LEACH TESTING OF IDAHO CHEMICAL PROCESSING PLANT FINAL WASTE FORMS

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A number of pellets and highly durable glasses prepared from nonradioactive-simulated high-level waste calcines have been leach tested. The leach tests are patterned on the IAEA standard test and the proposed Materials Characterization Center tests. Most tests are made with static distilled water at 25, 70, 95, 250, and 350°C and in refluxing distilled water, Soxhlet, at 95°C. Leach rates are determined by analyzing the leachate by instrumental activation analysis or spectrochemical analysis and from weight loss.

Leaches are run on glass using cast and core drilled cylinders, broken pieces and coarse ground material. Sample form has a considerable effect on leach rates; solid pieces gave higher leach rates than ground glass when expressed in g/cm^2/day. Cesium, molybdenum and weight loss leach rates of cast glass cylinders in distilled water varied from $<10^{-7}$ g/cm^2/day at 25°C to $\sim 10^{-3}$ g/cm^2/day at 250°C. The leach rates in static distilled water at 95°C were considerably lower than those in refluxing distilled water, Soxhlet, at the same temperature. Even at 25°C, sodium, cesium, and molybdenum readily leached from the porous pellets, but the pellets showed no visible attack, even at 250°C.

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Introduction

The Idaho Chemical Processing Plant, ICPP, reprocesses uranium fuels from test and defense reactors and recovers the uranium for reuse. The process includes dissolution of the entire fuel element, including the cladding, so the waste contains a large fraction of inert material, e.g., aluminum or zirconium plus process chemicals and only a small fraction of fission products and actinides. The compositions of some typical long-cooled waste calcines are given in Table I.[1] Waste forms made from these calcines will show much less radioactive heating and be subject to much less radiation damage than the forms made from commercial fuel reprocessing waste.[2]

The ICPP converts its high-level liquid wastes into solid in a fluidized-bed calciner and stores the calcine in stainless-steel bins inside near surface concrete vaults.[3] The calcine is dispersible and leachable in the very unlikely event of intrustion into or disruption of the vault, so for maximum safety, it may be necessary to incorporate the calcine in a highly durable glass or ceramic for disposal in a deep geological waste repository. A number of highly durable borosilicate glasses and some ceramic pellets are well developed and extensively tested and advanced ceramic forms are being studied. The compositions of some glasses that have been extensively leach tested are given in Table II. Frit #127 is the leading contender for vitrifying zirconia calcine; the CaF_2 in the calcine lowers the viscosity so that a high SiO_2 highly leach resistant glass can be formed at 1100°C. The ceramic pellets are strong, ∿5 mm diameter spheres which show little dusting, but leach more readily than glass due to their porosity. Pellets could be incorporated in concrete or metal matrices to produce a low-leach final waste form.

A number of standardized leach tests have been proposed for nuclear waste forms. The International Atomic Energy Agency, IAEA, proposed a test in 1971[4] and the International Standards Organization and the American Nuclear Society are both proposing tests.[5,6] The Materials Characterization Center, Battelle Pacific Northwest Laboratory, is proposing a series of tests, simple ones for scoping and extensive ones for predicting the long-term behavior of waste forms in actual repositories.[7,8]

Experimental

During initial formulation studies, the ICPP waste glasses are leached as the ground material -16+30 mesh, with 25°C 1M CH_3COOH, 0.1M CH_3COONa buffer, pH 3.8, and with refluxing boiling water, here 95°C, in a Soxhlet apparatus. The leach rates are determined from the weight loss. For more definitive tests solid pieces of glass, e.g., cast cylinders, core drilled cylinders, pressed sheets and broken pieces, are used as recommended by the standard tests.[4,8] Leach rates of individual elements are determined by analysis of the leachate by instrumental activation analysis and spectrochemical methods.

To date, most elemental leach rates have been determined in distilled water, either static or refluxing in a Soxhlet apparatus. A few tests have been run in salt brine, typical of the Waste Isolation Pilot Plant salt beds and in Climax, Nevada granite equilibrated water, see Table III. The leachant is contained in polypropylene or teflon bottles for static tests below boiling while the high temperature tests are run in a stainless steel autoclave. Solid pieces are suspended in the leachant by a stainless steel or polypropylene holder, while ground glass and pellets are contained in fine mesh stainless steel baskets. The Soxhlet extractors used for the dynamic leach tests on both solid pieces and ground glass are made from Pyrex glass or fused silica; the sample thimbles are bathed in steam to keep the water temperature at boiling.

The shorter times recommended by the standard tests often do not give high enough concentrations in the leachate for analysis, so fairly long leach times are normally employed. It required 240 days of leaching at 25°C to give leached element concentrations significantly greater than the blank. For static leaches at 70°C and 95°C, 28 days or 7 days followed by 21 days are commonly used. Three days are normally used for the autoclave leaches and 14 days or 3 days followed by 11 days for the Soxhlet tests. Some leach tests have been continued for many leach periods.

Only cold-simulated waste samples have been leached so far. Most glass samples are prepared by melting the frit and calcine components in alumina or platinum crucibles at 1100°C in a laboratory furnace. The nonvolatile fission products are added as fissium, a mixture of oxides and carbonates with the same elementary composition as nonvolatile ten year old ^{235}U fission products, see Table IV. Some fission products are simulated, Tc by Ru, Rh and Pd by NiO and the low yield fission product metals by Sb. Actinides are simulated by UO_2 and ThO_2. Some glasses are prepared using simulated calcine with the same composition as stored calcines, see Table I, while others are prepared from calcines containing 20% fissium to give better sensitivity in leachate analysis. After melting and fining at 1100°C, the glass is cast into graphite molds to form ~1.3 cm diameter by ~1.3 cm high cylinders or pressed between graphite plates to form thin sheets. Solid pieces are also made by core drilling 1.26 cm diameter cylinders and cutting them into 1 cm high pieces. Broken chunks are also used. The areas of the solid pieces are determined from their dimensions. For ground glass the fraction going through a 16 mesh screen and retained by a 30 mesh screen is taken and washed with acetone to remove fines. Microscopic examination of ground glass samples gave a specific area of 38.5 cm^2/g, which is assumed constant for all -16+30 mesh ground glass. Some glass samples are cooled in the air, air quenched, while others are annealed at 500°C, then slowly cooled to room temperature.

For static leaching of ground glass and autoclave leaching, 150 mL of leachant are used, while for static leaching of solid pieces below 100°C, a volume (cm^3) of leachant equal to ten times the sample surface area (cm^2) is usually used as recommended by the standard tests. The effect of varying the ratio of the volume of leachant to the area of sample has been investigated.

At the conclusion of the test, the pH of the leachate is measured then the container rinsed with dilute HCl or HNO_3, the rinse added to the leachate, and aliquots taken for activation analysis and spectrochemical analysis. Suspended solids, e.g., silica gel, are mixed with the leachate and analyzed while any solid that sticks to the container is discarded. The aliquots for instrumental activation analysis are evaporated nearly to dryness in teflon evaporating dishes, then dried in small polyethylene cups for irradiation. The dried leachate samples along with small samples of the original glass are irradiated for six hours in a pneumatic rabbit facility at $\sim 8 \times 10^{12}$ n/cm^2/sec. After a decay of about five days to allow 15 hr ^{24}Na to decay to the level of other activation products, the samples are counted with a calibrated Ge(Li) gamma spectrometer and the gamma activities calculated and corrected for decay by computer. A cobalt-aluminum alloy flux monitor is irradiated with the samples so corrections can be made for variations in neutron flux.

The elemental leach rates are calculated from the fraction leached as determined from the gamma activities. Fraction leached equals the corrected gamma activity in the leachate per mg sample leached divided by the corrected gamma activity in the glass per mg. The elemental leach rate in g/cm^2/day is then determined by dividing the fraction leached by the specific area, cm^2/g of the sample and the days leached. The elemental leach rate in cm/day is also determined by dividing the fraction leached by the area of the sample and the days leached and multiplying by the volume of the sample.

As an alternate method of determining leach rates, a few glass samples were irradiated before leaching and the activity in the leachate determined. Thin sheets were pressed, cut to size, ~5 cm^2 total area, then irradiated six hours in ~3×10^{12} $n/cm^2/sec$ flux along with small samples of the same glass. Glass sheets were used to minimize neutron self shielding and gamma dose. After one week cooling, leach tests were started in room temperature, ~25°C, distilled water, simulated WIPP brine, see Table III, and Climax, Nevada granite equilibrated water. The entire leachate was removed at the end of the leach period and counted with a standardized Ge(Li) gamma spectrometer along with the small glass monitors. Leach rates were determined from the fraction leached times the weight of the glass divided by the surface area and the days leached. Fresh leachant was added and the leach continued. After the first period, only the leach rate of cesium, 2.06 yr ^{134}Cs, could be determined. The glass samples appeared undamaged by the irradiation. The main advantage of the preirradiation is that it allowed elemental leach rates to be determined in typical repository leachants.

All leach tests made on pellets used laboratory pelletizer product. The pellets were contained in stainless steel baskets during leaching. Because the pellets are porous, leach rates were calculated as fraction of element leached during the leach period.

Results

Since frit 127 is the leading contender for vitrifying zirconia calcine, this glass has been most extensively tested. Extensive tests have also been run on frit 128 and variations of frit 127 in which TiO_2 and alkaline earth oxides are substituted for some of the SiO_2 and alkali and for CuO. Frits for vitrifying alumina calcine have been less extensively tested. Some glasses made from Savannah River Laboratory,[9] Battelle Pacific Northwest Laboratory,[10] British,[11] French,[2] and German[12] frits have also been studied.

The glasses are highly leach resistant. Some elemental leach rates of frit 127 zirconia calcine glass are given in Table V. At 25°C, both ground glass and cylinders show no significant weight change. Leach rates have also been obtained on activated glass sheets in 25°C leachants, see Table VI. The leach rate of Cs has been followed for a number of leach periods and is decreasing, see Figure 1. Leach rates tend to be greater in salt (WIPP) brine than in distilled water or granite equilibrated water. The irradiation may have increased the leach rate due to n,γ recoils and transmutation.

Some distilled water leach rates on various shapes of frit 127 zirconia waste glass are given in Table VII. The table shows the increase in leach rate with temperature. The solid pieces, all with 1.5-2.0 cm^2/g specific areas, show about the same leach rate at the same temperature. The ground glass shows a lower leach rate than the solid pieces. The leach rate in 95°C static distilled water is considerably lower than the rate in refluxing water in a Soxhlet apparatus, here also 95°C. The glass is not significantly altered except at 350°C where it is covered with a thick adherent crystalline coating. The variations of elemental leach rates for two frit compositions are shown in Tables VIII and IX. Elemental leach rates are also greater in 95°C Soxhlet tests than in 95°C static tests. At 350°C, a number of elements, e.g., Cs and Ca, are largely absorbed in the alteration layer and so show about the same leach rate at 250 and 350°C. The autoclave leach rates at 250°C for most glasses are not much greater than the Soxhlet leach rates.

Soxhlet leach rates have been carried on for extended periods, see Figures 2 and 3. The leach rates of Cs, Na, and Mo stayed about the same or decreased a little with time while the rates of La, Sm, and Hf varied eratically. The leach rates of frit 127 ground glass, see Table V, did not change much with time in a Soxhlet apparatus, but did drop for a 70°C static leach. Here too La leach rates varied eratically. The leach rates of air quenched and annealed samples do not vary greatly.

Some frit 127 Ti-Mg and frit 128 glasses have been varied by replacing MgO with other alkaline earth oxides or CuO with other oxides on a mole basis. The substituted glasses had about the same leach rates as the original. Typical leach rates of Ba, Cd, and Zn from some of the substituted glasses are given in Table X.

The alumina waste glasses tested are quite leach resistant at 70°C, but rapidly alter at 250°C, see Table XI. The borophosphate glasses are completely altered by a three day 250°C leach. Improved alumina glasses are being developed.

Leach tests have been run on laboratory produced pellets. The pellets showed almost no physical alteration due to distilled water leaching, even at 250°C, but a considerable percentage of Na and Cs were leached from them, see Table XII.

Conclusions

A number of glasses for vitrifying zirconia and alumina waste calcines have been extensively leach tested. The glasses are highly leach resistant at 25 and 70°C, the temperatures expected for the glass waste canisters in a geological repository, and the zirconia glasses are still highly durable at 250°C. Ground glass has a lower leach rate, g/cm^2/day, than solid pieces. Leach rates tend to be higher in salt (WIPP) brine than in distilled water or granite equilibrated water. Ceramic pellets have also been studied; they show no physical alteration due to leaching but a considerable fraction of their Na and Cs leach out.

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TABLE I. TYPICAL COMPOSITION OF ICPP WASTE CALCINES

	Alumina Calcine Cooled 16 years	Zirconia Calcine Cooled 13 years
Al_2O_3	87%	16%
CaF_2	3.9%	44%
ZrO_2	--	22%
$NaNO_3$	4.4%	1.9%
HgO	1.8%	--
CaO	--	13%
KNO_3	1.0%	0.2%
B_2O_3	--	2.1%
Fission Products	0.3%	0.1%
30.17 yr ^{137}Cs	69 μg/g	22 μg/g
Plutonium	3.2 μg/g	3.2 μg/g
Neptunium	5.0 μg/g	1.1 μg/g
Americium	0.1 μg/g	0.25 μg/g

TABLE II. COMPOSITION OF SOME ICPP WASTE GLASSES

Frit composition wt%	127	128	127 Ti-Mg	335	271	283
SiO_2	70.4	72.8	64.3	45.3	19.8	16.6
B_2O_3	8.6	8.8	8.4	16.6	33.1	25.2
P_2O_5	--	--	--	--	26.0	36.7
Na_2O	12.7	6.7	10.5	6.1	11.3	11.7
Li_2O	6.2	9.5	5.1	5.9	5.4	5.7
TiO_2	--	--	8.9	12.7	--	--
CuO	2.1	2.2	--	4.5	4.4	4.1
MgO	--	--	2.8	--	--	--
CaO	--	--	--	8.9	--	--
Calcine Type	ZrO_2	ZrO_2	ZrO_2	Al_2O_3	Al_2O_3	Al_2O_3
wt% Calcine in glass	33	33	33[a]	25	26	28

[a]Also prepared glass with 17% ZrO_2 calcine, 17% Al_2O_3 calcine, 66% frit.

TABLE III. SYNTHETIC SALT BRINE COMPOSITION IN PARTS PER MILLION

Na^+	115000	Cl^-	175000
K^+	15	$SO_4^=$	3500
Mg^{++}	10	B	10
Ca^{++}	900	HCO_3^-	10
Fe^{3+}	2	Br^-	400
Sr^{++}	15	I^-	10
Rb^+	1		
Cs^+	1		

	pH	6.5
Density	g/cm^3	1.2

CLIMAX GRANITE EQUILIBRATED WATER COMPOSITION IN PARTS PER MILLION PARTIAL ANALYSIS

Na^+	1.3	Cl^-	0.045
Ca^{++}	8.2	PO_4^{3-}(a)	0.007
Sr^{++}	0.09	Br^-	0.006
Al^{3+}	0.2	NO_3^-	0.001
Si	1.8	$SO_4^=$	0.38
		F^-	0.19
		$CO_3^=$(a)	47

pH 6.9

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[a]All forms, phosphate mainly $H_2PO_4^-$ and $HPO_4^=$ carbonate mainly CO_2 and HCO_3^-.

TABLE IV

FISSIUM FOR GLASS SAMPLES

Element	10 yr D[illegible], ^{235}U Fis[illegible] yield %	Added as	Mol. wt.	Wt. added, g	Activity After 6 h in ATR @ 1×10^{13} n/cm^2 sec + 7 day decay d/s. mg f.p.
Se	0.39	SeO_2	110.96	0.216	13000 ^{75}Se
Rb	3.17	Rb_2CO_3	230.97	1..83	365000 ^{86}Rb
Sr	7.35	$SrCO_3$	147.64	5.43	1400 ^{85}Sr
Y	4.79	La_2O_3	-	-	--
Zr	32.12	ZrO_2	123.22	19.79	2200 ^{95}Zr
Mo	24.32	MoO_3	143.95	17.50	79000 ^{99}Mo
Tc	6.14	Ru	-	-	--
Ru	11.04	Ru	101.70	8.74	157000 ^{103}Ru
Rh	3.00	NiO	-	-	--
Pd	1.60	NiO	-	-	--
Ag to Sb	0.21	Sb	121.76	0.128	38000 ^{124}Sb
Te	2.13	TeO_2	159.61	1.700	1720 ^{123}Te
Cs	12.12	Cs_2CO_3	325.893	14.76	312000 ^{134}Cs
Ba	8.10	$BaCO_3$	197.37	7.99	3950 ^{131}Ba
La	6.55	La_2O_3	328.84	13.72	5.4×10^6 ^{140}La
Ce	12.91	CeO_2	172.13	10.49	105000 ^{141}Ce
Pr	5.50	La_2O_3	-	-	--
Nd	20.46	Nd_2O_3	336.54	20.64	170000 ^{147}Nd
Pm	0.15	Nd_2O_3	-	-	--
Sm	3.62	Nd_2O_3	-	-	--
Eu	0.30	Nd_2O_3	-	-	--
Ni	0.00	NiO	74.69	1.718	--
Br	0.14				
Kr	5.41				
I	0.93	volatile and lost, none added to fissium			
Xe	21.72				

TABLE V. ELEMENTAL LEACH RATES OF 127[a] ZIRCONIA WASTE GLASS IN DISTILLED WATER, -16+30 MESH

$g/cm^2/day$

Leach Temp., °C	25	70				95			
Test	Static	Static				Soxhlet			
Glass Treatment	Air Quench	Air Quench		Annealed		Air Quench		Annealed	
Leach Time	241 days	first 7 d	next 21 d	first 7 d	next 21 d	first 3 d	next 21 d	first 3 d	next 21 d
Weight Loss	(gain)	2.9 E-6*		1.8 E-6*		9.9 E-5*		8.7 E-5*	
Sodium	--	9.6 E-6	3.3 E-6	7.5 E-6	3.8 E-6	1.2 E-4	3.6 E-5	1.1 E-4	9.8 E-5
Molybdenum	7.5 E-9	4.8 E-6	2.8 E-6	3.4 E-6	2.8 E-6	9.6 E-5	2.7 E-5	7.1 E-5	6.4 E-5
Cesium	3.7 E-8	4.5 E-6	3.4 E-6	5.0 E-6	3.2 E-6	1.1 E-4	3.4 E-5	8.5 E-5	7.2 E-5
Lanthanum	3.8 E-9	3.2 E-8	4.6 E-8	2.7 E-8	2.7 E-8	6.0 E-7	1.7 E-6	8.4 E-8	3.3 E-7
Uranium	--	9.8 E-7	6.1 E-7	1.7 E-6	5.3 E-7	6.9 E-6	7.4 E-6	1.8 E-6	--

*Leached for 28 d at 70° or 14 d in Soxhlet.

[a]High fissium glass, ~7% fissium.

TABLE VI. THREE DAY 25°C STATIC LEACH RATES OF ACTIVATED FRIT 127 ZIRCONIA GLASS SHEETS

g/cm^2/day

	Distilled Water	Salt Brine	Granite Equilibrated Water
Molybdenum	4.4 E-6	3.2 E-6	4.5 E-6
Cesium	1.8 E-6	2.0 E-6	2.7 E-7
Lanthanum	8.6 E-7	2.6 E-6	2.0 E-7
Neptunium	4.4 E-6	2.8 E-6	4.1 E-6

TABLE VII. DISTILLED WATER LEACH RATES OF FRIT 127 ZIRCONIA WASTE GLASS FROM WEIGHT LOSS

g/cm^2/day

		Core Drilled Cylinder	Broken Piece	Ground Glass -16+30	Pt Remelt Cast Cylinder	Al_2O_3 Remelt Cast Cylinder
70° Static	28 d	1.30 E-5	1.17 E-5	2.00 E-6	1.37 E-5	1.33 E-5
95° Static	28 d	2.00 E-5	1.99 E-5	4.12 E-6	2.25 E-5	2.11 E-5
95° Soxhlet	14 d	3.95 E-4	3.08 E-4	1.00 E-4	6.30 E-4	4.97 E-4
250° Autoclave	3 d	7.79 E-4	8.37 E-4	--	6.77 E-4	5.38 E-4
350° Autoclave	3 d	1.17 E-2	9.41 E-3	--	8.69 E-3	

TABLE VIII. ELEMENTAL LEACH RATES OF 128 Ti GLASS CYLINDERS IN STATIC DISTILLED WATER

$g/cm^2/day$

	70°C 28 days	250°C 3 days	350°C 3 days
Lithium	6.9 E-6	5.2 E-4	1.1 E-2
Boron	6.0 E-6	2.9 E-4	4.3 E-2
Sodium	7.2 E-6	7.0 E-4	8.4 E-3
Silicon	5.9 E-6	1.4 E-3	2.8 E-3
Calcium	1.1 E-5	7.1 E-5	3.7 E-5
Strontium	7.0 E-6	--	7.6 E-5
Molybdenum	6.6 E-6	6.1 E-4	--
Cesium	5.6 E-6	1.1 E-3	3.0 E-4
Lanthanum	3.1 E-7	7.5 E-6	--
From weight loss	5.0 E-6	1.8 E-4	6.4 E-3

TABLE IX. ELEMENTAL LEACH RATES OF 127 Ti-Mg ZIRCONIA WASTE GLASS CYLINDERS IN DISTILLED WATER

$g/cm^2/day$

	Static Leach				Soxhlet
	70°C	95°C	250°C	350°C	95°C
	28 d	28 d	3 d	3 d	14 d
Lithium	--	--	7.2 E-4	9.1 E-3	2.1 E-4
Boron	--	--	9.6 E-4	1.8 E-2	6.4 E-4
Sodium	1.4 E-5	2.4 E-5	9.4 E-4	8.9 E-3	4.2 E-4
Aluminum	--	--	7.5 E-4	4.2 E-3	1.5 E-4
Silicon	--	--	1.0 E-3	4.4 E-3	4.4 E-4
Calcium	--	--	1.8 E-4	6.5 E-5	1.4 E-4
Molybdenum	8.4 E-6	2.2 E-5	1.6 E-3	--	3.6 E-4
Cesium	9.6 E-6	1.9 E-5	1.2 E-3	1.6 E-3	3.7 E-4
Barium	--	--	9.5 E-5	--	--
Lanthanum	6.0 E-8	2.6 E-7	5.5 E-6	1.7 E-5	1.8 E-6
Uranium	1.8 E-7	6.1 E-7	2.4 E-5	4.4 E-4	1.6 E-6
From weight loss	1.1 E-5	1.7 E-5	4.4 E-4	5.8 E-3	4.4 E-4

TABLE X. LEACH RATES OF SUBSTITUTED ZIRCONIA WASTE GLASS

$g/cm^2/day$

Basic Frit	Temp. °C	Barium	Cadmium	Zinc
128[a]	70	8.9 E-6	2.6 E-6	--
127Ti[b]	70	3.5 E-6	--	4.7 E-7
	95 Static	7.0 E-6	--	3.1 E-6
	95 Soxhlet	9.2 E-5	--	6.0 E-5
	250	1.4 E-5	--	3.6 E-4

[a]Frit contains 1.5 mol% oxide replacing CuO.

[b]Frit contains 4.0 mol% oxide replacing MgO.

TABLE XI. LEACH RATES OF AIR QUENCHED ALUMINA WASTE GLASS CYLINDERS

Frit	Leach Time days	Leach Temp. °C	Leach Rates, $g/cm^2/day$			
			Weight Loss	Sodium	Cesium	Lanthanum
335	28	70	1.3 E-5	2.4 E-5	2.2 E-5	2.9 E-6
	14	95[a]	4.2 E-4	4.1 E-4	3.5 E-4	1.7 E-5
	3	250	3.2 E-3	1.4 E-3	6.8 E-4	--
271	28	70	2.4 E-5	6.6 E-5	2.2 E-5	6.1 E-7
	14	95[a]	4.7 E-4	3.6 E-4	3.1 E-4	4.1 E-6
	3	250	Completely Disintegrated			
283	240	25	7.5 E-7	7.1 E-7	4.6 E-7	6.9 E-9
	32	70	2.7 E-5	5.1 E-5	2.6 E-5	3.7 E-7
	14	95[a]	2.1 E-4	--	--	--
	3	250	Completely Disintegrated			
127	29	70	6.5 E-6	1.5 E-5	1.1 E-5	2.3 E-7
Ti-Mg[b]	14	95[a]	1.2 E-4	2.0 E-4	1.1 E-4	1.4 E-6
	3	250	6.9 E-4	7.7 E-4	4.0 E-3	5.9 E-6

[a]Soxhlet leach

[b]Glass contained 66% frit, 17% ZrO_2 calcine, 17% Al_2O_3 calcine.

TABLE XII. DISTILLED WATER LEACH OF FIRED ALUMINA CALCINE PELLETS

PERCENT LEACHED

Temp., °C	25	95 Soxhlet	250
Time of leach, days	18	3	3
Weight loss dried at 250°C	1.06%	--	1.54%
Sodium	11.3%	11.6%	30.7%
Cesium	20.8%	16.9%	4.1%
Lanthanum	--	0.023%	0.0687%

Figure 1

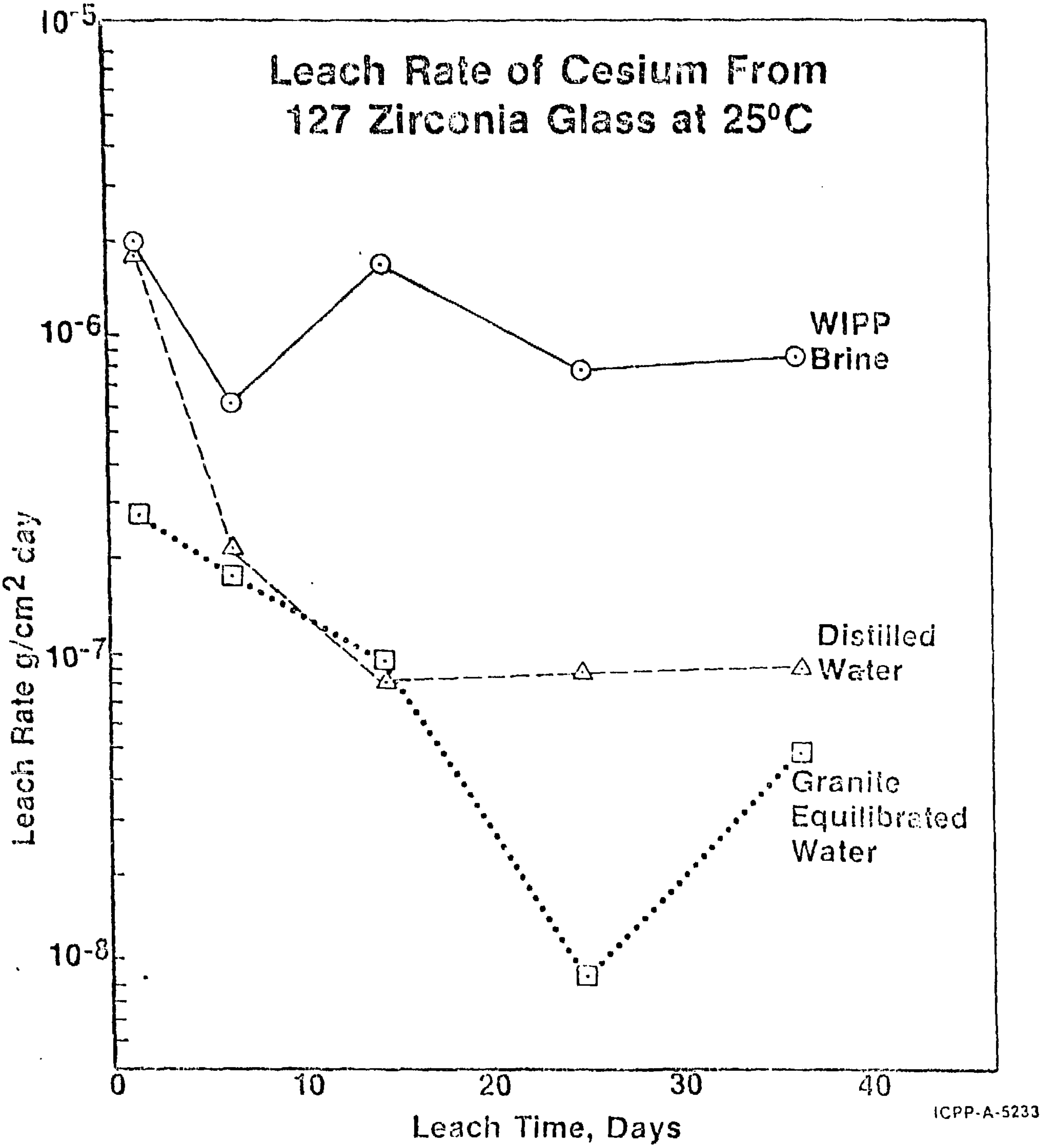

Leach Rate of Cesium From
127 Zirconia Glass at 25°C
WIPP
Brine
Distilled
Water
Granite
Equilibrated
Water
Leach Rate g/cm2 day
10-5
10-6
10-7
10-8
0
10
20
30
40
Leach Time, Days
ICPP-A-5233

Figure 2

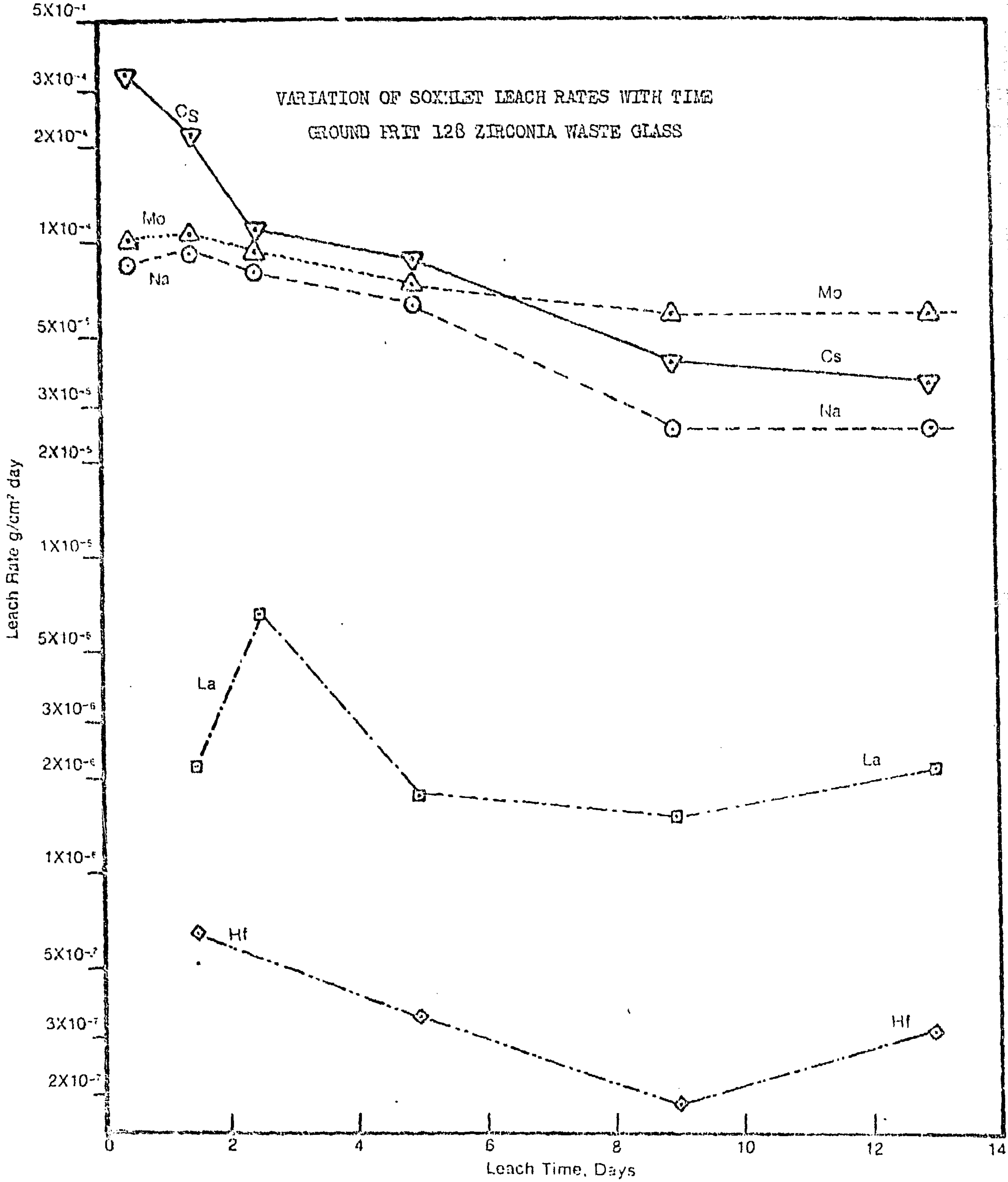
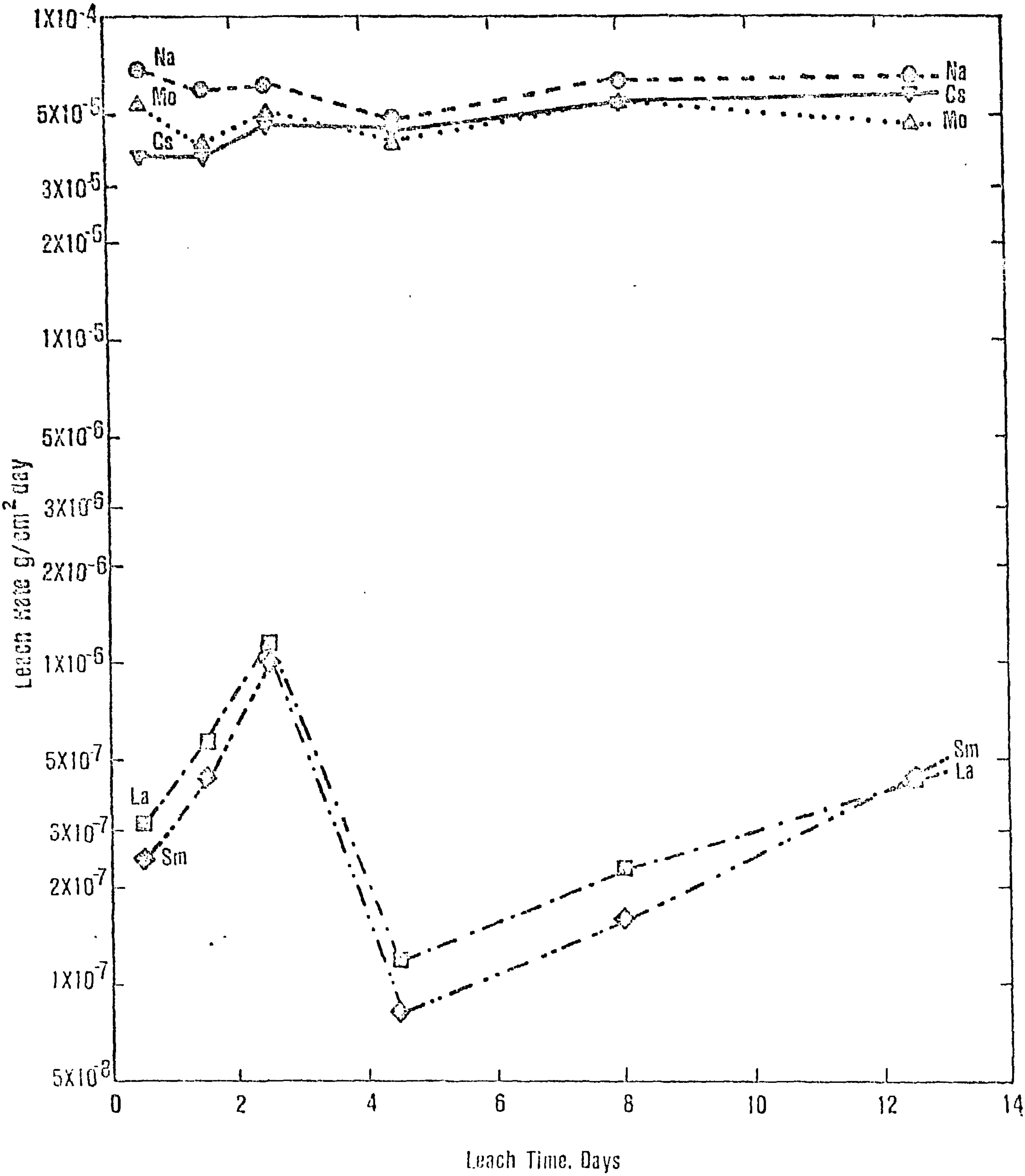

VARIATION OF SOXHLET LEACH RATES WITH TIME
GROUND FRIT 128 ZIRCONIA WASTE GLASS
Leach Rate g/cm² day
Leach Time, Days
5X10⁻⁴
3X10⁻⁴
2X10⁻⁴
1X10⁻⁴
5X10⁻⁵
3X10⁻⁵
2X10⁻⁵
1X10⁻⁵
5X10⁻⁶
3X10⁻⁶
2X10⁻⁶
1X10⁻⁶
5X10⁻⁷
3X10⁻⁷
2X10⁻⁷
0
2
4
6
8
10
12
14
Cs
Mo
Na
La
Hf

Figure 3

VARIATION OF SOXHLET LEACH RATE WITH TIME
GROUND FRIT 128 ZIRCONIA WASTE GLASS, 7% FISSIUM



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