874.755	102908.803	6667.999	2095713.065	-9353.337	-7281.736
ZrO_2	17890.969	-6514.831	42864.823	-32737.169	-16736.785	-9353.337	33140.190	-1150.326
Others	-363.724	-1173.851	-3878.191	-369.637	-2897.094	-7281.736	-1150.326	1042.873

Table A.5. Variance covariance matrix for HLW $T_{2\%}$

Term	Al_2O_3	B_2O_3	Bi_2O_3	Cr_2O_3	Fe_2O_3	Li_2O	MgO	MnO	Na_2O	NiO	RuO_2	TiO_2	ZnO	ZrO_2	Others	$Al_2O_3 \cdot Na_2O$	$ZrO_2 \cdot ZrO_2$
Al_2O_3	60368.27	-20613.59	-471.59	-23232.87	-1230.25	-12900.76	-17615.06	-204.61	36511.73	-9544.46	-152196.86	-448.53	20084.23	-856.41	-4149.22	-483655.12	10144.14
B_2O_3	-20613.59	17698.99	-7410.85	-5673.46	-2503.15	1129.30	6542.99	1347.34	-7189.48	5935.64	4225.23	-4439.65	-12233.95	-1505.35	44.57	126396.11	-3891.75
Bi_2O_3	-471.59	-7410.85	137578.42	-100575.	6775.61	13326.02	20528.15	4547.47	-341.88	-121900.33	755885.62	-33339.67	-9171.17	43686.68	-1746.88	2400.97	-438059.42
Cr_2O_3	-23232.87	-5673.46	-100575.	1110498.	23719.73	2226.62	61216.95	27819.63	-30185.42	113575.30	2145584.22	-19596.99	-7085.39	45860.52	-10272.6	215702.76	-407432.93
Fe_2O_3	-1230.25	-2503.15	6775.61	23719.73	15769.82	-67.11	2428.91	1385.40	-10125.87	8409.86	424971.63	17292.47	8193.02	-13350.45	-2301.69	50472.07	245738.97
Li_2O	-12900.76	1129.30	13326.02	2226.62	-67.11	90102.51	943.42	1429.88	6553.71	-28967.94	668307.09	-14329.94	-17417.53	1761.70	-5875.61	48601.46	-293698.81
MgO	-17615.06	6542.99	20528.15	61216.95	2428.91	943.42	709299.15	15238.16	-18771.81	30201.64	1037656.03	-51944.64	-32226.03	27544.73	-3902.98	144349.77	-268439.89
MnO	-204.61	1347.34	4547.47	27819.63	1385.40	1429.88	15238.16	52050.05	-6824.52	34792.05	-58522.84	-19271.56	-9937.39	29839.57	-3535.55	41911.02	-350375.98
Na_2O	36511.73	-7189.48	-341.88	-30185.42	-10125.9	6553.71	-18771.81	-6824.52	47547.00	-59350.78	-219485.71	-12973.24	-816.62	-10690.73	-3839.11	-415621.73	-22616.55
NiO	-9544.46	5935.64	-121900.	113575.30	8409.86	-28967.94	30201.64	34792.05	-59350.78	1014828.	570369.89	-105785.9	72690.31	-117909.88	-3607.64	251148.47	1298993.8
RuO_2	-152196.9	4225.23	755885.6	2145584.	424971.6	668307.09	1037656.	-58522.84	-219485.7	570369.89	170952473.	97577.52	-2409503.8	-1442569.	-206156.6	2370858.3	15238190.5
TiO_2	-448.53	-4439.65	-33339.67	-19596.99	17292.47	-14329.94	-51944.64	-19271.56	-12973.24	-105785.88	97577.52	789035.44	-22957.88	-38504.21	901.17	49773.71	899957.55
ZnO	20084.23	-12233.95	-9171.17	-7085.39	8193.02	-17417.53	-32226.03	-9937.39	-816.62	72690.31	-2409503.78	-22957.88	239519.88	39765.05	-5114.86	-39076.91	-409132.58
ZrO_2	-856.41	-1505.35	43686.68	45860.52	-13350.45	1761.70	27544.73	29839.57	-10690.73	-117909.88	-1442569.11	-38504.21	39765.05	408969.47	-4828.46	68236.47	-5266742.6
Others	-4149.22	44.57	-1746.88	-10272.59	-2301.69	-5875.61	-3902.98	-3535.55	-3839.11	-3607.64	-206156.57	901.17	-5114.86	-4828.46	2700.45	33479.29	59822.84
$Al_2O_3 \cdot Na_2O$	-483655.12	126396.11	2400.97	215702.76	50472.1	48601.46	144349.77	41911.02	-415621.7	251148.47	2370858.38	49773.71	-39076.91	68236.47	33479.29	4784519.66	166795.91
$ZrO_2 \cdot ZrO_2$	10144.14	-3891.75	-438059.42	-407432.93	245739	-293698.81	-268439.89	-350375.98	-22616.55	1298993.79	15238190.47	899957.55	-409132.6	-5266742.63	59822.84	166795.91	77191014.

Table A.6. Variance covariance matrix for HLW Nepheline

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.732	0.804	0.294	-64.085	498.338	-102.179	-522.382
1.654	0.974	0.255	-69.306	523.697	-102.02	-554.696
1.815	0.982	0.245	-69.82	504.258	-93.033	-530.758
2.012	0.607	0.286	-77.127	560.992	-107.989	-575.491
1.778	0.942	0.333	-71.162	556.967	-114.326	-586.02
1.807	0.593	0.274	-80.132	582.966	-109.369	-607.526
1.828	0.715	0.282	-66.338	496.473	-98.574	-514.944
1.705	0.899	0.322	-71.346	544.912	-109.32	-572.611
1.643	0.544	0.264	-34.3	395.61	-106.811	-425.436
1.672	1.03	0.277	-65.45	553.441	-119.95	-594.517
1.855	0.539	0.344	-93.729	631.804	-109.069	-649.925
1.65	0.637	0.267	-83.695	628.311	-126.212	-651.855
1.618	0.963	0.278	-50.874	408.029	-85.916	-431.775
1.794	0.705	0.29	-87.186	580.708	-98.442	-599.056
1.773	0.785	0.378	-73.586	556.052	-109.311	-584.665
1.686	0.782	0.316	-49.509	432.382	-98.655	-457.659
1.682	0.796	0.223	-52.026	496.116	-122.697	-522.931
1.777	0.916	0.324	-58.455	473.791	-100.744	-499.552
1.811	0.565	0.28	-62.782	478.354	-97.063	-493.649
1.662	1.019	0.379	-71.464	518.407	-94.556	-552.83
1.678	0.727	0.317	-65.711	497.053	-96.891	-523.932
1.784	0.831	0.318	-54.455	424.272	-86.466	-446.519
1.727	0.586	0.225	-80.038	590.794	-115.386	-610.845
1.586	0.784	0.28	-46.716	432.276	-104.302	-457.404
1.598	0.74	0.264	-57.88	499.073	-114.652	-524.028
1.554	1.114	0.253	-67.02	503.589	-96.995	-537.395
1.724	1.03	0.313	-75.168	554.308	-105.611	-586.15
1.576	0.914	0.232	-72.091	542.545	-105.792	-574.014
1.564	0.341	0.308	-85.379	629.37	-125.156	-646.389
1.633	0.723	0.283	-55.518	459.021	-101.074	-481.858
1.823	0.684	0.23	-111.343	684.572	-100.41	-703.098
1.692	0.868	0.235	-38.334	369.373	-90.123	-393.991
1.683	0.649	0.206	-63.333	504.042	-108.752	-519.71
1.98	0.922	0.281	-80.279	610.007	-122.045	-634.75
1.55	0.569	0.27	-44.1	439.951	-110.373	-468.211
1.658	0.869	0.364	-53.355	445.142	-96.213	-474.346
1.777	1.029	0.394	-82.927	595.326	-106.748	-632.852
1.659	1.037	0.309	-74.691	555.91	-108.841	-585.366
1.648	0.827	0.37	-65.326	509.463	-103.505	-539.408
1.717	0.941	0.343	-81.852	644.707	-131.087	-684.996
1.781	0.726	0.279	-43.645	405.697	-97.124	-427.978
1.61	0.83	0.271	-42.94	390.691	-91.639	-416.281
1.914	0.842	0.286	-49.111	395.753	-83.562	-415.137
1.644	0.776	0.368	-85.899	640.656	-123.517	-674.423
1.773	0.623	0.231	-53.73	438.293	-94.616	-457.759
1.772	0.707	0.218	-63.175	502.164	-108.146	-519.584
1.829	0.743	0.341	-67.748	497.377	-94.081	-521.316
1.857	0.799	0.308	-68.2	506.522	-99.81	-525.283
1.457	0.467	0.249	-17.905	379.496	-128.116	-415.328

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.796	0.811	0.301	-74.886	579.531	-118.729	-604.633
1.671	0.866	0.26	-58.668	481.495	-101.501	-512.106
1.736	0.976	0.332	-94.13	614.253	-99.672	-641.666
1.508	1.197	0.221	-78.467	583.29	-112.8	-619.686
1.746	1.151	0.323	-69.031	520.581	-101.346	-552.495
1.68	0.671	0.258	-55.552	433.197	-89.947	-451.495
1.574	0.683	0.346	-53.415	516.512	-125.909	-553.772
1.706	0.648	0.197	-58.025	468.677	-103.366	-483.504
1.763	0.767	0.225	-64.086	484.678	-97.498	-503.891
1.809	0.619	0.236	-65.693	513.159	-107.04	-530.324
1.887	0.757	0.308	-73.255	561.868	-113.53	-584.984
1.51	1.077	0.255	-77.196	608.643	-124.729	-649.542
1.66	0.875	0.199	-70.053	539.402	-109.061	-566.184
1.535	0.979	0.237	-54.018	434.202	-94.107	-457.697
1.729	0.745	0.25	-69.171	552.435	-118.968	-574.837
1.746	0.988	0.263	-57.687	473.168	-101.861	-500.892
1.711	0.736	0.263	-61.984	495.079	-105.753	-514.925
1.619	0.978	0.278	-79.411	601.83	-118.726	-636.697
1.649	0.597	0.249	-63.405	479.704	-94.752	-500.59
1.575	0.898	0.192	-59.337	486.45	-105.298	-512.822
1.681	0.863	0.221	-49.311	406.185	-89.523	-424.074
1.772	0.939	0.38	-33.256	408.445	-112.888	-446.064
1.64	0.613	0.224	-65.29	515.795	-110.236	-533.837
1.865	0.974	0.332	-80.414	612.099	-122.405	-641.065
1.814	0.721	0.293	-60.775	461.552	-93.25	-478.786
1.812	0.979	0.366	-61.145	480.306	-96.681	-510.683
1.795	0.658	0.29	-65.013	517.043	-110.437	-536.032
1.757	1.019	0.328	-81.555	621.4	-123.422	-656.274
1.806	1.076	0.417	-72.92	574.923	-117.574	-611.834
1.785	0.73	0.254	-67.465	538.582	-114.03	-562.416
1.932	0.791	0.252	-95.495	616.342	-99.732	-633.065
1.528	1.094	0.233	-61.142	541.303	-123.453	-583.155
1.696	0.813	0.311	-61.192	499.353	-107.116	-526.826
1.795	0.939	0.357	-60.73	457.462	-89.613	-482.421
1.698	0.768	0.323	-47.005	403.206	-87.956	-431.622
1.807	0.745	0.243	-69.383	544.932	-115.717	-562.926
1.547	0.758	0.331	-66.127	497.1	-98.248	-523.547
1.748	0.963	0.232	-81.239	620.363	-125.731	-648.265
1.656	0.496	0.191	-70.123	543.481	-113.332	-560.143
1.85	0.614	0.318	-58.022	477.286	-104.352	-496.386
1.853	0.891	0.28	-75.279	569.419	-115.722	-590.443
1.708	0.662	0.368	-59.414	491.152	-105.468	-519.082
1.678	0.596	0.153	-39.379	373.084	-93.491	-387.228
1.696	0.751	0.29	-73.708	578.795	-120.691	-605.324
1.475	0.732	0.191	-54.132	404.681	-78.65	-426.761
1.673	0.675	0.251	-54.113	448.129	-98.311	-468.955
1.804	0.835	0.332	-80.99	577.556	-107.722	-600.856
1.768	0.618	0.233	-92.581	611.565	-103.542	-626.845
1.764	0.499	0.414	-57.429	473.656	-102.412	-496.134
1.867	0.92	0.329	-64.17	506.547	-104.075	-534.172
1.749	0.887	0.303	-66.519	496.663	-95.557	-524.241
1.63	0.953	0.197	-64.118	505.728	-106.338	-530.679
1.779	0.706	0.319	-65.395	524.824	-110.347	-550.809
1.664	0.877	0.368	-73.841	597.995	-125.401	-636.265

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.54	0.659	0.208	-28.071	375.405	-109.848	-404.739
1.681	1.313	0.299	-105.006	719.667	-122.765	-764.89
1.78	0.739	0.317	-77.36	554.817	-102.486	-578.999
1.886	0.793	0.33	-81.45	554.373	-96.476	-574.174
1.437	1.139	0.274	-81.141	602.272	-112.379	-649
2.008	0.674	0.252	-79.259	547.907	-99.329	-559.744
1.711	0.723	0.398	-74.453	564.885	-110.727	-595.514
1.778	0.931	0.291	-65.447	521.998	-110.856	-546.636
1.627	1.001	0.325	-63.676	498.372	-100.173	-531.715
1.736	0.944	0.362	-80.694	582.035	-106.9	-614.684
1.728	0.67	0.182	-57.508	448.954	-95.813	-461.706
1.92	0.793	0.276	-70.939	531.751	-103.876	-554.952
1.624	0.882	0.263	-66.598	515.916	-105.591	-543.118
1.922	0.808	0.326	-63.837	532.372	-117.394	-555.903
1.798	0.618	0.215	-66.54	518.555	-109.402	-533.445
1.758	0.646	0.277	-63.348	474.016	-95.105	-489.598
1.801	0.714	0.352	-61.002	486.152	-101.381	-510.646
1.912	0.584	0.227	-83.07	577.52	-106.164	-588.441
1.859	0.743	0.3	-89.136	581.563	-97.841	-594.436
1.925	0.661	0.282	-78.394	557.477	-103.086	-576.479
1.712	0.657	0.342	-75.131	551.73	-105.473	-575.715
1.75	0.689	0.267	-58.937	463.073	-96.297	-483.775
1.754	0.898	0.317	-78.091	567.98	-107.528	-594.33
1.735	0.674	0.275	-63.785	499.75	-102.95	-522.582
1.747	0.92	0.257	-81.471	555.874	-95.291	-581.333
1.761	0.792	0.317	-58.626	480.875	-103.805	-506.122
1.762	0.865	0.226	-69.927	526.122	-101.99	-554.407
1.741	0.712	0.247	-73.316	554.38	-112.141	-574.384
1.812	0.791	0.293	-76.893	561.171	-107.452	-584.34
1.852	0.827	0.367	-47.787	418.646	-96.303	-441.796
1.729	0.649	0.177	-63.633	469.665	-92.177	-486.248
1.648	0.788	0.363	-69.957	534.682	-107.619	-562.239
1.731	0.671	0.249	-65.744	487.587	-95.784	-506.117
1.637	1.009	0.282	-46.497	412.023	-94.498	-440.417
1.698	0.653	0.278	-81.623	617.066	-124.411	-641.779
1.63	1.081	0.204	-105.875	698.113	-114.613	-731.753
1.888	1.03	0.479	-130.558	787.698	-107.32	-825.078
1.788	0.991	0.319	-59.042	484.777	-104.699	-511.921
1.629	0.745	0.245	-67.485	530.403	-111.503	-552.985
1.848	0.867	0.354	-55.493	453.401	-96.324	-478.658
1.714	0.756	0.272	-75.508	536.986	-97.744	-561.781
1.933	0.811	0.364	-75.974	557.205	-106.902	-579.818
1.805	1.011	0.326	-84.97	609.537	-112.564	-640.513
1.81	0.711	0.302	-62.116	498.829	-105.068	-522.325
1.606	0.698	0.235	-64.237	510	-109.74	-530.368
1.682	0.696	0.249	-65.672	508.714	-103.126	-533.323
1.587	0.888	0.268	-64.301	527.276	-114.508	-557.713
1.696	0.873	0.362	-43.647	424.347	-102.893	-457.667
1.785	0.589	0.186	-61.326	477.683	-98.965	-494.265
1.806	0.98	0.379	-82.145	632.689	-128.184	-664.268
1.758	0.904	0.346	-60.843	481.992	-100.827	-506.472
1.622	0.786	0.305	-76.583	597.806	-124.626	-625.849
1.607	0.862	0.233	-71.369	537.596	-106.293	-564.76
1.761	0.909	0.226	-80.239	596.473	-119.822	-616.945

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.615	0.661	0.187	-51.542	421.997	-90.498	-443.962
1.568	0.776	0.274	-60.361	490.547	-105.899	-516.283
1.577	0.861	0.298	-56.992	487.714	-110.108	-516.238
1.838	0.709	0.278	-69.332	516.48	-100.919	-537.274
1.86	0.656	0.309	-71.026	495.611	-89.676	-512.437
1.755	0.537	0.323	-103.895	641.663	-97.544	-655.118
1.718	0.985	0.403	-79.741	594.522	-113.984	-630.591
1.92	0.837	0.341	-66.983	524.129	-107.488	-549.109
1.559	0.479	0.286	-57.114	470.676	-102.369	-494.182
1.755	0.88	0.308	-78.639	576.96	-111.222	-602.148
1.521	0.966	0.181	-65.069	520.346	-109.275	-552.774
1.629	1.001	0.293	-73.846	558.725	-111.257	-589.672
1.741	0.85	0.3	-61.661	500.34	-107.884	-523.777
1.641	1.079	0.311	-84.487	607.231	-110.924	-644.217
1.608	0.714	0.204	-68.376	518.288	-104.672	-539.979
1.779	0.583	0.293	-71.812	520.2	-98.369	-538.31
1.644	0.994	0.272	-71.565	570.244	-119.37	-605.356
1.885	0.915	0.298	-59.814	444.201	-86.861	-462.479
1.871	0.929	0.289	-92.764	659.397	-122.838	-684.407
1.758	0.599	0.204	-57.185	458.355	-96.726	-478.202
1.873	0.675	0.362	-85.589	596.783	-107.916	-616.987
1.637	0.891	0.266	-60.731	478.913	-97.854	-508.009
1.737	0.656	0.316	-70.534	548.695	-115.095	-568.814
1.825	0.832	0.273	-80.756	590.078	-113.51	-612.233
1.768	0.767	0.39	-64.069	512.981	-105.575	-544.699
1.672	1.169	0.243	-90.443	657.199	-121.2	-698.826
1.737	0.92	0.368	-77.612	610.596	-122.815	-652.384
1.51	0.865	0.226	-71.628	531.636	-104.28	-558.783
1.737	0.78	0.326	-64.997	518.756	-108.006	-547.614
1.592	0.763	0.243	-56.1	471.261	-106.449	-493.688
1.751	0.785	0.237	-49.339	424.915	-96.086	-446.937
1.641	0.72	0.395	-50.532	451.817	-102.637	-483.896
1.555	0.75	0.305	-65.418	508.281	-104.139	-535.244
1.585	0.518	0.248	-65.376	490.388	-97.32	-510.14
1.701	0.967	0.334	-49.77	446.073	-102.218	-478.807
1.777	0.739	0.289	-53.413	482.439	-114.58	-506.073
1.57	0.824	0.315	-56.579	479.589	-107.818	-505.916
1.644	1.058	0.365	-89.868	684.573	-136.662	-724.284
1.734	0.713	0.288	-67.918	532.562	-111.971	-553.561
1.959	0.788	0.419	-104.635	648.296	-95.33	-670.653
1.563	0.548	0.18	-72.705	549.914	-113.261	-566.424
1.576	0.797	0.278	-80.082	605.017	-119.361	-637.621
1.6	0.878	0.294	-51.674	457.674	-103.351	-492.202
1.905	0.562	0.241	-71.741	541.322	-109.739	-554.702
1.686	0.687	0.262	-71.595	540.872	-108.791	-562.321
1.691	1.005	0.266	-66.992	561.859	-125.613	-591.127
1.678	0.783	0.263	-57.331	484.157	-108.016	-508.864
1.77	0.923	0.318	-81.913	641.91	-132.463	-674.973
1.652	0.942	0.276	-68.53	537.478	-110.156	-568.453
1.689	0.858	0.236	-61.028	489.127	-103.033	-516.279
1.827	0.813	0.288	-74.32	588.045	-122.174	-616.056
1.775	0.838	0.275	-60.565	487.202	-103.39	-510.689
1.546	1.125	0.308	-75.823	606.304	-123.699	-653.715
1.601	1.29	0.31	-73.521	542.43	-99.475	-587.439

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.652	0.878	0.246	-60.717	469.319	-96.015	-492.053
1.753	0.911	0.348	-62.865	480.48	-95.752	-506.643
1.736	0.976	0.363	-78.08	598.829	-119.356	-633.626
1.783	0.789	0.318	-62.691	500.769	-105.419	-525.805
1.874	0.77	0.331	-95.292	653.491	-116.707	-673.78
1.743	0.949	0.359	-74.833	582.909	-119.016	-615.645
1.742	0.697	0.299	-50.237	412.898	-89.934	-432.167
1.813	0.874	0.316	-66.269	498.455	-99.6	-518.967
1.64	0.789	0.274	-59.213	516.604	-116.217	-551.728
1.665	0.745	0.303	-65.656	523.554	-112.162	-547.404
1.769	0.836	0.372	-75.146	562.53	-107.808	-594.752
1.821	0.663	0.45	-69.491	518.096	-98.799	-545.086
1.571	0.838	0.282	-57.822	480.873	-104.091	-511.774
1.595	0.756	0.346	-55.306	498.151	-116.013	-530.216
1.822	0.951	0.377	-55.288	448.514	-95.137	-475.215
1.854	0.799	0.284	-70.502	552.694	-114.39	-576.391
1.894	1.107	0.413	-79	602.374	-116.947	-642.209
1.809	0.813	0.274	-62.067	492.108	-103.379	-513.374
1.596	1.121	0.274	-71.095	544.347	-107.679	-580.704
1.578	0.881	0.241	-71.968	551.404	-109.2	-584.211
1.636	0.909	0.241	-78.798	581.901	-111.45	-612.386
1.791	0.822	0.314	-70.811	537.916	-107.146	-563.358
1.696	0.753	0.348	-66.375	519.162	-107.787	-543.089
1.706	0.866	0.347	-47.053	393.152	-86.672	-415.433
1.768	0.802	0.214	-61.05	499.815	-107.407	-525.025
1.714	0.745	0.257	-81.237	566.895	-103.339	-586.899
1.646	0.799	0.239	-61.001	473.578	-98.023	-494.392
1.725	0.514	0.315	-70.963	540.284	-110.381	-558.432
1.807	0.751	0.344	-78.934	554.249	-100.916	-575.871
1.908	0.705	0.318	-64.969	495.337	-99.097	-514.451
1.916	0.942	0.347	-74.295	560.363	-111.297	-585.732
1.668	0.804	0.341	-79.221	561.089	-101.408	-589.167
1.551	1.267	0.375	-73.759	541.299	-100.721	-581.463
1.816	0.784	0.305	-57.98	443.18	-89.486	-462.108
1.831	1.195	0.285	-71.269	523.264	-99.253	-552.101
1.837	0.738	0.255	-71.44	538.995	-108.607	-558.056
1.774	0.782	0.398	-73.381	570	-116.62	-598.616
1.677	0.928	0.35	-67.344	531.918	-110.748	-561.591
1.771	0.911	0.4	-64.902	507.291	-102.746	-537.041
1.886	0.76	0.326	-50.543	428.889	-95.983	-448.942
1.905	0.892	0.309	-82.437	579.914	-106.333	-600.585
1.702	0.661	0.311	-64.758	516.166	-110.031	-537.585
1.708	0.66	0.263	-45.298	478.62	-126.182	-505.87
1.666	0.787	0.355	-70.449	501.876	-91.891	-527.052
1.646	0.543	0.278	-38.688	361.926	-87.264	-381.852
1.565	1.114	0.287	-62.56	484.419	-97.234	-516.037
1.683	0.823	0.277	-67.446	490.33	-92.508	-513.206
1.807	0.948	0.306	-67.455	534.214	-112.069	-560.266
1.926	0.829	0.289	-67.985	535.077	-110.609	-559.287
1.711	0.775	0.317	-60.592	481.112	-101.222	-503.472
1.536	0.629	0.29	-44.357	412.816	-98.335	-440.015
1.559	0.97	0.214	-80.347	603.875	-118.492	-637.307
1.807	0.712	0.323	-75.053	583.369	-119.399	-609.034
1.706	0.88	0.325	-60.516	483.651	-99.681	-513.68

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.624	0.826	0.27	-62.412	477.909	-96.721	-500.913
1.78	0.881	0.249	-60.791	495.797	-106.774	-520.719
1.608	0.753	0.283	-90.02	684.118	-137.716	-716.351
1.654	0.508	0.26	-63.533	505.724	-109.928	-521.698
1.853	1.036	0.462	-83.351	557.823	-93.378	-585.112
1.785	0.824	0.259	-65.228	531.854	-115.273	-556.584
1.648	0.54	0.245	-79.444	574.812	-110.708	-593.264
1.389	1.219	0.322	-67.799	549.64	-110.325	-604.459
1.727	0.949	0.346	-56.458	448.553	-93.51	-473.944
1.546	0.703	0.201	-62.98	492.314	-100.533	-519.122
1.831	0.763	0.301	-74.851	534.195	-98.721	-555.697
1.683	0.763	0.244	-55.898	457.981	-99.403	-479.963
1.82	0.822	0.217	-53.68	438.47	-94.636	-459.013
1.638	0.758	0.321	-38.987	370.285	-90.213	-393.161
1.535	0.781	0.256	-48.118	422.937	-96.877	-449.827
1.543	1.177	0.287	-79.313	611.401	-120.022	-658.062
1.476	1.117	0.309	-65.485	494.793	-95.091	-532.458
1.669	0.881	0.192	-69.115	524.672	-103.191	-552.796
1.651	0.808	0.21	-82.914	623.659	-124.522	-650.221
1.771	0.802	0.238	-80.052	542.921	-96.868	-557.042
1.697	1.017	0.291	-59.666	470.6	-97.03	-497.767
1.579	0.497	0.261	-48.111	428.161	-99.779	-451.226
1.781	0.786	0.313	-72.153	532.78	-103.384	-554.722
1.674	0.959	0.259	-77.348	558.083	-104.656	-585.486
1.708	0.811	0.365	-97.919	636.362	-102.057	-663.623
1.883	0.974	0.299	-90.313	615.69	-103.763	-647.809
1.727	0.831	0.339	-61.65	495.671	-106.082	-520.934
1.624	0.868	0.32	-71.949	590.391	-129.562	-621.051
1.635	0.642	0.255	-60.488	505.083	-112.246	-527.773
1.696	0.814	0.202	-60.301	467.34	-97.398	-486.792
1.949	0.788	0.324	-68.462	516.147	-102.311	-536.827
1.658	0.846	0.299	-68.522	535.017	-111.22	-560.691
1.76	0.803	0.391	-67.628	507.745	-98.513	-535.422
1.762	0.721	0.255	-64.051	462.143	-88.333	-477.861
1.591	0.699	0.317	-58.596	475.28	-100.208	-503.922
1.74	0.956	0.228	-57.078	449.23	-93.195	-471.539
1.697	0.94	0.369	-74.207	600.467	-127.529	-636.898
1.763	0.62	0.299	-58.247	457.569	-95.299	-476.517
1.848	0.675	0.325	-74.545	538.018	-99.619	-561.801
1.756	0.996	0.359	-72.922	530.223	-101.004	-555.562
1.686	0.795	0.306	-75.621	572.522	-115.135	-597.584
1.762	0.776	0.197	-79.405	588.025	-114.855	-610.63
1.757	0.765	0.28	-56.495	478.082	-107.506	-500.873
1.443	0.625	0.23	-34.438	373.923	-100.377	-398.262
1.854	0.668	0.318	-108.606	679.496	-104.837	-696.743
1.897	0.912	0.354	-92.581	601.054	-96.977	-624.164
1.821	0.905	0.258	-96.189	649.948	-110.285	-677.327
1.831	0.84	0.343	-75.435	572.512	-113.469	-601.416
1.85	0.553	0.222	-87.509	612.63	-112.48	-628.829
1.715	0.848	0.326	-62.118	483.011	-100.168	-505.875
1.624	0.723	0.31	-76.859	571.504	-111.416	-598.966
1.78	0.789	0.267	-56.816	449.406	-94.26	-469.463
1.81	0.609	0.226	-64.422	526.606	-115.076	-545.544
1.525	1.055	0.301	-76.342	563.24	-106.099	-600.498

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.719	1.02	0.375	-65.957	516.992	-103.888	-553.789
1.76	0.604	0.342	-64.182	529.047	-114.851	-554.118
1.754	1.011	0.188	-88.366	628.009	-114.221	-660.484
1.733	0.883	0.258	-64.964	611.597	-148.107	-649.798
1.615	0.787	0.252	-66.174	528.733	-112.523	-555.093
1.658	0.959	0.378	-74.346	573.799	-115.686	-607.467
1.77	0.943	0.306	-41.55	340.628	-70.919	-363.919
1.831	0.752	0.262	-73.246	551.863	-112.493	-568.558
1.798	0.855	0.336	-69.867	537.823	-108.976	-563.932
1.653	0.488	0.318	-67.524	525.318	-108.687	-546.558
1.674	0.658	0.28	-70.63	543.783	-110.648	-567.735
1.878	0.696	0.319	-106.174	634.958	-91.574	-645.461
1.822	0.924	0.304	-69.008	546.605	-115.008	-572.009
1.969	0.464	0.206	-51.479	423.463	-93.025	-435.275
1.695	0.65	0.265	-75.906	557.884	-107.147	-580.848
1.622	0.835	0.28	-62.129	518.413	-113.808	-547.821
1.868	0.851	0.187	-68.856	538.026	-113.774	-554.656
1.976	0.549	0.321	-62.287	524.05	-115.627	-545.99
1.87	0.905	0.194	-49.526	417.429	-94.659	-434.837
1.748	0.789	0.286	-71.711	537.331	-106.311	-560.184
1.91	0.767	0.343	-85.671	563.643	-94.51	-579.57
1.735	0.864	0.34	-55.96	429.263	-84.911	-453.689
1.644	0.756	0.274	-67.949	507.308	-97.677	-534.447
1.776	0.751	0.285	-70.294	533.213	-105.179	-558.857
1.78	0.842	0.31	-73.324	576.912	-120.351	-603.474
1.885	0.738	0.354	-76.359	566.818	-108.537	-593.529
1.647	0.667	0.141	-70.14	519.971	-102.73	-538.938
1.554	0.683	0.23	-88.437	618.713	-112.445	-643.539
1.666	0.759	0.266	-48.313	450.734	-107.41	-478.734
1.7	0.967	0.253	-83.177	562.263	-96.171	-588.233
1.61	0.596	0.295	-73.121	550.368	-109.813	-572.724
1.659	0.688	0.299	-66.734	502.331	-99.176	-524.749
1.838	0.818	0.39	-60.864	452.817	-85.774	-478.664
1.655	0.899	0.288	-66.73	533.596	-111.92	-564.721
1.714	0.735	0.255	-56.908	478.969	-107.108	-501.304
1.649	0.806	0.377	-86.206	590.305	-103.575	-615.408
1.753	0.572	0.248	-70.99	527.569	-105.086	-543.278
1.549	0.457	0.278	-51.56	449.429	-102.364	-473.213
1.757	0.544	0.237	-68.254	504.626	-99.813	-519.042
1.837	0.703	0.252	-44.959	430.226	-106.415	-451.033
1.786	0.612	0.257	-71.039	491.114	-89.584	-503.434
1.817	0.826	0.363	-122.013	752.966	-114.992	-771.024
2.026	0.782	0.323	-81.993	583.389	-106.499	-605.23
1.655	1.075	0.332	-107.491	690.773	-107.466	-725.592
1.589	0.925	0.231	-80.531	598.45	-115.956	-630.279
1.72	0.955	0.33	-69.293	538.618	-108.926	-569.186
1.746	0.999	0.367	-73.187	556.246	-109.476	-587.828
1.557	0.749	0.281	-50.645	462.363	-110.718	-489.431
1.629	1.047	0.34	-74.339	523.83	-93.03	-555.531
1.868	1.007	0.294	-70.186	518.638	-99.133	-545.289
1.89	0.844	0.362	-58.566	479.098	-101.509	-507.61
1.592	0.756	0.242	-51.519	423.82	-92.254	-445.55
2.033	0.651	0.118	-71.118	520.112	-103.047	-529.013
1.837	0.953	0.225	-57.238	445.066	-91.154	-466.273

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.649	0.777	0.146	-90.74	686.958	-139.203	-713.759
1.859	0.832	0.36	-79.97	601.16	-118.07	-629.464
1.611	0.717	0.183	-48.504	448.247	-108.448	-470.309
1.669	0.751	0.29	-58.921	481.227	-103.801	-505.983
1.901	0.865	0.322	-88.108	656.922	-126.724	-689.284
1.726	0.692	0.218	-73.443	529.679	-100.59	-548.638
1.668	0.643	0.311	-41.599	399.086	-97.206	-423.948
1.79	0.755	0.319	-71.423	541.965	-108.32	-565.519
1.847	0.879	0.349	-61.008	509.677	-112.482	-535.537
1.675	0.77	0.249	-62.693	477.882	-95.36	-500.982
1.64	0.755	0.265	-61.511	471.85	-97.69	-489.81
1.658	0.88	0.271	-63.039	495.189	-103.564	-518.779
1.811	0.739	0.212	-62.444	487.363	-101.122	-505.402
1.786	0.953	0.359	-75.805	606.489	-127.852	-639.893
1.757	0.914	0.242	-70.774	531.407	-105.328	-555.865
1.744	0.686	0.375	-84.733	604.42	-110.991	-631.378
1.728	0.639	0.249	-70.284	539.46	-108.305	-563.169
1.538	1.109	0.212	-74.957	548.256	-102.646	-583.538
1.74	0.719	0.245	-59.551	473.477	-100.826	-492.571
1.489	1.315	0.311	-88.015	596.741	-98	-640.77
1.751	0.711	0.315	-54.393	440.868	-94.344	-461.336
1.587	0.826	0.26	-52.99	439.104	-95.089	-466.36
1.564	0.63	0.231	-45.711	440.771	-109.515	-465.286
1.722	0.758	0.309	-67.225	571.327	-128.266	-599.935
1.739	0.751	0.199	-73.453	538.934	-105.417	-557.547
1.715	0.895	0.322	-81.328	607.805	-118.631	-638.448
1.64	0.856	0.25	-67.438	508.171	-100.046	-534.522
1.902	0.565	0.244	-77.365	541.38	-100.589	-552.373
1.808	0.871	0.321	-56.487	466.793	-100.144	-494.271
1.637	0.99	0.256	-65.46	513.869	-104.194	-546.815
1.627	0.628	0.291	-49.06	433.377	-100.069	-457.228
1.562	0.716	0.302	-70.917	539.671	-107.648	-567.065
1.734	0.574	0.182	-67.918	520.894	-106.299	-539.391
1.661	0.746	0.253	-61.565	492.624	-106.427	-513.735
1.651	0.715	0.268	-44.9	449.265	-112.412	-479.771
1.501	0.839	0.297	-52.294	458.27	-103.256	-491.663
1.65	0.807	0.32	-61.485	475.62	-94.007	-505.489
1.613	0.274	0.206	-65.983	522.961	-112.1	-535.95
1.778	0.878	0.352	-67.496	546.591	-118.552	-571.836
1.66	1.078	0.287	-87.542	621.319	-112.072	-656.847
1.671	0.817	0.316	-76.988	537.469	-95.024	-564.34
1.902	0.748	0.282	-63.238	512.904	-112.032	-530.082
1.696	0.898	0.373	-71.926	561.709	-114.751	-594.362
1.685	0.72	0.286	-70.616	511.166	-94.892	-537.273
1.735	0.531	0.253	-71.291	541.129	-110.35	-557.878
1.674	0.568	0.184	-59.116	458.372	-96.672	-470.741
1.583	0.934	0.333	-73.295	558.674	-110.901	-591.942
1.718	0.759	0.25	-44.155	414.346	-100.242	-437.673
2.033	0.794	0.279	-126.842	781.414	-120.237	-791.785
1.832	0.795	0.351	-70.334	495.339	-90.265	-515.454
1.681	0.627	0.251	-55.448	426.115	-86.606	-444.638
2.043	0.705	0.299	-122.497	761.809	-118.824	-773.049
1.571	0.853	0.269	-63.956	504.852	-105.537	-533.28
1.665	0.555	0.272	-77.209	555.787	-106.455	-572.736

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.72	0.937	0.257	-43.851	385.008	-89.338	-407.418
1.634	1.003	0.185	-127.288	851.812	-143.866	-890.744
1.872	0.83	0.306	-61.232	463.453	-94.34	-480.138
1.713	0.678	0.243	-54.098	461.849	-102.887	-485.342
1.88	0.547	0.264	-61.879	506.621	-109.947	-526.264
1.937	0.776	0.306	-65.119	478.505	-91.213	-498.518
1.739	0.638	0.32	-89.657	666.732	-131.849	-690.996
1.77	0.9	0.353	-66.977	539.283	-112.909	-570.313
1.839	0.886	0.364	-70.37	516.026	-97.289	-542.264
1.719	0.764	0.303	-69.111	537.214	-108.682	-565.111
1.747	0.989	0.316	-72.662	534.863	-102.612	-562.25
1.664	0.614	0.247	-63.799	480.302	-96.78	-496.732
1.701	0.548	0.191	-51.068	398.686	-84.469	-410.643
1.692	0.946	0.294	-63.264	500.366	-105.015	-526.227
1.698	0.79	0.257	-70.278	550.843	-115.446	-574.073
1.475	0.951	0.19	-80.475	613.578	-123.135	-648.495
1.749	0.651	0.335	-46.374	402.498	-91.628	-423.572
1.654	1.16	0.284	-68.76	549.669	-115.356	-584.783
1.661	0.657	0.22	-40.554	416.247	-107.138	-440.846
1.756	0.719	0.279	-58.426	474.029	-102.118	-495.272
1.668	0.722	0.323	-68.004	509.648	-98.693	-536.608
1.626	0.772	0.284	-49.723	417.957	-92.167	-441.982
1.743	0.839	0.281	-47.666	489.364	-127.31	-518.542
1.568	0.719	0.205	-72.774	561.673	-112.874	-591.61
1.669	0.971	0.216	-84.279	570.114	-96.721	-597.614
1.771	0.865	0.317	-54.512	441.045	-93.175	-465.948
1.805	0.84	0.301	-100.768	693.977	-122.709	-721.006
1.696	1.103	0.341	-166.685	987.162	-129.973	-1032.924
1.805	0.458	0.208	-61.297	516.26	-115.683	-533.919
1.678	1.096	0.385	-93.102	615.735	-97.51	-654.605
1.803	1.135	0.31	-69.474	508.605	-95.952	-537.209
1.71	0.711	0.266	-75.252	557.212	-109.253	-579.298
1.74	0.858	0.317	-52.268	454.175	-103.679	-479.73
1.765	0.786	0.253	-67.742	510.237	-101.012	-532.429
1.681	0.799	0.304	-57.646	441.841	-87.84	-465.017
1.485	1.023	0.233	-67.567	530.477	-107.516	-567.049
1.633	0.849	0.32	-56.864	498.42	-112.734	-532.114
1.677	0.599	0.24	-64.986	493.878	-99.931	-512.767
1.69	0.843	0.302	-68.771	530.338	-108.114	-556.582
1.702	0.818	0.259	-50.816	437.875	-99.107	-462.574
1.637	0.635	0.241	-51.24	419.811	-89.713	-442.754
1.528	0.92	0.332	-57.848	507.8	-114.47	-545.695
1.747	0.715	0.177	-64.119	484.892	-98.239	-500.938
1.676	0.532	0.304	-62.548	498.999	-107.309	-516.709
1.791	0.635	0.288	-89.875	576.965	-93.694	-590.97
1.728	0.831	0.315	-59.24	494.122	-108.211	-521.005
1.689	1.102	0.411	-72.275	571.952	-117.016	-610.753
1.917	0.717	0.313	-84.585	601.336	-113.724	-617.414
1.578	0.715	0.248	-58.122	508.227	-118.607	-533.289
1.697	0.972	0.295	-76.234	612.285	-128.334	-648.727
1.791	0.868	0.293	-62.606	476.017	-94.788	-499.142
1.884	0.934	0.367	-88.298	646.044	-124.868	-671.994
1.582	0.651	0.196	-41.871	437.575	-114.675	-462.715
1.985	0.414	0.146	-82.409	577.852	-108.419	-583.786

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.686	0.949	0.304	-57.693	461.789	-96.999	-489.092
1.626	0.778	0.352	-96.604	687.774	-125.95	-721.375
1.833	0.866	0.352	-76.111	584.273	-116.388	-615.649
1.494	1.062	0.361	-48.261	425.249	-95.317	-461.693
1.706	0.542	0.213	-59	472.359	-102.353	-487.398
1.566	0.964	0.181	-76.575	562.03	-108.506	-588.742
1.731	0.799	0.407	-85.644	673.397	-137.353	-713.495
1.723	0.796	0.333	-42.309	383.134	-90.984	-403.83
1.613	1.094	0.277	-68.215	519.33	-101.086	-555.998
1.572	0.982	0.208	-62.692	485.147	-98.842	-512.423
1.764	0.658	0.307	-101.536	697.408	-125.598	-718.004
1.74	0.63	0.259	-70.405	538.064	-108.826	-559.137
1.442	0.825	0.269	-63.518	504.184	-104.325	-536.837
1.886	0.789	0.255	-90.828	640.891	-117.547	-663.541
1.886	1.096	0.408	-92.013	624.767	-106.437	-655.788
1.745	0.63	0.282	-75.551	550.561	-106.881	-567.621
1.769	0.697	0.305	-77.311	549.478	-103.048	-567.304
1.664	0.752	0.213	-64.583	530.601	-117.757	-552.38
1.763	0.709	0.21	-68.748	521.292	-106.781	-536.579
1.876	0.928	0.377	-79.163	593.728	-113.842	-627.988
1.692	0.793	0.331	-65.246	499.605	-101.232	-522.672
1.739	0.886	0.277	-76.837	571.863	-112.226	-595.635
1.747	0.965	0.373	-76.752	597.399	-121.227	-630.533
1.531	0.964	0.295	-63.356	489.939	-98.06	-522.437
1.555	0.691	0.261	-69.632	512.219	-99.378	-534.193
1.864	0.844	0.237	-61.249	451.658	-86.19	-472.51
1.621	0.402	0.295	-67.798	503.782	-96.391	-527.265
1.66	1.038	0.349	-71.867	543.789	-101.459	-587.527
1.834	0.793	0.286	-48.871	433.94	-99	-458.757
1.842	0.89	0.338	-124.048	776.6	-120.681	-798.073
1.788	0.627	0.266	-76.269	569.092	-113.031	-587.683
1.652	0.764	0.326	-54.872	452.237	-99.499	-473.732
1.943	0.624	0.25	-58.617	461.338	-96.388	-477.503
1.732	0.468	0.332	-69.086	516.053	-103.842	-530.855
1.712	0.787	0.338	-53.498	436.861	-93.79	-460.367
1.897	0.883	0.314	-80.952	555.171	-98.133	-574.529
1.821	0.809	0.353	-57.773	469.138	-98.29	-496.514
1.793	0.814	0.288	-63.245	483.413	-95.759	-507.99
1.833	0.786	0.262	-74.48	553.95	-108.756	-575.657
1.619	0.885	0.245	-61.305	490.341	-103.539	-517.113
1.4	0.821	0.235	-45.08	415.514	-98.001	-447.168
1.812	0.84	0.364	-76.263	563.813	-109.005	-589.929
1.601	0.561	0.279	-36.564	390.87	-101.595	-417.243
1.642	0.934	0.259	-75.603	547.738	-105.112	-570.259
1.743	0.755	0.335	-65.859	497.042	-99.568	-517.96
1.69	0.624	0.253	-67.721	511.694	-102.228	-531.814
1.631	0.707	0.271	-69.957	518.698	-101.208	-541
1.561	0.611	0.313	-60.442	491.718	-105.477	-517.997
1.58	0.718	0.341	-62.782	501.238	-103.803	-531.53
1.861	0.566	0.281	-65.747	525.982	-111.14	-547.244
1.805	0.717	0.248	-54.632	417.342	-85.462	-432.425
1.633	0.989	0.22	-61.251	481.275	-99.417	-508.392
1.675	0.868	0.302	-53.384	444.477	-97.908	-468.183
1.627	0.745	0.293	-63.617	490.577	-100.211	-513.777

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.798	0.96	0.422	-75.28	555.688	-105.74	-586.497
1.583	0.626	0.296	-58.019	485.243	-106.027	-512.548
1.613	0.627	0.234	-67.16	503.576	-100.034	-524.642
1.707	0.889	0.347	-65.943	544.747	-117.858	-576.632
2.107	0.795	0.315	-128.221	754.828	-107.402	-760.229
1.492	0.891	0.219	-57.234	475.355	-102.986	-505.657
1.684	0.887	0.303	-60.546	495.345	-106.028	-524.97
1.731	0.868	0.278	-62.336	500.13	-106.429	-524.406
1.716	0.777	0.295	-65.102	513.96	-107.767	-537.791
1.546	0.952	0.279	-57.481	464.622	-96.449	-498.498
1.801	0.769	0.296	-72.271	523.038	-99.913	-542.774
1.577	0.718	0.258	-47.934	411.965	-91.407	-437.725
1.696	1.006	0.401	-69.59	546.196	-111.41	-581.094
1.669	0.605	0.315	-76.512	562.773	-108.817	-585.531
1.683	0.718	0.231	-58.006	487.783	-110.707	-507.228
1.526	0.951	0.28	-53.208	449.004	-97.357	-481.638
1.837	0.65	0.232	-80.906	579.518	-110.081	-596.692
1.801	0.954	0.21	-56.053	453.408	-98.061	-474.249
1.548	0.758	0.24	-50.67	456.184	-106.893	-484.921
1.651	0.764	0.29	-43.103	399.49	-96.039	-422.911
1.82	0.988	0.304	-52.687	460.103	-105.282	-486.813
1.584	0.617	0.274	-45.581	402.204	-92.43	-425.472
1.631	0.676	0.251	-76.025	570.53	-114.634	-591.313
1.692	0.799	0.239	-42.133	366.865	-84.929	-385.504
1.623	0.787	0.301	-57.452	451.08	-92.853	-475.726
1.78	0.831	0.319	-88.704	606.43	-107.141	-628.327
1.781	0.726	0.349	-77.852	550.314	-99.848	-573.639
1.486	0.955	0.268	-59.925	496.893	-107.58	-530.795
1.775	0.892	0.325	-66.43	500.604	-100.956	-520.565
1.551	0.905	0.321	-62.928	507.086	-105.395	-542.012
1.808	0.716	0.297	-65.433	492.815	-97.915	-512.739
1.469	0.613	0.325	-53.925	449.934	-99.002	-474.723
1.696	0.803	0.25	-83.044	577.21	-102.025	-604.312
1.852	0.566	0.303	-68.486	513.452	-101.479	-531.37
1.827	0.948	0.269	-54.643	459.37	-102.712	-482.015
1.828	0.66	0.225	-77.026	543.569	-101.495	-557.934
1.622	0.937	0.233	-64.808	511.449	-106.701	-539.011
1.763	0.937	0.339	-70.381	542.898	-108.752	-573.231
1.637	0.941	0.257	-58.624	475.814	-101.564	-503.341
1.81	0.935	0.356	-79.574	582.893	-110.626	-611.047
1.592	0.642	0.27	-57.236	519.628	-118.831	-557.745
1.78	0.839	0.298	-64.603	505.63	-105.177	-528.256
1.622	0.899	0.263	-55.831	452.385	-98.242	-475.193
1.658	0.762	0.27	-64.653	500.075	-104.216	-519.88
1.758	0.743	0.276	-69.064	527.776	-106.661	-549.781
1.824	0.706	0.266	-58.378	448.015	-91.176	-465.971
1.633	0.831	0.184	-87.594	644.918	-121.578	-680.736
1.371	0.748	0.229	-74.947	565.963	-111.758	-597.689
1.491	0.7	0.212	-53.851	427.405	-89.08	-450.572
1.689	0.993	0.241	-65.412	491.97	-98.176	-515.557
1.799	0.765	0.388	-80.862	590.338	-110.814	-620.403
1.571	0.737	0.287	-55.315	485.017	-111.894	-511.778
1.688	0.738	0.201	-61.813	482.768	-99.649	-504.155
1.748	0.659	0.246	-55.785	439.433	-93.428	-454.598

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.761	0.911	0.329	-67.119	528.378	-109.592	-555.269
1.771	0.838	0.34	-70.289	529.102	-105.284	-553.26
1.542	0.961	0.259	-87.437	630.837	-117.969	-665.295
1.763	0.59	0.252	-69.756	488.668	-89.538	-502.749
1.721	0.238	0.242	-94.167	663.477	-122.538	-678.64
1.684	0.914	0.272	-74.252	516.711	-91.975	-539.908
1.484	0.858	0.242	-27.83	366.817	-108.195	-397.433
1.894	0.837	0.322	-58.823	453.932	-91.539	-476.179
1.644	0.78	0.189	-56.419	475.476	-106.718	-498.97
1.624	0.965	0.238	-56.664	461.684	-99.65	-487.621
1.712	0.91	0.329	-85.324	618.954	-117.006	-648.918
1.757	0.768	0.309	-69.69	510.08	-98.337	-530.452
1.675	1.222	0.422	-58.301	467.115	-97.07	-500.359
1.878	0.778	0.235	-65.288	521.878	-112.443	-540.196
1.676	0.848	0.311	-60.176	479.574	-99.862	-506.984
1.676	0.642	0.285	-72.849	528.073	-101.052	-546.831
1.787	0.864	0.275	-63.593	484.192	-97.469	-505.693
1.796	0.584	0.191	-67.034	494.766	-99.236	-505.812
1.899	0.78	0.301	-68.397	523.116	-105.825	-543.615
1.862	0.839	0.374	-74.498	563.463	-112.049	-588.502
1.71	0.896	0.325	-67.137	504.086	-99.105	-529.445
1.633	0.853	0.254	-80.104	586.632	-113.045	-612.783
1.828	1.028	0.293	-47.827	419.72	-96.213	-444.592
1.671	0.644	0.326	-71.732	540.196	-106.368	-565.115
1.848	0.603	0.34	-49.757	444.432	-103.429	-465.898
1.883	0.655	0.296	-59.415	470.936	-101.03	-486.032
1.901	0.848	0.264	-64.506	505.953	-105.474	-526.019
1.843	0.783	0.339	-78.646	607.908	-122.144	-638.024
1.826	0.865	0.285	-80.222	586.795	-113.146	-609.666
1.843	0.87	0.322	-62.589	486.372	-98.003	-512.793
1.669	0.706	0.19	-69.427	540.772	-113.388	-560.442
1.715	0.706	0.216	-69.967	521.229	-104.049	-538.549
1.535	0.659	0.311	-88.813	580.97	-96.62	-600.798
1.819	0.614	0.288	-70.1	536.952	-111.25	-552.835
1.578	0.861	0.218	-60.06	466.733	-96.279	-489.788
1.912	0.696	0.323	-84.078	602.416	-111.108	-627.439
1.674	0.877	0.283	-42.123	429.523	-110.878	-456.234
1.691	0.552	0.311	-73.236	533.422	-102.204	-553.687
1.465	0.933	0.241	-67.792	531.442	-107.898	-566.951
1.682	0.573	0.336	-54.155	443.754	-94.412	-468.533
1.614	0.884	0.294	-64.947	544.416	-120.41	-576.306
1.836	0.942	0.367	-79.244	571.009	-107.217	-596.931
1.826	0.736	0.363	-68.6	540.404	-110.884	-568.808
1.841	0.831	0.329	-51.314	443.411	-98.49	-469.943
1.852	0.999	0.339	-73.112	505.244	-88.004	-530.988
1.614	0.586	0.206	-67.862	527.683	-108.935	-548.736
1.925	0.91	0.257	-72.76	525.85	-100.116	-545.171
1.709	0.968	0.211	-63.984	480.044	-94.588	-503.193
1.443	0.931	0.215	-71.531	544.506	-104.688	-584.934
1.549	1.021	0.359	-55.776	440.317	-88.789	-473.272
1.674	0.724	0.324	-49.987	441.635	-101.27	-467.478
1.588	0.704	0.227	-64.264	534.057	-117.773	-561.652
1.709	0.949	0.355	-54.156	436.581	-92.069	-463.936
1.726	0.818	0.314	-76.796	564.19	-108.82	-588.448

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.711	0.904	0.286	-91.076	624.105	-107.633	-655.298
1.875	0.755	0.327	-80.189	595.651	-116.014	-618.651
1.649	0.779	0.203	-45.442	419.508	-99.968	-444.758
1.69	1.054	0.357	-58.7	474.999	-99.962	-506.242
1.764	0.746	0.246	-78.773	556.816	-102.141	-577.379
1.928	0.751	0.346	-59.636	489.179	-104.295	-514.176
1.803	0.578	0.247	-67.174	523.06	-111.756	-535.171
1.678	1.041	0.335	-61.696	491.709	-100.279	-526.707
1.656	0.818	0.276	-71.609	509.431	-93.571	-532.79
1.655	0.835	0.246	-60.687	452.36	-88.846	-474.246
1.828	0.824	0.309	-62.569	479.761	-96.181	-502.565
1.804	0.749	0.279	-58.296	456.655	-94.878	-476.136
1.985	0.766	0.372	-133.63	787.828	-105.659	-809.594
1.562	0.874	0.286	-45.344	419.694	-99.248	-450.138
1.814	0.755	0.358	-79.183	576.245	-107.662	-603.756
1.482	0.486	0.28	-79.549	576.287	-110.602	-597.688
1.749	1.002	0.249	-100.689	620.757	-89.282	-648.132
1.725	0.924	0.306	-70.058	531.415	-106.219	-558.204
1.788	0.795	0.307	-64.878	490.493	-96.083	-515.188
1.793	0.819	0.298	-62.027	516.845	-112.598	-545.491
1.634	0.808	0.317	-44.501	421.546	-101.501	-450.788
1.746	0.728	0.292	-70.343	556.178	-115.549	-583.296
1.639	0.708	0.234	-64.061	516.49	-109.066	-542.814
1.597	0.688	0.214	-82.887	619.091	-123.273	-643.052
1.612	0.613	0.268	-60.222	480.769	-99.723	-506.69
1.69	0.847	0.238	-80.567	611.432	-123.002	-637.467
1.738	0.687	0.191	-89.38	625.431	-113.605	-647.675
1.797	0.991	0.259	-68.388	530.281	-107.761	-558.201
1.695	0.952	0.255	-71.795	549.595	-108.417	-583.27
1.658	0.715	0.314	-65.527	491.55	-95.094	-518.278
1.825	0.868	0.316	-55.558	502.708	-119.254	-529.114
2	0.629	0.145	-60.857	435.819	-84.273	-441.543
1.737	0.977	0.321	-66.044	521.773	-107.492	-552.509
1.442	0.824	0.229	-72.759	533.191	-101.983	-561.54
1.769	1.026	0.374	-77.564	553.664	-101.414	-583.444
1.838	0.864	0.348	-55.233	468.651	-105.653	-491.493
1.795	0.894	0.315	-51.192	431.576	-95.156	-454.115
1.853	0.893	0.378	-84.284	586.764	-106.289	-609.431
1.826	0.786	0.244	-64.061	478.862	-95.888	-494.003
1.769	0.795	0.307	-66.652	525.945	-108.755	-553.409
1.812	0.807	0.325	-78.27	573.227	-110.186	-596.351
1.726	0.74	0.27	-59.778	455.226	-91.971	-473.449
1.727	1.088	0.448	-87.362	635.215	-116.481	-677.422
1.723	0.882	0.296	-65.582	497.223	-97.372	-525.579
1.782	0.789	0.398	-66.631	518.204	-104.373	-546.524
1.931	0.591	0.351	-76.166	556.087	-107.816	-571.897
1.723	0.924	0.283	-63.486	505.391	-105.834	-533.094
1.83	0.642	0.327	-82.604	604.81	-116.983	-625.459
1.78	0.747	0.274	-64.013	499.895	-104.602	-519.754
1.527	0.896	0.301	-65.786	536.118	-114.525	-569.808
1.409	1.315	0.275	-66.035	533.35	-109.544	-582.234
1.558	1.275	0.355	-69.92	526.524	-100.827	-567.008
1.668	0.831	0.256	-79.244	595.099	-115.53	-626.717
1.705	0.852	0.326	-58.066	471.353	-100.119	-498.266

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.895	1.033	0.364	-55.453	446.031	-92.866	-472.955
1.929	0.626	0.407	-61.472	494.148	-104.148	-516.233
1.513	0.557	0.323	-74.904	555.225	-107.64	-580.849
1.516	0.9	0.241	-54.972	480.174	-111.259	-507.364
1.744	0.789	0.295	-59.232	483.305	-102.237	-510.419
1.724	0.925	0.296	-51.266	440.625	-97.753	-469.575
1.738	0.509	0.3	-48.319	438.329	-102.527	-460.495
1.653	0.631	0.246	-65.866	561.107	-126.226	-588.392
1.617	1.201	0.284	-79.932	605.387	-117.426	-648.329
1.617	0.696	0.269	-74.246	546.237	-106.998	-567.995
1.724	0.839	0.209	-83.799	631.526	-126.333	-658.363
1.672	0.593	0.275	-68.333	523.669	-105.702	-546.54
1.834	0.956	0.305	-60.31	475.253	-96.883	-503.412
1.743	0.795	0.307	-64.565	518.998	-110.636	-543.367
1.582	0.793	0.159	-71.235	560.301	-119.679	-581.852
1.768	0.626	0.292	-71.965	542.078	-108.665	-561.756
1.999	0.729	0.314	-52.079	414.328	-87.13	-430.084
1.557	0.844	0.145	-64.904	510.402	-107.637	-533.47
1.717	0.633	0.23	-51.382	453.529	-105.399	-474.609
1.56	1.12	0.261	-87.154	644.539	-122.991	-685.644
1.828	0.833	0.252	-62.163	460.789	-89.669	-481.347
1.606	0.67	0.263	-46.576	394.881	-88.389	-415.465
1.56	0.871	0.312	-69.208	534.64	-108.071	-565.907
1.668	0.687	0.254	-57.432	460.553	-96.348	-485.437
1.784	1.061	0.349	-53.52	443.822	-96.039	-471.509
1.369	1.042	0.267	-50.85	461.649	-106.061	-503.821
1.718	0.769	0.288	-54.947	457.062	-101.518	-477.783
1.633	0.55	0.318	-63.455	544.758	-122.307	-573.43
1.805	0.825	0.315	-90.92	598.495	-97.844	-622.238
1.74	0.666	0.299	-66.458	488.028	-93.177	-510.468
1.665	1.007	0.292	-70.085	546.879	-111.733	-577.919
1.618	0.601	0.274	-64.644	482.968	-94.854	-504.181
1.66	0.949	0.266	-72.033	558.973	-113.475	-590.811
1.812	0.909	0.446	-58.314	477.438	-99.429	-511.377
1.641	0.817	0.319	-64.725	494.799	-99.165	-520.521
1.849	0.842	0.24	-76.744	570.19	-111.62	-592.604
1.733	0.903	0.268	-63.173	487.833	-97.879	-515.663
1.836	1.072	0.368	-69.555	504.06	-93.388	-532.087
1.658	0.948	0.412	-60.37	461.221	-90.381	-491.134
1.787	0.826	0.348	-79.976	590.08	-111.986	-620.052
1.708	0.857	0.418	-59.059	470.036	-96.894	-498.752
1.762	0.617	0.261	-43.412	423.616	-107.38	-443.262
1.662	0.761	0.313	-51.265	426.268	-93.798	-449.024
1.481	0.85	0.261	-71.099	527.45	-102.048	-556.154
1.847	0.687	0.27	-77.422	572.94	-112.027	-592.552
1.656	0.659	0.309	-58.041	485.764	-109.935	-505.372
1.786	0.864	0.305	-62.272	478.724	-94.711	-505.81
1.73	0.535	0.248	-82.445	604.301	-118.074	-622.315
1.671	0.948	0.245	-85.299	620.813	-116.408	-654.833
1.72	0.673	0.261	-65.131	522.69	-112.846	-543.532
1.838	0.794	0.342	-75.915	564.724	-110.246	-588.953
1.644	0.676	0.226	-64.374	510.285	-107.999	-531.871
1.876	0.822	0.264	-57.948	463.846	-99.971	-481.292
1.656	0.555	0.304	-59.777	470.796	-98.051	-491.968

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.725	0.782	0.246	-45.231	423.031	-102.948	-446.049
1.624	0.671	0.275	-66.218	529.604	-111.805	-555.276
1.579	0.757	0.239	-59.054	455.563	-92.316	-479.897
1.626	0.913	0.291	-42.772	425.816	-108	-453.389
1.65	0.88	0.341	-53.205	483.849	-111.342	-519.593
1.87	0.777	0.371	-61.964	471.193	-92.482	-494.945
1.827	0.618	0.267	-83.288	613.706	-119.943	-634.28
1.726	0.933	0.284	-62.764	504.275	-107.36	-531.114
1.644	0.95	0.346	-72.895	537.494	-101.42	-570.394
1.84	0.865	0.341	-63.78	500.144	-102.589	-524.677
1.43	0.7	0.212	-47.643	445.948	-108.633	-473.337
1.739	0.728	0.189	-60.504	466.433	-95.637	-484.695
1.761	0.702	0.321	-71.333	562.1	-117.63	-586.992
1.809	0.927	0.326	-75.663	556.882	-105.974	-584.554
1.796	0.838	0.28	-63.411	516.207	-112.092	-538.411
1.811	0.867	0.278	-58.655	482.68	-103.919	-508.836
1.682	0.742	0.325	-59.153	471.833	-99.465	-496.222
1.731	0.98	0.337	-61.053	487.572	-102.905	-514.917
1.822	0.872	0.303	-62.868	499.632	-103.023	-527.303
1.675	0.998	0.319	-89.134	608.076	-105.236	-638.33
1.922	0.532	0.308	-70.968	545.356	-112.409	-561.34
1.643	0.912	0.298	-71.77	538.546	-109.606	-558.901
1.693	0.902	0.268	-63.321	501.138	-104.027	-528.861
1.832	0.639	0.267	-87.409	630.718	-120.514	-649.545
1.655	0.7	0.246	-63.884	510.228	-108.512	-532.335
1.873	0.83	0.358	-67.521	523.851	-107.186	-547.856
1.841	0.638	0.264	-70.272	523.743	-104.396	-539.505
1.819	0.55	0.189	-72.947	523.209	-102.464	-531.011
1.746	1.005	0.338	-62.364	488.201	-98.983	-519.268
1.776	0.861	0.279	-90.007	607.921	-105.851	-628.902
2.004	0.878	0.429	-95.244	678.659	-124.28	-708.459
1.773	0.791	0.316	-82.706	586.121	-107.684	-610.422
1.64	0.873	0.287	-72.45	555.233	-113.011	-581.775
1.651	0.829	0.26	-55.235	457.75	-100.142	-483.168
1.895	1.035	0.317	-97.598	634.229	-101.649	-660.783
1.647	0.613	0.266	-63.102	516.052	-113.001	-537.672
1.613	0.587	0.28	-64.343	496.621	-100.227	-520.562
1.709	1.093	0.373	-70.477	542.855	-108.467	-576.735
1.69	0.966	0.319	-68.968	556.718	-118.353	-588.921
1.846	0.779	0.34	-57.253	460.024	-96.348	-485.17
1.749	0.523	0.241	-49.587	404.011	-89.458	-416.209
1.797	0.881	0.364	-64.664	502.736	-101.177	-532.124
1.598	0.911	0.269	-79.66	567.803	-101.813	-602.562
1.724	0.788	0.327	-68.682	516.302	-102.919	-538.158
1.777	0.59	0.321	-67.391	534.475	-111.93	-556.923
1.841	0.78	0.297	-61.789	472.646	-95.004	-494.225
1.813	0.98	0.337	-71.188	529.414	-101.009	-560.803
1.771	0.827	0.323	-57.456	480.359	-105.587	-506.276
1.741	0.663	0.261	-66.795	508.397	-103.424	-526.57
1.664	0.934	0.384	-78.726	593.937	-117.317	-626.396
1.713	1.012	0.392	-68.482	521.364	-102.424	-553.504
1.54	0.508	0.277	-67.157	506.919	-102.496	-526.967
1.682	1.024	0.33	-66.93	503.264	-97.093	-535.559
1.734	0.865	0.257	-51.682	420.539	-90.048	-442.59

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.714	0.449	0.272	-70.082	536.567	-109.053	-555.333
1.661	0.711	0.248	-58.999	498.315	-113.172	-518.568
1.847	1.21	0.3	-82.023	641.086	-129.585	-682.273
1.817	0.946	0.209	-45.838	407.373	-93.703	-431.596
1.958	0.635	0.352	-80.914	567.021	-103.643	-584.162
1.695	0.64	0.259	-56.99	442.37	-91.927	-458.486
1.908	0.874	0.31	-78.282	560.793	-104.073	-582.626
1.774	0.612	0.158	-57.328	479.601	-107.784	-496.432
1.844	0.855	0.333	-69.583	536.55	-108.804	-561.92
1.575	0.794	0.134	-67.311	521.637	-106.952	-546.332
1.867	0.652	0.284	-58.663	438.614	-84.851	-457.401
1.659	0.896	0.327	-60.446	501.591	-108.179	-534.321
1.516	0.987	0.347	-67	520.995	-104.773	-556.011
1.84	0.472	0.202	-93.927	615.636	-104.829	-624.121
1.696	1.085	0.32	-58.104	465.644	-97.677	-495.454
1.654	0.488	0.279	-65.045	515.463	-110.036	-532.46
1.805	0.721	0.16	-56.32	449.885	-96.156	-465.831
1.733	0.678	0.297	-63.324	485.035	-98.438	-506.103
1.632	0.764	0.36	-62.049	519.403	-111.943	-554.166
1.577	0.639	0.253	-91.018	682.331	-136.638	-710.047
1.465	0.83	0.271	-63.683	503.58	-100.817	-539.648
1.529	1.19	0.269	-50.357	465.617	-108.957	-506.121
1.914	0.732	0.273	-47.031	448.746	-110.608	-470.351
1.666	0.576	0.258	-79.362	604.5	-123.477	-626.229
1.736	0.819	0.289	-73.035	564.956	-116.584	-589.554
1.637	0.529	0.27	-70.108	527.752	-105.2	-548.063
1.862	1.041	0.349	-65.662	507.085	-101.381	-535.192
1.649	0.692	0.313	-49.841	461.623	-108.423	-492.726
1.932	0.77	0.356	-59.646	480.219	-98.537	-508.224
1.622	0.944	0.267	-64.909	505.015	-100.674	-538.396
1.615	0.719	0.288	-66.415	515.112	-104.542	-541.679
1.617	0.979	0.375	-64.811	507.605	-103.931	-538.758
1.699	0.735	0.247	-69.623	544.908	-114.217	-567.565
2.104	0.439	0.24	-151.17	889.793	-125.588	-891.761
1.639	0.762	0.28	-39.218	426.095	-111.312	-459.087
1.59	0.961	0.29	-69.066	529.301	-105.571	-561.092
1.833	0.954	0.216	-62.241	471.518	-95.622	-489.073
1.781	1.137	0.317	-71.811	519.247	-94.379	-552.2
1.708	0.982	0.205	-77.298	575.28	-112.87	-601.852
1.762	0.934	0.317	-51.586	460.347	-104.914	-491.861
1.785	0.849	0.372	-59.746	478.448	-99.472	-507.32
1.612	0.676	0.331	-107.854	716.736	-122.623	-739.941
1.699	0.83	0.301	-74.757	584.432	-119.679	-615.363
1.952	0.671	0.259	-67.925	529.312	-107.349	-551.22
1.902	0.765	0.351	-66.852	508.896	-101.693	-531.02
1.725	0.962	0.32	-59.44	475.323	-99.347	-503.434
1.736	0.692	0.202	-54.802	451.465	-99.653	-469.193
1.872	0.607	0.281	-61.778	478.498	-98.121	-496.61
1.744	0.512	0.216	-64.033	484.129	-98.495	-498.008
1.783	0.837	0.285	-80.91	551.404	-97.013	-570.433
1.669	0.835	0.263	-58.438	489.824	-107.552	-518.89
1.784	1.182	0.379	-78.105	583.012	-112.129	-619.832
1.671	1.085	0.332	-69.176	532.288	-107.48	-563.224
1.876	0.63	0.278	-63.631	457.704	-85.365	-475.123

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.838	0.799	0.335	-66.893	524.879	-109.716	-547.403
1.696	0.936	0.383	-68.257	521.586	-105.035	-549.523
1.619	0.951	0.304	-48.225	427.621	-98.784	-455.558
1.729	0.95	0.362	-74.076	540.712	-99.479	-574.686
1.692	0.778	0.24	-62.975	487.425	-101.826	-504.965
1.506	0.652	0.317	-51.449	438.667	-98.367	-464.798
1.743	0.817	0.355	-70.429	553.384	-112.29	-585.64
1.627	0.656	0.271	-46.353	437.417	-104.647	-465.111
1.794	0.567	0.139	-67.431	482.743	-92.561	-493.185
1.499	1.072	0.243	-67.398	559.918	-118.626	-605.982
1.789	0.561	0.232	-77.521	563.454	-108.035	-580.386
1.711	0.972	0.363	-74.233	518.882	-91.553	-547.987
1.606	1.239	0.326	-88.765	680.924	-135.898	-727.409
1.777	0.773	0.282	-45.548	395.328	-91.399	-413.7
1.496	1.071	0.225	-76.264	582.644	-115.531	-621.088
1.802	0.778	0.425	-79.579	599.456	-115.447	-634.123
1.814	0.501	0.265	-76.591	561.548	-107.989	-580.566
1.881	0.672	0.217	-63.466	517.17	-112.342	-535.795
1.62	0.921	0.317	-58.408	466.304	-96.791	-496.304
1.741	0.884	0.301	-70.637	557.11	-115.754	-585.472
1.701	0.937	0.213	-65.817	502.028	-100.355	-526.869
1.503	0.932	0.234	-67.287	554.504	-119.452	-590.93
1.765	0.933	0.313	-54.444	449.028	-94.817	-479.528
1.688	0.705	0.28	-71.254	539.537	-109.465	-559.498
1.816	0.882	0.408	-67.138	513.834	-102.771	-542.048
1.97	0.691	0.289	-86.521	614.048	-114.923	-630.999
1.766	0.564	0.267	-83.142	588.99	-111.146	-603.409
1.556	0.837	0.301	-57.131	463.659	-99.736	-489.736
1.684	0.723	0.297	-52.834	453.487	-99.519	-482.059
1.717	0.886	0.251	-59.963	462.743	-94.409	-486.139
1.865	0.865	0.345	-66.643	513.267	-103.407	-538.401
1.632	1.154	0.321	-86.908	630.515	-115.449	-673.047
1.529	0.539	0.333	-13.277	296.041	-100.86	-326.287
1.742	0.969	0.303	-35.516	402.953	-109.259	-434.525
1.506	0.909	0.277	-70.877	557.043	-113.681	-594.293
1.811	0.937	0.399	-87.134	602.441	-105.678	-630.999
1.67	0.783	0.342	-68.241	500.711	-94.414	-527.657
1.564	0.837	0.194	-58.584	471.365	-100.611	-495.581
1.894	0.914	0.352	-94.826	618.648	-98.565	-645.646
1.932	0.832	0.335	-70.788	534.283	-105.178	-557.443
1.62	1.21	0.34	-82.045	588.823	-104.891	-633.514
1.851	0.907	0.263	-67.693	526.626	-110.092	-548.044
1.768	0.747	0.358	-71.283	631.456	-147.941	-662.479
1.806	0.729	0.319	-57.919	457.047	-96.46	-476.414
1.602	0.599	0.195	-62.829	501.582	-106.862	-523.442
1.777	0.947	0.354	-66.027	516.235	-108.372	-539.016
1.662	0.678	0.304	-73.247	550.673	-109.917	-572.7
1.727	0.975	0.342	-81.317	572.97	-104.607	-599.372
1.78	0.722	0.31	-75.679	564.292	-111.319	-587.311
1.707	0.902	0.381	-81.694	614.48	-118.615	-652.61
1.966	0.941	0.403	-74.415	547.14	-104.078	-573.261
1.626	0.89	0.352	-63.735	534.352	-117.125	-568.891
1.757	0.735	0.231	-54.2	434.636	-92.767	-453.226
1.652	0.597	0.326	-70.779	562.077	-119.816	-584.452

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.939	0.855	0.383	-93.217	629.685	-107.3	-655.047
1.782	0.754	0.294	-75.294	574.602	-116.32	-598.187
1.66	0.558	0.206	-59.559	445.586	-88.574	-461.905
1.435	0.608	0.282	-66.261	504.554	-102.12	-528.174
1.616	0.823	0.284	-62.407	506.725	-110.725	-531.965
1.799	0.917	0.418	-70.752	501.23	-89.945	-528.132
1.644	0.827	0.27	-64.374	502.082	-101.809	-530.916
1.843	1.004	0.232	-67.225	488.466	-92.922	-509.528
2.029	0.685	0.269	-92.499	581.049	-89.995	-593.718
1.741	0.946	0.271	-69.25	522.447	-101.703	-552.512
1.813	0.766	0.284	-50.676	405.813	-84.486	-427.635
1.587	1.04	0.211	-68.912	554.977	-116.153	-591.474
1.764	0.692	0.157	-63.105	517.495	-116.351	-531.065
1.609	0.892	0.165	-80.177	617.82	-124.001	-652.34
1.775	0.751	0.322	-74.827	562.83	-110.267	-590.074
1.751	0.465	0.191	-60.664	448.772	-88.501	-462.109
1.712	0.724	0.303	-49.643	424.778	-94.312	-449.162
1.718	0.622	0.327	-80.541	588.543	-112.277	-613.14
1.75	1.012	0.349	-50.602	408.626	-86.708	-432.501
1.862	1.121	0.435	-86.044	616.195	-113.956	-648.211
1.62	1.039	0.278	-71.5	546.976	-108.683	-581.338
1.704	0.868	0.324	-70.791	519.747	-100.348	-543.637
1.59	0.589	0.231	-55.043	463.736	-102.929	-486.67
1.603	0.679	0.319	-44.92	393.227	-90.378	-415.463
1.751	0.905	0.315	-75.927	570.188	-112.227	-598.176
1.431	1.167	0.316	-60.256	509.614	-109.995	-554.492
1.852	0.823	0.259	-46.853	460.823	-116.395	-485.295
1.602	0.687	0.335	-80.177	613.674	-125.041	-641.551
1.713	0.774	0.183	-60.23	483.685	-103.657	-505.206
1.805	0.747	0.3	-77.745	555.155	-102.438	-578.524
1.766	0.752	0.311	-75.887	597.794	-123.619	-627.692
1.764	0.693	0.295	-52.135	450.127	-102.003	-472.548
1.77	0.595	0.271	-69.91	520.971	-101.479	-541.907
1.634	1.016	0.327	-40.203	404.374	-101.403	-436.071
1.7	1.285	0.29	-102.127	707.877	-121.671	-753.827
1.419	0.929	0.244	-66.423	502.944	-97.303	-538.091
1.34	0.591	0.19	-44.512	434.776	-109.3	-462.64
1.531	0.742	0.246	-75.905	552.909	-105.668	-578.206
1.662	0.903	0.278	-61.514	477.686	-95.795	-507.318
1.726	1.027	0.33	-59.393	480.169	-101.134	-510.105
1.708	0.599	0.266	-67.127	517.362	-105.829	-538.183
1.53	0.608	0.182	-42.722	411.479	-102.215	-434.318
1.792	0.675	0.235	-76.301	570.189	-113.774	-588.019
1.597	0.853	0.257	-63.481	572.34	-135.118	-607.729
1.693	0.949	0.297	-64.05	517.081	-111.432	-543.395
1.731	0.786	0.249	-54.161	440.954	-94.592	-463.549
1.752	0.586	0.214	-67.919	508.417	-100.161	-528.079
1.805	0.84	0.3	-70.588	541.575	-109.634	-565.174
1.623	0.685	0.243	-87.813	641.731	-122.431	-669.39
1.614	0.747	0.327	-71.701	564.468	-118.826	-591.154
1.87	0.972	0.35	-75.317	568.847	-111.666	-598.207
1.726	0.782	0.301	-65.817	506.316	-103.917	-527.862
1.958	0.865	0.455	-120.295	698.589	-90.516	-718.77
1.566	0.826	0.282	-75.061	575.791	-117.562	-603.598

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.664	0.773	0.292	-58.216	447.422	-89.648	-470.918
1.754	0.645	0.238	-72.834	534.597	-102.745	-554.565
1.719	0.785	0.301	-87.062	578.015	-98.32	-596.973
1.818	0.89	0.334	-68.223	517.553	-104.351	-540.261
1.67	1.054	0.355	-90.528	630.506	-108.927	-671.307
1.707	0.732	0.344	-68.688	501.621	-95.944	-523.738
1.84	0.561	0.289	-79.727	610.965	-125.589	-629.213
1.494	0.775	0.296	-67.476	520.242	-106.167	-547.624
1.912	0.82	0.338	-124.245	740.068	-103.757	-757.923
1.889	0.652	0.334	-62.028	508.475	-108.493	-533.47
1.721	1.035	0.347	-53.489	472.746	-109.157	-503.89
1.76	0.955	0.36	-72.493	511.938	-91.548	-539.288
1.587	0.846	0.237	-40.069	423.519	-112.894	-449.823
1.689	0.991	0.328	-76.531	577.92	-113.346	-610.965
1.717	1.15	0.406	-66.394	504.12	-98.331	-538.519
1.956	0.712	0.261	-58.858	443.65	-89.013	-458.607
1.754	0.688	0.321	-65.951	517.075	-106.296	-541.679
1.581	0.813	0.195	-56.585	471.703	-102.278	-500.198
1.779	0.869	0.242	-61.227	498.42	-108.147	-520.733
1.516	1.07	0.277	-62.385	488.661	-97.337	-525.809
1.725	0.833	0.334	-60.858	476.264	-95.989	-505.138
1.796	0.902	0.37	-68.07	481.735	-87.118	-505.992
1.779	0.663	0.248	-37.235	413.783	-111.826	-439.274
1.703	0.73	0.273	-77.294	585.16	-118.128	-608.864
1.742	0.883	0.259	-62.081	500.828	-106.83	-525.777
1.779	0.749	0.383	-69.861	508.936	-95.305	-534.288
1.631	0.883	0.241	-64.783	507.425	-106.461	-531.376
1.715	0.685	0.186	-67.887	514.86	-104.194	-533.126
1.776	0.774	0.282	-70.62	510.57	-97.952	-529.089
1.753	0.739	0.218	-66.116	511.914	-106.321	-531.379
1.675	0.819	0.328	-48.806	408.06	-90.081	-430.409
1.651	1.095	0.382	-64.86	521.719	-109.24	-555.795
1.407	0.628	0.154	-74.18	559.015	-110.704	-585.791
1.904	0.586	0.265	-63.539	485.712	-99.126	-500.255
1.664	0.862	0.342	-54.685	466.771	-103.633	-497.734
1.659	0.813	0.29	-84.647	618.531	-114.361	-654.021
1.515	1.135	0.197	-62.131	504.269	-109.586	-533.928
1.693	0.688	0.212	-53.23	398.281	-78.489	-414.845
1.53	0.777	0.217	-51.727	422.592	-91.207	-445.891
1.773	1.039	0.343	-67.03	528.015	-109.341	-557.288
1.815	0.659	0.218	-68.066	534.19	-110.119	-556.256
1.722	0.805	0.331	-71.044	533.867	-106.515	-557.577
1.722	0.813	0.33	-62.199	486.656	-101.341	-510.184
1.743	0.801	0.25	-55.227	452.253	-99.662	-470.721
1.799	0.774	0.344	-57.792	471.066	-102.703	-492.001
1.793	0.785	0.28	-62.829	499.984	-104.909	-524.152
1.98	0.886	0.312	-85.907	625.662	-117.945	-651.823
1.471	0.711	0.279	-78.808	595.583	-120.639	-622.269
1.788	0.947	0.206	-104.296	773.793	-151.709	-806.361
1.53	0.876	0.336	-60.789	492.963	-103.379	-526.483
1.663	0.704	0.271	-59.299	486.752	-107.54	-507.818
1.901	0.709	0.297	-73.394	566.739	-117.738	-585.265
1.566	0.798	0.267	-62.12	488.259	-100.581	-516.367
1.792	0.728	0.296	-58.726	485.561	-105.121	-509.724

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.69	0.588	0.255	-76.511	593.558	-122.841	-616.7
1.59	0.89	0.237	-75.184	571.916	-114.432	-601.952
1.777	0.717	0.294	-62.987	490.425	-100.785	-512.51
1.933	0.92	0.29	-86.296	578.074	-96.163	-602.992
1.764	0.782	0.329	-69.849	564.726	-121.469	-590.327
1.564	1.031	0.232	-87.594	656.043	-127.073	-694.621
1.708	0.688	0.22	-56.113	465.359	-103.402	-485.609
1.865	0.933	0.304	-69.425	523.521	-102.475	-550.966
1.585	0.913	0.28	-62.1	486.705	-101.588	-511.677
1.755	0.836	0.299	-74.132	580.495	-119.218	-610.252
1.695	0.749	0.306	-62.661	497.724	-103.853	-523.946
1.745	0.867	0.346	-66.326	513.926	-104.641	-541.044
1.704	0.803	0.322	-76.113	561.797	-109.974	-584.777
1.712	0.929	0.355	-54.925	448.014	-93.461	-479.067
1.924	0.775	0.298	-66.448	537.23	-115.373	-559.914
1.671	0.649	0.262	-86.727	546.167	-85.746	-560.42
1.816	0.874	0.29	-60.43	503.396	-111.299	-527.669
1.808	0.775	0.347	-56.873	447.293	-92.411	-468.49
1.56	0.933	0.309	-66.2	543.929	-118.079	-576.366
1.752	0.584	0.315	-78.166	570.084	-109.202	-591.767
1.61	0.666	0.238	-67.073	526.239	-110.474	-549.009
1.837	0.726	0.194	-48.836	428.289	-99.558	-445.614
1.653	0.803	0.272	-65.369	488.373	-93.16	-517.214
1.758	0.93	0.3	-72.113	542.816	-105.251	-572.647
1.806	0.64	0.187	-69.407	515.101	-103.732	-527.343
1.661	0.813	0.328	-110.6	723.986	-121.162	-747.948
1.438	0.929	0.287	-68.861	514.094	-98.044	-549.04
1.722	1.102	0.292	-76.661	560.626	-105.123	-593.443
1.711	1.198	0.278	-72.632	563.244	-114.404	-597.101
1.724	0.718	0.279	-50.752	434.402	-98.895	-454.521
1.743	0.923	0.36	-65.513	487.191	-95.882	-510.034
1.625	1.042	0.357	-68.319	511.568	-98.106	-545.884
1.633	1.018	0.323	-63.25	491.215	-101.344	-518.347
1.698	0.769	0.305	-56.153	477.812	-109.396	-498.527
1.762	0.88	0.325	-67.832	497.628	-96.347	-518.694
1.962	0.722	0.306	-88.752	626.065	-116.624	-642.039
1.671	0.691	0.111	-60.077	464.933	-95.948	-483.478
1.752	0.825	0.268	-51.663	419.672	-89.506	-441.98
1.718	0.99	0.438	-73.72	550.029	-105.063	-584.802
1.905	0.563	0.292	-68.221	539.898	-115.519	-554.297
1.741	0.72	0.313	-76.756	547.295	-100.947	-570.255
1.58	0.722	0.273	-64.014	505.145	-105.86	-529.044
1.81	0.921	0.284	-71.591	533.253	-101.863	-563.578
1.656	0.578	0.329	-65.155	498.818	-101.629	-518.979
1.689	0.573	0.318	-72.064	544.123	-107.713	-567.468
1.59	0.72	0.273	-64.289	517.367	-109.038	-545.677
1.934	0.876	0.305	-51.873	417.86	-88.522	-438.142
1.624	0.788	0.308	-78.798	562.56	-103.835	-590.097
1.68	1.008	0.366	-77.165	595.543	-118.786	-633.62
1.718	0.69	0.243	-54.025	432.639	-91.169	-453.682
1.642	0.798	0.251	-71.802	544.923	-108.83	-570.557
1.613	0.815	0.34	-66.17	548.983	-117.258	-585.192
1.732	0.777	0.3	-44.571	374.38	-81.713	-396.721
1.576	0.916	0.246	-52.39	455.688	-104.826	-482.25

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.414	1.238	0.371	-65.486	499.707	-95.459	-544.315
1.966	0.803	0.225	-157.524	873.567	-101.894	-891.673
1.773	0.862	0.317	-65.181	527.235	-111.4	-556.364
1.676	0.706	0.305	-60.767	500.151	-109.978	-522.85
1.876	0.952	0.305	-82.646	617.543	-121.154	-645.112
1.668	0.706	0.195	-62.779	495.564	-102.777	-518.667
1.852	0.752	0.358	-76.384	579.127	-115.084	-605.323
1.598	0.66	0.233	-63.345	507.995	-110.447	-527.466
1.707	0.545	0.291	-65.087	501.806	-102.413	-522.35
1.901	0.732	0.262	-90.307	595.755	-101.785	-609.116
1.712	0.696	0.322	-55.798	460.605	-98.43	-487.419
1.768	0.753	0.257	-61.293	474.774	-96.938	-495.534
1.838	0.903	0.405	-64.857	516.986	-105.729	-549.962
1.596	0.705	0.233	-42.036	380.139	-89.221	-402.707
1.716	1.008	0.297	-59.417	500.599	-109.418	-533.946
1.705	0.949	0.284	-63.808	481.635	-93.869	-509.328
1.737	0.724	0.282	-76.334	575.746	-114.955	-600.268
1.671	0.781	0.253	-58.675	476.367	-102.13	-500.601
1.773	0.895	0.44	-59.744	474.857	-97.29	-505.314
1.627	1.033	0.224	-66.987	521.306	-105.434	-553.511
1.887	0.85	0.334	-60.855	484.556	-101.432	-507.672
1.742	0.86	0.268	-57.922	483.501	-106.25	-509.786
1.813	0.743	0.28	-81.556	613.04	-123.506	-632.792
1.714	0.711	0.313	-107.318	760.265	-139.261	-791.616
1.74	0.748	0.252	-45.647	472.579	-122.493	-500.624
1.657	0.733	0.248	-64.367	507.51	-106.846	-529.406
1.695	0.99	0.356	-60.406	476.865	-97.639	-506.311
1.84	0.656	0.366	-88.914	624.461	-112.574	-649.267
1.682	0.95	0.166	-71.486	529.79	-105.186	-551.475
1.788	0.901	0.318	-62.525	509.936	-109.48	-537.396
1.584	0.843	0.209	-51.136	435.893	-99.084	-458.066
1.724	0.775	0.376	-67.785	537.813	-111.906	-566.945
1.821	0.934	0.313	-65.916	486.452	-93.136	-510.659
1.546	0.684	0.227	-59.092	462.103	-96.56	-482.63
1.65	0.792	0.265	-62.148	485.19	-99.488	-510.676
1.649	1.064	0.308	-90.762	623.572	-108.247	-656.764
1.756	0.846	0.363	-69.979	527.516	-102.724	-555.978
1.709	0.865	0.278	-66.512	539.318	-116.778	-563.556
1.751	1.058	0.329	-79.587	575.342	-106.116	-608.779
1.593	0.629	0.255	-71.502	541.108	-107.516	-565.589
1.629	0.853	0.332	-77.632	574.867	-110.459	-606.349
1.749	0.689	0.244	-66.474	497.019	-98.458	-516.124
1.744	0.703	0.297	-59.855	516.827	-117.033	-542.805
1.707	0.758	0.238	-69.812	494.621	-90.836	-514.612
1.689	0.847	0.333	-52.994	436.384	-93.81	-462.979
1.575	0.922	0.233	-70.701	524.502	-101.07	-553.424
1.659	0.818	0.222	-73.782	559.256	-111.997	-585.272
1.632	0.839	0.289	-73.491	589.689	-125.67	-621.047
1.717	0.803	0.299	-68.622	545.363	-112.176	-576.4
1.682	0.801	0.385	-61.279	514.879	-113.604	-545.15
1.866	0.613	0.348	-72.013	538.89	-107.519	-555.871
1.3	1.004	0.306	-63.184	532.645	-112.562	-583.069
1.666	0.75	0.299	-64.043	523.707	-115.213	-547.091
1.595	1.083	0.324	-63.842	484.639	-94.832	-517.695

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.663	0.795	0.252	-62.917	489.973	-100.933	-513.453
1.469	0.643	0.361	-50.415	437.717	-99.082	-466.292
1.677	0.936	0.264	-90.831	705.986	-148.23	-736.443
1.677	0.752	0.418	-61.139	445.573	-83.931	-468.534
1.798	0.876	0.283	-62.503	478.572	-96.681	-500.898
1.617	0.65	0.279	-65.773	477.994	-90.321	-498.837
1.751	1.017	0.337	-66.34	510.904	-103.643	-538.591
1.742	0.846	0.31	-55.292	444.767	-95.334	-466.339
1.821	0.744	0.331	-52.272	437.727	-95.045	-462.245
1.673	0.818	0.257	-80.519	603.988	-119.207	-632.555
1.478	0.689	0.24	-61.63	520.849	-115.417	-551.434
1.661	0.769	0.304	-67.192	542.07	-113.397	-574.215
1.787	0.853	0.203	-67.482	492.999	-95.141	-512.152
1.819	1.042	0.31	-74.999	556.263	-109.196	-580.328
1.618	0.923	0.355	-71.207	548.575	-112.461	-576.479
1.731	0.682	0.367	-68.789	532.772	-109.179	-556.118
1.735	0.91	0.322	-65.237	507.318	-102.474	-537.051
1.844	0.695	0.244	-54.224	434.146	-93.152	-449.981
1.723	0.644	0.252	-49.735	407.14	-87.967	-426.271
1.525	0.733	0.27	-54.716	424.953	-89.429	-442.982
1.549	0.668	0.303	-61.65	499.446	-106.779	-527.642
1.815	0.774	0.276	-77.151	597.503	-121.761	-623.589
1.76	0.883	0.379	-63.568	482.753	-95.557	-507.635
1.818	0.909	0.285	-69.824	517.797	-101.452	-540.012
1.635	0.804	0.273	-50.487	427.008	-94.805	-451.325
1.577	0.887	0.305	-44.331	410.909	-97.41	-440.684
1.59	1.015	0.274	-58.136	480.429	-103.586	-511.54
1.784	0.698	0.243	-62.223	525.267	-116.754	-549.786
1.767	0.919	0.319	-67.38	510.906	-100.907	-537.28
1.772	1.035	0.356	-76.602	584.115	-116.414	-614.94
1.707	0.673	0.284	-95.154	647.433	-115.976	-664.944
1.68	0.923	0.318	-64.062	505.976	-103.705	-536.318
1.648	0.995	0.312	-80.346	596.257	-113.657	-631.412
1.63	0.985	0.271	-55.553	450.337	-96.178	-477.081
1.646	0.766	0.329	-79.434	583.401	-110.432	-613.406
1.532	0.995	0.275	-61.935	498.906	-104.472	-532.325
1.782	1.099	0.374	-117.457	738.824	-111.28	-773.74
1.733	0.83	0.292	-74	549.44	-106.934	-574.517
1.874	0.825	0.353	-75.76	562.083	-108.133	-588.171
1.901	0.735	0.357	-77.523	556.657	-103.994	-577.71
1.758	0.737	0.209	-56.894	474.701	-104.721	-496.385
1.66	0.604	0.294	-61.333	495.457	-106.681	-516.117
1.561	0.653	0.212	-36.69	397.468	-107.647	-420.283
1.688	0.579	0.194	-73.626	545.401	-108.167	-562.25
1.806	0.598	0.298	-103.016	689.33	-118.525	-708.65
1.722	0.699	0.239	-55.53	457.506	-99.33	-478.934
1.54	0.808	0.27	-56.642	453.553	-96.01	-478.474
1.662	0.671	0.302	-77.725	557.791	-105.616	-578.302
1.643	0.809	0.303	-43.331	420.434	-103.571	-448.167
1.691	0.822	0.41	-56.265	458.869	-96.677	-489.268
1.455	0.942	0.257	-63.249	542.155	-122.821	-576.452
1.588	0.697	0.257	-53.86	433.359	-93.767	-451.903
1.734	0.758	0.306	-73.423	548.451	-107.118	-573.493
1.803	0.77	0.252	-65.734	499.69	-101.224	-518.378

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.717	0.659	0.244	-68.526	532.71	-110.545	-553.592
1.777	0.894	0.378	-89.02	628.295	-114.271	-656.022
1.681	0.793	0.384	-71.892	541.411	-104.791	-573.436
1.955	1.002	0.323	-76.659	545.155	-98.135	-572.039
1.591	0.72	0.185	-51.955	405.088	-83.945	-424.24
1.874	0.623	0.201	-80.031	567.89	-106.927	-581.748
1.659	0.55	0.224	-89.133	635.352	-120.816	-653.128
1.904	0.687	0.335	-82.612	597.039	-114.38	-616.355
1.849	0.806	0.271	-88.283	630.913	-119.84	-649.835
1.673	0.79	0.285	-72.081	543.605	-109.116	-566.724
1.56	0.938	0.261	-83.578	652.29	-133.825	-689.925
1.763	0.802	0.349	-75.81	554.096	-106.526	-577.495
1.532	0.788	0.341	-53.829	438.777	-92.769	-467.722
1.841	0.802	0.379	-56.807	496.525	-110.717	-528.414
1.726	0.779	0.301	-96.565	709.471	-135.945	-740.923
1.75	0.717	0.288	-84.542	582.079	-103.855	-602.02
1.555	0.803	0.189	-65.154	490.597	-98.491	-512.964
1.863	0.75	0.217	-50.952	421.897	-93.724	-437.118
1.718	1.001	0.295	-76.024	580.233	-115.536	-612.163
1.858	0.57	0.176	-62.411	464.24	-92.584	-476.325
1.619	1.055	0.306	-76.298	591.087	-119.464	-628.302
1.77	0.782	0.359	-56.766	455.436	-95.672	-479.703
1.508	0.595	0.241	-42.529	437.854	-110.636	-470.215
1.78	1.013	0.326	-75.413	595.988	-122.741	-631.56
1.708	0.783	0.309	-66.692	505.432	-100.338	-529.21
1.798	0.781	0.328	-63.924	483.915	-97.729	-502.513
1.798	1.096	0.441	-83.46	601.356	-106.525	-643.926
2.023	0.729	0.236	-120.046	700.843	-95.569	-710.227
1.553	0.652	0.201	-77.04	548.219	-102.706	-568.42
1.662	0.902	0.363	-71.171	505.174	-90.049	-535.821
1.837	0.718	0.238	-96.201	635.77	-106.868	-653.282
1.594	1.017	0.372	-80.963	562.616	-96.747	-598.266
1.658	0.849	0.274	-54.446	480.716	-110.135	-510.349
1.752	0.892	0.213	-76.896	585.645	-117.744	-612.447
1.757	0.628	0.231	-76.484	547.913	-104.95	-562.892
1.748	0.964	0.354	-56.141	456.824	-97.46	-483.616
1.781	0.85	0.301	-78.197	603.748	-121.378	-635.292
1.946	0.611	0.228	-73.04	486.433	-84.856	-494.504
1.694	1.084	0.348	-69.263	544.596	-109.996	-582.14
1.761	0.799	0.233	-80.493	615.554	-124.788	-641.158
1.833	0.751	0.291	-78.923	581.663	-113.039	-603.714
1.736	0.783	0.338	-62.607	494.022	-101.025	-522.227
1.95	1.109	0.358	-75.473	579.811	-117.691	-609.89
1.757	0.7	0.234	-70.54	564.555	-120.901	-585.618
1.768	0.896	0.324	-75.267	552.189	-103.626	-582.319
1.673	0.969	0.296	-53.313	430.696	-92.214	-455.226
1.599	0.836	0.146	-74.132	568.473	-117.309	-591.676
1.939	1.173	0.403	-90.267	632.555	-109.978	-670.051
1.586	0.892	0.297	-56.85	450.99	-94.294	-476.399
1.853	1.022	0.378	-84.522	608.027	-113.267	-637.605
1.515	0.758	0.311	-50.914	418.09	-90.45	-442.62
1.723	0.844	0.4	-59.745	488.11	-101.266	-522.516
1.803	0.633	0.289	-60.409	457.899	-90.938	-477.09
1.5	0.978	0.174	-75.97	600.078	-123.33	-639.052

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.741	0.567	0.321	-42.837	449.671	-116.343	-476.914
1.856	1.182	0.341	-63.333	465.72	-88.147	-492.225
1.636	0.899	0.285	-50.916	411.593	-86.852	-437.115
1.424	0.535	0.226	-59.993	431.277	-80.577	-450.905
1.892	0.803	0.374	-47	390.995	-85.143	-411.556
1.919	0.946	0.35	-64.48	485.29	-95.305	-508.493
1.737	0.628	0.254	-67.951	508.488	-102.019	-525.499
1.674	0.76	0.304	-50.509	454.037	-105.262	-483.078
1.87	0.849	0.31	-56.336	486.866	-111.536	-510.219
1.672	0.718	0.369	-87.207	619.661	-113.427	-648.265
1.622	1.069	0.224	-62.64	479.923	-97.393	-506.775
1.871	0.596	0.305	-66.615	527.678	-110.341	-548.526
1.563	1.037	0.271	-63.811	536.815	-116.629	-576.337
1.756	0.819	0.319	-57.032	449.301	-93.634	-471.086
1.764	0.675	0.187	-50.423	407.923	-86.621	-426.369
1.756	0.819	0.323	-65.467	504.406	-99.65	-533.44
1.686	0.717	0.269	-69.871	513.026	-100.452	-530.776
1.791	0.808	0.342	-64.535	507.501	-103.141	-536.59
1.838	0.693	0.316	-84.142	564.338	-98.565	-578.214
1.685	0.983	0.376	-51.882	429.756	-91.401	-460.531
1.82	0.823	0.234	-66.637	540.627	-118.02	-561.999
1.627	1.218	0.35	-69.385	517.97	-97.351	-557.335
1.733	0.671	0.305	-59.326	446.414	-87.196	-466.801
1.775	0.681	0.289	-66.311	518.242	-107.53	-539.381
1.74	1.065	0.375	-61.097	487.972	-100.626	-521.032
1.992	0.58	0.349	-76.365	588.149	-118.97	-609.193
1.562	0.866	0.249	-88.244	666.439	-132.395	-700.727
1.698	1.126	0.293	-57.124	477.813	-103.274	-512.326
1.738	0.863	0.251	-71.487	545.662	-108.186	-574.236
1.78	0.994	0.411	-79.336	581.072	-109.993	-612.372
1.46	0.624	0.284	-41.508	411.59	-101.858	-442.52
1.593	0.545	0.279	-57.266	451.474	-95.391	-469.775
1.642	0.83	0.305	-61.25	489.637	-102.879	-517.456
1.812	0.923	0.233	-56.593	452.21	-97.536	-470.512
1.621	0.803	0.3	-63.948	520.67	-112.219	-548.016
1.671	0.581	0.348	-84.085	594.762	-108.956	-618.809
1.656	0.964	0.304	-66.324	545.967	-119.103	-577.195
1.857	0.866	0.311	-63.801	502.525	-102.664	-529.877
1.703	0.81	0.372	-76.231	570.446	-108.966	-603.635
1.541	0.596	0.211	-52.136	432.482	-95.194	-452.756
1.819	0.987	0.321	-59.106	461.012	-94.592	-485.912
1.576	0.729	0.275	-67.523	514.522	-102.715	-540.431
1.608	1.162	0.293	-96.262	669.029	-114.29	-715.182
1.755	0.762	0.272	-62.829	513.054	-110.835	-537.068
1.619	1.054	0.279	-84.131	596.179	-107.356	-631.284
1.608	0.761	0.24	-61.583	489.4	-105.702	-508.102
1.848	0.908	0.32	-68.578	520.831	-103.477	-545.893
1.606	0.908	0.314	-79.352	561.128	-99.374	-595.091
1.603	0.817	0.202	-77.217	584.156	-114.58	-615.705
1.736	0.719	0.275	-86.725	656.339	-131.603	-683.849
1.564	1.051	0.26	-52.34	447.966	-100.392	-478.305
1.66	0.869	0.311	-52.648	430.531	-91.778	-457.396
1.761	0.745	0.239	-74	542.089	-103.216	-565.202
1.69	0.706	0.304	-97.167	726.761	-141.322	-759.359

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.65	1.192	0.317	-77.24	531.461	-89.362	-567.706
1.854	0.691	0.277	-57.202	441.581	-89.868	-460.262
1.568	0.947	0.258	-67.329	510.134	-100.653	-540.631
1.735	0.962	0.347	-88.183	635.518	-118.482	-666.689
1.822	0.925	0.321	-63.093	476.811	-93.279	-502.241
1.671	0.922	0.29	-60.002	474.105	-97.909	-501.574
1.79	0.936	0.359	-81.391	596.261	-112.527	-627.662
1.573	0.775	0.319	-50.132	421.624	-91.535	-450.245
1.618	0.828	0.317	-79.194	573.291	-108.377	-600.115
1.683	0.922	0.249	-60.434	451.949	-88.029	-475.587
1.821	0.751	0.289	-85.204	641.378	-127.85	-666.56
1.795	0.93	0.242	-66.77	521.824	-110.821	-541.118
1.843	0.575	0.214	-70.278	526.99	-105.744	-541.444
1.734	0.974	0.32	-73.065	536.302	-101.769	-565.736
1.84	0.847	0.352	-78.569	577.408	-109.034	-607.389
1.503	1.008	0.231	-73.687	576.146	-117.685	-613.205
1.709	0.7	0.263	-72.908	576.748	-122.058	-600.504
1.739	0.775	0.292	-78.292	594.128	-118.569	-622.272
1.754	0.86	0.358	-59.528	482.073	-101.167	-510.381
1.579	0.834	0.344	-56.852	487.392	-108.882	-519.089
1.721	0.492	0.26	-68.523	483.74	-89.533	-498.068
1.835	0.633	0.244	-56.208	460.825	-102.909	-474.177
1.765	0.838	0.282	-74.61	543.02	-101.647	-569.428
1.827	0.679	0.296	-72.536	533.79	-103.647	-552.829
1.656	0.698	0.276	-68.937	521.555	-102.645	-548.741
1.772	0.745	0.265	-65.116	529.565	-113.696	-554.579
1.564	0.918	0.227	-86.045	613.633	-112.43	-646.436
1.699	0.68	0.253	-87.35	614.449	-111.706	-638.318
1.757	0.748	0.288	-63.539	490.265	-98.926	-514.081
1.773	0.901	0.337	-60.536	485.278	-102.64	-510.686
1.495	1.084	0.298	-52.022	456.349	-102.049	-494.97
1.732	0.978	0.342	-53.024	442.944	-95.416	-472.858
1.578	0.72	0.312	-49.816	477.127	-114.824	-512.271
1.797	0.68	0.286	-63.863	510.653	-108.204	-532.343
1.84	0.944	0.41	-75.102	569.869	-113.755	-597.956
1.967	0.849	0.291	-63.742	477.954	-94.145	-496.539
1.737	1.153	0.281	-79.416	589.185	-111.031	-627.706
1.702	0.716	0.295	-100.354	665.489	-112.593	-688.473
1.843	0.817	0.308	-70.486	531.909	-106.097	-554.351
1.753	1.035	0.365	-106.573	654.416	-94.193	-683.14
1.65	0.827	0.257	-60.477	510.186	-113.892	-535.623
1.754	0.927	0.342	-90.017	710.39	-147.473	-748.75
1.722	1.021	0.26	-69.081	516.712	-99.797	-545.278
1.865	1.105	0.407	-86.768	643.166	-121.952	-681.906
1.867	0.881	0.333	-60.312	489.741	-103.119	-517.949
1.717	0.881	0.331	-72.028	567.777	-115.883	-602.161
1.45	0.836	0.259	-68.904	540.017	-112.287	-569.21
1.797	0.559	0.303	-91.303	675.024	-133.048	-694.391
1.753	0.661	0.292	-68.319	531.686	-109.365	-555.154
1.589	0.896	0.393	-90.336	665.037	-123.666	-708.636
1.739	0.637	0.326	-64.471	523.649	-113.886	-544.041
1.796	0.64	0.251	-74.379	600.936	-131.59	-620.239
1.691	0.968	0.308	-101.28	697.023	-119.187	-735.912
1.814	0.765	0.322	-76.021	607.67	-128.811	-635.225

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.666	0.986	0.286	-80.48	624.361	-127.093	-660.344
1.609	0.984	0.339	-68.041	515.971	-100.609	-548.61
1.721	0.663	0.232	-64.251	492.42	-100.548	-511.151
1.552	0.935	0.26	-63.285	509.218	-107.136	-540.897
1.693	0.686	0.307	-61.439	514.166	-113.539	-540.056
1.724	0.907	0.361	-77.149	509.831	-81.481	-537.564
1.657	0.995	0.208	-67.95	513.732	-101.761	-540.725
1.662	0.762	0.308	-66.623	524.118	-107.497	-552.969
1.661	0.538	0.305	-85.036	639.512	-126.942	-663.835
1.772	0.742	0.342	-61.756	486.049	-101.177	-508.194
1.57	1.097	0.25	-59.642	472.605	-98.143	-502.559
1.787	0.719	0.29	-68.798	528.897	-108.431	-549.497
1.623	0.736	0.309	-49.173	430.46	-97.654	-457.089
1.745	0.677	0.204	-72.9	578.268	-124.848	-596.664
1.744	0.87	0.438	-55.011	478.561	-106.683	-513.032
1.71	0.818	0.26	-73.781	595.324	-127.396	-623.404
1.636	0.767	0.29	-92.154	625.808	-107.199	-653.378
1.749	0.851	0.352	-59.106	482.099	-103.308	-508.849
1.791	0.908	0.355	-64.369	543.681	-119.303	-576.884
1.577	0.893	0.246	-39.768	385.228	-94.239	-413.96
1.58	0.584	0.219	-53.007	422.345	-91.44	-437.777
1.585	0.882	0.231	-65.46	495.141	-96.492	-524.782
1.727	0.879	0.301	-70.562	551.379	-114.379	-578.313
1.714	0.907	0.288	-66.304	532.267	-114.456	-557.811
1.666	0.993	0.338	-64.055	527.095	-111.843	-564.593
1.75	0.623	0.266	-64.153	511.34	-110.38	-528.593
1.645	1.151	0.279	-74.156	567.998	-111.259	-607.753
1.804	0.883	0.308	-73.702	567.675	-112.632	-600.497
1.701	0.613	0.322	-82.393	591.4	-111.385	-612.888
1.65	0.722	0.282	-61.721	500.264	-105.424	-527.29
1.655	0.682	0.289	-49.426	424.843	-96.333	-446.727
1.794	0.81	0.352	-69.847	526.397	-101.621	-555.372
1.715	0.618	0.244	-57.281	484.082	-108.034	-506.354
1.698	0.849	0.287	-91.982	630.207	-111.258	-655.034
1.595	0.661	0.237	-66.689	517.932	-106.395	-541.988
1.806	0.686	0.193	-75.312	591.271	-128.013	-604.231
1.697	0.683	0.306	-75.235	572.265	-115.859	-595.35
1.623	0.682	0.343	-79.032	587.37	-113.275	-616.963
1.698	0.81	0.28	-58.178	469.455	-98.011	-497.435
1.602	1.202	0.199	-103.152	690.892	-117.482	-724.973
1.691	0.832	0.236	-68.916	522.891	-104.637	-547.268
1.784	0.754	0.345	-55.583	463.407	-102.015	-486.641
1.585	0.893	0.289	-61.976	498.949	-105.784	-527.247
1.733	0.774	0.281	-53.462	454.265	-101.114	-479.498
1.702	1.041	0.352	-70.569	559.179	-116.037	-592.954
1.603	0.658	0.255	-68.888	508.926	-98.566	-530.528
1.69	0.706	0.235	-59.353	483.869	-104.718	-506.175
1.784	0.762	0.28	-63.181	499.655	-104.069	-523.069
1.591	0.98	0.315	-54.899	470.667	-104.458	-503.08
1.692	0.909	0.208	-52.793	420.447	-87.121	-444.626
1.747	0.989	0.313	-53.465	421.3	-86.051	-447.52
1.812	0.699	0.253	-63.484	469.888	-91.722	-487.305
1.634	1.02	0.22	-57.946	473.757	-102.682	-500.003
1.786	0.769	0.317	-61.882	487.721	-101.694	-510.709

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.95	0.726	0.274	-67.309	509.054	-103.128	-523.621
1.679	0.697	0.364	-68.255	505.655	-97.793	-529.897
1.823	0.679	0.239	-72.281	525.49	-102.383	-540.263
1.797	0.601	0.256	-72.423	528.316	-101.001	-547.332
1.794	0.777	0.278	-55.975	444.125	-93.23	-464.317
1.704	0.874	0.213	-75.077	562.18	-109.983	-589.36
1.885	0.858	0.327	-70.291	537.745	-107.833	-561.682
1.537	0.987	0.211	-61.458	502.67	-106.009	-538.747
1.924	0.616	0.304	-60.571	465.889	-93.363	-484.706
1.738	0.77	0.367	-44.609	414.775	-98.283	-442.837
1.755	0.668	0.276	-74.233	544.939	-105.838	-564.022
1.719	0.761	0.289	-55.91	450.07	-94.851	-473.084
1.751	0.788	0.298	-68.956	523.83	-104.93	-546.681
1.751	0.678	0.292	-68.535	544.385	-114.579	-568.795
1.867	0.535	0.355	-60.024	474.14	-99.477	-491.107
1.714	0.834	0.35	-62.933	522.494	-114.099	-551.231
1.802	0.965	0.332	-59.326	474.238	-98.726	-502.03
1.538	0.745	0.317	-57.852	493.326	-108.882	-527.018
1.741	0.715	0.254	-76.169	573.066	-113.644	-596.479
1.58	0.862	0.245	-67.272	505.449	-97.351	-536.572
1.825	0.8	0.27	-61.492	496.334	-106.127	-518.566
1.699	0.751	0.274	-57.917	462.008	-98.735	-480.754
1.764	0.887	0.389	-78.077	595.379	-117.934	-628.622
1.755	0.756	0.266	-75.109	558.652	-110.194	-579.91
1.601	0.709	0.283	-50.417	411.965	-89.061	-433.41
1.639	0.872	0.325	-59.782	480.795	-101.877	-508.804
1.926	0.889	0.326	-74.375	557.083	-109.52	-580.631
1.831	0.877	0.326	-73.724	545.336	-105.597	-570.024
1.674	1.001	0.294	-66.467	520.256	-106.049	-552.861
1.778	0.667	0.292	-72.819	550.775	-110.201	-571.699
1.75	0.884	0.302	-61.721	492.551	-104.741	-515.928
1.918	0.88	0.3	-64.095	481.591	-94.604	-503.165
1.522	0.636	0.219	-54.653	469.291	-106.851	-492.377
1.469	0.867	0.189	-54.683	450.87	-98.325	-477.852
1.689	0.872	0.274	-86.173	575.435	-98.211	-596.907
1.748	0.696	0.132	-70.093	508.407	-98.275	-524.645
1.709	0.98	0.315	-57.483	453.63	-93.021	-481.91
1.657	0.653	0.232	-76.204	557.243	-106.196	-582.009
1.711	0.928	0.202	-61.412	462.326	-92.198	-483.819
1.799	0.656	0.37	-56.59	454.09	-94.411	-477.771
1.737	0.859	0.331	-76.937	600.491	-125.311	-628.026
1.852	0.638	0.25	-55.791	430.767	-89.528	-444.314
1.817	0.992	0.188	-61.157	489.485	-105.093	-510.722
1.687	0.69	0.272	-53.555	450.389	-98.981	-473.909
1.643	0.982	0.25	-65.27	542.886	-118.264	-576.671
1.791	0.81	0.289	-64.878	537.2	-120.198	-558.03
1.747	0.94	0.365	-74.203	591.166	-123.959	-623.902
1.662	0.857	0.29	-104.803	663.897	-102.215	-690.18
1.58	0.872	0.288	-48.903	461.158	-112.235	-490.956
1.62	0.921	0.272	-77.46	586.619	-114.986	-621.213
1.581	0.94	0.282	-32.978	364.579	-96.88	-394.616
1.725	0.766	0.304	-68.396	525.274	-107.035	-548.33
1.68	0.73	0.293	-56.6	469.482	-102.582	-493.887
1.714	0.733	0.221	-36.987	363.484	-91.679	-383.54

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.716	0.552	0.268	-61.321	493.292	-107.23	-510.175
1.672	0.882	0.377	-63.365	530.325	-115.962	-562.79
1.906	0.727	0.287	-51.87	431.689	-94.902	-449.841
1.601	0.791	0.3	-49.311	402.308	-86.845	-424.55
1.635	0.786	0.291	-50.657	422.621	-93.657	-444.337
1.678	0.597	0.311	-66.219	526.229	-110.411	-550.356
1.708	0.803	0.347	-39.329	447.729	-120.126	-483.515
1.759	0.577	0.261	-68.877	511.398	-103.471	-523.704
1.682	0.8	0.29	-55.862	432.846	-88.343	-454.464
1.689	0.945	0.302	-58.347	481.208	-105.308	-507.114
1.466	0.877	0.295	-24.268	321.077	-94.083	-350.758
1.725	0.725	0.365	-63.951	492.949	-99.437	-517.702
1.723	0.518	0.207	-56.362	465.36	-104.142	-479.318
1.618	0.749	0.261	-77.053	596.588	-121.897	-625.73
1.57	0.787	0.272	-62.108	513.173	-112.745	-539.286
1.772	0.456	0.21	-107.598	699.072	-117.653	-708.871
1.644	0.871	0.229	-59.808	498.612	-107.727	-530.606
1.792	0.647	0.282	-75.087	580.447	-117.736	-605.135
1.777	0.737	0.215	-61.699	487.735	-102.778	-507.001
1.687	0.744	0.25	-56.355	466.746	-102.596	-489.325
1.854	0.728	0.284	-78.073	536.47	-90.947	-563.127
1.824	0.873	0.299	-80.395	608.908	-119.266	-640.913
1.777	0.953	0.369	-73.913	541.066	-102.459	-569.01
1.743	0.858	0.337	-61.061	493.343	-105.699	-517.998
1.688	0.954	0.258	-91.188	623.482	-108.994	-650.428
1.474	0.815	0.193	-72.454	560.656	-114.663	-589.679
1.892	0.785	0.312	-79.337	581.245	-109.483	-608.973
1.712	0.967	0.345	-69.426	559.19	-119.431	-589.915
1.609	1.026	0.312	-84.834	638.474	-123.831	-679.039
1.68	0.73	0.266	-60.973	484.934	-102.799	-507.291
1.742	0.878	0.273	-67.963	514.709	-101.463	-540.753
1.607	0.747	0.144	-51.867	438.539	-97.002	-461.791
1.701	0.962	0.255	-89.149	620.12	-109.285	-650.993
1.709	0.79	0.324	-81.767	599.358	-115.554	-625.326
1.752	0.794	0.364	-55.957	432.424	-87.077	-455.898
1.48	1.173	0.368	-49.801	455.827	-101.962	-505.049
1.493	0.801	0.253	-68.52	517.976	-99.78	-551.774
1.816	0.895	0.236	-52.253	450.066	-102.347	-472.815
1.847	0.805	0.355	-68.769	542.913	-112.541	-570.328
1.771	0.934	0.209	-108.624	679.722	-104.183	-701.947
1.713	0.694	0.222	-61.241	495.498	-106.643	-515.731
1.593	0.908	0.21	-53.88	504.01	-119.872	-540.435
1.745	1.188	0.304	-66.886	515.526	-104.73	-544.95
1.785	0.981	0.399	-90.325	658	-124.135	-692.812
1.829	0.835	0.379	-60.133	476.676	-96.264	-506.542
1.836	0.608	0.174	-72.997	486.913	-84.961	-496.024
1.726	0.902	0.259	-66.256	510.142	-104.28	-533.815
1.782	0.888	0.389	-79.081	592.413	-115.289	-623.022
1.696	0.84	0.318	-53.685	420.057	-85.842	-443.861
1.653	0.85	0.274	-46.816	445.024	-109.129	-472.113
1.663	0.69	0.264	-51.479	429.182	-94.972	-449.766
1.8	0.726	0.296	-49.391	426.614	-95.015	-452.21
1.694	0.897	0.302	-56.228	468.088	-103.332	-494.067
1.663	1.022	0.356	-42.404	387.372	-90.873	-415.95

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.59	0.634	0.282	-28.879	360.709	-103.041	-387.975
1.615	0.528	0.256	-69.713	544.875	-113.114	-567.271
1.744	0.587	0.26	-55.492	423.616	-85.292	-440.464
1.873	0.539	0.27	-85.69	552.216	-89.887	-564.706
1.797	0.654	0.388	-83.96	574.778	-99.477	-598.534
1.797	0.849	0.28	-73.121	559.412	-113.524	-582.413
1.712	0.923	0.206	-99.109	623.339	-95.229	-646.106
1.666	1.039	0.256	-79.507	592.19	-112.725	-629.492
1.831	1.046	0.29	-63.433	500.193	-104.635	-523.886
1.574	1.056	0.177	-71.969	545.209	-108.446	-575.498
1.767	0.908	0.189	-82.072	574.774	-104.405	-596.809
2.016	0.585	0.399	-88.443	598.227	-105.575	-610.423
1.947	0.846	0.272	-62.214	478.93	-98.87	-494.984
1.791	0.672	0.285	-68.288	531.356	-110.981	-550.525
2.05	0.666	0.306	-55.236	431.928	-89.812	-446.562
1.638	0.957	0.288	-62.423	488.534	-101.145	-515.4
1.777	0.707	0.307	-41.262	391.036	-94.737	-414.146
1.575	0.579	0.313	-69.287	506.355	-95.016	-531.136
1.87	0.748	0.376	-54.797	439.393	-92.713	-459.972
1.683	0.558	0.236	-62.747	495.902	-105.451	-513.816
1.365	0.843	0.24	-62.201	547.684	-124.446	-589.414
1.788	0.563	0.293	-77.717	576.998	-113.84	-596.28
1.717	0.858	0.29	-52.376	439.127	-96.535	-464.214
1.663	0.7	0.305	-62.978	497.614	-105.125	-518.634
1.877	0.847	0.334	-149.775	826.249	-94.712	-846.709
1.681	0.832	0.131	-65.249	540.81	-121.976	-561.185
1.749	0.65	0.317	-51.259	423.131	-91.993	-443.373
1.812	1.263	0.263	-87.203	622.035	-113.464	-656.116
1.766	0.916	0.262	-57.179	483.032	-108.046	-508.504
1.772	0.75	0.347	-68.412	513.712	-101.47	-536.378
1.552	0.768	0.289	-51.51	464.014	-109.572	-491.12
1.611	0.958	0.261	-55.44	454.558	-99.354	-479.502
1.783	0.608	0.271	-52.884	458.564	-105.445	-477.482
1.515	0.671	0.201	-57.913	444.365	-87.133	-471.621
1.782	0.93	0.325	-54.976	462.505	-101.757	-489.698
1.703	0.972	0.335	-69.035	526.426	-104.464	-556.882
1.844	0.735	0.22	-72.133	556.912	-112.957	-579.334
1.655	0.834	0.302	-77.436	549.225	-97.109	-582.23
1.603	0.67	0.226	-69.9	522.463	-100.474	-549.557
1.396	0.992	0.227	-62.08	473.508	-93.748	-505.069
1.734	0.799	0.289	-42.788	402.695	-98.152	-425.63
1.817	0.519	0.211	-62.124	471.515	-95.768	-485.379
1.504	1.424	0.324	-69.716	519.844	-96.318	-566.155
1.738	0.582	0.281	-72.268	502.333	-92.18	-517.207
1.729	0.542	0.288	-55.377	449.344	-95.294	-470.471
1.47	0.608	0.3	-54.021	443.037	-96.738	-466.564
1.766	0.698	0.273	-66.92	500.056	-98.294	-520.64
1.587	0.66	0.294	-85.512	660.771	-135.456	-690.056
1.643	0.807	0.363	-69.078	548.572	-115.46	-578.465
1.945	0.661	0.325	-63.645	492.61	-101.734	-509.157
2.024	0.809	0.335	-115.571	719.76	-107.118	-742.019
1.61	0.924	0.319	-59.42	465.435	-94.542	-494.109
1.672	0.627	0.3	-67.387	518.098	-105.009	-540.833
1.842	0.852	0.215	-83.074	610.414	-119.328	-631.414

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.68	0.906	0.357	-69.311	548.71	-114.007	-579.716
1.811	0.747	0.304	-66.375	503.917	-101.077	-524.472
1.675	0.619	0.224	-71.454	552.714	-114.709	-572.315
1.852	0.894	0.403	-109.635	671.837	-95.512	-698.671
1.708	0.643	0.234	-78.307	572.408	-113.663	-587.866
1.856	0.635	0.324	-66.299	479.154	-91.014	-495.026
1.77	1.024	0.305	-69.675	521.678	-103.474	-546.409
1.951	0.729	0.349	-71.454	526.278	-101.114	-546.782
1.615	0.808	0.246	-72.549	573.387	-120.036	-602.928
1.867	0.879	0.352	-76.543	592.737	-119.157	-623.851
1.75	0.616	0.283	-45.974	407.187	-93.916	-427.324
1.834	0.649	0.315	-92.865	631.829	-115.799	-642.87
1.729	0.798	0.258	-64.376	491.954	-98.65	-516.315
1.649	0.837	0.249	-39.819	400.286	-100.649	-428.293
1.909	1.084	0.243	-67.973	526.592	-107.034	-555.112
1.77	0.929	0.404	-79.706	627.925	-128.855	-664.09
1.745	0.674	0.291	-49.668	425.33	-95.779	-447.472
1.737	0.722	0.355	-73.896	494.677	-82.593	-516.651
1.552	1.236	0.301	-83.604	607.162	-109.928	-653.809
1.803	0.557	0.332	-81.057	601.453	-115.874	-626.659
1.843	0.979	0.318	-72.934	572.311	-116.082	-606.344
1.691	0.743	0.283	-48.658	422.512	-98.347	-441.727
1.669	0.752	0.304	-58.875	494.459	-108.172	-522.743
1.745	0.662	0.266	-42.841	433.15	-109.917	-459.376
1.675	0.854	0.155	-92.823	704.097	-142.365	-731.993
1.753	0.783	0.312	-63.736	530.12	-116.685	-556.91
1.679	0.808	0.353	-84.569	594.307	-106.474	-623.321
1.66	0.987	0.323	-77.151	610.675	-127.684	-645.087
1.661	0.714	0.269	-75.538	562.497	-109.474	-588.518
1.968	0.641	0.33	-74.942	534.839	-101.146	-549.772
1.691	0.484	0.295	-50.727	431.329	-97.187	-450.321
1.682	0.95	0.275	-69.735	557.169	-116.763	-588.354
1.716	0.969	0.31	-71.801	557.578	-112.772	-589.472
1.724	0.748	0.199	-69.38	550.39	-116.166	-572.88
1.506	1.174	0.245	-68.45	538.261	-109.845	-576.823
1.664	0.743	0.285	-91.378	645.022	-118.891	-669.862
1.629	0.618	0.346	-79.568	587.531	-112.609	-615.167
1.683	0.878	0.304	-59.897	489.128	-105.008	-517.193
1.871	1.063	0.393	-87.156	589.665	-98.324	-621.651
1.589	1.018	0.253	-56.743	461.701	-96.635	-494.569
1.749	0.8	0.321	-64.588	517.875	-112.293	-538.834
1.855	0.634	0.204	-82.484	576.922	-106.686	-590.719
1.762	0.837	0.303	-62.702	477.93	-97.162	-497.753
1.586	0.776	0.347	-81.056	605.907	-117.989	-638.079
1.806	0.746	0.247	-59.086	472.843	-100.962	-491.599
1.669	0.718	0.286	-23.583	365.066	-113.391	-395.367
1.623	0.684	0.314	-58.505	503.577	-112.748	-533.876
1.697	1.112	0.313	-101.35	631.5	-93.071	-661.23
1.848	0.762	0.336	-71.289	530.313	-101.845	-556.056
1.816	0.826	0.248	-64.462	494.77	-100.383	-516.061
1.485	1.024	0.308	-69.806	522.979	-99.971	-559.89
1.918	0.856	0.341	-84.458	608.907	-113.438	-635.664
1.809	0.698	0.279	-61.057	485.729	-102.217	-507.253
1.366	0.509	0.316	-57.142	530.396	-126.357	-567.271

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.689	0.699	0.317	-59.175	468.582	-97.776	-490.94
1.795	0.948	0.281	-75.464	556.09	-106.097	-584.835
1.751	0.894	0.295	-62.306	538.681	-124.033	-565.618
1.591	0.934	0.275	-80.98	580.392	-104.33	-617.765
1.632	0.625	0.299	-66.882	542.029	-118.787	-564.042
1.615	0.735	0.297	-72.726	544.852	-106.787	-571.87
1.851	0.8	0.348	-73.351	540.168	-103.678	-563.719
1.972	0.696	0.343	-68.213	503.361	-97.622	-521.874
1.633	0.516	0.187	-58.249	450.578	-94.252	-464.227
1.861	0.705	0.364	-66.393	504.543	-97.627	-532.268
1.597	0.781	0.238	-71.801	556.714	-114.473	-582.945
1.537	0.809	0.221	-76.413	573.929	-114.266	-601.311
1.829	0.871	0.348	-74.587	537.034	-98.534	-564.414
1.654	0.949	0.271	-54.079	485.075	-111.059	-520.82
1.807	0.664	0.261	-68.35	500.701	-96.482	-519.164
1.715	1.058	0.337	-91.147	663.563	-124.532	-701.382
1.733	0.957	0.316	-70.815	568.604	-118.57	-602.842
1.798	0.994	0.224	-53.478	435.67	-94.878	-455.828
1.639	0.699	0.271	-41.121	418.298	-105.395	-448.7
2.017	0.729	0.31	-110.255	694.518	-106.955	-712.79
1.695	1.109	0.274	-58.747	471.56	-99.293	-500.811
1.621	0.748	0.296	-68.476	533.473	-111.355	-556.909
1.812	0.828	0.344	-61.484	511.477	-112.121	-537.841
1.705	0.89	0.267	-64.027	500.696	-104.975	-522.401
1.594	0.768	0.312	-71.572	567.408	-118.831	-597.653
1.584	0.567	0.187	-50.729	439.01	-101.168	-457.965
1.77	0.654	0.294	-51.533	408.777	-86.063	-425.814
1.821	0.933	0.341	-61.767	487.769	-101.42	-512.827
1.722	0.746	0.269	-71.308	545.878	-110.732	-569.03
1.633	1.033	0.263	-75.956	545.652	-98.331	-580.984
1.839	0.531	0.323	-66.742	503.758	-99.182	-524.261
1.676	0.802	0.273	-58.603	496.24	-111.68	-520.854
1.778	0.905	0.346	-73.653	500.3	-86.864	-521.47
1.699	0.829	0.295	-64.108	504.492	-106.715	-526.272
1.644	0.818	0.353	-52.534	424.398	-88.03	-452.816
1.658	0.72	0.253	-53.513	439.788	-95.558	-461.336
1.727	0.873	0.212	-55.503	470.763	-104.018	-496.294
1.635	1.003	0.309	-65.805	583.428	-132.191	-628.742
1.939	0.628	0.324	-67.741	520.229	-104.177	-542.132
1.769	0.882	0.308	-60.358	460.187	-91.62	-484.269
1.76	0.93	0.347	-76.93	557.23	-103.108	-588.092
1.514	1.072	0.206	-58.644	459.363	-94.425	-488.607
1.623	1.087	0.331	-61.934	493.124	-100.781	-529.711
1.782	0.861	0.237	-64.981	493.417	-102.257	-508.647
1.771	0.772	0.278	-56.935	455.527	-97.453	-474.86
1.48	0.716	0.267	-65.453	509.212	-105.582	-534.085
1.714	0.812	0.276	-79.169	593.761	-117.374	-619.885
1.675	0.86	0.361	-64.568	509.822	-104.303	-539.907
1.577	0.576	0.29	-82.231	589.359	-110.154	-614.281
1.794	1.018	0.337	-78.342	574.954	-107.255	-608.234
1.661	0.811	0.266	-45.369	464.892	-121.052	-491.989
1.568	0.678	0.286	-67.832	532.862	-112.778	-555.758
1.734	0.584	0.321	-84.769	583.651	-106.195	-598.477
1.853	0.961	0.299	-69.05	524.735	-104.574	-550.494

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.57	0.647	0.206	-50.532	428.27	-97.79	-446.233
1.751	0.82	0.235	-69.865	499.512	-93.664	-518.846
1.661	0.579	0.234	-55.599	474.674	-107.458	-495.732
1.884	0.371	0.298	-77.175	525.088	-94.088	-533.489
1.599	0.783	0.212	-70.316	501.215	-93.132	-523.269
1.847	0.533	0.242	-83.169	613.432	-120.707	-629.696
1.676	0.552	0.339	-96.027	648.34	-113.479	-667.343
1.556	0.669	0.298	-80.751	624.613	-127.155	-656.341
1.68	0.956	0.279	-52.647	430.999	-92.488	-457.506
1.765	1.02	0.332	-67.289	480.96	-88.368	-506.099
1.715	0.565	0.269	-72.22	547.978	-109.043	-570.184
1.452	0.958	0.262	-80.138	570.334	-101.874	-608.458
1.812	0.597	0.358	-60.537	471.101	-96.133	-492.899
1.811	0.939	0.384	-89.585	670.454	-129.966	-708.366
1.85	0.691	0.241	-88.087	605.878	-109.887	-619.424
1.793	0.881	0.281	-66.951	515.673	-104.376	-539.714
1.6	1.173	0.266	-94.84	737.95	-146.949	-791.402
1.72	0.826	0.279	-64.126	482.913	-92.856	-509.795
1.791	0.949	0.345	-71.885	498.602	-88.076	-521.686
1.545	0.969	0.239	-61.085	474.942	-96.689	-502.975
1.56	0.708	0.201	-75.034	567.195	-114.642	-591.018
1.759	0.88	0.374	-89.394	639.043	-119.542	-666.235
1.686	0.619	0.335	-71.372	519.981	-99.394	-541.687
1.515	0.727	0.198	-57.273	530.824	-127.346	-564.002
1.724	1.026	0.351	-65.206	539.676	-115.423	-575.453
1.863	0.717	0.257	-75.294	541.602	-102.948	-558.068
1.708	0.956	0.24	-47.14	397.771	-87.845	-421.894
1.828	1.036	0.21	-55.096	456.127	-99.9	-480.288
1.576	0.85	0.292	-67.839	523.848	-106.405	-551.625
1.81	0.75	0.297	-66.952	476.878	-88.454	-496.021
1.688	0.836	0.31	-74.99	580.272	-119.74	-607.519
1.872	0.644	0.312	-56.849	468.748	-103.318	-486.794
1.69	0.824	0.348	-74.36	568.028	-115.183	-594.748
1.788	1.006	0.437	-61.228	499.531	-106.016	-532.035
1.735	0.985	0.335	-70.565	548.099	-111.025	-579.871
1.669	0.628	0.183	-56.199	437.629	-92.103	-451.875
1.514	0.897	0.247	-87.558	667.693	-133.435	-705.663
1.583	0.902	0.298	-44.072	400.35	-94.025	-428.618
1.685	0.836	0.331	-71.447	538.436	-105.713	-566.341
1.918	0.968	0.355	-71.965	548.054	-108.691	-576.451
1.675	0.939	0.238	-55.728	462.683	-103.087	-485.037
1.636	0.9	0.373	-52.616	414.496	-83.844	-441.897
1.569	0.659	0.298	-55.979	429.707	-87.218	-451.121
1.777	0.842	0.437	-82.835	632.005	-126.557	-663.676
1.765	0.838	0.247	-56.569	459.131	-98.716	-482.015
1.579	0.957	0.227	-75.63	568.74	-113.994	-596.716
1.784	0.87	0.297	-82.068	625.83	-125.666	-654.394
1.986	0.829	0.33	-129.762	810.247	-126.386	-825.687
1.726	1.001	0.301	-56.447	463.441	-101.057	-489.262
1.528	1.105	0.355	-80.728	597.223	-114.628	-634.724
2.003	0.71	0.24	-78.722	546.903	-100.933	-557.506
1.695	0.811	0.224	-48.236	422.392	-96.507	-446.499
1.635	0.701	0.231	-35.253	398.673	-107.439	-427.542
1.869	0.682	0.308	-64.71	515.502	-108.618	-536.268

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.729	0.862	0.268	-58.357	468.151	-98.91	-492.377
1.734	0.632	0.259	-70.948	550.923	-113.671	-573.256
1.646	1.063	0.272	-78.494	610.112	-121.685	-652.245
1.758	1.032	0.387	-59.337	494.409	-103.828	-533.255
1.713	0.764	0.204	-58.714	474.321	-101.676	-496.465
1.868	0.626	0.257	-63.709	469.195	-91.166	-484.726
1.642	1.151	0.288	-70.646	526.339	-100.978	-560.861
1.862	0.83	0.313	-57.869	462.384	-96.461	-487.365
1.843	0.886	0.305	-63.196	510.055	-108.212	-535.665
1.601	0.981	0.312	-65.005	542.076	-117.923	-577.536
1.783	0.821	0.35	-79.534	608.808	-121.934	-638.34
1.776	0.903	0.357	-61.613	489.845	-102.405	-517.351
1.828	0.874	0.315	-106.456	695.178	-115.411	-716.932
1.729	0.907	0.324	-48.729	459.936	-111.182	-490.345
1.783	0.914	0.296	-66.727	503.755	-99.47	-528.954
1.756	0.81	0.282	-84.932	643.017	-127.467	-673.368
1.923	1.045	0.327	-64.48	493.94	-98.971	-519.88
1.68	0.668	0.229	-67.809	544.771	-118.361	-565.333
1.794	1.114	0.355	-65.2	497.868	-99.282	-526.921
1.845	0	0.243	-71.104	492.271	-91.137	-495.521
1.844	0.728	0.297	-72.966	518.343	-94.944	-539.847
1.603	1.193	0.278	-88.042	649.159	-123.55	-689.235
1.682	0.647	0.316	-56.179	460.208	-100.815	-480.259
1.858	0.81	0.34	-48.721	399.866	-86.647	-418.959
1.71	0.589	0.301	-67.131	534.214	-112.313	-557.139
1.808	0.917	0.339	-51.123	473.626	-111.499	-506.823
1.762	0.991	0.335	-60.025	513.135	-113.066	-547.256
1.693	0.591	0.229	-67.795	534.264	-111.851	-556.178
1.376	1.076	0.26	-82.809	679.003	-144.093	-731.986
1.794	0.644	0.313	-65.046	523.861	-110.815	-548.185
1.746	0.355	0.24	-93.902	611.056	-102.989	-619.135
1.896	0.861	0.312	-54.856	473.518	-107.202	-497.168
1.815	0.79	0.296	-68.714	523.668	-104.858	-546.355
1.615	0.577	0.208	-71.179	555.783	-115.13	-579.036
1.748	0.91	0.294	-64.19	501.557	-103.202	-527.965
1.685	0.579	0.315	-88.203	685.525	-141.541	-715.746
1.718	0.872	0.339	-85.904	576.5	-98.764	-598.178
1.638	0.795	0.291	-60.463	441.779	-84.461	-462.248
1.721	0.71	0.238	-58.95	480.033	-105.996	-496.87
1.712	0.681	0.252	-69.709	522.456	-103.389	-544.232
1.601	0.891	0.238	-58.67	475.367	-100.624	-504.157
1.721	0.788	0.245	-59.281	487.588	-106.622	-511.67
1.711	0.849	0.271	-76.312	545.247	-101.881	-567.943
1.846	0.869	0.234	-74.511	575.633	-118.85	-598.601
1.512	0.77	0.249	-60.257	510.282	-115.244	-536.693
1.595	0.824	0.27	-43.251	419.624	-104.071	-447.293
1.559	0.476	0.262	-78.123	570.709	-107.646	-596.531
1.911	0.578	0.298	-57.477	456.675	-96.903	-472.531
1.804	0.511	0.245	-76.908	554.285	-105.667	-568.82
1.656	0.981	0.378	-74.028	519.935	-91.227	-552.465
1.776	0.749	0.271	-65.978	506.708	-104.172	-526.236
1.73	0.645	0.263	-55.237	422.271	-85.776	-439.136
1.79	0.917	0.315	-59.992	479.821	-98.999	-509.918
1.793	0.772	0.314	-81.069	591.755	-113.8	-614.949

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.739	0.797	0.211	-62.844	496.896	-106.328	-515.638
1.818	1.115	0.316	-59.546	446.39	-85.132	-474.558
1.664	1.074	0.226	-116.388	767.598	-126.6	-802.583
1.732	0.906	0.312	-61.625	492.153	-102.426	-520.897
1.774	0.756	0.29	-72.243	546.466	-107.496	-572.396
1.762	0.891	0.35	-64.48	482.285	-93.745	-508.124
1.608	0.72	0.307	-38.117	420.094	-109.743	-456.246
1.727	0.815	0.286	-61.145	477.868	-99.098	-499.939
1.678	0.941	0.346	-60.989	481.945	-99.535	-510.366
1.811	0.903	0.255	-62.279	465.361	-90.805	-486.279
1.655	0.978	0.249	-71.075	530.994	-104.546	-557.34
1.673	0.925	0.204	-41.698	396.086	-98.714	-417.32
1.878	0.936	0.357	-77.624	586.975	-113.293	-622.228
1.999	0.738	0.365	-68.222	503.266	-95.779	-525.092
1.836	0.765	0.298	-75.348	566.309	-113.665	-587.167
1.637	0.812	0.249	-74.02	590.559	-123.926	-622.583
1.795	0.92	0.429	-70.589	540.782	-107.183	-572.048
1.859	0.684	0.312	-70.898	555.619	-113.912	-580.438
1.575	0.7	0.27	-54.99	446.939	-97.57	-466.732
1.714	0.844	0.318	-75.165	570.949	-115.443	-596.586
1.753	0.877	0.329	-80.303	629.851	-129.684	-663.031
1.692	0.77	0.277	-65.615	513.181	-106.533	-536.715
1.682	0.793	0.237	-56.714	525.936	-124.918	-558.881
1.566	0.73	0.219	-60.233	476.396	-100.683	-498.051
1.709	0.925	0.394	-80.965	576.607	-106.059	-605.356
1.815	0.931	0.354	-59.668	471.398	-98.032	-496.082
1.586	0.896	0.284	-53.496	437.803	-94.56	-463.172
1.611	0.749	0.297	-52.82	440.391	-95.511	-466.55
1.811	0.528	0.239	-50.493	424.892	-94.206	-442.714
1.846	0.709	0.333	-77.787	543.556	-97.523	-563.828
1.717	0.755	0.344	-58.06	463.619	-96.329	-490.368
1.718	0.629	0.312	-62.327	511.403	-109.283	-538.099
1.717	0.752	0.332	-71.833	538.771	-105.715	-562.718
1.59	0.858	0.382	-73.488	547.87	-104.136	-582.535
1.633	0.649	0.259	-71.75	552.381	-112.973	-575.916
1.68	0.921	0.321	-49.52	404.106	-86.286	-427.996
1.558	0.814	0.339	-67.795	522.305	-106.552	-550.049
1.654	0.854	0.298	-62.557	466.023	-89.994	-490.713
1.61	0.724	0.188	-73.965	557.007	-112.606	-577.986
1.496	1.081	0.252	-55.368	475.317	-106.285	-509.205
1.709	0.679	0.242	-79.155	555.806	-102.845	-573.893
1.578	0.647	0.333	-108.214	784.767	-148.942	-820.044
1.591	0.749	0.207	-64.796	498.834	-100.831	-522.739
1.626	0.9	0.203	-86.242	642.615	-125.843	-673.965
1.894	0.826	0.347	-93.915	641.704	-113.617	-662.793
1.515	0.961	0.249	-50.651	428.348	-93.768	-459.055
1.581	0.846	0.299	-60.847	488.81	-100.982	-520.946
1.696	0.974	0.301	-76.685	570.191	-110.069	-602.158
1.772	0.862	0.265	-66.911	512.554	-105.14	-533.848
1.695	1.052	0.328	-75.126	571.857	-111.117	-609.983
1.688	0.542	0.272	-65.931	509.652	-105.846	-526.866
1.781	0.607	0.273	-72.288	541.386	-106.182	-563.982
1.448	1.035	0.3	-82.181	590.329	-106.958	-630.585
1.737	0.793	0.285	-74.924	544.18	-102.733	-568.633

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.858	0.583	0.284	-47.356	435.694	-102.507	-459.195
1.633	0.978	0.183	-63.392	505.482	-106.694	-532.149
1.552	0.743	0.183	-62.237	493.696	-105.38	-513.816
1.597	0.952	0.236	-66.931	511.525	-101.957	-541.091
1.904	0.871	0.343	-88.158	604.513	-104.979	-630.511
1.979	0.921	0.443	-118.378	718.233	-99.994	-747.144
1.685	0.78	0.351	-63.325	530.473	-115.489	-562.516
1.817	1.22	0.315	-71.517	552.869	-110.883	-587.595
2.051	0.758	0.308	-71.405	503.924	-92.58	-520.391
1.785	0.785	0.27	-55.351	491.071	-115.331	-513.734
1.67	0.693	0.301	-99.78	651.408	-110.107	-666.885
1.791	0.895	0.317	-61.373	501.818	-107.05	-530.734
1.76	0.73	0.273	-60.767	482.256	-100.739	-504.741
1.762	0.496	0.259	-70.589	526.2	-103.975	-543.586
1.644	0.956	0.211	-67.94	528.002	-106.72	-558.748
1.765	0.736	0.316	-69.138	528.135	-106.253	-551.093
1.664	0.602	0.252	-76	586.232	-121.21	-607.087
1.768	0.765	0.297	-61.85	467.239	-93.841	-485.616
1.952	0.551	0.302	-46.172	391.426	-88.945	-403.863
1.872	0.708	0.291	-88.959	681.501	-140.005	-705.003
1.88	1.022	0.32	-79.103	546.972	-95.866	-572.017
1.796	0.861	0.382	-67.08	522.525	-105.834	-551.717
1.65	0.76	0.243	-63.079	495.102	-103.608	-516.551
1.706	0.866	0.353	-78.213	572.883	-107.735	-604.157
1.761	0.847	0.323	-80.425	587.994	-111.958	-615.483
1.675	0.929	0.352	-79.767	613.197	-121.566	-651.764
1.624	0.868	0.233	-53.59	442.132	-96.536	-465.717
1.557	0.893	0.217	-71.343	567.169	-120.73	-594.799
1.885	0.972	0.34	-64.27	486.314	-96.323	-510.048
1.744	0.67	0.328	-65.908	498.236	-98.278	-521.04
1.767	1.009	0.37	-64.848	481.975	-91.048	-512.709
1.92	1.069	0.425	-111.661	717.112	-108.804	-755.375
1.667	0.767	0.158	-36.104	351.4	-89.058	-369.137
1.73	0.881	0.374	-74.748	570.087	-112.389	-602.167
1.772	0.623	0.317	-69.883	508.221	-96.248	-528.175
1.725	1.007	0.294	-60.826	466.016	-94.863	-489.338
1.596	0.805	0.275	-39.079	363.864	-86.329	-389.506
1.678	0.939	0.235	-34.315	381.484	-101.545	-412.022
1.807	0.696	0.263	-77.063	533.646	-97.578	-548.495
1.73	0.852	0.332	-68.206	528.642	-106.647	-557.586
1.769	1.025	0.329	-53.32	471.725	-109.54	-499.991
1.858	0.925	0.294	-84.424	568.884	-97.972	-589.04
1.677	0.935	0.229	-89.746	648.965	-121.245	-681.235
1.849	0.826	0.28	-79.796	583.994	-112.747	-604.265
1.792	0.965	0.445	-94.065	619.634	-99.053	-651.941
1.721	0.922	0.274	-59.386	479.257	-101.379	-506.505
1.632	1.014	0.292	-48.801	411.919	-92.09	-436.715
1.737	0.773	0.296	-75.522	542.492	-102.27	-564.644
1.616	0.883	0.272	-61.127	469.311	-93.987	-496.378
1.822	1.041	0.308	-69.393	533.194	-105.104	-564.9
1.479	0.817	0.219	-62.092	483.301	-100.374	-506.511
1.806	0.718	0.303	-62.203	474.667	-96.036	-493.789
1.784	0.779	0.362	-71.462	522.15	-98.826	-546.878
1.562	0.766	0.203	-53.356	464.217	-106.895	-488.878

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.726	0.799	0.274	-73.727	554.425	-111.26	-576.333
1.739	0.763	0.292	-93.133	679.783	-129.769	-708.986
1.541	0.72	0.279	-83.443	586.194	-104.122	-616.531
1.702	1.022	0.306	-57.534	457.922	-95.672	-484.745
1.833	0.861	0.284	-75.274	544.203	-102.806	-567.53
1.617	0.963	0.266	-75.061	570.031	-111.995	-603.468
1.618	0.577	0.214	-64.964	501.083	-102.32	-521.666
1.849	0.706	0.222	-52.867	426.976	-91.807	-443.449
1.688	0.739	0.294	-64.964	472.252	-90.071	-491.517
1.657	0.874	0.32	-36.092	389.775	-102.506	-420.006
1.665	0.892	0.296	-39.896	410.95	-105.868	-439.911
1.717	0.965	0.287	-59.55	470.408	-98.857	-494.455
1.72	0.883	0.313	-87.856	585.609	-99.902	-607.524
1.503	0.772	0.148	-62.39	494.672	-102.334	-522.539
1.896	0.706	0.275	-106.41	657.591	-100.61	-668.759
1.846	0.647	0.278	-65.073	529.699	-113.775	-553.283
1.748	0.892	0.312	-65.608	496.529	-97.313	-522.807
1.795	0.796	0.299	-77.849	552.106	-102.425	-573.281
1.757	0.707	0.302	-60.474	469.074	-96.394	-489.888
1.597	1.027	0.296	-132.587	784.583	-105.496	-817.523
1.835	0.673	0.326	-78.531	596.119	-118.45	-622.625
1.756	0.679	0.308	-81.27	568.485	-103.234	-589.478
1.719	1.059	0.249	-92.957	677.905	-124.047	-721.771
1.634	0.728	0.333	-47.225	441.376	-105.906	-469.106
1.743	0.769	0.254	-63.899	500.44	-104.498	-520.998
1.639	0.929	0.301	-47.633	431.032	-100.798	-459.551
1.654	1.035	0.145	-58.989	465.017	-94.629	-494.7
1.856	0.625	0.289	-105.997	702.138	-120.293	-717.518
1.685	0.845	0.312	-64.621	502.331	-103.381	-527.795
1.811	0.817	0.302	-90.892	656.491	-124.971	-680.264
1.477	0.859	0.226	-42.336	395.763	-96.513	-420.96
1.853	0.624	0.266	-67.712	517.936	-106.396	-532.497
1.657	0.907	0.321	-71.474	528.25	-100.202	-559.027
1.488	0.545	0.244	-58.963	505.969	-116.185	-529.303
1.587	0.837	0.258	-74.176	580.669	-120.007	-611.14
1.791	0.702	0.307	-69.439	535.322	-109.631	-556.681
1.722	0.925	0.378	-64.712	509.305	-103.655	-541.55
1.579	0.776	0.271	-67.275	559.171	-122.415	-590.585
1.552	1.14	0.301	-64.134	513.069	-105.819	-551.247
1.757	0.789	0.278	-61.35	494.69	-106.16	-517.148
1.779	0.869	0.335	-60.281	481.872	-101.502	-507.331
1.826	0.886	0.35	-92.624	702.649	-139.222	-738.138
1.788	0.73	0.278	-57.504	463.453	-98.111	-484.9
1.712	1.004	0.282	-77.238	572.762	-108.254	-606.669
1.904	0.755	0.33	-79.4	577.623	-108.535	-602.481
1.658	0.903	0.395	-74.392	510.689	-86.818	-541.557
1.643	0.701	0.179	-55.974	466.652	-104.793	-485.265
1.788	0.878	0.151	-76.225	581.61	-120.977	-600.028
1.782	0.656	0.174	-60.2	457.943	-93.257	-472.988
1.458	0.993	0.177	-75.804	603.153	-126.336	-640.309
1.575	0.949	0.281	-70.511	514.513	-96.127	-544.915
1.695	0.956	0.3	-76.336	606.518	-125.905	-641.352
1.762	0.689	0.322	-56.068	464.651	-101.55	-487.537
1.748	0.666	0.344	-70.791	525.015	-100.132	-551.404

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.782	0.744	0.332	-74.744	565.462	-113.129	-588.916
1.883	0.779	0.292	-64.512	517.818	-109.734	-540.317
1.787	0.917	0.33	-71.413	571.45	-120.209	-601.536
1.525	0.76	0.339	-82.118	620.016	-121.031	-656.54
1.646	0.697	0.267	-71.829	553.753	-113.004	-578.678
1.882	0.634	0.22	-68.937	536.295	-114.629	-548.219
1.804	0.882	0.396	-75.565	586.24	-117.239	-621.088
1.559	0.797	0.238	-62.273	487.053	-98.947	-516.351
1.738	0.702	0.228	-57.821	501.95	-117.157	-522.408
1.466	0.989	0.275	-74.226	576.009	-112.676	-622.395
1.627	0.874	0.219	-51.793	437.689	-97.925	-461.309
1.701	0.982	0.342	-82.416	588.351	-108.018	-618.507
1.773	0.736	0.31	-61.444	474.18	-96.54	-495.49
1.778	0.577	0.28	-57.531	467.034	-101.148	-484.863
1.827	0.61	0.244	-60.848	484.878	-105.398	-498.171
1.813	1.107	0.251	-81.058	581.57	-106.857	-611.349
1.82	0.79	0.241	-70.169	580.81	-129.864	-602.111
1.903	1.012	0.397	-84.1	614.234	-115.211	-646.757
1.703	1.023	0.34	-78.101	579.92	-108.404	-618.504
1.61	0.943	0.302	-57.372	482.778	-105.908	-514.365
1.68	0.839	0.234	-61.291	490.002	-104.086	-512.83
1.64	0.47	0.197	-63.158	483.446	-99.482	-498.789
1.82	0.686	0.197	-71.075	554.058	-115.314	-572.783
1.791	0.868	0.262	-79.855	585.931	-112.076	-612.17
1.666	1.053	0.359	-80.635	619.588	-123.709	-658.935
1.587	1.151	0.187	-72.207	535.377	-102.406	-568.866
1.903	0.787	0.348	-66.836	513.792	-103.153	-536.659
1.752	0.98	0.303	-54.311	436.748	-91.793	-462.209
1.576	0.973	0.348	-60.308	518.362	-115.641	-554.074
1.796	0.815	0.3	-67.87	500.928	-96.886	-522.714
1.61	0.738	0.256	-65.107	523.225	-112.137	-547.171
1.732	0.584	0.286	-62.813	483.988	-99.216	-502.596
1.648	0.738	0.279	-64.61	484.799	-96.418	-506.246
1.948	0.733	0.363	-98.852	686.824	-122.863	-711.416
1.626	1.078	0.306	-75.673	557.425	-104.642	-594.613
1.757	0.704	0.251	-70.961	539.345	-109.414	-558.558
1.697	0.586	0.284	-69.032	543.85	-113.332	-565.949
1.801	0.591	0.239	-60.951	490.038	-104.796	-508.69
1.617	0.881	0.319	-57.773	443.371	-87.299	-472.213
1.692	0.837	0.286	-73.232	535.01	-101.235	-560.076
1.666	0.673	0.186	-85.525	647.295	-130.209	-673.399
1.483	0.974	0.262	-72.882	583.349	-122.107	-621.663
1.589	1.066	0.299	-64.499	513.751	-107.497	-546.721
1.575	0.629	0.274	-45.472	425.039	-102.947	-449.464
1.624	0.822	0.184	-71.483	525.797	-102.838	-546.887
1.788	0.962	0.331	-64.212	475.854	-91.641	-499.48
1.677	0.728	0.319	-75.616	578.452	-116.599	-605.558
1.961	0.781	0.305	-64.235	484.472	-97.757	-499.957
1.428	0.9	0.253	-54.867	454.798	-98.063	-485.775
1.86	0.754	0.31	-66.975	499.495	-98.864	-518.152
1.829	0.82	0.314	-85.103	644.795	-129.672	-671.642
1.694	1.19	0.215	-111.35	704.688	-109.526	-733.582
1.7	0.733	0.275	-67.018	515.65	-106.265	-536.088
1.704	0.695	0.289	-68.999	520.665	-102.68	-543.93

α_6 (B_2O_3)	α_1 (Li_2O)	α_3 (CaO)	β0	β1	β2	β3
1.605	0.845	0.228	-82.187	592.908	-112.185	-618.095
1.721	0.739	0.294	-69.486	517.683	-103.106	-537.442
1.348	1.039	0.295	-80.246	612.241	-117.1	-663.644
1.588	0.669	0.313	-54.024	435.392	-93.914	-455.495
1.839	0.59	0.209	-59.081	466.484	-97.404	-483.269
1.758	0.628	0.272	-82.51	626.034	-126.993	-647.731
1.7	0.681	0.294	-53.598	447.47	-96.981	-472.766
1.567	1.033	0.384	-30.994	389.525	-109.562	-430.354

Table A.7. Variance covariance matrix for HLW Viscosity

Term	Al_2O_3	B_2O_3	CaO	Cr_2O_3	F	LN_2O_3	Li_2O	MnO	Na_2O	NiO	P_2O_5	SiO_2	SrO	TiO_2	UO_3	ZrO_2	Others
Al_2O_3	0.050	-0.029	-0.022	-0.142	-0.082	0.000	-0.046	-0.001	-0.021	0.042	-0.053	0.005	-0.012	0.075	-0.002	0.026	0.009
B_2O_3	-0.029	0.060	0.000	0.052	-0.097	0.060	0.012	0.015	0.005	0.009	0.001	-0.011	0.009	-0.090	0.005	-0.014	-0.006
CaO	-0.022	0.000	0.137	-0.010	-0.308	0.006	0.024	0.011	0.010	-0.008	0.024	-0.005	0.010	0.028	0.006	-0.009	0.000
Cr_2O_3	-0.142	0.052	-0.010	9.590	-3.040	-0.019	0.057	-0.297	-0.022	-0.362	-0.520	-0.013	0.060	1.322	0.032	-0.011	-0.006
F	-0.082	-0.097	-0.308	-3.040	15.635	-0.703	-0.093	0.129	0.003	-0.862	-0.483	0.063	-0.012	-0.167	-0.300	-0.029	-0.046
LN_2O_3	0.000	0.060	0.006	-0.019	-0.703	0.613	0.019	0.083	0.013	-0.272	0.020	-0.032	0.027	0.116	-0.027	-0.019	0.013
Li_2O	-0.046	0.012	0.024	0.057	-0.093	0.019	0.389	0.013	0.054	0.018	0.049	-0.040	-0.002	-0.149	0.024	-0.042	0.001
MnO	-0.001	0.015	0.011	-0.297	0.129	0.083	0.013	0.406	-0.005	-0.100	0.052	-0.008	-0.104	0.045	-0.012	-0.016	-0.020
Na_2O	-0.021	0.005	0.010	-0.022	0.003	0.013	0.054	-0.005	0.057	-0.047	0.010	-0.014	0.009	-0.009	0.001	-0.020	-0.005
NiO	0.042	0.009	-0.008	-0.362	-0.862	-0.272	0.018	-0.100	-0.047	3.240	-0.460	-0.012	-0.003	0.092	0.100	-0.015	-0.013
P_2O_5	-0.053	0.001	0.024	-0.520	-0.483	0.020	0.049	0.052	0.010	-0.460	1.102	0.007	0.053	-0.634	0.005	-0.026	-0.047
SiO_2	0.005	-0.011	-0.005	-0.013	0.063	-0.032	-0.040	-0.008	-0.014	-0.012	0.007	0.012	-0.001	0.027	0.003	-0.002	-0.008
SrO	-0.012	0.009	0.010	0.060	-0.012	0.027	-0.002	-0.104	0.009	-0.003	0.053	-0.001	0.312	0.273	-0.116	-0.018	-0.016
TiO_2	0.075	-0.090	0.028	1.322	-0.167	0.116	-0.149	0.045	-0.009	0.092	-0.634	0.027	0.273	11.097	-0.072	0.196	-0.228
UO_3	-0.002	0.005	0.006	0.032	-0.300	-0.027	0.024	-0.012	0.001	0.100	0.005	0.003	-0.116	-0.072	0.466	-0.050	-0.020
ZrO_2	0.026	-0.014	-0.009	-0.011	-0.029	-0.019	-0.042	-0.016	-0.020	-0.015	-0.026	-0.002	-0.018	0.196	-0.050	0.132	0.011
Others	0.009	-0.006	0.000	-0.006	-0.046	0.013	0.001	-0.020	-0.005	-0.013	-0.047	-0.008	-0.016	-0.228	-0.020	0.011	0.037

Table A.8. Variance covariance matrix for HLW Sulfate

Term	Al_2O_3	B_2O_3	CaO	Cl	Fe_2O_3	Li_2O	Na_2O	SiO_2	V_2O_5	ZrO_2	Others
Al_2O_3	0.367	-0.323	-0.118	2.196	0.130	-0.416	-0.173	0.081	0.136	0.119	-0.089
B_2O_3	-0.323	0.518	0.194	0.850	-0.195	-0.348	-0.016	-0.034	0.192	0.139	0.073
CaO	-0.118	0.194	0.636	10.628	-0.002	-0.087	-0.007	-0.059	0.099	0.065	-0.056
Cl	2.196	0.850	10.628	1352.916	-13.047	-10.925	6.204	1.304	12.125	11.862	-14.486
Fe_2O_3	0.130	-0.195	-0.002	-13.047	0.584	0.455	-0.148	-0.088	0.217	-0.376	0.166
Li_2O	-0.416	-0.348	-0.087	-10.925	0.455	5.357	1.111	-0.587	-1.687	-0.949	0.077
Na_2O	-0.173	-0.016	-0.007	6.204	-0.148	1.111	0.680	-0.172	-0.313	-0.104	-0.162
SiO_2	0.081	-0.034	-0.059	1.304	-0.088	-0.587	-0.172	0.113	0.021	0.072	-0.037
V_2O_5	0.136	0.192	0.099	12.125	0.217	-1.687	-0.313	0.021	4.207	0.548	-0.066
ZrO_2	0.119	0.139	0.065	11.862	-0.376	-0.949	-0.104	0.072	0.548	1.476	-0.182
Others	-0.089	0.073	-0.056	-14.486	0.166	0.077	-0.162	-0.037	-0.066	-0.182	0.312

Table A.9. Variance covariance matrix for LAW PCT

Term	Al_2O_3	B_2O_3	CaO	K_2O	Li_2O	MgO	Na_2O	P_2O_5	SiO_2	SnO_2	TiO_2	ZrO_2	Others	$B_2O_3\times B_2O_3$	$K_2O\times K_2O$	$Al_2O_3\times Li_2O$	$CaO\times Li_2O$	$Li_2O\times Li_2O$	$B_2O_3\times Na_2O$	$K_2O\times Na_2O$	$Li_2O\times Na_2O$	$Na_2O\times Na_2O$
Al_2O_3	1.013	-1.878	0.029	-0.770	-1.828	0.145	-1.113	0.230	0.225	0.230	0.509	0.126	0.164	8.083	-2.792	-20.321	3.973	18.004	1.894	6.609	15.842	2.058
B_2O_3	-1.878	43.732	-1.333	4.584	-16.823	-1.918	-2.995	-0.700	-2.186	-0.892	-3.374	-2.930	-1.659	-205.279	-8.583	0.909	-11.416	144.499	-29.551	-32.885	57.039	9.398
CaO	0.029	-1.333	0.643	-0.696	-2.126	0.164	-1.236	0.212	0.195	-0.012	0.584	0.315	0.166	5.506	2.965	5.268	-11.690	17.528	2.093	4.922	12.420	3.266
K_2O	-0.770	4.584	-0.696	16.850	2.239	-0.335	2.034	0.091	-0.361	-0.326	-3.111	-0.308	-0.801	-23.286	-188.420	-5.355	5.967	-1.464	-3.366	-41.545	-21.732	-5.720
Li_2O	-1.828	-16.823	-2.126	2.239	119.479	-3.045	32.741	-1.476	-3.577	-0.853	-2.707	-3.586	-2.344	71.149	-73.657	-98.258	-56.501	-868.660	-4.015	-2.388	-496.237	-84.031
MgO	0.145	-1.918	0.164	-0.335	-3.045	1.551	-1.239	-0.006	0.252	0.042	-0.001	0.332	0.133	7.525	-2.234	1.689	3.631	15.484	4.071	3.680	15.092	2.637
Na_2O	-1.113	-2.995	-1.236	2.034	32.741	-1.239	16.396	-1.496	-1.714	-1.015	-2.073	-1.643	-1.319	22.809	-10.069	-21.228	-9.123	-170.604	-21.903	-19.918	-172.718	-41.097
P_2O_5	0.230	-0.700	0.212	0.091	-1.476	-0.006	-1.496	4.717	0.152	-0.021	0.454	0.302	0.074	0.419	-9.639	-1.736	1.216	9.018	4.736	4.822	10.324	3.354
SiO_2	0.225	-2.186	0.195	-0.361	-3.577	0.252	-1.714	0.152	0.388	0.150	0.248	0.328	0.170	8.692	2.024	2.860	1.426	20.205	4.507	2.856	18.164	3.900
SnO_2	0.230	-0.892	-0.012	-0.326	-0.853	0.042	-1.015	-0.021	0.150	1.717	0.700	0.049	0.184	2.937	-13.892	-5.292	10.158	-7.227	4.190	4.932	4.261	1.544
TiO_2	0.509	-3.374	0.584	-3.111	-2.707	-0.001	-2.073	0.454	0.248	0.700	4.661	0.853	0.112	19.031	23.306	4.040	1.856	1.648	1.840	12.511	21.653	6.343
ZrO_2	0.126	-2.930	0.315	-0.308	-3.586	0.332	-1.643	0.302	0.328	0.049	0.853	1.536	0.286	12.508	-4.379	6.631	-0.370	18.409	4.996	3.730	17.297	3.407
Others	0.164	-1.659	0.166	-0.801	-2.344	0.133	-1.319	0.074	0.170	0.184	0.112	0.286	0.587	8.338	4.200	2.760	3.027	6.130	1.760	5.020	13.772	3.676
$B_2O_3\times B_2O_3$	8.083	-205.279	5.506	-23.286	71.149	7.525	22.809	0.419	8.692	2.937	19.031	12.508	8.338	1059.776	133.488	36.004	93.718	-713.695	31.511	137.960	-240.895	-40.476
$K_2O\times K_2O$	-2.792	-8.583	2.965	-188.420	-73.657	-2.234	-10.069	-9.639	2.024	-13.892	23.306	-4.379	4.200	133.488	4116.753	374.910	-42.274	307.374	-69.922	-131.780	337.169	69.399
$Al_2O_3\times Li_2O$	-20.321	0.909	5.268	-5.355	-98.258	1.689	-21.228	-1.736	2.860	-5.292	4.040	6.631	2.760	36.004	374.910	1185.957	-36.162	78.082	7.946	-70.077	128.766	82.532
$CaO\times Li_2O$	3.973	-11.416	-11.690	5.967	-56.501	3.631	-9.123	1.216	1.426	10.158	1.856	-0.370	3.027	93.718	-42.274	-36.162	703.693	-77.100	11.620	-24.359	179.508	24.134
$Li_2O\times Li_2O$	18.004	144.499	17.528	-1.464	-868.660	15.484	-170.604	9.018	20.205	-7.227	1.648	18.409	6.130	-713.695	307.374	78.082	-77.100	9033.259	-5.957	-80.419	3215.376	389.557
$B_2O_3\times Na_2O$	1.894	-29.551	2.093	-3.366	-4.015	4.071	-21.903	4.736	4.507	4.190	1.840	4.996	1.760	31.511	-69.922	7.946	11.620	-5.957	174.187	55.109	48.683	23.286
$K_2O\times Na_2O$	6.609	-32.885	4.922	-41.545	-2.388	3.680	-19.918	4.822	2.856	4.932	12.511	3.730	5.020	137.960	-131.780	-70.077	-24.359	-80.419	55.109	318.414	130.617	44.618
$Li_2O\times Na_2O$	15.842	57.039	12.420	-21.732	-496.237	15.092	-172.718	10.324	18.164	4.261	21.653	17.297	13.772	-240.895	337.169	128.766	179.508	3215.376	48.683	130.617	2463.752	455.719
$Na_2O\times Na_2O$	2.058	9.398	3.266	-5.720	-84.031	2.637	-41.097	3.354	3.900	1.544	6.343	3.407	3.676	-40.476	69.399	82.532	24.134	389.557	23.286	44.618	455.719	114.386

Table A.10. Variance covariance matrix for LAW VHT

Term	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	Li_2O	Na_2O	SiO_2	SnO_2	TiO_2	ZrO_2	Others	CaO·CaO	$Li_2O \cdot Li_2O$	$K_2O \cdot Na_2O$	$Li_2O \cdot Na_2O$	$CaO \cdot SiO_2$	$K_2O \cdot K_2O$	$Li_2O \cdot SiO_2$
Al_2O_3	12.746	0.717	-44.230	5.183	1.344	-113.697	-2.794	-2.544	6.346	9.709	2.318	2.947	52.426	485.601	-17.296	280.223	103.449	90.626	107.165
B_2O_3	0.717	10.804	-40.807	3.351	-6.163	0.816	0.844	-3.543	5.031	0.519	3.699	0.975	76.321	-102.487	24.771	-63.066	81.805	32.649	23.555
CaO	-44.230	-40.807	617.498	-37.925	-29.592	312.852	-24.581	38.237	-43.182	-28.746	-12.014	-29.643	-795.889	-1514.524	116.451	-626.993	-1368.016	-280.083	-349.151
Fe_2O_3	5.183	3.351	-37.925	12.907	-2.946	-60.692	0.104	-3.717	7.813	-7.885	5.458	3.207	70.259	157.710	1.496	119.081	83.080	86.574	81.063
K_2O	1.344	-6.163	-29.592	-2.946	414.284	-676.601	-3.878	1.107	6.921	-33.011	10.215	0.378	3.334	2956.842	-1435.935	1635.399	95.804	-2562.025	694.912
Li_2O	-113.697	0.816	312.852	-60.692	-676.601	5618.445	66.341	20.844	-95.659	-150.804	-131.107	-71.612	-1081.111	-26761.881	3310.805	-12174.931	-673.883	178.923	-6401.233
Na_2O	-2.794	0.844	-24.581	0.104	-3.878	66.341	10.316	-4.120	-2.805	3.097	-6.046	-1.016	47.683	-656.006	23.449	-246.026	45.487	71.573	34.983
SiO_2	-2.544	-3.543	38.237	-3.717	1.107	20.844	-4.120	4.451	-2.990	-6.681	-1.574	-2.421	-52.270	111.298	-23.053	24.855	-84.717	-5.993	-82.258
SnO_2	6.346	5.031	-43.182	7.813	6.921	-95.659	-2.805	-2.990	24.829	10.163	4.776	2.651	88.206	203.569	-31.182	201.058	96.865	-53.258	105.113
TiO_2	9.709	0.519	-28.746	-7.885	-33.011	-150.804	3.097	-6.681	10.163	97.242	9.776	2.336	108.370	85.139	159.999	135.046	60.480	123.403	324.192
ZrO_2	2.318	3.699	-12.014	5.458	10.215	-131.107	-6.046	-1.574	4.776	9.776	23.459	3.287	70.999	480.686	-25.555	220.229	19.980	-143.365	162.848
Others	2.947	0.975	-29.643	3.207	0.378	-71.612	-1.016	-2.421	2.651	2.336	3.287	9.340	20.976	376.337	20.973	147.949	71.223	-48.571	72.778
CaO×CaO	52.426	76.321	-795.889	70.259	3.334	-1081.111	47.683	-52.270	88.206	108.370	70.999	20.976	4832.705	-6889.248	-160.396	131.261	759.346	1345.902	3164.818
$Li_2O \times Li_2O$	485.601	-102.487	-1514.524	157.710	2956.842	-26761.881	-656.006	111.298	203.569	85.139	480.686	376.337	-6889.248	282652.050	-14440.190	81168.356	6545.537	-7117.321	7483.857
$K_2O \times Na_2O$	-17.296	24.771	116.451	1.496	-1435.935	3310.805	23.449	-23.053	-31.182	159.999	-25.555	20.973	-160.396	-14440.190	8228.991	-9463.356	-318.559	-1617.293	-2859.521
$Li_2O \times Na_2O$	280.223	-63.066	-626.993	119.081	1635.399	-12174.931	-246.026	24.855	201.058	135.046	220.229	147.949	131.261	81168.356	-9463.356	40141.239	1899.236	3175.249	6950.847
$CaO \times SiO_2$	103.449	81.805	-1368.016	83.080	95.804	-673.883	45.487	-84.717	96.865	60.480	19.980	71.223	759.346	6545.537	-318.559	1899.236	3327.562	229.069	201.205
$K_2O \times K_2O$	90.626	32.649	-280.083	86.574	-2562.025	178.923	71.573	-5.993	-53.258	123.403	-143.365	-48.571	1345.902	-7117.321	-1617.293	3175.249	229.069	53642.927	-465.127
$Li_2O \times SiO_2$	107.165	23.555	-349.151	81.063	694.912	-6401.233	34.983	-82.258	105.113	324.192	162.848	72.778	3164.818	7483.857	-2859.521	6950.847	201.205	-465.127	12262.160

Table A.11. Variance covariance matrix for LAW K-3 Neck Corrosion

Term	Al_2O_3	B_2O_3	CaO	Cr_2O_3	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	P_2O_5	SiO_2	SnO_2	TiO_2	V_2O_5	ZnO	ZrO_2	Others	MgO×MgO	$Li_2O \times P_2O_5$	$Na_2O \times P_2O_5$	$SiO_2 \times TiO_2$	$Na_2O \times V_2O_5$	$V_2O_5 \times$ZnO	$SnO_2 \times$Others
Al_2O_3	1.221	-0.076	-0.082	-0.432	-0.073	0.075	-1.502	0.440	-0.656	-2.757	0.158	0.098	-4.742	-1.721	-0.812	0.314	-0.210	-19.572	31.342	15.318	11.589	-0.516	58.617	-13.609
B_2O_3	-0.076	1.634	-0.467	-1.029	0.271	0.002	1.278	0.725	0.138	2.296	-0.417	0.963	-5.864	1.702	-0.572	0.429	-1.142	-30.149	-49.941	-8.486	15.447	-6.467	5.696	-10.627
CaO	-0.082	-0.467	1.236	1.175	0.344	0.196	-1.160	-2.311	-0.047	-2.030	0.053	-0.500	3.213	-4.153	-0.378	0.171	-0.488	72.567	41.805	10.578	-5.992	12.383	31.957	61.119
Cr_2O_3	-0.432	-1.029	1.175	180.761	-0.767	-0.305	-5.593	9.739	-1.802	69.659	0.300	-45.505	32.021	-2.782	0.863	0.079	5.351	-212.958	-1323.156	-336.205	-58.112	58.465	-1015.350	2492.961
Fe_2O_3	-0.073	0.271	0.344	-0.767	1.186	-0.391	-0.148	-0.617	-0.031	0.060	-0.218	2.578	0.517	0.472	0.030	0.791	-0.417	8.466	-0.755	-2.979	-0.301	-1.819	33.108	-127.001
K_2O	0.075	0.002	0.196	-0.305	-0.391	2.108	1.849	1.052	0.259	4.698	-0.265	-5.018	-5.856	-3.661	-0.474	0.220	0.293	-12.704	-71.499	-23.250	15.266	13.324	22.216	445.272
Li_2O	-1.502	1.278	-1.160	-5.593	-0.148	1.849	14.460	5.020	3.130	47.110	-1.705	0.612	-18.963	-2.385	0.081	-0.687	0.359	-162.457	-816.760	-215.811	48.105	20.218	-95.077	-13.422
MgO	0.440	0.725	-2.311	9.739	-0.617	1.052	5.020	86.686	-0.888	4.598	-1.238	9.502	-15.994	-1.703	-4.967	1.202	5.059	-2274.683	-124.851	-34.090	36.928	11.249	40.756	-481.985
Na_2O	-0.656	0.138	-0.047	-1.802	-0.031	0.259	3.130	-0.888	1.022	9.533	-0.414	0.784	-4.854	1.612	0.502	-0.557	-0.020	40.549	-146.074	-45.412	12.234	-2.293	-47.241	-77.863
P_2O_5	-2.757	2.296	-2.030	69.659	0.060	4.698	47.110	4.598	9.533	1812.446	-5.886	-56.662	-122.566	17.484	6.576	-1.182	3.621	-679.942	-32061.469	-8471.361	313.660	-35.652	-651.416	5159.127
SiO_2	0.158	-0.417	0.053	0.300	-0.218	-0.265	-1.705	-1.238	-0.414	-5.886	0.412	-0.497	6.776	-1.564	-0.375	-0.290	0.008	27.046	94.924	26.834	-17.521	3.347	27.199	10.981
SnO_2	0.098	0.963	-0.500	-45.505	2.578	-5.018	0.612	9.502	0.784	-56.662	-0.497	80.005	-0.388	1.492	-1.509	-3.294	0.380	-129.183	1082.934	229.969	4.599	-20.404	578.491	-6561.121
TiO_2	-4.742	-5.864	3.213	32.021	0.517	-5.856	-18.963	-15.994	-4.854	-122.566	6.776	-0.388	520.421	-58.847	-2.967	-11.124	-1.491	599.431	2025.336	531.455	-1283.638	191.836	506.500	-245.139
V_2O_5	-1.721	1.702	-4.153	-2.782	0.472	-3.661	-2.385	-1.703	1.612	17.484	-1.564	1.492	-58.847	257.351	18.625	-2.686	3.743	154.743	-318.970	-64.224	131.245	-528.481	-5083.903	329.670
ZnO	-0.812	-0.572	-0.378	0.863	0.030	-0.474	0.081	-4.967	0.502	6.576	-0.375	-1.509	-2.967	18.625	8.062	-0.739	1.908	84.784	-31.510	-36.443	5.454	-27.096	-445.202	202.217
ZrO_2	0.314	0.429	0.171	0.079	0.791	0.220	-0.687	1.202	-0.557	-1.182	-0.290	-3.294	-11.124	-2.686	-0.739	4.107	-0.885	-54.482	-9.059	16.961	27.173	-4.968	115.730	182.968
Others	-0.210	-1.142	-0.488	5.351	-0.417	0.293	0.359	5.059	-0.020	3.621	0.008	0.380	-1.491	3.743	1.908	-0.885	5.645	-107.767	-50.172	-27.485	3.880	-2.301	-108.316	9.504
MgO×MgO	-19.572	-30.149	72.567	-212.958	8.466	-12.704	-162.457	-2274.683	40.549	-679.942	27.046	-129.183	599.431	154.743	84.784	-54.482	-107.767	69459.709	12166.362	3361.524	-1396.751	-1132.268	2754.270	124.032
$Li_2O \times P_2O_5$	31.342	-49.941	41.805	-1323.156	-0.755	-71.499	-816.760	-124.851	-146.074	-32061.469	94.924	1082.934	2025.336	-318.970	-31.510	-9.059	-50.172	12166.362	593929.474	148142.141	-5190.311	991.599	10515.689	-97200.545
$Na_2O \times P_2O_5$	15.318	-8.486	10.578	-336.205	-2.979	-23.250	-215.811	-34.090	-45.412	-8471.361	26.834	229.969	531.455	-64.224	-36.443	16.961	-27.485	3361.524	148142.141	40472.588	-1359.444	93.011	2031.022	-21807.393
$SiO_2 \times TiO_2$	11.589	15.447	-5.992	-58.112	-0.301	15.266	48.105	36.928	12.234	313.660	-17.521	4.599	-1283.638	131.245	5.454	27.173	3.880	-1396.751	-5190.311	-1359.444	3192.268	-446.287	-962.560	460.891
$Na_2O \times V_2O_5$	-0.516	-6.467	12.383	58.465	-1.819	13.324	20.218	11.249	-2.293	-35.652	3.347	-20.404	191.836	-528.481	-27.096	-4.968	-2.301	-1132.268	991.599	93.011	-446.287	1902.362	4583.929	1098.163
$V_2O_5 \times$ZnO	58.617	5.696	31.957	-1015.350	33.108	22.216	-95.077	40.756	-47.241	-651.416	27.199	578.491	506.500	-5083.903	-445.202	115.730	-108.316	2754.270	10515.689	2031.022	-962.560	4583.929	155520.756	-50357.458
$SnO_2 \times$Others	-13.609	-10.627	61.119	2492.961	-127.001	445.272	-13.422	-481.985	-77.863	5159.127	10.981	-6561.121	-245.139	329.670	202.217	182.968	9.504	124.032	-97200.545	-21807.393	460.891	1098.163	-50357.458	615219.982

Table A.12. Variance covariance matrix for LAW Sulfate

Term	Al_2O_3	B_2O_3	CaO	Cl	Cr_2O_3	K_2O	Li_2O	Na_2O	P_2O_5	SiO_2	SnO_2	V_2O_5	ZrO_2	Others	$Li_2O x Li_2O$
Al_2O_3	0.228	-0.04	-0.05	-0.0483	-0.392	0.021	-0.063	-0.0754	0.0049	0.00593	0.044	-0.0206	0.02127	0.00042	-1.156
B_2O_3	-0.038	0.165	-0.03	-0.6468	-0.225	-0.003	-0.013	0.02625	0.0808	-0.0371	0.055	0.01019	0.01786	0.01591	0.9863
CaO	-0.045	-0.03	0.17	-0.2871	0.181	-0.037	-0.328	0.00582	0.1068	-0.01581	0.123	-0.0888	0.04882	0.03159	4.4471
Cl	-0.048	-0.65	-0.29	19.6498	6.2705	0.824	3.6138	-0.5416	-1.489	0.243986	-0.26	1.5278	-0.8566	-0.114	-58.96
Cr_2O_3	-0.392	-0.23	0.181	6.27046	26.834	-0.365	-1.181	-0.3685	-0.996	0.231613	-3	-1.1946	-0.7319	-0.0177	0.8038
K_2O	0.021	-0	-0.04	0.82383	-0.365	0.341	0.4523	0.01943	-0.18	-0.02992	-0.1	0.20537	-0.0582	0.03152	-4.118
Li_2O	-0.063	-0.01	-0.33	3.61376	-1.181	0.452	5.1086	0.16011	-0.599	-0.11048	0.078	0.3264	-0.1426	0.14457	-81.36
Na_2O	-0.075	0.026	0.006	-0.5416	-0.369	0.019	0.1601	0.09633	-9×10^{-04}	-0.03053	-0	-0.0406	-0.0434	0.01919	0.9899
P_2O_5	0.0049	0.081	0.107	-1.4887	-0.996	-0.18	-0.599	-0.0009	2.7017	-0.03085	0.215	-0.2128	0.21784	-0.0254	8.9113
SiO_2	0.0059	-0.04	-0.02	0.24399	0.2316	-0.03	-0.11	-0.0305	-0.031	0.038062	-0.05	-0.0134	-0.0591	-0.0445	0.2602
SnO_2	0.0443	0.055	0.123	-0.2615	-2.998	-0.099	0.0777	-0.0022	0.2146	-0.05104	1.279	0.27211	-0.0925	0.08384	-0.689
V_2O_5	-0.021	0.01	-0.09	1.5278	-1.195	0.205	0.3264	-0.0406	-0.213	-0.01344	0.272	1.04019	-0.023	0.04337	-2.685
ZrO_2	0.0213	0.018	0.049	-0.8566	-0.732	-0.058	-0.143	-0.0434	0.2178	-0.05906	-0.09	-0.023	0.68582	0.07489	0.5904
Others	0.0004	0.016	0.032	-0.114	-0.018	0.032	0.1446	0.01919	-0.025	-0.04455	0.084	0.04337	0.07489	0.0931	-1.661
$Li_2O x Li_2O$	-1.156	0.986	4.447	-58.956	0.8038	-4.118	-81.36	0.9899	8.9113	0.260196	-0.69	-2.6847	0.5904	-1.6606	1623.9

Table A.13. Variance covariance matrix for LAW Viscosity

Term	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	P_2O_5	SiO_2	SnO_2	TiO_2	V_2O_5	ZnO	ZrO_2	Others
Al_2O_3	0.119	-0.017	-0.014	0.006	-0.006	-0.083	-0.029	-0.041	0.030	0.006	0.024	0.036	0.000	-0.003	-0.017	-0.030
B_2O_3	-0.017	0.138	-0.002	0.013	0.001	-0.029	-0.017	-0.008	-0.014	-0.023	0.044	0.029	-0.023	-0.016	-0.006	-0.003
CaO	-0.014	-0.002	0.064	0.008	0.012	-0.013	0.019	0.010	0.019	-0.010	0.018	0.034	-0.025	0.001	0.001	-0.033
Fe_2O_3	0.006	0.013	0.008	0.132	-0.009	-0.010	-0.011	-0.002	-0.007	-0.019	0.045	-0.114	0.017	0.030	0.020	0.102
K_2O	-0.006	0.001	0.012	-0.009	0.229	0.075	0.028	0.017	0.058	-0.010	-0.107	-0.094	-0.008	0.001	-0.054	0.030
Li_2O	-0.083	-0.029	-0.013	-0.010	0.075	0.616	-0.006	0.153	0.052	-0.048	-0.152	-0.013	-0.162	-0.018	-0.043	-0.096
MgO	-0.029	-0.017	0.019	-0.011	0.028	-0.006	0.568	0.033	-0.049	-0.022	-0.063	-0.178	-0.069	0.009	-0.023	0.043
Na_2O	-0.041	-0.008	0.010	-0.002	0.017	0.153	0.033	0.059	0.005	-0.017	-0.044	-0.017	-0.048	0.006	-0.030	-0.059
P_2O_5	0.030	-0.014	0.019	-0.007	0.058	0.052	-0.049	0.005	1.714	-0.012	-0.110	-0.013	-0.047	-0.010	0.072	-0.298
SiO_2	0.006	-0.023	-0.010	-0.019	-0.010	-0.048	-0.022	-0.017	-0.012	0.022	-0.002	-0.022	0.019	-0.045	-0.008	-0.022
SnO_2	0.024	0.044	0.018	0.045	-0.107	-0.152	-0.063	-0.044	-0.110	-0.002	0.463	0.122	-0.116	0.043	-0.007	0.007
TiO_2	0.036	0.029	0.034	-0.114	-0.094	-0.013	-0.178	-0.017	-0.013	-0.022	0.122	1.025	0.109	-0.003	0.111	-0.093
V_2O_5	0.000	-0.023	-0.025	0.017	-0.008	-0.162	-0.069	-0.048	-0.047	0.019	-0.116	0.109	0.653	0.048	0.059	-0.095
ZnO	-0.003	-0.016	0.001	0.030	0.001	-0.018	0.009	0.006	-0.010	-0.045	0.043	-0.003	0.048	0.567	-0.003	0.051
ZrO_2	-0.017	-0.006	0.001	0.020	-0.054	-0.043	-0.023	-0.030	0.072	-0.008	-0.007	0.111	0.059	-0.003	0.295	-0.018
Others	-0.030	-0.003	-0.033	0.102	0.030	-0.096	0.043	-0.059	-0.298	-0.022	0.007	-0.093	-0.095	0.051	-0.018	1.716

Appendix B

Table B.1 Analytical HLW RSDs derived from Dodd and Kaiser (2006)

Comp	Analytical RSD	Comp	Analytical RSD	Comp	Analytical RSD
Ac	22.5%	Mn	5.0%	Ti	10.8%
Ag	6.6%	Mo	15.0%	Tl	15.0%
Al	5.0%	Na	5.0%	U	14.1%
Am	22.5%	Nb	25.0%	V	25.0%
As	30.0%	Nd	6.6%	W	20.0%
B	15.0%	Ni	5.0%	Y	24.2%
Ba	10.0%	Np	22.5%	Zn	9.4%
Be	20.0%	P	10.0%	Zr	14.6%
Bi	25.0%	Pa	22.5%		
Ca	5.0%	Pb	10.0%		
Cd	15.0%	Pd	25.0%		
Ce	8.9%	Pr	10.0%		
Cl	15.0%	Pu	22.5%		
Cm	22.5%	Ra	15.0%		
Co	15.0%	Rb	30.0%		
Cr	10.0%	Rh	20.0%		
Cs	30.0%	Ru	45.4%		
Cu	14.8%	S	15.0%		
Eu	50.0%	Sb	25.0%		
F	15.0%	Se	50.0%		
Fe	5.0%	Si	5.0%		
Gd	15.0%	Sm	15.0%		
Hg	20.0%	Sn	15.0%		
I	15.0%	Sr	6.5%		
K	5.0%	Ta	13.2%		
La	11.0%	Tc	22.5%		
Li	9.9%	Te	50.0%		
Mg	13.6%	Th	15.0%		

Rad	Analytical RSD	Rad	Analytical RSD
59Ni	22.5%	233U	22.5%
60Co	22.5%	234U	22.5%
63Ni	22.5%	235U	22.5%
79Se	22.5%	236U	22.5%
90Sr	22.5%	237Np	22.5%
90Y	22.5%	238Pu	22.5%
93mNb	22.5%	238U	22.5%
93Zr	22.5%	239Pu	22.5%
99Tc	22.5%	240Pu	22.5%
106Ru	22.5%	241Am	22.5%
113mCd	22.5%	241Pu	22.5%
125Sb	22.5%	242Cm	22.5%
126Sn	22.5%	242Pu	22.5%
129I	22.5%	243Am	22.5%
134Cs	22.5%	243Cm	22.5%
137mBa	22.5%	244Cm	22.5%
137Cs	22.5%		
151Sm	22.5%		
152Eu	22.5%		
154Eu	22.5%		
155Eu	22.5%		
226Ra	22.5%		
227Ac	22.5%		
228Ra	22.5%		
229Th	22.5%		
231Pa	22.5%		
232Th	22.5%		
232U	22.5%		

Table B.2 Analytical LAW RSDs derived from Dodd and Kaiser (2005)

Comp	CRV aRSD	Comp	CRV aRSD	Comp	CRV aRSD
Ac	25.0%	Mn	15.0%	Ti	25.0%
Ag	20.0%	Mo	10.0%	Tl	25.0%
Al	5.0%	Na	10.0%	U	5.0%
Am	25.0%	Nb	15.0%	V	15.0%
As	25.0%	Nd	15.0%	W	15.0%
B	25.0%	Ni	10.0%	Y	25.0%
Ba	15.0%	Np	25.0%	Zn	25.0%
Be	25.0%	P	10.0%	Zr	15.0%
Bi	15.0%	Pa	25.0%		
Ca	5.0%	Pb	15.0%		
Cd	10.0%	Pd	15.0%		
Ce	10.0%	Pr	15.0%		
Cl	10.0%	Pu	25.0%		
Cm	25.0%	Ra	15.0%		
Co	25.0%	Rb	25.0%		
Cr	5.0%	Rh	20.0%		
Cs	15.0%	Ru	25.0%		
Cu	25.0%	S	5.0%		
Eu	10.0%	Sb	25.0%		
F	10.0%	Se	25.0%		
Fe	5.0%	Si	5.0%		
Gd	15.0%	Sm	10.0%		
Hg	10.0%	Sn	25.0%		
I	10.0%	Sr	5.0%		
K	5.0%	Ta	15.0%		
La	10.0%	Tc	25.0%		
Li	15.0%	Te	25.0%		
Mg	25.0%	Th	25.0%		

Appendix C

Minimum, maximum, and most likely concentration of components in each GFC (based on values reported in Table A-4 of Vienna and Kim 2014).

Min	Kyanite	Borax	Boric Acid	Wollastonite	Hematite	Li Carbonate	Olivine	Cr_2O_3 ('e)	Silica	Rutile	Zincite	Zircon	V_2O_5 (b)	SnO_2 (d)
Ac_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ag_2O	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Al_2O_3	0.54	0	0	0.0013	0.0099	0	0.0003	0	0.0004	0	0	0.001	0	0
Am_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
As_2O_5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B_2O_3	0	0.369	0.5625	0	0	0	0	0	0	0	0	0	0	0
BaO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BeO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bi_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CaO	0	0	0	0.4477	0	0	0	0	0	0	0	0	0	0
CdO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ce_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cl	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cm_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CoO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cr_2O_3	0	0	0	0	0	0	0	0.985	0	0	0	0	0	0
Cs_2O	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CuO	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Min	Kyanite	Borax	Boric Acid	Wollastonite	Hematite	Li Carbonate	Olivine	Cr_2O_3 (e)	Silica	Rutile	Zincite	Zircon	V_2O_5 (b)	SnO_2 (d)
Eu_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fe_2O_3	0.0042	0	0	0.0029	0.9615	0	0.0468	0	0.0001	0	0	0.0006	0	0
Gd_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HgO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K_2O	0	0	0	0	0	0	0	0	0	0	0	0	0	0
La_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Li_2O	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0
MgO	0	0	0	0	0.0001	0	0.4634	0	0	0	0	0	0	0
MnO	0	0	0	0.0009	0.0003	0	0	0	0	0	0	0	0	0
MoO_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Na_2O	0	0.164	0	0	0	0	0	0	0	0	0	0	0	0
Nb_2O_5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nd_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NiO	0	0	0	0	0	0	0.0022	0	0	0	0	0	0	0
NpO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P_2O_5	0	0	0	0	0.0018	0	0	0	0	0	0	0	0	0
Pa_2O_5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PbO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PdO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pr_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PuO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RaO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rb_2O	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rh_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Min	Kyanite	Borax	Boric Acid	Wollastonite	Hematite	Li Carbonate	Olivine	Cr_2O_3 ('e)	Silica	Rutile	Zincite	Zircon	V_2O_5 (b)	SnO_2 (d)
RuO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SO_3	0	0	0	0	0.0006	0	0	0	0	0	0	0	0	0
Sb_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SeO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SiO_2	0.39	0	0	0.48	0.0084	0	0.4085	0	0.992	0	0	0.32	0	0
Sm_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SnO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.999
SrO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ta_2O_5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc_2O_7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TeO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ThO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TiO_2	0.005	0	0	0.0001	0	0	0	0	0	0.928	0	0.0007	0	0
Tl_2O	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UO_3	0	0	0	0	0	0	0	0	0	0	0	0.0003	0	0
V_2O_5	0	0	0	0	0	0	0	0	0	0	0	0	0.992	0
WO_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Y_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZnO	0	0	0	0	0	0	0	0	0	0	0.993	0	0	0
ZrO_2	0	0	0	0	0	0	0	0	0	0	0	0.65	0	0

Max	Kyanite	Borax	Boric Acid	Wollastonite	Hematite	Li Carbonate	Olivine	Cr_2O_3 (e)	Silica	Rutile	Zincite	Zircon	V_2O_5 ©	SnO_2 (d)
Ac_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ag_2O	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Al_2O_3	0.6	0	0	0.0027	0.0201	0	0.0078	0	0.004	0.0075	0	0.004	0	0
Am_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
As_2O_5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B_2O_3	0	0.382	0.568	0	0	0	0	0	0	0	0	0	0	0
BaO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BeO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bi_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00017
CaO	0.0004	0	0	0.5023	0.0008	0.022	0.0003	0	0.0002	0	0	0	0	0
CdO	0	0	0	0	0	0	0	0	0	0	0.0002	0	0	0
Ce_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cl	0	0.0007	0	0	0	0.0001	0	0	0	0	0	0	0	0
Cm_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CoO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cr_2O_3	0	0	0	0	0	0.0002	0.0078	0.991	0	0.0075	0	0	0	0
Cs_2O	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CuO	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Max	Kyanite	Borax	Boric Acid	Wollastonite	Hematite	Li Carbonate	Olivine	Cr_2O_3 ('e)	Silica	Rutile	Zincite	Zircon	V_2O_5 ©	SnO_2 (d)
Eu_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fe_2O_3	0.01	0.0001	0	0.0051	0.9785	0.0001	0.1068	0.0003	0.0004	0.025	0.0001	0.0009	0.00057189	0.00021
Gd_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HgO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K_2O	0.0007	0	0	0	0	0.0001	0	0	0.0002	0	0	0	0.00018069	0
La_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Li_2O	0	0	0	0	0	0.4044	0	0	0	0	0	0	0	0
MgO	0.0004	0	0	0.001	0.0037	0.0002	0.4934	0	0.0001	0	0	0	0	0
MnO	0	0	0	0.0011	0.0039	0	0	0	0	0	0.0001	0	0	0
MoO_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Na_2O	0.0042	0.17	0	0	0	0.0011	0.0004	0	0.0002	0	0	0	0.00033699	0
Nb_2O_5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nd_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NiO	0	0	0	0	0	0	0.0052	0	0	0	0	0	0	0
NpO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P_2O_5	0	0	0	0	0.0054	0	0	0	0	0.0007	0	0	0	0
Pa_2O_5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PbO	0	0	0	0	0	0	0	0	0	0	0.0001	0	0	0.00054
PdO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pr_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PuO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RaO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rb_2O	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rh_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Max	Kyanite	Borax	Boric Acid	Wollastonite	Hematite	Li Carbonate	Olivine	Cr_2O_3 ('e)	Silica	Rutile	Zincite	Zircon	V_2O_5 ©	SnO_2 (d)
RuO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SO_3	0	0.0005	0.0003	0	0.0009	0.0004	0	0	0	0.0007	0	0	0	0
Sb_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00018
SeO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SiO_2	0.42	0	0	0.53	0.0186	0	0.4385	0	0.999	0.025	0	0.325	0.00021393	0
Sm_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SnO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9999
SrO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ta_2O_5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc_2O_7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TeO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ThO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TiO_2	0.016	0	0	0.0003	0	0	0	0	0.0005	0.936	0	0.0014	0	0
Tl_2O	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UO_3	0	0	0	0	0	0	0	0	0	0	0	0.0008	0	0
V_2O_5	0	0	0	0	0	0	0	0	0	0.0075	0	0	0.996	0
WO_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Y_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZnO	0	0	0	0	0	0	0	0	0	0	0.9999	0	0	0
ZrO_2	0	0	0	0	0	0	0	0	0	0.025	0	0.67	0	0

Most likely	Kyanite	Borax	Boric Acid	Wollastonite	Hematite	Li Carbonate	Olivine	Cr_2O_3 ('e)	Silica	Rutile	Zincite	Zircon	V_2O_5 (a)	SnO_2 (d)
Ac_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ag_2O	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Al_2O_3	0.5703	0	0	0.002	0.015	0	0.0019	0	0.0014	0.005	0	0.0025	0	0
Am_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
As_2O_5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B_2O_3	0	0.375	0.5652	0	0	0	0	0	0	0	0	0	0	0
BaO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BeO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bi_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CaO	0.0003	0	0	0.475	0.0004	0	0.0002	0	0.0001	0	0	0	0	0
CdO	0	0	0	0	0	0	0	0	0	0	0.0001	0	0	0
Ce_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cl	0	0	0	0	0	0.0001	0	0	0	0	0	0	0	0
Cm_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CoO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cr_2O_3	0	0	0	0	0	0.0001	0.0013	0.991	0	0.0016	0	0	0	0
Cs_2O	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CuO	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Most likely	Kyanite	Borax	Boric Acid	Wollastonite	Hematite	Li Carbonate	Olivine	Cr_2O_3 ('e)	Silica	Rutile	Zincite	Zircon	V_2O_5 (a)	SnO_2 (d)
Eu_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fe_2O_3	0.0078	0	0	0.004	0.97	0	0.0768	0	0.0002	0.007	0	0.0008	0	0
Gd_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HgO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K_2O	0	0	0	0	0	0	0	0	0	0	0	0	0	0
La_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Li_2O	0	0	0	0	0	0.402	0	0	0	0	0	0	0	0
MgO	0.0001	0	0	0.001	0.001	0.0001	0.4801	0	0.0001	0	0	0	0	0
MnO	0	0	0	0.001	0.0012	0	0	0	0	0	0	0	0	0
MoO_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Na_2O	0.0042	0.167	0	0	0	0.0008	0.0003	0	0.0002	0	0	0	0	0
Nb_2O_5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nd_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NiO	0	0	0	0	0	0	0.0037	0	0	0	0	0	0	0
NpO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P_2O_5	0	0	0	0	0.0027	0	0	0	0	0	0	0	0	0
Pa_2O_5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PbO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PdO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pr_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PuO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RaO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rb_2O	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rh_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Most likely	Kyanite	Borax	Boric Acid	Wollastonite	Hematite	Carbonate Li	Olivine	Cr_2O_3 ('e)	Silica	Rutile	Zincite	Zircon	V_2O_5 (a)	SnO_2 (d)
RuO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SO_3	0	0	0	0	0.0007	0.0003	0	0	0	0	0	0	0	0
Sb_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SeO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SiO_2	0.4067	0	0	0.51	0.0135	0	0.4252	0	0.997	0.022	0	0.3225	0	0
Sm_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SnO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.99945
SrO	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ta_2O_5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tc_2O_7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TeO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ThO_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TiO_2	0.0079	0	0	0.0002	0	0	0	0	0.0001	0.932	0	0.001	0	0
Tl_2O	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UO_3	0	0	0	0	0	0	0	0	0	0	0	0.0004	0	0
V_2O_5	0	0	0	0	0	0	0	0	0	0.0045	0	0	0.994	0
WO_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Y_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZnO	0	0	0	0	0	0	0	0	0	0	0.999	0	0	0
ZrO_2	0	0	0	0	0	0	0	0	0	0.019	0	0.66	0	0

Appendix D

Minimum, maximum, and most likely PERT distribution in $\ln\left[\frac{1}{1-\nu_i}\right]$ with minimum, based on the values reported by Nelson (2013).

Comp	ln(DF), Min	ln(DF), Most likely	ln(DF), Max		Comp	ln(DF), Min	ln(DF), Most likely	ln(DF), Max		Comp	ln(DF), Min	ln(DF), Most likely	ln(DF), Max
Ac_2O_3	2.9601	6.8772	11.1239		MoO_3	1.8563	4.194	6.4944		UO_3	2.9601	6.8772	11.1239
Ag_2O	1.8563	4.194	6.4944		Na_2O	3.4874	4.8633	6.4944		V_2O_5	1.8563	4.194	6.4944
Al_2O_3	5.0764	7.0814	8.8901		Nb_2O_5	2.9601	6.8772	11.1239		WO_3	2.9601	6.8772	11.1239
Am_2O_3	1.8563	4.194	6.4944		Nd_2O_3	2.9601	6.8772	11.1239		Y_2O_3	2.9601	6.8772	11.1239
As_2O_5	0.0945	1.5296	4.237		NiO	3.9299	4.7875	6.3835		ZnO	4.7353	6.2383	7.8709
B_2O_3	3.708	4.5886	5.8519		NpO_2	2.9601	6.8772	11.1239		ZrO_2	7.2204	8.7143	11.1239
BaO	2.9601	6.8772	11.1239		P_2O_5	2.9601	5.1381	6.7822					
BeO	2.9601	6.8772	11.1239		Pa_2O_5	2.9601	6.8772	11.1239					
Bi_2O_3	1.8563	4.194	6.4944		PbO	3.2542	4.4716	6.2971					
CaO	5.2311	7.0825	8.6034		PdO	2.9601	6.8772	11.1239					
CdO	2.9601	6.8772	11.1239		Pr_2O_3	2.9601	6.8772	11.1239					
Ce_2O_3	2.9601	6.8772	11.1239		PuO_2	2.9601	6.8772	11.1239					
Cl	0.0979	0.7583	1.9095		RaO	0.0945	1.5296	4.237					
Cm_2O_3	2.9601	6.8772	11.1239		Rb_2O	1.8563	4.194	6.4944					
CoO	2.9601	6.8772	11.1239		Rh_2O_3	2.9601	6.8772	11.1239					
Cr_2O_3	1.8563	3.0681	5.3033		RuO_2	1.8563	4.194	6.4944					
Cs_2O	0.47	2.3609	4.237		SO_3	0.6308	1.9694	3.2089					
CuO	2.9601	6.8772	11.1239		Sb_2O_3	0.0945	1.5296	4.237					
Eu_2O_3	2.9601	6.8772	11.1239		SeO_2	0.0945	1.5296	4.237					
F	0.1179	1.4682	2.4361		SiO_2	5.3471	7.5372	9.7527					
Fe_2O_3	4.9381	6.6712	8.8984		Sm_2O_3	2.9601	6.8772	11.1239					
Gd_2O_3	2.9601	6.8772	11.1239		SnO_2	2.9601	6.8772	11.1239					
HgO	0	0	0		SrO	2.9601	6.8772	11.1239					
I	0.0945	0.5807	2.266		Ta_2O_5	2.9601	6.8772	11.1239					
K_2O	2.0669	3.3844	5.5607		Tc_2O_7	0.0953	0.47	1.6094					
La_2O_3	2.9601	6.8772	11.1239		TeO_2	0.0945	1.5296	4.237					
Li_2O	3.4689	5.987	7.2894		ThO_2	2.9601	6.8772	11.1239					
MgO	7.2464	8.8618	11.0268		TiO_2	4.6308	6.1247	8.074					
MnO	2.9601	6.8772	11.1239		Tl_2O	0.0945	1.5296	4.237					

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