PNNL-11865
UC-510

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September 1998

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831; prices available from (615) 576-8401.

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Summary

Vitrification is currently being explored as an option for plutonium waste immobilization because of its ability to convert plutonium-bearing materials into a safe, durable, and accountable waste form with reduced need for safeguarding. A glass frit composition was developed for a widely varying evaporator bottoms waste from Los Alamos National Laboratory (LANL). The glass was optimized to allow maximum variation in waste composition while maintaining acceptable product quality and processability. Property-composition relationships based on measured viscosity and leach resistance (toxicity characteristic leach procedure) data were used to optimize the glass. All glass property measurements were made on glasses with cerium used as a surrogate for plutonium. The methods and data used to develop the optimized glass composition are reported.

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Introduction

Vitrification is an attractive treatment option for meeting the stabilization and final disposal requirements of many plutonium (Pu) bearing materials and wastes at the Los Alamos National Laboratory (LANL) TA-55 facility, Rocky Flats Environmental Technology Site (RFETS), Hanford, and other Department of Energy (DOE) sites. The Environmental Protection Agency (EPA) has declared that vitrification is the "best demonstrated available technology" for high-level radioactive wastes (HLW) (Federal Register 1990) and has produced a handbook of vitrification technologies for treatment of hazardous and radioactive waste (US EPA, 1992). This technology has been demonstrated to convert Pu-containing materials (Kormanos, 1997) into durable (Lutze, 1988) and accountable (Forsberg, 1995) waste forms with reduced need for safeguarding (McCullum, 1996). The composition of the Evaporator Bottoms Waste (EVB) at LANL, like that of many other Pu-bearing materials, varies widely and is generally unpredictable. The goal of this study is to optimize the composition of glass for EVB waste at LANL, and present the basic techniques and tools for developing optimized glass compositions for other Pu-bearing materials in the complex.

This report outlines an approach for glass formulation with fixed property restrictions, using glass property-composition databases. This approach is applicable to waste glass formulation for many variable waste streams and vitrification technologies. Also reported are the preliminary property data for simulated evaporator bottom glasses, including glass viscosity and glass leach resistance using the Toxicity Characteristic Leaching Procedure (TCLP).

Approach

The approach to waste glass formulation has been under development at PNNL for several years (Hrma et al. 1994, Hrma 1994, Vienna et al. 1997, Hrma et al. 1996, Vienna et al. 1997). Piepel et al. (1997) described the steps to develop a qualified glass composition region based on experimental data. This general approach to glass formulation was used to develop a frit composition for EVB waste vitrification. A slightly modified (compared to Piepel et al. 1997) set of steps for this method is listed below.

Step 1. Identify a Waste Composition Uncertainty Region (WCUR) that is expected to include the true range of waste compositions.
Step 2. Specify the acceptability constraints on glass composition, glass quality properties, and glass processing properties.
Step 3. Define a Glass Composition Experimental Region (GCER) containing glass compositions that might be made from wastes in the WCUR.
Step 4. Construct an experimental design that augments any relevant existing composition-property data with new compositions to adequately cover the GCER.
Step 5. Melt the new glass compositions from the experimental design and measure their glass properties.
Step 6. Fit property-composition relationships to new and existing data to enable prediction.
Step 7. Validate property-composition relationships with data not used in their development.

Step 8. Develop glass formulations by interpolation of glass property data (using defined constraints, waste compositions, and property-composition relationships).
Step 9. Validate glass acceptability and property predictions with experimental study.

This process can be, and often is, an iterative one. The optimization of a glass frit composition for vitrifying the widely varying LANL EVB waste stream, following steps 1-8 above, is discussed below.

Waste Compositions *(Step 1)*

EVB is transuranic waste remaining after evaporating the nitric acid-based effluent from ion-exchange processes at the TA-55 plutonium processing facility. Six types of EVB waste – hot distillate (HD), oxalate filtrate (OX), lean residue (LR), ATLAS (ATL), dissolution (DS), and chloride (CL) – were characterized by analysis of 324 samples. The samples were taken from homogeneous solutions, and analyzed by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES) for major components, by cold vapor atomic fluorescence for Hg, by germanium gamma spectrometer for Am, and by alpha proportional counter for Pu. Appendix A tabulates the measured waste compositions.

The analytical method left several gaps in the analysis of major waste components, including Al, Ca, Cr, Fe, K, Mg, and Na. A missing value in one of these major components would significantly alter the waste composition when the concentrations are normalized to wt% oxides. The affected waste compositions were therefore either removed from consideration, or were altered by substituting the average component concentration for the missing component. Waste compositions with missing data on one or more of the major components were deleted if the concentrations of the existing major components were within the ranges of other wastes of their type. Of the 324 original compositions, 130 such compositions were deleted, leaving 194 compositions. Alternatively, the average concentration from wastes in a specific waste type was substituted for a missing major component. This occurred with five compositions – 10EVDIST27BF1, EVDIS062596B2, EVOX041096B1, EVDS030896A1, and EVDS012297B1. Deleted waste compositions and substituted major component values are marked in Appendix A. Two of the waste types (ATL and CL) were not considered, since they are not typical of future waste streams. These two types contained 31 compositions, leaving 163 compositions for consideration. Table I summarizes the composition range for the remaining 163 waste compositions, including the minimum, maximum, mean, median, standard deviation, and 10th and 90th percentiles for the oxide component concentrations. The summary statistics in Table I indicate that the distributions of some component values are skewed (not symmetric) or have outlying values.

Table I. Evaporator bottom waste composition summary in wt% oxides

	Min	Mean	Median	Max	10%	90%	std dev
Ag_2O	0.00	0.00	0.00	0.01	.000	.001	0.00
Al_2O_3	0.00	3.34	2.62	45.60	1.46	5.10	4.25
Am_2O_3	0.00	0.03	0.02	0.13	0.01	0.05	0.02
As_2O_3	0.00	0.01	0.00	0.07	.000	.009	0.01
BaO	0.00	0.01	0.01	0.12	0.00	0.03	0.02
BeO	0.00	0.18	0.08	1.40	0.00	0.51	0.29
CaO	0.00	23.28	23.70	62.72	13.4	30.0	7.53
CdO	0.00	0.00	0.00	0.12	0.00	0.00	0.01
Cr_2O_3	0.32	2.69	2.24	10.71	1.35	4.60	1.57
Fe_2O_3	0.00	11.31	9.51	41.24	5.63	19.2	6.47
K_2O	0.00	14.21	12.91	44.42	3.50	23.6	8.14
MgO	0.00	40.07	39.11	92.57	25.9	51.8	13.10
Na_2O	0.06	2.99	1.11	59.09	0.50	5.33	7.08
NiO	0.03	1.36	1.10	6.41	0.70	2.22	0.85
PbO	0.01	0.10	0.07	0.51	0.03	0.19	0.08
PuO_2	0.00	0.38	0.23	2.52	0.12	0.84	0.38
TlO_x	0.00	0.02	0.01	0.25	0.01	0.03	0.03
U_3O_8	0.00	0.02	0.01	0.10	0.01	0.03	0.02

Figure 1 shows a scatter plot matrix of the seven major components (Al, Ca, Cr, Fe, K, Mg, and Na) for the final 163 waste compositions. In general, waste compositions are very diverse. However, many of the wastes cluster, leaving several outlying waste compositions. Examples of outlying wastes are the two highest Al wastes and the seven highest Na wastes. The strong correlation between Cr and Fe suggests that those two components are products of dissolved steel. Additional investigation of the Ni levels supports this thesis.

Glass Constraints *(Step 2)*

For vitrification to be successful, a glass must be developed that is processable, durable, and tolerant to changing or uncertain waste composition. The uncertainty and variation of waste composition is a challenging aspect to glass formulation. Alkaline and alkaline earth oxides (Na_2O, K_2O, CaO, and MgO) tend to decrease glass durability and viscosity (at melting temperature), while refractories (e.g., Al_2O_3 and SiO_2) increase glass durability and viscosity. Wide variation in the concentrations of these components will alter the glass processability and quality. For the EVB wastes, the concentrations of alkaline, alkaline earth, and aluminum oxides in the waste range from 1-60 wt%, 0-96 wt%, and 0-46 wt%, respectively. These diverse wastes are expected to be vitrified with a single frit composition at a single waste loading (WL) or fraction of waste in the glass. The ability to make processable and acceptable glass out of the diverse wastes ultimately determines the allowable WL.

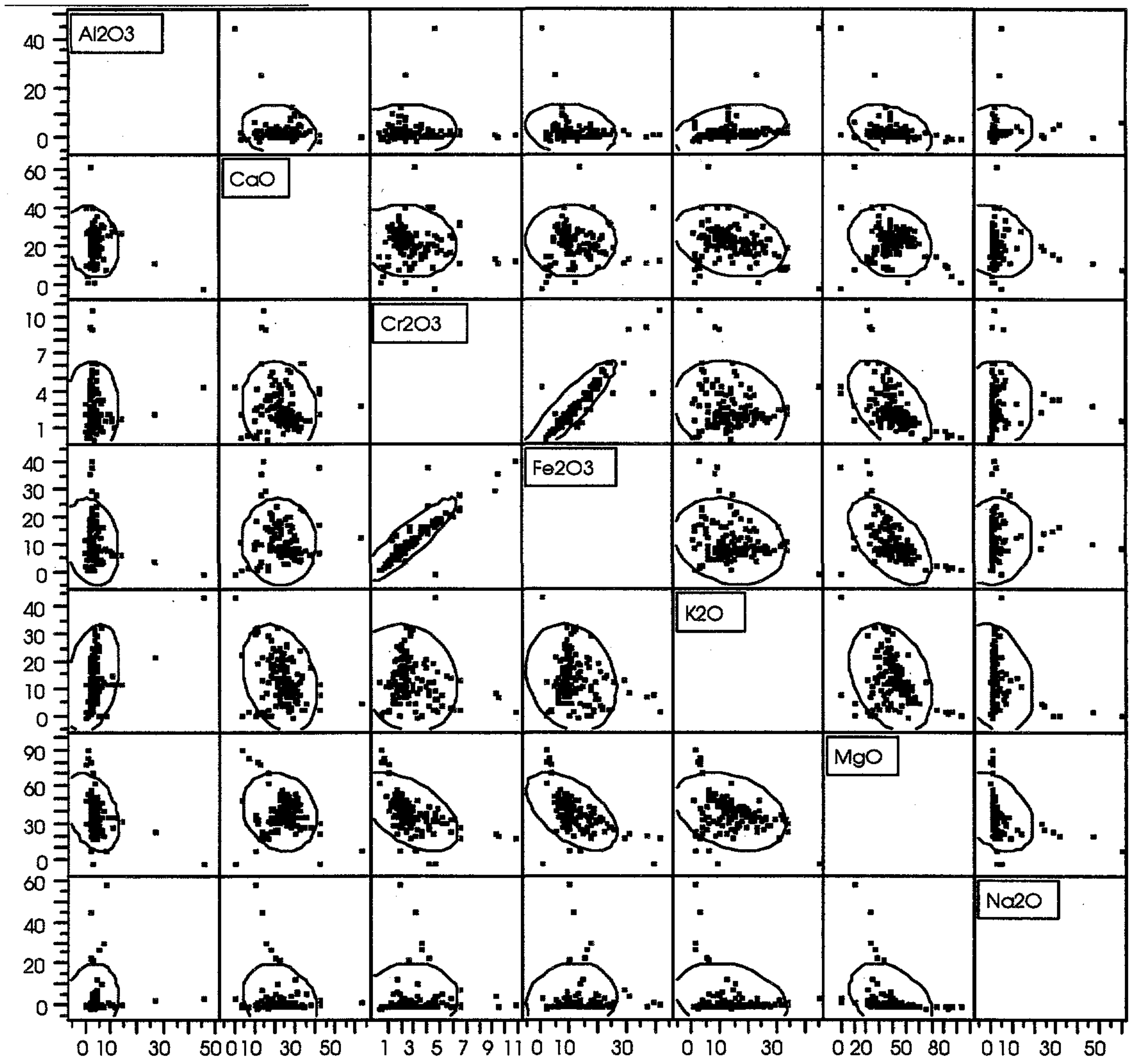

Figure 1. Scatter plot matrix of 163 waste compositions in wt% oxides (lines represent 95% bivariate normal density ellipses)

This waste is to be disposed of in the Waste Isolation Pilot Project (WIPP) and is restricted by the WIPP waste acceptance criteria (WAC). The WIPP WAC doesn't specify a durability constraint on waste material. However, to ensure a durable waste form for interim storage, the Toxicity Characteristic Leach Procedure (TCLP) was used as a leach resistance criterion for these glasses. The release of hazardous metals (including As, Ba, Cd, Cr, Pb, Hg, Se, and Ag) will be restricted to below the universal treatment standards (UTS) accepted levels for TCLP leaching (US EPA, 1997). This is a significantly more stringent standard than is required to ensure acceptability and safe storage these wastes. However, this does not limit the acceptability of many wastes, and has no impact on waste loading.

In addition to meeting the UTS, glass compositions must be designed to protect the environment and human health by ensuring acceptable leach resistance. The leach test criterion being used to judge the acceptability of HLW glasses fabricated at Savannah River Site (SRS) and West Valley Nuclear Services (WVNS) — the product consistency test (PCT) — is used as a measure of leach resistance for these glasses. For HLW glasses, the normalized release of B, Na, and Li (r_B, r_{Na}, and r_{Li}, respectively) by PCT must be lower than the corresponding releases from Defense Waste Processing Facilities (DWPF) Environmental Assessment (EA) glass (Jantzen et al., 1993). This criterion, while not required for transportation or disposal, was also applied to the calculated EVB waste glasses to ensure high durability.

Acceptability of the waste form in the WIPP also requires safeguards termination (i.e., reduction to level E safeguards), which requires Pu concentrations below 5 wt% (McCullum, 1996). Additional limits have been imposed on the shipping of TRU waste to ensure criticality safety. This limit translates to 200 fissile gram equivalents in a 208 L drum (55 gal). The practical limitation, however, is based on measurement uncertainty. This limit is 200 g Pu minus two times the measurement uncertainty, typically ~167 g Pu per drum for LANL waste forms. The current vitrification flowsheet specifies a waste loading target of 25% on an oxide weight basis. This translates to an average Pu loading of 0.1 wt% PuO_2 in glass.

Additional restrictions are placed on the frit composition to ensure that the glass can be processed in the melter system developed for the process. The glass development for this waste stream began before the melter technology was determined. Generally, viscosity, electrical conductivity, and liquidus temperature are controlled for melter systems (Bickford et al., 1990). The viscosity is restricted between 2 and 10 Pa·s at melting temperature to ensure smooth bottom drain operation. In addition, the glass viscosity at the processing temperature (η_T) should be maintained above 2 Pa·s to avoid excessive corrosion of the melter construction material, and below 10 or 15 Pa·s to keep processing times reasonable. Electrical conductivity should be strictly controlled at levels specific to the melter design for induction heating or maintained between roughly 10 and 100 S/m at the processing temperature for Joule-heated melters. Currently, LANL plans to use resistance heating rather than induction or Joule. However, LANL may change the melter technology in the future. Liquidus temperature (T_L) is often a processing concern for waste glass melters. The T_L of glass is often maintained below the melting temperature to avoid accumulation of crystals, which can short heating electrodes or clog pour spouts in melters.

Testing was performed on glasses designed before the design of the melter system was complete. The initial assumptions about processing requirements that the glass would meet include: 1) no restriction on electrical conductivity (because the melter was initially assumed to be resistance heated), 2) the processing temperature would be 1100°C, 3) η_{1100} would be between 2 and 10 Pa·s, and 4) no restriction would be placed on T_L. The glass composition experimental region and test matrix described in Steps 3 and 4 were based upon these assumptions. However, refinement of the melter design changed the processing temperature to 1050°C. That change is reflected in the restrictions used for frit composition optimization, described below.

Table II lists the restrictions used for frit development in this study. These restrictions are dependent upon the waste stream, the disposal path, and vitrification technology; and are not generally applicable to every vitrification problem.

Table II. Glass property restrictions

Restriction	Test	Limiting values
Universal treatment standard	TCLP	0.3 Ag, 5 As, 7.6 Ba, 0.19 Cd, 0.86 Cr, 5 Ni, and 0.37 Pb (all mg/L)
Glass durability	PCT	$r_B < 8.5$ and $r_{Na} < 6.6$ g/m^2
Processability	Viscosity	$2 < \eta_{1050} < 10$ Pa·s
Waste loading	-	25 wt% oxide in glass

Glass Composition Experimental Region *(Step 3)*

Preliminary calculations of glass compositions were made using existing glass property databases (Hrma et al. 1994, Bulkley and Vienna 1997, and Vienna et al. 1996). Preliminary calculations narrowed the glass composition region expected for the EVB to that listed in Table III. The EVB glass composition experimental region (GCER) is described by the minimum and maximum columns in Table III. The methods used to select the glass compositions in the GCER for experimental study are described in the following section. In addition to the single component ranges listed in Table III, the GCER was further restricted by constraints that the combined alkalis (Na_2O, K_2O, and Li_2O) be less than 25 wt% of glass, and the calculated glass viscosities range between 2 and 10 Pa·s at 1100°C. The composition ranges for the Hanford HLW CVS and Pu residue studies included in Table III are discussed later.

Table III. Glass composition experimental regions for the EVB, HLW, and Pu residue glass studies

	EVB GCER		CVS HLW[a]		Pu Res Study[b]	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Al_2O_3	0.00	12.00	0.00	15.00	0.00	10.00
B_2O_3	2.00	20.00	5.00	20.00	0.00	12.00
CaO	0.00	12.00	0.00	10.00	0.00	8.00
CeO_2	-	-	-	-	???	???
Cr_2O_3	-	-	-	-	-	-
Fe_2O_3	0.00	12.00	0.50	15.00	-	-
K_2O	0.00	15.00[c]	-	-	0.00	6.00
Li_2O	0.00	10.00[c]	1.00	7.00	0.00	4.50
MgO	0.00	12.00	0.00	8.00	2.00	8.00
Na_2O	0.00	16.00[c]	5.00	20.00	0.00	8.00
NiO	-	-	-	-	-	-
PbO	0.00	5.00[d]	-	-	0.00	10.00
SiO_2	40.00	66.00	41.00	57.00	40.00	55.00
SnO	-	-	-	-	0.00	4.00
TiO_2	-	-	-	-	0.00	5.00
ZrO_2	-	-	0.00	13.00	0.00	5.00
Others	0.10	4.00	1.00	10.00	5.00	6.80[e]

[a] from Hrma, et al. 1994, [b] from Bulkley and Vienna 1996, [c] $K_2O+Li_2O+Na_2O \leq 25$wt%, [d] PbO varies as a part of the others component except for one composition included in the test matrix which is discussed later, [e] Others was not directly varied in this study, but only offset changes in the listed components, - Denotes components in glass (as Others) at low levels that were not systematically varied.

Experimental Matrix Design *(Step 4)*

Table IV lists the test matrix of 36 glasses used to explore the EVB GCER defined in Table III. The 36 glasses were selected in two stages. In the first stage, glasses LANL-A to LANL-U were selected, using a fractional factorial type design. The fraction of the factorial design was chosen based on subject matter knowledge and interest rather than according to statistical methods for fractionating factorial designs. In the second stage, glasses LANL-V to LANL-AK were selected to optimally augment the 21 first-stage glasses, using computer-aided statistical experimental design techniques and software as described in the following paragraph.

The MCCVRT routine of the MIXSOFT software (Piepel 1994) was used to generate the 2269 vertices of the EVB GCER defined in Table III (with the exception that PbO was not included as a varied component). Two additional restrictions were added to the design – the glass viscosity at 1100°C was restricted to 2 to 10 Pa·s and the total alkali was maintained below 25 wt%. The decision was made later to restrict the viscosity (2 to 10 Pa·s) at 1050°C instead of 1100°C. These 2269 vertex glass compositions were appended to the 21 LANL-A to LANL-U compositions to yield a set of candidate points from which the final experimental design of 36 compositions was constructed.

The ACED software (Welch 1987) was used to generate the final 36-composition experimental design. First, the 21 first-stage LANL compositions (LANL-A to LANL-U) were "forced" into the design. Then, the D-optimality criterion and the excursion algorithm of ACED were used to select 15 compositions from the 2269 EVB GCER vertices to optimally augment the 21 existing LANL compositions. The D-optimality criterion involves minimizing $|(X'X)^{-1}|$, where in this case X represents the 36 x 10 matrix of compositions ultimately selected for the experimental design. X' represents the matrix transpose of X, and the superscript -1 indicates the matrix inverse. For this application, D-optimality means that design points are selected to minimize the uncertainty in property-composition coefficients estimated from the resulting property-composition data. Spreading points out as far as possible in the GCER minimizes uncertainty in property-composition relationships. That is why the vertices of the EVB GCER were used as candidate points to augment the 21 first-stage LANL glasses.

The ACED software uses mathematical optimization methods to select design points that minimize $|(X'X)^{-1}|$. The "excursion algorithm" in ACED considers designs of sizes smaller and larger than the desired size (36 points in this case) as one way to avoid suboptimization (i.e., stopping at local minima). ACED also avoids suboptimization by generating designs from different randomly chosen starting points. Ultimately, there were many nearly optimal ways to select 15 vertices from 2269 vertices to augment the 21 first-stage points. One of those options was selected, based on other statistical properties and on a review of glass science. In summary, ACED was used to select a set of 15 vertices spread around the boundary of the GCER. This was done in a way that optimally augments the 21 first-stage LANL glasses, to minimize the uncertainty in estimating property-composition relationships from the measured data.

Table IV. Experimental glass compositions in wt% oxides

Glass	Al_2O_3	B_2O_3	BaO	CaO	CeO_2*	Cr_2O_3	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	Nd_2O_3	NiO	PbO	SiO_2
LANL-A	5.00	6.00	0.00	6.70	0.19	0.23	1.91	1.66	5.00	7.64	12.27	0.00	0.18	0.02	53.20
LANL-B	0.68	6.00	0.00	6.70	0.19	0.23	1.91	1.66	5.00	7.64	11.92	0.00	0.18	0.02	57.87
LANL-C	0.68	6.00	0.00	6.70	0.19	0.23	1.91	5.00	5.00	7.64	9.76	0.00	0.18	0.02	56.69
LANL-D	5.00	15.00	0.00	6.70	0.19	0.23	1.91	1.66	0.00	7.64	16.53	0.00	0.18	0.02	44.94
LANL-E	5.00	15.00	0.00	6.70	0.19	0.23	1.91	5.00	0.00	7.64	14.38	0.00	0.18	0.02	43.76
LANL-F	5.00	15.00	0.00	6.70	0.19	0.23	1.91	1.66	5.00	7.64	5.38	0.00	0.18	0.02	51.09
LANL-G	0.68	15.00	0.00	6.70	0.19	0.23	1.91	1.66	0.00	7.64	16.18	0.00	0.18	0.02	49.61
LANL-H	0.68	15.00	0.00	6.70	0.19	0.23	1.91	1.66	5.00	7.64	5.03	0.00	0.18	0.02	55.76
LANL-I	5.00	15.00	0.00	12.00	0.19	0.23	1.91	1.66	0.00	7.64	12.13	0.00	0.18	0.02	44.04
LANL-J	5.00	15.00	0.00	6.70	0.19	0.23	1.91	1.66	0.00	12.00	13.93	0.00	0.18	0.02	43.18
LANL-K	5.00	15.00	0.01	10.05	0.28	0.34	2.86	2.50	0.00	11.46	10.29	0.00	0.27	0.02	41.91
LANL-L	5.00	15.00	0.00	6.70	0.19	0.23	5.00	1.66	0.00	7.64	15.04	0.00	0.18	0.02	43.33
LANL-M	5.00	15.00	0.00	6.70	0.19	0.23	1.91	1.66	0.00	7.64	13.48	0.00	0.18	5.00	43.00
LANL-N	5.00	5.00	0.00	6.70	0.19	0.23	1.91	5.00	5.00	7.64	10.88	0.00	0.18	0.02	52.25
LANL-O	5.00	15.00	0.00	6.70	0.19	0.23	1.91	5.00	5.00	7.64	3.23	0.00	0.18	0.02	49.90
LANL-P	0.68	15.00	0.00	12.00	0.19	0.23	1.91	1.66	5.00	7.64	0.78	0.00	0.18	0.02	54.70
LANL-Q	0.68	5.00	0.00	12.00	0.19	0.23	1.91	1.66	5.00	7.64	8.28	0.00	0.18	0.02	57.21
LANL-R	0.68	5.00	0.00	6.70	0.19	0.23	1.91	1.66	5.00	12.00	10.08	0.00	0.18	0.02	56.35
LANL-S	1.02	5.00	0.01	10.05	0.28	0.34	2.86	2.50	5.00	11.46	6.47	0.00	0.27	0.02	54.71
LANL-T	5.00	5.00	0.00	6.70	0.19	0.23	1.91	5.00	5.00	12.00	8.28	0.00	0.18	0.02	50.49
LANL-U	0.68	11.68	0.00	6.70	0.19	0.23	1.91	1.66	5.87	7.64	5.65	0.00	0.18	0.02	57.60
LANL-V‡	0.00	20.00	0.00	0.00	0.00	0.05	12.00	15.00	3.09	0.00	6.91	0.02	0.02	0.00	42.90
LANL-X‡	12.00	20.00	0.01	12.00	0.17	1.89	0.00	0.00	8.23	0.00	0.00	0.91	0.97	0.05	43.77
LANL-Y	0.00	20.00	0.01	12.00	0.17	1.89	12.00	0.00	5.20	0.00	0.00	0.91	0.97	0.05	46.80
LANL-Z	12.00	2.18	0.01	12.00	0.17	1.89	0.00	15.00	10.00	0.00	0.00	0.91	0.97	0.05	44.82
LANL-AA	12.00	2.00	0.01	0.00	0.17	1.89	12.00	0.00	8.76	12.00	9.24	0.91	0.97	0.05	40.00
LANL-AB	12.00	5.36	0.01	0.00	0.17	1.89	0.00	15.00	10.00	12.00	0.00	0.91	0.97	0.05	41.64
LANL-AC	0.00	2.00	0.00	0.00	0.00	0.05	12.00	0.00	9.97	0.00	15.03	0.02	0.02	0.00	60.90
LANL-AD	4.16	2.00	0.01	0.00	0.17	1.89	0.00	0.00	7.84	0.00	16.00	0.91	0.97	0.05	66.00
LANL-AE	12.00	2.00	0.00	12.00	0.00	0.05	12.00	15.00	4.76	0.00	0.00	0.02	0.02	0.00	42.14
LANL-AF	12.00	20.00	0.00	0.00	0.00	0.05	12.00	0.00	4.06	11.84	0.00	0.02	0.02	0.00	40.00
LANL-AG	12.00	20.00	0.00	0.00	0.00	0.05	0.00	0.00	9.99	0.00	0.00	0.02	0.02	0.00	57.91
LANL-AH	0.00	20.00	0.01	0.00	0.17	1.89	0.00	15.00	0.00	0.00	9.68	0.91	0.97	0.05	51.32
LANL-AI	0.00	2.00	0.01	12.00	0.17	1.89	12.00	15.00	0.00	12.00	0.17	0.91	0.97	0.05	42.83
LANL-AJ	12.00	2.00	0.01	12.00	0.17	1.89	12.00	0.00	1.06	0.00	16.00	0.91	0.97	0.05	40.94
LANL-AK	0.00	2.00	0.01	0.00	0.17	1.89	12.00	0.00	8.89	12.00	0.00	0.91	0.97	0.05	61.11

* CeO_2 was added to glasses as a surrogate for PuO_2. ‡ There is no LANL-W composition due to a lettering error.
Note: LANL-M is the only composition in the test matrix that varied PbO beyond the negligible levels in the other glasses. Thus, this data point could be highly influential in data analyses.

The scatterplot matrix in Figure 2 shows that the 36-composition test matrix in Table IV covers the EVB GCER reasonably well. The LANL-A to LANL-U glasses have restricted ranges for most of the glass components, compared to the EVB GCER ranges.

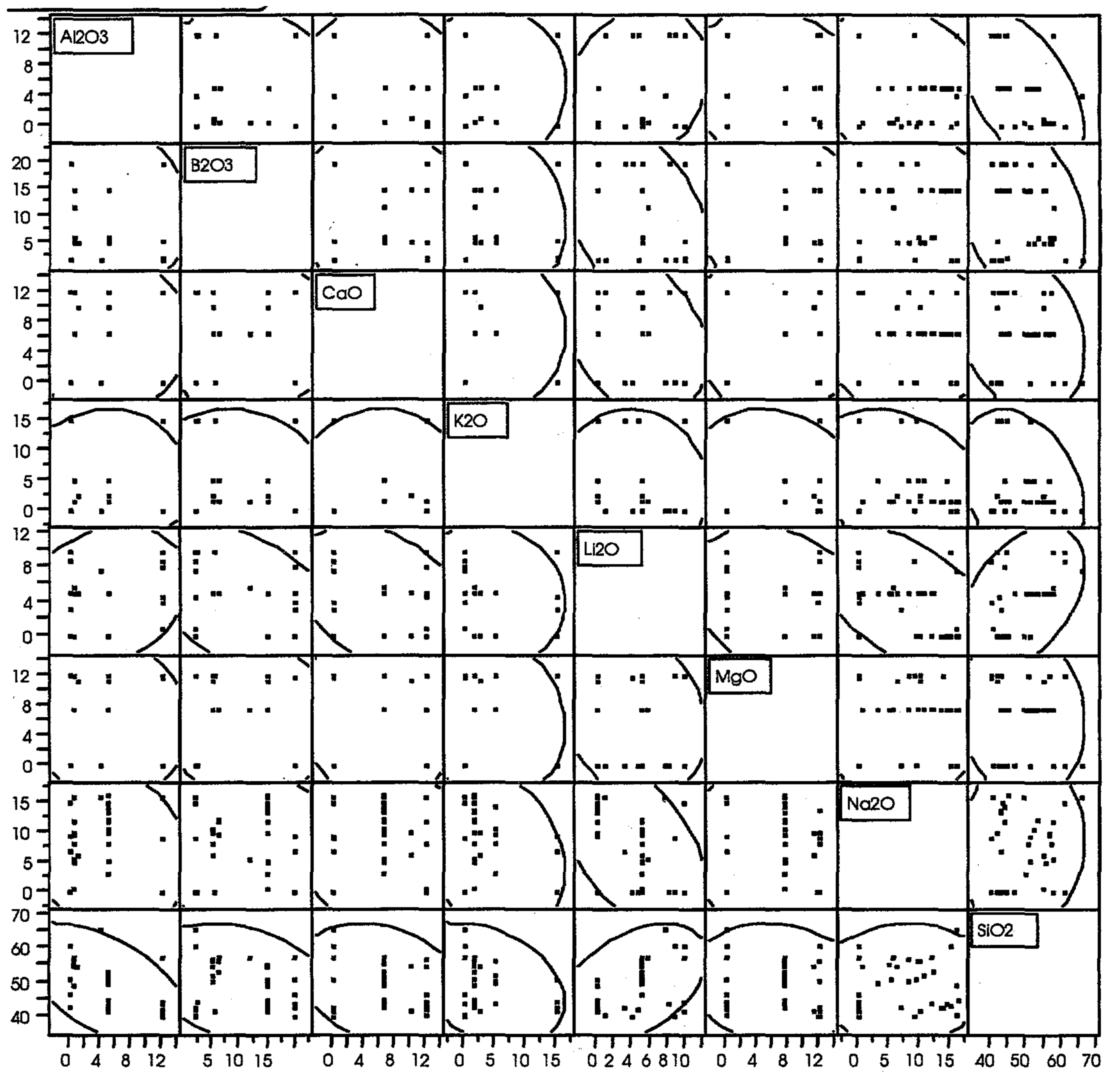

Figure 2. Scatter plot matrix of 36 test glass compositions (lines represent 95% bivariate normal density ellipses), Fe_2O_3 and others were omitted from the plot for ease of viewing

Testing and Glass Property Data *(Step 5)*

Each glass was melted in a Pt-10% Rh crucible with lid for 1 h in 350 g batches, ground in a tungsten carbide mill for 2-8 min, and re-melted for 1 h. The glass was quenched to room temperature on a steel plate. TCLP was performed on quenched glass in acetic acid at pH 4.7 for 18 h at 25°C with a glass surface area to solution volume ratio (S) of 45 m^{-1}. The resulting solutions were analyzed using inductively coupled plasma atomic emission spectroscopy (ICP/AES). TCLP releases were normalized to mass of element released per mass of element in glass (in g/g). Glass viscosity vs. temperature profiles were measured between approximately 2 and 50 Pa·s with a calibrated spindle viscometer, according to procedures reported previously (Hrma, et al. 1994). The PCT was performed according to the ASTM 1285 standard test procedure (ASTM 1995) in de-ionized water for 7 days at 90°C. PCT data were normalized to g/m^2 release, according to standard Materials Characterization Center (MCC) procedures (Hrma, et al. 1994).

Toxicity Characteristic Leach Procedure

TCLP data are reported as absolute releases (mg/L) for the restricted metals Cr, Ni, and Ba in Table V. Two other restricted metals (Pb and Cd) were present in the Table IV glasses; however, their releases were below the detection limit with three exceptions (two for Cd and one for Pb). Both As and Se were reported in the waste in very low quantities, but were not used in glass fabrication. The UTS and RCRA limits for restricted metal release from a glass waste form are also listed in Table V for comparison. The TCLP Ba releases for tested glasses range from

0.01 mg/L to 0.14 mg/L, all well below the UTS and RCRA limits. The TCLP Cd releases for tested glasses range from ≤0.02 mg/L to 0.04 mg/L, all well below the UTS and RCRA limits. The TCLP Cr releases for tested glasses range from well below the UTS limits (≤0.06 mg/L) to well above them (3.10 mg/L), while all were below the RCRA limits. The TCLP Ni releases for tested glasses range from well below the UTS limits (≤ 0.06 mg/L) to well above them (8.25 mg/L). RCRA doesn't restrict Ni release in a glass waste form. The TCLP Pb releases for tested glasses range from well below both the UTS and RCRA limits (≤0.30 mg/L) to well above them (26.95 mg/L).

Table V. TCLP results for LANL EVB glasses (mg/L)

Glass	B	Ba	Cd	Cr	Ni	Pb	Glass	B	Ba	Cd	Cr	Ni	Pb
LANL-A	13.13	0.03	0.04	0.12	1.03	(0.30)	LANL-S	1.36	0.02	(0.02)	0.08	0.20	(0.30)
LANL-B	1.45	0.01	(0.02)	(0.06)	0.13	(0.30)	LANL-T	18.89	0.06	0.04	0.32	1.81	(0.30)
LANL-C	3.29	0.02	(0.02)	(0.06)	0.20	(0.30)	LANL-U	1.37	0.01	(0.02)	(0.06)	0.07	(0.30)
LANL-D	115.77	0.08	(0.02)	0.09	3.10	(0.30)	LANL-V	147.56	-	-	(0.06)	0.40	(0.24)
LANL-E	108.33	0.07	(0.02)	0.13	2.98	(0.30)	LANL-X	2.97	0.02	-	0.06	0.38	(0.30)
LANL-F	4.89	0.01	(0.02)	(0.06)	0.10	(0.30)	LANL-Y	16.97	0.06	-	0.12	2.24	(0.24)
LANL-G	117.61	0.11	(0.02)	(0.06)	3.26	(0.30)	LANL-Z	5.16	0.07	-	2.49	3.49	(0.30)
LANL-H	5.24	0.02	(0.02)	(0.06)	0.12	(0.30)	LANL-AA	0.72	0.02	-	0.09	0.31	(0.24)
LANL-I	98.61	0.09	(0.02)	(0.06)	2.61	(0.30)	LANL-AB	12.77	0.03	-	2.13	4.27	(0.30)
LANL-J	93.54	0.09	(0.02)	0.09	2.64	(0.30)	LANL-AC	0.12	-	-	(0.06)	(0.06)	(0.24)
LANL-K	66.38	0.06	(0.02)	0.06	2.82	(0.30)	LANL-AD	0.08	0.01	-	(0.06)	0.07	(0.30)
LANL-L	53.06	0.05	(0.02)	(0.06)	1.52	(0.30)	LANL-AE	0.13	-	-	(0.06)	(0.06)	(0.24)
LANL-M	71.21	0.07	(0.02)	(0.06)	2.15	26.95	LANL-AF	0.91	-	-	(0.06)	(0.06)	(0.24)
LANL-N	19.54	0.07	0.02	0.27	1.79	(0.30)	LANL-AG	0.53	-	-	(0.06)	(0.06)	(0.30)
LANL-O	17.78	0.03	(0.02)	0.06	0.59	(0.30)	LANL-AH	80.92	0.14	-	3.10	8.25	(0.30)
LANL-P	19.70	0.04	(0.02)	0.06	0.66	(0.30)	LANL-AI	2.35	0.05	-	0.54	1.58	(0.30)
LANL-Q	1.07	0.01	(0.02)	(0.06)	0.12	(0.30)	LANL-AJ	0.27	0.02	-	0.13	0.08	(0.24)
LANL-R	2.89	0.02	(0.02)	0.07	0.30	(0.30)	LANL-AK	0.13	0.01	-	(0.06)	0.08	(0.24)
Blank-1	(0.03)	0.01	0.03	(0.06)	0.07	(0.30)	Blank-3	0.05	(0.01)	(0.02)	(0.06)	(0.06)	(0.30)
Blank-2	(0.03)	(0.01)	(0.02)	(0.06)	(0.06)	(0.30)	Blank-4	0.09	0.02	(0.02)	(0.06)	(0.06)	(0.30)
UTS limit	N/A	7.60	0.19	0.86	5.00	0.97	RCRA limit	N/A	100.00	1.00	5.00	N/A	5.00

Parenthetical values signify the detection limit, below which the value lies. "-" indicates that the component was not present in the glass. Four "Blank" samples were measured and included for information in the table. No attempt was made to correct for blank sample measured values.

Glass leach resistance under TCLP conditions can be estimated by the negative logarithm of the fractional release, -ln[f_i]. Equation (1) illustrates the conversion between TCLP release values and f_i:

$$f_i = \frac{C_i}{g_i m_i S}, \tag{1}$$

where C_i is the solution concentration of the i[th] element (mg/L), g_i is the mass fraction of the i[th] oxide in glass, m_i is the mass fraction of the i[th] element in the oxide, and S is the glass surface area to solution volume ratio. Note in Eq. (1) that the C_i values are not blank-corrected. Four blank solutions were submitted for chemical analysis along with TCLP solutions. However, the blank results were almost always below detection limits, so that blank-correcting the data would have introduced biases or increased variance into the raw TCLP release data. Thus, blank corrections were not performed. Table VI lists the -ln[f_i] values, where i denotes the element among B, Ba, Cd, Cr, Ni, and Pb.

Table VI. Negative logarithm of fractional release, -ln[f_i]

Glass	B	Ba	Cd	Cr	Ni	Pb	Glass	B	Ba	Cd	Cr	Ni	Pb
LANL-A	4.26	3.95	3.12	6.46	4.22		LANL-S	6.34	5.05		7.22	6.27	
LANL-B	6.46	4.83			6.32		LANL-T	3.72	3.41	3.11	5.47	3.66	
LANL-C	5.65	4.63			5.87		LANL-U	7.19	4.96			6.85	
LANL-D	3.00	3.10		6.73	3.12		LANL-V	3.05				3.16	
LANL-E	3.07	3.19		6.38	3.16		LANL-X	6.95	5.72		9.27	6.92	
LANL-F	6.17	5.05			6.58		LANL-Y	5.21	4.39		8.59	5.14	
LANL-G	2.99	2.83			3.06		LANL-Z	4.18	4.27		5.56	4.69	
LANL-H	6.10	4.60			6.39		LANL-AA	6.06	5.41		8.92	7.10	
LANL-I	3.16	2.97			3.29		LANL-AB	4.18	5.05		5.72	4.49	
LANL-J	3.21	3.04		6.72	3.28		LANL-AC	7.85					
LANL-K	3.56	3.78		7.50	3.62		LANL-AD	8.29	6.20			8.61	
LANL-L	3.78	3.58			3.83		LANL-AE	7.79					
LANL-M	3.49	3.19			3.48	4.46	LANL-AF	8.14					
LANL-N	3.68	3.26	3.72	5.67	3.66		LANL-AG	8.69					
LANL-O	4.88	4.01		7.14	4.77		LANL-AH	3.65	3.58		5.34	3.83	
LANL-P	4.77	3.86		7.14	4.66		LANL-AI	4.88	4.53		7.08	5.49	
LANL-Q	6.59	4.98			6.39		LANL-AJ	7.04	5.67		8.49	8.48	
LANL-R	5.59	4.32		6.97	5.47		LANL-AK	7.76	6.01			8.52	

Note: Missing values are those with concentrations below the detection limits or glasses without the component being measured.

Salt separation

The chromate separation shown in Figure 3 was identified in samples of compositions LANL-X, -Y, -Z, -AA, -AB, -AD, and -AK from this study, and in SRC-Mg-2 and -Mg-3 in Bulkley and Vienna (1996). All seven of the LANL glasses that formed the chromate phase contained the highest Cr_2O_3 concentration tested, 1.89 wt%. Ten glasses were tested with 1.89 wt% Cr_2O_3 including those listed above plus LANL-AH, -AI, and -AJ. The Li_2O concentration of the three glasses with 1.89 wt% Cr_2O_3 that didn't form chromate phase were 0.00 wt%, 0.00 wt%, and 1.06 wt%, respectively. The Li_2O concentration of the glasses which did form chromate was much higher, ranging from 5.20 wt% to 10.00 wt%. No other compositional trends were found. Chromate separation was shown to form in highly basic waste glass melts (Hlavac and Maruskova 1995, Li et al. 1997, and Darab et al. 1995). The basicity of all glasses was calculated according to the methods described by Volf (1988). No correlation between calculated glass basicity and chromate formation was seen for the high-Cr_2O_3 LANL glasses.

Chromate forms at low-temperatures in low viscosity, alkaline salt melts, while the glass batch materials begin to react. The phase then floats to the top of the higher density glass phase. Because the test glass melts in this study were formed from mixtures of metal oxides and carbonates, the formation of chromate in a glass melter with prefused glass frit and nitrate waste feed cannot be predicted from these data. Nearly full scale testing with waste simulant and prefused frit is recommended to test the possibility of chromate formation in the production plant.

To help avoid the separation of chromate in glass, high-Cr wastes can be blended to reduce Cr_2O_3 concentration, the melt can be reduced, or the Cr can be precipitated from the melt in the form of iron-nickel-chrome spinels. Spinel formation is a preferred method for accommodating high concentrations of Cr since: 1) the spinel rapidly crystallizes from glass below the liquidus temperature (T_L) (Reynolds and Hrma 1997), 2) it's known to have little effect on glass durability (Kim, et al. 1995), 3) its formation is easily induced and predicted (Mika et al. 1997 and Hrma et al. 1998), and 4) it has little effect on in-can glass processing. To increase the T_L of spinel in waste glasses while maintaining adequate properties, Al_2O_3 should be added to the frit and Li_2O should be used as a flux rather than Na_2O (Vienna et al. 1997).

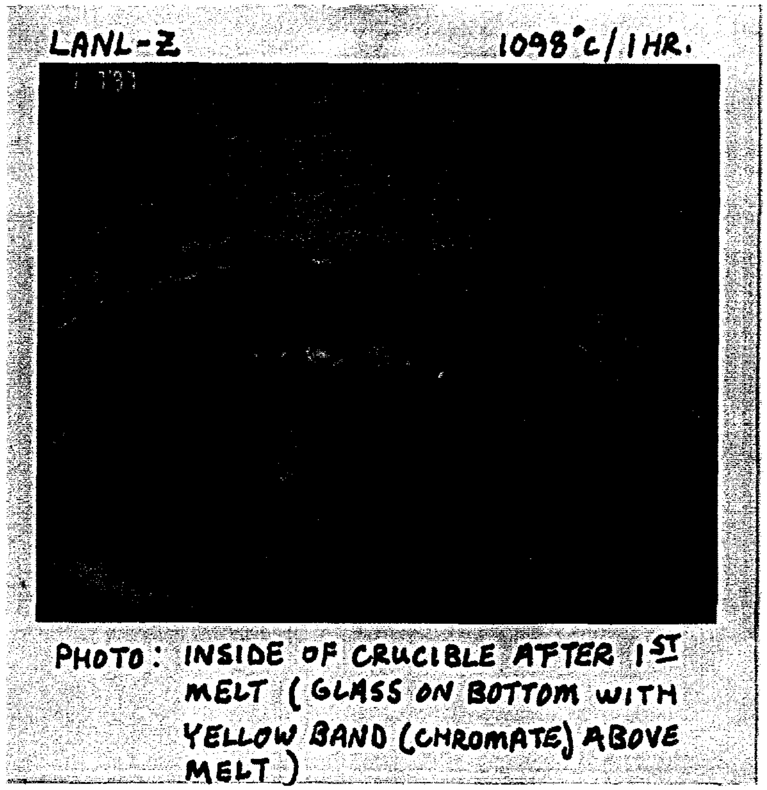

Figure 3. Chromate phase separation in LANL-Z glass

Property-Composition Relationships *(Step 6)*

Three data sets were used to develop or make predictions with property-composition relationships. The first data set is for the glasses in Table IV, which were designed to cover the composition region expected from vitrifying EVB wastes at LANL. The second data set is for glasses designed in a one-component-at-a-time change study based on a similar Pu-bearing material (Bulkley and Vienna 1997). The third data set is from glasses developed to cover the composition region expected from Hanford HLW glasses (Hrma et al. 1994). The first and second data sets were used to develop TCLP-composition relationships for LANL EVB glasses. The second and third data sets were used to develop viscosity-composition relationships for LANL EVB glasses. The third data set was used to develop electrical conductivity-composition relationships, as well as PCT release-composition relationships for LANL EVB glasses. A limited number of glasses from the first data set were used to validate the viscosity and PCT predictions based on the third data set.

Glass property data were interpolated, and in some cases extrapolated, to glass compositions of interest using property-composition relationships estimated from measured data. To explain this, consider the property-composition relationship:

$$P = \sum_{i=1}^{n} a_i g_i , \tag{2}$$

where P is a property or a transformed property (e.g., $-\ln[f_B]$), n is the number of major glass components, a_i is the ith component's partial specific property, and g_i is the ith component's mass fraction in the glass. Henceforth Eq. (2) is referred to as a first-order mixture (FOM) model.

While the "linear blending" form of Eq. (2) is widely known and used, it is not ideal for interpretation purposes. For constrained glass composition regions, the a_i coefficients obtained by fitting Eq. (2) to data are extrapolated predictions of property values for pure components. Hence, the a_i coefficients provide little basis for interpretation if they correspond to significant extrapolations. Eq. (2) can be rewritten in the mathematically equivalent form:

$$P = P_0 + \sum_{i=1}^{n} b_i s_i (1-s_i) g_i \,, \tag{3a}$$

where,

$$\sum_{i=1}^{n} b_i s_i (1-s_i) = 0 \,. \tag{3b}$$

In these equations, s_i is the mass fraction of glass component i in a particular glass composition $\mathbf{s}=(s_1, s_2, ..., s_n)$ of interest (usually somewhere in the center of the glass composition space of interest). P_0 is the predicted value of P at **s**, and is calculated via:

$$P_0 = \sum_{i=1}^{n} a_i s_i \,. \tag{4a}$$

The coefficient b_i is the slope of the relationship (2) at the composition **s**, along the direction of adding/subtracting the ith component to/from **s**. The b_i coefficients are obtained from the a_i values via:

$$b_i = \frac{a_i - P_0}{1 - s_i} \,. \tag{4b}$$

Hence the b_i can usefully be interpreted as the slopes of the property response surface corresponding to additions/subtractions of the ith component to/from a "baseline" glass composition, **s**. The equality constraint on the b_i in Eq. (3b) is needed to avoid over-parameterization resulting from converting Eq. (2) having n parameters (a_1, a_2, ..., a_n) to Eq. (3a) having n+1 parameters (P_0, b_1, b_2, ..., b_n).

Estimates of glass leach resistance under the TCLP conditions are given by the -ln[f_i] values in Table VI. Insufficient data exists to develop glass composition relationships to the release of each of the restricted metals individually. In addition, many of the restricted metals participate in secondary reactions, which further complicates prediction of their releases under TCLP conditions. To predict the TCLP release of restricted elements, the -ln[f_i] value for boron, -ln[f_B], is fitted to the compositions of the glasses according to Eq. (2). Because boron doesn't participate in ion-exchange processes and is seldom involved in secondary reactions in the leached solution, it is a good indicator of glass dissolution. The data from the Pu residue study of Bulkley and Vienna (1997) and the LANL EVB data were separately fitted to FOM models. Table VII shows the component coefficients (a_i values) for -ln[f_B] fitted to both data sets, along with the slopes of the component change vs. -ln[f_B] response taken at two glass compositions – the centroid of the LANL glasses and the baseline of the Pu residue study. The differences in apparent component effects (slopes) between the two data sets suggest that the data sets should not be combined without adding terms to account for the non-linear response of -ln[f_B] to change in composition.

The R^2 values from the FOM models in Table VI are 0.827 and 0.865, meaning that the models account for 82.7% and 86.5% of the variation in the measured –ln[f_i] values from the LANL EVB and Pu residue data sets, respectively. Although these are reasonably good R^2 values, they indicate that there likely exist non-linear blending effects of the glass components on TCLP releases. Adding four pure-quadratic terms (g_i^2) to the LANL EVB FOM model increased the R^2 from 0.827 to 0.931. Adding five pure-quadratic blending terms to the Pu residue FOM model increased the R^2 from 0.865 to 0.994. However, FOM models without second-order terms are better able to predict the properties of glasses not strictly in the composition range covered by model data.

Figure 4 compares the predicted TCLP B release values with the measured TCLP release values for restricted elements. The 45° line at "y=x" in Figure 4 represents the ideal in which predicted values exactly equal measured values. Data points below the 45° line represent conservative predictions (the predicted values are higher than the measured values), while data points above the 45° line represent under predictions. An additional 45° line at "y=x+10" in Figure 4 shows and order of magnitude under-prediction. For Cr, the most restrictive component, the predictions are conservative in every case. Likewise, the prediction for Pb release are always conservative. Predictions for Ba and Cd with measured releases below 0.1 mg/L tend to be non-conservative. Predictions for Ni release are scattered around the 45° line, indicating roughly accurate predictions. Those Ni releases calculated to be below the UTS Limit of 5 mg/L are below 5 mg/L. Conservative predictions might have been expected given that TCLP B releases are expected to bound releases of the restricted elements. However, non-conservatism is seen for Ba and Cd, both components are known to participate in ion-exchange processes during glass leaching.

Based upon these model results, the TCLP release limits used for glass development will be altered to ensure conservative prediction. The limits for Cr, Ni, and Pb releases used in glass formulation will be the UTS limits (0.86 mg/L, 5 mg/L, and 5 mg/L, respectively). The formulation limits on TCLP releases of all other metals will be one order-of-magnitude below the UTS limit (0.03 mg/L Ag, 0.5 mg/L As, 0.76 mg/L Ba, and 0.019 mg/L Cd).

Table VII. First-order mixture (FOM) and slope models for $-\ln[f_B]$[a] fitted to the LANL and Pu residue data sets

Component	36 LANL EVB Glasses FOM	Slope FOM LANL Cent.	Slope FOM Pu res Baseline	32 Pu residue Glasses [b] FOM	Slope FOM LANL Cent.	Slope FOM Pu res Baseline
Intercept [c]	N/A	5.25	3.72	N/A	5.24	7.93
Al_2O_3	21.10	16.83	18.28	12.78	8.01	5.11
B_2O_3	-9.23	-15.91	-13.79	-12.19	-19.15	-21.40
CaO	-7.92	-13.85	-12.24	-3.06	-8.73	-11.56
CeO_2				16.21	10.99	8.67
Fe_2O_3	11.55	6.65	7.82			
K_2O	-15.58	-22.69	-19.91	-11.67	-18.43	-20.21
Li_2O	-23.13	-29.98	-27.97	-6.28	-12.17	-14.80
MgO	-11.04	-17.19	-15.07	-5.56	-11.40	-13.77
Na_2O	-20.09	-27.00	-26.46	1.71	-3.77	-6.92
PbO				4.90	-0.34	-3.06
SiO_2	19.00	26.37	27.77	12.85	14.60	8.95
SnO				12.66	7.41	4.72
TiO_2				13.10	7.86	5.22
ZrO_2				16.14	10.90	8.46
LANL Others	-6.54	-12.03	-12.85[d]	N/A	N/A	N/A
Pu res Others	N/A	N/A	N/A	14.51	9.98	7.35
R^2	0.827	0.827	0.827	0.865	0.865	0.865
R^2(adj)	0.768	0.768	0.768	0.768	0.768	0.768

(a) TCLP B release was selected as representative or conservative of other normalized releases, including the restricted metals Ba, Cd, Cr, Ni, and Pb that were released in detectable amounts from glasses in the LANL EVB test matrix.

(b) The four glasses in this data set involving one-at-a-time variations in Gd_2O_3 were not used because TCLP was not present in the available database. Apparently, these data are available, and the results should be redone to account for the effect on TCLP of Gd_2O_3 (which is present in the 32 Pu residue glasses used to develop these models).

(c) The intercept is the predicted value of $-\ln[f_B]$ at the: (i) centroid of the LANL glass composition experimental region (obtained by averaging the 2269 extreme vertices of the region), or (ii) the baseline composition of the Pu residue study.

(d) Based on an extrapolation outside the component range for data used to develop the empirical model.

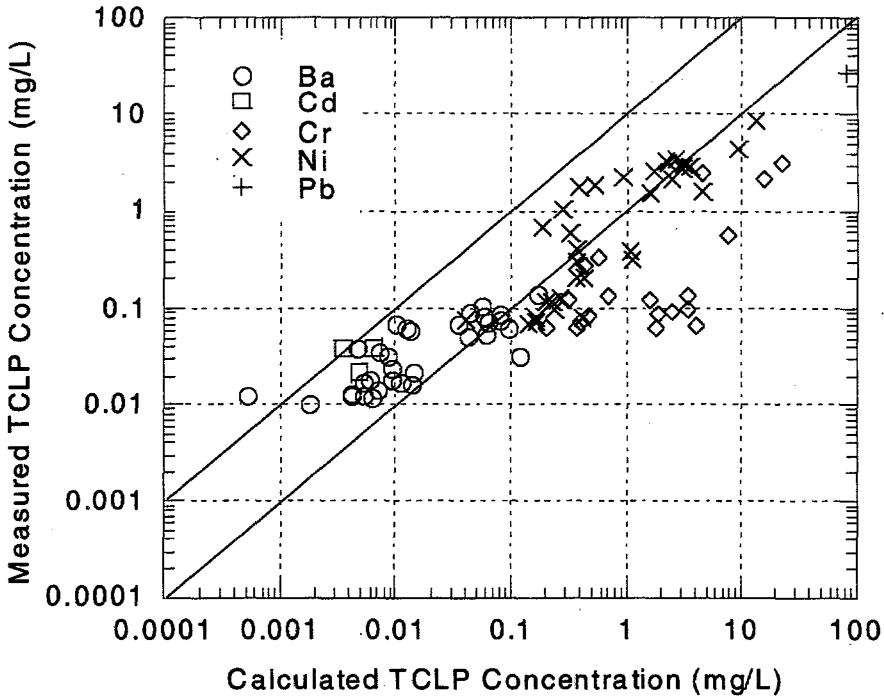

Figure 4. Measured and calculated TCLP releases of Ba, Cd, Cr, Ni, and Pb

The final a_i coefficient values for viscosity, electrical conductivity, TCLP, and PCT are shown in Table VIII. These coefficients were used to calculate the glass property values for proposed EVB glasses to optimize the frit composition, as described in the next section.

Table VIII. FOM model coefficient (partial specific property) values used in glass composition development

Property	Viscosity		Electrical Conductivity		TCLP	PCT	
Model*	A_η	B_η	A_ε	B_ε	$-\ln[f_B]$	$\ln(r_{Na})$	$\ln(r_B)$
Al_2O_3	-4.089	21186.0	7.140	-8227.2	21.1	-25.429	-26.103
B_2O_3	-13.659	10868.0	12.820	-15135.0	-9.23	9.405	10.530
CaO	-22.750	21522.0	14.410	-18769.0	-7.92	-1.957	-8.953
Fe_2O_3	-6.404	8774.0	9.940	-10608.0	11.55	-4.095	-2.214
K_2O	-1.780	0.0	5.318	2616.1	-15.58	-1.531	3.963
Li_2O	-4.514	-42288.0	7.470	22484.0	-23.13	19.064	18.668
MgO	-21.105	25767.0	10.390	-13414.0	-11.04	11.823	10.924
Na_2O	-9.604	-1217.1	6.050	7089.5	-20.09	19.401	15.286
SiO_2	-11.084	28539.0	8.120	-10283.0	19	-4.412	-3.452
Others	-17.017	23027.0	18.110	-20653.0	-6.54	-0.665	1.667
Data sets	CVS	CVS	CVS	CVS	LANL	CVS	CVS
R^2	0.97	0.97	0.96	0.96	0.83	0.85	0.78
Adj R^2	0.97	0.97	0.96	0.96	0.77	0.83	0.75

*For viscosity and electrical conductivity, Arrhenius coefficients are used, for example $\ln[\eta]=A_\eta+B_\eta/T$

Model Validation (*Step 7*)

Validation glasses were used to estimate the accuracy of the glass property predictions used for frit optimization. Validation glasses are glasses that were not used to fit the predictive property-composition relationships. The validation glasses were fabricated, and their properties were measured and compared to the predicted values. These results are reported, by property, in this section.

Specifically, two glasses were selected for validating the viscosity and TCLP property-composition relationships. Table IX lists the compositions of the two glasses, along with their predicted and measured properties. The first of these glasses, LANL-AL, is outside the composition region covered by the 163 glasses of this study. However, it is within the GCER. This glass is thus an extreme composition, for purposes of validation. The second validation glass tested, LANL-AM, is the mean glass composition for the 163 glasses of this study. Both glasses formed spinel at the melting temperature. Viscosity and PCT release were measured for several additional glasses and electrical conductivity was measured for one additional glass. These glasses and validation results are discussed below.

Table IX. Composition and properties for two validation glasses, LANL-AL and -AM

Glass Composition			Glass Properties		
	AL	AM	**LANL-AL**	Calc	Meas
Al_2O_3	8.00	5.47	A_η	-11.3	-10.33
BaO	0.00	0.00	B_η (K)	18,242	16,961
B_2O_3	4.60	5.00	η_{1050} (Pa·s)	12.6	12.0
CaO	6.40	5.82	TCLP $-\ln[f_B]$	6.37	7.92
CdO	-	0.00	TCLP C_{Cr} (mg/l)	0.47	<0.06
CeO_2	0.10	-	TCLP C_{Ni} (mg/l)	0.27	0.08
Cr_2O_3	0.80	0.67	PCT r_{Na} (g/m^2)	*	*
Fe_2O_3	3.60	2.83	PCT r_B (g/m^2)	*	*
HfO_2	-	0.09	**LANL-AM**		
K_2O	4.40	3.55	A_η	-11.6	-11.81
La_2O_3	-	0.01	B_η (K)	18,054	18,627
Li_2O	5.90	7.00	η_{1050} (Pa·s)	8.0	9.7
MgO	8.50	10.02	TCLP $-\ln[f_B]$	5.92	5.44
Na_2O	6.70	6.44	TCLP C_{Cr} (mg/l)	0.62	<0.06
NiO	0.40	0.34	TCLP C_{Ni} (mg/l)	0.36	0.55
PbO	-	0.02	PCT r_{Na} (g/m^2)	1.26	1.78
SiO_2	50.60	52.67	PCT r_B (g/m^2)	1.30	1.70

*PCT values were not measured for LANL-AL

Toxicity Characteristic Leach Procedure data

The TCLP Cr and Ni releases of LANL-AL and LANL-AM are compared to predicted values in Table IX. As concluded in Step 6, the Cr releases are conservatively predicted. The Ni releases, predicted to be below the UTS limits, are below the UTS limits and are both close to the calculated values. No other data has been taken for TCLP model validation.

Viscosity data

For Hanford HLW glass data (Hrma et al. 1994), the viscosity/temperature relationship was shown to be adequately represented by an Arrhenius equation with parameters expressed as first-order functions of composition. To formulate EVB glass compositions, viscosity at 1050°C was predicted using the coefficients given in Table VIII. These coefficients are from the Hanford HLW glass composition variation study (CVS), with the addition of a K_2O coefficient based upon the Pu residue study data (see Table III). Five data points, chosen to be at extremes in the EVB glass composition space, were tested to confirm and validate the viscosity predictive model. Table X lists the predicted and measured viscosity results for LANL-F, -H, -Q, -R, and -U, in addition to the two previously discussed validation glasses (LANL-AL and -AM). The calculated values are within 10% of the measured values, with the exception of LANL-AM, which has a calculated value 16% below the measured value. This is an excellent agreement, considering that the data used for fitting was based on glasses with higher melting temperatures. The increased measured viscosity (over the calculated value) for LANL-AL and -AM was likely caused by the spinel that formed in the glass at temperatures above 1050°C. In summary, the viscosity model in Table VIII appears to adequately represent the relationship between viscosity at 1050°C and glass composition over the LANL EVB GCER. Hence, glasses made with frit optimized using these models should have viscosity at 1050°C values within or close to the desired 2 to 10 Pa·s range.

Table X. Calculated and measured glass viscosity values for selected glasses

	Calculated			Measured		
	A_η	B_η (K)	η_{1050} (Pa·s)	A_η	B_η (K)	η_{1050} (Pa·s)
LANL-F	-12.05	18,810	8.7	-11.11	17,671	9.5
LANL-H	-12.36	19,232	8.8	-11.51	17,987	8.1
LANL-Q	-12.67	19,662	8.9	-11.25	17,807	9.1
LANL-R	-12.46	19,375	8.9	-11.21	17,631	8.3
LANL-U	-12.21	19,023	8.8	-11.51	17,987	8.1
LANL-AL	-11.25	18,242	12.6	-10.33	16,961	12.0
LANL-AM	-11.57	18,054	8.0	-11.81	18,627	9.7

Product consistency test data

Several glasses were tested for PCT to validate the FOM model in Table VIII. The results of these tests are listed in Table XI, and are compared to predicted values in Figure 5. The values predicted to be below 3 g/m^2 were closely predicted. Glasses with PCT releases calculated to be above 3 g/m^2 were not well predicted, showing high scatter in Figure 6. There was as much as 6 g/m^2 difference between predicted and measured values (LANL-B). The poor prediction performance for larger PCT releases is expected since the data used to generate the model was based on lower release glasses (Hrma et al., 1994). Except for one validation glass, larger PCT releases are under predicted by the PCT-composition relationship in Table VIII. Under-predicting larger PCT releases means that some glass compositions with PCT releases larger than the limits specified in Table II may be allowed during the glass optimization in Step 8.

A margin of error of 3× and 2× for r_B and r_{Na}, respectively will ensure that glasses with predicted releases below the stated limit will actually have releases below that limit. For the purposes of glass optimization (Step 8), release limit of 2.83 g/m^2 and 3.3 g/m^2 will be used for r_B and r_{Na}, respectively.

Table XI. Calculated and measured 7-day PCT results for selected glasses

Glass	r_B (g/m^2)		r_{Na} (g/m^2)	
	Calc	Meas	Calc	Meas
LANL-B	4.6	11.9	5.9	8.6
LANL-C	3.7	10.6	3.9	8.1
LANL-F	1.9	0.8	1.7	1.4
LANL-H	4.3	9.9	3.9	7.8
LANL-N	1.6	0.6	1.8	0.7
LANL-O	1.5	1.1	1.1	1.3
LANL-P	1.3	1.3	1.6	3.1
LANL-Q	1.4	0.6	2.4	1.2
LANL-R	5.0	6.4	6.7	4.8
LANL-S	1.8	2.0	2.7	1.9
LANL-T	1.7	1.4	1.9	1.5
LANL-AM	1.3	1.7	1.3	1.8

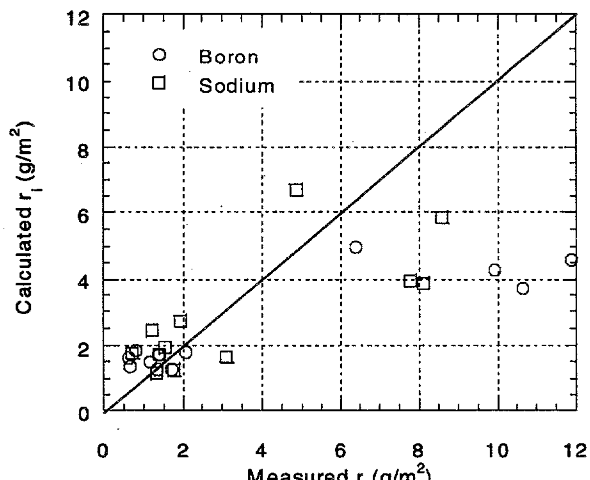

Figure 5. Comparison of calculated and measured PCT data for validation glasses

Electrical conductivity data

For Hanford HLW glass data (Hrma et al. 1994), the electrical conductivity-temperature relationship was shown to be adequately represented by an Arrhenius equation with parameters expressed as first-order functions of composition. To formulate EVB frit compositions, electrical conductivity at 1100°C was predicted using the coefficients in Table VIII (from the Hanford HLW CVS, Hrma et al. 1994). No restrictions were placed on electrical conductivity (see Table II), so predictions were only for general consideration in selecting a frit composition.

Because the electrical conductivity-composition relationship was not used to restrict and formulate the EVB frit and glass compositions, only one glass was used to validate the relationship. The value predicted for LANL-U glass (18.00 S/m) is close to the measured value (22.36 S/m). Since the electrical conductivity is easily adjusted and predicted in waste glasses, and is not crucial to the success of an in-can melting operation, no further measurements were performed.

Frit Optimization *(Step 8)*

An iterative solution routine was used to optimize the frit composition for the vitrification of all 163 waste compositions at a fixed waste loading (25 wt%) with the maximum number of glasses meeting the criteria listed in Table II. For this step, each of the waste compositions was blended (via calculation) with the same concentration of the same frit. Then the resultant glass composition was substituted into property-composition relationships, using the property-composition coefficients in Table VIII to predict property values.

Ideally, the uncertainties in the property-composition relationships should be accounted for in developing frit/glass compositions. Accounting for such uncertainties would increase the probability of frit and glass compositions having acceptable property values. However, the limited funding for this work did not permit accounting for uncertainties in property-composition relationships. To ensure that glasses predicted to meet the property restrictions in Table II, safety margins were added to the "predicted property values" as discussed in Step 7. Table XII shows the limits used for predicted property values used for glass optimization.

Table XII. Restrictions used for glass optimization

Restriction	Property Limit*	Predicted Value Limit
TCLP [Ag]	0.3 mg/L	0.03 mg/L
TCLP [As]	5 mg/L	0.5 mg/L
TCLP [Ba]	7.6 mg/L	0.76 mg/L
TCLP [Cd]	0.19 mg/L	0.019 mg/L
TCLP [Cr]	0.86 mg/L	0.86 mg/L
TCLP [Ni]	5 mg/L	5 mg/L
TCLP [Pb]	0.37 mg/L	0.37 mg/L
PCT r_B	8.5 g/m^2	2.83 g/m^2
TCLP r_{Na}	6.6 g/m^2	3.3 g/m^2
viscosity at 1050°C	$2 < \eta < 10$ Pa·s	$2 < \eta < 10$ Pa·s

* Value from Table II.

The frit composition was altered using a constrained non-linear optimization routine, to maintain the properties of a maximum number of glasses within the acceptable ranges specified in Table II. The resulting frit composition is: 70.26 wt% SiO_2, 8.00 wt% B_2O_3, 5.66 wt% Na_2O, 10.08 wt% Li_2O, and 6.00 wt% Al_2O_3. The ranges of glass compositions for this frit mixed with 25% of each of the 163 waste compositions are given in Table XIII.

Table XIII. Summary of glass compositions with optimized frit in wt%

	Mean	Median	StDev	Min	Max
Ag_2O	0.000	0.000	0.000	0.000	0.001
Al_2O_3	5.335	5.155	1.063	4.500	15.899
Am_2O_3	0.008	0.006	0.006	0.000	0.032
As_2O_3	0.001	0.001	0.002	0.000	0.018
B_2O_3	6.000	6.000	0.000	6.000	6.000
BaO	0.003	0.002	0.004	0.000	0.031
BeO	0.046	0.020	0.072	0.000	0.351
CaO	5.820	5.924	1.882	0.000	15.681
CdO	0.001	0.000	0.003	0.000	0.030
Cr_2O_3	0.673	0.559	0.392	0.079	2.677
Fe_2O_3	2.829	2.378	1.617	0.000	10.311
K_2O	3.552	3.227	2.036	0.000	11.106
Li_2O	7.560	7.560	0.000	7.560	7.560
MgO	10.017	9.777	3.275	0.000	23.142
Na_2O	4.993	4.522	1.770	4.260	19.016
NiO	0.340	0.275	0.212	0.007	1.602
PbO	0.024	0.019	0.021	0.002	0.128
PuO_2	0.094	0.058	0.095	0.000	0.631
SiO_2	52.695	52.695	0.000	52.695	52.695
TlO_x	0.004	0.003	0.007	0.000	0.063
U_3O_8	0.004	0.003	0.004	0.000	0.026

Several glasses (37) that fall outside of the acceptable property restrictions defined in Table II, or that are outside of the GCER, are listed in Table XIV. The two glasses with predicted viscosities higher than 15 Pa·s should not be processed without further testing. The nine glasses with r_{Na} and/or r_B above the specified upper limit values correspond to compositions outside the GCER or have higher than acceptable TCLP releases. Of the 37 glasses in Table XIV, 29 (78.4%) are outside the GCER due to high MgO, 21 of which would be inside the GCER if the MgO limit were increased from 12 to 15 wt%. Glasses with compositions outside the GCER have not been tested and may not melt properly, may not form durable glasses, and/or may not have adequate properties. For these extreme waste compositions, we recommend one of four options:

1) use blended wastes to adjust the chemistry,
2) vitrify the waste at a lower WL,
3) test glass compositions before processing to increase the acceptable region, or
4) treat the waste using an alternative system.

Table XIV. Summary of glasses falling outside of property restrictions or GCER

Set	User Sample ID	Comments	Set	User Sample ID	Comments
HD	2EVDIST15BF1	15.7 wt% CaO	DS	EVDS082696A1	12.3 wt% MgO
HD	EVDIS122195B1	12.7 wt% MgO	DS	EVDS091396A1	13.5 wt% MgO
HD	EVDIS091096B1	12.9 wt% MgO	DS	EVDS091396A2	12.6 wt% MgO
HD	EVDIS091796B1	12.2 wt% MgO	DS	EVDS092596A1	13.5 wt% MgO
HD	EVDIS100496B1	13.0 wt% MgO	DS	EVDS092596A2	13.9 wt% MgO
HD	EVDIS100996B1	12.9 wt% MgO	DS	EVDS100496A1	15.1 wt% MgO
HD	EVDIS101796B2	T_{Cd}=0.032 mg/L	DS	EVDS100496A2	14.1 wt% MgO
HD	EVDIS102996B1	13.5 wt% MgO	DS	EVDS101096A2	13.8 wt% MgO
HD	EVDIS031197B1	20.1 wt% MgO, r_B=5.23 g/m^2, r_{Na}=5.15 g/m^2	DS	EVDS101096A3	13.2 wt% MgO
HD	EVDIS040297A1	18.4 wt% MgO, r_B=3.44 g/m^2, r_{Na}=3.62 g/m^2	DS	EVDS101096A1	12.8 wt% MgO
HD	EVDIS101896A2	15.9 wt% Al_2O_3, η=35.4 Pa·s	DS	EVDS102396A1	12.7 wt% MgO
OX	12OX13AF1	T_{Cr}=0.997 mg/L	DS	EVDS102396A2	12.1 wt% MgO
OX	12OX17AF1	r_B=5.14 g/m^2, r_{Na}=6.88 g/m^2, T_{Cr}=1.940 mg/L	DS	EVDS102496A1	12.8 wt% MgO
OX	12OX18AF1	19.0 wt% Na_2O, r_B=4.59 g/m^2, r_{Na}=6.80 g/m^2, T_{Cr}=1.057 mg/L	DS	EVDS012297B1	16.1 wt% MgO
OX	4OX6BF1	T_{Cr}=1.155 mg/L	DS	EVDS040297B2	20.7 wt% MgO, r_B=5.16 g/m^2, r_{Na}=5.20 g/m^2
DS	ATLDS11EFB4	12.5 wt% MgO	DS	EVDS040297B1	20.3 wt% MgO, r_B=4.96 g/m^2, r_{Na}=4.90 g/m^2
DS	EVDS021396B2	12.9 wt% MgO, r_B=2.84 g/m^2	DS	EVDS040497B1	23.1 wt% MgO, r_B=8.51 g/m^2, r_{Na}=7.79 g/m^2
DS	EVDS030896A1	11.0 wt% Al_2O_3, η=16.4 Pa·s	DS	EVDS040497B2	21.4 wt% MgO, r_B=6.55 g/m^2, r_{Na}=6.04 g/m^2
DS	EVDS050696B1	13.0 wt% MgO, T_{Cd}=0.021 mg/L			

The calculated TCLP releases are summarized in Table XV for the 163 glasses. The current RCRA and UTS limits for each element are also shown in Table XV for comparison. As can be seen from the summary statistics, the calculated releases of Ag, As, and Ba are an order of magnitude below even the more stringent UTS limits. The conservative order-of-magnitude safety margin for TCLP Cd release, however, has made 2 of the glasses violate the TCLP limit, one of which is also outside of the GCER. The calculated releases of Ni and Pb, are below the UTS limits for all 163 glasses. Four glasses have predicted TCLP Cr releases above the UTS limits. Of these four high-Cr release glasses, two are predicted to have higher than acceptable PCT releases

Table XV. Summary of calculated TCLP releases for the 163 LANL EVB glasses

Element	Current RCRA Limit (mg/L)	UTS Limit (mg/L)	Calculation Limit (mg/L)	Max Calculated Release (mg/L)	Mean Calculated Release (mg/L)	# of Glasses with Calculated Releases > Calculation Limit
Ag	5	0.3	0.03	0.00147	0.00013	0
As	5	5	0.5	0.01660	0.00113	0
Ba	100	7.6	0.76	0.03858	0.00337	0
Cd	1	0.19	0.019	0.03169	0.00098	2
Cr	5	0.86	0.86	1.94042	0.55353	4
Ni	-	5	5	0.90550	0.32795	0
Pb	5	0.37	0.37	0.13196	0.02946	0

Optimized Glass Validation *(Step 9)*

The final step to glass development is the validation/verification of the properties of optimized glasses. This step is outside of the scope of this report. It is recommended that glasses made with the optimized frit covering the expected glass composition region be fabricated using the final glass melter technology. Further, the properties of these glasses should be measured to validate the predictions and assertions of this study.

Discussion and Recommendations

A frit composition was optimized for vitrifying the diverse EVB wastes at LANL, at a waste loading of 25% on an oxide weight basis. Based on model predictions, a majority (roughly 77%) of the glasses formed by combining EVB wastes with 75wt% of the optimized frit will meet the specified set of glass property constraints. The frit composition – 70.26 wt% SiO_2, 8.00 wt% B_2O_3, 5.66 wt% Na_2O, 10.08 wt% Li_2O, and 6.00 wt% Al_2O_3 – was optimized specifically to make good glasses with the maximum amount of variation allowed in the waste composition. We recommend this frit composition for use as a baseline frit in EVB vitrification demonstrations and operations at LANL. Any variation in the restrictions, listed in Table II, may alter the optimum frit composition. If changes arise, it is recommended that calculations and limited testing be performed to re-optimize the frit composition.

Several (23%) of the glasses resulting from mixing (via calculation) the optimized frit with 25 wt% of each of the 163 waste compositions either fall outside the glass composition experimental region and/or the property restrictions set for this study. It is recommended that one of four options be implemented for these compositions: 1) blend wastes to adjust the chemistry, 2) vitrify the waste at a lower WL, 3) test glass compositions before processing, or 4) treat the waste using an alternative system. In particular, it is not clear whether more than 12wt% MgO is compatible with high-durability, low-temperature glasses.

Conservative leaching criteria were used for glass optimization. These include meeting or exceeding Universal Treatment Standard (UTS) limits with the Toxicity Characteristic Leach

Procedure (TCLP), and Environmental Assessment standard in the product consistency test (PCT). These requirements are beyond the regulatory requirements for these wastes; however, they ensure that durable waste glass is produced.

It was difficult to fabricate the two validation glasses at 1050°C from their oxide and carbonate precursors. These glasses took several hours of melting at temperature to form homogeneous glass. It is difficult or impossible to translate this experience to their processability in the melter system. However, testing is recommended to ensure the processability of waste glass compositions, using frit and waste simulants.

Chromate separation was seen in a number of test glasses while melting from oxide and carbonate precursors. It is difficult to assess when a chromate phase may form. An attempt was made in frit design to increase the spinel liquidus temperature in glasses with higher chromium content. This may force the chromium into spinel, rather than having it oxidize and separate into an alkali chromate phase. Both validation glasses, LANL-AL and -AM, formed spinel and not chromate. Large scale prototype testing with waste simulant and pre-fused frit is recommended to determine the propensity of waste streams to chromate separation.

The properties of the optimized glass were not adequately validated (or verified). It is recommended that glasses encompassing the expected processing composition region be fabricated and tested to ensure adequate properties. The fabrication of these glasses should, ideally, be performed using the final melter system before radioactive start-up.

Acknowledgments

This study was performed for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830. The authors would like to acknowledge Michael J. Schweiger for laboratory assistance, and Pavel R. Hrma and Hong Li for insightful conversations and assistance. RP Thimpke acknowledges partial funding by the Science and Engineering Research Semester Program under the management of Associated Western Universities, Northwest. The cooperation and support of Stephen O. Bates, Idaho National Engineering and Environmental Laboratory, is greatly appreciated.

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Appendix: Evaporator Bottoms Waste Compositions

Table AI lists the compositions of evaporator bottoms waste samples measured at LANL, using Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES) for major components, cold vapor atomic fluorescence for Hg, germanium gamma spectrometry for Am, and alpha proportional counter for Pu. These samples were taken from homogeneous liquid waste streams. Adjustments were made to this composition data to ensure that representative data were used in frit optimization. These adjustments are described in Step 1 of the main report. The resulting compositions in wt% oxides, shown in Table AII, were then used for the glass composition calculations described in this report.

Table AI. Solution concentration of components in EVB waste

†	User Sample ID	Ag	Al	Am*	As	Ba	Be	Ca	Cd	Cr	Fe	Hg	K	Mg	Na	Ni	Pb	Pu*	Se	Tl	U
1	10EVDIST27BF1	< 1		0.0942	< 5	80	19		21	7000	28000	< 5				4600	360	2.42	< 8	NR 0	< 20
~~1~~	~~11EVDIST1BF1~~	~~< 10~~		~~0.0602~~	~~< 50~~	~~70~~	~~15~~		~~< 10~~	~~5700~~	~~23000~~	~~< 50~~				~~4000~~	~~300~~	~~2.52~~	~~< 80~~	~~NR 0~~	~~< 200~~
~~1~~	~~11EVDIST8AF1~~	~~< 1~~		~~0.0251~~	~~< 5~~	~~48~~	~~5.2~~		~~9~~	~~4200~~	~~15000~~	~~< 25~~				~~2300~~	~~110~~	~~1.47~~	~~< 8~~	~~350~~	~~< 100~~
~~1~~	~~11EVDIST8BF1~~	~~< 1~~		~~0.0585~~	~~< 5~~	~~79~~	~~16~~		~~20~~	~~6000~~	~~23000~~	~~< 25~~				~~2600~~	~~280~~	~~1.83~~	~~< 8~~	~~730~~	~~< 100~~
~~1~~	~~11EVDIST17BF1~~	~~< 1~~		~~0.0364~~	~~< 5~~	~~51~~	~~3~~		~~4.6~~	~~4000~~	~~15000~~	~~< 5~~				~~2300~~	~~140~~	~~1.57~~	~~< 8~~	~~780~~	~~< 20~~
1	12EVDIST6AF1	< 1	1700	0.0377	< 5	37	4.7	25000	3.8	5000	20000	< 5	5300	32000	3300	2400	76	1.8	< 8	NR 0	< 20
~~1~~	~~12EVDIST15AF1~~	~~< 1~~		~~0.033~~	~~< 5~~	~~51~~	~~19~~	~~41000~~	~~4.3~~	~~4200~~	~~17000~~	~~< 5~~	~~13000~~	~~64000~~	~~7900~~	~~2100~~	~~120~~	~~1.47~~	~~< 8~~	~~NR 0~~	~~< 20~~
~~1~~	~~12EVDIST15AF1R~~	~~< 1~~		~~0~~	~~< 5~~	~~76~~	~~31~~	~~56000~~	~~6.2~~	~~6600~~	~~26000~~	~~< 5~~	~~17000~~	~~95000~~	~~13000~~	~~3100~~	~~170~~	~~0~~	~~< 8~~	~~NR 0~~	~~< 20~~
1	12EVDIST21AF1	< 1	6500	0.0247	< 5	35	< 1	62000	< 1	3100	15000	< 5	12000	57000	12000	1900	82	1.59	< 8	NR 0	< 20
1	2EVDIST14AF1	< 1	1700	0.0228	15	29	80	11000	3	6200	21000	< 5	7700	14000	3900	2700	150	0.728	< 8	< 20	< 20
1	2EVDIST15BF1	< 1	1400	0.0131	< 5	25	37	64000	< 1	2900	13000	< 5	6800	8400	2500	1900	56	0.29	< 8	< 20	< 20
1	2EVDIST16AF1	< 1	700	0.0062	< 5	11	16	2400	< 1	1100	5100	< 5	2900	2900	1700	670	51	0.159	< 8	< 20	< 20
1	3EVDIST14BF1	< 1	2500	0.0203	< 5	30	37	12000	< 1	3500	14000	< 5	11000	14000	3200	2400	110	0.48	< 8	< 20	< 20
1	3EVDIST20BF1	< 1	430	0.0034	< 5	6.5	7.7	2200	< 1	1600	6300	< 5	470	2600	200	1100	14	0.163	< 8	< 20	< 20
1	3EVDIST24BF1	< 1	1100	0.0138	< 5	7.7	18	2800	< 1	1100	4900	< 5	6100	7600	790	880	18	0.059	< 8	< 20	< 20
1	3EVDIST28BF1	< 1	3800	0.0233	< 5	44	11	31000	< 1	3400	13000	< 5	13000	35000	6400	2800	120	1.54	< 8	< 20	< 20
1	3EVDIST29BF1	< 1	8100	0.0319	< 5	55	14	41000	< 1	5700	25000	< 5	18000	37000	1000	4300	230	1.9	< 8	< 20	< 20
1	3EVDIST31BF1	< 1	3500	0.0242	< 5	30	21	18000	< 1	4400	17000	< 5	9200	25000	6100	3300	120	1.29	< 8	< 20	< 20
1	4EVDIST12BF1A	< 1	2100	0.0084	< 5	22	4.7	30000	< 1	4900	20000	< 5	4400	39000	1500	2600	25	0.504	< 25	< 20	< 20
1	4EVDIST12BF1B	< 1	1700	0.0087	< 5	17	4.7	21000	< 1	3600	15000	< 5	4800	36000	1200	2300	25	0.383	< 25	< 20	< 20
1	4EVDIST21BF1A	< 1	5300	0.113	< 5	19	900	34000	< 1	3000	14000	< 5	43000	56000	1900	1800	190	0.438	< 25	< 20	< 20
1	4EVDIST21BF1B	< 1	8400	0.161	< 5	32	1400	63000	< 1	5000	24000	< 5	62000	69000	3200	2700	280	0.92	< 25	< 20	< 20

†	User Sample ID	Ag	Al	Am*	As	Ba	Be	Ca	Cd	Cr	Fe	Hg	K	Mg	Na	Ni	Pb	Pu*	Se	Tl	U
1	4EVDIST25BF1	< 1	5700	0.122	< 5	24	940	38000	< 1	3600	17000	< 5	45000	57000	2100	2200	180	0.553	< 25	< 20	< 20
1	5EVDIST3BF1	< 1	1100	0.0275	< 5	6	150	7900	< 1	1200	5200	< 5	9900	13000	1000	760	58	0.384	< 25	< 20	< 20
1	5EVDIST8BF1	< 1	1000	0.033	< 5	3	81	7600	< 1	1200	5000	< 5	9800	17000	430	740	75	0.12	< 25	< 20	< 20
1	5EVDIST4BF1	< 1	660	0.0179	< 5	3.3	72	3900	< 1	890	3800	< 5	6100	7000	300	500	33	0.057	< 25	< 20	< 30
1	5EVDIST24BF1	< 1	2700	0.0625	< 5	10	110	32000	< 1	2900	11000	< 5	30000	56000	1000	1700	180	0.742	< 25	< 20	< 20
1	7EVDIST17BF1	< 1	1400	0.0324	< 5	7.5	49	17000	< 1	1900	7100	< 5	16000	25000	420	1000	81	0.258	< 25	< 20	< 20
1	EVDIS090895A2	< 1	1800	0.0439	< 5	16	14	28000	< 1	2400	12000	< 5	19000	41000	990	1300	120	0.389	< 25	< 20	< 20
1	EVDIS090895A1	< 1	1500	0.0336	< 5	11	9	24000	< 1	2300	11000	< 5	16000	34000	840	1300	95	0.177	< 25	< 20	< 20
1	EVDIS091295A1	< 1	770	0.0166	< 5	7	< 5	11000	< 1	2000	8800	< 5	7500	14000	500	1100	48	0.088	< 25	< 20	< 20
1	EVDIS091395A1	< 1	3000	0.0819	< 5	19	150	48000	< 1	3400	14000	< 5	31000	69000	3600	1800	150	0.502	< 25	< 20	< 20
1	EVDIS092595B1	< 1	3800	0.0725	< 5	23	57	47000	< 1	6100	28000	< 5	49000	66000	1700	2800	180	0.562	< 25	< 20	< 20
1	EVDIS092795B1	< 1	2200	0.0441	< 5	14	35	25000	< 1	3700	18000	< 5	28000	52000	1000	1900	120	0.38	< 25	< 20	< 20
1	EVDIS100495A1	< 1	930	0.018	< 5	11	14	9900	< 1	2500	11000	< 5	11000	16000	450	1300	44	0.211	< 25	< 20	< 20
1	EVDIS101095A1	< 1	890	0.013	< 5	9	9	10000	< 1	1800	8100	< 5	6800	17000	470	1100	28	0.188	< 25	< 20	< 20
1	EVDIS100695B1	< 1	1800	0.0323	< 5	15	190	27000	< 1	2800	12000	< 5	29000	39000	900	1500	100	0.366	< 25	< 20	< 20
1	EVDIS101995A1	1.3	770	0.0178	< 5	9.7	22	8400	< 1	1700	7400	< 5	9800	14000	390	1000	38	0.155	< 25	< 20	< 20
1	EVDIS101995B1	1.5	1500	0.0436	5.4	10	90	21000	< 1	2000	8400	< 5	19000	32000	1100	1200	64	0.301	< 25	< 20	< 20
1	EVDIS102395A1	1.4	400	0.0074	< 5	6.2	8.9	3400	< 1	1000	4200	< 5	3500	5100	350	580	17	0.08	< 25	< 20	< 20
1	EVDIS102495B1	< 1	8900	0.102	< 5	30	250	33000	< 1	4900	21000	< 5	27000	36000	19000	2600	350	1.34	< 25	< 20	< 20
~~1~~	~~EVDIS102495B1~~	~~< 1~~		~~0~~	~~< 5~~	~~30~~	~~250~~	~~33000~~	~~< 1~~	~~4900~~	~~21000~~	~~< 5~~		~~36000~~	~~19000~~	~~2600~~	~~350~~	~~0~~	~~< 25~~	~~< 20~~	~~< 20~~
1	EVDIS121895A1	< 1	4300	0.0537	< 5	15	23	49000	< 1	3300	15000	< 5	39000	81000	2600	1600	120	0.385	< 25	< 20	< 20
1	EVDIS122195B1	1.8	5500	0.0657	< 5	17	48	56000	< 1	3800	18000	< 5	41000	110000	5200	2100	180	0.535	< 25	< 20	< 20
1	EVDIS010996A1	< 1	5300	0.0442	6.6	15	85	41000	< 1	3500	15000	< 5	47000	57000	3600	1800	94	0.369	< 25	< 20	< 20

†	User Sample ID	Ag	Al	Am*	As	Ba	Be	Ca	Cd	Cr	Fe	Hg	K	Mg	Na	Ni	Pb	Pu*	Se	Tl	U
1	EVDIS012596B1	< 1	5600	0.0499	< 5	17	89	43000	< 1	4200	18000	< 5	48000	57000	3500	2100	96	0.404	< 25	< 20	< 20
1	EVDIS032296A2	< 1	23000	0.134	13	17	< 1	47000	< 1	3000	11000	< 5	24000	46000	2700	2100	180	0.501	< 25	< 20	< 20
1	EVDIS032296A1	< 1	16000	0.0982	11	16	< 1	45000	< 1	3600	14000	< 5	24000	52000	3400	2400	150	0.452	< 25	< 20	< 20
~~1~~	~~EVDIS040896A1~~	< ~~1~~		~~0.0605~~	< ~~5~~	~~14~~	< ~~1~~	~~27000~~	< ~~1~~	~~2000~~	~~13000~~	< ~~5~~			~~2200~~	~~1100~~	~~110~~	~~0.329~~	< ~~25~~	< ~~20~~	< ~~20~~
~~1~~	~~EVDIS041696B1~~	< ~~1~~		~~0.021~~	< ~~5~~	~~6~~	~~6~~	~~22000~~	< ~~1~~	~~1800~~	~~7600~~	< ~~5~~		~~38000~~	~~990~~	~~970~~	~~39~~	~~0.197~~	< ~~25~~	< ~~20~~	< ~~20~~
~~1~~	~~EVDIS041796A1~~	< ~~1~~		~~0.0357~~	< ~~5~~	~~12~~	~~9~~	~~40000~~	< ~~1~~	~~3900~~	~~17000~~	< ~~5~~		~~75000~~	~~1900~~	~~2500~~	~~57~~	~~0.326~~	< ~~25~~	< ~~20~~	< ~~20~~
~~1~~	~~EVDIS041696B2~~	< ~~1~~		~~0.0433~~	< ~~5~~	~~11~~	~~9~~	~~43000~~	< ~~1~~	~~3500~~	~~19000~~	< ~~5~~		~~73000~~	~~2000~~	~~1900~~	~~69~~	~~0.365~~	< ~~25~~	< ~~20~~	< ~~20~~
~~1~~	~~EVDIS042296A1~~	< ~~1~~		~~0.0238~~	< ~~5~~	~~10~~	~~9~~	~~26000~~	< ~~1~~	~~3000~~	~~14000~~	< ~~5~~		~~46000~~	~~1200~~	~~1700~~	~~40~~	~~0.267~~	< ~~25~~	< ~~20~~	< ~~20~~
~~1~~	~~EVDIS042296A2~~	< ~~1~~		~~0.0061~~	< ~~5~~	~~3~~	~~2~~	~~6700~~	< ~~1~~	~~1600~~	~~6500~~	< ~~5~~		~~11000~~	~~200~~	~~970~~	~~11~~	~~0.072~~	< ~~25~~	< ~~20~~	< ~~20~~
~~1~~	~~EVDIS041896A1~~	< ~~1~~		~~0.0206~~	< ~~5~~	~~9~~	~~5~~	~~21000~~	< ~~1~~	~~2300~~	~~10000~~	< ~~5~~		~~41000~~	~~1000~~	~~1400~~	~~30~~	~~0.154~~	< ~~25~~	< ~~20~~	< ~~20~~
~~1~~	~~EVDIS042596B1~~	< ~~1~~		~~0.032~~	< ~~5~~	~~8~~	~~29~~	~~21000~~	< ~~1~~	~~2500~~	~~11000~~	< ~~5~~		~~50000~~	~~950~~	~~1800~~	~~48~~	~~0.192~~	< ~~25~~	< ~~20~~	< ~~20~~
~~1~~	~~EVDIS050396A1~~	< ~~1~~		~~0.0959~~	< ~~5~~	~~11~~	~~150~~	~~29000~~	< ~~1~~	~~2500~~	~~11000~~	< ~~5~~		~~45000~~	~~1300~~	~~1900~~	~~130~~	~~0.122~~	< ~~25~~	< ~~20~~	< ~~20~~
~~1~~	~~EVDIS043096A1~~	< ~~1~~		~~0.14~~	< ~~5~~	~~14~~	~~230~~	~~42000~~	< ~~1~~	~~3300~~	~~13000~~	< ~~5~~		~~61000~~	~~1900~~	~~2400~~	~~200~~	~~0.192~~	< ~~25~~	< ~~20~~	< ~~20~~
~~1~~	~~EVDIS050696B1~~	< ~~1~~		~~0.0815~~	< ~~5~~	~~15~~	~~26~~	~~43000~~	~~160~~	~~5000~~	~~20000~~	< ~~5~~		~~66000~~	~~1400~~	~~3100~~	~~57~~	~~1~~	< ~~25~~	< ~~20~~	< ~~20~~
~~1~~	~~EVDIS050896A1~~	< ~~1~~		~~0.105~~	< ~~5~~	~~14~~	~~90~~	~~51000~~	~~23~~	~~4200~~	~~15000~~	< ~~5~~		~~69000~~	~~4200~~	~~2300~~	~~140~~	~~1.27~~	< ~~25~~	< ~~20~~	< ~~20~~
~~1~~	~~EVDIS052296A1~~	< ~~1~~		~~0.0924~~	< ~~5~~	< ~~1~~	< ~~1~~	~~35000~~	~~60~~	~~3400~~	~~14000~~	< ~~5~~		~~55000~~	~~2400~~	~~2100~~	~~65~~	~~1.11~~	< ~~25~~	< ~~20~~	< ~~20~~
~~1~~	~~EVDIS052296A2~~	< ~~1~~		~~0.173~~	< ~~5~~	< ~~1~~	< ~~1~~	~~43000~~	~~12~~	~~3200~~	~~12000~~	< ~~5~~		~~63000~~	~~3700~~	~~1900~~	~~110~~	~~0.942~~	< ~~25~~	< ~~20~~	< ~~20~~
~~1~~	~~EVDIS053196B1~~	< ~~1~~		~~0.0629~~	< ~~5~~	< ~~1~~	< ~~1~~	~~24000~~	< ~~1~~	~~2900~~	~~11000~~	< ~~5~~		~~36000~~	~~2500~~	~~1900~~	~~50~~	~~1.71~~	< ~~25~~	< ~~20~~	< ~~20~~
~~1~~	~~EVDIS062596B1~~	< ~~1~~		~~0.173~~	< ~~5~~	~~20~~	~~100~~	~~51000~~	< ~~1~~	~~4700~~	~~18000~~	< ~~5~~		~~58000~~	~~3700~~	~~2100~~	~~100~~	~~0.544~~	< ~~25~~	< ~~20~~	< ~~20~~
1	EVDIS 062596B2	< 1	[redacted]	0.15	< 5	16	85	87000	< 1	4700	17000	< 5	[redacted]	58000	3200	2000	95	0.475	< 25	< 20	< 20
~~1~~	~~EVDIS070996A1~~	< ~~1~~		~~0.116~~	< ~~5~~	~~20~~	~~50~~	~~35000~~	~~60~~	~~5400~~	~~21000~~	< ~~5~~		~~47000~~	~~2100~~	~~2600~~	~~70~~	~~0.693~~	< ~~25~~	< ~~20~~	< ~~20~~
~~1~~	~~EVDIS071296B1~~	< ~~1~~		~~0.0631~~	< ~~5~~	~~20~~	~~90~~	~~37000~~	~~20~~	~~4400~~	~~17000~~	< ~~5~~		~~62000~~	~~1400~~	~~2200~~	~~60~~	~~0.694~~	< ~~25~~	< ~~20~~	< ~~20~~
~~1~~	~~EVDIS071196B1~~	< ~~1~~		~~0.0591~~	< ~~5~~	~~10~~	~~70~~	~~39000~~	~~20~~	~~3800~~	~~15000~~	< ~~5~~		~~66000~~	~~1200~~	~~1900~~	~~60~~	~~0.529~~	< ~~25~~	< ~~20~~	< ~~20~~

†	User Sample ID	Ag	Al	Am*	As	Ba	Be	Ca	Cd	Cr	Fe	Hg	K	Mg	Na	Ni	Pb	Pu*	Se	Tl	U
~~1~~	~~EVDIS071296A1~~	~~< 1~~		~~0.0516~~	~~< 5~~	~~10~~	~~50~~	~~33000~~	~~10~~	~~2700~~	~~11000~~	~~< 5~~		~~66000~~	~~1100~~	~~1500~~	~~60~~	~~0.266~~	~~< 25~~	~~< 20~~	~~< 20~~
1	EVDIS082296B1	< 1	4100	0.0663	< 5	20	70	33000	< 1	6700	26000	< 5	19000	49000	5000	3700	100	0.662	< 25	< 20	< 20
1	EVDIS082796B1	< 1	4200	0.0474	< 5	10	50	38000	< 1	3200	12000	< 5	22000	55000	1100	1800	80	0.152	< 25	< 20	< 20
1	EVDIS082396B1	< 1	4000	0.0529	< 5	10	40	34000	< 1	3200	12000	< 5	29000	51000	1200	2100	90	0.149	< 25	< 20	< 20
1	EVDIS090696B1	< 1	5800	0.0507	< 5	15	700	42000	< 1	2300	8800	< 5	19000	54000	800	1300	40	0.399	< 25	< 20	< 20
1	EVDIS091096B1	< 1	4200	0.0793	< 5	10	520	45000	< 1	2900	12000	< 5	19000	77000	860	1800	50	1.01	< 25	< 20	< 20
1	EVDIS091196B1	< 1	4100	0.0576	< 5	15	780	48000	10	3700	16000	< 5	24000	70000	1300	2100	60	0.854	< 25	< 20	< 20
1	EVDIS091796B2	3	4500	0.0509	< 5	20	480	50000	< 1	5300	22000	< 5	24000	77000	2300	2400	80	0.48	< 25	< 20	< 20
1	EVDIS091796B1	< 1	4500	0.0496	< 5	20	350	49000	< 1	5000	21000	< 5	22000	84000	2300	2800	140	0.413	< 25	< 20	< 20
1	EVDIS100496B1	< 1	2900	0.0426	< 5	20	250	36000	3	3400	15000	< 5	18000	71000	1900	2300	110	0.469	< 25	< 20	< 20
1	EVDIS100896B1	< 1	2900	0.0373	< 5	20	260	39000	20	3900	17000	< 5	19000	53000	1600	2200	90	0.674	< 25	< 20	< 20
1	EVDIS100996B1	< 1	3300	0.0394	< 5	20	160	45000	5	3900	17000	< 5	16000	79000	1200	2300	90	0.471	< 25	< 20	< 20
1	EVDIS101796B2	< 1	3100	0.113	< 5	10	400	29000	250	6100	26000	< 5	41000	54000	1300	3500	200	0.968	< 25	< 20	< 20
1	EVDIS101796B1	< 1	3200	0.0718	< 5	< 1	30	61000	10	5700	35000	< 5	59000	56000	1500	340	20	0.636	< 25	< 20	< 20
1	EVDIS102296B1	< 1	3000	0.0842	< 5	20	230	41000	120	6000	26000	< 5	30000	59000	1700	3500	80	0.832	< 25	< 20	< 20
~~1~~	~~EVDIS102496B1~~			~~0.0412~~														~~0.287~~			
1	EVDIS102996B1	< 1	3900	0.0823	< 5	10	280	25000	10	840	4000	< 5	14000	47000	300	670	70	0.373	< 25	< 20	< 20
~~1~~	~~EVDIS103196B1~~	~~< 1~~		~~0.0473~~	~~< 5~~	~~20~~	~~80~~	~~38000~~	~~30~~	~~3600~~	~~16000~~	~~< 5~~		~~55000~~	~~600~~	~~2600~~	~~40~~	~~0.4~~	~~< 25~~	~~< 20~~	~~< 20~~
~~1~~	~~EVDIS110496B1~~	~~< 1~~		~~0.0294~~	~~< 5~~	~~10~~	~~60~~	~~34000~~	~~< 1~~	~~3800~~	~~20000~~	~~< 5~~		~~71000~~	~~700~~	~~2400~~	~~20~~	~~0.245~~	~~< 25~~	~~< 20~~	~~< 20~~
~~1~~	~~EVDIS101096B2~~	~~< 1~~		~~0.0159~~	~~< 5~~	~~10~~	~~30~~	~~17000~~	~~< 1~~	~~2700~~	~~13000~~	~~< 5~~		~~32000~~	~~330~~	~~1600~~	~~20~~	~~0.173~~	~~< 25~~	~~< 20~~	~~< 20~~
~~1~~	~~EVDIS012997B2~~	~~< 1~~		~~0.0366~~	~~< 5~~	~~10~~	~~30~~	~~30000~~	~~< 1~~	~~1200~~	~~5300~~	~~< 5~~		~~110000~~	~~260~~	~~900~~	~~90~~	~~0.16~~	~~< 25~~	~~< 20~~	~~< 20~~
~~1~~	~~EVDIS012997B1~~	~~< 1~~		~~0.0585~~	~~< 5~~	~~10~~	~~40~~	~~52000~~	~~< 1~~	~~1900~~	~~8200~~	~~< 5~~		~~120000~~	~~590~~	~~1200~~	~~130~~	~~0.24~~	~~< 25~~	~~< 25~~	~~< 25~~
~~1~~	~~EVDIS012797B1~~	~~< 1~~		~~0.0366~~	~~< 5~~	~~10~~	~~30~~	~~32000~~	~~< 1~~	~~1320~~	~~5500~~	~~< 5~~		~~93000~~	~~220~~	~~820~~	~~90~~	~~0.165~~	~~< 25~~	~~< 20~~	~~< 20~~

†	User Sample ID	Ag	Al	Am*	As	Ba	Be	Ca	Cd	Cr	Fe	Hg	K	Mg	Na	Ni	Pb	Pu*	Se	Tl	U
~~1~~	~~EVDIS013097B1~~	~~< 1~~		~~0.0593~~	~~< 5~~	~~10~~	~~20~~	~~22000~~	~~< 1~~	~~1400~~	~~5500~~	~~< 5~~		~~68000~~	~~1400~~	~~970~~	~~100~~	~~0.789~~	~~< 25~~	~~< 20~~	~~< 20~~
~~1~~	~~EVDIS013097B2~~	~~< 1~~		~~0.0603~~	~~< 5~~	~~10~~	~~30~~	~~25000~~	~~< 1~~	~~1600~~	~~6500~~	~~< 5~~		~~77000~~	~~890~~	~~1100~~	~~100~~	~~0.966~~	~~< 25~~	~~< 20~~	~~< 20~~
~~1~~	~~EVDIS062596B2~~	~~< 1~~		~~0.15~~	~~< 5~~	~~16~~	~~85~~	~~57000~~	~~< 1~~	~~4700~~	~~17000~~	~~< 5~~		~~58000~~	~~3200~~	~~2000~~	~~95~~	~~0.475~~	~~< 25~~	~~< 20~~	~~< 20~~
~~1~~	~~EVDIS031197B1~~	~~1~~		~~0.0333~~	~~5~~	~~10~~	~~10~~	~~24000~~	~~1~~	~~1900~~	~~7300~~	~~5~~	~~5900~~	~~141000~~	~~370~~	~~1400~~	~~70~~	~~0.572~~	~~25~~	~~20~~	~~20~~
~~1~~	~~EVDIS031197B2~~	~~< 1~~		~~0.0329~~	~~< 5~~	~~10~~	~~< 1~~	~~25000~~	~~< 1~~	~~1500~~	~~7600~~	~~< 5~~		~~135000~~	~~380~~	~~1600~~	~~70~~	~~0.616~~	~~< 25~~	~~< 20~~	~~< 20~~
1	EVDIS040297A1	< 1	3100	0.0327	< 5	10	< 1	25000	< 1	1300	5200	< 5	5100	95000	240	980	50	0.568	< 25	< 20	< 20
~~1~~	~~EVDIS040397A1~~	~~< 1~~		~~0.015~~	~~< 5~~	~~10~~	~~10~~	~~8000~~	~~< 1~~	~~790~~	~~3200~~	~~< 5~~	~~2400~~	~~85000~~	~~130~~	~~690~~	~~20~~	~~0.241~~	~~< 25~~	~~< 20~~	~~< 20~~
~~1~~	~~EVDIS041897A1~~			~~0.0528~~														~~1.19~~			
~~1~~	~~EVDIS060497A1~~			~~0.0165~~														~~0.3~~			
~~1~~	~~EVDIS101896A2~~	~~< 1~~	~~24000~~	~~0~~	~~11~~	~~23~~	~~0~~		~~1~~	~~2200~~		~~< 5~~	~~26000~~		~~2600~~	~~16~~	~~150~~	~~0~~	~~NR 0~~	~~< 20~~	~~0~~
~~1~~	~~10EVDIST21AF1~~			~~0.144~~														~~0.635~~			
~~1~~	~~10EVDIST22AF1~~			~~0.0156~~														~~0.435~~			
~~1~~	~~11EVDIST19BF1~~			~~0.0333~~														~~1.11~~			
~~1~~	~~5EVDIST25BF1~~	~~< 1~~		~~0.0761~~	~~< 5~~	~~81~~			~~23~~	~~5300~~		~~< 5~~				~~4000~~	~~350~~	~~2.38~~	~~< 8~~	~~< 20~~	~~260~~
~~2~~	~~10OX26AF1~~	~~< 1~~		~~0.0153~~	~~< 5~~	~~34~~	~~3.8~~		~~4.1~~	~~2900~~	~~11000~~	~~< 5~~				~~1700~~	~~85~~	~~1.45~~	~~< 8~~	~~NR 0~~	~~< 20~~
2	12OX13AF1	< 1	2300	0.0203	< 5	35	12	25000	3.2	2800	11000	< 5	7900	32000	28000	1400	75	1.68	< 8	NR 0	< 20
2	12OX17AF1	2.8	1100	0.0058	< 5	36	3.2	9300	1.9	2100	8000	< 5	2000	13000	35000	980	60	0.829	< 8	NR 0	< 20
2	12OX18AF1	NR 0	4500	0.0025	< 5	< 5	1.7	5500	1.4	970	5500	< 5	620	5200	36000	710	26	0.155	< 8	< 20	59
2	4OX6BF1	< 1	1700	0.0074	< 5	28	40	18000	< 1	3400	13000	< 5	4700	21000	22000	2400	33	0.803	< 8	< 20	< 20
2	5OX9BF1	< 1	1500	0.0286	< 5	4.8	100	10000	< 1	1200	5500	< 5	16000	21000	620	880	44	0.579	< 25	< 20	< 20
2	9OX22AF1	< 1	3500	0.0588	< 5	21	38	45000	< 1	4800	21000	< 5	45000	73000	1800	2400	160	0.89	< 25	< 20	< 20
~~2~~	~~EVOX040996B1~~	~~< 1~~		~~0.052~~	~~< 5~~	~~32~~	~~< 1~~	~~28000~~	~~< 1~~	~~3300~~	~~27000~~	~~< 5~~			~~2600~~	~~1100~~	~~130~~	~~0.514~~	~~< 25~~	~~< 20~~	~~< 20~~
2	EVOX041096B1	< 1	[illegible]	0.0389	< 5	26	< 1	39000	< 1	3700	36000	< 5	[illegible]	[illegible]	2700	940	64	1.29	< 25	< 20	< 20

†	User Sample ID	Ag	Al	Am*	As	Ba	Be	Ca	Cd	Cr	Fe	Hg	K	Mg	Na	Ni	Pb	Pu*	Se	Tl	U
~~2~~	~~EVOX102996B1~~	~~< 1~~		~~0.0498~~	~~< 5~~	~~20~~	~~110~~	~~45000~~	~~30~~	~~2500~~	~~11000~~	~~< 5~~		~~58000~~	~~800~~	~~1500~~	~~40~~	~~0.463~~	~~< 25~~	~~< 20~~	~~< 20~~
~~2~~	~~1OX8BF1~~			~~0.0758~~														~~1.61~~			
~~3~~	~~11LR9BF1~~	~~2.3~~		~~0.0754~~	~~< 5~~	~~90~~	~~19~~		~~19~~	~~7000~~	~~23000~~	~~< 5~~				~~2200~~	~~390~~	~~2.26~~	~~< 8~~	~~790~~	~~< 20~~
~~3~~	~~11LR16AF1~~	~~< 1~~		~~0.0647~~	~~< 5~~	~~70~~	~~9.3~~		~~6.5~~	~~520~~	~~16000~~	~~< 5~~				~~2400~~	~~200~~	~~2.23~~	~~< 8~~	~~710~~	~~< 20~~
3	12LR21AF1	< 1	6300	0.0291	< 5	42	12	56000	< 1	2900	15000	< 5	22000	57000	15000	1900	140	1.91	< 8	NR 0	< 20
3	LRA19F1	NR 0	640	0.005	< 5	< 10	34	1500	< 1	320	1600	< 5	60	1800	3100	200	17	0.129	< 8	< 20	NR 0
3	LRA20F2	NR 0	320	0.0019	< 5	< 10	15	1100	< 1	220	990	< 5	60	1400	1900	150	8.3	0.082	< 8	< 20	NR 0
3	ATLLRA23B	< 1	2200	0.0228	< 5	37	5	11000	< 1	2100	13000	< 5	8100	12000	1700	1300	220	0.905	< 8	< 20	< 20
3	2LR22AF1	< 1	1600	0.0092	< 5	24	6	13000	< 1	2600	11000	< 5	4800	17000	3300	1600	36	0.864	< 8	< 20	< 20
3	2LR22AF2	< 1	1600	0.017	< 5	24	6	13000	< 1	2600	11000	< 5	4800	17000	3300	1600	36	1.25	< 8	< 20	< 20
3	2LR22AF3	< 1	1600	0.0145	< 5	24	6	13000	< 1	2600	11000	< 5	4800	17000	3300	1600	36	1.13	< 8	< 20	< 20
3	ATLLRA23B1	< 1	4000	0.0295	< 5	42	18	14000	< 1	2200	15000	< 5	31000	15000	3400	1800	340	2.11	< 8	< 20	< 20
3	4LR4BF1A	< 1	3000	0.0104	< 5	40	3.9	34000	< 1	7200	26000	< 5	5300	39000	1200	4500	42	0.562	< 8	< 20	< 20
3	4LR4BF1B	< 1	2800	0.0102	< 5	40	3.9	33000	< 1	6600	25000	< 5	5100	36000	1200	4100	42	0.566	< 8	< 20	< 20
3	4LR10BF1C	< 1	2200	0.0092	< 5	37	< 1	33000	< 1	5600	22000	< 5	3800	46000	1000	2300	18	0.387	< 8	< 20	< 20
3	4LR10BF1B	< 1	3200	0.0104	< 5	39	< 1	51000	< 1	9300	34000	< 5	5400	36000	1100	2700	21	0.498	< 8	< 20	< 20
3	4LR10BF1A	< 1	3100	0.0108	< 5	38	< 1	46000	< 1	8700	33000	< 5	5400	33000	2000	2700	21	0.504	< 8	< 20	< 20
3	4LR17BF1	< 1	5000	0.0346	< 5	93	17	81000	< 1	8000	34000	< 5	7800	39000	6600	3800	130	1.16	< 25	< 20	< 20
~~3~~	~~11LR20AF1A~~			~~0.0204~~														~~0.068~~			
4	~~ATL2B1~~	~~< 1~~		~~0.0376~~	~~< 5~~	~~1.8~~	~~< 1~~	~~2200~~	~~< 1~~	~~36~~	~~18000~~	~~< 5~~		~~170~~	~~5600~~	~~5~~	~~< 5~~	~~0.153~~	~~< 8~~	~~< 20~~	~~430~~
4	~~ATL2B2~~	~~< 1~~		~~0.0299~~	~~< 5~~	~~1.8~~	~~< 1~~	~~2100~~	~~< 1~~	~~27~~	~~17000~~	~~< 5~~		~~110~~	~~5400~~	~~5~~	~~< 5~~	~~0.151~~	~~< 8~~	~~< 20~~	~~280~~
4	~~ATL2B3~~	~~< 1~~		~~0.0126~~	~~< 5~~	~~22~~	~~1.6~~	~~14000~~	~~2.2~~	~~2600~~	~~13000~~	~~< 5~~		~~17000~~	~~5700~~	~~1600~~	~~40~~	~~1~~	~~< 8~~	~~NR 0~~	~~< 20~~
4	~~ATL2B4~~	~~< 1~~		~~0.0056~~	~~< 5~~	~~12~~	~~< 1~~	~~6100~~	~~< 1~~	~~1100~~	~~6400~~	~~< 5~~		~~7300~~	~~1800~~	~~740~~	~~17~~	~~0.296~~	~~< 8~~	~~NR 0~~	~~< 20~~

†	User Sample ID	Ag	Al	Am*	As	Ba	Be	Ca	Cd	Cr	Fe	Hg	K	Mg	Na	Ni	Pb	Pu*	Se	Tl	U
4	~~ATL22~~	~~NR 0~~	~~1000~~	~~0.021~~	~~< 5~~	~~24~~	~~32~~	~~2100~~		~~5.8~~ ~~870~~	~~4100~~	~~< 5~~	~~3800~~	~~2300~~	~~10000~~	~~610~~	~~66~~	~~1.99~~	~~< 8~~	~~< 20~~	~~NR 0~~
4	~~ATLT9B~~	~~NR 0~~	~~1300~~	~~0.108~~	~~< 5~~	~~32~~	~~910~~	~~14000~~	~~16~~	~~6000~~	~~30000~~	~~NR 0~~	~~17000~~	~~12000~~	~~9500~~	~~3000~~	~~160~~	~~0.383~~	~~< 8~~	~~< 20~~	~~NR 0~~
4	~~ATLT10B~~	~~NR 0~~	~~3600~~	~~0.13~~	~~< 5~~	46	~~220~~	~~8100~~	~~18~~	~~6200~~	~~34000~~	~~< 5~~	~~26000~~	~~13000~~	~~11000~~	~~4500~~	~~250~~	~~0.161~~	~~< 8~~	~~< 20~~	~~3800~~
4	~~ATLT9B2~~	~~< 1~~	~~5~~	~~0.136~~	~~< 5~~	~~< 1~~	~~200~~	~~22000~~	~~< 1~~	~~9000~~	~~54000~~	~~< 5~~	~~1800~~	~~17000~~	~~14000~~	~~4300~~	~~190~~	~~0.224~~	~~< 8~~	~~< 20~~	~~2.6~~
4	~~ATL14B~~	~~NR 0~~		~~0.0545~~	~~< 10~~	~~120~~	~~< 2~~	~~9100~~	~~3.2~~	~~1600~~	~~31000~~	~~NR 0~~		~~3500~~	~~13000~~	~~1600~~	~~< 10~~	~~1.66~~	~~< 20~~	~~< 40~~	~~3100~~
4	~~ATL12794B~~	~~< 1~~	~~610~~	~~0.0037~~	~~< 5~~	~~19~~	~~8~~	~~1800~~	~~< 1~~	~~700~~	~~3000~~	~~< 5~~	~~7200~~	~~26000~~	~~72000~~	~~460~~	~~36~~	~~0.449~~	~~< 8~~	~~< 20~~	~~< 20~~
5	ATLDS11EFB1	< 1	2000	0.0091	< 5	27	10	33000	< 1	1300	5800	< 5	17000	44000	3200	1000	89	0.287	< 8	< 20	< 20
5	ATLDS11EFB3	< 1	6700	0.0178	< 5	29	2.1	58000	< 1	2600	11000	< 5	33000	37000	2000	1400	56	0.089	< 8	< 20	< 20
5	ATLDS11EFB2	< 1	8200	0.0094	< 5	11	1.2	39000	< 1	1200	5500	< 5	19000	44000	1200	940	7	0.047	< 8	< 20	< 20
5	ATLDS11EFB4	< 1	6400	0.0078	< 5	7.5	< 1	29000	< 1	1100	4600	< 5	15000	47000	550	920	10	0.039	< 8	< 20	< 20
5	ATLDS11EFB5	< 1	7200	0.0209	< 5	10	< 1	39000	< 1	1500	6300	< 5	21000	38000	390	1100	16	0.104	< 8	< 20	< 20
5	ATLDS11F1B	< 1	4200	0.032	< 5	33	7.4	24000	< 1	1900	7700	< 5	20000	32000	4800	1200	58	0.605	< 8	< 20	< 20
5	ATLDS11EFB6	< 1	5500	0.034	< 5	53	1.2	31000	< 1	1900	6000	< 5	13000	41000	1100	1000	72	0.398	< 8	< 20	< 20
5	ATLDS11F1B2	< 1	8400	0.152	< 5	9.6	12	29000	< 1	3000	12000	< 5	54000	30000	1600	2100	84	0.561	< 8	< 20	< 20
5	ATLDS11F1B1	< 1	6300	0.0907	< 5	12	28	31000	< 1	1900	11000	< 5	38000	31000	2300	1200	61	0.222	< 8	< 20	< 20
5	ATLDS11EF15B	< 1	5800	0.0787	< 5	11	28	38000	< 1	2900	12000	< 5	47000	38000	1200	1700	42	2	< 25	< 20	< 20
5	ATLDS11EF15B1	< 1	7000	0.0598	< 5	11	29	29000	< 1	2800	12000	< 5	40000	40000	1500	1700	54	0.392	< 25	< 20	< 20
5	4DS19BF1A	< 1	6800	0.15	< 5	27	1300	46000	< 1	4200	19000	< 5	50000	58000	3100	2200	200	0.635	< 25	< 20	< 20
5	4DS19BF1B	< 1	6900	0.146	< 5	22	1300	48000	< 1	4000	19000	< 5	51000	58000	2900	2000	230	0.613	< 25	< 20	< 20
5	4DS26BF1A	< 1	5700	0.211	< 5	7.6	490	59000	< 1	4100	17000	< 5	55000	43000	1400	2100	530	0.38	< 25	< 20	< 20
5	4DS26BF1B	< 1	4900	0.19	< 5	7.1	420	49000	< 1	3300	14000	< 5	47000	59000	1100	1900	460	0.298	< 25	< 20	< 20
5	5DS10BF1A	< 1	3700	0.0681	< 5	7.9	81	54000	< 1	2700	12000	< 5	47000	62000	1000	1400	210	0.474	< 25	< 20	< 20

†	User Sample ID	Ag	Al	Am*	As	Ba	Be	Ca	Cd	Cr	Fe	Hg	K	Mg	Na	Ni	Pb	Pu*	Se	Tl	U
5	5DS10BF1B	< 1	4300	0.0696	< 5	7.5	100	43000	< 1	2600	11000	< 5	42000	55000	1000	1400	220	0.387	< 25	< 20	< 20
5	ATLDS11EF15B2	< 1	8900	0.0983	< 5	5.9	140	32000	< 1	3200	16000	< 5	48000	51000	2700	2000	48	0.263	< 25	< 20	< 20
5	ATLDS11EF15B3	< 1	9100	0.0941	< 5	5.1	130	32000	< 1	3200	17000	< 5	52000	52000	2900	2000	52	0.472	< 25	< 20	< 20
5	ATLDS11EF15B4	< 1	5600	0.0662	< 5	14	270	24000	< 1	2800	13000	< 5	36000	43000	7000	1900	60	0.632	< 25	< 20	< 20
5	ATLDS16B	< 1	4800	0.14	< 5	< 1	97	24000	< 1	2900	12000	< 5	48000	43000	3000	1900	280	0.611	< 25	< 20	< 20
5	EVDS090795A1	< 1	3000	0.0678	< 5	15	12	53000	< 1	2800	13000	< 5	30000	79000	1700	1500	180	0.342	< 25	< 20	< 20
5	EVDS092195B1	< 1	3100	0.0565	< 5	16	56	35000	< 1	4900	23000	< 5	36000	64000	1200	2300	160	0.467	< 25	< 20	< 20
5	EVDS100495B1	< 1	3700	0.0606	< 5	18	33	65000	< 1	4100	19000	< 5	31000	75000	1900	2000	99	0.793	< 25	< 20	< 20
5	EVDS100495A1	< 1	1600	0.0471	< 5	8.5	13	26000	< 1	1800	8900	< 5	13000	39000	850	1000	44	0.33	< 25	< 20	< 20
5	EVDS100495A2	< 1	2800	0.0285	< 5	12	17	51000	< 1	2700	13000	< 5	19000	68000	1500	1500	65	0.55	< 25	< 20	< 20
5	EVDS121495A1	< 1	16000	0.152	< 5	40	280	110000	< 1	5700	51000	< 5	51000	72000	51000	3000	600	1.7	< 25	< 20	< 20
5	EVDS121495B1	< 1	7300	0.12	< 5	22	140	93000	< 1	3800	37000	< 5	59000	78000	21000	2500	380	0.912	< 25	< 20	< 20
5	EVDS121595B1	1.3	5200	0.0756	< 5	14	45	49000	< 1	3700	18000	< 5	40000	76000	4900	1800	180	0.637	< 25	< 20	< 20
5	EVDS121495A2	2.3	4400	0.0575	< 5	5.8	6.4	51000	< 1	2800	14000	< 5	41000	80000	2800	910	120	0.416	< 25	< 20	< 20
5	EVDS011896B1	< 1	5600	0.0579	< 5	17	100	42000	< 1	4100	17000	< 5	50000	57000	3400	2000	110	0.486	< 25	< 20	< 20
5	EVDS011896B2	< 1	5900	0.063	< 5	19	79	46000	< 1	4200	17000	< 5	55000	55000	3900	2000	130	0.502	< 25	< 20	< 20
5	EVDS012696B1	< 1	3900	0.0656	< 5	13	113	32000	< 1	2700	11000	< 5	45000	48000	2300	1400	99	0.327	< 25	< 20	< 20
5	EVDS020696B1	< 1	4700	0.0921	< 5	12	150	38000	< 1	3400	14000	< 5	35000	56000	1900	2000	140	0.399	< 25	< 20	< 20
5	EVDS012996B1	< 1	4300	0.0849	< 5	12	140	34000	< 1	2800	13000	< 5	32000	47000	1800	1900	120	0.384	< 25	< 20	< 20
5	EVDS020896B1	< 1	4300	0.0743	< 5	5.7	66	34000	< 1	3200	14000	< 5	35000	52000	1900	1800	130	0.509	< 25	< 20	< 20
5	EVDS020896B2	< 1	3800	0.067	< 5	4.9	59	29000	< 1	2700	13000	< 5	31000	50000	1800	1800	130	0.524	< 25	< 20	< 20
5	EVDS021396B2	< 1	4600	0.0864	< 5	13	115	4100	< 1	2800	14000	< 5	34000	54000	1700	2000	130	1.07	< 25	< 20	< 20
5	EVDS021396B1	< 1	5400	0.0965	13	16	140	46000	< 1	3500	17000	< 5	41000	61000	2200	2500	170	0.558	< 25	< 20	< 20

†	User Sample ID	Ag	Al	Am*	As	Ba	Be	Ca	Cd	Cr	Fe	Hg	K	Mg	Na	Ni	Pb	Pu*	Se	Tl	U
5	EVDS021496B3	< 1	20000	0.107	< 5	8.2	210	53000	< 1	2300	12000	< 5	26000	55000	1900	1400	240	0.68	< 25	< 20	< 20
5	EVDS021496B1	< 1	17000	0.0909	< 5	8.8	260	49000	< 1	2800	11000	< 5	25000	52000	1900	1400	220	0.405	< 25	< 20	< 20
5	EVDS020896B1	< 1	4300	0.0743	< 5	5.7	66	34000	< 1	3200	14000	< 5	35000	52000	1900	1800	130	0.509	< 25	< 20	< 20
~~5~~	~~EVDS022796B2~~	~~< 1~~	~~15000~~	~~0.0797~~	~~12~~	~~19~~			~~< 1~~	~~2500~~		~~< 5~~	~~26000~~		~~2500~~	~~1600~~	~~220~~	~~0.542~~	~~NR 0~~	~~< 20~~	
~~5~~	~~EVDS022796B1~~	~~< 1~~	~~18000~~	~~0.0829~~	~~17~~	~~13~~			~~< 1~~	~~2200~~		~~< 5~~	~~25000~~		~~2100~~	~~1400~~	~~230~~	~~0.497~~	~~NR 0~~	~~< 20~~	
5	EVDS021496B2	< 1	20000	0.0767	< 5	11	300	62000	< 1	3400	15000	< 5	34000	45000	2300	1500	270	0.486	< 25	< 20	< 20
5	EVDS030896A1	< 1	27000	0.135	12	18			< 1	2200		< 5	26000		3700	1600	150	0.487	NR 0	< 20	
~~5~~	~~EVDS030896A2~~	~~< 1~~	~~8200~~	~~0.045~~	~~NR 0~~	~~15~~			~~< 1~~	~~2500~~		~~< 5~~	~~24000~~		~~4200~~	~~1400~~	~~100~~	~~0.317~~	~~NR 0~~	~~< 20~~	
~~5~~	~~EVDS030896B1~~	~~< 1~~	~~14000~~	~~0.0813~~	~~NR 0~~	~~21~~			~~< 1~~	~~2500~~		~~< 5~~	~~26000~~		~~4700~~	~~1700~~	~~140~~	~~0.527~~	~~NR 0~~	~~< 20~~	
~~5~~	~~EVDS101895B1~~	~~< 1~~	~~4800~~	~~0.0625~~	~~8~~	~~18~~			~~< 1~~	~~2400~~		~~< 5~~	~~25000~~		~~2900~~	~~1600~~	~~150~~	~~0.435~~	~~NR 0~~	~~< 20~~	
~~5~~	~~EVDS101895B2~~	~~< 1~~	~~3000~~	~~0.0494~~	~~NR 0~~	~~18~~			~~NR 0~~	~~3200~~		~~NR 0~~	~~24000~~		~~3500~~	~~1800~~	~~100~~	~~0.341~~	~~NR 0~~	~~< 20~~	~~0~~
5	EVDS030896B2	< 1	14000	0.0893	< 5	< 1	< 5	44000	< 1	3700	14000	< 5	24000	52000	3700	2400	150	0.454	< 25	< 20	< 20
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†	User Sample ID	Ag	Al	Am*	As	Ba	Be	Ca	Cd	Cr	Fe	Hg	K	Mg	Na	Ni	Pb	Pu*	Se	Tl	U
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†	User Sample ID	Ag	Al	Am*	As	Ba	Be	Ca	Cd	Cr	Fe	Hg	K	Mg	Na	Ni	Pb	Pu*	Se	Tl	U
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†	User Sample ID	Ag	Al	Am*	As	Ba	Be	Ca	Cd	Cr	Fe	Hg	K	Mg	Na	Ni	Pb	Pu*	Se	Tl	U
~~5~~	~~EVDS050797B1~~			~~0.0063~~														~~0.047~~			
~~5~~	~~EVDS050897B1~~			~~0.0206~~														~~0.141~~			
~~5~~	~~EVDS050897B2~~			~~0.0174~~														~~0.108~~			
~~5~~	~~EVDS050897B3~~			~~0.0184~~														~~0.137~~			
~~5~~	~~EVDS052297B4~~			~~0.101~~														~~1.44~~			
~~5~~	~~EVDS052797B1~~			~~0.0881~~														~~1.22~~			
~~5~~	~~EVDS060497B1~~			~~0.0111~~														~~0.8~~			
~~6~~	~~EVCL042497B1~~			~~0.0524~~														~~0.19~~			
~~6~~	~~EVCL042497B2~~			~~0.0523~~														~~0.179~~			
~~6~~	~~EVCL042497B3~~			~~0.0459~~														~~0.169~~			
~~6~~	~~EVCL040897B1~~			~~0.0781~~														~~0.172~~			
~~6~~	~~EVCL040897B2~~			~~0.0774~~														~~0.137~~			
~~6~~	~~EVCL040897B3~~			~~0.0751~~														~~0.144~~			
~~6~~	~~EVCL040897B4~~			~~0.0736~~														~~0.137~~			
~~6~~	~~EVCL040897A1~~			~~0.0723~~														~~0.141~~			
~~6~~	~~EVCL040897A2~~			~~0.0717~~														~~0.137~~			
~~6~~	~~EVCL040897A3~~			~~0.0747~~														~~0.142~~			
~~6~~	~~EVCL040897A4~~			~~0.0732~~														~~0.149~~			
~~6~~	~~EVCL040397B1~~	< ~~1~~		~~0.0801~~	< ~~5~~	~~2~~	~~2~~	~~4800~~	< ~~1~~	~~1200~~	~~4600~~	< ~~5~~	~~16100~~	~~17000~~	~~980~~	~~960~~	~~100~~	~~0.145~~	< ~~25~~	< ~~20~~	< ~~20~~
~~6~~	~~EVCL040397B2~~	< ~~1~~		~~0.0799~~	< ~~5~~	~~2~~	< ~~1~~	~~4200~~	< ~~1~~	~~1150~~	~~4400~~	< ~~5~~	~~14000~~	~~14400~~	~~880~~	~~950~~	~~120~~	~~0.14~~	< ~~25~~	< ~~20~~	< ~~20~~
~~6~~	~~EVCL040497B1~~	< ~~1~~		~~0.102~~	< ~~5~~	~~3~~	~~70~~	~~6600~~	~~10~~	~~1200~~	~~5700~~	< ~~5~~	~~23000~~	~~31000~~	~~4100~~	~~900~~	~~70~~	~~0.222~~	< ~~25~~	< ~~20~~	< ~~20~~
~~6~~	~~EVCL040497B2~~	< ~~1~~		~~0.112~~	< ~~5~~	~~3~~	~~90~~	~~6600~~	~~10~~	~~1300~~	~~6200~~	< ~~5~~	~~26000~~	~~12000~~	~~4400~~	~~970~~	~~80~~	~~0.198~~	< ~~25~~	< ~~20~~	< ~~20~~
~~6~~	~~EVCL041497B1~~			~~0.0686~~														~~0.119~~			

†	User Sample ID	Ag	Al	Am*	As	Ba	Be	Ca	Cd	Cr	Fe	Hg	K	Mg	Na	Ni	Pb	Pu*	Se	Tl	U
6	~~EVCL041497B2~~			~~0.378~~														~~0.121~~			
6	~~EVCL041497B3~~			~~0.0682~~														~~0.123~~			
6	~~EVCL041497B4~~			~~0.0675~~														~~0.126~~			
6	~~EVCL042897B1~~			~~0.0533~~														~~0.141~~			
6	~~EVCL042897B2~~			~~0.0562~~														~~0.161~~			
6	~~EVCL042897B3~~			~~0.0478~~														~~0.123~~			
6	~~EVCL060497A2~~			~~0.0155~~														~~0.135~~			
6	~~EVCL060497A3~~			~~0.0115~~														~~0.111~~			

*Solution concentrations are in ppm, except for Pu and Am, for which they are g/l.
†Waste types: 1 - hot distillate (HD), 2 - oxalate filtrate (OX), 3 - lean residue (LR), 4 - ATLAS (ATL), 5 - dissolution (DS), and 6 - chloride (CL)
Those wastes crossed out were not considered in calculations; those with grey fields were adjusted and used as described in Step 1.

Table AII. Reduced EVB waste compositions in weight fraction of oxides

†	User Sample ID	Ag_2O	Al_2O_3	Am_2O_3	As_2O_3	BaO	BeO	CaO	CdO	Cr_2O_3	Fe_2O_3	K_2O	MgO	Na_2O	NiO	PbO	PuO_2	TlO_x	U_3O_8
1	10EVDIST27BF1	0.0000	0.0185	0.0009	0.0001	0.0008	0.0005	0.1264	0.0002	0.0943	0.3691	0.0788	0.2153	0.0107	0.0540	0.0051	0.0252	0.0000	0.0002
1	12EVDIST6AF1	0.0000	0.0160	0.0003	0.0000	0.0003	0.0001	0.2457	0.0000	0.0513	0.2008	0.0448	0.3726	0.0312	0.0214	0.0008	0.0143	0.0000	0.0002
1	12EVDIST21AF1	0.0000	0.0347	0.0001	0.0000	0.0002	0.0000	0.3456	0.0000	0.0180	0.0854	0.0576	0.3765	0.0644	0.0096	0.0005	0.0072	0.0000	0.0001
1	2EVDIST14AF1	0.0000	0.0229	0.0002	0.0002	0.0003	0.0022	0.1549	0.0000	0.0912	0.3022	0.0934	0.2337	0.0529	0.0346	0.0023	0.0083	0.0002	0.0002
1	2EVDIST15BF1	0.0000	0.0131	0.0001	0.0000	0.0002	0.0007	0.6272	0.0000	0.0297	0.1302	0.0574	0.0976	0.0236	0.0169	0.0006	0.0023	0.0002	0.0002
1	2EVDIST16AF1	0.0000	0.0375	0.0003	0.0003	0.0005	0.0018	0.1342	0.0000	0.0643	0.2915	0.1396	0.1922	0.0916	0.0341	0.0031	0.0072	0.0009	0.0009
1	3EVDIST14BF1	0.0000	0.0372	0.0002	0.0001	0.0004	0.0011	0.1865	0.0000	0.0568	0.2223	0.1472	0.2579	0.0479	0.0339	0.0019	0.0060	0.0003	0.0003
1	3EVDIST20BF1	0.0000	0.0264	0.0002	0.0003	0.0003	0.0010	0.1410	0.0001	0.1071	0.4124	0.0259	0.1974	0.0123	0.0641	0.0010	0.0084	0.0010	0.0010
1	3EVDIST24BF1	0.0000	0.0405	0.0004	0.0002	0.0002	0.0014	0.1077	0.0000	0.0442	0.1927	0.2021	0.3466	0.0293	0.0308	0.0008	0.0018	0.0006	0.0006
1	3EVDIST28BF1	0.0000	0.0318	0.0001	0.0000	0.0003	0.0002	0.2711	0.0000	0.0311	0.1162	0.0979	0.3627	0.0539	0.0223	0.0012	0.0109	0.0001	0.0001
1	3EVDIST29BF1	0.0000	0.0530	0.0002	0.0000	0.0003	0.0002	0.2801	0.0000	0.0407	0.1745	0.1059	0.2995	0.0066	0.0267	0.0017	0.0105	0.0001	0.0001
1	3EVDIST31BF1	0.0000	0.0368	0.0002	0.0001	0.0003	0.0005	0.1977	0.0000	0.0505	0.1908	0.0870	0.3254	0.0646	0.0330	0.0015	0.0115	0.0002	0.0002
1	4EVDIST12BF1A	0.0000	0.0180	0.0001	0.0000	0.0002	0.0001	0.2681	0.0000	0.0457	0.1827	0.0339	0.4131	0.0129	0.0211	0.0002	0.0036	0.0001	0.0001
1	4EVDIST12BF1B	0.0000	0.0177	0.0001	0.0001	0.0001	0.0001	0.2279	0.0000	0.0408	0.1663	0.0448	0.4629	0.0125	0.0227	0.0003	0.0034	0.0002	0.0002
1	4EVDIST21BF1A	0.0000	0.0306	0.0005	0.0000	0.0001	0.0108	0.2050	0.0000	0.0189	0.0863	0.2232	0.4001	0.0110	0.0099	0.0013	0.0021	0.0001	0.0001
1	4EVDIST21BF1B	0.0000	0.0328	0.0005	0.0000	0.0001	0.0113	0.2566	0.0000	0.0213	0.0999	0.2174	0.3331	0.0126	0.0100	0.0013	0.0030	0.0001	0.0001
1	4EVDIST25BF1	0.0000	0.0307	0.0005	0.0000	0.0001	0.0105	0.2140	0.0000	0.0212	0.0978	0.2182	0.3804	0.0114	0.0113	0.0011	0.0025	0.0001	0.0001
1	5EVDIST3BF1	0.0000	0.0252	0.0005	0.0001	0.0001	0.0071	0.1888	0.0000	0.0300	0.1270	0.2037	0.3682	0.0230	0.0165	0.0015	0.0074	0.0004	0.0004

†	User Sample ID	Ag_2O	Al_2O_3	Am_2O_3	As_2O_3	BaO	BeO	CaO	CdO	Cr_2O_3	Fe_2O_3	K_2O	MgO	Na_2O	NiO	PbO	PuO_2	TlO_x	U_3O_8
1	5EVDIST8BF1	0.0000	0.0213	0.0005	0.0001	0.0001	0.0036	0.1689	0.0000	0.0279	0.1135	0.1875	0.4477	0.0092	0.0150	0.0018	0.0022	0.0004	0.0004
1	5EVDIST4BF1	0.0000	0.0264	0.0005	0.0002	0.0001	0.0060	0.1630	0.0000	0.0389	0.1623	0.2195	0.3468	0.0121	0.0190	0.0015	0.0019	0.0007	0.0010
1	5EVDIST24BF1	0.0000	0.0179	0.0003	0.0000	0.0001	0.0015	0.2212	0.0000	0.0209	0.0777	0.1785	0.4587	0.0067	0.0107	0.0014	0.0041	0.0001	0.0001
1	7EVDIST17BF1	0.0000	0.0184	0.0003	0.0001	0.0001	0.0013	0.2337	0.0000	0.0273	0.0997	0.1893	0.4072	0.0056	0.0125	0.0012	0.0029	0.0002	0.0002
1	EVDIS090895A2	0.0000	0.0154	0.0003	0.0000	0.0001	0.0002	0.2497	0.0000	0.0224	0.1094	0.1459	0.4333	0.0085	0.0105	0.0012	0.0028	0.0001	0.0001
1	EVDIS090895A1	0.0000	0.0150	0.0003	0.0000	0.0001	0.0002	0.2514	0.0000	0.0252	0.1177	0.1443	0.4220	0.0085	0.0124	0.0011	0.0015	0.0002	0.0002
1	EVDIS091295A1	0.0000	0.0155	0.0003	0.0001	0.0001	0.0002	0.2314	0.0000	0.0439	0.1892	0.1358	0.3490	0.0101	0.0210	0.0011	0.0015	0.0003	0.0003
1	EVDIS091395A1	0.0000	0.0157	0.0003	0.0000	0.0001	0.0016	0.2619	0.0000	0.0194	0.0781	0.1456	0.4462	0.0189	0.0089	0.0009	0.0022	0.0001	0.0001
1	EVDIS092595B1	0.0000	0.0172	0.0003	0.0000	0.0001	0.0005	0.2227	0.0000	0.0302	0.1355	0.1999	0.3705	0.0078	0.0121	0.0009	0.0022	0.0001	0.0001
1	EVDIS092795B1	0.0000	0.0152	0.0002	0.0000	0.0001	0.0005	0.1807	0.0000	0.0279	0.1329	0.1742	0.4453	0.0070	0.0125	0.0010	0.0022	0.0001	0.0001
1	EVDIS100495A1	0.0000	0.0162	0.0002	0.0001	0.0002	0.0005	0.1800	0.0000	0.0475	0.2044	0.1722	0.3448	0.0079	0.0215	0.0009	0.0031	0.0003	0.0003
1	EVDIS101095A1	0.0000	0.0175	0.0002	0.0001	0.0001	0.0004	0.2053	0.0000	0.0386	0.1699	0.1202	0.4135	0.0093	0.0205	0.0006	0.0031	0.0003	0.0003
1	EVDIS100695B1	0.0000	0.0146	0.0002	0.0000	0.0001	0.0032	0.2285	0.0000	0.0247	0.1038	0.2113	0.3911	0.0073	0.0115	0.0009	0.0025	0.0001	0.0001
1	EVDIS101995A1	0.0000	0.0164	0.0003	0.0001	0.0002	0.0010	0.1864	0.0000	0.0394	0.1678	0.1872	0.3682	0.0083	0.0202	0.0009	0.0028	0.0004	0.0004
1	EVDIS101995B1	0.0000	0.0159	0.0004	0.0001	0.0001	0.0020	0.2330	0.0000	0.0232	0.0953	0.1815	0.4208	0.0118	0.0121	0.0008	0.0027	0.0002	0.0002
1	EVDIS102395A1	0.0001	0.0200	0.0003	0.0002	0.0003	0.0009	0.1772	0.0000	0.0544	0.2236	0.1570	0.3149	0.0176	0.0275	0.0010	0.0034	0.0008	0.0008
1	EVDIS102495B1	0.0000	0.0543	0.0005	0.0000	0.0002	0.0032	0.2105	0.0000	0.0326	0.1369	0.1483	0.2721	0.1168	0.0151	0.0025	0.0069	0.0001	0.0001
1	EVDIS121895A1	0.0000	0.0200	0.0002	0.0000	0.0001	0.0002	0.2379	0.0000	0.0167	0.0744	0.1630	0.4660	0.0122	0.0071	0.0006	0.0015	0.0001	0.0001
1	EVDIS122195B1	0.0000	0.0205	0.0002	0.0000	0.0001	0.0004	0.2179	0.0000	0.0154	0.0716	0.1373	0.5072	0.0195	0.0074	0.0008	0.0017	0.0001	0.0001
1	EVDIS010996A1	0.0000	0.0284	0.0002	0.0000	0.0001	0.0009	0.2293	0.0000	0.0204	0.0857	0.2263	0.3777	0.0194	0.0092	0.0006	0.0017	0.0001	0.0001
1	EVDIS012596B1	0.0000	0.0288	0.0002	0.0000	0.0001	0.0009	0.2312	0.0000	0.0236	0.0989	0.2222	0.3632	0.0181	0.0103	0.0006	0.0018	0.0001	0.0001
1	EVDIS032296A2	0.0000	0.1344	0.0006	0.0001	0.0001	0.0000	0.2869	0.0000	0.0191	0.0686	0.1261	0.3327	0.0159	0.0117	0.0012	0.0025	0.0001	0.0001
1	EVDIS032296A1	0.0000	0.0918	0.0004	0.0001	0.0001	0.0000	0.2698	0.0000	0.0225	0.0858	0.1239	0.3695	0.0196	0.0131	0.0010	0.0022	0.0001	0.0001
1	EVDIS 062596B2	0.0000	0.0000	0.0005	0.0000	0.0001	0.0008	0.4142	0.0000	0.0234	0.0827	0.1252	0.3273	0.0147	0.0087	0.0005	0.0018	0.0001	0.0001
1	EVDIS082296B1	0.0000	0.0255	0.0003	0.0000	0.0001	0.0009	0.2143	0.0000	0.0455	0.1725	0.1062	0.3771	0.0313	0.0219	0.0007	0.0035	0.0001	0.0001
1	EVDIS082796B1	0.0000	0.0278	0.0002	0.0000	0.0001	0.0007	0.2624	0.0000	0.0231	0.0847	0.1308	0.4500	0.0073	0.0113	0.0006	0.0008	0.0001	0.0001
1	EVDIS082396B1	0.0000	0.0269	0.0003	0.0000	0.0001	0.0006	0.2390	0.0000	0.0235	0.0862	0.1755	0.4248	0.0081	0.0134	0.0007	0.0008	0.0001	0.0001
1	EVDIS090696B1	0.0000	0.0388	0.0003	0.0000	0.0001	0.0097	0.2935	0.0000	0.0168	0.0628	0.1143	0.4472	0.0054	0.0083	0.0003	0.0023	0.0001	0.0001
1	EVDIS091096B1	0.0000	0.0228	0.0003	0.0000	0.0000	0.0058	0.2551	0.0000	0.0172	0.0695	0.0927	0.5173	0.0047	0.0093	0.0003	0.0046	0.0001	0.0001
1	EVDIS091196B1	0.0000	0.0216	0.0002	0.0000	0.0001	0.0085	0.2647	0.0000	0.0213	0.0902	0.1140	0.4575	0.0069	0.0105	0.0004	0.0038	0.0001	0.0001
1	EVDIS091796B2	0.0000	0.0215	0.0002	0.0000	0.0001	0.0048	0.2498	0.0000	0.0277	0.1123	0.1032	0.4559	0.0111	0.0109	0.0004	0.0019	0.0001	0.0001
1	EVDIS091796B1	0.0000	0.0211	0.0002	0.0000	0.0001	0.0034	0.2396	0.0000	0.0255	0.1049	0.0926	0.4867	0.0108	0.0125	0.0008	0.0016	0.0001	0.0001
1	EVDIS100496B1	0.0000	0.0171	0.0002	0.0000	0.0001	0.0031	0.2218	0.0000	0.0219	0.0944	0.0955	0.5184	0.0113	0.0129	0.0007	0.0023	0.0001	0.0001
1	EVDIS100896B1	0.0000	0.0189	0.0002	0.0000	0.0001	0.0035	0.2650	0.0001	0.0277	0.1180	0.1111	0.4267	0.0105	0.0136	0.0007	0.0037	0.0001	0.0001
1	EVDIS100996B1	0.0000	0.0174	0.0002	0.0000	0.0001	0.0018	0.2484	0.0000	0.0225	0.0959	0.0760	0.5169	0.0064	0.0115	0.0005	0.0021	0.0001	0.0001
1	EVDIS101796B2	0.0000	0.0174	0.0005	0.0000	0.0000	0.0046	0.1698	0.0012	0.0373	0.1556	0.2067	0.3747	0.0073	0.0186	0.0013	0.0046	0.0001	0.0001
1	EVDIS101796B1	0.0000	0.0136	0.0002	0.0000	0.0000	0.0003	0.2706	0.0000	0.0264	0.1587	0.2254	0.2944	0.0064	0.0014	0.0001	0.0023	0.0001	0.0001
1	EVDIS102296B1	0.0000	0.0161	0.0003	0.0000	0.0001	0.0026	0.2294	0.0005	0.0351	0.1487	0.1445	0.3912	0.0092	0.0178	0.0005	0.0038	0.0001	0.0001
1	EVDIS102996B1	0.0000	0.0361	0.0006	0.0000	0.0001	0.0054	0.2418	0.0001	0.0085	0.0395	0.1166	0.5387	0.0028	0.0059	0.0007	0.0029	0.0002	0.0002
1	EVDIS031197B1	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.1155	0.0000	0.0095	0.0359	0.0244	0.8038	0.0017	0.0061	0.0004	0.0022	0.0001	0.0001
1	EVDIS040297A1	0.0000	0.0194	0.0002	0.0000	0.0001	0.0000	0.1631	0.0000	0.0089	0.0347	0.0286	0.7343	0.0015	0.0058	0.0004	0.0030	0.0001	0.0001

†	User Sample ID	Ag_2O	Al_2O_3	Am_2O_3	As_2O_3	BaO	BeO	CaO	CdO	Cr_2O_3	Fe_2O_3	K_2O	MgO	Na_2O	NiO	PbO	PuO_2	TiO_x	U_3O_8
1	EVDIS101896A2	0.0000	0.4560	0.0000	0.0002	0.0004	0.0000	0.0000	0.0000	0.0456	0.0000	0.4442	0.0000	0.0497	0.0003	0.0033	0.0000	0.0003	0.0000
2	12OX13AF1	0.0000	0.0190	0.0001	0.0000	0.0002	0.0002	0.2158	0.0000	0.0252	0.0970	0.0587	0.3273	0.2328	0.0110	0.0007	0.0117	0.0000	0.0001
2	12OX17AF1	0.0000	0.0144	0.0001	0.0001	0.0004	0.0001	0.1269	0.0000	0.0299	0.1116	0.0235	0.2103	0.4603	0.0122	0.0009	0.0091	0.0000	0.0002
2	12OX18AF1	0.0000	0.0734	0.0000	0.0001	0.0001	0.0001	0.0937	0.0000	0.0173	0.0957	0.0091	0.1050	0.5909	0.0110	0.0005	0.0021	0.0003	0.0008
2	4OX6BF1	0.0000	0.0182	0.0001	0.0001	0.0002	0.0009	0.2009	0.0000	0.0396	0.1483	0.0452	0.2777	0.2365	0.0244	0.0004	0.0072	0.0002	0.0002
2	5OX9BF1	0.0000	0.0243	0.0004	0.0001	0.0001	0.0034	0.1691	0.0000	0.0212	0.0950	0.2329	0.4208	0.0101	0.0135	0.0008	0.0079	0.0003	0.0003
2	9OX22AF1	0.0000	0.0163	0.0002	0.0000	0.0001	0.0004	0.2194	0.0000	0.0245	0.1046	0.1889	0.4219	0.0085	0.0106	0.0009	0.0035	0.0001	0.0001
2	EVOX041096B1	0.0000	0.0246	0.0003	0.0000	0.0002	0.0000	0.4128	0.0000	0.0409	0.3893	0.0830	0.0000	0.0275	0.0090	0.0007	0.0110	0.0002	0.0002
3	12LR21AF1	0.0000	0.0326	0.0001	0.0000	0.0002	0.0001	0.3029	0.0000	0.0164	0.0829	0.1025	0.3654	0.0782	0.0093	0.0008	0.0084	0.0000	0.0001
3	LRA19F1	0.0000	0.0634	0.0004	0.0005	0.0008	0.0070	0.1553	0.0001	0.0346	0.1693	0.0053	0.2208	0.3092	0.0188	0.0019	0.0108	0.0017	0.0000
3	LRA20F2	0.0000	0.0474	0.0002	0.0007	0.0012	0.0046	0.1702	0.0001	0.0356	0.1566	0.0080	0.2568	0.2833	0.0211	0.0014	0.0102	0.0025	0.0000
3	ATLLRA23B	0.0000	0.0392	0.0003	0.0001	0.0006	0.0002	0.2050	0.0000	0.0409	0.2475	0.1299	0.2650	0.0305	0.0220	0.0045	0.0136	0.0003	0.0003
3	2LR22AF1	0.0000	0.0263	0.0001	0.0001	0.0003	0.0002	0.2233	0.0000	0.0467	0.1931	0.0710	0.3461	0.0546	0.0250	0.0007	0.0120	0.0003	0.0003
3	2LR22AF2	0.0000	0.0262	0.0002	0.0001	0.0003	0.0002	0.2221	0.0000	0.0464	0.1920	0.0706	0.3442	0.0543	0.0249	0.0007	0.0173	0.0003	0.0003
3	2LR22AF3	0.0000	0.0262	0.0002	0.0001	0.0003	0.0002	0.2225	0.0000	0.0465	0.1924	0.0707	0.3448	0.0544	0.0249	0.0007	0.0156	0.0003	0.0003
3	ATLLRA23B1	0.0000	0.0440	0.0002	0.0001	0.0004	0.0004	0.1608	0.0000	0.0264	0.1761	0.3066	0.2042	0.0376	0.0188	0.0043	0.0196	0.0002	0.0002
3	4LR4BF1A	0.0000	0.0225	0.0001	0.0000	0.0003	0.0001	0.2665	0.0000	0.0590	0.2082	0.0358	0.3623	0.0091	0.0321	0.0004	0.0036	0.0001	0.0001
3	4LR4BF1B	0.0000	0.0222	0.0001	0.0000	0.0003	0.0001	0.2735	0.0000	0.0571	0.2117	0.0364	0.3536	0.0096	0.0309	0.0004	0.0038	0.0001	0.0001
3	4LR10BF1C	0.0000	0.0169	0.0001	0.0000	0.0002	0.0000	0.2647	0.0000	0.0469	0.1803	0.0262	0.4372	0.0077	0.0168	0.0002	0.0025	0.0001	0.0001
3	4LR10BF1B	0.0000	0.0204	0.0001	0.0000	0.0002	0.0000	0.3403	0.0000	0.0648	0.2318	0.0310	0.2847	0.0071	0.0164	0.0002	0.0027	0.0001	0.0001
3	4LR10BF1A	0.0000	0.0211	0.0001	0.0000	0.0002	0.0000	0.3276	0.0000	0.0647	0.2401	0.0331	0.2785	0.0137	0.0175	0.0002	0.0029	0.0001	0.0001
3	4LR17BF1	0.0000	0.0248	0.0001	0.0000	0.0004	0.0002	0.4199	0.0000	0.0433	0.1801	0.0348	0.2396	0.0330	0.0179	0.0007	0.0049	0.0001	0.0001
5	ATLDS11EFB1	0.0000	0.0169	0.0001	0.0000	0.0002	0.0002	0.2910	0.0000	0.0120	0.0523	0.1291	0.4599	0.0272	0.0080	0.0009	0.0020	0.0001	0.0001
5	ATLDS11EFB3	0.0000	0.0416	0.0001	0.0000	0.0002	0.0000	0.3765	0.0000	0.0176	0.0730	0.1844	0.2846	0.0125	0.0083	0.0004	0.0005	0.0001	0.0001
5	ATLDS11EFB2	0.0000	0.0631	0.0001	0.0000	0.0001	0.0000	0.3137	0.0000	0.0101	0.0452	0.1316	0.4194	0.0093	0.0069	0.0001	0.0003	0.0001	0.0001
5	ATLDS11EFB4	0.0000	0.0552	0.0001	0.0000	0.0001	0.0000	0.2611	0.0000	0.0103	0.0423	0.1163	0.5016	0.0048	0.0075	0.0001	0.0003	0.0001	0.0001
5	ATLDS11EFB5	0.0000	0.0581	0.0001	0.0000	0.0001	0.0000	0.3290	0.0000	0.0132	0.0543	0.1525	0.3799	0.0032	0.0084	0.0001	0.0007	0.0001	0.0001
5	ATLDS11F1B	0.0000	0.0405	0.0002	0.0000	0.0003	0.0001	0.2415	0.0000	0.0200	0.0792	0.1732	0.3816	0.0465	0.0110	0.0006	0.0049	0.0002	0.0002
5	ATLDS11EFB6	0.0000	0.0494	0.0002	0.0000	0.0004	0.0000	0.2907	0.0000	0.0186	0.0575	0.1050	0.4556	0.0099	0.0085	0.0007	0.0030	0.0002	0.0002
5	ATLDS11F1B2	0.0000	0.0580	0.0008	0.0000	0.0001	0.0002	0.2092	0.0000	0.0226	0.0884	0.3353	0.2564	0.0111	0.0138	0.0007	0.0033	0.0001	0.0001
5	ATLDS11F1B1	0.0000	0.0489	0.0005	0.0000	0.0001	0.0004	0.2512	0.0000	0.0161	0.0911	0.2650	0.2976	0.0180	0.0088	0.0005	0.0015	0.0001	0.0001
5	ATLDS11EF15B	0.0000	0.0373	0.0004	0.0000	0.0001	0.0004	0.2553	0.0000	0.0203	0.0824	0.2718	0.3025	0.0078	0.0104	0.0003	0.0109	0.0001	0.0001
5	ATLDS11EF15B1	0.0000	0.0492	0.0003	0.0000	0.0001	0.0004	0.2129	0.0000	0.0215	0.0900	0.2528	0.3479	0.0106	0.0113	0.0004	0.0023	0.0001	0.0001
5	4DS19BF1A	0.0000	0.0331	0.0006	0.0000	0.0001	0.0131	0.2340	0.0000	0.0223	0.0988	0.2190	0.3497	0.0152	0.0102	0.0011	0.0026	0.0001	0.0001
5	4DS19BF1B	0.0000	0.0332	0.0005	0.0000	0.0001	0.0130	0.2413	0.0000	0.0210	0.0976	0.2207	0.3455	0.0140	0.0091	0.0013	0.0025	0.0001	0.0001
5	4DS26BF1A	0.0000	0.0288	0.0008	0.0000	0.0000	0.0051	0.3110	0.0000	0.0226	0.0916	0.2496	0.2686	0.0071	0.0101	0.0031	0.0016	0.0001	0.0001
5	4DS26BF1B	0.0000	0.0252	0.0007	0.0000	0.0000	0.0045	0.2629	0.0000	0.0185	0.0768	0.2171	0.3751	0.0057	0.0093	0.0027	0.0013	0.0001	0.0001
5	5DS10BF1A	0.0000	0.0187	0.0003	0.0000	0.0000	0.0008	0.2847	0.0000	0.0149	0.0646	0.2133	0.3874	0.0051	0.0067	0.0012	0.0020	0.0001	0.0001
5	5DS10BF1B	0.0000	0.0249	0.0003	0.0000	0.0000	0.0012	0.2598	0.0000	0.0164	0.0679	0.2185	0.3938	0.0058	0.0077	0.0015	0.0019	0.0001	0.0001
5	ATLDS11EF15B2	0.0000	0.0510	0.0004	0.0000	0.0000	0.0017	0.1916	0.0000	0.0200	0.0979	0.2474	0.3618	0.0156	0.0109	0.0003	0.0013	0.0001	0.0001
5	ATLDS11EF15B3	0.0000	0.0503	0.0004	0.0000	0.0000	0.0015	0.1847	0.0000	0.0193	0.1003	0.2584	0.3557	0.0161	0.0105	0.0003	0.0022	0.0001	0.0001

†	User Sample ID	Ag_2O	Al_2O_3	Am_2O_3	As_2O_3	BaO	BeO	CaO	CdO	Cr_2O_3	Fe_2O_3	K_2O	MgO	Na_2O	NiO	PbO	PuO_2	TlO_x	U_3O_8
5	ATLDS11EF15B4	0.0000	0.0391	0.0004	0.0000	0.0001	0.0039	0.1749	0.0000	0.0213	0.0968	0.2259	0.3714	0.0492	0.0126	0.0005	0.0037	0.0001	0.0001
5	ATLDS16B	0.0000	0.0324	0.0007	0.0000	0.0000	0.0014	0.1691	0.0000	0.0213	0.0864	0.2912	0.3590	0.0204	0.0122	0.0022	0.0035	0.0001	0.0001
5	EVDS090795A1	0.0000	0.0147	0.0003	0.0000	0.0001	0.0001	0.2716	0.0000	0.0150	0.0681	0.1324	0.4798	0.0084	0.0070	0.0010	0.0014	0.0001	0.0001
5	EVDS092195B1	0.0000	0.0167	0.0002	0.0000	0.0001	0.0006	0.1973	0.0000	0.0288	0.1325	0.1747	0.4275	0.0065	0.0118	0.0010	0.0021	0.0001	0.0001
5	EVDS100495B1	0.0000	0.0167	0.0002	0.0000	0.0001	0.0003	0.3061	0.0000	0.0202	0.0914	0.1257	0.4185	0.0086	0.0086	0.0005	0.0030	0.0001	0.0001
5	EVDS100495A1	0.0000	0.0156	0.0003	0.0000	0.0001	0.0003	0.2651	0.0000	0.0192	0.0927	0.1141	0.4713	0.0084	0.0093	0.0005	0.0027	0.0002	0.0002
5	EVDS100495A2	0.0000	0.0158	0.0001	0.0000	0.0001	0.0002	0.2997	0.0000	0.0166	0.0781	0.0961	0.4736	0.0085	0.0080	0.0004	0.0026	0.0001	0.0001
5	EVDS121495A1	0.0000	0.0417	0.0003	0.0000	0.0001	0.0015	0.2995	0.0000	0.0162	0.1419	0.1196	0.2323	0.1338	0.0074	0.0018	0.0037	0.0000	0.0000
5	EVDS121495B1	0.0000	0.0226	0.0003	0.0000	0.0001	0.0009	0.3009	0.0000	0.0128	0.1223	0.1643	0.2991	0.0655	0.0074	0.0014	0.0024	0.0001	0.0001
5	EVDS121595B1	0.0000	0.0239	0.0003	0.0000	0.0001	0.0004	0.2356	0.0000	0.0186	0.0884	0.1656	0.4330	0.0227	0.0079	0.0010	0.0025	0.0001	0.0001
5	EVDS121495A2	0.0000	0.0204	0.0002	0.0000	0.0000	0.0001	0.2468	0.0000	0.0142	0.0692	0.1708	0.4588	0.0131	0.0040	0.0006	0.0016	0.0001	0.0001
5	EVDS011896B1	0.0000	0.0289	0.0002	0.0000	0.0001	0.0011	0.2264	0.0000	0.0231	0.0936	0.2320	0.3641	0.0177	0.0098	0.0007	0.0021	0.0001	0.0001
5	EVDS011896B2	0.0000	0.0294	0.0002	0.0000	0.0001	0.0008	0.2392	0.0000	0.0228	0.0903	0.2462	0.3389	0.0195	0.0095	0.0007	0.0021	0.0001	0.0001
5	EVDS012696B1	0.0000	0.0250	0.0003	0.0000	0.0001	0.0015	0.2139	0.0000	0.0189	0.0751	0.2590	0.3802	0.0148	0.0085	0.0007	0.0018	0.0001	0.0001
5	EVDS020696B1	0.0000	0.0279	0.0004	0.0000	0.0001	0.0018	0.2355	0.0000	0.0220	0.0886	0.1867	0.4112	0.0113	0.0113	0.0010	0.0020	0.0001	0.0001
5	EVDS012996B1	0.0000	0.0290	0.0004	0.0000	0.0001	0.0020	0.2397	0.0000	0.0206	0.0936	0.1942	0.3926	0.0122	0.0122	0.0009	0.0022	0.0001	0.0001
5	EVDS020896B1	0.0000	0.0271	0.0004	0.0000	0.0000	0.0009	0.2240	0.0000	0.0220	0.0943	0.1985	0.4060	0.0121	0.0108	0.0009	0.0027	0.0001	0.0001
5	EVDS020896B2	0.0000	0.0262	0.0004	0.0000	0.0000	0.0008	0.2089	0.0000	0.0203	0.0957	0.1922	0.4268	0.0125	0.0118	0.0010	0.0031	0.0001	0.0001
5	EVDS021396B2	0.0000	0.0356	0.0005	0.0000	0.0001	0.0018	0.0331	0.0000	0.0236	0.1156	0.2364	0.5169	0.0132	0.0147	0.0012	0.0070	0.0001	0.0001
5	EVDS021396B1	0.0000	0.0279	0.0004	0.0001	0.0001	0.0015	0.2484	0.0000	0.0197	0.0938	0.1906	0.3903	0.0114	0.0123	0.0010	0.0024	0.0001	0.0001
5	EVDS021496B3	0.0000	0.1071	0.0004	0.0000	0.0000	0.0023	0.2964	0.0000	0.0134	0.0686	0.1252	0.3645	0.0102	0.0071	0.0015	0.0031	0.0001	0.0001
5	EVDS021496B1	0.0000	0.0975	0.0004	0.0000	0.0000	0.0031	0.2936	0.0000	0.0175	0.0674	0.1290	0.3692	0.0110	0.0076	0.0015	0.0020	0.0001	0.0001
5	EVDS020896B1	0.0000	0.0271	0.0004	0.0000	0.0000	0.0009	0.2240	0.0000	0.0220	0.0943	0.1985	0.4060	0.0121	0.0108	0.0009	0.0027	0.0001	0.0001
5	EVDS021496B2	0.0000	0.1021	0.0003	0.0000	0.0000	0.0032	0.3305	0.0000	0.0189	0.0817	0.1560	0.2843	0.0118	0.0073	0.0016	0.0021	0.0001	0.0001
5	EVDS030896A1	0.0000	0.2603	0.0010	0.0001	0.0001	0.0010	0.1346	0.0000	0.0231	0.0468	0.2255	0.2510	0.0359	0.0147	0.0017	0.0040	0.0002	0.0001
5	EVDS030896B2	0.0000	0.0816	0.0004	0.0000	0.0000	0.0001	0.2679	0.0000	0.0235	0.0871	0.1258	0.3752	0.0217	0.0133	0.0010	0.0022	0.0001	0.0001
5	EVDS050696B1	0.0000	0.0000	0.0004	0.0000	0.0001	0.0005	0.2852	0.0008	0.0324	0.1295	0.0000	0.5183	0.0092	0.0179	0.0003	0.0051	0.0001	0.0001
5	EVDS082196A1	0.0000	0.0359	0.0003	0.0000	0.0001	0.0008	0.2416	0.0000	0.0279	0.1022	0.1219	0.4246	0.0233	0.0129	0.0008	0.0074	0.0001	0.0001
5	EVDS082196A2	0.0000	0.0334	0.0003	0.0001	0.0001	0.0010	0.2178	0.0000	0.0341	0.1335	0.1125	0.4000	0.0409	0.0188	0.0006	0.0066	0.0002	0.0002
5	EVDS082196A3	0.0000	0.0401	0.0003	0.0000	0.0001	0.0008	0.2560	0.0000	0.0235	0.0951	0.1269	0.4320	0.0127	0.0106	0.0009	0.0008	0.0001	0.0001
5	EVDS082196A4	0.0000	0.0370	0.0003	0.0000	0.0001	0.0008	0.2413	0.0000	0.0210	0.0822	0.1177	0.4767	0.0109	0.0102	0.0008	0.0007	0.0001	0.0001
5	EVDS082696A1	0.0000	0.0268	0.0003	0.0000	0.0001	0.0005	0.2378	0.0000	0.0222	0.0868	0.1097	0.4931	0.0082	0.0124	0.0008	0.0012	0.0001	0.0001
5	EVDS082796A1	0.0000	0.0278	0.0002	0.0000	0.0001	0.0007	0.3047	0.0000	0.0203	0.0778	0.1014	0.4514	0.0045	0.0094	0.0004	0.0011	0.0001	0.0001
5	EVDS082796A2	0.0000	0.0283	0.0002	0.0000	0.0001	0.0007	0.2960	0.0000	0.0209	0.0774	0.1185	0.4405	0.0052	0.0106	0.0005	0.0009	0.0001	0.0001
5	EVDS082696A2	0.0000	0.0267	0.0003	0.0000	0.0001	0.0006	0.2370	0.0000	0.0233	0.0926	0.1680	0.4212	0.0087	0.0197	0.0007	0.0010	0.0001	0.0001
5	EVDS082996A1	0.0000	0.0292	0.0002	0.0000	0.0001	0.0008	0.2843	0.0000	0.0246	0.0921	0.0895	0.4601	0.0073	0.0101	0.0004	0.0010	0.0001	0.0001
5	EVDS090596A1	0.0000	0.0347	0.0002	0.0000	0.0001	0.0055	0.2911	0.0000	0.0222	0.0798	0.1100	0.4375	0.0075	0.0090	0.0003	0.0017	0.0001	0.0001
5	EVDS090696A1	0.0000	0.0357	0.0002	0.0000	0.0001	0.0075	0.2817	0.0000	0.0184	0.0712	0.1091	0.4590	0.0051	0.0090	0.0004	0.0023	0.0001	0.0001
5	EVDS091196A1	0.0000	0.0196	0.0003	0.0000	0.0001	0.0139	0.2585	0.0001	0.0225	0.0991	0.1530	0.4084	0.0104	0.0113	0.0005	0.0021	0.0001	0.0001
5	EVDS091196A2	0.0000	0.0179	0.0002	0.0000	0.0001	0.0140	0.2327	0.0002	0.0222	0.0982	0.1481	0.4436	0.0097	0.0106	0.0004	0.0020	0.0001	0.0001
5	EVDS091396A1	0.0000	0.0187	0.0002	0.0000	0.0000	0.0014	0.2185	0.0000	0.0198	0.0822	0.0990	0.5382	0.0111	0.0089	0.0006	0.0012	0.0001	0.0001

†	User Sample ID	Ag_2O	Al_2O_3	Am_2O_3	As_2O_3	BaO	BeO	CaO	CdO	Cr_2O_3	Fe_2O_3	K_2O	MgO	Na_2O	NiO	PbO	PuO_2	TlO_x	U_3O_8
5	EVDS091396A2	0.0000	0.0198	0.0002	0.0000	0.0000	0.0030	0.2343	0.0000	0.0199	0.0891	0.1079	0.5036	0.0105	0.0094	0.0005	0.0014	0.0001	0.0001
5	EVDS092596A1	0.0000	0.0117	0.0002	0.0000	0.0000	0.0019	0.2606	0.0000	0.0162	0.1020	0.0525	0.5387	0.0051	0.0086	0.0006	0.0017	0.0001	0.0001
5	EVDS092596A2	0.0000	0.0155	0.0002	0.0000	0.0000	0.0028	0.2146	0.0000	0.0206	0.0889	0.0799	0.5567	0.0078	0.0105	0.0006	0.0016	0.0001	0.0001
5	EVDS100496A1	0.0000	0.0106	0.0002	0.0000	0.0001	0.0018	0.2288	0.0000	0.0164	0.0668	0.0529	0.6042	0.0060	0.0095	0.0007	0.0019	0.0001	0.0001
5	EVDS100496A2	0.0000	0.0109	0.0002	0.0000	0.0001	0.0019	0.2541	0.0000	0.0189	0.0752	0.0576	0.5626	0.0064	0.0091	0.0007	0.0023	0.0001	0.0001
5	EVDS101096A2	0.0000	0.0101	0.0002	0.0000	0.0000	0.0007	0.2894	0.0000	0.0145	0.0563	0.0623	0.5540	0.0027	0.0076	0.0002	0.0018	0.0001	0.0001
5	EVDS101096A3	0.0000	0.0109	0.0002	0.0000	0.0000	0.0006	0.3090	0.0000	0.0147	0.0554	0.0700	0.5267	0.0027	0.0074	0.0002	0.0019	0.0001	0.0001
5	EVDS101096A1	0.0000	0.0121	0.0002	0.0000	0.0000	0.0010	0.2767	0.0001	0.0187	0.0825	0.0794	0.5124	0.0037	0.0105	0.0003	0.0021	0.0001	0.0001
5	EVDS102296A1	0.0000	0.0164	0.0003	0.0000	0.0001	0.0016	0.2594	0.0004	0.0231	0.0970	0.1089	0.4724	0.0054	0.0115	0.0005	0.0027	0.0001	0.0001
5	EVDS102396A1	0.0000	0.0380	0.0002	0.0000	0.0001	0.0010	0.2927	0.0002	0.0129	0.0565	0.0728	0.5088	0.0075	0.0065	0.0004	0.0022	0.0001	0.0001
5	EVDS102396A2	0.0000	0.0303	0.0002	0.0000	0.0001	0.0010	0.3164	0.0002	0.0135	0.0587	0.0834	0.4821	0.0050	0.0065	0.0002	0.0022	0.0001	0.0001
5	EVDS102496A1	0.0000	0.0414	0.0002	0.0000	0.0001	0.0008	0.3068	0.0001	0.0124	0.0549	0.0576	0.5124	0.0045	0.0063	0.0002	0.0021	0.0001	0.0001
5	EVDS012297B1	0.0000	0.0308	0.0001	0.0000	0.0000	0.0001	0.1669	0.0000	0.0032	0.0146	0.1349	0.6460	0.0006	0.0017	0.0008	0.0002	0.0001	0.0001
5	EVDS032797B2	0.0000	0.0286	0.0013	0.0001	0.0000	0.0000	0.1125	0.0000	0.0288	0.1173	0.3361	0.3266	0.0219	0.0209	0.0030	0.0020	0.0004	0.0004
5	EVDS040197B1	0.0000	0.0289	0.0012	0.0001	0.0000	0.0000	0.1117	0.0000	0.0259	0.1087	0.3207	0.3573	0.0205	0.0194	0.0027	0.0022	0.0003	0.0003
5	EVDS040197B2	0.0000	0.0295	0.0013	0.0001	0.0000	0.0000	0.1078	0.0000	0.0282	0.1141	0.3315	0.3422	0.0204	0.0193	0.0028	0.0022	0.0003	0.0003
5	EVDS040197B3	0.0000	0.0276	0.0012	0.0001	0.0000	0.0000	0.0979	0.0000	0.0261	0.1079	0.3305	0.3640	0.0203	0.0192	0.0025	0.0021	0.0003	0.0003
5	EVDS040197B4	0.0000	0.0289	0.0012	0.0001	0.0000	0.0000	0.1006	0.0000	0.0273	0.1049	0.3118	0.3815	0.0194	0.0183	0.0031	0.0022	0.0003	0.0003
5	EVDS040297B2	0.0000	0.0114	0.0001	0.0000	0.0000	0.0000	0.1131	0.0000	0.0046	0.0193	0.0189	0.8262	0.0006	0.0031	0.0002	0.0023	0.0001	0.0001
5	EVDS040297B1	0.0000	0.0128	0.0001	0.0000	0.0000	0.0000	0.1116	0.0000	0.0062	0.0251	0.0243	0.8113	0.0011	0.0043	0.0003	0.0024	0.0001	0.0001
5	EVDS040497B1	0.0000	0.0025	0.0001	0.0000	0.0000	0.0002	0.0371	0.0000	0.0038	0.0142	0.0110	0.9257	0.0021	0.0025	0.0001	0.0005	0.0001	0.0001
5	EVDS040497B2	0.0000	0.0057	0.0001	0.0000	0.0000	0.0004	0.0674	0.0000	0.0068	0.0272	0.0280	0.8545	0.0044	0.0038	0.0003	0.0013	0.0001	0.0001

†Waste types: 1 - hot distillate (HD), 2 - oxalate filtrate (OX), 3 - lean residue (LR), 4 - ATLAS (ATL), 5 - dissolution (DS), and 6 - chloride (CL)

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