U.S. DEPARTMENT OF ENERGY

Nuclear Energy

Environmental Management

Glass Quantities and Compositions

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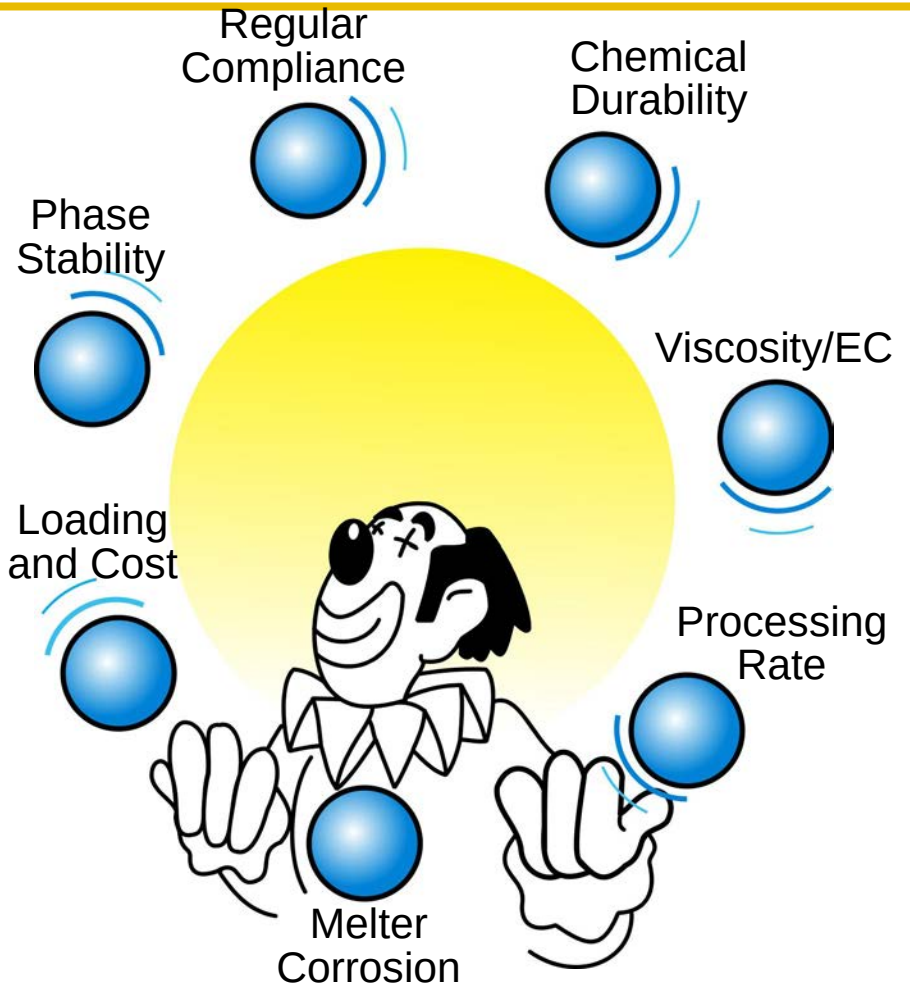
NWTRB questions addressed

May 15, 2017 pre-meeting briefing questions for DOE:

- Provide an overview of the compositions and projected quantities of existing and future HLW glass at the West Valley Demonstration Project, Savannah River Site, and the Hanford Site (including "German" glass logs).
  - How is the variability in DOE HLW glass composition taken account of in DOE's glass corrosion models?
  - How well are the glass corrosion model parameters supported by experimental data?
- What is the status of DOE R&D activities to understand and model the long-term performance of borosilicate HLW glass?
  - Which R&D activities are run or managed by the different DOE offices and programs [DOE-NE (including NEUP), DOE-EM, DOE Office of Science (if any)] and how are these activities integrated? What are the accomplishments?
  - A detailed plan for joint DOE-NE and DOE-EM R&D activities on glass corrosion initially was developed in 2011 (Ryan et al. 2011)1 that included experiments and modeling. What are the status and results of the tasks described in the plan?
  - How are the results of international R&D activities integrated with the results of DOE R&D?
- From DOE's perspective, what are the remaining technical uncertainties and gaps in data and understanding of the long-term performance of HLW glass? How is DOE addressing these uncertainties and gaps?
- How is DOE integrating process-level models of HLW glass corrosion and radionuclide release into generic repository performance assessments?
  - How is the DOE approach to HLW glass performance modeling different from that for the low-activity waste (LAW) glass to be disposed of at the Hanford Site Integrated Disposal Facility?
  - What lessons learned from LAW glass corrosion experiments and modeling can be applied to HLW glass?
- What is the technical basis for extrapolating the results of short-term, small-scale tests on glass corrosion to long-term glass waste form performance in a repository?

Glass Composition Design

- **A range of glass compositions are to be generated**
- **Glasses are designed to meet specific physical, chemical, and regulatory compliance constraints (examples shown)**
- **Glasses are designed specifically for waste compositions to be immobilized**
  - Waste composition vary both between SRS, WVDP, and Hanford and within SRS and Hanford tank farms



Glass Quantities

- Glass quantities for the West Valley Demonstration Project (WVDP) and the "German glass" (FRG) are known.
- Glass quantities for the Defense Waste Processing Facility (DWPF) and the Hanford Tank Waste Treatment and Immobilization Plant (WTP) can be projected.

Type	Glass Produced		Glass Projected to be Produced		Primary Source
	# of Cans	Mass, t	# of Cans	Mass, t	
FRG	34	5.37	-	-	Holton et al. 1989
WVDP	275	573.8	-	-	Palmer et al. 2004
DWPF[a]	4,242	7,200	~3,928	~6,667	Chew and Hamm 2016
WTP-HLW[b]	-	-	~10,586	~31,968	Certa et al. 2011

(a) Current *System Plan* projection is 8,170 canisters. This is somewhat uncertain; 4,242 canisters have been produced to date (Jantzen 2017).
(b) Based on *System Plan* rev. 6 base-case projections. Estimates vary from 7,650 to 18,000 canisters depending on formulation approach and flowsheet assumptions. (e.g., Vienna et al. 2013)

FRG Glass Compositions

- **34 canisters were produced**
  - Two demonstration cans
  - Two instrumented cans
  - 10 each from three campaigns: RLFCM-7, -8, and -9

- **Average compositions for each campaign listed (wt%) (Holton et al. 1989)**

Oxide	RLFCM-7	RLFCM-8	RLFCM-9
Al_2O_3	2.88	2.58	2.17
B_2O_3	13.68	14.65	14.84
BaO	1.05	1.13	1.02
CaO	1.52	1.25	0.79
Cr_2O_3	0.58	0.38	0.45
Cs_2O	5.02	2.08	5.74
Fe_2O_3	11.18	10.10	9.93
La_2O_3	1.04	1.07	1.53
Li_2O	0.31	0.00	0.00
MgO	0.78	0.54	0.44
MnO_2	0.80	1.20	1.11
Na_2O	16.5	13.22	11.58
Nd_2O_3	0.65	0.71	0.89
NiO	0.39	0.25	0.44
PbO	0.16	0.00	0.00
SiO_2	41.25	48.02	46.59
SrO	1.65	2.67	2.34
TiO_2	0.19	0.07	0.03
ZrO_2	0.15	0.04	0.05

RLFCM-7 Glass Composition Variation

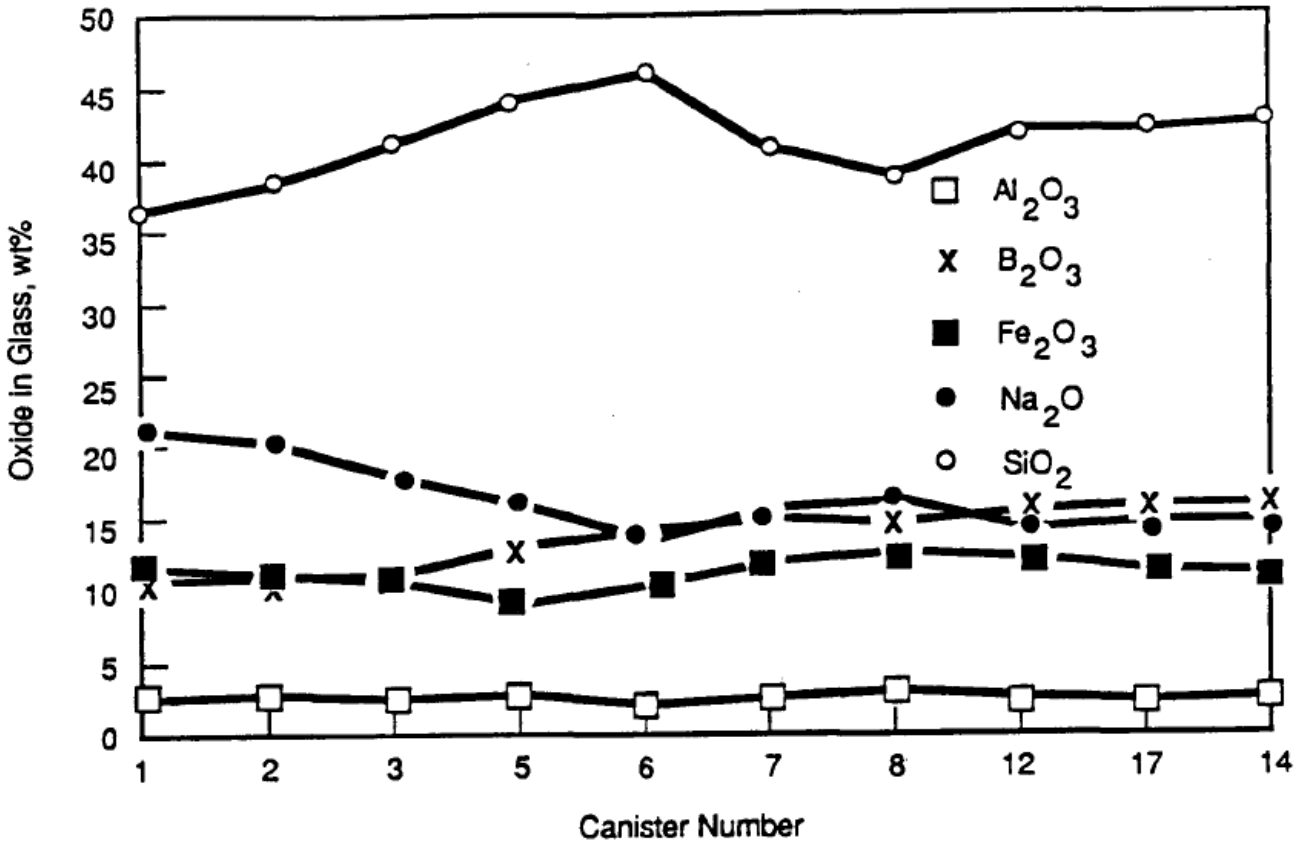


FIGURE 2.3. RLFCM-7 Major Glass Component Concentrations

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RLFCM-8 Glass Composition Variation

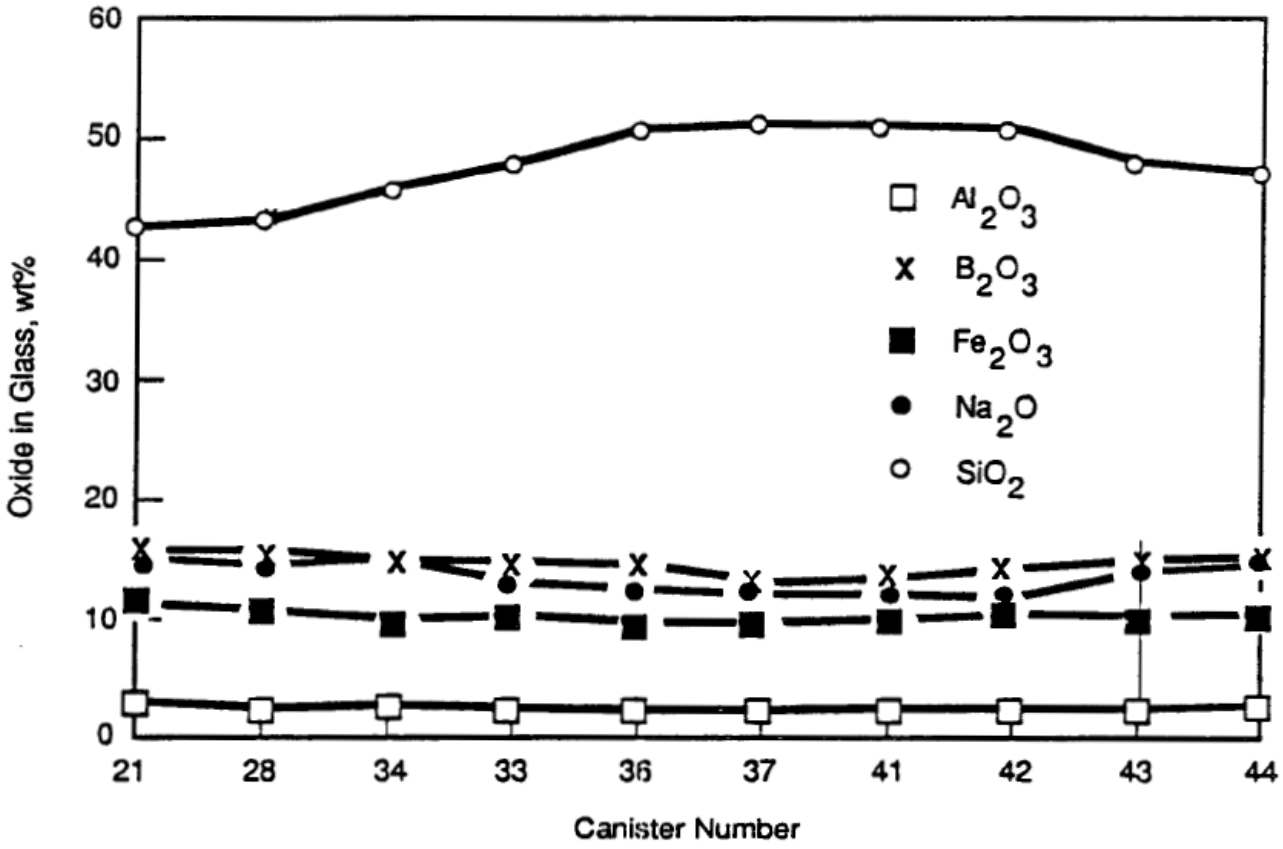

FIGURE 2.6. RLFCM-8 Major Glass Component Concentrations

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RLFCM-9 Glass Composition Variation

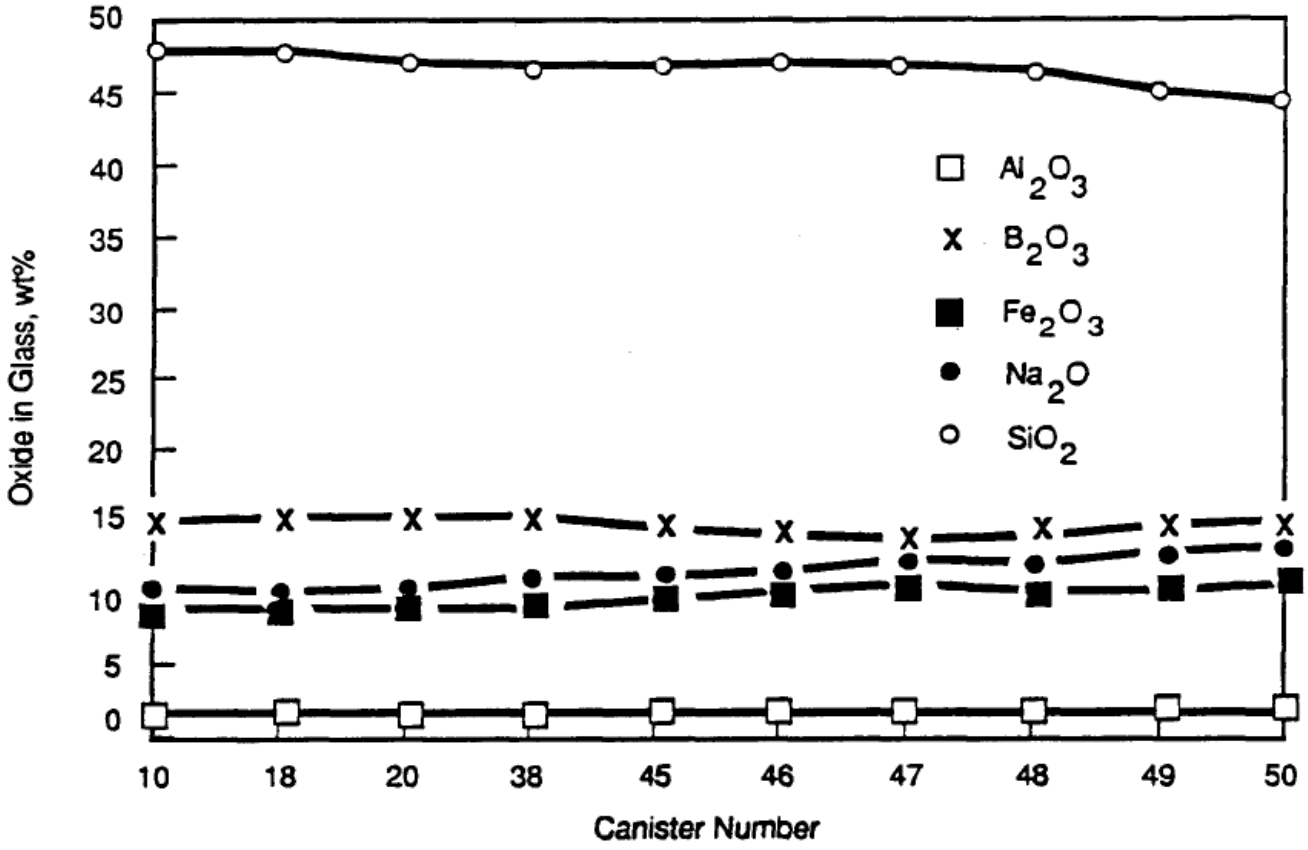

FIGURE 2.8. RLFCM-9 Major Glass Component Concentrations

WVDP Glass Compositions

- WVDP glass compositions (wt%) relatively constant (Palmer et al. 2004)

Oxide	Target	Min	Max
Al_2O_3	6.00	5.6	7.1
B_2O_3	12.89	11.2	14.8
BaO	0.16	NR	NR
CaO	0.48	0.21	0.6
Ce_2O_3	0.31	NR	NR
Cr_2O_3	0.14	NR	NR
Fe_2O_3	12.02	10.7	13.5
K_2O	5.00	4.1	5.3
Li_2O	3.71	3.3	4.2
MgO	0.89	0.7	1.3
MnO	0.82	0.7	0.9
Na_2O	8.00	7.1	8.6
Nd_2O_3	0.14	NR	NR
NiO	0.25	NR	NR
P_2O_5	1.20	1.0	1.4
SO_3	0.23	NR	NR
SiO_2	40.98	39.5	48.4
ThO_2	3.56	0.1	3.6
TiO_2	0.80	0.7	0.9
UO_3	0.63	0.1	0.8
ZrO_2	1.32	1.2	1.4

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Measured WVDP Glass Composition Variation

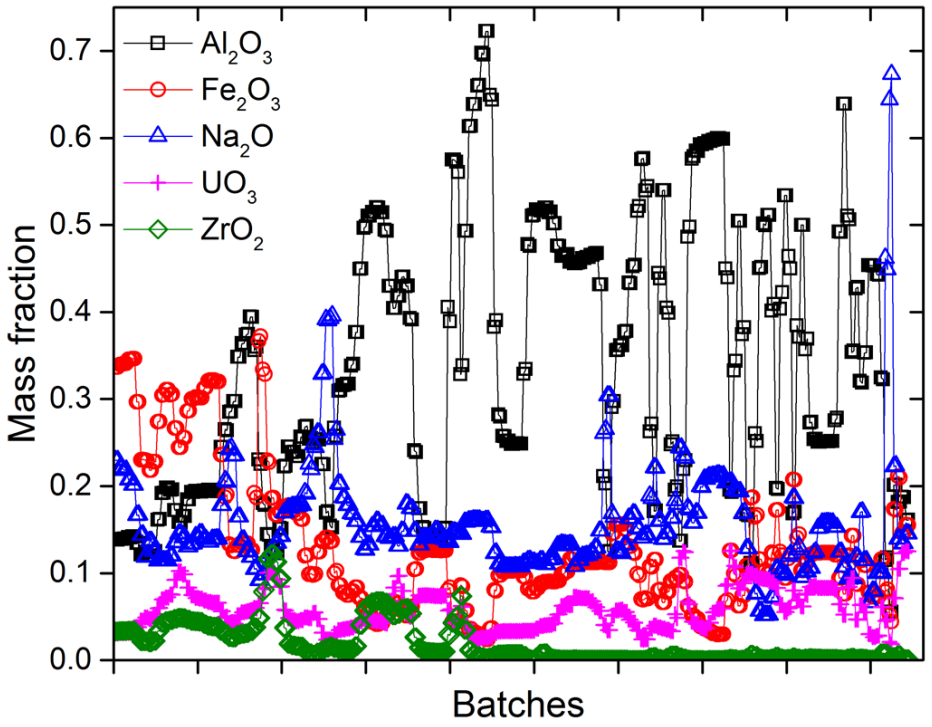
DWPF Glass Compositions

MacroBatch	1	2	3	4	5	6	7	8
Al_2O_3	4.3	5.37	4.34	4.79	7.78	6.71	9.83	8.59
B_2O_3	8.2	8.18	4.44	4.44	8.29	5.58	4.91	4.27
CaO	1.3	1.39	1.31	1.03	0.72	0.70	0.55	0.46
Fe_2O_3	12.6	10.5	12.2	10.80	8.21	8.53	9.21	8.37
Li_2O	3.6	3.53	5.27	4.96	5.25	5.55	5.04	4.56
MgO	2.1	2.16	1.16	1.16	0.78	0.51	0.35	0.27
MnO	1.1	1.76	1.47	2.09	1.62	1.73	2.44	2.01
Na_2O	12.1	11.5	11.3	11.90	11.50	13.40	13.59	12.45
NiO	0.21	NR	0.55	0.55	0.48	0.96	1.11	1.22
P_2O_5	0.39	0.63	0.48	0.29	0.25	0.21	0.20	BD
SO_4	NR	NR	0.25	0.39	0.36	BD	0.24	BD
Sb_2O_5	NR	NR	0.07	0.14	BD	BD	0.02	BD
SiO_2	48.1	52.4	49.3	51.00	50.70	54.60	44.77	47.07
SnO_2	NR	NR	0.08	0.14	BD	BD	NR	BD
SrO	NR	NR	0.32	0.28	0.01	0.02	0.02	0.03
ThO_2	NR	NR	NR	NR	NR	NR	0.68	0.69
TiO_2	NR	NR	0.06	0.06	0.07	0.20	0.04	0.66
U_3O_8	1.0	1.1	3.36	3.51	2.23	2.22	2.03	2.43
ZrO_2	0.13	0.19	0.08	0.05	0.17	0.11	0.16	0.15

(a) Estimates for the remaining ~3,928 canisters of glass are not projected, but, expected to be similar to those reported (SNL 2014).

WTP HLW Glass Compositions

- Hanford HLW glass component concentration ranges for System Plan rev. 6 baseline case (wt%)



High-level waste composition estimates based on Kim 2015

Comp	Min	Median	Max
Al_2O_3	2.02	13.27	18.89
B_2O_3	4.00	10.41	20.00
Bi_2O_3	0.00	0.92	3.20
CaO	0.00	0.77	3.07
Fe_2O_3	4.00	4.34	17.40
K_2O	0.00	0.16	2.55
Li_2O	0.93	6.00	6.00
MnO	0.00	1.15	5.73
Na_2O	4.18	8.90	21.40
P_2O_5	0.00	1.26	2.50
SiO_2	31.51	42.24	53.00
SrO	0.00	0.12	3.68
ThO_2	0.00	0.07	2.84
UO_3	0.00	2.03	6.30
ZrO_2	0.00	0.13	13.50

Glass composition region based on Certa et al. 2011

WTP HLW Glass Compositions

- A broader range of glass compositions are possible depending primarily on the flowsheet decisions and glass formulation approach
- The range of projected glass compositions covering a broad range of these potential variables are given for information only (unpublished data)
- Once final decisions on flowsheet and formulation approach are made, the composition region is expected to be narrowed significantly

Range	min	max
Al_2O_3	2.38	32.00
B_2O_3	4.00	22.00
Bi_2O_3	0.00	6.15
CaO	0.00	10.00
CdO	0.00	0.56
Cr_2O_3	0.00	1.37
F	0.00	0.32
Fe_2O_3	0.88	20.00
K_2O	0.00	2.70
Li_2O	0.00	6.00
MgO	0.00	4.84
MnO	0.00	10.00
Na_2O	4.10	23.71
NiO	0.00	2.27
P_2O_5	0.00	0.74
SiO_2	22.00	53.00
SrO	0.00	3.65
ThO_2	0.00	4.16
TiO_2	0.00	0.06
UO_3	0.00	8.45
ZnO	0.00	4.00
ZrO_2	0.00	13.50

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