Chemical Engineering Division

ANL-03/29

Static Leach Tests with the EBR-II Metallic Waste Form

by W. L. Ebert, M. A. Lewis, T. L. Barber, T. DiSanto, and S. G. Johnson

Argonne National Laboratory, Argonne, Illinois 60439
operated by The University of Chicago
for the United States Department of Energy under Contract W-31-109-Eng-38

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by

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September 2003

ACKNOWLEDGEMENTS

Insights regarding microstructure, corrosion behavior, and modeling approaches for the metallic waste form provided by T. H. Bauer, D. D. Keiser, Jr., and S. M. McDeavitt are gratefully acknowledged. Solution analyses were performed by S. Lopykinski and Y. Tsai at ANL-E and by J. Giglio and M. Noy at ANL-W. The metallic waste form ingot was provided for testing by S. M. McDeavitt. Test specimens were cut from the ingot and prepared for testing at ANL-E Central Shops. This work is supported by the U.S. Department of Energy, Office of Nuclear Engineering, Science and Technology under contract W-31-109-Eng-38.

ACRONYMS

ANL	Argonne National Laboratory
ANL-E	Argonne National Laboratory-East (Illinois)
ANL-W	Argonne National Laboratory-West (Idaho)
ASTM	American Society for Testing and Materials (ASTM International)
BSC	Bechtel SAIC Company
CWF	Ceramic Waste Form
DWPF	Defense Waste Processing Facility
EBR-II	Experimental Breeder Reactor-II
HLW	High-Level Radioactive Waste
ICP-AES	Inductively Coupled Plasma-Atomic Emission Spectroscopy
ICP-MS	Inductively Coupled Plasma-Mass Spectrometry
INEEL	Idaho National Engineering and Environmental Laboratory
MCC-1	Material Characterization Center-Static Leach Test Number 1
MWF	Metallic Waste Form
NL(*i*)	Normalized Elemental Mass Loss (based on element *i*)
NR(*i*)	Normalized Dissolution Rate (based on element *i*)
OCRWM	DOE Office of Civilian Radioactive Waste Management
PCT	Product Consistency Test
S/V	Solid Surface Area-to-Solution Volume Ratio
TSPA	Total System Performance Assessment
WASRD	Waste Acceptance System Requirements Document
WTP	(Hanford) Waste Treatment and Immobilization Plant
WVDP	West Valley Demonstration Project

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ABSTRACT

A metallic waste form (MWF) will be used to immobilize contaminated cladding hulls recovered after electrometallurgical treatment of spent sodium-bonded nuclear fuel from the Experimental Breeder Reactor-II (EBR-II). Tests were conducted to determine if the high-level waste (HLW) glass degradation model developed for total system performance assessment (TSPA) calculations for the Yucca Mountain repository system can be used to represent the degradation of disposed MWF. Static tests were conducted at 50, 70, and 90ºC with monolithic samples of MWF in pH buffer solutions spiked with NaCl at a MWF surface-to-solution volume ratio of about 200 m^{-1}. Test specimens were prepared from a surrogate MWF ingot containing about 10 mass% U. Solutions were exchanged after 14, 28, and 70 days. The cumulative amount of U released into solution through 70 days was used to calculate the MWF degradation rate for each test condition. The rate was independent of temperature. The rate was highest in acidic solutions, lowest in neutral solutions, and intermediate in alkaline solutions. The uranium release rate from a breached canister, which is the product of the MWF degradation rate and the surface area of two MWF ingots in a canister, was compared with the release rate calculated with the HLW glass degradation model for a glass log at the same temperature and pH values. The uranium release rates measured for MWF are less than the degradation rates calculated for HLW glass (compared on a mass per time basis).

EXECUTIVE SUMMARY

A metallic waste form (MWF) will be used to immobilize contaminated cladding hulls recovered after electrometallurgical treatment of spent sodium-bonded nuclear fuel rods from the Experimental Breader Reactor-II (EBR-II). The MWF must be qualified for disposal in the Yucca Mountain repository as high-level radioactive waste. Work is in progress to generate laboratory data that show the MWF meets acceptance requirements for HLW waste forms. In this report, we discuss the results of laboratory tests that were conducted to determine if the model that will be used in total system performance assessment (TSPA) calculations to account for the release of radionuclides during the degradation of high-level waste (HLW) glass can be used to account for the release of radionuclides during degradation of the MWF. Tests were conducted to directly compare the rates at which U is released from the MWF at various temperatures and pH values with the rates calculated using the HLW glass degradation model at the same temperature and pH. The release rate of U is used to represent the release rates of all other radionuclides from the MWF. Test conditions were selected to measure the uranium release rate from the MWF when the rate-slowing effects of both solution feedback and the formation of a passivating oxide layer are small.

Static tests were conducted at 50, 70, and 90°C with monolithic MWF samples in pH buffer solutions with nominal values of pH 3, 4, 6, 8, 9, 10, and 12 at a MWF surface area-to-solution volume ratio of about 200 m^{-1}. Test specimens were cut from a surrogate MWF ingot containing about 15 mass% Zr and 10 mass% U. Because chloride ions are known to promote MWF degradation, 1,000 ppm Cl^- was added to each buffer solution to simulate the dissolution of halite (NaCl) from ceramic waste forms that will be co-disposed with the MWF. This is estimated to be the highest chloride concentration in a breached co-disposal canister. Tests were interrupted after 14 and 28 days to replace the solutions with fresh leachant. This was done to maintain (1) low concentrations of dissolved components, (2) a nearly constant pH, and (3) a nearly constant concentration of dissolved oxygen. The test solutions collected during each exchange were analyzed for Cr, Fe, Mn, Mo, Ni, U, and Zr. The cumulative release of U through 70 days was used to calculate the average degradation rate for comparison with the rate from the HLW glass degradation model. The three samplings indicated that the degradation rate decrease slightly with time; this is probably due to passivation of the surface. Temperature had no apparent effect on the measured MWF degradation rates, which indicates the rate-controlling step is not a thermally activated process. The highest rates were measured in acidic solutions (<pH6) and the lowest rates were measured in near-neutral solutions (pH 6 and pH 8).

Supplemental tests were conducted at 50ºC with pH 4, 8, 9, 10, and 12 buffers spiked with 10,000 ppm Cl^- and with buffers without added NaCl to measure the effect of the chlorine concentration on the U release rate. Those test results confirmed that the addition of 1,000 ppm Cl^- adequately represents the possible effects of dissolved halite on the MWF degradation rate. Higher degradation rates were measured in tests with leachants having added NaCl than in tests without added NaCl.

The degradation rates were calculated for each test condition as the product of the specific dissolution rates measured in the experiments with 1,000 ppm Cl^- and the geometric surface area of two MWF ingots in a breeched canister (about 0.76 m^2). These were compared directly with

the TSPA HLW degradation rate model. During execution, the TSPA HLW degradation rate model will select parameter values from ranges to calculate the degradation rate and the exposed glass surface area. The range in rates accounts for variance in the compositions of the glasses and the water exposure conditions. The range in surface area accounts for variance in the extent of cracking, access of water to tight cracks, and lower reactivity in tight cracks. Comparison to the HLW glass degradation model was done using the minimum glass surface area considered in the HLW glass degradation model, which is about 30 m^2, and the range of possible glass dissolution rates at 20ºC. This is near the lowest possible repository temperature and provides the most conservative comparison with the MWF degradation rate since the latter does not depend on temperature. It was found that the range of HLW glass degradation model rates at 20ºC bracket the degradation rates measured for the MWF at all pH values and temperatures.

These test results support the approach of using the HLW glass degradation model to represent MWF degradation for the purpose of the repository system performance assessment. The radionuclide inventory in the EBR-II waste forms is included in the overall average inventory for HLW that will be used as the inventory in HLW glass for TSPA calculations. The results summarized in this report will be combined with other test data for the MWF and CWF waste forms to present the argument that the performance of the MWF (and CWF) does not have to be modeled explicitly in TSPA calculations.

1. INTRODUCTION

Waste forms have been developed at Argonne National Laboratory (ANL) to immobilize two waste streams generated during electrometallurgical treatment of spent sodium-bonded nuclear fuel from the Experimental Breeder Reactor-II (EBR-II). The electrorefining process separates components of the spent fuel into recovered uranium and two high-level radioactive waste streams of salt and metals. Salt wastes contain the LiCl-KCl salt electrolyte used in the electrorefiner and radionuclides that were oxidized to form chloride salts, including transuranic actinides (e.g., Pu, Np, and Am), active fission products (e.g., Cs, Sr, and I), and rare earth element fission products (e.g., Ce, Nd, and Pr). The salt waste will be immobilized in a glass-bonded sodalite ceramic waste form (CWF). The other waste stream contains metallic constituents that are inert to the electrochemical treatment process, which are primarily irradiated stainless steel and Zircaloy cladding hulls plus residual zirconium from driver fuel rods. Stainless steel cladding will account for more than 90% of the metal waste stream generated from the EBR-II inventory. The metallic waste stream will be immobilized in the metallic waste form (MWF). The MWF will be made by melting the metal waste stream in a casting furnace with added zirconium and depleted uranium. The zirconium and uranium are added to alloy radionuclides within the waste form, and the amounts of each are controlled to produce waste forms with consistent compositions, phase assemblages, and microstructures. Laboratory-scale samples of many alloy compositions were generated and tested to select the optimum alloy composition and processing temperature for MWF production [1, 2]. An alloy with 15 mass% Zr and 10 mass% U was selected as the target for the MWF, with control limits of 5 to 20 mass% Zr and 0 to 11 mass% U. A simple eutectic microstructure occurs over this composition range. The MWF is composed of the Fe solid solution phases ferrite and austenite and the Laves intermetallic $Zr(Fe,Cr,Ni)_{2+x}$ phase. Actinides and noble metal fission products reside primarily in the intermetallic phase; Mo and Tc are distributed between the two phases.

The MWF must be qualified for disposal in the federal high-level radioactive waste disposal system as a non-standard high-level waste (HLW) form. (Borosilicate glass is the standard HLW waste form.) Laboratory tests and analyses have been in progress for several years to develop a data base to support qualification of the MWF for disposal. Two sources have provided guidance for qualification testing. The first is the Waste Acceptance System Requirements document (WASRD), which "establishes waste acceptance technical requirements for the U.S. Department of Energy's (DOE) Civilian Radioactive Waste Management System (CRWMS)" and lists "acceptance criteria imposed by the CRWMS on spent nuclear fuel and high-level waste delivered into the CRWMS" [3, Section 1.1]. The second source of guidance is the collection of models that will be used in Total System Performance Assessment (TSPA) calculations to be conducted by Bechtel SAIC Company (BSC) under the auspices of the DOE Office of Civilian Radioactive Waste Management (OCRWM). Those calculations will be used as part of the Yucca Mountain repository license application to show that the combined performance of the waste forms, engineered system, and host geology will meet regulatory containment requirements. The objective of many requirements in the WASRD is to assure that the integrated repository system meets safety and regulatory requirements, as will be demonstrated using TSPA calculations. The requirements in the WASRD have evolved as the design of the engineered repository and TSPA models have matured. For example, the current version of the WASRD (revision 04) is much less prescriptive than earlier versions.

The objective of this report is to show that the impact of disposed MWF on dose does not need to be calculated explicitly in TSPA calculations, and that the HLW glass degradation model can be used to represent the degradation rate of MWF. In TSPA calculations, the release of radionuclides from a HLW glass waste form is calculated as the product of three terms: the specific dissolution rate of the glass (that is, the rate expressed as mass glass dissolved per unit surface area per unit time), the exposed surface area of glass, and the radionuclide inventory in the glass (e.g., as curies per gram of glass) [4]. Use of the HLW glass degradation model to represent MWF is evaluated by comparing these three terms for HLW glass and MWF.

Radionuclide Inventory: The TSPA calculations will not distinguish either the radionuclide inventories or compositions of different HLW waste forms. A range of HLW glass compositions will be made at DOE facilities at the Waste Valley Demonstration Plant (WVDP), the Defense Waste Processing Facility (DWPF), and the Hanford Waste Treatment and Immobilization Plant (WTP). [High-level wastes at the Idaho Engineering and Environmental Laboratory (INEEL) may also be vitrified.] Variations in the tank waste compositions will result in glasses with different matrix compositions and different inventories being produced at these different facilities. An average radionuclide inventory will be assumed for all HLW waste forms [5]. The same inventory identified in the Final Environmental Impact Statement for Yucca Mountain will be used for TSPA calculations. That inventory is based on projected HLW inventories from WVDP, DWPF, Hanford WTP, and INEEL, *plus the EBR-II inventory*. That is, waste to be immobilized in CWF and MWF is already included in the radionuclide inventory for HLW glass that will be used in TSPA calculations. Since the same inventory is used to calculate radionuclide release, this term is the same for HLW glass and the MWF.

Exposed Surface Area: The surface area of HLW glasses that will be used in TSPA calculations is based on the dimensions of the glass pour canisters, the fill volume, and a cracking factor based on analyses of thermally and impact-cracked glass. The geometric surface area of a HLW glass log in the pour canister will be about 8.5 m^2 for the long (4.5 m) canisters of Hanford glass and about 4.8 m^2, for the short (3 m) canisters of DWPF and WVDP glass. Assuming 66% of the disposed canisters are long canisters and 34% of the disposed canisters are short canisters, the average geometric surface area of glass in a canister will be

$$S = (0.66 \times 8.5\ m^2) + (0.34 \times 4.8\ m^2) = 7.2\ m^2 \qquad (1)$$

Thermal and impact cracking will increase the surface area of glass available for reaction, although glass within tight cracks may not be accessible to water and will not be as reactive as glass at the surface. The HLW glass degradation model assumes the exposed surface area of glass will be at least 4 times and at most 17 times the geometric surface area (28.8 and 122 m^2 respectively), with an increase of 4 times the geometric surface area being most probable. For the purpose of comparison with the MWF, the exposed surface area of an HLW glass log is taken to be 30 m^2.

The MWF ingots will be cast as ingots with a right square cylinder geometry 14 to16 inches in diameter and 2 to 5 inches thick. One or two MWF ingots will likely be co-disposed with two ceramic waste form monoliths in a disposal canister. The MWF ingots are not expected to fracture due to cooling or impact, so the geometric surface area represents the maximum

surface area that can be exposed to water. The surface area of a representative ingot 16 inches (40 cm) in diameter and 4 inches (10 cm) thick is about 0.38 m^2. The exposed surface area of two MWF ingots in a breached canister is about 0.76 m^2, which is only about 2.5% that of HLW glass.

Specific Glass Degradation Rate: The key issue for using the HLW glass degradation model to represent degradation of the MWF is the relative radionuclide release rates. The release rates of all radionuclides from HLW glass are modeled in TSPA calculations to be the same as the glass degradation rate. (Note that the term *degradation* refers to the breakdown of the waste form matrix due to interaction with water vapor, dripping water, or water. Degradation and release of radionuclides from the waste form can occur without the radionuclides dissolving and being transported away from the waste form. In the TSPA calculations, transport is modeled separately from waste form degradation. The HLW glass degradation model addresses only the release of radionuclides from the glass matrix.) To compare the release of radionuclides from the MWF with the HLW glass degradation model, it is necessary to consider the mechanism behind the HLW glass degradation model, its role in TSPA calculations, its experimental basis, and how the calculated rate depends on conditions in a breached waste package in the repository.

1.1 SUMMARY OF HLW GLASS DEGRADATION MODEL FOR TSPA

The HLW glass degradation model that will be used in TSPA calculations is a simplification of a mechanistically based rate expression that has been used to model borosilicate waste glasses for about 20 years. It is based on an expression that was originally developed for the dissolution of aluminosilicate minerals using non-equilibrium thermodynamics to model hydrolysis of an Si-O bond at the surface [6]. That expression was simplified and adapted for application to glass dissolution [7]. The mechanistic rate expression includes four key terms: a rate coefficient that depends on the composition of the dissolving solid, a term for pH dependence, a term for temperature dependence, and a term for the chemical affinity. The expression was further simplified for use in TSPA by combining the rate coefficient and chemical affinity terms into a single parameter that is referred to as the effective rate coefficient, k_E [4]. Separate sets of parameter values were determined for glass degradation in acidic and alkaline solutions. This is because the rate-controlling step for glass dissolution in alkaline solutions is hydrolysis of an Si-O bond, whereas the rate-controlling step for glass dissolution in acidic solutions is hydrolysis of an Al-O bond. The same rate expression is used for both reactions but with different parameter values. Values of the parameters for the pH and temperature dependence were determined from tests with a glass representing DWPF waste glasses under conditions in which the chemical affinity term (and the effective rate coefficient) remained constant. The temperature and pH dependencies are not very sensitive to glass composition, and the same set of values is used for all HLW glasses.

The same expression is used to model HLW glass degradation of HLW glass exposed to humid air, dripping water, and immersed in water. A range of k_E values is used to account for the ranges of HLW glass compositions and water exposure conditions likely to occur in the repository. The k_E values for acidic and alkaline solutions were determined by calibrating the model with glass degradation rates measured using tests that simulate the range of water-contact conditions. The maximum values of the rate coefficient were determined from the results of tests

in which glasses were immersed in water. The minimum values were determined from the results of tests in which glasses were exposed to saturated water vapor or contacted by dripping water. In the TSPA calculations, the value of the rate coefficient will be selected from a triangular probability distribution that accounts for the range of water contact scenarios in the disposal system. Because contact by humid air is the most likely scenario in the repository, the minimum value of the rate coefficient is assigned the highest probability in the distribution and the maximum value of the rate coefficient is assigned the lowest probability. The rates measured for the MWF are compared with the HLW glass degradation rates ($rate_G$) calculated using the maximum values of the rate coefficients for acidic and alkaline solutions. The maximum specific degradation rates from the HLW glass model at particular temperature and pH values are calculated using Eq. 2 for acidic solutions and Eq. 3 for alkaline solutions [4]:

$$rate_G,\ g/(m^2 \bullet d) = k_E \bullet 10^{-0.49\ pH} \bullet \exp(-31\ kJ/mol) / RT) \quad (2)$$

$$rate_G,\ g/(m^2 \bullet d) = k_E \bullet 10^{0.49\ pH} \bullet \exp(-69\ kJ/mol) / RT) \quad (3)$$

where $rate_G$ is the specific degradation rate, k_E is the rate coefficient, the pH is measured at room temperature, $R = 8.314 \times 10^{-3}$ kJ/(mol•K) is the gas constant, and T is the absolute temperature. The values -0.49 and 0.49 are the pH dependence parameters, and the values 31 and 69 kJ/mol are the temperature dependence parameters for dissolution in acidic and alkaline solutions, respectively. Limiting values of k_E were determined by solving Eqns. 2 and 3 for rates measured in tests with glass exposed to humid air, dripping water, and immersed in water. The maximum values of k_E are 1.15×10^7 g/(m^2•d) in acidic solutions and 3.47×10^4 g/(m^2•d) in alkaline solutions. The minimum values of k_E are 8.41×10^3 g/(m^2•d) for acidic solutions and 28.2 g/(m^2•d) for alkaline solutions. The higher of the rates that are calculated by using Eqns. 2 and 3 at a particular temperature and pH value is used for TSPA calculations.

The release of boron into solution provides the best single measure of the degradation rate of the glass matrix because boron is not solubility-limited and is not incorporated into alteration phases. The release rates of other glass components into solution as the glass degrades, including most radionuclides, are lower than that of boron due, in part, to solubility limitations or sequestration into alteration phases. Most parameter values in the HLW glass degradation model were determined based on the release rates of boron measured in laboratory tests. The minimum value of k_E for alkaline solutions was determined from the alteration layer thickness measured in vapor hydration tests. The effects of solubility, sorption, colloid formation, etc. on radionuclide transport will be taken into account using other models in TSPA.

1.2 APPROACH FOR MWF

The glass degradation model can be used to account for the MWF degradation by using the degradation rate calculated for HLW glass at a particular temperature and pH as the degradation rate of the MWF under those same conditions. We recommend this approach because only a very small fraction of waste packages disposed in the repository (less than 1%) will contain MWFs, and a separate MWF degradation model in TSPA calculations is not justified. Nevertheless, the release of radionuclides from all waste forms must be taken into account in TSPA calculations because waste form containers will be randomly selected for

premature failure and degradation in the simulations. It is possible that a container with MWF will be simulated to fail in TSPA calculations. Therefore, it is important to verify that the performance of the MWF is adequately represented by HLW glass.

Laboratory tests were conducted to measure the dissolution rates of a reference MWF over a range of pH and temperature values for comparison with the rates calculated using the HLW glass degradation model. The test conditions were selected so that the dissolution rates of the MWF samples were measured under conditions relevant to those represented by the HLW glass model. The dissolution rate of borosilicate glasses is sensitive to the concentration of dissolved silica in the solution contacting it, and decreases as the concentration of dissolved silica increases until an apparent solubility limit is reached. Glass is thermodynamically unstable and a true equilibrium with solution cannot be attained. The apparent solubility limit represents a kinetic limit where the dissolution rate is immeasurably low. The glass dissolution rate is not an explicit function of time; rather, the effect of time on the glass degradation rate is through the buildup of dissolved silica that occurs over time.

Unlike HLW glasses, degradation of the MWF and the release of uranium are not significantly affected by feedback effects of dissolved MWF components, and the solid surface area-to-solution volume (S/V) ratio of the test is not expected to affect the MWF degradation rate. However, the MWF degradation rate *is* expected to change over time due to the formation of a passivating oxide layer as the waste form corrodes. Radionuclides in the MWF are alloyed in either the stainless steel or intermetallic phase. In tests with the MWF, the release of uranium is used to represent the release of all radionuclides. This is because the uranium content in the MWF is high enough that solution concentrations are readily measurable and provide a direct measure of radionuclide release. Although uranium is present only in the intermetallic phase, tests have shown it to be released faster than technetium [8], which is present in both the intermetallic and steel phases.

1.3 SELECTION OF TEST CONDITIONS

The test conditions used to measure the degradation rate of the MWF were selected to represent the same conditions used to determine the maximum values of k_E for the HLW glass degradation model. Alkaline solutions are generated due to dealkalization reactions that occur at the glass surface as it dissolves. The maximum value of k_E used in the HLW glass degradation model for alkaline solutions was determined using the results of product consistency tests (PCTs) conducted with a range of glass compositions. The PCT is conducted for seven days with crushed glass in demineralized water at a glass-to-water mass ratio of 1:10 [9]. Most HLW glasses have densities near 2.7 g/cm^3, so these conditions result in an S/V ratio of about 2000 m^{-1}. Solution feedback effects (due primarily to silica) are significant under these test conditions. This S/V ratio is equivalent to a 0.5-mm-thick film of water covering the surface of a waste glass, which is reasonable representation of the amount of water that could contact waste glass in a breached waste package when the primary mode for water penetration is condensation of humid air. The solution feedback that occurs in a 7-day PCT is similar to that expected over long disposal times as glass dissolved into a surface film of water. In addition, the WASRD requires that the chemical durability of a glass as measured with a 7-day PCT exceeds that of a benchmark glass.

Acidic solutions will result in a breached waste package due to reactions other than glass degradation, such as the corrosion of metal components and radiolysis. Glass dissolution will neutralize the acid and drive the solution toward alkaline pH values. The maximum value of k_E used in the HLW glass degradation model for acidic solutions was determined using the results of tests following the Material Characterization Center Static Leach Test number 1 (MCC-1) procedure, which has been standardized by the American Society for Testing and Materials (ASTM) International as method C1220 [10]. The MCC-1 tests were conducted with monolithic specimens in pH buffer solutions at an S/V ratio of about 10 m^{-1}. The solution volume was large enough that feedback effects of dissolved glass components (particularly silica) were insignificant in short-term tests. These tests excluded feedback effects that may lower the dissolution rate, and provide a conservative maximum rate over long disposal times.

The response of the MWF in PCT is too low for that test to be useful for either monitoring the consistency of MWF products or measuring the uranium release rate [11]. Instead, MCC-1 tests were conducted and related to PCTs with glass by scaling with the product of the S/V ratio and the reaction time. For HLW glasses, the test solutions (and the extent of glass reaction) will be similar in tests conducted for similar [(S/V) •t] if the solution pH does not change significantly. Tests with MWF were conducted at an S/V ratio of 200 m^{-1} for a total of 70 days. Using these conditions, the tests with MWF and PCT with HLW glass are conducted at the same product of the S/V ratio and the test duration [(S/V) •t], namely, 14,000 d/m.

Whereas the extent of HLW glass degradation is affected by the buildup of silica in the solution, the extent of MWF degradation is affected by the formation of a surface oxide layer. The solution was replaced with fresh leachant after 14 and 28 days of reaction. Replacing the solution is not expected to impact the MWF degradation rate or generation of the oxide layer. However, analysis of the solutions after 14, 28, and 70 days provides an indication of whether formation of the layer is affecting the degradation rate at each test condition. About 60 mL of air was present within the test vessel. The consumption of oxygen during MWF corrosion is presumed not to limit the degradation rate because the oxygen concentration in solution is rapidly replenished from the air in the vessel and the air was refreshed during the 14- and 28-day exchanges.

It is expected that all MWFs will be co-disposed with CWF. The majority of canisters with EBR-II wastes will contain only CWF. Initial contact of the CWF by water will result in dissolution of halite (NaCl) inclusions at the outer surface. Corrosion of steel (and the MWF) is known to be promoted by the presence of dissolved chloride. The buffer solutions used in the tests with the MWF were spiked with 1000 ppm Cl^- to account for the impact of dissolved halite on the release of radionuclides from the MWF. Although the dependence of the MWF dissolution rate on chloride concentration is not taken into account directly by using the HLW glass model, as discussed above, the addition of 1000 ppm Cl^- to the test leachants (buffer solutions) provides a realistic upper bound to the Cl^- concentration that can occur in a breached waste package. In this way, the effect of Cl^- is taken into account through the measured MWF degradation rate that is compared with the rates from the HLW glass degradation model. Several tests were conducted at 50ºC in leachants spiked with 10,000 ppm Cl^- and in leachants without added NaCl to measure the sensitivity of the MWF degradation rate to the Cl^- concentration under these test conditions.

Because tests were conducted in Teflon vessels, the MWF specimens were electrically isolated during the tests. One test was conducted in a titanium-lined Type 304L stainless steel vessel to measure the effect of electrically grounding the MWF: test number 9-10k/Ti was conducted at 50ºC in pH 9 leachant with 10,000 ppm Cl^-. The effect of grounding was evaluated by directly comparing the responses of tests conducted in Teflon and steel vessels.

2. EXPERIMENTAL

The same procedures were followed for tests conducted at ANL-E and ANL-W, except for the few minor differences that are noted below. The pH buffer solutions and Teflon test vessels used at ANL-E and ANL-W were obtained from the same suppliers. All test coupons were cut from the same MWF ingot and prepared as a single lot. Coupons were cut from the MWF ingot and polished at ANL-E. A final polish of all test coupons was performed at ANL-W. Details regarding the coupons, leachant solutions, and test procedure are given below.

2.1 MWF MATERIAL USED IN TESTING

An ingot of MWF identified as SS15ZR-29 was used for testing. That ingot contained about 10 mass% U and 15 mass% Zr, which are the target concentrations for MWF products. Chemical analysis was conducted using three sets of triplicate samples taken from different locations in the ingot. The samples were dissolved in mineral acids and the resulting solutions were analyzed with inductively coupled plasma-atomic emission spectroscopy (ICP-AES). Results are summarized in Table 1 for the measured compositions and for the normalized mass fractions. The normalized mass fractions were calculated by dividing the measured elemental mass percent of each element by the total measured mass percent of all elements, then dividing by 100. The mean values of the normalized mass fractions were used to calculate the degradation rate.

Table 1. Results of Replicate Composition Analyses of Ingot SS15ZR-29

Sample	Cr	Fe	Mn	Mo	Ni	U	Zr	Total
Measured Composition, in elemental mass %								
A1	12.5	51.4	0.91	1.62	7.72	9.95	14.1	98.20
A3	11.8	48.6	0.86	1.53	7.24	9.25	18.3	97.58
A5	12.4	50.6	0.90	1.62	7.66	9.95	14.0	97.13
B1	12.4	50.9	0.92	1.59	7.71	9.92	14.5	97.94
B3	12.5	50.9	0.91	1.62	7.66	9.32	14.6	97.51
B5	12.3	50.7	0.92	1.61	7.74	9.81	14.7	97.78
C1	12.4	50.6	0.91	1.58	7.71	10.1	13.6	96.90
C3	12.4	50.1	0.89	1.67	7.24	7.01	16.4	95.71
C5	12.3	49.9	0.89	1.56	7.44	9.97	15.6	97.66
Normalized Elemental Mass Fraction								
A1	0.127	0.523	0.00927	0.0165	0.0786	0.101	0.144	1.00
A3	0.121	0.498	0.00881	0.0157	0.0742	0.095	0.188	1.00
A5	0.128	0.521	0.00927	0.0167	0.0789	0.102	0.144	1.00
B1	0.127	0.520	0.00939	0.0162	0.0787	0.101	0.148	1.00
B3	0.128	0.522	0.00933	0.0166	0.0786	0.096	0.150	1.00
B5	0.126	0.519	0.00941	0.0165	0.0792	0.100	0.150	1.00
C1	0.128	0.522	0.00939	0.0163	0.0796	0.104	0.140	1.00
C3	0.130	0.523	0.00930	0.0174	0.0756	0.073	0.171	1.00
C5	0.126	0.511	0.00911	0.0160	0.0762	0.102	0.160	1.00
Mean:	0.127	0.518	0.00925	0.0164	0.0777	0.0973	0.155	1.00
Std. Dev.	0.00245	0.00830	0.000189	0.00050	0.00188	0.00953	0.01545	

Test specimens were prepared by saw-cutting a piece of the cast ingot into wafers having dimensions of about 1.5 cm x 1.5 cm x 0.2 cm and preparing the surfaces with a 20-μm surface finish. All sample faces were then polished to a final 600-grit finish using abrasive paper. The sample dimensions were measured with calipers and the surface areas calculated geometrically. Visual inspection showed the presence of voids on the surfaces of some specimens. Specimens with few or no visible voids were selected for testing. Small differences in the exposed surface area due to voids and variability in the fractions of each phase that are exposed in different samples will contribute to the scatter in the test results. The effect of sample inhomogeneity can be significant in tests with relatively small exposed sample surface areas such as those discussed in this report. Replicate tests provide insight into the impact of sample variability. However, the variabilities in the test specimens are assumed to represent the variability of the surface of a waste form.

2.2 LEACHANT SOLUTIONS

Commercial pH buffers used to calibrate pH electrodes were used as leachants for these tests. These are fairly dilute solutions with small buffer capacities. These were used to impose an initial pH without interfering in the corrosion reactions or complexing released elements. Degradation of the MWF was not expected to affect the solution pH significantly. Buffers were selected to span the range from about pH 3 to pH 12, which is the range of pH values modeled for water in a breached waste package containing HLW glass. The low end of the range is due to corrosion of carbon steel internal components of the waste package and the high end of the range is due to corrosion of HLW glass. The maximum pH value in a breached waste package with CWF and MWF will not be as high as in a waste package with HLW glass. Tests were conducted over the range pH 3 to pH 12 to demonstrate that the MWF degradation rate was bounded by the HLW glass degradation model under all conditions that could be modeled.

Reagent-grade NaCl was added to the pH buffers to simulate the dissolution of halite from CWF that is co-disposed with the MWF. The amount of NaCl added was based on consideration of the maximum concentration that could contact the MWF in a 24-inch canister with two CWF products and one MWF product. The highest possible chloride ion concentration will be attained when water enters a breached canister, contacts the CWF to dissolve all the halite present over the entire surface, then collects at the bottom of the canister. The configuration used to calculate the maximum NaCl concentration was that of a DOE 24S co-disposal canister with an inner diameter of 22 inches laying horizontally with two CWF products (20-inch outer diameter) and MWF product (16-inch outer diameter) located concentrically with respect to each other and centered in the canister. The volume of water needed to fill the bottom of the canister to the minimum level contacting the MWF was calculated for two geometric configurations. The first configuration represents a co-disposal canister in which the internal supports remain intact and the CWF and MWF monoliths remain fixed in their original geometry. The second configuration represents a co-disposal canister in which the internal supports have failed. The CWF monoliths rest on the bottom of the canister and the MWF monolith remains concentric with the CWF. These configurations are shown in Fig. 1. Note that both the CWF and MWF will be placed in steel cans (liners) after manufacture and that these cans will be loaded into the canister. These cans are ignored in these volume calculations.

Likewise, the volume at the ends of the canister and the volume occupied by the waste form support structure were ignored. About 13 and 0.9 L of water, respectively, are required to fill the bottoms of canisters with intact and collapsed waste forms and contact the bottom surface of the MWF.

The amount of halite (NaCl) at the surface of the CWF available to be dissolved was calculated using the results of laboratory tests. Tests conducted with crushed CWF were used to estimate the surface halite rather than tests conducted with monolithic samples because some halite was probably lost from the surface during preparation of monolith samples. Laboratory tests in which various amounts of -100 +200 mesh crushed CWF were contacted by water at a 1:10 CWF-to-water mass ratio resulted in solution concentrations of about 330 mg/L Cl^- [12; see Table 13]. The specific surface area of that size fraction of crushed CWF is about 0.023 m^2/g, so about 140 mg Cl^- (in halite) per m^2 was dissolved. Halite exposed at the sample surface dissolves immediately when the CWF is contacted by water, whereas halite in the bulk CWF does not dissolve until the matrix degrades enough to expose the halite inclusions to water. This is reflected in laboratory tests where the release of Cl^- occurs rapidly when CWF is first contacted by water and halite exposed at the surface dissolves, but the release of Cl^- occurs slowly as the bulk CWF dissolves [12; see Figures 17 c and d]. The dissolution of halite at the CWF surface will be the dominant source of chloride ions in the solution that contacts the MWF. The surface concentration of halite measured to be released when water contacts the surface of crushed CWF can be scaled to the surface area of a large monolithic waste forms. Two 1-m-long CWF waste forms have a total surface area of about 4 m^2. Multiplying the halite surface concentration of 140 mg/m^2 by this area gives about 560 mg Cl^- available. Actual CWF waste forms will not be this long, but this provides an upper limit to the concentration.

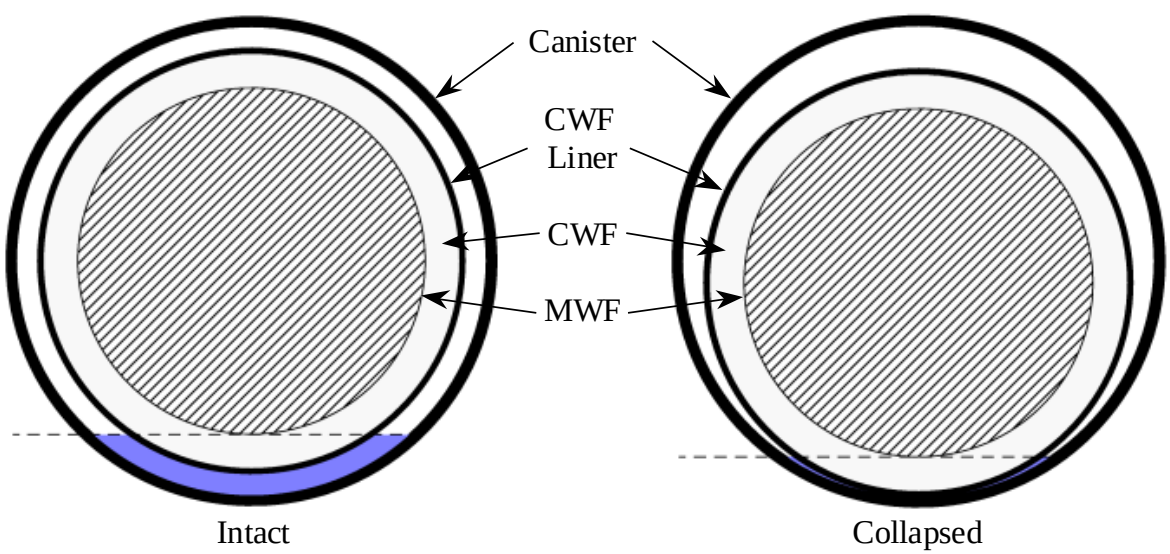


Figure 1. Schematic Cross-Section Geometry of Intact and Collapsed Canister Configurations. The dashed lines show the levels of water that first contact the MWF.

Dissolution of 560 mg Cl^- into 13 and 0.9 L of water for the intact and collapsed configurations results in concentrations of about 43 and 620 mg Cl^-/L, respectively. A slightly lower Cl^- concentration limit would apply to a canister with two MWF ingots because it has less free volume. The concentrations will decrease as more water fills the breached canister. These calculations indicate that the tests with 1000 mg/L Cl^- represent the maximum concentration of dissolved halite concentration that could contact 1 or 2 MWFs in a breached canister.

Most tests were conducted using leachants with 1000 ppm Cl^- made by adding NaCl. (Note: The units mg/L and ppm are equivalent for these solutions.) For example, the pH 4 solution used in tests at ANL-E was made by adding 0.42 g NaCl to commercial pH 4 buffer to make 250 g of solution:

$$(0.42 \text{ g NaCl}/250.0 \text{ g solution})\ (35.5 \text{ g } Cl^-/58.5 \text{ g NaCl}) = 1.02 \times 10^{-3} \text{ g } Cl^-/\text{g solution} \qquad (4)$$

A few supplemental tests were conducted at 50ºC using the same buffers without added NaCl and buffers with 10,000 ppm Cl^- to measure the sensitivity of the test response to the chloride concentration. The leachant solutions are summarized in Table 2. The pH values of the leachants were measured at each test sampling. (Note that ANL-W reported pH values to the nearest 0.1 pH unit for all tests.) The densities of solutions made at ANL-E were calculated based on the mass of solution that filled a 100-mL volumetric flask. The volume of the flask was calibrated based on the mass of demineralized water.

Table 2. Buffer Solutions Used as Leachants

Nominal pH	Buffer	Measured pH[a]	Density, g/mL
3	Potassium hydrogen phthalate + 1000 ppm Cl^-	2.9	not measured
4	Potassium hydrogen phthalate	4.01	1.003
4	Potassium hydrogen phthalate + 1000 ppm Cl^-	4.09	1.004
4	Potassium hydrogen phthalate + 10,000 ppm Cl^-	3.96	not measured
6	Potassium phosphate + 1000 ppm Cl^-	5.9	not measured
8	Potassium phosphate monobasic / NaOH	7.99	1.005
8	Potassium phosphate monobasic / NaOH + 1000 ppm Cl^-	7.96	1.006
8	Potassium phosphate monobasic / NaOH + 10,000 ppm Cl^-	7.72	1.006
9	Sodium tetraborate / NaOH	9.01	1.005
9	Sodium tetraborate / NaOH + 1000 ppm Cl^-	9.03	1.003
9	Sodium tetraborate / NaOH + 10,000 ppm Cl^-	8.86	1.005
10	Sodium tetraborate / NaOH	9.96	1.002
10	Sodium tetraborate / NaOH + 1000 ppm Cl^-	9.99	1.014
10	Sodium tetraborate / NaOH + 10,000 ppm Cl^-	9.80	not measured
12	Sodium hydrogen phosphate / NaOH	11.97	1.003
12	Sodium hydrogen phosphate / NaOH + 1000 ppm Cl^-	12.00	1.004
12	Sodium hydrogen phosphate / NaOH + 10,000 ppm Cl^-	11.77	1.014

[a]Typical values. See Appendix A, Tables A.1 and A.2, for initial pH values.

2.3 TEST PROCEDURE

Tests were conducted following a modification of the ASTM C1220 procedure [10] using commercial pH buffers spiked with NaCl to generate 1000 ppm Cl^- solutions. Tests were conducted by placing a monolithic MWF sample on a Teflon stand inside a Teflon vessel then adding a mass of buffer solution in grams equal to one-half the surface area in cm^2 (typically about 2.8 g of buffer solution was added, measured to the nearest 0.01 g). This was sufficient to completely immerse the sample and attain an S/V ratio of about 200 m^{-1}. The top of the Teflon support stand was a concave mesh that allowed almost total access of solution to the bottom of the sample. The vessel lids were placed on the vessels and tightened using plastic wrenches provided by the vessel manufacturer. The sealed vessels were weighed and then placed in secondary containers with demineralized water. This was done to minimize the difference in vapor pressure between water vapor inside and outside the vessel and to lower the partial pressure of CO_2 at the outer surface of the vessel (CO_2 can diffuse through Teflon and lower the solution pH). The secondary containers were placed in ovens set at 50, 70, or 90°C and left undisturbed during the test interval.

After 14, 28, or 70 days, the vessels were removed from the ovens and weighed. The difference between the total vessel masses before and after the test was attributed to loss of water during the test. The vessels were then opened and separate aliquots of the test solution were taken for pH measurements and for composition analysis. The MWF samples were briefly flushed with a stream of demineralized water and then placed on a clean support in a clean test vessel. Approximately the same amount of fresh leachant as when the test was started was added to the vessels, then the vessels were sealed, weighed, and placed back in the oven to resume the test. Most tests were resumed within an hour after sampling. The emptied vessels were rinsed to remove any residual test solution and then filled with a nitric acid solution, recapped, and left to soak overnight at 90°C. This was done to dissolve any material that had become fixed to the vessel or sample stand during the test interval. Acid soaks at ANL-E were done by adding about 25 mL of a 2% nitric acid solution whereas acid soaks at ANL-W were done with 4 g of a 50% nitric acid solution. The acid soak solution filled the vessel walls past the level contacted by the test solutions in both methods. The vessel was then opened and an aliquot of the acid soak solution taken for analysis. Aliquots of all test solutions and acid soak solutions were analyzed for Cr, Fe, Mo, Mn, Ni, U, and Zr with inductively coupled plasma-mass spectrometry (ICP-MS). Aliquots of the test solutions were analyzed for pH with a combination electrode (at room temperature). The addition of NaCl to the leachants made it necessary to severely dilute the analytical aliquots to avoid saturating the detectors. Although this reduced the sensitivity for minor components, the measured concentrations of uranium exceeded the detection limit except in tests that were conducted at pH 6 and 70°C.

2.4 TEST MATRIX

Test conditions were selected to span a suitable range of temperature and pH values for comparison with HLW glass model. The range of pH values was selected based on the expected range of values in a breached waste package with HLW glass, which is about pH 3 to pH 12. Test temperatures were selected to span the anticipated range of temperatures at which water can accumulate in a breached waste package. The test matrix is summarized in Table 3. The matrix represents the combination of three series of tests. The initial series of tests was developed from two-level factorial designs with two factors (temperature and pH) and triplicate center points for each lab. The high and low factors for the ANL-W factorial design are: 90°C and 50°C, and pH 9 and pH 3; triplicate center point tests were performed at 70°C and pH 6. Tests to evaluate accuracy of model were conducted at 90°C and pH 4, 50°C and pH 6, and 70°C and pH 8. The high and low factors for the ANL-E factorial design are: 90°C and 50°C, and pH 12 and pH 4; triplicate center point tests were performed at 70°C and pH 8. Tests to evaluate the accuracy of model were conducted at 90°C and pH 8, 50°C and pH 9, and at 70°C and pH 10. Interlaboratory precision can be evaluated from the results of tests performed at both labs at 90°C pH 4, 70°C pH 6, and 50°C pH 9. The design allows the results of tests performed at each lab to be pooled or evaluated separately to derive empirical expressions (models) that predict the response of the MWF to the leach test at any combination of temperature and pH within the range(s) tested. However, to compare MWF response to HLW glass response over the widest possible range of conditions, the results must be pooled because extrapolation of the empirical model is unreliable. Several additional experiments were included to evaluate interlaboratory test precision. Replicate tests and tests under the same conditions were conducted at both laboratories to evaluate the repeatability and reproducibility of the tests. Tests conducted as part of the initial matrix are denoted by the letters E and W in Table 3. The samplings of some tests at ANL-E scheduled for 70 days were mistakenly delayed until a total reaction time of 98 days (the final interval was 70 days). Those tests are indicated by a suffix "(98)" in the test matrix. Tests under those conditions were repeated; a suffix "R" is appended to the test numbers to identify repeated tests. The results of both the original series of tests and the repeated tests are presented, but only the repeated test results are used to evaluate the MWF degradation rate. The suffix "(3)" in the test number indicates that triplicate tests were conducted under those conditions. Blank tests were not conducted as part of the initial series of tests. Instead, the leachants were analyzed directly to determine background concentrations of key MWF components. Blanks were not run because U was the sole analyte of interest and was not expected to be present in detectable levels in blank test solutions.

After analysis of the initial data set, a second series of tests was conducted at 50ºC using leachants with 1000 ppm Cl^- (added as NaCl) to expand the data base. Extra tests were only conducted at 50ºC because the results of the initial series indicated that the test temperature did not affect the uranium release rate. The tests in this series of extra tests conducted at ANL-E and ANL-W are indicated by the suffixes "EX" and "WX", respectively. These tests were used as an additional measure of test repeatability to assess whether differences between tests at different temperatures and pH values indicated an actual dependence or were simply test uncertainty. Blank tests were conducted in parallel with the extra tests by placing the leachant solutions in Teflon vessels and heating to 50ºC for either 14 days or carrying out the exchanges through 70 days. These solutions were analyzed and used as background concentrations for the tests with

MWF. The same background concentrations were used for all test intervals and for all temperatures. The vessels used in blank tests conducted at ANL-W were acid soaked after the 70-day sampling. The demineralized water from the purifier used to make the nitric acid soak solutions for tests with MWF at ANL-E was analyzed to determine if background subtraction was required for the acid soak solution results. The concentrations of all MWF components in the demineralized water were below detection limits and no background subtraction was necessary for calculating the masses of elements in the acid soak solutions.

Finally, a supplemental series of tests was conducted at ANL-E to measure the effect of the dissolved chloride concentration on the MWF degradation rate. This third series of tests was conducted at 50ºC using leachants with 10,000 ppm Cl^- (added as NaCl) and using leachants without added NaCl at pH 4, 8, 9, 10, and 12. Those tests are indicated with a suffix "ES" in Table 3. One test was conducted in a titanium lined Type 304L stainless steel vessel to determine if electrically grounding the MWF sample affected its degradation rate. That test (test number 9-10k/Ti) was conducted in the pH 9 leachant with 10,000 ppm Cl^-.

Table 3. Test Matrix[a]

Nominal pH	Temperature		
	50°C	70°C	90°C
3	W, WX	--	W
4	E, EX, ES	--	E, W
6	W, WX	W(3)	--
8	EX, ES, WX	E(98), ER(3), W	E(98), ER
9	E(98), ER, EX, ES, W, WX	--	W
10	EX, EX	E	--
12	E, EX, ES	--	E

[a] "E" indicates tests conducted at ANL-E in leachants with 1000 ppm Cl^-.
"W" indicates tests conducted at ANL-W in leachants with 1000 ppm Cl^-.
"(98)" indicates tests sampled after 14, 28, and 98 days in leachants with 1000 ppm Cl^-.
"ER" indicates repeated tests conducted at ANL-E in leachants with 1000 ppm Cl^-.
"EX" indicates extra tests conducted at ANL-E in leachants with 1000 ppm Cl^-.
"ES" indicates supplemental tests conducted at ANL-E in leachants with 10,000 ppm Cl^- and without added NaCl.
"WX" indicates extra tests conducted at ANL-W in leachants with 1000 ppm Cl^-.
"(3)" indicates triplicate tests were conducted.
"--" indicates tests not conducted under those conditions.

3. RESULTS

3.1 TESTING AND ANALYTICAL DATA

The test execution data are summarized in Appendix A, in Table A.1 for tests conducted at ANL-E and in Table A.2 for tests conducted at ANL-W. These tables contain details regarding the sample, test solution, and vessel masses, measured pH values, analytical aliquots, etc. The measured pH values and concentrations of Cr, Fe, Mn, Mo, Ni, U, and Zr in the various test solutions are tabulated in Appendix B—Table B.1 for the 0-14 day test interval, Table B.2 for the 14-28 day test interval, and Table B.3 for the 28-70 day test interval. The tabulated values have been adjusted for dilutions made prior to submission for analysis by using the dilution factors from Tables A.1 and A.2. Note that the amounts of leachant added to the test were tracked by mass rather than volume and that a density of 1.00 g/mL was used to calculate the elemental masses from the concentrations of all solutions. The concentrations in the acid soak solutions are tabulated in Appendix C—Table C.1, for the 0-14 day test interval, Table C.2 for the 14-28 day test interval, and Table C.3 for the 28-70 day test interval. The results for analysis of the blank test solutions are summarized in Appendix D, Table D.1. These results show a negligible effect of test temperature on the concentrations in the blanks, so the same background concentrations were used for tests conducted at different temperatures. The background concentrations used for each test series are summarized in Table D.2 (the same background concentrations are used for all test intervals).

The total masses released over the 0- to 14-day, 14- to 28-day, and 28- to 70-day intervals are given in Appendix E in Tables E.1, E.2, and E.3, respectively. These are calculated as the sum of the masses in the test and acid soak solutions minus the background concentrations. The results of blank tests with the leachants are used as the background concentrations for the test solutions. The mass in the test solution (m_{TS}) is calculated as

$$m_{TS} = (\text{concentration in test solution} - \text{concentration in blank test}) \times (\text{volume of test solution}) \quad (5)$$

The concentrations in the test solutions are given in Appendix B and the concentrations in the blank tests are given in Appendix D. The volumes of the test solutions are given in Appendix A. Note that the masses added at the beginning of the tests are used for the calculations. Although the measured mass losses during the test are within the measurement uncertainty (about 0.03 g) for the two measurements in most cases, several tests at ANL-E had mass *gains* (the mass losses in Table A.1 are negative numbers). The increase in mass probably indicates that a small amount of water from the secondary container was trapped in the threads of the test vessel and vessel cap when the vessel was weighed. The mass change of the assembled vessel does not provide a reliable measure of the loss of test solution due to leakage. Only one test had a significant mass loss: test pH8-90C-E3(98) had a loss of 0.10 g. The mass in the acid soak solution (m_{AS}) is calculated as

$$m_{AS} = (\text{concentration in acid soak solution}) \times (\text{volume of acid soak solution}) \quad (6)$$

The concentrations in the acid soak solutions are given in Appendix C and the volumes of the acid soak solutions are given in Appendix A. The concentrations measured in the acid soak

solutions are used directly to calculate the mass since the concentrations of MWF components in demineralized water (which gives the background concentrations for the acid soaks) are all below the detection limits.

The amounts of uranium released through 14, 28, and 70 days are summarized in Table 4. The results of tests conducted at ANL-E and ANL-W are distinguished to show the reproducibility of the tests. The cumulative uranium concentrations for tests at various pH values and temperatures are plotted against the reaction time in Figs. 2a-f. The values plotted at 28 days represent the sum of uranium in the aliquots analyzed after 14 and 28 days, and the values plotted at 70 days represent the sum of uranium in the aliquots analyzed after 14, 28, and 70 days. The masses of uranium released in different tests can be compared directly because the S/V ratios are essentially the same in all tests (see Tables A.1 and A.2). Figure 2a shows the results of tests conducted at 90°C in acidic solutions. The greatest amounts of uranium are released in tests at pH 3 and pH 4. The release in tests at 90°C and pH 4 conducted at ANL-W is nearly constant with time, whereas the release in tests at 90°C and pH 4 conducted at ANL-E decreases with time. Figure 2b shows the results of tests conducted at 90°C in alkaline solutions. The release in tests at pH 12 is nearly constant with time, whereas the release in tests at pH 8 and pH 9 decrease with time. Figures 2c and 2d show the results of tests conducted at 50°C, including replicate tests under some test conditions. The releases in tests at pH 3 are nearly constant with time, whereas the releases at other pH values decrease with time.

The results of replicate tests conducted at different times (i.e., with the initial test series and with the extra tests) at pH 3, pH 4, pH 6, and pH 12 show the repeatability of test in the same laboratory and the reproducibility of tests between laboratories to exceed the analytical uncertainty, which is about 10% for each plotted point (uncertainty bars are omitted from the plots for clarity). Part of the difference can be attributed to slight differences in the relative amounts of steel and intermetallic phases exposed a the surfaces of different test specimens.

3.2 NORMALIZED ELEMENTAL MASS LOSS

The releases of different components and different test configurations (e.g., tests at different S/V ratios) can be compared directly using normalized elemental mass loss values, NL(i). The mass of an element i that is released from the MWF is divided by the surface area of the test specimen and by the mass fraction of element i in the MWF, as expressed in Eq. (7):

$$NL(i) = [m_{TS}(i) + m_{AS}(i)] / [S \bullet f(i)] \tag{7}$$

where $m_{TS}(i)$ and $m_{AS}(i)$ are the masses of element i in the test solution and acid soak solution (see Eqns. 5 and 6), S is the specimen surface area, and f(i) is the mass fraction of element i. Values of NL(i) for i =Cr, Fe, Mn, Mo, Ni, U, and Zr calculated using masses released during the 0-14 day test interval and using the cumulative masses released over 28 day and 70 day total test durations are given in Appendix F.

The cumulative values of NL(i) for these elements for dissolution through the 70-day test period are plotted in Figs. 3a and b for tests conducted at 90 and 50°C, respectively. (Results of tests at ANL-E and ANL-W are not distinguished in the figure.) The NL(i) values for different

elements span a range of about two orders of magnitude in most tests. The values for elements other than Zr are similar to each other in acidic solutions, but more widely distributed in alkaline solutions. Differences in the NL(*i*) values are due to differences in both the release and solubility limits of different elements. The values of NL(U) and NL(Fe) are similar under most test conditions. Values of NL(U) are compared to assess the effects of test duration, temperature, and pH, and to calculate the normalized dissolution rates of the MWF for direct comparison with the HLW glass degradation model.

Table 4. Mass of Uranium Released from MWF, micrograms

	Nominal pH						
	3	4	6	8	9	10	12
Cumulative through 14 days							
90°C	W: 123	E: 76.3 W: 33.4		ER: 0.264	W: 7.71		E: 10.1
70°C			W: 0.154 W: 0.205 W: 0.182	ER: 0.209 ER: 0.499 ER: 0.400 W: 0.218		E: 8.03	
50°C	W: 121 WX: 240	E: 112 EX: 57.7 WX: 76.9	W: 0.338 WX: 0.610	EX: 0.310 WX: 1.14	ER: 4.04 EX: 0.932 W: 9.25 WX: 12.1	EX: 3.05	E: 0.945 EX: 2.09
Cumulative through 28 days							
90°C	W: 219	E: 121 W: 129		ER: 0.619	W: 15.3		E: 19.5
70°C			W: 0.219 W: 0.251 W: 0.224	ER: 0.785 ER: 1.17 ER: 0.829 W: 0.272		E: 11.3	
50°C	W: 142 WX: 372	E: 194 EX: 164 WX: 272	W: 0.742 WX: 0.657	EX: 0.420 WX: 1.33	ER: 7.31 EX: 1.76 W: 21.8 WX: 24.6	EX: 3.68	E: 1.26 EX: 2.38
Cumulative through 70 days							
90°C	W: 322	E: 201 W: 609		ER: 1.08	W: 18.6		E: 37.8
70°C			W: 0.257 W: 0.290 W: 0.264	ER: 0.939 ER: 1.38 ER: 1.03 W: 0.309		E: 22.1	
50°C	W: 485 WX: 528	E: 263 EX: 275 WX: 324	W: 0.838 WX: 0.700	EX: 0.483 WX: 11.3	ER: 21.5 EX: 4.79 W: 35.5 WX: 62.1	EX: 4.71	E: 1.71 EX: 2.83

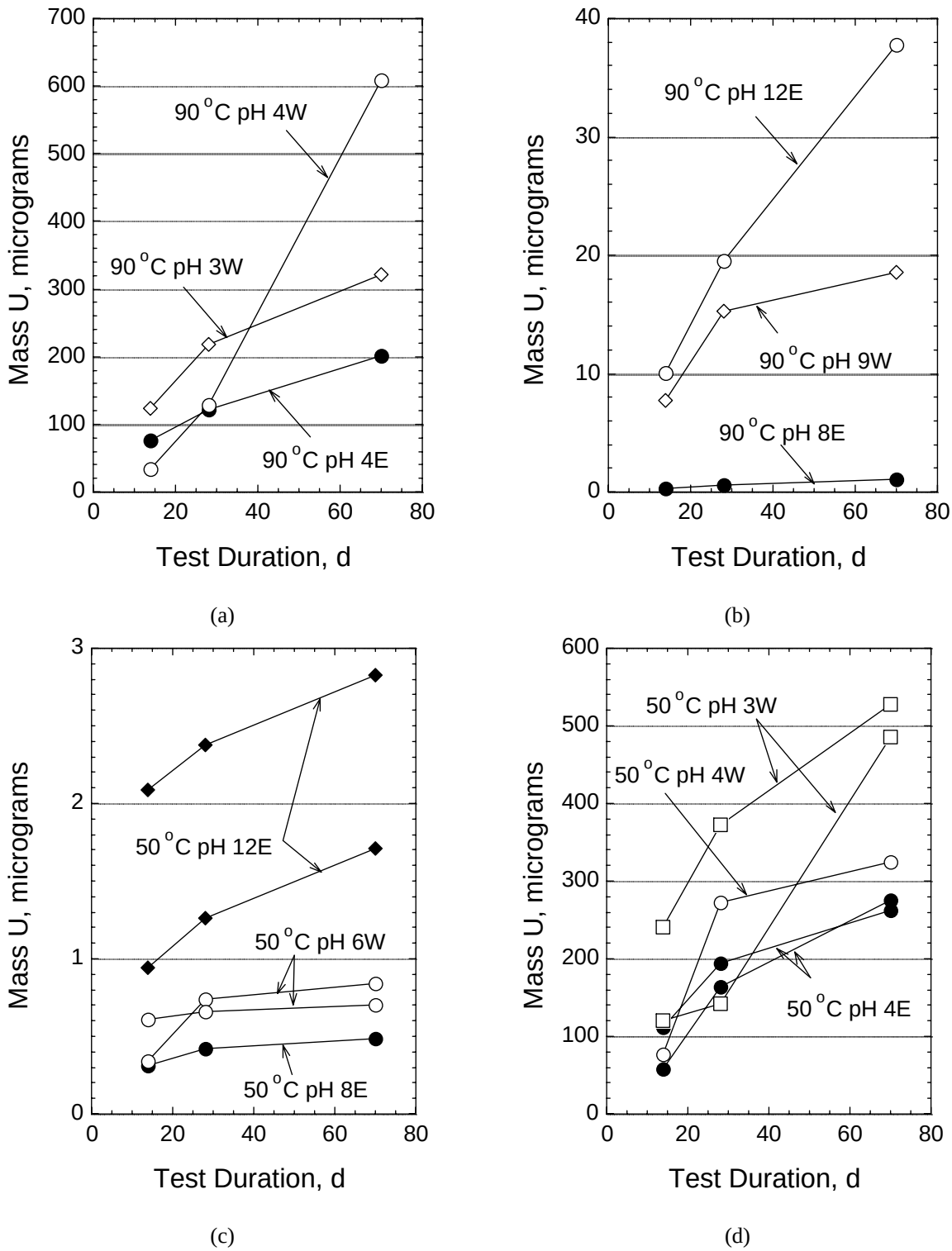
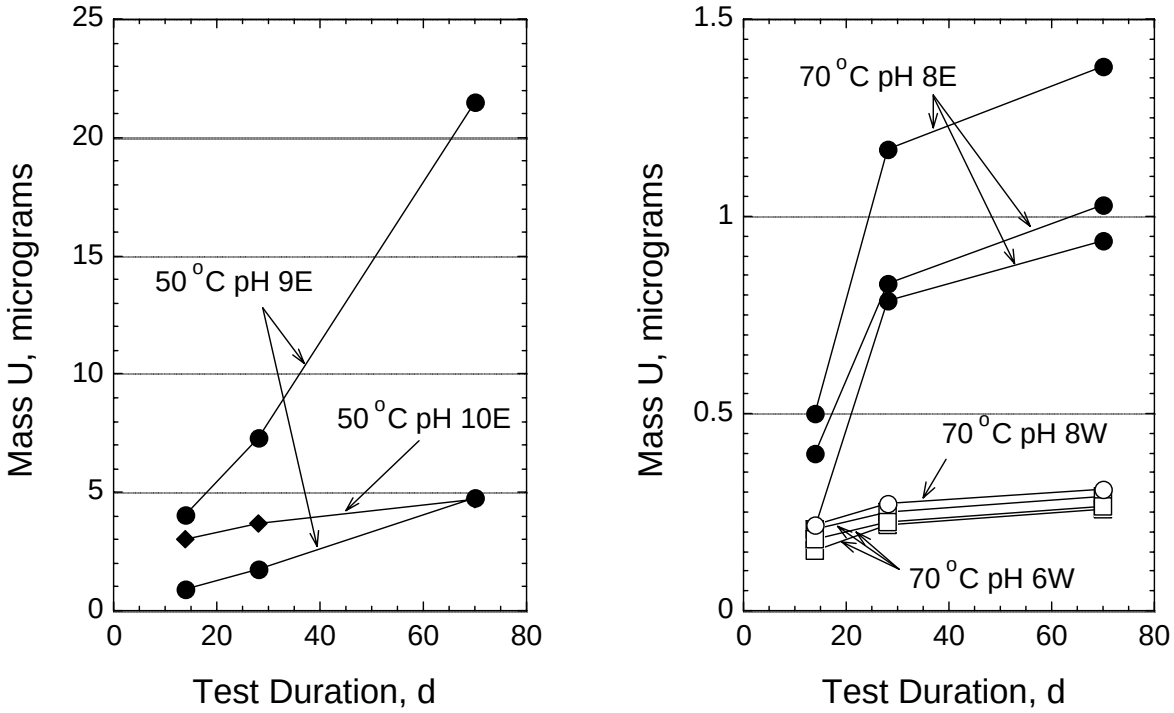
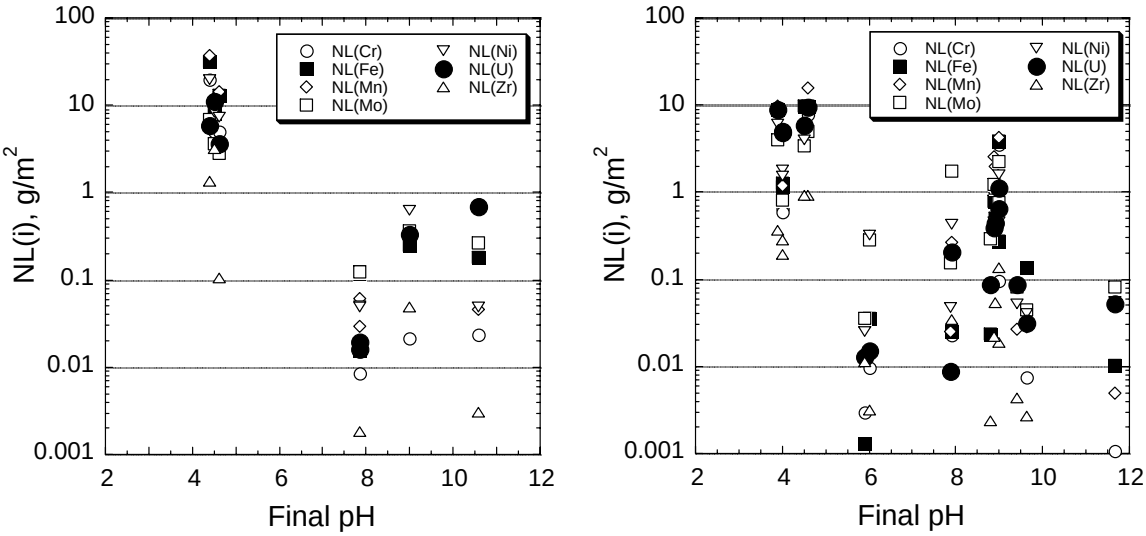


Figure 2. Cumulative Mass of Uranium Released Through Samplings at 14, 28, and 70 Days for Tests at (a, b) 90ºC, (c-e) 50ºC, and (f) 70ºC. All tests conducted with leachants spiked with 1000 ppm Cl^-. Tests conducted at ANL-E (filled symbols) and ANL-W (open symbols), also indicated by E or W following pH in labels.



(e) (f)

Figure 2. (contd.)



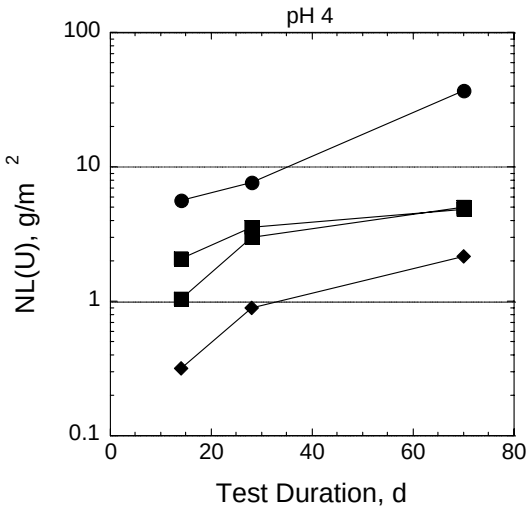
(a) (b)

Figure 3. Cumulative Normalized Elemental Mass Loss Values for 70-Day Test Duration for Tests Conducted at (a) 90ºC and (b) 50ºC in Leachants Spiked with 1000 ppm Cl^-.

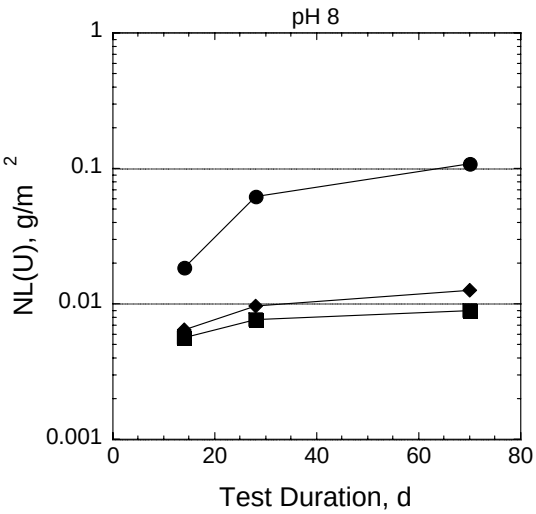
3.3 TESTS IN LEACHANTS SPIKED WITH 10,000 ppm Cl^- AND LEACHANTS WITHOUT ADDED NaCl

Additional tests were conducted at nominal pH values of 4, 8, 9, 10, and 12 at 50ºC using leachant solutions spiked with 10,000 ppm Cl^- and leachants without added NaCl. These tests were conducted to measure the effect of the chloride concentration on the degradation rate. The test execution data and solution analysis results for these additional tests are given in Appendix G. The cumulative values of NL(U) after 14, 28, and 70 days are plotted in Fig. 4 for tests conducted with 10,000 ppm Cl^-, 1000 ppm Cl^-, and no added NaCl. The cumulative NL(U) values through 70-days are summarized in Table 6 (Section 4). The averages of the values from Table 5 (Section 4) for tests conducted at ANL-E at 50ºC in leachants with 1000 ppm Cl^- are included in Table 6 for comparison. Comparison of the results for tests with different amounts of added NaCl shows the highest NL(U) values were attained at pH 4, 8, and 10 in tests with 10,000 ppm Cl^-, whereas the highest values at pH 9 and 12 occurred in tests without added NaCl (except for the test in the titanium lined vessel). At pH 9 and pH 12, very similar results are obtained with 10,000 ppm Cl^- and without added NaCl, and both are significantly higher than the results obtained with 1000 ppm Cl^-. Based on the similarities in NL(U) values for tests in solutions with 10,000 ppm Cl^- and with no added NaCl, we attribute the differences observed in alkaline solutions to test uncertainty. The difference at pH 4 is probably real.

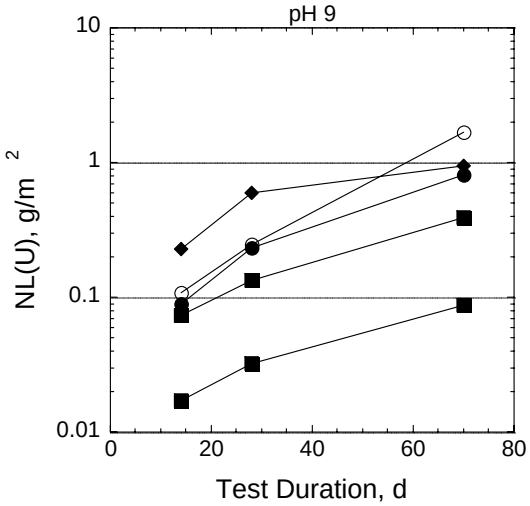
These results show that, except in strongly acidic solutions, the concentrations of chloride ions that can occur in a breach co-disposal canister with CWF and MWF will not significantly affect MWF degradation or the release of radionuclides. The results of tests with 1000 ppm Cl^- adequately bound the effect of dissolved halite.



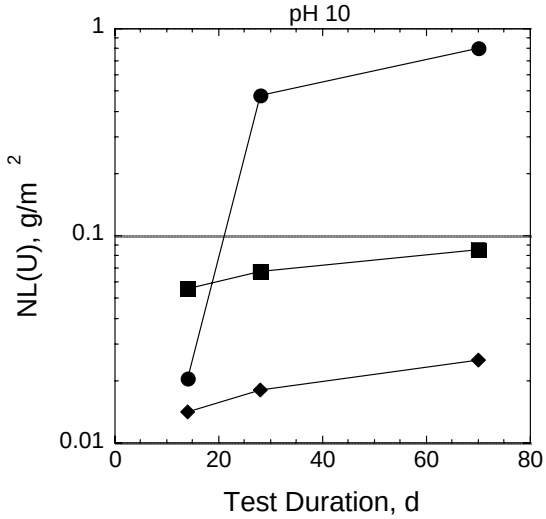
(a)



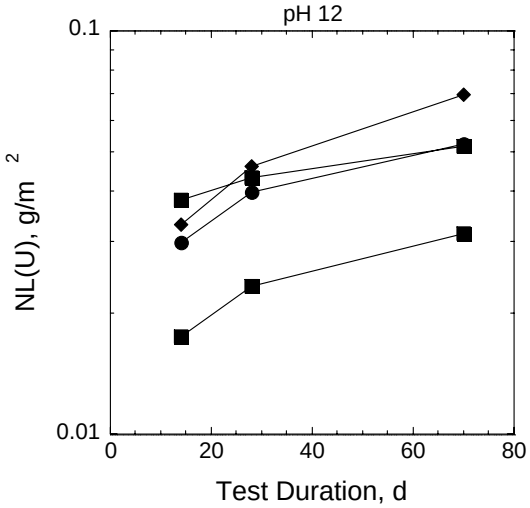
(b)



(c)



(d)



(e)

Figure 4. Cumulative NL(U) for Tests at 50ºC at (a) pH 4, (b) pH 8, (c) pH 9, (d) pH 10, and (e) pH 12 for Leachants with (●) 10,000 ppm Cl^-, (■) 1000 ppm Cl^-, (◆) Without Added NaCl, and (○) With 10,000 ppm Cl^- in a Titanium-Lined Steel Vessel

4. DISCUSSION

In the HLW glass degradation model, the release of boron is used as an upper bound for the release of radionuclides because boron is released as fast as or faster than any radionuclide as the glass corrodes. This is a conservative approach for the release of most radionuclides. Previous tests with MWF materials have shown that uranium is released faster than other radionuclides, so the release rate of uranium is used to represent the release of all radionuclides from the MWF. The present test results indicate that the release of uranium also provides a good indication of the extent of dissolution of the MWF matrix, even though uranium is not present in the steel phase. The observation that NL(Fe) is greater than NL(U) in tests in acidic solutions but less than NL(U) in neutral and alkaline solutions suggests that the steel phase dissolves faster than the intermetallic phase in acidic solutions, but slower than the intermetallic phase in neutral and alkaline solutions.

The TSPA glass degradation model takes into account the decrease in the glass dissolution rate as the concentration of dissolved silica increases in the test solution through selection of the k_E term. Even the maximum degradation rate is affected by the dissolved silica concentration. (The maximum rate in the TSPA model is about 40 times lower than the rate in the absence of feedback effects from dissolved silica.) The oxide layer that forms on the MWF surface has a similar slowing effect, although the layer formation occurs much more slowly as the MWF corrodes than the increase of silica occurs as HLW glass dissolves. A direct comparison of test results with MWF with the rates calculated using the glass model provides a reasonable indication of the relative durabilities over long time in the repository. The test solutions recovered from the exchanges at 14, 28, and 70 days were analyzed to determine if the amount of uranium released decreased measurably with reaction time. A slight decrease in the release rate is seen in Figs. 2a–d even on a logarithmic scale. We attribute the decrease to the initial formation of an oxide layer at the surfaces of the MWF samples. Visual inspection of the MWF samples after the 70-day sampling indicated that they were dulled and some samples were discolored black or orange. However, the oxide layers were too thin to observe microscopically. The decrease in the amounts of uranium (and other components) released between the exchanges after 14 and 28 days is consistent with the reduction in rate due to formation of a surface layer rather than to solution feedback effects because solution feedback effects should have been similar over the two 14-day test intervals after the solutions were exchanged. The uranium concentrations given in Table 4 were used to calculate the cumulative concentration through 70 days, the normalized uranium mass losses, and the cumulative dissolution rates for the different test conditions. The average dissolution rate over the 70-day test duration was calculated by dividing the cumulative value of NL(U) by 70 days. These values are summarized in Table 5. Note that NL(U) and NR(U) are given in units of $mg/(m^2d)$ and mg/m^2, respectively.

The specific dissolution rates calculated for HLW glass at 50, 70, and 90°C (T= 323, 343, and 363 K) using Eqs. 1 and 2 are shown as lines in Fig. 5a for comparison with the specific dissolution rates measured for the MWF at these temperatures, which are plotted in Fig. 5a. Note that the specific dissolution rates of the MWF are plotted at the nominal pH values of the buffers. The measured pH values for the three samplings differed slightly from the nominal values; in most cases the measured values were slightly more neutral than the nominal values (see Appendix A). The small change in pH over the test duration, which is greatest at the

extreme pH values, is attributed primarily to interactions between the test solution and air. Degradation of the MWF does not affect the solution pH significantly, which is why leachants with low buffer capacity were used. The specific dissolution rates are similar for MWF and HLW glass under the respective test conditions. However, unlike the HLW glass degradation rate, temperature does not affect the MWF dissolution rate in these tests. The rates measured at 50ºC are greater than the rates measured at 70 and 90ºC for tests at several pH values. This suggests that the rate-determining step for MWF dissolution is not a thermally activated process, and the differences in rates at the same pH value but different temperatures is due to test uncertainty. Likewise, the apparent V-shaped pH dependence similar to that of HLW glass is probably only scatter in the results. In the case of HLW glasses, the V-shape pH dependence is because dissolution occurs by the hydrolysis of Al-O bonds in acidic solutions and by the hydrolysis of Si-O bonds in alkaline solutions. The mechanism responsible for the pH dependence of the MWF (if any) is not known. The primary effect of pH is probably through the solubility limit.

In Fig. 5b, we compare the glass dissolution rate calculated as the product of the maximum specific dissolution rate and the surface area of 30 m^2 with the MWF dissolution rate calculated as the product of the measured specific dissolution rates (from Table 5) and a surface area of 0.76 m^2, which is the surface area of two MWF monoliths. Note that the rates are in units of grams of glass or MWF per day. From the maximum and minimum values of k_E in the TSPA HLW glass degradation model, the minimum rates will be about 1000X less than the maximum rates in both acidic and alkaline solutions. The dashed lines in Fig. 6b show the maximum and minimum rates calculated with the HLW glass degradation model at 20ºC. This shows that the dissolution rates of the MWF measured at temperatures up to 90°C are within the range of rates calculated by the TSPA glass model at 20°C. That is, although the MWF dissolution rate may not depend on temperature, it will be bounded by the range of HLW glass dissolution rates calculated at temperatures and pH values (at least between pH 3 and pH 12) that can occur with water in a breached waste package. Although it is improbable, water may be simulated to be present in a breached waste package at temperatures as high as about 110ºC in TSPA calculations. The HLW glass degradation model is extended to these conditions based on tests conducted in water vapor between 90 and 200ºC rather than immersion tests in water. Scoping tests with MWF in water vapor at elevated temperatures have resulted in negligible corrosion. Additional tests in water vapor and in dripping water are in progress at ANL-E and results will be published elsewhere.

Table 5. Cumulative Mass Released, Cumulative Normalized Mass Loss, and Cumulative Normalized Dissolution Rate Based on the Release of Uranium Through 70 Days in Leachants Spiked with 1000 ppm Cl^-

	Nominal pH						
Temp., °C	3	4	6	8	9	10	12
Cumulative mass released, μg							
90°C	W: 322	E: 201 W: 609	--[a]	ER: 1.08	W: 18.6	--	E: 37.8
70°C	--	--	W: 0.257 W: 0.290 W: 0.264	ER: 0.939 ER: 1.38 ER: 1.03 W: 0.309	--	E: 22.1	--
50°C	W: 485 WX: 528	E: 263 EX: 275 WX: 324	W: 0.838 WX: 0.700	EX: 0.483 WX: 11.3	ER: 21.5 EX: 4.79 W: 35.5 WX: 62.1	EX: 4.71	E: 1.71 EX: 2.83
Cumulative NL(U), mg/m^2							
90	W: 5810.	E: 3690 W: 11000	--	ER: 19.7	W: 336	--	E: 696
70	--	--	W: 4.64 W: 5.22 W: 4.77	ER: 17.2 ER: 25.2 ER: 18.9 W: 5.58	--	E: 407	--
50	W: 8760 WX: 9520	E: 4850 E: 5030 WX: 5900	W: 15.1 WX: 12.7	EX: 8.84 WX: 204	ER: 392 EX: 87.2 W: 640 WX: 1130	EX: 85.9	E: 31.5 EX: 51.7
Cumulative NR(U), $mg/(m^2 \bullet d)$							
90	W: 83.1	E: 52.7 W: 157	--	ER: 0.282	W: 4.79	--	E: 9.94
70	--	--	W: 0.0663 W: 0.0746 W: 0.0681	ER: 0.246 ER: 0.359 ER: 0.270 W: 0.0797	--	E: 5.82	--
50	W: 125 WX: 136	E: 69.2 EX: 71.8 WX: 84.3	W: 0.216 WX: 0.181	EX: 0.126 WX: 2.92	ER: 5.61 EX: 1.25 W: 9.15 WX: 16.1	EX: 1.23	E: 0.450 EX: 0.739

[a]"--" means not measured.

Table 6. Cumulative Normalized Uranium Mass Loss at 50ºC Through 70 Days for Tests with Leachants Spiked with 10,000 and 1000 ppm Cl^-, and without NaCl, g/m^2

Added NaCl	pH				
	4	8	9	10	12
10,000 ppm	36.8	0.107	0.804[b]	0.805	0.0523
1000 ppm[a]	4.94	0.0884	0.239	0.0859	0.0416
0 ppm	2.14	0.0126	0.940	0.0251	0.0694

[a]Average of NL(U) values measured at ANL-E (see Table 5).
[b]Cumulative NL(U) for tests at pH 9 in titanium-lined vessels was 1.68 g/m^2.

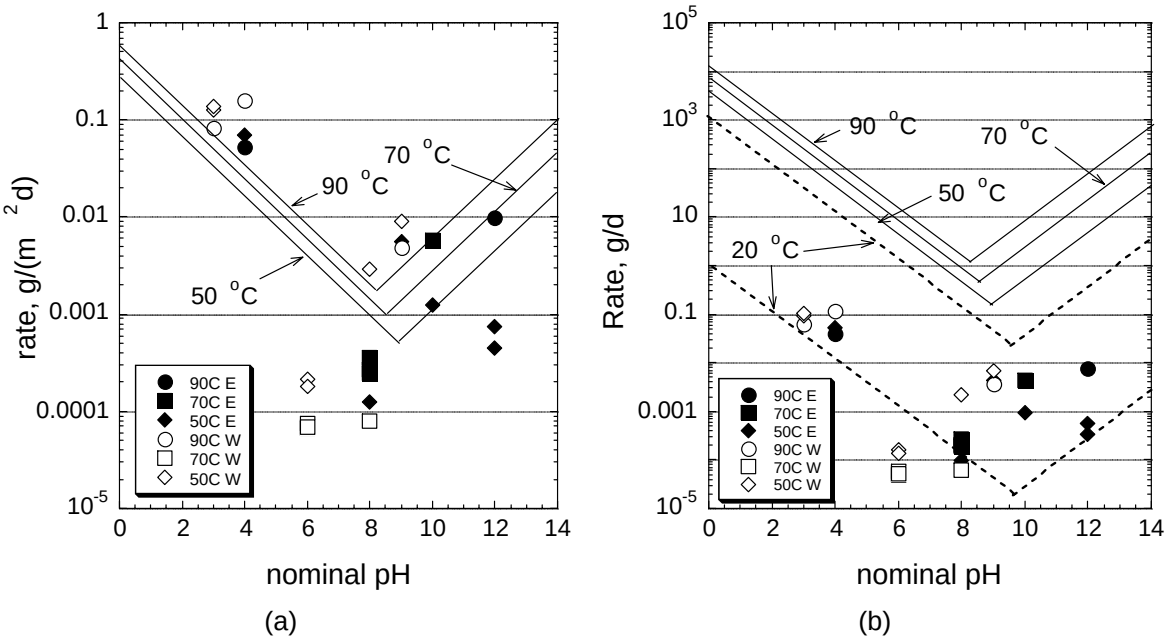


Figure 5. Comparison of Dissolution Rate of MWF with Rates from HLW Glass Model: (a) Specific Dissolution Rate (per unit area) and (b) Dissolution Rate. Tests with MWF were conducted in leachants spiked with 1000 ppm Cl^-.

5. CONCLUSIONS

The test results discussed in this report support the proposition that waste packages containing MWF (with co-disposed CWF) do not need to be distinguished from packages with HLW glass in TSPA calculations. Use of the HLW glass model to account for the impact of MWFs on the performance of the disposal system is supported by consideration of the three terms used to calculate the release rates of radionuclides from HLW glass to track dose in TSPA simulations: the specific waste form degradation rate, the surface area contacted by water, and the radionuclide inventory. The average inventory used for all HLW glasses already includes radionuclides that will be immobilized in the MWF. The exposed surface area of two MWF ingots in a co-disposal canister is about 40 times less than the exposed surface area of HLW glass used in the glass degradation model. The specific release rate of uranium from a surrogate MWF is similar to the specific rate calculated with the HLW glass degradation model used for TSPA over the range of temperatures and pH values that were evaluated.

Comparison of the degradation rates (i.e., the products of the specific degradation rates and exposed surface areas) for the MWF and HLW glass shows that the radionuclide release rate from the MWF will be well represented by the radionuclide release rates calculated for HLW glass over the expected range of temperatures and pH values within a breached waste package. (The same inventory will be used to calculate the dose associated with the release of a particular radionuclide, so the inventory is not included in the comparison.) The release rate of U from the MWF shows no simple dependence on temperature or pH, although the rate was highest in acidic solutions and lowest in neutral solutions. The MWF degradation rates measured at 50, 70, and 90ºC in solutions spiked with 1000 ppm Cl^- are within the range of rates calculated using the HLW glass degradation rate at 20ºC for all pH values. These tests demonstrate that the HLW glass model bounds the effect of Cl^- on MWF degradation.

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APPENDIX A. TEST EXECUTION DATA

These tables summarize data generated during sample preparation, test initiation, and test interruption for sampling. Table A.1 provides data for tests conducted at ANL-E and Table A.2 provides data for tests conducted at ANL-W. Note that third sampling of some tests conducted at ANL-E did not occur until 98 days after test initiation (the final interval was 70 days). The designator "(98)" is appended to the test numbers for these tests. Those tests were repeated. The same test number was used with an "R" suffix. After the test results were analyzed, it was decided to conduct more tests at 50ºC at all pH values. This resulted in replicate tests at some pH values. The same test numbers were used by the experimenters with an "EX" suffix for tests conducted at ANL-E and a "WX" suffix for tests conducted at ANL-W. The headings for columns in Tables A.1 and A.2 are defined below.

Test No.	Test number. First term gives nominal pH, second term gives nominal temperature, and third term gives interval number, lab, and replicate number if more than one replicate test was conducted.
Temp.	Test temperature, in ºC.
pH Buffer	Nominal pH of buffer solution used as leachant.
Vessel No.	Unique number etched on Teflon test vessel for test identification.
Coupon No.	Unique number or identifier assigned to MWF sample coupon. Note that some coupons were polished after initial use and used in another test.
Coupon Area	Geometric surface area of MWF sample coupon calculated from measured dimensions, in cm^2.
Coupon Mass	Measured mass of MWF sample coupon, in g
Initial pH	Measured pH of leachant used in tests (measured at room temperature), no units.
Final pH	Measured pH of test solution (measured at room temperature).
Initiation Date	Calendar date test was initiated.
Sampling Date	Calendar date test was sampled.
Interval	Duration of test interval, in days.
Vessel Mass	Mass of empty Teflon test vessel, in g.
Vessel + Coupon	Mass of test vessel with MWF sample coupon, in g.
Total Mass In	Mass of test vessel with MWF sample coupon + leachant prior to placing in oven, in g.
Leachant Mass	Measured mass of leachant, calculated as *Total Mass In – (Vessel + Coupon)*, in g.

Sample calculation for pH4-90C-1E:

$$48.54\ g - 45.73\ g = 2.81\ g$$

or as *Total Mass In – Vessel Mass – Coupon Mass*, in g

Sample calculation for pH3-90C-1W:

$$48.92\ g - 42.57\ g - 3.487 = 2.86\ g$$

S/V	Surface area-to-solution volume ratio calculated as *Coupon Area x Leachant Mass*, in m^{-1}.

Sample calculation for pH4-90C-1E:

$$5.61\ cm^2 \bullet (1\ m^2/1000\ cm^2) / [2.81\ g\ (1\ cm^3/g) \bullet (1 \times 10^{-6}\ m^3/cm^3)] = 199.6\ m^{-1}$$

Total Mass Out	Mass of test vessel with MWF sample coupon and leachant after removal from oven for sampling, in g.
Water Loss	Mass of water lost during test calculated as *Total Mass In – Total Mass Out*, in g.

Sample calculation for pH4-90C-1E:

Water Loss = 48.54 g – 48.51 g = 0.03 g.

Bottle Mass	Mass of bottle used to collect aliquot of test solution for analysis, in g.
Bottle + Aliquot	Mass of bottle plus aliquot of test solution for analysis, in g.
Aliquot	Mass of aliquot of test solution collected for analysis calculated as *(Bottle + Aliquot) – Bottle Mass*, in g.

Sample calculation for pH4-90C-1:

Aliquot = 10.45 g – 8.28 g = 2.17 g.

B + A + water + HNO_3	Mass of bottle plus aliquot of test solution for analysis plus demineralized water added + HNO_3 for dilution plus concentrated nitric acid added to acidify solution, in g.
Dilution Factor	Dilution factor calculated as [(*B + A + water +* HNO_3) *– Bottle*]/ *Aliquot*, no units.

Sample calculation for pH4-90C-1:

Dilution Factor = (21.05 g -8.28 g) / 2.17 g = 5.885

Vessel + AS Mass	Mass of test vessel plus dilute nitric acid solution (or demineralized water plus concentrated nitric acid) used for acid soak, in g.
AS Aliquot Mass	Mass of acid soak solution calculated as *(Vessel + AS Mass) – Vessel Mass*, in g.

Sample calculation for pH4-90C-1:

AS Aliquot Mass = 69.32 g – 42.13 g =27.19 g.

Table A.1. Test Data for Tests Conducted at ANL-E

Test No.[a]	Temp. °C	pH Buffer	Vessel No.	Coupon No.	Coupon Area, cm^2	Coupon mass, g	Initial pH	Initiation Date	Sampling Date	Interval, d	Vessel Mass, g	Vessel+ Coupon, g	Total Mass In, g
pH4-90C-1E	90	4	7	1	5.61	3.5944	3.96	1/28/02	2/11/02	14	42.13	45.73	48.54
pH4-90C-2E	90	4	7B	1	5.61	3.5944	3.95	2/14/02	2/28/02	14	42.37	45.97	48.77
pH4-90C-3E	90	4	7C	1	5.61	3.5944	3.98	2/28/02	4/12/02	70	42.47	46.06	48.87
pH4-50C-1E	50	4	3	6	5.58	3.5450	3.96	1/28/02	2/11/02	14	42.55	46.10	48.89
pH4-50C-2E	50	4	3B	6	5.58	3.5450	3.95	2/14/02	2/28/02	14	42.07	45.62	48.41
pH4-50C-3E	50	4	3C	6	5.58	3.5450	3.98	2/28/02	4/12/02	70	42.50	46.05	48.84
pH4-50C-1EX	50	4	1	1	5.62	3.5971	3.90	7/19/02	8/2/02	14	42.11	45.71	48.53
pH4-50C-2EX	50	4	7	1	5.62	3.5971	3.95	8/2/02	8/16/02	14	42.56	nm	48.96
pH4-50C-3EX	50	4	12	1	5.62	3.5971	3.91	8/16/02	9/27/02	42	42.54	45.35	48.94
pH8-90C-1E	90	8	6	2	5.61	3.5620	7.96	12/21/01	1/4/02	14	42.36	45.92	48.73
pH8-90C-2E	90	8	6B	2	5.61	3.5620	7.96	1/4/02	1/18/02	14	42.60	46.20	49.00
pH8-90C-3E(98)	90	8	6C	2	5.61	3.5620	7.91	1/28/02	4/8/02	98	42.50	46.07	48.88
pH8-90C-1ER	90	8	14	14	5.62	3.6347	7.92	4/15/02	4/29/02	14	42.64	46.31	49.13
pH8-90C-2ER	90	8	14B	14	5.62	3.6347	7.89	4/30/02	5/14/02	14	42.41	46.08	48.89
pH8-90C-3ER	90	8	14C	14	5.62	3.6347	7.88	5/14/02	6/27/02	42	42.16	45.84	48.66
pH8-70C1-1E	70	8	8	3	5.62	3.5722	7.96	12/21/01	1/4/02	14	42.53	46.10	48.91
pH8-70C1-2E	70	8	8B	3	5.62	3.5722	7.96	1/4/02	1/18/02	14	42.63	46.23	49.03
pH8-70C1-3E(98)	70	8	8C	3	5.62	3.5722	7.91	1/28/02	4/8/02	98	42.15	45.72	48.53
pH8-70C2-1E	70	8	9	4	5.62	3.6139	7.96	12/21/01	1/4/02	14	42.40	46.01	48.82
pH8-70C2-2E	70	8	9B	4	5.62	3.6139	7.96	1/4/02	1/18/02	14	42.47	46.17	48.98
pH8-70C2-3E(98)	70	8	9C	4	5.62	3.6139	nm[a]	1/28/02	4/8/02	98	42.57	46.19	49.00
pH8-70C3-1E	70	8	10	5	5.59	3.5073	7.96	12/21/01	1/4/02	14	42.50	46.01	48.81
pH8-70C3-2E	70	8	10B	5	5.59	3.5073	7.96	1/4/02	1/18/02	14	42.46	46.02	48.80
pH8-70C3-3E(98)	70	8	10C	5	5.59	3.5073	Nm	1/28/02	4/8/02	98	42.24	45.75	48.55
pH8-70C-1ER-1	70	8	11	11	5.63	3.6738	7.93	4/15/02	4/29/02	14	42.36	46.03	48.84
pH8-70C-2ER-1	70	8	11B	11	5.63	3.6738	7.88	4/30/02	5/14/02	14	42.47	46.14	48.97
pH8-70C-3ER-1	70	8	11C	11	5.63	3.6738	7.88	5/14/02	6/27/02	42	42.47	46.14	48.97
pH8-70C-1ER-2	70	8	12	12	5.62	3.6727	7.93	4/15/02	4/29/02	14	41.99	45.67	48.48
pH8-70C-2ER-2	70	8	12B	12	5.62	3.6727	7.88	4/30/02	5/14/02	14	42.53	46.20	49.01
pH8-70C-3ER-2	70	8	12C	12	5.62	3.6727	7.88	5/14/02	6/27/02	42	42.51	46.18	48.99
pH8-70C-1ER-3	70	8	13	13	5.62	3.6577	7.93	4/15/02	4/29/02	14	42.62	46.28	49.08
pH8-70C-2ER-3	70	8	13B	13	5.62	3.6577	7.88	4/30/02	5/14/02	14	42.53	46.18	48.99
pH8-70C-3ER-3	70	8	13C	13	5.62	3.6577	7.88	5/14/02	6/27/02	42	42.32	45.97	48.79

[a]Suffix "E" in Test No. indicates test conducted at ANL-E.
Suffix "EX" in Test No. indicates extra test conducted at ANL-E.
Suffix "(98)" in Test No. indicates total test duration was 98 days and third test interval was 70 days.
Suffix "ER" in Test No. indicates repeated test conducted at ANL-E.
[b]"nm" means not measured.

Table A.1. (contd.)

Test No.[a]	Leachant Mass, g	S/V, m^{-1}	Total Mass Out, g	Water Loss, g	Final pH	Bottle Mass, g	Bottle + Aliquot, g	Aliquot, g	B + A + water + HNO_3, g	Dilution Factor	Vessel + AS Mass, g	AS Aliquot Mass, g
pH4-90C-1E	2.81	199.6	48.51	0.03	3.93	8.28	10.45	2.17	21.05	5.88	69.32	27.19
pH4-90C-2E	2.80	200.4	48.77	0.00	3.98	8.22	10.31	2.09	20.18	5.72	71.59	29.22
pH4-90C-3E	2.81	199.6	48.86	0.01	4.61	8.33	10.42	2.09	20.53	5.84	69.56	27.09
pH4-50C-1E	2.79	200.0	48.89	0.00	3.94	8.34	10.52	2.18	19.08	4.93	67.77	25.22
pH4-50C-2E	2.79	200.0	48.41	0.00	4.00	8.28	10.42	2.14	20.35	5.64	71.13	29.06
pH4-50C-3E	2.79	200.0	48.86	-0.02	4.00	8.29	10.36	2.07	20.46	5.88	69.50	27.00
pH4-50C-1EX	2.82	199.3	nm	nm	4.00	10.87	12.98	2.11	20.97	4.79	71.07	28.96
pH4-50C-2EX	2.81	200.0	48.99	-0.03	4.02	10.85	12.92	2.07	20.47	4.65	68.48	25.92
pH4-50C-3EX	2.80	200.7	nm	nm	4.01	10.81	12.84	2.03	21.06	5.05	68.41	25.87
pH8-90C-1E	2.81	199.6	48.73	0.00	7.9	8.34	10.55	2.21	20.58	5.54	68.69	26.33
pH8-90C-2E	2.84	197.5	49.00	0.00	7.91	8.22	10.41	2.19	20.54	5.63	68.92	26.30
pH8-90C-3E(98)	2.81	199.6	48.78	0.10	7.85	8.27	10.38	2.11	20.11	5.61	69.25	26.72
pH8-90C-1ER	2.86	196.5	49.13	0.00	7.90	8.24	10.34	2.10	20.19	5.69	68.75	26.11
pH8-90C-2ER	2.85	197.2	48.91	-0.02	7.95	10.88	12.92	2.04	22.51	5.70	68.92	26.51
pH8-90C-3ER	2.86	196.5	48.66	-0.01	7.86	11.01	13.15	2.14	19.55	3.99	69.24	27.08
pH8-70C1-1E	2.81	200.0	48.94	-0.03	7.88	8.25	10.57	2.32	20.58	5.31	69.25	26.73
pH8-70C1-2E	2.83	198.6	49.02	0.01	7.91	8.33	10.49	2.16	20.70	5.73	69.57	26.91
pH8-70C1-3E(98)	2.81	200.0	48.52	0.01	7.86	8.26	10.35	2.09	21.06	6.12	70.26	28.08
pH8-70C2-1E	2.81	200.0	48.92	-0.10	7.88	8.32	10.55	2.23	20.87	5.63	68.60	26.20
pH8-70C2-2E	2.90	193.8	48.96	0.02	7.91	8.21	10.49	2.28	20.55	5.41	69.81	27.31
pH8-70C2-3E(98)	2.81	200.0	48.97	0.03	7.86	8.29	10.39	2.10	20.38	5.76	70.87	28.27
pH8-70C3-1E	2.80	199.6	48.96	-0.15	7.88	8.28	10.44	2.16	20.47	5.64	68.72	26.22
pH8-70C3-2E	2.83	197.5	48.79	0.01	7.91	8.30	10.50	2.20	20.69	5.63	69.56	27.08
pH8-70C3-3E(98)	2.81	198.9	48.54	0.02	7.86	8.24	10.29	2.05	23.89	7.63	69.71	27.45
pH8-70C1-1ER	2.81	200.4	48.86	-0.02	7.90	8.24	10.33	2.09	20.75	5.99	68.74	26.38
pH8-70C1-2ER	2.82	199.6	48.98	-0.01	7.87	10.84	12.94	2.10	21.93	5.28	69.84	27.37
pH8-70C1-3ER	2.83	198.9	48.99	-0.02	7.88	10.92	13.06	2.14	17.61	3.13	68.58	26.11
pH8-70C2-1ER	2.82	199.3	48.51	-0.02	7.91	8.26	10.36	2.10	20.48	5.82	69.01	27.02
pH8-70C2-2ER	2.80	200.7	49.05	-0.04	7.86	11.02	13.00	1.98	22.20	5.65	69.69	27.16
pH8-70C2-3ER	2.81	200.0	49.05	-0.06	7.88	10.84	12.76	1.92	18.07	3.77	70.29	27.78
pH8-70C3-1ER	2.81	200.0	49.10	-0.01	7.91	8.29	10.36	2.07	20.48	5.89	70.28	27.66
pH8-70C3-2ER	2.81	200.0	49.01	-0.02	7.86	10.93	13.00	2.07	22.37	5.53	68.96	26.43
pH8-70C3-3ER	2.81	200.0	48.81	-0.02	7.88	10.87	12.95	2.08	19.73	4.26	69.18	26.87

[a]Suffix "E" in Test No. indicates test conducted at ANL-E.
Suffix "EX" in Test No. indicates extra test conducted at ANL-E.
Suffix "(98)" in Test No. indicates total test duration was 98 days and third test interval was 70 days.
Suffix "ER" in Test No. indicates repeated test conducted at ANL-E.
[b]"nm" means not measured.

Table A.1. (contd.)

Test No.[a]	Temp. °C	pH Buffer	Vessel No.	Coupon No.	Surface Area, cm^2	Coupon mass, g	Initial pH	Initiation Date	End Date	Interval, d	Vessel Mass, g	Vessel+ Coupon, g	Total Mass In, g
pH8-50C-1EX	50	8	2	2	5.63	3.5770	7.90	7/19/02	8/2/02	14	42.14	45.72	48.54
pH8-50C-2EX	50	8	8	2	5.63	3.5770	7.89	8/2/02	8/16/02	14	42.42	nm	48.82
pH8-50C-3EX	50	8	13	2	5.63	3.5770	7.87	8/16/02	9/27/02	42	42.54	45.36	48.96
pH9-50C-1E	50	9	2	8	5.59	3.5966	9.03	12/21/01	1/4/02	14	42.34	45.94	48.77
pH9-50C-2E	50	9	2B	8	5.59	3.5966	9.03	1/4/02	1/18/02	14	42.63	46.23	49.02
pH9-50C-3E(98)	50	9	2C	8	5.59	3.5966	8.99	1/28/02	4/8/02	98	42.51	46.11	48.90
pH9-50C-1ER	50	9	15	15	5.63	3.7191	8.98	4/15/02	4/29/02	14	42.77	46.49	49.30
pH9-50C-2ER	50	9	15B	15	5.63	3.7191	8.92	4/30/02	5/14/02	14	42.50	46.22	49.05
pH9-50C-3ER	50	9	15C	15	5.63	3.7191	8.88	5/14/02	6/27/02	42	42.56	46.28	49.10
pH9-50C-1EX	50	9	3	3	5.65	3.6477	8.91	7/19/02	8/2/02	14	42.25	45.90	48.73
pH9-50C-2 EX	50	9	9	3	5.65	3.6477	8.87	8/2/02	8/16/02	14	42.94	nm	49.41
pH9-50C-3EX	50	9	14	3	5.65	3.6477	8.80	8/16/02	9/27/02	42	42.42	45.25	48.90
pH10-70C-1E	70	10	4	7	5.58	3.4784	9.97	1/28/02	2/11/02	14	42.21	45.69	48.49
pH10-70C-2E	70	10	4B	7	5.58	3.4784	9.95	2/14/02	2/28/02	14	42.52	46.00	48.79
pH10-70C-3E	70	10	4C	7	5.58	3.4784	9.86	1/28/02	4/8/02	70	43.27	46.75	49.54
pH10-50C-1EX	50	10	4	4	5.64	3.6430	9.84	7/19/02	8/2/02	14	42.40	46.04	48.84
pH10-50C-2EX	50	10	10	4	5.64	3.6430	9.76	8/2/02	8/16/02	14	42.61	nm	49.08
pH10-50C-3EX	50	10	15	4	5.64	3.6430	9.69	8/16/02	9/27/02	42	42.33	45.18	48.82
pH12-90C-1E	90	12	5	10	5.59	3.5449	11.84	1/28/02	2/11/02	14	42.38	45.92	48.73
pH12-90C-2E	90	12	5B	10	5.59	3.5449	11.94	2/14/02	2/28/02	14	42.59	46.14	48.94
pH12-90C-3E	90	12	5C	10	5.59	3.5449	11.88	2/28/02	4/12/02	70	42.24	45.79	48.59
pH12-50C-1E	50	12	1	9	5.58	3.5121	11.84	1/28/02	2/11/02	14	42.31	45.82	48.61
pH12-50C-2E	50	12	1B	9	5.58	3.5121	11.87	2/14/02	2/28/02	14	42.45	45.96	48.75
pH12-50C-3E	50	12	1C	9	5.58	3.5121	11.88	2/28/02	4/12/02	70	42.02	45.53	48.32
pH12-50C-1EX	50	12	5	5	5.63	3.6399	11.82	7/19/02	8/2/02	14	42.76	46.40	48.86
pH12-50C-2EX	50	12	11	5	5.63	3.6399	11.78	8/2/02	8/16/02	14	42.46	nm	48.92
pH12-50C-3EX	50	12	16	5	5.63	3.6399	11.68	8/16/02	9/27/02	42	42.21	45.04	48.70

[a]Suffix "E" in Test No. indicates test conducted at ANL-E.
Suffix "EX" in Test No. indicates extra test conducted at ANL-E.
Suffix "(98)" in Test No. indicates total test duration was 98 days and third test interval was 70 days.
Suffix "ER" in Test No. indicates repeated test conducted at ANL-E.
[b]"nm" means not measured.

Table A.1. (contd.)

Test No.[a]	Total Mass Out, g	Leachant Mass, g	S/V, m^{-1}	Water Loss, g	Final pH	Bottle Mass, g	Bottle + Aliquot, g	Aliquot, g	B + A + water + HNO_3, g	Dilution Factor	Vessel + AS Mass, g	AS Aliquot Mass, g
pH8-50C-1EX	nm	2.82	199.6	nm	7.90	10.92	13.05	2.13	20.73	4.61	70.47	28.33
pH8-50C-2EX	48.85	2.83	198.9	-0.03	7.90	10.98	12.87	1.89	20.42	4.99	68.48	26.06
pH8-50C-3EX	nm	2.84	198.2	nm	7.87	10.96	13.03	2.07	21.00	4.85	69.00	26.46
pH9-50C-1E	48.78	2.83	197.5	-0.01	8.85	8.27	10.55	2.28	20.56	5.39	68.69	26.35
pH9-50C-2E	49.02	2.79	200.4	0.00	8.85	8.27	10.41	2.14	20.47	5.70	69.48	26.83
pH9-50C-3E(98)	48.90	2.79	200.4	0.00	8.90	8.34	10.49	2.15	23.56	7.08	70.86	28.33
pH9-50C-1ER	49.30	2.83	198.9	0.00	8.83	8.22	10.42	2.20	20.09	5.40	70.26	27.49
pH9-50C-2ER	49.05	2.85	197.5	-0.01	8.81	10.88	13.06	2.18	22.52	5.34	69.76	27.26
pH9-50C-3ER	49.11	2.80	201.1	-0.01	8.87	11.07	13.36	2.29	17.98	3.02	69.28	26.72
pH9-50C-1EX	nm	2.80	201.8	nm	8.85	10.86	12.96	2.10	20.93	4.80	70.54	28.29
pH9-50C-2 EX	49.46	2.80	201.8	-0.05	8.83	10.91	13.07	2.16	20.55	4.46	70.41	27.47
pH9-50C-3EX	nm	2.79	202.5	nm	8.81	10.82	12.89	2.07	20.86	4.85	68.22	25.80
pH10-70C-1E	48.48	2.78	200.7	0.01	9.93	8.22	10.51	2.29	20.22	5.24	67.85	25.64
pH10-70C-2E	48.80	2.79	200.0	-0.01	9.68	8.26	10.43	2.17	20.39	5.59	68.64	26.12
pH10-70C-3E	49.55	2.47	225.9	-0.01	9.49	8.24	10.28	2.04	22.16	6.82	70.73	27.46
pH10-50C-1EX	nm	2.82	200.0	nm	9.45	10.95	13.06	2.11	20.78	4.66	70.10	27.70
pH10-50C-2EX	49.09	2.85	197.9	-0.01	9.47	10.81	12.83	2.02	20.43	4.76	69.60	26.99
pH10-50C-3EX	nm	2.81	200.7	nm	9.40	11.02	13.17	2.15	21.77	5.00	69.43	27.10
pH12-90C-1E	48.71	2.82	198.2	0.02	11.55	8.24	10.47	2.23	21.33	5.87	67.88	25.50
pH12-90C-2E	48.93	2.82	198.2	0.01	11.47	8.27	10.42	2.15	20.81	5.83	72.20	29.61
pH12-90C-3E	48.68	2.83	197.5	-0.09	10.57	8.26	10.27	2.01	24.67	8.16	71.26	29.02
pH12-50C-1E	48.62	2.83	197.2	0.00	11.44	8.32	10.62	2.30	20.27	5.20	67.95	25.64
pH12-50C-2E	48.75	2.83	197.2	0.00	11.16	8.23	10.36	2.13	20.46	5.74	71.54	29.09
pH12-50C-3E	48.33	2.80	199.3	-0.01	9.63	8.24	10.41	2.17	21.77	6.24	68.48	26.46
pH12-50C-1EX	nm	2.80	201.1	nm	11.06	10.77	12.96	2.19	20.74	4.55	71.86	29.10
pH12-50C-2EX	48.96	2.79	201.8	-0.04	NM	10.96	12.35	1.39	20.26	6.69	70.44	27.98
pH12-50C-3EX	nm	2.80	201.1	nm	11.10	10.86	13.01	2.15	21.20	4.81	69.33	27.12

[a]Suffix "E" in Test No. indicates test conducted at ANL-E.
Suffix "EX" in Test No. indicates extra test conducted at ANL-E.
Suffix "(98)" in Test No. indicates total test duration was 98 days and third test interval was 70 days.
Suffix "ER" in Test No. indicates repeated test conducted at ANL-E.
[b]"nm" means not measured.

Table A.2. Test Data for Tests Conducted at ANL-W

Test No.[a]	Temp. °C	pH Buffer	Vessel No.	Coupon No.	Coupon Area, cm^2	Coupon mass, g	Initial pH	Start Date	Initiation Date	Interval, d	Vessel Mass, g	Vessel+ Coupon, g
pH3-90C-1W	90	3	21	pH3-90C-1	5.70	3.487	3.0	2/7/02	2/21/02	14	42.57	nm[b]
pH3-90C-2W	90	3	31	pH3-90C-1	5.70	3.487	3.0	2/21/02	3/7/02	14	42.28	nm
pH3-90C-3W	90	3	41	pH3-90C-1	5.70	3.487	3.0	3/7/02	4/18/02	42	42.22	nm
pH3-50C-1W	50	3	22	pH3-50C-1	5.70	3.478	3.0	2/7/02	2/21/02	14	42.12	nm
pH3-50C-2W	50	3	32	pH3-50C-2	5.70	3.478	3.0	2/21/02	3/7/02	14	42.33	nm
pH3-50C-3W	50	3	42	pH3-50C-3	5.70	3.478	3.0	3/7/02	4/18/02	42	42.62	nm
pH3-50C-1WX	50	3	51	pH3-50C-A	5.70	3.6353	3.0	7/17/02	7/31/02	14	42.52	nm
pH3-50C-2WX	50	3	61	pH3-50C-A	5.70	3.6866	3.0	7/31/02	8/14/02	14	42.33	nm
pH3-50C-3WX	50	3	66	pH3-50C-A	5.70	3.6845	3.0	8/14/02	9/25/02	42	42.21	nm
pH4-90C-1W	90	4	23	pH4-90C-1	5.70	3.492	4.0	2/7/02	2/21/02	14	42.09	nm
pH4-90C-2W	90	4	33	pH4-90C-1	5.70	3.492	4.0	2/21/02	3/7/02	14	42.36	nm
pH4-90C-3W	90	4	43	pH4-90C-1	5.70	3.492	4.0	3/7/02	4/18/02	42	42.37	nm
pH4-50C-1WX	50	4	52	pH4-50C-B	5.64	3.4316	4.0	7/17/02	7/31/02	14	42.49	nm
pH4-50C-2WX	50	4	62	pH4-50C-B	5.64	3.4671	4.0	7/31/02	8/14/02	14	42.57	nm
pH4-50C-3WX	50	4	67	pH4-50C-B	5.64	3.4808	4.0	8/14/02	9/25/02	42	42.87	nm
pH6-70C1-1W	70	6	24	pH6-70C-1	5.70	3.510	6.0	2/7/02	2/21/02	14	42.49	nm
pH6-70C1-2W	70	6	34	pH6-70C-1	5.70	3.510	6.0	2/21/02	3/7/02	14	42.21	nm
pH6-70C1-3W	70	6	44	pH6-70C-1	5.70	3.510	6.0	3/7/02	4/18/02	42	42.60	nm
pH6-70C2-1W	70	6	25	pH6-70C-2	5.70	3.531	6.0	2/7/02	2/21/02	14	42.42	nm
pH6-70C2-2W	70	6	35	pH6-70C-2	5.70	3.531	6.0	2/21/02	3/7/02	14	42.00	nm
pH6-70C2-3W	70	6	45	pH6-70C-2	5.70	3.531	6.0	3/7/02	4/18/02	42	42.58	nm
pH6-70C3-1W	70	6	26	pH6-70C-3	5.70	3.494	6.0	2/7/02	2/21/02	14	42.50	nm
pH6-70C3-2W	70	6	36	pH6-70C-3	5.70	3.494	6.0	2/21/02	3/7/02	14	42.52	nm
pH6-70C3-3W	70	6	46	pH6-70C-3	5.70	3.494	6.0	3/7/02	4/18/02	42	42.58	nm
pH6-50C-1W	50	6	27	pH6-50C-1	5.70	3.159	6.0	2/7/02	2/21/02	14	42.35	nm
pH6-50C-2W	50	6	37	pH6-50C-1	5.70	3.159	6.0	2/21/02	3/7/02	14	42.40	nm
pH6-50C-3W	50	6	47	pH6-50C-1	5.70	3.159	6.0	3/7/02	4/18/02	42	42.51	nm
pH6-50C-1WX	50	6	53	pH6-50C-C	5.67	3.6405	6.0	7/17/02	7/31/02	14	42.50	nm
pH6-50C-2WX	50	6	63	pH6-50C-C	5.67	3.7468	6.0	7/31/02	8/14/02	14	42.23	nm
pH6-50C-3WX	50	6	68	pH6-50C-C	5.67	3.6885	6.0	8/14/02	9/25/02	42	42.69	nm
pH8-70C-1W	70	8	28	pH8-70C-1	5.70	3.530	8.0	2/7/02	2/21/02	14	42.08	nm
pH8-70C-2W	70	8	38	pH8-70C-1	5.70	3.530	8.0	2/21/02	3/7/02	14	42.57	nm
pH8-70C-3W	70	8	19	pH8-70C-1	5.70	3.530	8.0	3/7/02	4/18/02	42	42.57	nm
pH8-50C-1WX	50	8	54	pH8-50C-D	5.68	3.6180	7.9	7/17/02	7/31/02	14	42.53	nm
pH8-50C-2WX	50	8	64	pH8-50C-D	5.68	3.6622	8.0	7/31/02	8/14/02	14	41.98	nm
pH8-50C-3WX	50	8	69	pH8-50C-D	5.68	3.6584	8.0	8/14/02	9/25/02	42	42.53	nm

[a]Suffix "W" in Test No. indicates test conducted at ANL-W.
Suffix "WX" in Test No. indicates extra test conducted at ANL-W.
[b]"nm" means not measured.

Table A.2. (contd.)

Test No.[a]	Total Mass In, g	Leachant Mass, g	S/V, m^{-1}	Total Mass Out, g	Water Loss, g	Final pH	AS Aliquot Mass, g
pH3-90C-1W	48.92	2.85	200.0	48.92	0.00	4.2	4.0
pH3-90C-2W	48.66	2.85	200.0	48.66	0.00	3.7	4.0
pH3-90C-3W	48.58	2.85	200.0	48.57	0.01	4.4	4.0
pH3-50C-1W	48.45	2.85	200.0	48.45	0.00	3.4	4.0
pH3-50C-2W	48.73	2.86	200.0	48.78	-0.05	3.0	4.0
pH3-50C-3W	48.99	2.85	199.3	48.99	-0.00	3.9	4.0
pH3-50C-1WX	49.03	2.88	197.9	49.03	0.00	3.5	4.0
pH3-50C-2WX	48.88	2.84	200.7	48.87	0.01	3.3	4.0
pH3-50C-3WX	48.74	2.85	200.0	48.76	-0.02	4.6	4.0
pH4-90C-1W	48.43	2.85	200.0	48.39	0.04	4.2	4.0
pH4-90C-2W	48.76	2.85	200.0	48.73	0.03	4.1	4.0
pH4-90C-3W	48.75	2.85	200.0	48.73	0.02	4.5	4.0
pH4-50C-1WX	48.74	2.81	200.7	48.74	0.00	4.1	4.0
pH4-50C-2WX	48.89	2.84	198.6	48.88	0.01	4.2	4.0
pH4-50C-3WX	49.16	2.82	200.0	49.18	-0.02	4.5	4.0
pH6-70C1-1W	48.84	2.85	200.0	48.86	-0.02	6.0	4.0
pH6-70C1-2W	48.63	2.85	200.0	48.64	-0.01	5.8	4.0
pH6-70C1-3W	49.03	2.85	200.0	49.05	-0.02	6.1	4.0
pH6-70C2-2W	48.41	2.85	200.0	48.43	-0.02	5.9	4.0
pH6-70C2-3W	49.05	2.86	199.3	49.04	-0.01	6.0	4.0
pH6-70C2-1W	48.81	2.85	200.0	48.80	0.01	6.0	4.0
pH6-70C3-1W	48.85	2.85	200.0	48.85	0.00	6.0	4.0
pH6-70C3-2W	48.93	2.85	200.0	48.93	0.00	5.9	4.0
pH6-70C3-3W	48.99	2.87	198.6	48.93	0.01	5.9	4.0
pH6-50C-1W	48.37	2.86	199.3	48.37	0.00	6.0	4.0
pH6-50C-2W	48.48	2.86	199.3	48.54	-0.06	5.8	4.0
pH6-50C-3W	48.59	2.85	200.0	48.54	-0.01	6.0	4.0
pH6-50C-1WX	48.97	2.83	200.4	48.96	0.01	5.7	4.0
pH6-50C-2WX	48.82	2.84	199.6	48.81	0.01	5.9	4.0
pH6-50C-3WX	49.21	2.83	200.4	49.21	0.00	5.9	4.0
pH8-70C-1W	48.46	2.85	200.0	48.46	0.00	7.9	4.0
pH8-70C-2W	48.99	2.85	200.0	49.02	-0.03	7.9	4.0
pH8-70C-3W	49.10	2.85	200.0	49.10	-0.00	8.0	4.0
pH8-50C-1WX	48.99	2.84	200.0	48.99	0.00	7.9	4.0
pH8-50C-2WX	48.49	2.85	199.3	48.49	0.00	7.9	4.0
pH8-50C-3WX	49.05	2.86	198.6	49.05	0.00	7.9	4.0

[a]Suffix "W" in Test No. indicates test conducted at ANL-W.
Suffix "WX" in Test No. indicates extra test conducted at ANL-W.
[b]"nm" means not measured.

Table A.2. (contd.)

Test No.[a]	Temp. °C	pH Buffer	Vessel No.	Coupon No.	Coupon Area, cm^2	Coupon mass, g	Initial pH	Initiation Date	Sampling Date	Interval, d	Vessel Mass, g	Vessel+ Coupon, g
pH9-90C-1W	90	9	29	pH9-90C-1	5.70	3.506	9.0	2/7/02	2/21/02	14	42.31	nm[b]
pH9-90C-2W	90	9	39	pH9-90C-1	5.70	3.506	9.0	2/21/02	3/7/02	14	42.80	nm
pH9-90C-3W	90	9	17	pH9-90C-1	5.70	3.506	9.0	3/7/02	4/18/02	42	42.44	nm
pH9-50C-1W	50	9	30	pH9-50C-1	5.70	3.561	9.0	2/7/02	2/21/02	14	42.22	nm
pH9-50C-2W	50	9	40	pH9-50C-1	5.70	3.561	9.0	2/21/02	3/7/02	14	42.85	nm
pH9-50C-3W	50	9	18	pH9-50C-1	5.70	3.561	9.0	3/7/02	4/18/02	42	42.85	nm
pH9-50C-1WX	50	9	55	pH9-50C-E	5.67	3.5276	9.0	7/17/02	7/31/02	14	42.17	nm
pH9-50C-2WX	50	9	65	pH9-50C-E	5.67	3.5827	9.0	7/31/02	8/14/02	14	42.61	nm
pH9-50C-3WX	50	9	70	pH9-50C-E	5.67	3.5773	9.0	8/14/02	9/25/02	42	42.50	nm

[a]Suffix "W" in Test No. indicates test conducted at ANL-W.
Suffix "WX" in Test No. indicates extra test conducted at ANL-W.
[b]"nm" means not measured.

Table A.2. (contd.)

Test No.	Total Mass In, g	Leachant Mass, g	S/V m^{-1}	Total Mass Out, g	Final pH	Water Loss, g	AS Aliquot Mass, g
pH9-90C-1W	48.67	2.85	200.0	48.70	8.9	-0.03	4.0
pH9-90C-2W	49.19	2.85	200.0	49.18	8.8	0.01	4.0
pH9-90C-3W	48.88	2.86	199.5	48.86	9.0	0.02	4.0
pH9-50C-1W	48.64	2.85	200.0	48.64	8.9	0.00	4.0
pH9-50C-2W	49.31	2.85	200.0	49.32	8.9	-0.01	4.0
pH9-50C-3W	48.64	2.85	200.0	48.63	9.0	0.01	4.0
pH9-50C-1WX	49.04	2.85	198.9	49.05	8.8	-0.01	4.0
pH9-50C-2WX	49.04	2.84	199.6	49.04	8.8	0.00	4.0
pH9-50C-3WX	48.93	2.85	198.9	48.94	9.0	-0.01	4.0

APPENDIX B. MEASURED CONCENTRATIONS IN TEST SOLUTIONS

These tables summarize the results of solution analysis of the test solutions. Table B.1 provides data for the 14-day samplings, Table B.2 provides data for the 28-day samplings, and Table B.3 provides data for the 70-day samplings. Note that third sampling of some tests conducted at ANL-E occurred 98 days after test initiation (the final interval was 70 days). The designator "(98)" is appended to the test numbers for these tests. The headings for columns in Tables B.1, B.2, and B.2 are defined below.

Test No.	Test number.
Lab	Laboratory where test was conducted and solution analyzed: E = ANL-E and W = ANL-W
Temp.	Test temperature, in ºC.
Nominal pH	Nominal pH of leachant solution, no units.
Final pH	Measured pH of test solution (measured at room temperature), no units.
i	Element analyzed.

The values given in these tables for tests conducted at ANL-E are the products of the measured concentrations times the dilution factors for dilutions made by the experimenter. Dilution factors are given in Table A.1. Solutions from tests conducted at ANL-W were not diluted by the experimenter. (Adjustments due to additional dilutions made by the analyst during solution analysis were made before the results were reported.)

Table B.1. Concentrations in Test Solutions for 0-14 Day Interval, ng/mL[a]

Test No.	Nominal pH	Temp. °C	Final pH	Cr	Fe	Mn	Mo	Ni	U	Zr
pH3-90C-1W	3	90	4.20	32600	398000	16100	2100	66100	33800	297
pH3-50C-1W	3	50	3.40	50000	253000	4400	3100	23600	32700	3300
pH3-50C-1WX	3	50	3.50	16800	80900	2540	3100	18800	73900	3980
pH4-90C-1W	4	90	4.20	7200	34000	2480	498	11600	10600	127
pH4-90C-1E	4	90	3.93	15400	97100	4470	1570	22400	25100	641
pH4-50C-1E	4	50	3.94	8230	56100	1000	1200	11700	39800	2270
pH4-50C-1EX	4	50	4.00	3010	26500	503	536	5550	19600	1920
pH4-50C-1WX	4	50	4.10	7090	39200	912	948	7890	25400	2480
pH6-70C1-1W	6	70	6.00	30.2	<100	56.9	85.1	434	40.0	10.0
pH6-70C2-1W	6	70	6.00	11.0	<100	74.1	83.6	1020	57.8	<10
pH6-70C3-1W	6	70	6.00	17.6	<100	81.7	62.5	671	49.7	<10
average				*19.6*	*<100*	*70.9*	*77.1*	*708*	*49.2*	*10*
pH6-50C-1W	6	50	6.00	33.1	<100	279	264	2560	58.4	10
pH6-50C-1WX	6	50	5.70	<3	<30	21.8	33.6	83.2	33.2	4.15
pH8-70C-1W	8	70	7.90	<10.0	<100	16.2	76.6	81.3	55.3	15.0
pH8-90C-1E	8	90	7.90	66.5	81.4	27.7	49.1	55.1	118	3.38
pH8-90C-1ER	8	90	7.90	7.74	1195	24.8	102	82.5	92.2	6.07
pH8-50C-1EX	8	50	7.90	7.28	377	26.4	32.0	234	96.7	13.6
pH8-50C-1WX	8	50	7.90	4.35	<30	13.5	18.9	38.5	59.0	8.00
pH8-70C1-1E	8	70	7.88	67.5	199	40.8	85.6	88.2	120	4.41
pH8-70C2-1E	8	70	7.88	68.1	312	42.4	135	89.5	143	4.61
pH8-70C3-1E	8	70	7.88	67.7	167	40.4	126	67.7	102	3.78
average				*67.8*	*226*	*41.2*	*115*	*81.8*	*122*	*4.27*
pH8-70C1-1ER	8	70	7.90	6.05	1010	28.6	132	111	66.4	5.33
pH8-70C2-1ER	8	70	7.91	7.45	1120	33.6	53.4	130	170	4.73
pH8-70C3-1ER	8	70	7.91	8.72	1410	39.2	162	137	138	5.87
average				*7.40*	*1180*	*33.8*	*116*	*126*	*125*	*5.31*
pH9-90C-1W	9	90	8.90	143	8760	184	196	2630	1820	485
pH9-50C-1W	9	50	8.90	47.6	536	603	828	2200	3020	29.4
pH9-50C-1WX	9	50	8.80	262	420	388	980	1950	1860	75.6
pH9-50C-1E	9	50	8.85	100	490	16.7	69.0	69.0	940	0
pH9-50C-1ER	9	50	8.83	54.5	1710	69.6	108	202	1300	5.22
pH9-50C-1EX	9	50	8.85	5.23	377	8.30	33.2	21.8	315	5.99
pH10-70C-1E	10	70	9.93	121	2210	23.0	237	177	2860	50.9
pH10-50C-1EX	10	50	9.45	7.45	295	3.25	78.7	333	1060	59.2
pH12-90C-1E	12	90	11.55	126	3490	20.9	223	95.1	3610	15.3
pH12-50C-1E	12	50	11.44	25.4	2750	-16	34.5	59.2	336	11.3
pH12-50C-1EX	12	50	11.06	18.5	1402	-2	67.4	19.2	733	8.19

[a]Values in table are measured concentrations multiplied by dilution factor.

Table B.2. Concentrations in Test Solutions for 14-28 Day Interval, ng/mL[a]

Test No.	Nominal pH	Temp (C)	Final pH	Cr	Fe	Mn	Mo	Ni	U	Zr
pH3-90C-2W	3	90	3.7	18300	233000	14200	1060	60300	12800	35.0
pH3-50C-2W	3	50	3.0	23600	99200	1800	1080	8610	6880	867
pH3-50C-2WX	3	50	3.3	95300	532000	8810	6900	38900	34700	6890
pH4-90C-2W	4	90	4.1	12100	60700	4620	570	18700	7010	<10
pH4-90C-2E	4	90	3.98	12500	130000	6870	549	26100	9500	33
pH4-50C-2E	4	50	4.0	2800	28991	463	524	6091	28600	1040
pH4-50C-2EX	4	50	4.02	2690	27400	530	660	6878	36900	2440
pH4-50C-2WX	4	50	4.0	56600	316000	6270	4100	36000	61100	7000
pH6-70C1-2W	6	70	5.8	6.70	139	15.4	58.4	42.4	10.5	<0.3
pH6-70C2-2W	6	70	5.9	11.5	<30	22.7	200	163	14.1	0.525
pH6-70C3-2W	6	70	5.9	12.3	<30	18.9	90.2	47.6	12.7	<0.3
average				*10.2*	*66.3*	*19.0*	*116*	*84.3*	*12.4*	*0.375*
pH6-50C-2W	6	50	5.8	13.3	<30	141	307	860	91.5	5.15
pH6-50C-2WX	6	50	5.9	2.55	<30	6.80	25.6	22.7	6.65	1.63
pH8-70C-2W	8	70	7.9	22.6	50.1	11.7	238	9.63	14.0	3.88
pH8-90C-2E	8	90	7.91	18.8	2840	44.9	20.1	83.3	28.4	15.4
pH8-90C-2ER	8	90	7.95	10.7	1030	26.8	56.7	70.7	123	6.39
pH8-50C-2EX	8	50	7.9	8.44	352	16.7	270	64.4	37.4	16.0
pH8-50C-2WX	8	50	7.9	3.45	<30	8.05	2.23	29.6	21.5	168
pH8-70C1-2E	8	70	7.91	18.7	2230	25.4	16.7	98.5	22.3	11.8
pH8-70C2-2E	8	70	7.91	17.9	2150	37.7	74.1	108	30.7	12.3
pH8-70C3-2E	8	70	7.91	20.7	2478	25.7	24.9	98.0	18.5	12.4
average				*19.1*	*2290*	*29.6*	*38.6*	*102*	*23.8*	*12.2*
pH8-70C-1-2ER	8	70	7.87	9.9	956	24.8	137	68.1	197	5.60
pH8-70C-2-2ER	8	70	7.86	13.9	1220	23.7	119	89.8	227	6.21
pH8-70C-3-2ER	8	70	7.86	15.3	1030	26.4	77.4	82.3	147	6.47
average				*13.0*	*1070*	*24.9*	*111*	*80.1*	*190*	*6.09*
pH9-90C-2W	9	90	8.8	166	8200	170	442	2990	2360	909
pH9-50C-2W	9	50	8.9	38.2	4960	309	634	1870	4100	208
pH9-50C-2WX	9	50	8.8	126	422	1060	1450	3200	882	8.20
pH9-50C-2E	9	50	8.85	1174	6390	165	397	770	2210	164
pH9-50C-2ER	9	50	8.81	10.1	519	11.2	101	28.7	1150	6.09
pH9-50C-2 EX	9	50	8.83	29.4	536	12.9	93.7	49.5	287	12.8
pH10-70C-2E	10	70	9.68	43.8	2270	12.4	246	67.1	1170	24.7
pH10-50C-2EX	10	50	9.47	4.38	304	2.70	45.5	13.6	220	45.0
pH12, 90C-2E	12	90	11.47	94.5	2570	11.0	122	63.6	3280	26.5
pH12, 50C-2E	12	50	11.16	31.7	2730	10.5	33.6	65.4	110	26.1
pH12-50C-2EX	12	50	11.78	13.7	850	<3.18	58.9	108	99.0	9.30

[a]Values in table are measured concentrations multiplied by dilution factor.

Table B.3. Concentrations in Test Solutions for 28-70 Day Interval, ng/mL[a]

Test No.	Nominal pH	Temp (C)	Final pH	Cr	Fe	Mn	Mo	Ni	U	Zr
pH3-90C-3W	3	90	4.40	43300	256000	29200	1170	126000	17500	<10
pH3-50C-3W	3	50	3.90	55900	214000	10000	4710	52500	110000	<10
pH3-50C-3WX	3	50	4.60	31500	110000	11400	1530	63300	31300	581
pH4-90C-3W	4	90	4.50	20400	23600	10400	718	40000	11300	<10
pH4-90C-3E	4	90	4.61	63000	562000	12800	3421	46700	23200	472
pH4-50C-3E	4	50	4.00	4920	42200	711	882	9350	24800	2050
pH4-50C-3EX	4	50	4.01	8180	62100	1151	1252	11000	38600	3460
pH4-50C-3WX	4	50	4.50	69300	428000	1530	4200	8250	9000	3820
pH6-70C1-3W	6	70	6.10	<3	<30	11.9	142	94.4	9.60	<3
pH6-70C2-3W	6	70	6.00	<3	<30	12.0	99.5	144	13.2	<3
pH6-70C3-3W	6	70	5.90	<3	<30	17.5	66.4	107	11.1	<3
average				*<3*	*<30*	*13.8*	*103*	*115*	*11.3*	*<3*
pH6-50C-3W	6	50	6.00	<3	<30	103	87.2	682	23.2	<3
pH6-50C-3WX	6	50	5.90	4.95	<30	6.18	1.05	24.6	3.60	13.5
pH8-70C-3W	8	70	8.00	6.20	<30	5.80	64.3	30.7	12.6	<3
pH8-90C-3E(98)	8	90	7.85	123	7630	28.7	152	141	145	31.0
pH8-90C-3ER	8	90	7.86	9.8	862	16.7	84.2	63.5	160	4.39
pH8-50C-3EX	8	50	7.87	3.50	412	14.6	86.3	55.3	21.7	6.31
pH8-50C-3WX	8	50	7.90	452	2560	448	5800	6150	3470	30.9
pH8-70C1-3E(98)	8	70	7.86	129	7410	30.3	178	161	20.0	34.3
pH8-70C2-3E(98)	8	70	7.86	127	6970	30.8	42.4	197	27.8	32.6
pH8-70C3-3E(98)	8	70	7.86	151	9160	39.1	47.1	158	13.7	44.0
average				*136*	*7847*	*33.4*	*89.2*	*172*	*20.5*	*37.0*
pH8-70C1-3ER	8	70	7.88	5.10	788	18.4	216	67.5	51.0	9.47
pH8-70C2-3ER	8	70	7.88	7.08	<627	14.2	99.0	57.1	70.7	7.88
pH8-70C3-3ER	8	70	7.88	7.28	1108	23.4	271	57.1	70.7	7.88
average				*6.49*	*948*	*18.7*	*196*	*60.6*	*64.1*	*8.41*
pH9-90C-3W	9	90	9.00	176	6300	199	421	3510	809	<3
pH9-50C-3W	9	50	9.00	208	11200	517	867	2450	4290	<3
pH9-50C-3WX	9	50	9.00	10.0	<30	2.55	8.78	71.0	31.1	69.5
pH9-50C-3E(98)	9	50	8.90	26800	40209	3271	3065	4771	4736	1409
pH9-50C-3ER	9	50	8.87	10300	81200	4320	3470	6190	4980	655
pH9-50C-3EX	9	50	8.81	567	3700	139	747	333	1060	59.2
pH10-70C-3E	10	70	9.49	201	8666	28.2	162	155	3848	40.7
pH10-50C-3EX	10	50	9.40	4.51	<394	2.62	33.8	20.0	363	16.3
pH12, 90C-3E	12	90	10.57	361	11103	21.8	183	146	6556	45.0
pH12, 50C-3E	12	50	9.63	130	7170	29.1	29.9	97.3	159	33.9
pH12-50C-3EX	12	50	11.68	9.9	408	2.57	39.6	11.8	160	4.60

[a]Values in table are measured concentrations multiplied by dilution factor.

APPENDIX C. MEASURED CONCENTRATIONS IN ACID SOAK SOLUTIONS

These tables summarize the results of solution analysis of the acid soak solutions and leachant solutions. Table C.1 provides data for the 14-day samplings, Table C.2 provides data for the 28-day samplings, and Table C.3 provides data for the 70-day samplings. Note that third sampling of some tests conducted at ANL-E occurred 98 days after test initiation (the final interval was 70 days). The designator "(98)" is appended to the test numbers for these tests. The headings for columns in Tables C.1, C.2, and C.2 are defined below.

Test No.	Test number.
i	Element analyzed.

The values given in these tables are the measured concentrations.

Table C.1 Results for Acid Soak Solutions for 0-14 Day Interval, ng/mL

Test No.	Cr	Fe	Mn	Mo	Ni	U	Zr
pH3-90C-1W	40000	299000	1130	2370	6250	6600	4000
pH3-50C-1W	9700	40600	717	764	4130	7010	1600
pH3-50C-1WX	12600	52700	265	847	2320	7540	4050
pH4-90C-1W	2000	53500	161	188	859	799	247
pH4-90C-1E	974	12200	17.3	81.0	225	209	37.7
pH4-50C-1E	28.0	471	<3	7.17	20.4	24.6	15.4
pH4-50C-1EX	17.1	151	1.64	7.68	28.4	79.8	28.0
pH4-50C-1WX	550	2320	47.0	163	497	1170	1130
pH6-70C1-1W	24.0	487	<10	62.5	34.6	<10	<10
pH6-70C2-1W	12.1	1100	<10	40.9	90.7	<10	25.5
pH6-70C3-1W	27.9	1420	10.7	21.4	64.9	<10	26.0
average	*21.3*	*1002*	*10.2*	*41.6*	*63.4*	*<10*	*20.5*
pH6-50C-1W	81.9	856	21.2	89.8	273	42.8	58.9
pH6-50C-1WX	46.0	<30	9.78	30.2	135	129	258
pH8-70C-1W	<10	<100	<10	77.7	67.6	15.0	31.9
pH8-90C-1E	<2	5	0	1	14	0	0
pH8-90C-1ER	1	72.3	0	8	11	0	0
pH8-50C-1EX	0.502	50.2	0.421	8.83	14.8	1.33	0.44
pH8-50C-1WX	76.9	<30	14.8	33.5	193	244	493
pH8-70C1-1E	<2	14	0	3	13	0.23	0.05
pH8-70C2-1E	<2	7	0	2	8	0.28	0.06
pH8-70C3-1E	<2	15	0	4	13	0.27	0.03
average	*<2*	*12*	*0*	*3*	*11*	*0.26*	*0.05*
pH8-70C1-1ER	2	<29	0	8	8	0.83	0.34
pH8-70C2-1ER	1	<29	0	5	21	1	1
pH8-70C3-1ER	<0.2	<29	0.2	13.8	14.5	0.4	0.3
average	*1*		*0*	*9*	*15*	*1*	*1*
pH9-90C-1W	<10	686	16.2	21.1	126	632	53.9
pH9-50C-1W	67.8	2170	46.8	92.2	133	162	117
pH9-50C-1WX	2610	8810	141	172	860	1700	820
pH9-50C-1E	7.50	66.2	2.42	6.28	56.6	7.36	0.790
pH9-50C-1ER	0.784	0	<29	16.2	0.588	14.0	0.357
pH9-50C-1EX	0.37	<41	0.288	7.48	50.4	1.22	0.448
pH10-70C-1E	2.86	445	<3	3.39	50.0	0.67	2.36
pH10-50C-1EX	0.312	<41	4.26	9.18	13.4	1.91	2.47
pH12-90C-1E	2.82	440	<3	2.95	33.2	0.93	2.28
pH12-50C-1E	2.39	409	<3	2.37	21.6	0.32	2.28
pH12-50C-1EX	0.795	<41	0.436	6.6	18.2	0.646	0.594

Table C.2. Results for Acid Soak Solutions for 14-28 Day Interval, ng/mL

Test No.	Cr	Fe	Mn	Mo	Ni	U	Zr
pH3-90C-2W	63800	388000	1280	4320	9340	14900	14800
pH3-50C-2W	1650	<30	69.0	<10	<10	400	265
pH3-50C-2WX	11400	36800	670	1270	4710	8290	7820
pH4-90C-2W	15100	131000	796	1460	8760	18800	15400
pH4-90C-2E	1390	23100	53.2	131	488	615	124
pH4-50C-2E	21.0	142	1.51	7.42	29.1	80.8	31.5
pH4-50C-2EX	16.9	113	1.62	4.27	30.3	98.2	30.8
pH4-50C-2WX	6960	41400	311.0	517	2410	5430	4310
pH6-70C1-2W	60.1	1310	9.40	121	47.6	8.83	20.6
pH6-70C2-2W	15.4	223	7.43	106	156	1.50	6.83
pH6-70C3-2W	14.6	<30	4.13	32.7	43.2	1.60	19.1
average	*30*	*521*	*7.0*	*87*	*82*	*4.0*	*16*
pH6-50C-2W	64.6	1690	14.6	88.3	335	36	22.2
pH6-50C-2WX	8.18	<30	2.78	21.2	72.2	7.08	22.3
pH8-70C-2W	8.15	<30	3.10	40.8	23	4	16.2
pH8-90C-2E	3	442	-3	4	20	0	2
pH8-90C-2ER	1	52	0	7	26	0	1
pH8-50C-2EX	0	<41	<0.13	3.86	10.2	0.175	0.371
pH8-50C-2WX	11.3	<30	3.0	4.0	76	31.5	121
pH8-70C1-2E	3	434	<3	4	23	0	2
pH8-70C2-2E	3	468	<3	8	49	0	2
pH8-70C3-2E	3	446	<3	3	16	0	2
average	*3*	*449*	*<3*	*5*	*29*	*0*	*2*
pH8-70C1-2ER	1	63	0	6	14	0	1
pH8-70C2-2ER	1	67	0	4	21	1	1
pH8-70C3-2ER	1.3	226	1.3	1.0	20.7	0.6	1.0
average	*1*	*119*	*0*	*3*	*19*	*1*	*1*
pH9-90C-2W	20.3	321	9.83	73.9	239	211	42.8
pH9-50C-2W	191	1530	23.3	31.6	186	207	83.3
pH9-50C-2WX	17200	52000	556	1040	2340	2510	511
pH9-50C-2E	162	700	6.26	4.88	50.8	66.5	12.2
pH9-50C-2ER	1.38	58.8	0.52	4.22	26.7	0.498	1.05
pH9-50C-2 EX	1.46	<41	0.548	1.66	25.0	0.669	0.451
pH10-70C-2E	1.50	35	0.468	6.66	7.24	1.47	3.61
pH10-50C-2EX	0.264	<41	0	1.85	9.14	0.495	0.496
pH12, 90C-2E	0.873	34.3	0.46	27.9	5.04	5.29	1.03
pH12, 50C-2E	0.779	41.4	0.30	0.96	14.6	0.48	0.86
pH12-50C-2EX	0.248	<41	0.225	2.67	8.2	0.149	0.345

Table C.3. Results for Acid Soak Solutions for 28-70 Day Interval, ng/mL

Test No.	Cr	Fe	Mn	Mo	Ni	U	Zr
pH3-90C-3W	183000	1050000	3770	6420	22400	13400	11100
pH3-50C-3W	46600	212000	539	2210	3490	7360	3220
pH3-50C-3WX	16600	119000	3540	1280	15700	16600	550
pH4-90C-3W	43400	323000	2720	5500	31700	112000	54200
pH4-90C-3E	1260	20900	150	157	1070	570	51
pH4-50C-3E	6.5	55.8	0.2	3.1	23.5	9.7	18.7
pH4-50C-3EX	113	447	1.7	14.8	29.1	87.1	40.9
pH4-50C-3WX	8200	101000	491	698	4000	6400	4960
pH6-70C1-3W	13.7	199	3.55	84.4	87.7	2.65	<3
pH6-70C2-3W	6.08	66.3	2.03	24.7	118	<0.3	<3
pH6-70C3-3W	14.4	166	3.13	42.2	102	2.18	15.1
average	*11.4*	*143.7*	*2.9*	*45.6*	*103*	*1.7*	*7.0*
pH6-50C-3W	6.08	<30	2.2	29.3	85.1	7.38	55.2
pH6-50C-3WX	2.83	<30	5.03	6.98	21.6	8.25	32.1
pH8-70C-3W	4.53	<30	0.925	22.0	29.8	<0.3	<3.0
pH8-90C-3E(98)	0.7	<49	0.3	13.9	22.1	1.1	0.2
pH8-90C-3ER	0.3	<83	<0.3	4.7	22.4	0.2	0.2
pH8-50C-3EX	0.495	45.8	0.26	1.43	18.0	<0.06	0.350
pH8-50C-3WX	3.65	<30	1.80	10.9	53.2	6.38	18.3
pH8-70C1-3E(98)	0.7	<49	0.2	3.85	23.0	0.2	1.3
pH8-70C2-3E(98)	<0.4	<49	0.1	0.86	3.2	0.1	0.2
pH8-70C3-3E(98)	<0.4	<49	<0.1	2.42	10.8	0.1	0.4
average	*0.0*		*0.1*	*2.38*	*12.3*	*0.1*	*0.6*
pH8-70C1-3ER	0.5	<83	<0.3	5.78	32.7	0.2	0.4
pH8-70C2-3ER	<0.2	<83	<0.3	3.15	15.1	0.2	0.1
pH8-70C3-3ER	<0.2	<83	<0.3	3.15	15.1	0.2	0.1
average	*0.0*	<83	<0.3	*4.03*	*21.0*	*0.2*	*0.2*
pH9-90C-3W	14.2	907	5.58	68.2	137	254	17.2
pH9-50C-3W	1270	4740	28.2	60.5	235	378	70.9
pH9-50C-3WX	42200	221000	3880	2360	10900	9340	1560
pH9-50C-3E(98)	9.19	121.0	10.3	4.6	40.3	5.28	0.80
pH9-50C-3ER	13.7	155.0	9.76	19.8	36.7	5.01	1.50
pH9-50C-3EX	2.14	<40	1.13	2.45	22.4	1.01	0.438
pH10-70C-3E	0.472	<49	0.175	3.59	23.6	1.08	0.424
pH10-50C-3EX	0.530	<40	0.304	0.992	25.3	0.065	0.216
pH12, 90C-3E	0.450	<49	0.166	2.48	11.9	0.208	0.722
pH12, 50C-3E	<0.4	<49	0.177	2.83	8.15	0.034	0.463
pH12-50C-3EX	0.689	<40	0.206	1.45	49.1	0.109	0.289

APPENDIX D. MEASURED CONCENTRATIONS IN BLANK TEST SOLUTIONS

These tables summarize the results of solution analysis for blank tests conducted with leachant only. Table D.1 provides data for the 14-day blank test solutions and demineralized water. Table C.2 provides the background values used for each test series (the same background concentrations are used for all samplings). The headings for columns in Tables D.1 and D.2 are defined below.

Test Series	Test numbers without digits indicating test interval.
Lab	Laboratory where test was conducted and solution analyzed: E = ANL-E and W = ANL-W
Temp.	Test temperature, in ºC.
Nominal pH	Nominal pH of leachant solution, no units.
i	Element analyzed.

Table D.1. Concentrations Measured in 14-Day Blank Tests and in Demineralized Water, ng/mL

Lab [a]	Nominal pH	Temp., °C	Cr	Fe	Mn	Mo	Ni	U	Zr
Leachant Solutions from Blank Tests									
W	3	50	26.0	172	1.39	5.47	84.2	<1	13.0
E	4	90	49.3	1240	8.89	8.87	56.5	<0.2	6.20
E	4	50	27.1	1040	2.4	3.78	4.54	<0.2	6.66
W	4	50	27.2	352	3.88	14.2	21.7	<1	6.83
W	6	50	5.28	27.2	2.40	7.81	21.8	<1	37.6
E	8	90	15.8	1150	6.12	5.79	6.09	<0.2	7.09
E	8	70	14.3	1070	4.71	5.05	5.23	<0.2	7.00
W	8	50	5.55	61.8	2.14	56.4	16.5	<1	18.8
E	9	50	16.3	1620	4.96	5.1	<4.1	<0.2	6.02
W	9	50	1.85	40.0	1.88	27.1	26.2	<1	9.48
E	10	70	10.5	1090	2.5	3.2	<4.1	<0.2	6.00
E	10	70	9.72	1040	3.27	5.69	<4.1	<0.2	5.68
E	12	90	10.9	1020	1.05	3.61	<4.1	<0.2	10.3
E	12	50	10.7	1010	<1	3.52	<4.1	<0.2	7.27
Demineralized Water Used for Acid Soak									
E			<0.26	<39.4	<0.13	<0.29	<1.0	<0.06	<0.02

[a]"E" indicates leachants analyzed at ANL-E.
"W" indicates leachants analyzed at ANL-W.

Table D.2. Background Concentrations Used for All Test Intervals, ng/mL

Test Series[a]	Cr	Fe	Mn	Mo	Ni	U	Zr
pH3-90C-W	26.0	172	1.39	5.47	84.2	<1	13.0
pH3-50C-W	26.0	172	1.39	5.47	84.2	<1	13.0
pH3-50C-WX	26.0	172	1.39	5.47	84.2	<1	13.0
pH4-90C-W	27.2	352	3.88	14.2	21.7	<1	6.83
pH4-90C-E	49.3	1240	8.89	8.87	56.5	<0.2	6.20
pH4-50C-E	27.1	1040	2.4	3.78	4.54	<0.2	6.66
pH4-50C-EX	27.1	1040	2.4	3.78	4.54	<0.2	6.66
pH4-50C-WX	27.2	352	3.88	14.2	21.7	<1	6.83
pH6-70C1-W	5.28	27.2	2.40	7.81	21.8	<1	37.6
pH6-70C2-W	5.28	27.2	2.40	7.81	21.8	<1	37.6
pH6-70C3-W	5.28	27.2	2.40	7.81	21.8	<1	37.6
pH6-50C-W	5.28	27.2	2.40	7.81	21.8	<1	37.6
pH6-50C-WX	5.28	27.2	2.40	7.81	21.8	<1	37.6
pH8-70C-W	5.55	61.8	2.14	56.4	16.5	<1	18.8
pH8-90C-E(98)	15.8	1150	6.12	5.79	6.09	<0.2	7.09
pH8-90C-ER	15.8	1150	6.12	5.79	6.09	<0.2	7.09
pH8-50C-EX	15.8	1150	6.12	5.79	6.09	<0.2	7.09
pH8-50C-WX	5.55	61.8	2.14	56.4	16.5	<1	9.48
pH8-70C1-E(98)	14.3	1070	4.71	5.05	5.23	<0.2	7.00
pH8-70C2-E(98)	14.3	1070	4.71	5.05	5.23	<0.2	7.00
pH8-70C3-E(98)	14.3	1070	4.71	5.05	5.23	<0.2	7.00
pH8-70C1-ER	14.3	1070	4.71	5.05	5.23	<0.2	7.00
pH8-70C2-ER	14.3	1070	4.71	5.05	5.23	<0.2	7.00
pH8-70C3-ER	14.3	1070	4.71	5.05	5.23	<0.2	7.00
pH9-90C-W	1.85	40.0	1.88	27.1	26.2	<1	9.48
pH9-50C-W	1.85	40.0	1.88	27.1	26.2	<1	9.48
pH9-50C-WX	1.85	40.0	1.88	27.1	26.2	<1	9.48
pH9-50C-E(98)	16.3	1620	4.96	5.1	<4.1	<0.2	6.02
pH9-50C-ER	16.3	1620	4.96	5.1	<4.1	<0.2	6.02
pH9-50C-EX	16.3	1620	4.96	5.1	<4.1	<0.2	6.02
pH10-70C-E	10.5	1090	2.5	3.2	<4.1	<0.2	6.00
pH10-50C-EX	10.5	1090	2.5	3.2	<4.1	<0.2	6.00
pH12-90C-E	10.9	1020	1.05	3.61	<4.1	<0.2	10.3
pH12-50C-E	10.7	1010	<1	3.52	<4.1	<0.2	7.27
pH12-50C-EX	10.7	1010	<1	3.52	<4.1	<0.2	7.27

[a]Suffix "E" indicates tests conducted at ANL-E.
Suffix "ER" indicates repeated test conducted at ANL-E.
Suffix "EX" indicates extra test conducted at ANL-E.
Suffix "W" indicates tests conducted at ANL-W.
Suffix "WX" indicates extra test conducted at ANL-W.
Suffix "(98)" indicates test conducted for 98 days at ANL-E.

APPENDIX E. TOTAL MASS RELEASED

These tables summarize the total mass released during the test intervals and the cumulative mass released. Table E.1 provides data for the 14-day samplings, Table E.2 provides data for the 28-day samplings, and Table E.3 provides data for the 70-day samplings. Note that third sampling of some tests conducted at ANL-E occurred 98 days after test initiation (the final interval was 70 days). The designator "(98)" is appended to the test numbers for these tests. The headings for columns in Tables E.1, E.2, and E.3 are defined below.

Test No.	Test number. The suffix indicates the laboratory where test was conducted and solution analyzed: E = ANL-E and W = ANL-W.
i	Element analyzed, no units. The mass released is the sum of the masses in the test solution and acid soak solution, minus the background concentrations. The blank tests are used to determine the backgrounds for the test solutions at the same nominal pH. Demineralized water is used to determine the backgrounds for the acid soak solutions, which is zero for all elements.
Test Series	Test numbers without digits indicating test interval.

The mass in the test solution is calculated as

(Concentration in test solution – concentration in blank test) x (volume of test solution)

The mass in the acid soak solution is calculated as

(Concentration in acid soak solution) x (volume of acid soak solution)

Values used in these calculations are obtained from other Appendices:
Concentration in test solution is from Appendix B column "i"
Concentration in blank test is from Appendix D column "i"
Volume of test solution is from Appendix A column "Leachant Mass"
Concentration in acid soak solution is from Appendix C column "i"
Volume of acid soak solution is from Appendix A column "AS mass"

Sample calculation for Cr in test pH3-90C-1W
Concentration in test solution from Appendix B Table B.1 column "Cr" is 32600 ng/mL.
Concentration in blank test from Appendix D Table D.2 column "Cr" is 26 ng/mL.
Volume of test solution from Appendix A Table A.2 column "Leachant Mass" is 2.85 g.
Concentration in acid soak solution from Appendix C Table C.1 column "Cr" is 40000.
Volume of acid soak solution from Appendix A, Table A.2, column "AS Aliquot mass" is 4.0 g.

(32600 -26 ng/mL) x (2.85 g) x (1 mL/g) + (40000 ng/mL) x (4.0 g) x (1 mL/g) =
2.528×10^5 ng = 2.528×10^2 micrograms.

Table E.1. Total Mass Released During 0-14 Day Interval, micrograms[a]

Test No.	Cr	Fe	Mn	Mo	Ni	U	Zr
pH3-90C-1W	2.53E+02	2.33E+03	5.04E+01	1.54E+01	2.13E+02	1.23E+02	1.68E+01
pH3-50C-1W	1.81E+02	8.83E+02	1.54E+01	1.19E+01	8.35E+01	1.21E+02	1.58E+01
pH3-50C-1WX	9.81E+01	4.40E+02	8.28E+00	1.22E+01	6.25E+01	2.40E+02	2.75E+01
pH4-90C-1W	2.84E+01	3.10E+02	7.70E+00	2.13E+00	3.64E+01	3.34E+01	1.33E+00
pH4-90C-1E	6.95E+01	6.01E+02	1.30E+01	6.58E+00	6.90E+01	7.63E+01	2.81E+00
pH4-50C-1E	2.36E+01	1.66E+02	2.86E+00	3.24E+00	3.32E+01	1.12E+02	6.69E+00
pH4-50C-1EX	8.91E+00	7.61E+01	1.46E+00	1.72E+00	1.65E+01	5.77E+01	6.19E+00
pH4-50C-1WX	2.23E+01	1.20E+02	2.77E+00	3.31E+00	2.44E+01	7.69E+01	1.16E+01
pH6-70C1-1W	1.67E-01	2.16E+00	1.95E-01	4.70E-01	1.31E+00	1.54E-01	0
pH6-70C2-1W	6.47E-02	4.61E+00	2.44E-01	3.80E-01	3.21E+00	2.05E-01	2.33E-02
pH6-70C3-1W	1.47E-01	5.89E+00	2.69E-01	2.41E-01	2.11E+00	1.82E-01	2.53E-02
average	1.26E-01	4.22E+00	2.36E-01	3.64E-01	2.21E+00	1.80E-01	3.34E-03
pH6-50C-1W	4.07E-01	3.63E+00	8.73E-01	1.09E+00	8.33E+00	3.38E-01	1.57E-01
pH6-50C-1WX	1.78E-01	1.28E-01	9.41E-02	1.94E-01	7.15E-01	6.10E-01	9.36E-01
pH8-70C-1W	5.27E-02	5.09E-01	8.01E-02	3.68E-01	4.55E-01	2.18E-01	1.43E-01
pH8-90C-1E	1.95E-01	0	5.48E-02	1.40E-01	5.14E-01	3.38E-01	0
pH8-90C-1ER	2.80E-03	2.01E+00	6.39E-02	4.74E-01	4.92E-01	2.64E-01	1.35E-03
pH8-50C-1EX	0	0	6.91E-02	3.24E-01	1.06E+00	3.10E-01	3.08E-02
pH8-50C-1W	3.04E-01	2.95E-02	9.17E-02	2.72E-02	8.33E-01	1.14E+00	1.97E+00
pH8-70C1-1E	2.03E-01	0	1.08E-01	3.17E-01	5.89E-01	3.43E-01	0
pH8-70C2-1E	2.04E-01	0	1.00E-01	4.06E-01	4.38E-01	4.10E-01	0
pH8-70C3-1E	2.03E-01	0	1.06E-01	4.33E-01	5.16E-01	2.94E-01	0
average	2.03E-01	0	1.05E-01	3.85E-01	5.14E-01	3.49E-01	0
pH8-70C1-1ER	2.18E-02	6.00E-01	7.36E-02	5.82E-01	5.21E-01	2.09E-01	4.27E-03
pH8-70C2-1ER	0	9.33E-01	8.59E-02	2.72E-01	9.19E-01	4.99E-01	2.71E-02
pH8-70C3-1ER	0	1.77E+00	1.01E-01	8.23E-01	7.72E-01	4.00E-01	4.39E-03
average	2.18E-02	1.77E+00	8.69E-02	5.59E-01	7.37E-01	3.69E-01	1.19E-02
pH9-90C-1W	4.42E-01	2.76E+01	5.84E-01	5.66E-01	7.92E+00	7.71E+00	1.57E+00
pH9-50C-1W	4.02E-01	1.01E+01	1.90E+00	2.65E+00	6.73E+00	9.25E+00	5.25E-01
pH9-50C-1WX	1.12E+01	3.63E+01	1.66E+00	3.39E+00	8.90E+00	1.21E+01	3.47E+00
pH9-50C-1E	4.32E-01	0	9.65E-02	3.44E-01	1.67E+00	2.82E+00	3.72E-03
pH9-50C-1ER	1.29E-01	2.64E-01	9.79E-01	7.36E-01	5.73E-01	4.04E+00	7.57E-03
pH9-50C-1EX	0	0	1.77E-02	2.92E-01	1.48E+00	9.32E-01	1.26E-02
pH10-70C-1E	3.83E-01	1.45E+01	1.34E-01	7.41E-01	1.77E+00	8.03E+00	1.86E-01
pH10-50C-1EX	4.14E-05	0	1.20E-01	4.67E-01	1.30E+00	3.05E+00	2.18E-01
pH12-90C-1E	3.95E-01	1.81E+01	1.32E-01	6.90E-01	1.10E+00	1.01E+01	7.22E-02
pH12-50C-1E	1.02E-01	1.54E+01	3.06E-02	1.47E-01	7.08E-01	9.45E-01	6.96E-02
pH12-50C-1EX	4.52E-02	2.27E+00	3.15E-03	3.73E-01	5.73E-01	2.09E+00	1.99E-02

[a]Values less than zero reported as zero.

Table E.2. Total Mass Released During 14-28 Day Interval, micrograms[a]

Test No.	Cr	Fe	Mn	Mo	Ni	U	Zr
pH3-90C-2W	3.07E+02	2.22E+03	4.56E+01	2.03E+01	2.09E+02	9.61E+01	5.93E+01
pH3-50C-2W	7.38E+01	2.82E+02	5.40E+00	3.10E+00	2.43E+01	2.12E+01	3.49E+00
pH3-50C-2WX	3.17E+02	1.66E+03	2.77E+01	2.47E+01	1.29E+02	1.32E+02	5.08E+01
pH4-90C-2W	9.48E+01	6.96E+02	1.63E+01	7.42E+00	8.83E+01	9.52E+01	6.16E+01
pH4-90C-2E	7.54E+01	1.04E+03	2.08E+01	5.34E+00	8.72E+01	4.46E+01	3.70E+00
pH4-50C-2E	8.36E+00	8.21E+01	1.33E+00	1.67E+00	1.78E+01	8.21E+01	3.79E+00
pH4-50C-2EX	7.91E+00	7.69E+01	1.52E+00	1.95E+00	2.01E+01	1.06E+02	7.62E+00
pH4-50C-2WX	1.89E+02	1.06E+03	1.91E+01	1.37E+01	1.12E+02	1.96E+02	3.71E+01
pH6-70C1-2W	2.44E-01	5.56E+00	7.47E-02	6.28E-01	2.49E-01	6.52E-02	0
pH6-70C2-2W	7.93E-02	9.00E-01	8.76E-02	9.72E-01	1.03E+00	4.62E-02	0
pH6-70C3-2W	7.84E-02	1.28E-01	6.35E-02	3.66E-01	2.46E-01	4.26E-02	0
average	1.34E-01	2.20E+00	7.53E-02	6.55E-01	5.07E-01	5.13E-02	0
pH6-50C-2W	2.81E-01	6.77E+00	4.53E-01	1.21E+00	3.73E+00	4.04E-01	0
pH6-50C-2WX	2.50E-02	1.28E-01	2.36E-02	1.35E-01	2.91E-01	4.72E-02	0
pH8-70C-2W	8.12E-02	8.67E-02	3.96E-02	6.81E-01	7.12E-02	5.45E-02	4.88E-02
pH8-90C-2E	8.54E-02	1.64E+01	1.88E-01	1.56E-01	7.32E-01	9.07E-02	8.62E-02
pH8-90C-2ER	1.83E-02	1.04E+00	5.16E-02	3.33E-01	8.69E-01	3.55E-01	2.98E-02
pH8-50C-2EX	0	0	3.24E-02	8.46E-01	4.30E-01	1.10E-01	3.48E-02
pH8-50C-2WX	3.91E-02	2.95E-02	2.88E-02	0	3.41E-01	1.87E-01	9.37E-01
pH8-70C1-2E	8.61E-02	1.49E+01	1.39E-01	1.33E-01	8.72E-01	5.43E-02	7.05E-02
pH8-70C2-2E	9.26E-02	1.58E+01	1.74E-01	3.99E-01	1.63E+00	9.43E-02	7.20E-02
pH8-70C3-2E	9.05E-02	1.60E+01	1.40E-01	1.49E-01	6.98E-01	4.34E-02	7.79E-02
average	8.97E-02	1.56E+01	1.51E-01	2.27E-01	1.07E+00	6.40E-02	7.34E-02
pH8-70C1-2ER	2.49E-03	4.72E-01	6.14E-02	5.11E-01	7.52E-01	5.75E-01	3.00E-02
pH8-70C2-2ER	3.55E-02	2.23E+00	4.62E-02	4.20E-01	8.19E-01	6.76E-01	2.77E-02
pH8-70C3-2ER	3.57E-02	5.87E+00	9.57E-02	2.30E-01	7.64E-01	4.29E-01	2.47E-02
average	2.46E-02	4.05E+00	6.78E-02	3.87E-01	7.78E-01	5.60E-01	2.74E-02
pH9-90C-2W	5.49E-01	2.45E+01	5.18E-01	1.48E+00	9.40E+00	7.57E+00	2.73E+00
pH9-50C-2W	8.68E-01	2.01E+01	9.68E-01	1.86E+00	6.00E+00	1.25E+01	8.99E-01
pH9-50C-2WX	6.92E+01	2.09E+02	5.23E+00	8.20E+00	1.84E+01	1.25E+01	2.04E+00
pH9-50C-2E	7.58E+00	3.21E+01	6.15E-01	1.22E+00	3.50E+00	7.94E+00	7.67E-01
pH9-50C-2ER	2.07E-02	0	3.19E-02	3.89E-01	8.11E-01	3.27E+00	2.93E-02
pH9-50C-2 EX	7.72E-02	0	3.75E-02	2.96E-01	8.16E-01	8.31E-01	3.16E-02
pH10-70C-2E	1.32E-01	4.20E+00	3.99E-02	8.51E-01	3.65E-01	3.30E+00	1.46E-01
pH10-50C-2EX	0	0	9.42E-03	1.69E-01	2.74E-01	6.34E-01	1.23E-01
pH12, 90C-2E	2.60E-01	5.35E+00	4.14E-02	1.16E+00	3.16E-01	9.33E+00	7.60E-02
pH12, 50C-2E	8.11E-02	5.99E+00	3.53E-02	1.11E-01	5.95E-01	3.20E-01	7.73E-02
pH12-50C-2EX	1.54E-02	6.96E-01	1.24E-02	2.31E-01	5.24E-01	2.83E-01	1.54E-02

[a]Values less than zero reported as zero.

Table E.3. Total Mass Released During 28-70 Day Interval, micrograms[a]

Test No.	Cr	Fe	Mn	Mo	Ni	U	Zr
pH3-90C-3W	8.55E+02	4.93E+03	9.83E+01	2.90E+01	4.48E+02	1.03E+02	4.44E+01
pH3-50C-3W	3.46E+02	1.46E+03	3.07E+01	2.22E+01	1.63E+02	3.43E+02	1.29E+01
pH3-50C-3WX	1.56E+02	7.89E+02	4.66E+01	9.46E+00	2.43E+02	1.56E+02	3.82E+00
pH4-90C-3W	2.32E+02	1.36E+03	4.05E+01	2.40E+01	2.41E+02	4.80E+02	2.17E+02
pH4-90C-3E	2.11E+02	2.14E+03	3.98E+01	1.38E+01	1.60E+02	8.05E+01	2.67E+00
pH4-50C-3E	1.38E+01	1.16E+02	1.98E+00	2.53E+00	2.67E+01	6.93E+01	6.21E+00
pH4-50C-3EX	2.58E+01	1.83E+02	3.27E+00	3.89E+00	3.15E+01	1.11E+02	1.08E+01
pH4-50C-3WX	2.30E+02	1.62E+03	6.32E+00	1.47E+01	3.95E+01	5.13E+01	3.07E+01
pH6-70C1-3W	4.82E-02	8.04E-01	4.11E-02	7.20E-01	5.58E-01	3.80E-02	0
pH6-70C2-3W	1.78E-02	2.73E-01	3.56E-02	3.02E-01	8.20E-01	3.87E-02	0
pH6-70C3-3W	5.09E-02	6.71E-01	5.55E-02	3.36E-01	6.52E-01	4.02E-02	0
average	3.90E-02	5.83E-01	4.40E-02	4.53E-01	6.76E-01	3.90E-02	0
pH6-50C-3W	1.78E-02	1.28E-01	2.96E-01	3.43E-01	2.22E+00	9.55E-02	1.22E-01
pH6-50C-3WX	1.04E-02	1.28E-01	3.08E-02	8.75E-03	9.43E-02	4.32E-02	6.03E-02
pH8-70C-3W	2.00E-02	2.94E-02	1.41E-02	1.11E-01	1.59E-01	3.72E-02	0
pH8-90C-3E(98)[b]	3.19E-01	1.95E+01	7.09E-02	7.81E-01	9.71E-01	4.36E-01	7.24E-02
pH8-90C-3ER	0	1.44E+00	3.80E-02	3.49E-01	7.68E-01	4.58E-01	0
pH8-50C-3EX	0	0	3.07E-02	2.65E-01	6.15E-01	6.28E-02	7.06E-03
pH8-50C-3WX	1.29E+00	7.27E+00	1.28E+00	1.65E+01	1.78E+01	9.96E+00	1.34E-01
pH8-70C1-3E(98)[b]	3.41E-01	1.92E+01	7.86E-02	5.95E-01	1.08E+00	6.15E-02	1.14E-01
pH8-70C2-3E(98)[b]	3.27E-01	1.79E+01	7.66E-02	1.29E-01	6.31E-01	8.18E-02	7.62E-02
pH8-70C3-3E(98)[b]	3.95E-01	2.40E+01	9.92E-02	1.84E-01	7.25E-01	4.13E-02	1.14E-01
average	3.54E-01	2.04E+01	8.48E-02	3.03E-01	8.13E-01	6.15E-02	1.01E-01
pH8-70C1-3ER	0	0	4.26E-02	9.56E-01	5.54E-01	1.54E-01	1.41E-02
pH8-70C2-3ER	0	0	3.49E-02	3.52E-01	5.65E-01	2.03E-01	6.50E-03
pH8-70C3-3ER	0	2.34E+00	6.05E-02	8.33E-01	5.51E-01	2.03E-01	6.37E-03
average	0	0	4.60E-02	7.13E-01	5.57E-01	1.87E-01	9.00E-03
pH9-90C-3W	5.53E-01	2.15E+01	5.85E-01	1.39E+00	1.05E+01	3.32E+00	5.04E-02
pH9-50C-3W	5.67E+00	5.08E+01	1.58E+00	2.63E+00	7.85E+00	1.37E+01	2.65E-01
pH9-50C-3WX	1.69E+02	8.84E+02	1.55E+01	9.39E+00	4.37E+01	3.74E+01	6.41E+00
pH9-50C-3E(98)[b]	7.49E+01	1.11E+02	9.41E+00	8.67E+00	1.44E+01	1.34E+01	3.94E+00
pH9-50C-3ER	2.93E+01	2.28E+02	1.24E+01	1.03E+01	1.84E+01	1.42E+01	1.87E+00
pH9-50C-3EX	1.61E+00	6.94E+00	4.08E-01	2.16E+00	1.51E+00	3.03E+00	1.62E-01
pH10-70C-3E	5.43E-01	2.25E+01	7.67E-02	5.41E-01	1.07E+00	1.08E+01	1.09E-01
pH10-50C-3EX	0	0	8.58E-03	1.13E-01	7.31E-01	1.03E+00	3.50E-02
pH12-90C-3E	9.93E-01	2.97E+01	6.29E-02	5.74E-01	7.44E-01	1.84E+01	1.18E-01
pH12-50C-3E	3.42E-01	1.85E+01	8.29E-02	1.48E-01	4.76E-01	4.44E-01	8.65E-02
pH12-50C-3EX	1.64E-02	0	1.00E-02	1.41E-01	1.35E+00	4.56E-01	2.82E-04

[a]Values less than zero reported as zero.
[b]Total mass released during 28-98 day interval.

Table E.4. Cumulative Mass Released Through 28 Days, micrograms

Test Series	Cr	Fe	Mn	Mo	Ni	U	Zr
pH3-90C-W	5.60E+02	4.55E+03	9.60E+01	3.57E+01	4.22E+02	2.19E+02	7.61E+01
pH3-50C-W	2.55E+02	1.17E+03	2.08E+01	1.50E+01	1.08E+02	1.42E+02	1.93E+01
pH3-50C-WX	4.15E+02	2.10E+03	3.60E+01	3.69E+01	1.92E+02	3.72E+02	7.83E+01
pH4-90C-W	1.23E+02	1.01E+03	2.40E+01	9.55E+00	1.25E+02	1.29E+02	6.29E+01
pH4-90C-E	1.45E+02	1.64E+03	3.38E+01	1.19E+01	1.56E+02	1.21E+02	6.51E+00
pH4-50C-E	3.19E+01	2.48E+02	4.19E+00	4.90E+00	5.10E+01	1.94E+02	1.05E+01
pH4-50C-EX	1.68E+01	1.53E+02	2.98E+00	3.68E+00	3.66E+01	1.64E+02	1.38E+01
pH4-50C-WX	2.11E+02	1.18E+03	2.18E+01	1.70E+01	1.36E+02	2.72E+02	4.87E+01
pH6-70C1-W	4.11E-01	7.71E+00	2.70E-01	1.10E+00	1.56E+00	2.19E-01	0
pH6-70C2-W	1.44E-01	5.51E+00	3.32E-01	1.35E+00	4.23E+00	2.51E-01	2.33E-02
pH6-70C3-W	2.25E-01	6.02E+00	3.32E-01	6.07E-01	2.36E+00	2.24E-01	2.53E-02
average	2.60E-01	6.41E+00	3.11E-01	1.02E+00	2.72E+00	2.31E-01	1.62E-02
pH6-50C-W	6.88E-01	1.04E+01	1.33E+00	2.30E+00	1.21E+01	7.42E-01	1.57E-01
pH6-50C-WX	2.02E-01	2.56E-01	1.18E-01	3.29E-01	1.01E+00	6.57E-01	9.36E-01
pH8-70C-W	1.34E-01	5.96E-01	1.20E-01	1.05E+00	5.26E-01	2.72E-01	1.92E-01
pH8-90C-E(98)	2.80E-01	1.64E+01	2.43E-01	2.95E-01	1.25E+00	4.29E-01	8.62E-02
pH8-90C-ER	2.11E-02	3.05E+00	1.16E-01	8.06E-01	1.36E+00	6.19E-01	3.12E-02
pH8-50C-EX	0	0	1.02E-01	1.17E+00	1.49E+00	4.20E-01	6.56E-02
pH8-50C-WX	3.43E-01	5.90E-02	1.21E-01	2.72E-02	1.17E+00	1.33E+00	2.90E+00
pH8-70C1-E(98)	2.89E-01	1.49E+01	2.46E-01	4.50E-01	1.46E+00	3.97E-01	7.05E-02
pH8-70C2-E(98)	2.96E-01	1.58E+01	2.74E-01	8.05E-01	2.07E+00	5.04E-01	7.20E-02
pH8-70C3-E(98)	2.93E-01	1.60E+01	2.46E-01	5.82E-01	1.21E+00	3.37E-01	7.79E-02
average	2.93E-01	1.56E+01	2.56E-01	6.12E-01	1.58E+00	4.13E-01	7.34E-02
pH8-70C1-ER	2.43E-02	1.07E+00	1.35E-01	1.09E+00	1.27E+00	7.85E-01	3.43E-02
pH8-70C2-ER	3.55E-02	3.16E+00	1.32E-01	6.92E-01	1.74E+00	1.17E+00	5.48E-02
pH8-70C3-ER	3.57E-02	7.64E+00	1.97E-01	1.05E+00	1.54E+00	8.29E-01	2.91E-02
average	4.64E-02	5.82E+00	1.55E-01	9.46E-01	1.52E+00	9.29E-01	3.94E-02
pH9-90C-W	9.91E-01	5.21E+01	1.10E+00	2.04E+00	1.73E+01	1.53E+01	4.31E+00
pH9-50C-W	1.27E+00	3.02E+01	2.87E+00	4.51E+00	1.27E+01	2.18E+01	1.42E+00
pH9-50C-WX	8.03E+01	2.45E+02	6.88E+00	1.16E+01	2.73E+01	2.46E+01	5.51E+00
pH9-50C-E(98)	8.01E+00	3.21E+01	7.12E-01	1.57E+00	5.17E+00	1.08E+01	7.71E-01
pH9-50C-ER	1.50E-01	2.64E-01	1.01E+00	1.12E+00	1.38E+00	7.31E+00	3.69E-02
pH9-50C-EX	7.72E-02	0	5.52E-02	5.88E-01	2.29E+00	1.76E+00	4.42E-02
pH10-70C-E	5.15E-01	1.87E+01	1.74E-01	1.59E+00	2.13E+00	1.13E+01	3.33E-01
pH10-50C-EX	4.14E-05	0	1.30E-01	6.36E-01	1.57E+00	3.68E+00	3.42E-01
pH12-90C-E	6.55E-01	2.35E+01	1.73E-01	1.85E+00	1.42E+00	1.95E+01	1.48E-01
pH12-50C-E	1.83E-01	2.13E+01	6.59E-02	2.59E-01	1.30E+00	1.26E+00	1.47E-01
pH12-50C-EX	6.06E-02	2.97E+00	1.56E-02	6.04E-01	1.10E+00	2.38E+00	3.53E-02

Table E.5. Cumulative Mass Released Through 70 Days, micrograms

Test Series	Cr	Fe	Mn	Mo	Ni	U	Zr
pH3-90C-W	1.42E+03	9.47E+03	1.94E+02	6.47E+01	8.71E+02	3.22E+02	1.20E+02
pH3-50C-W	6.01E+02	2.62E+03	5.15E+01	3.72E+01	2.71E+02	4.85E+02	3.21E+01
pH3-50C-WX	5.71E+02	2.89E+03	8.26E+01	4.63E+01	4.35E+02	5.28E+02	8.21E+01
pH4-90C-W	3.55E+02	2.36E+03	6.45E+01	3.36E+01	3.65E+02	6.09E+02	2.80E+02
pH4-90C-E	3.55E+02	3.77E+03	7.36E+01	2.57E+01	3.16E+02	2.01E+02	9.18E+00
pH4-50C-E	4.58E+01	3.64E+02	6.17E+00	7.43E+00	7.77E+01	2.63E+02	1.67E+01
pH4-50C-EX	4.27E+01	3.36E+02	6.26E+00	7.57E+00	6.81E+01	2.75E+02	2.46E+01
pH4-50C-WX	4.41E+02	2.81E+03	2.82E+01	3.17E+01	1.76E+02	3.24E+02	7.94E+01
pH6-70C1-W	4.60E-01	8.52E+00	3.11E-01	1.82E+00	2.12E+00	2.57E-01	0
pH6-70C2-W	1.62E-01	5.78E+00	3.67E-01	1.65E+00	5.05E+00	2.90E-01	2.33E-02
pH6-70C3-W	2.76E-01	6.69E+00	3.88E-01	9.43E-01	3.01E+00	2.64E-01	2.53E-02
average	2.99E-01	7.00E+00	3.55E-01	1.47E+00	3.39E+00	2.70E-01	1.62E-02
pH6-50C-W	7.06E-01	1.05E+01	1.62E+00	2.64E+00	1.43E+01	8.38E-01	2.79E-01
pH6-50C-WX	2.13E-01	3.84E-01	1.48E-01	3.38E-01	1.10E+00	7.00E-01	9.96E-01
pH8-70C-W	1.54E-01	6.25E-01	1.34E-01	1.16E+00	6.86E-01	3.09E-01	1.92E-01
pH8-90C-E(98)[a]	5.99E-01	3.59E+01	3.14E-01	1.08E+00	2.22E+00	8.66E-01	1.59E-01
pH8-90C-ER	2.11E-02	4.49E+00	1.54E-01	1.16E+00	2.13E+00	1.08E+00	3.12E-02
pH8-50C-EX	0	0	1.32E-01	1.43E+00	2.11E+00	4.83E-01	7.27E-02
pH8-50C-WX	1.64E+00	7.33E+00	1.40E+00	1.65E+01	1.89E+01	1.13E+01	3.04E+00
pH8-70C1-E(98)	6.30E-01	3.41E+01	3.25E-01	1.04E+00	2.54E+00	4.59E-01	1.85E-01
pH8-70C2-E(98)	6.23E-01	3.38E+01	3.51E-01	9.34E-01	2.70E+00	5.86E-01	1.48E-01
pH8-70C3-E(98)	6.88E-01	4.01E+01	3.45E-01	7.67E-01	1.94E+00	3.78E-01	1.92E-01
average	6.47E-01	3.60E+01	3.40E-01	9.15E-01	2.39E+00	4.74E-01	1.75E-01
pH8-70C1-ER	2.43E-02	1.07E+00	1.78E-01	2.05E+00	1.83E+00	9.39E-01	4.84E-02
pH8-70C2-ER	3.55E-02	3.16E+00	1.67E-01	1.04E+00	2.30E+00	1.38E+00	6.13E-02
pH8-70C3-ER	3.57E-02	7.64E+00	2.57E-01	1.89E+00	2.09E+00	1.03E+00	3.55E-02
average	3.19E-02	3.96E+00	2.01E-01	1.66E+00	2.07E+00	1.12E+00	4.84E-02
pH9-90C-W	1.54E+00	7.36E+01	1.69E+00	3.44E+00	2.78E+01	1.86E+01	4.36E+00
pH9-50C-W	6.94E+00	8.10E+01	4.45E+00	7.14E+00	2.06E+01	3.55E+01	1.69E+00
pH9-50C-WX	2.49E+02	1.13E+03	2.24E+01	2.10E+01	7.10E+01	6.21E+01	1.19E+01
pH9-50C-E(98)	8.29E+01	1.43E+02	1.01E+01	1.02E+01	1.96E+01	2.41E+01	4.71E+00
pH9-50C-ER	2.94E+01	2.29E+02	1.34E+01	1.14E+01	1.98E+01	2.15E+01	1.91E+00
pH9-50C-EX	1.69E+00	6.94E+00	4.64E-01	2.75E+00	3.80E+00	4.79E+00	2.06E-01
pH10-70C-E	1.06E+00	4.12E+01	2.51E-01	2.13E+00	3.20E+00	2.21E+01	4.41E-01
pH10-50C-EX	4.14E-05	0.00E+00	1.38E-01	7.50E-01	2.30E+00	4.71E+00	3.77E-01
pH12-90C-E	1.65E+00	5.31E+01	2.36E-01	2.42E+00	2.16E+00	3.78E+01	2.66E-01
pH12-50C-E	5.26E-01	3.98E+01	1.49E-01	4.07E-01	1.78E+00	1.71E+00	2.33E-01
pH12-50C-EX	7.70E-02	2.97E+00	2.56E-02	7.46E-01	2.45E+00	2.83E+00	3.55E-02

[a] "(98)" means cumulative mass released through 98 days.

APPENDIX F. CUMULATIVE NORMALIZED MASS LOSS AND NORMALIZED DISSOLUTION RATE

These tables summarize the cumulative normalized mass loss. Table F.1 provides data for the 14-day samplings, Table F.2 provides the cumulative values for the combined 14- and 28-day samplings, and Table F.3 provides the cumulative values for the combined 14-, 28-, and 70-day samplings. Table F.4 provides the average normalized dissolution rate over the 70-day (or 98-day) test period. Note that third sampling of some tests conducted at ANL-E occurred 98 days after test initiation (the final interval was 70 days). The designator "(98)" is appended to the test numbers for these tests. The headings for columns in Tables F.1, F.2, F.3, and F.4 are defined below.

Test Series Test numbers without digits indicating test interval.

NL(i) Normalized mass loss based on concentration of element i.

NL(*i*) = (cumulative mass released)/ (surface area • mass fraction of element *i*)

The cumulative mass released is obtained from Appendix E.
The surface area is obtained from Appendix A.
The mass fraction of element i is obtained from Table 1.

Sample calculation for NL(Cr) for test series pH3-90C-W

The 0-14 day interval is test pH3-90C-1W, the 14-28 days interval is pH3-90C-2W, and the 28-70 day interval is test pH3-90C-3W
From Appendix E Table E.1, the cumulative mass Cr released is 1420 micrograms = 1.42×10^{-3} g.
From Appendix A Table A.2, the surface area for the sample used in test series pH3-90C-1W is 5.70 cm^2 = 5.70×10^{-4} m^2.
From Table 1, the mean mass fraction of Cr is 0.127.

$NL(Cr) = 1.42 \times 10^{-3}\ g / \{5.70 \times 10^{-4}\ m^2 \bullet 0.127) = 19.6\ g/m^2$.

Values are given to 3 significant figures.
NR(i) Normalized dissolution rate based on concentration of element i., in g/m^2.

NR(*i*) = (normalized mass loss)/ (cumulative reaction time)

The normalized mass loss is obtained from Appendix F.
The cumulative reaction time is obtained from Appendix A.

Sample calculation for NL(Cr) for 70-day test period for test series pH3-90C-W

From Table F.1, the cumulative normalized mass loss is = 19.6 g/m^2.
$NR(Cr) = = (19.6\ g/m^2) / 70\ days = 0.280\ g/(m^2 \bullet d)$

Values are given in the tables to 3 significant figures.

Table F.1. Normalized Elemental Mass Loss for 0-14 Day Interval, g/m^2

Test Series	NL(Cr)	NL(Fe)	NL(Mn)	NL(Mo)	NL(Ni)	NL(U)	NL(Zr)
pH3-90C-W	3.50E+00	7.90E+00	9.56E+00	1.65E+00	4.81E+00	2.21E+00	1.90E-01
pH3-50C-W	2.51E+00	2.99E+00	2.92E+00	1.27E+00	1.89E+00	2.19E+00	1.78E-01
pH3-50C-WX	1.36E+00	1.49E+00	1.57E+00	1.30E+00	1.41E+00	4.34E+00	3.11E-01
pH4-90C-W	3.94E-01	1.05E+00	1.46E+00	2.27E-01	8.22E-01	6.03E-01	1.51E-02
pH4-90C-E	9.78E-01	2.07E+00	2.50E+00	7.13E-01	1.58E+00	1.40E+00	3.23E-02
pH4-50C-E	3.34E-01	5.74E-01	5.54E-01	3.53E-01	7.66E-01	2.06E+00	7.74E-02
pH4-50C-EX	1.25E-01	2.62E-01	2.81E-01	1.87E-01	3.77E-01	1.05E+00	7.11E-02
pH4-50C-WX	3.12E-01	4.10E-01	5.31E-01	3.57E-01	5.56E-01	1.40E+00	1.32E-01
pH6-70C1-W	2.31E-03	7.30E-03	3.70E-02	5.02E-02	2.96E-02	2.78E-03	0.00E+00
pH6-70C2-W	8.96E-04	1.56E-02	4.63E-02	4.05E-02	7.24E-02	3.69E-03	2.64E-04
pH6-70C3-W	2.03E-03	2.00E-02	5.10E-02	2.58E-02	4.76E-02	3.28E-03	2.87E-04
average	1.75E-03	1.43E-02	4.48E-02	3.88E-02	4.99E-02	3.25E-03	1.84E-04
pH6-50C-W	5.64E-03	1.23E-02	1.66E-01	1.16E-01	1.88E-01	6.09E-03	1.78E-03
pH6-50C-WX	2.47E-03	4.36E-04	1.79E-02	2.08E-02	1.62E-02	1.11E-02	1.07E-02
pH8-70C-W	7.30E-04	1.72E-03	1.52E-02	3.93E-02	1.03E-02	3.92E-03	1.62E-03
pH8-90C-E(98)	2.74E-03	0.00E+00	1.06E-02	1.52E-02	1.18E-02	6.20E-03	0.00E+00
pH8-90C-ER	3.94E-05	6.92E-03	1.23E-02	5.13E-02	1.13E-02	4.82E-03	1.55E-05
pH8-50C-EX	0.00E+00	0.00E+00	1.33E-02	3.51E-02	2.43E-02	5.68E-03	3.54E-04
pH8-50C-WX	4.23E-03	1.00E-04	1.74E-02	2.91E-03	1.89E-02	2.07E-02	2.23E-02
pH8-70C1-E(98)	2.85E-03	0.00E+00	2.07E-02	3.43E-02	1.35E-02	6.27E-03	0.00E+00
pH8-70C2-E(98)	2.86E-03	0.00E+00	1.92E-02	4.40E-02	1.00E-02	7.49E-03	0.00E+00
pH8-70C3-E(98)	2.86E-03	0.00E+00	2.06E-02	4.72E-02	1.19E-02	5.40E-03	0.00E+00
average	2.86E-03	0.00E+00	2.02E-02	4.18E-02	1.18E-02	6.39E-03	0.00E+00
pH8-70C1-ER	3.06E-04	2.06E-03	1.41E-02	6.30E-02	1.19E-02	3.82E-03	4.89E-05
pH8-70C2-ER	0.00E+00	3.21E-03	1.65E-02	2.95E-02	2.10E-02	9.13E-03	3.11E-04
pH8-70C3-ER	0.00E+00	6.07E-03	1.94E-02	8.91E-02	1.77E-02	7.32E-03	5.04E-05
average	3.07E-04	6.07E-03	1.67E-02	6.05E-02	1.69E-02	6.76E-03	1.37E-04
pH9-90C-W	6.13E-03	9.35E-02	1.11E-01	6.04E-02	1.79E-01	1.39E-01	1.78E-02
pH9-50C-W	5.56E-03	3.42E-02	3.60E-01	2.83E-01	1.52E-01	1.67E-01	5.94E-03
pH9-50C-WX	1.56E-01	1.24E-01	3.16E-01	3.64E-01	2.02E-01	2.19E-01	3.95E-02
pH9-50C-E(98)	6.10E-03	0.00E+00	1.87E-02	3.74E-02	3.85E-02	5.18E-02	4.29E-05
pH9-50C-ER	1.81E-03	9.07E-04	1.88E-01	7.95E-02	1.31E-02	7.38E-02	8.68E-05
pH9-50C-EX	0.00E+00	0.00E+00	3.38E-03	3.14E-02	3.36E-02	1.70E-02	1.44E-04
pH10-70C-E	5.42E-03	5.03E-02	2.60E-02	8.08E-02	4.07E-02	1.48E-01	2.15E-03
pH10-50C-EX	5.80E-07	0.00E+00	2.30E-02	5.04E-02	2.96E-02	5.56E-02	2.50E-03
pH12-90C-E	5.58E-03	6.27E-02	2.55E-02	7.51E-02	2.54E-02	1.86E-01	8.33E-04
pH12-50C-E	1.45E-03	5.31E-02	5.93E-03	1.61E-02	1.63E-02	1.74E-02	8.05E-04
pH12-50C-EX	6.34E-04	7.80E-03	6.05E-04	4.04E-02	1.31E-02	3.82E-02	2.28E-04

Table F.2. Cumulative Normalized Elemental Mass Loss through 28 Days, g/m^2

Test Series	NL(Cr)	NL(Fe)	NL(Mn)	NL(Mo)	NL(Ni)	NL(U)	NL(Zr)
pH3-90C-W	7.76E+00	1.54E+01	1.82E+01	3.82E+00	9.53E+00	3.95E+00	8.61E-01
pH3-50C-W	3.53E+00	3.95E+00	3.94E+00	1.60E+00	2.44E+00	2.57E+00	2.18E-01
pH3-50C-WX	5.74E+00	7.12E+00	6.83E+00	3.94E+00	4.33E+00	6.71E+00	8.87E-01
pH4-90C-W	1.71E+00	3.41E+00	4.56E+00	1.02E+00	2.81E+00	2.32E+00	7.12E-01
pH4-90C-E	2.04E+00	5.64E+00	6.50E+00	1.29E+00	3.58E+00	2.22E+00	7.48E-02
pH4-50C-E	4.52E-01	8.58E-01	8.11E-01	5.35E-01	1.18E+00	3.57E+00	1.21E-01
pH4-50C-EX	2.36E-01	5.26E-01	5.74E-01	3.98E-01	8.37E-01	3.00E+00	1.59E-01
pH4-50C-WX	2.95E+00	4.05E+00	4.18E+00	1.83E+00	3.11E+00	4.97E+00	5.57E-01
pH6-70C1-W	5.70E-03	2.61E-02	5.12E-02	1.17E-01	3.53E-02	3.95E-03	0.00E+00
pH6-70C2-W	1.99E-03	1.87E-02	6.29E-02	1.44E-01	9.56E-02	4.53E-03	2.64E-04
pH6-70C3-W	3.12E-03	2.04E-02	6.30E-02	6.48E-02	5.32E-02	4.04E-03	2.87E-04
average[a]	3.60E-03	2.17E-02	5.90E-02	1.09E-01	6.13E-02	4.17E-03	1.84E-04
pH6-50C-W	9.53E-03	3.52E-02	2.51E-01	2.45E-01	2.72E-01	1.34E-02	1.78E-03
pH6-50C-WX	2.82E-03	8.72E-04	2.24E-02	3.53E-02	2.28E-02	1.19E-02	1.07E-02
pH8-70C-W	1.85E-03	2.02E-03	2.27E-02	1.12E-01	1.19E-02	4.91E-03	2.18E-03
pH8-90C-E(98)	3.95E-03	5.63E-02	4.68E-02	3.20E-02	2.86E-02	7.86E-03	9.92E-04
pH8-90C-ER	2.97E-04	1.05E-02	2.22E-02	8.73E-02	3.12E-02	1.13E-02	3.58E-04
pH8-50C-EX	0.00E+00	0.00E+00	1.95E-02	1.27E-01	3.42E-02	7.69E-03	7.53E-04
pH8-50C-WX	4.77E-03	2.01E-04	2.29E-02	2.91E-03	2.66E-02	2.41E-02	3.30E-02
pH8-70C1-E(98)	4.06E-03	5.13E-02	4.74E-02	4.87E-02	3.34E-02	7.27E-03	8.09E-04
pH8-70C2-E(98)	4.16E-03	5.43E-02	5.27E-02	8.72E-02	4.73E-02	9.22E-03	8.26E-04
pH8-70C3-E(98)	4.14E-03	5.53E-02	4.76E-02	6.34E-02	2.79E-02	6.20E-03	8.99E-04
average	4.12E-03	5.36E-02	4.92E-02	6.64E-02	3.62E-02	7.56E-03	8.45E-04
pH8-70C1-ER	3.41E-04	3.68E-03	2.59E-02	1.18E-01	2.91E-02	1.43E-02	3.93E-04
pH8-70C2-ER	4.99E-04	1.09E-02	2.54E-02	7.49E-02	3.98E-02	2.15E-02	6.29E-04
pH8-70C3-ER	5.02E-04	2.63E-02	3.78E-02	1.14E-01	3.52E-02	1.52E-02	3.34E-04
average	6.52E-04	2.00E-02	2.97E-02	1.02E-01	3.47E-02	1.70E-02	4.52E-04
pH9-90C-W	1.37E-02	1.77E-01	2.09E-01	2.18E-01	3.91E-01	2.76E-01	4.87E-02
pH9-50C-W	1.76E-02	1.02E-01	5.44E-01	4.81E-01	2.87E-01	3.93E-01	1.61E-02
pH9-50C-WX	1.12E+00	8.36E-01	1.31E+00	1.24E+00	6.19E-01	4.46E-01	6.27E-02
pH9-50C-E(98)	1.13E-01	1.11E-01	1.38E-01	1.71E-01	1.19E-01	1.98E-01	8.90E-03
pH9-50C-ER	2.10E-03	9.07E-04	1.94E-01	1.22E-01	3.16E-02	1.34E-01	4.23E-04
pH9-50C-EX	1.08E-03	0.00E+00	1.06E-02	6.33E-02	5.22E-02	3.21E-02	5.04E-04
pH10-70C-E	7.29E-03	6.49E-02	3.37E-02	1.74E-01	4.91E-02	2.09E-01	3.85E-03
pH10-50C-EX	5.80E-07	0.00E+00	2.48E-02	6.87E-02	3.59E-02	6.71E-02	3.91E-03
pH12-90C-E	9.25E-03	8.12E-02	3.35E-02	2.01E-01	3.26E-02	3.58E-01	1.71E-03
pH12-50C-E	2.60E-03	7.39E-02	1.28E-02	2.82E-02	3.01E-02	2.33E-02	1.70E-03
pH12-50C-EX	8.50E-04	1.02E-02	2.99E-03	6.53E-02	2.51E-02	4.34E-02	4.04E-04

[a]Calculated from average cumulative mass released.

Table F.3. Cumulative Normalized Elemental Mass Loss through 70 Days, g/m^2

Test Series	NL(Cr)	NL(Fe)	NL(Mn)	NL(Mo)	NL(Ni)	NL(U)	NL(Zr)
pH3-90C-W	1.96E+01	3.21E+01	3.68E+01	6.91E+00	1.97E+01	5.81E+00	1.36E+00
pH3-50C-W	8.32E+00	8.89E+00	9.76E+00	3.97E+00	6.12E+00	8.76E+00	3.64E-01
pH3-50C-WX	7.91E+00	9.79E+00	1.57E+01	4.95E+00	9.81E+00	9.52E+00	9.30E-01
pH4-90C-W	4.92E+00	8.01E+00	1.22E+01	3.58E+00	8.25E+00	1.10E+01	3.17E+00
pH4-90C-E	5.00E+00	1.30E+01	1.42E+01	2.79E+00	7.24E+00	3.69E+00	1.06E-01
pH4-50C-E	6.48E-01	1.26E+00	1.20E+00	8.11E-01	1.79E+00	4.85E+00	1.93E-01
pH4-50C-EX	5.99E-01	1.16E+00	1.20E+00	8.19E-01	1.56E+00	5.03E+00	2.82E-01
pH4-50C-WX	6.18E+00	9.61E+00	5.39E+00	3.42E+00	4.01E+00	5.90E+00	9.08E-01
pH6-70C1-W	6.37E-03	2.89E-02	5.90E-02	1.94E-01	4.79E-02	4.64E-03	0.00E+00
pH6-70C2-W	2.24E-03	1.96E-02	6.97E-02	1.77E-01	1.14E-01	5.22E-03	2.64E-04
pH6-70C3-W	3.82E-03	2.27E-02	7.35E-02	1.01E-01	6.79E-02	4.77E-03	2.87E-04
average[a]	4.14E-03	2.37E-02	6.74E-02	1.57E-01	7.66E-02	4.88E-03	1.84E-04
pH6-50C-W	9.78E-03	3.57E-02	3.08E-01	2.82E-01	3.22E-01	1.51E-02	3.16E-03
pH6-50C-WX	2.96E-03	1.31E-03	2.83E-02	3.62E-02	2.50E-02	1.27E-02	1.13E-02
pH8-70C-W	2.13E-03	2.12E-03	2.54E-02	1.24E-01	1.55E-02	5.58E-03	2.18E-03
pH8-90C-E(98)[b]	8.43E-03	1.24E-01	6.04E-02	1.17E-01	5.09E-02	1.59E-02	1.82E-03
pH8-90C-ER	2.97E-04	1.54E-02	2.95E-02	1.25E-01	4.88E-02	1.97E-02	3.58E-04
pH8-50C-EX	0.00E+00	0.00E+00	2.54E-02	1.55E-01	4.82E-02	8.84E-03	8.34E-04
pH8-50C-WX	2.27E-02	2.49E-02	2.67E-01	1.77E+00	4.29E-01	2.04E-01	3.45E-02
pH8-70C1-E(98)	8.75E-03	1.16E-01	6.19E-02	1.12E-01	5.76E-02	8.30E-03	2.10E-03
pH8-70C2-E(98)	8.75E-03	1.16E-01	6.74E-02	1.01E-01	6.18E-02	1.07E-02	1.70E-03
pH8-70C3-E(98)	9.66E-03	1.38E-01	6.64E-02	8.30E-02	4.44E-02	6.92E-03	2.20E-03
average	9.14E-03	1.24E-01	6.58E-02	9.96E-02	5.51E-02	8.72E-03	2.02E-03
pH8-70C1-ER	3.42E-04	3.69E-03	3.42E-02	2.22E-01	4.19E-02	1.72E-02	5.56E-04
pH8-70C2-ER	4.98E-04	1.09E-02	3.20E-02	1.13E-01	5.26E-02	2.52E-02	7.02E-04
pH8-70C3-ER	5.02E-04	2.63E-02	4.95E-02	2.04E-01	4.78E-02	1.89E-02	4.07E-04
average	4.47E-04	1.36E-02	3.86E-02	1.80E-01	4.74E-02	2.04E-02	5.55E-04
pH9-90C-W	2.14E-02	2.49E-01	3.20E-01	3.67E-01	6.28E-01	3.36E-01	4.93E-02
pH9-50C-W	9.61E-02	2.75E-01	8.44E-01	7.62E-01	4.64E-01	6.40E-01	1.91E-02
pH9-50C-WX	3.47E+00	3.85E+00	4.27E+00	2.25E+00	1.61E+00	1.13E+00	1.36E-01
pH9-50C-E(98)	1.17E+00	4.95E-01	1.96E+00	1.11E+00	4.52E-01	4.44E-01	5.44E-02
pH9-50C-ER	4.12E-01	7.85E-01	2.58E+00	1.23E+00	4.52E-01	3.92E-01	2.19E-02
pH9-50C-EX	2.36E-02	2.37E-02	8.87E-02	2.96E-01	8.66E-02	8.72E-02	2.35E-03
pH10-70C-E	1.50E-02	1.43E-01	4.86E-02	2.33E-01	7.38E-02	4.07E-01	5.10E-03
pH10-50C-EX	5.80E-07	0.00E+00	2.65E-02	8.09E-02	5.26E-02	8.59E-02	4.31E-03
pH12-90C-E	2.33E-02	1.84E-01	4.57E-02	2.64E-01	4.97E-02	6.96E-01	3.07E-03
pH12-50C-E	7.44E-03	1.38E-01	2.88E-02	4.44E-02	4.10E-02	3.15E-02	2.70E-03
pH12-50C-EX	1.08E-03	1.02E-02	4.92E-03	8.06E-02	5.60E-02	5.17E-02	4.07E-04

[a]Calculated from average cumulative mass released.
[b]"(98)" means cumulative normalized mass loss through 98 days.

Table F4. Normalized Elemental Dissolution Rate Through 70 Days, g/(m^2•d)

Test Series	NR(Cr)	NR(Fe)	NR(Mn)	NR(Mo)	NR(Ni)	NR(U)	NR(Zr)
pH3-90C-W	2.80E-01	4.59E-01	5.26E-01	9.87E-02	2.81E-01	8.31E-02	1.95E-02
pH3-50C-W	1.19E-01	1.27E-01	1.39E-01	5.68E-02	8.75E-02	1.25E-01	5.20E-03
pH3-50C-WX	1.13E-01	1.40E-01	2.24E-01	7.07E-02	1.40E-01	1.36E-01	1.33E-02
pH4-90C-W	7.02E-02	1.14E-01	1.75E-01	5.12E-02	1.18E-01	1.57E-01	4.52E-02
pH4-90C-E	7.15E-02	1.86E-01	2.03E-01	3.99E-02	1.03E-01	5.27E-02	1.51E-03
pH4-50C-E	9.25E-03	1.80E-02	1.71E-02	1.16E-02	2.56E-02	6.92E-02	2.76E-03
pH4-50C-EX	8.56E-03	1.65E-02	1.72E-02	1.17E-02	2.23E-02	7.18E-02	4.03E-03
pH4-50C-WX	8.83E-02	1.37E-01	7.71E-02	4.89E-02	5.73E-02	8.43E-02	1.30E-02
pH6-70C1-W	9.10E-05	4.12E-04	8.43E-04	2.77E-03	6.84E-04	6.63E-05	0.00E+00
pH6-70C2-W	3.20E-05	2.80E-04	9.95E-04	2.52E-03	1.63E-03	7.46E-05	3.77E-06
pH6-70C3-W	5.46E-05	3.24E-04	1.05E-03	1.44E-03	9.70E-04	6.81E-05	4.10E-06
average	5.92E-05	3.39E-04	9.63E-04	2.24E-03	1.09E-03	6.97E-05	2.62E-06
pH6-50C-W	1.40E-04	5.10E-04	4.39E-03	4.02E-03	4.60E-03	2.16E-04	4.51E-05
pH6-50C-WX	4.23E-05	1.87E-05	4.04E-04	5.18E-04	3.57E-04	1.81E-04	1.62E-04
pH8-70C-W	3.04E-05	3.03E-05	3.63E-04	1.77E-03	2.21E-04	7.97E-05	3.11E-05
pH8-90C-E(98)[a]	8.60E-05	1.26E-03	6.17E-04	1.19E-03	5.19E-04	1.62E-04	1.86E-05
pH8-90C-ER	4.24E-06	2.20E-04	4.22E-04	1.79E-03	6.97E-04	2.82E-04	5.11E-06
pH8-50C-EX	0.00E+00	0.00E+00	3.63E-04	2.22E-03	6.89E-04	1.26E-04	1.19E-05
pH8-50C-WX	3.25E-04	3.56E-04	3.82E-03	2.53E-02	6.13E-03	2.92E-03	4.93E-04
pH8-70C1-E(98)	8.93E-05	1.18E-03	6.31E-04	1.14E-03	5.88E-04	8.47E-05	2.14E-05
pH8-70C2-E(98)	8.93E-05	1.18E-03	6.88E-04	1.03E-03	6.30E-04	1.09E-04	1.74E-05
pH8-70C3-E(98)	9.86E-05	1.40E-03	6.77E-04	8.47E-04	4.53E-04	7.06E-05	2.25E-05
average	9.32E-05	1.27E-03	6.71E-04	1.02E-03	5.62E-04	8.90E-05	2.06E-05
pH8-70C1-ER	4.89E-06	5.27E-05	4.89E-04	3.18E-03	5.99E-04	2.46E-04	7.95E-06
pH8-70C2-ER	7.11E-06	1.55E-04	4.58E-04	1.61E-03	7.52E-04	3.59E-04	1.00E-05
pH8-70C3-ER	7.17E-06	3.75E-04	7.07E-04	2.92E-03	6.83E-04	2.70E-04	5.81E-06
average	6.39E-06	1.94E-04	5.51E-04	2.57E-03	6.78E-04	2.92E-04	7.93E-06
pH9-90C-W	3.06E-04	3.56E-03	4.57E-03	5.24E-03	8.97E-03	4.79E-03	7.04E-04
pH9-50C-W	1.37E-03	3.92E-03	1.21E-02	1.09E-02	6.63E-03	9.15E-03	2.73E-04
pH9-50C-WX	4.96E-02	5.50E-02	6.10E-02	3.22E-02	2.30E-02	1.61E-02	1.94E-03
pH9-50C-E(98)	1.20E-02	5.05E-03	2.00E-02	1.14E-02	4.61E-03	4.53E-03	5.55E-04
pH9-50C-ER	5.89E-03	1.12E-02	3.68E-02	1.76E-02	6.46E-03	5.61E-03	3.12E-04
pH9-50C-EX	3.38E-04	3.39E-04	1.27E-03	4.23E-03	1.24E-03	1.25E-03	3.36E-05
pH10-70C-E	2.14E-04	2.04E-03	6.94E-04	3.32E-03	1.05E-03	5.82E-03	7.29E-05
pH10-50C-EX	8.28E-09	0.00E+00	3.78E-04	1.16E-03	7.51E-04	1.23E-03	6.16E-05
pH12-90C-E	3.32E-04	2.62E-03	6.53E-04	3.77E-03	7.11E-04	9.94E-03	4.39E-05
pH12-50C-E	1.06E-04	1.97E-03	4.12E-04	6.34E-04	5.86E-04	4.50E-04	3.86E-05
pH12-50C-EX	1.54E-05	1.46E-04	7.03E-05	1.15E-03	8.00E-04	7.39E-04	5.82E-06

[a]"(98)" means normalized dissolution rate through 98 days.

APPENDIX G. TESTS CONDUCTED IN LEACHANTS SPIKED WITH 10,000 ppm Cl^- AND IN LEACHANTS WITHOUT ADDED NaCl

These tables summarize the test execution data, solution analysis results, and calculated values of NL(i) for the supplemental tests at 50ºC conducted at ANL-E with leachant solutions spiked with10,000 ppm Cl^- and in leachants without added NaCl.

Table G.1 gives the test execution data for all tests. Column headings are defined below:

Test No.	Test number. First term gives nominal pH, second term gives amount of added NaCl (10k = 10,000 ppm Cl^- and 0k = no added NaCl), third term gives interval number. (Note that experimentalist did not include -1 for initial time period in scientific notebook or solution analysis. The -1 is included here for clarity.)
pH Buffer	Nominal pH of buffer solution used as leachant.
Vessel No.	Unique number etched on Teflon test vessel for test identification.
Coupon No.	Unique number or identifier assigned to MWF sample coupon. Note that some coupons were polished after initial use and used in another test.
Coupon Area	Geometric surface area of MWF sample coupon calculated from measured dimensions, in cm^2.
Coupon Mass	Measured mass of MWF sample coupon, in g
Initial pH	Measured pH of leachant used in tests (measured at room temperature), no units.
Initiation Date	Calendar date tests were initiated.
Sampling Date	Calendar date test was sampled.
Interval	Duration of test interval, in days
Vessel Mass	Mass of empty Teflon test vessel, in g.
Vessel + Coupon	Mass of test vessel with MWF sample coupon, in g.
Total Mass In	Mass of test vessel with MWF sample coupon + leachant prior to placing in oven, in g.
Total Mass Out	Mass of test vessel with MWF sample coupon and leachant after removing from oven for sampling, in g.
Leachant Mass	Measured mass of leachant, calculated as *Total Mass In – (Vessel + Coupon)*, in g,

Sample calculation for 4-10k-1:

$$44.52\ g - 41.70\ g = 2.82\ g$$

S/V	Surface area-to-solution volume ratio calculated as *Coupon Area x Leachant Mass*, in m^{-1}.

Sample calculation for pH4-10k-1:

$$5.648\ cm^2 \cdot (1\ m^2/1000\ cm^2) / [2.82\ g\ (1\ cm^3/g) \cdot (1 \times 10^{-6}\ m^3/cm^3)] = 200.3\ m^{-1}$$

Water Loss	Mass of water lost during test calculated as *Total Mass In – Total Mass Out*, in g.

Sample calculation for 4-10k-1:

Water Loss = 44.52 g – 44.51 g = -0.01 g.

Final pH	Measured pH of test solution (measured at room temperature).
Bottle Mass	Mass of bottle used to collect aliquot of test solution for analysis, in g.
Bottle + Aliquot	Mass of bottle plus aliquot of test solution for analysis, in g.
Aliquot	Mass of aliquot of test solution collected for analysis calculated as *(Bottle + Aliquot) – Bottle Mass*, in g.

Sample calculation for 4-10k-1:

Aliquot = 12.90 g – 10.79 g = 2.11 g.

B + A + water + HNO_3	Mass of bottle plus aliquot of test solution for analysis plus demineralized water added for dilution plus concentrated nitric acid added to acidify solution, in g.
Dilution Factor	Dilution factor calculated as [(*B + A + water +* HNO_3) *– Bottle*]/ *Aliquot*, no units.

Sample calculation for 4-10k-1:

Dilution Factor = (13.19 g -10.79 g) / 2.11 g = 1.137

Vessel + AS Mass	Mass of test vessel plus dilute nitric acid solution (or demineralized water plus concentrated nitric acid) used for acid soak, in g.
AS Mass	Mass of acid soak solution calculated as *(Vessel + AS Mass) – Vessel Mass*, in g.

Sample calculation for 4-10k-1:

AS Aliquot Mass = 57.81 g – 38.03 g =19.78 g.

Tables G.2, G.3, and G.4 give the concentrations measured in the test solutions, the acid soak solutions, and the blank tests. The column headings are defined below:

Test No.	Test number.
i	Element analyzed.

The values given in Tables G.2 and G.3 are the products of the measured concentrations times the dilution factors. The values given in Table G.4 are the measured concentrations.

Table G.5 gives the total mass of each element released over each test interval. The column headings are defined below:

Test No.	Test number.
i	Element analyzed.

The values given in Table G.5 are the sums of the masses released over each test interval, in micrograms. The mass in the test solution is calculated as

(Concentration in test solution – concentration in blank test) x (volume of test solution)

The mass in the acid soak solution is calculated as

(Concentration in acid soak solution) x (volume of acid soak solution)

Values used in these calculations are obtained from other Tables in this Appendix:
Concentration in test solution is from Table G.2 column "i"
Concentration in blank test is from Table G.4 column "i"
Volume of test solution is from Table G.1 column "Leachant Mass"
Concentration in acid soak solution is from Table G.3 column "i"
Volume of acid soak solution is from Table G.1 column "AS mass"

Sample calculation for Cr in test 4-10k-1
Concentration in test solution from Table G.2 column "Cr" is
84171 ng/mL.
Concentration in blank test from Table G.4 column "Cr" is 9.27 ng/mL.
Volume of test solution from Table G.1 column "Leachant Mass" is 2.82 mL (mass = 2.82 g).
Concentration in acid soak solution from Table G.3 column "Cr" is 4740 ng/mL.
Volume of acid soak solution from Table G.1 column "AS Aliquot mass" is 19.78 g.

(84171 -9.27 ng/mL) x (2.82 g) x (1 mL/g) + (4740 ng/mL) x (19.78 g) x (1 mL/g) =
3.311×10^5 *ng =* 3.31×10^2 *micrograms.*

Values are given to three significant figures.

Table G.6 gives the normalized mass loss for each test interval and Table G.7 gives the cumulative normalized mass losses through 70 days. The headings for columns in these tables are defined below:

Test Series Test numbers without digits indicating test interval.

NL(i) Normalized mass loss based on concentration of element i.

$$NL(i) = (\text{cumulative mass released})/ (\text{surface area} \bullet \text{mass fraction of element } i)$$

The cumulative mass released is obtained from Table G.5.
The surface area is obtained from Table G.1.
The mass fraction of element i is obtained from Table 1.

Sample calculation for NL(Cr) for test series 4-10k

The 0-14 day interval is test 4-10k-1, the 14-28 days interval is 4-10k-2, and the 28-70 day interval is test 4-10k-3
From Table G.5, the cumulative mass Cr released is 331 micrograms $= 3.31 \times 10^{-4}$ g.
From Table G.1, the surface area for the sample used in test series 4-10k is $5.648\ cm^2 = 5.648 \times 10^{-4}\ m^2$.
From Table 1, the mean mass fraction of Cr is 0.127.

$$NL(Cr) = 3.31 \times 10^{-4}\ g / \{5.648 \times 10^{-4}\ m^2 \bullet 0.127\} = 4.61\ g/m^2.$$

Values are given in the table to 3 significant figures.

The cumulative value through 70 days is the sum of the NL(i) for the three samplings for each test series, that is, the sum of NL(i) for the -1, -2, and -3 tests.

Sample calculation of cumulative NL(Cr) for series pH4-10k:
From Table G.6: pH4-10k-1 = 4.61 g/m^2; pH4-10k-1 = 10.0 g/m^2; pH4-10k-1 = 83.3 g/m^2. The cumulative NL(Cr) is

$$4.61 + 10.0 + 83.3\ g/m^2. = 97.91\ g/m^2.$$

Values are given in the table to 3 significant figures.

NR(i) Normalized dissolution rate based on concentration of element i, in g/m^2.

$$NR(i) = \text{(normalized mass loss)/ (cumulative reaction time)}$$

The normalized mass loss is obtained from Appendix F.
The cumulative reaction time is obtained from Appendix A.

Sample calculation for NL(Cr) for 70-day test period for test series pH3-90C-W

From Table F.1, the cumulative normalized mass loss is = 19.6 g/m^2.

$NR(Cr) = = (19.6\ g/m^2) / 70\ days = 0.280\ g/(m^2 \bullet d)$

Values are given to 3 significant figures.

Table G.1. Test Data for Effects of NaCl Tests Conducted at ANL-E

Test No.	pH Buffer	Vessel No.	Coupon No.	Coupon Area, cm^2	Coupon mass, g	Initial pH	Initiation Date	Sampling Date	Interval, d	Vessel Mass, g	Vessel+ Coupon, g	Total Mass In, g
Leachants with 10,000 ppm Cl^-												
4-10k-1	4	1	9C	5.648	3.6698	3.82	1/7/2003	1/22/2003	14	38.03	41.70	44.52
4-10k-2	4	1'	9C	5.648	3.6698		1/22/2003	2/7/2003	14	37.86	41.53	44.35
4-10k-3	4	1	9C	5.648	3.6698		2/7/2003	3/24/2003	42	37.76	41.42	44.25
8-10k-1	8	2	10C	5.645	3.6762	7.79	1/7/2003	1/22/2003	14	37.79	41.47	44.30
8-10k-2	8	2'	10C	5.645	3.6762		1/22/2003	2/7/2003	14	37.74	41.41	44.25
8-10k-3	8	2	10C	5.645	3.6762		2/7/2003	3/24/2003	42	37.76	41.44	44.27
9-10k-1	9	3	12C	5.611	3.6202	8.85	1/7/2003	1/22/2003	14	37.58	41.20	44.00
9-10k-2	9	3'	12C	5.611	3.6202		1/22/2003	2/7/2003	14	37.73	41.35	44.17
9-10k-3	9	3	12C	5.611	3.6202		2/7/2003	3/24/2003	42	38.04	41.66	44.48
10-10k-1	10	4	13C	5.608	3.6045	9.75	1/7/2003	1/22/2003	14	38.03	41.64	44.445
10-10k-2	10	4'	13C	5.608	3.6045		1/22/2003	2/7/2003	14	37.73	41.33	44.140
10-10k-3	10	4	13C	5.608	3.6045		2/7/2003	3/24/2003	42	38.07	41.68	44.49
12-10k-1	12	5	15C	5.656	3.6893	11.71	1/7/2003	1/22/2003	14	37.99	41.67	44.52
12-10k-2	12	5'	15C	5.656	3.6893		1/22/2003	2/7/2003	14	38.04	41.73	44.57
12-10k-3	12	5	15C	5.656	3.6893		2/7/2003	3/24/2003	42	37.74	41.43	44.26
9-10k/Ti-1	9	Ti 1	21C	5.643	3.6514		1/7/2003	1/22/2003	14	68.37	72.025	74.85
9-10k/Ti-2	9	Ti #7	21C	5.643	3.6514		1/22/2003	2/7/2003	14	68.53	72.18	75.01
9-10k/Ti-3	9	Ti 1	21C	5.643	3.6514		2/7/2003	3/24/2003	42	68.61	72.26	75.06
Leachants without Added NaCl												
4-0k-1	4	6	16C	5.667	3.7014	4.03	1/7/2003	1/22/2003	14	37.98	41.69	44.51
4-0k-2	4	6'	16C	5.667	3.7014		1/22/2003	2/7/2003	14	38.02	41.73	44.56
4-0k-3	4	6	16C	5.667	3.7014		2/7/2003	3/24/2003	42	37.96	41.66	44.49
8-0k-1	8	7	17C	5.624	3.6343	8.00	1/7/2003	1/22/2003	14	37.91	41.54	44.35
8-0k-2	8	7'	17C	5.624	3.6343		1/22/2003	2/7/2003	14	37.98	41.62	44.45
8-0k-3	8	7	17C	5.624	3.6343		2/7/2003	3/24/2003	42	37.87	41.5	44.31
9-0k-1	9	8	18C	5.623	3.6172	9.00	1/7/2003	1/22/2003	14	37.46	41.08	43.89
9-0k-2	9	8'	18C	5.623	3.6172		1/22/2003	2/7/2003	14	37.71	41.33	44.16
9-0k-3	9	8	18C	5.623	3.6172		2/7/2003	3/24/2003	42	37.42	41.03	43.84
10-0k-1	10	9	19C	5.607	3.5621	9.95	1/7/2003	1/22/2003	14	38.04	41.6	44.41
10-0k-2	10	9'	19C	5.607	3.5621		1/22/2003	2/7/2003	14	37.94	41.50	44.32
10-0k-3	10	9	19C	5.607	3.5621		2/7/2003	3/24/2003	42	37.66	41.21	44.02
12-0k-1	12	10	20C	5.626	3.6336	12.00	1/7/2003	1/22/2003	14	37.75	41.36	44.19
12-0k-2	12	10'	20C	5.626	3.6336		1/22/2003	2/7/2003	14	37.94	41.58	44.40
12-0k-3	12	10	20C	5.626	3.6336		2/7/2003	3/24/2003	42	37.64	41.28	44.10

Table G.1. (contd.)

Test No.[a]	Total Mass Out, g	Leachant Mass, g	S/V, m-1	Water Loss, g	Final pH	Bottle Mass, g	Bottle + Aliquot, g	Aliquot, g	B + A + water + HNO_3, g	Dilution Factor	Vessel + AS Mass, g	AS Aliquot Mass, g
Leachants with 10,000 ppm Cl^-												
4-10k-1	44.51	2.82	200.3	-0.01	4.54	10.79	12.90	2.11	13.19	1.137	57.81	19.78
4-10k-2	44.35	2.82	200.3	0.00		10.86	12.72	9.86	20.72	5.301	58.36	20.50
4-10k-3	44.27	2.83	199.6	0.02		10.78	12.77	15.87	26.65	7.975	57.83	20.07
8-10k-1	44.30	2.83	199.5	0.00	7.785	10.91	13.13	2.22	13.16	1.016	57.56	19.77
8-10k-2	44.27	2.84	198.8	0.02		10.84	12.94	8.65	19.49	4.119	58.66	20.93
8-10k-3	44.29	2.83	199.5	0.02		10.94	13.16	7.28	18.22	3.279	58.00	20.24
9-10k-1	44.01	2.80	200.4	0.01	8.77	10.87	13.13	2.27	13.17	1.018	58.61	21.03
9-10k-2	44.18	2.82	199.0	0.01		10.84	12.96	9.36	20.2	4.415	59.59	21.86
9-10k-3	44.46	2.82	199.0	-0.02		10.83	13.01	7.83	18.66	3.592	58.73	20.69
10-10k-1	44.44	2.81	199.6	-0.01	9.30	10.80	13.02	2.22	13.07	1.023	56.89	18.86
10-10k-2	44.56	2.81	199.6	0.42		10.97	13.12	9.5	20.47	4.419	58.60	20.87
10-10k-3	44.49	2.81	199.6	-0.01		10.93	13.01	7.25	18.18	3.486	60.16	22.09
12-10k-1	44.51	2.85	198.5	-0.01	10.51	10.88	13.20	2.32	13.25	1.022	59.42	21.43
12-10k-2		2.84	199.2			10.91	13.07	8.99	19.9	4.162	59.48	21.44
12-10k-3	44.28	2.83	199.9	0.02		10.92	13.11	7.30	18.22	3.333	57.87	20.13
9-10k/Ti-1	74.84	2.82	200.1	-0.01	8.91	10.95	13.17	2.22	13.22	1.023	86.03	17.66
9-10k/Ti-2	74.99	2.83	199.4	-0.02		10.96	13.02	9.04	20.00	4.388	85.70	17.17
9-10k/Ti-3		2.80	201.5			10.81	12.81	7.22	18.03	3.610	87.49	18.88
Leachants without Added NaCl												
4-0k-1	44.50	2.82	201.0	-0.01	4.05	10.92	12.96	2.04	13.09	1.064	57.03	19.05
4-0k-2	44.55	2.83	200.2	-0.01		10.90	13.03	2.26	13.16	1.061	58.19	20.17
4-0k-3	44.49	2.83	200.2	0.00		11.08	13.12	7.29	18.37	3.574	58.21	20.25
8-0k-1	44.35	2.81	200.1	0.00	7.97	10.89	13.05	2.16	13.19	1.065	57.88	19.97
8-0k-2	44.43	2.83	198.7	-0.02		10.93	13.18	2.39	13.32	1.062	58.45	20.47
8-0k-3	44.31	2.81	200.1	0.00		10.90	13.10	7.49	18.39	3.405	59.04	21.17
9-0k-1	43.88	2.81	200.1	-0.01	8.90	10.93	13.16	2.23	13.30	1.063	58.45	20.99
9-0k-2	44.14	2.83	198.7	-0.02		10.89	13.05	2.31	13.20	1.069	59.04	21.33
9-0k-3	43.83	2.81	200.1	-0.01		10.96	13.09	7.33	18.29	3.441	58.36	20.94
10-0k-1	44.40	2.81	199.5	-0.01	9.50	10.97	13.19	2.22	13.34	1.068	57.55	19.51
10-0k-2	44.38	2.82	198.8	0.06		10.85	13.01	2.30	13.15	1.065	58.82	20.88
10-0k-3	44.01	2.81	199.5	-0.01		10.98	13.07	7.35	18.33	3.517	60.32	22.66
12-0k-1	44.18	2.83	198.8	-0.01	11.13	11.04	13.28	2.24	13.42	1.063	58.72	20.97
12-0k-2	44.38	2.82	199.5	-0.02		10.80	13.13	2.47	13.27	1.060	60.19	22.25
12-0k-3	44.09	2.82	199.5	-0.01		10.90	13.08	7.40	18.30	3.394	57.32	19.68

Table G.2. Concentrations in Test Solutions for Tests with Leachants Spiked with 10,000 ppm Cl^- and without NaCl, ng/mL

Sample No.	Cr	Fe	Mn	Mo	Ni	U	Zr
Leachants with 10,000 ppm Cl^-							
4-10k-1	84171	84171	70408	8281	63242	102938	7780
4-10k-2	141000	510000	16800	11500	89100	10655	11291
4-10k-3	29109	1291950	33894	21533	165880	14116	3429
8-10k-1	193	193	43.8	57.2	257	355	17.5
8-10k-2	618	5808	88.6	1079	556	663	48.6
8-10k-3	918	8361	151	281	885	843	40.0
9-10k-1	1649	1649	1028	1689	1353	1689	105
9-10k-2	8345	40089	1841	2918	2918	2556	236
9-10k-3	7328	33262	1577	4095	3179	10165	686
10-10k-1	3763	3763	338	1319	867	336	184
10-10k-2	18735	39856	884	3720	3385	8793	401
10-10k-3	4009	9621	301	3385	662	5996	207
12-10k-1	17.7	17.7	2.3	41.3	18.3	574	8.44
12-10k-2	25.3	2314	14.0	1061	38.5	196	27.6
12-10k-3	19.0	1620	6.87	16.0	24.8	239	13.8
Leachants with 10,000 ppm Cl^- in Titanium-lined Vessel							
9-10k/Ti-1	1656	1656	425	2485	561	591	106
9-10k/Ti-2	3322	14087	531	2804	992	992	137
9-10k/Ti-3	17003	4115	1722	8989	3682	4982	762
Leachants without Added NaCl							
4-0k-1	464	464	172	218	1936	5936	510
4-0k-2	422	9433	161	172	3056	11035	574
4-0k-3	457	13188	239	197	5290	21980	890
8-0k-1	18.0	18.0	26.3	33.9	91.0	120	12.9
8-0k-2	16.9	901	16.8	306	64.8	61.3	7.8
8-0k-3	19.9	882	9.7	10.7	60.6	54.5	13.9
9-0k-1	1552	1552	674	1924	1233	3741	182
9-0k-2	2663	11229	450	2748	1065	5775	296
9-0k-3	2343	6779	747	3992	871	5609	296
10-0k-1	7.89	7.89	3.25	31.2	15.1	272	11.9
10-0k-2	8.52	806	6.19	211	17.0	74.5	7.68
10-0k-3	20.0	538	3.69	27.3	19.8	132	145
12-0k-1	17.0	17.0	3.64	89.0	17.4	636	11.1
12-0k-2	12.5	718	4.01	251	13.5	253	10.1
12-0k-3	19.3	550	4.1	19.8	32.2	445	14.7

Table G.3. Concentrations in Acid Soak Solutions for Tests with Leachants Spiked with 10,000 ppm Cl^- and without NaCl, ng/mL

Test No.	Cr	Fe	Mn	Mo	Ni	U	Zr
Leachants with 10,000 ppm Cl^-							
4-10k-1	4740	32000	45.3	321	362	861	546
4-10k-2	15700	82500	155	1450	1190	3960	1080
4-10k-3	293475	1283955	4259	20256	37721	77994	12122
8-10k-1	1.47	33.6	0.285	0.106	3.44	0.625	0.301
8-10k-2	92.2	530	5.77	10.5	31.8	22.8	3.12
8-10k-3	14.8	266	<5.6	6.76	24.8	6.23	4.72
9-10k-1	23.1	434	15.7	0.122	31.4	7.27	1.01
9-10k-2	126	1100	23.1	9.45	61.5	28.4	5.59
9-10k-3	230	4633	79.0	35.9	270	121	20.8
10-10k-1	23.5	187	3.72	2.26	12.9	8.06	2.13
10-10k-2	137	1040	14.3	8.45	53.6	14.4	5.17
10-10k-3	495	1408	24.8	23.3	82.3	44.3	17.1
12-10k-1	0.241	<18.4	<0.09	<0.1	3.68	0.733	0.388
12-10k-2	0.821	107	0.404	3.98	4.82	<0.56	2.08
12-10k-3	2.68	1720	<5.73	5.17	10.90	0.40	6.57
Test with 10,000 ppm Cl^- in Titanium-lined Vessel							
9-10k/Ti-1	607	2900	158	0.219	224	226	0.1222
9-10k/Ti-2	601	5440	179	2.59	390	231	0.983
9-10k/Ti-3	10469	85918	1791	28.2	4188	3422	42.237
Leachants without Added NaCl							
4-0k-1	7.13	102	1.45	1.08	14.9	44.7	13.5
4-0k-2	3.54	281	1.33	19.3	12.2	28.5	16.0
4-0k-3	12.5	396.7	<6.1	9.11	77.2	312.7	67.5
8-0k-1	0.818	39.5	0.36	<0.1	6.09	0.629	0.051
8-0k-2	0.917	101	0.676	14.1	5.02	<0.56	1.21
8-0k-3	3.17	531	<5.86	9.81	19.1	0.55	3.92
9-0k-1	167	1810	41.9	5.69	151	92.5	13.8
9-0k-2	257	1130	24.5	21.2	90.5	181	32.6
9-0k-3	254	1122	48.9	25.2	109	142	30.7
10-0k-1	<0.22	<18.4	0.102	<0.1	3.25	0.289	2.16
10-0k-2	0.810	79.2	0.474	9.6	5.12	<0.56	1.3
10-0k-3	2.36	193	<6.05	7.81	10.73	0.83	4.54
12-0k-1	0.35	67.5	0.146	<0.1	3.21	0.517	0.127
12-0k-2	1.10	86.9	0.463	7.74	6.49	<0.56	1.27
12-0k-3	4.11	201	<5.84	8.01	13.85	1.64	4.14

Table G.4. Background Concentrations for Tests with Leachants Spiked with 10,000 ppm Cl^- and without NaCl, ng/mL

Test No.	Cr	Fe	Mn	Mo	Ni	U	Zr
Leachants with 10,000 ppm Cl^-							
4-10k-3b	9.27	319	0	67.2	5.67	0	3.98
8-10k-3b	9.76	289	0	79.5	7.97	0	4.13
9-10k-3b	1.56	289	0	73.3	4.38	0	4.01
10-10k-3b	1.73	289	0	35.9	4.00	0	4.01
12-10k-3b	3.41	432	0	14.6	6.10	1.82	12.6
Leachants without Added NaCl							
4-0k-3b	7.78	193	0	22.1	10.5	0	3.98
8-0k-3b	9.22	301	0	33.6	7.33	0	4.34
9-0k-3b	1.23	235	0	35.5	4.52	0	35.5
10-0k-3b	2.01	248	0	35.6	4.09	0.102	4.22
12-0k-3b	2.06	278	0	31.0	4.34	1.62	12.8

Table G.5. Total Mass Released in Tests with Leachants Spiked with 10,000 ppm Cl^- and without NaCl, micrograms

Test No.	Cr	Fe	Mn	Mo	Ni	U	Zr
Leachants with 10,000 ppm Cl^-							
4-10k-1	3.31E+02	1.42E+03	1.99E+02	2.95E+01	1.85E+02	3.07E+02	3.27E+01
4-10k-2	7.20E+02	3.13E+03	5.05E+01	6.20E+01	2.76E+02	1.11E+02	5.40E+01
4-10k-3	5.97E+03	2.94E+04	1.81E+02	4.67E+02	1.23E+03	1.61E+03	2.53E+02
8-10k-1	5.48E-01	6.89E+00	1.30E-01	-6.10E-02	7.73E-01	1.02E+00	4.37E-02
8-10k-2	3.65E+00	2.68E+01	3.72E-01	3.06E+00	2.22E+00	2.36E+00	1.91E-01
8-10k-3	2.87E+00	2.82E+01	4.26E-01	7.08E-01	2.98E+00	2.51E+00	1.97E-01
9-10k-1	5.10E+00	5.76E+01	3.21E+00	4.53E+00	4.44E+00	4.88E+00	3.04E-01
9-10k-2	2.63E+01	1.36E+02	5.69E+00	8.22E+00	9.55E+00	7.82E+00	7.75E-01
9-10k-3	2.54E+01	1.89E+02	6.08E+00	1.21E+01	1.45E+01	3.12E+01	2.35E+00
10-10k-1	1.11E+01	4.05E+01	1.03E+00	3.65E+00	2.70E+00	1.12E+00	5.51E-01
10-10k-2	5.55E+01	1.33E+02	2.79E+00	1.05E+01	1.06E+01	2.50E+01	1.22E+00
10-10k-3	2.22E+01	5.73E+01	1.39E+00	9.93E+00	3.67E+00	1.78E+01	9.48E-01
12-10k-1	4.49E-02	1.36E+00	6.67E-03	7.61E-02	9.97E-02	1.64E+00	6.85E-03
12-10k-2	7.61E-02	7.18E+00	4.68E-02	3.04E+00	1.75E-01	5.51E-01	7.83E-02
12-10k-3	4.44E-02	3.80E+01	1.94E-02	1.08E-01	2.72E-01	6.78E-01	1.36E-01
Test with 10,000 ppm Cl^- in Titanium-lined Vessel							
9-10k/Ti-1	1.61E+01	8.31E+01	4.18E+00	6.82E+00	5.80E+00	5.93E+00	2.92E-01
9-10k/Ti-2	2.19E+01	1.53E+02	5.24E+00	7.79E+00	1.09E+01	7.63E+00	3.97E-01
9-10k/Ti-3	2.45E+02	1.63E+03	3.86E+01	2.55E+01	8.94E+01	7.86E+01	2.92E+00
Leachants without Added NaCl							
4-0k-1	1.42E+00	3.64E+01	5.13E-01	5.72E-01	5.71E+00	1.76E+01	1.68E+00
4-0k-2	1.25E+00	3.18E+01	4.84E-01	8.13E-01	8.87E+00	3.18E+01	1.94E+00
4-0k-3	1.53E+00	4.48E+01	6.76E-01	6.80E-01	1.65E+01	6.85E+01	3.87E+00
8-0k-1	4.10E-02	3.03E+00	8.11E-02	7.50E-04	3.57E-01	3.51E-01	2.50E-02
8-0k-2	4.05E-02	3.77E+00	6.13E-02	1.06E+00	2.65E-01	1.73E-01	3.47E-02
8-0k-3	9.70E-02	1.29E+01	2.73E-02	1.43E-01	5.54E-01	1.65E-01	1.10E-01
9-0k-1	7.86E+00	7.83E+01	2.77E+00	5.43E+00	6.62E+00	1.25E+01	7.01E-01
9-0k-2	1.30E+01	5.52E+01	1.80E+00	8.13E+00	4.93E+00	2.02E+01	1.43E+00
9-0k-3	1.19E+01	4.19E+01	3.12E+00	1.16E+01	4.71E+00	1.87E+01	1.37E+00
10-0k-1	1.65E-02	2.36E+00	1.11E-02	0	9.42E-02	7.69E-01	6.35E-02
10-0k-2	3.53E-02	3.23E+00	2.73E-02	6.94E-01	1.43E-01	2.10E-01	3.69E-02
10-0k-3	4.79E-02	5.20E+00	1.04E-02	1.53E-01	2.87E-01	3.90E-01	4.98E-01
12-0k-1	4.96E-02	2.99E+00	1.34E-02	1.64E-01	1.04E-01	1.81E+00	2.66E-03
12-0k-2	5.40E-02	3.17E+00	2.16E-02	7.94E-01	1.70E-01	7.10E-01	2.05E-02
12-0k-3	7.50E-02	4.71E+00	1.17E-02	1.26E-01	3.51E-01	1.28E+00	8.68E-02

Table G.6. Normalized Mass Loss for Each Test Interval with Leachants Spiked with 10,000 ppm Cl^- and without NaCl, ng/mL

Test No.	NL(Cr)	NL(Fe)	NL(Mn)	NL(Mo)	NL(Ni)	NL(U)	NL(Zr)
Leachants with 10,000 ppm Cl^-							
4-10k-1	4.61E+00	4.87E+00	3.82E+01	3.19E+00	4.23E+00	5.59E+00	3.74E-01
4-10k-2	1.00E+01	1.07E+01	9.66E+00	6.69E+00	6.28E+00	2.03E+00	6.17E-01
4-10k-3	8.33E+01	1.01E+02	3.47E+01	5.04E+01	2.79E+01	2.92E+01	2.89E+00
8-10k-1	7.64E-03	2.36E-02	2.48E-02	-6.59E-03	1.76E-02	1.85E-02	5.00E-04
8-10k-2	5.10E-02	9.15E-02	7.13E-02	3.30E-01	5.06E-02	4.30E-02	2.19E-03
8-10k-3	4.00E-02	9.65E-02	8.16E-02	7.65E-02	6.80E-02	4.57E-02	2.25E-03
9-10k-1	7.16E-02	1.98E-01	6.18E-01	4.92E-01	1.02E-01	8.95E-02	3.49E-03
9-10k-2	3.68E-01	4.68E-01	1.10E+00	8.93E-01	2.19E-01	1.43E-01	8.91E-03
9-10k-3	3.57E-01	6.50E-01	1.17E+00	1.31E+00	3.34E-01	5.71E-01	2.71E-02
10-10k-1	1.55E-01	1.39E-01	1.98E-01	3.97E-01	6.19E-02	2.05E-02	6.34E-03
10-10k-2	7.79E-01	4.59E-01	5.37E-01	1.14E+00	2.44E-01	4.58E-01	1.41E-02
10-10k-3	3.12E-01	1.97E-01	2.69E-01	1.08E+00	8.42E-02	3.27E-01	1.09E-02
12-10k-1	6.25E-04	4.64E-03	1.27E-03	8.20E-03	2.27E-03	2.99E-02	7.82E-05
12-10k-2	1.06E-03	2.45E-02	8.94E-03	3.28E-01	3.98E-03	1.00E-02	8.93E-04
12-10k-3	6.18E-04	1.30E-01	3.71E-03	1.16E-02	6.20E-03	1.23E-02	1.55E-03
Test with 10,000 ppm Cl^- in Titanium-lined Vessel							
9-10k/Ti-1	2.25E-01	2.84E-01	8.01E-01	7.37E-01	1.32E-01	1.08E-01	3.33E-03
9-10k/Ti-2	3.06E-01	5.22E-01	1.00E+00	8.41E-01	2.49E-01	1.39E-01	4.54E-03
9-10k/Ti-3	3.42E+00	5.59E+00	7.40E+00	2.75E+00	2.04E+00	1.43E+00	3.34E-02
Leachants without Added NaCl							
4-0k-1	1.97E-02	1.24E-01	9.78E-02	6.16E-02	1.30E-01	3.19E-01	1.91E-02
4-0k-2	1.73E-02	1.08E-01	9.23E-02	8.75E-02	2.01E-01	5.77E-01	2.21E-02
4-0k-3	2.12E-02	1.53E-01	1.29E-01	7.32E-02	3.75E-01	1.24E+00	4.41E-02
8-0k-1	5.74E-04	1.04E-02	1.56E-02	8.13E-05	8.17E-03	6.41E-03	2.87E-04
8-0k-2	5.67E-04	1.29E-02	1.18E-02	1.15E-01	6.07E-03	3.17E-03	3.98E-04
8-0k-3	1.36E-03	4.42E-02	5.24E-03	1.55E-02	1.27E-02	3.01E-03	1.26E-03
9-0k-1	1.10E-01	2.69E-01	5.33E-01	5.88E-01	1.52E-01	2.28E-01	8.04E-03
9-0k-2	1.82E-01	1.90E-01	3.46E-01	8.82E-01	1.13E-01	3.70E-01	1.64E-02
9-0k-3	1.67E-01	1.44E-01	6.00E-01	1.26E+00	1.08E-01	3.43E-01	1.58E-02
10-0k-1	2.32E-04	8.12E-03	2.14E-03	0	2.16E-03	1.41E-02	7.31E-04
10-0k-2	4.95E-04	1.11E-02	5.27E-03	7.55E-02	3.29E-03	3.85E-03	4.25E-04
10-0k-3	6.73E-04	1.79E-02	2.00E-03	1.67E-02	6.59E-03	7.16E-03	5.73E-03
12-0k-1	6.95E-04	1.03E-02	2.57E-03	1.78E-02	2.39E-03	3.30E-02	3.05E-05
12-0k-2	7.55E-04	1.09E-02	4.15E-03	8.60E-02	3.89E-03	1.30E-02	2.35E-04
12-0k-3	1.05E-03	1.62E-02	2.24E-03	1.37E-02	8.03E-03	2.34E-02	9.95E-04

Table G.7. Cumulative Normalized Mass Loss for Tests with Leachants Spiked with 10,000 ppm Cl^- and without Added NaCl, g/m^2

Test No.	NL(Cr)	NL(Fe)	NL(Mn)	NL(Mo)	NL(Ni)	NL(U)	NL(Zr)
Cumulative Normalized Mass Loss Through 14 Days							
Leachants with 10,000 ppm Cl							
pH4-10k	4.61E+00	4.87E+00	3.82E+01	3.19E+00	4.23E+00	5.59E+00	3.74E-01
pH810k	7.64E-03	2.36E-02	2.48E-02	-6.59E-03	1.76E-02	1.85E-02	5.00E-04
pH9-10k	7.16E-02	1.98E-01	6.18E-01	4.92E-01	1.02E-01	8.95E-02	3.49E-03
pH10-10k	1.55E-01	1.39E-01	1.98E-01	3.97E-01	6.19E-02	2.05E-02	6.34E-03
pH12-10k	6.25E-04	4.64E-03	1.27E-03	8.20E-03	2.27E-03	2.99E-02	7.82E-05
Test with 10,000 ppm Cl in Titanium-lined Vessel							
pH9-10k/Ti	2.25E-01	2.84E-01	8.01E-01	7.37E-01	1.32E-01	1.08E-01	3.33E-03
Leachants without Added NaCl							
pH4-0k	1.97E-02	1.24E-01	9.78E-02	6.16E-02	1.30E-01	3.19E-01	1.91E-02
pH80k	5.74E-04	1.04E-02	1.56E-02	8.13E-05	8.17E-03	6.41E-03	2.87E-04
pH9-0k	1.10E-01	2.69E-01	5.33E-01	5.88E-01	1.52E-01	2.28E-01	8.04E-03
pH10-0k	2.32E-04	8.12E-03	2.14E-03	-1.37E-03	2.16E-03	1.41E-02	7.31E-04
pH12-0k	6.95E-04	1.03E-02	2.57E-03	1.78E-02	2.39E-03	3.30E-02	3.05E-05
Cumulative Normalized Mass Loss Through 28 Days							
Leachants with 10,000 ppm Cl							
pH4-10k	1.46E+01	1.56E+01	4.78E+01	9.88E+00	1.05E+01	7.62E+00	9.91E-01
pH810k	5.86E-02	1.15E-01	9.61E-02	3.24E-01	6.83E-02	6.15E-02	2.69E-03
pH9-10k	4.40E-01	6.67E-01	1.71E+00	1.39E+00	3.21E-01	2.33E-01	1.24E-02
pH10-10k	9.34E-01	5.98E-01	7.36E-01	1.54E+00	3.06E-01	4.78E-01	2.04E-02
pH12-10k	1.69E-03	2.91E-02	1.02E-02	3.36E-01	6.25E-03	3.99E-02	9.71E-04
Test with 10,000 ppm Cl in Titanium-lined Vessel							
pH9-10k/Ti	5.31E-01	8.06E-01	1.81E+00	1.58E+00	3.82E-01	2.47E-01	7.87E-03
Leachants without Added NaCl							
pH4-0k	3.70E-02	2.33E-01	1.90E-01	1.49E-01	3.31E-01	8.96E-01	4.12E-02
pH80k	1.14E-03	2.33E-02	2.74E-02	1.15E-01	1.42E-02	9.58E-03	6.85E-04
pH9-0k	2.92E-01	4.58E-01	8.79E-01	1.47E+00	2.64E-01	5.97E-01	2.45E-02
pH10-0k	7.27E-04	1.92E-02	7.41E-03	7.42E-02	5.45E-03	1.80E-02	1.16E-03
pH12-0k	1.45E-03	2.12E-02	6.72E-03	1.04E-01	6.28E-03	4.60E-02	2.66E-04
Cumulative Normalized Mass Loss Through 70 Days							
Leachants with 10,000 ppm Cl							
pH4-10k	9.79E+01	1.16E+02	8.25E+01	6.03E+01	3.85E+01	3.68E+01	3.88E+00
pH8-10k	9.87E-02	2.12E-01	1.78E-01	4.00E-01	1.36E-01	1.07E-01	4.94E-03
pH9-10k	7.97E-01	1.32E+00	2.89E+00	2.70E+00	6.54E-01	8.04E-01	3.95E-02
pH10-10k	1.25E+00	7.96E-01	1.00E+00	2.62E+00	3.90E-01	8.05E-01	3.13E-02
pH12-10k	2.30E-03	1.59E-01	1.39E-02	3.48E-01	1.24E-02	5.23E-02	2.52E-03
Test with 10,000 ppm Cl in Titanium-lined Vessel							
pH9-10k/Ti	3.95E+00	6.39E+00	9.21E+00	4.33E+00	2.42E+00	1.68E+00	4.12E-02
Leachants without Added NaCl							
pH4-0k	5.82E-02	3.85E-01	3.19E-01	2.22E-01	7.06E-01	2.14E+00	8.53E-02
pH8-0k	2.50E-03	6.75E-02	3.26E-02	1.30E-01	2.69E-02	1.26E-02	1.95E-03
pH9-0k	4.59E-01	6.02E-01	1.48E+00	2.73E+00	3.72E-01	9.40E-01	4.02E-02
pH10-0k	1.40E-03	3.71E-02	9.41E-03	9.08E-02	1.20E-02	2.51E-02	6.89E-03
pH12-0k	2.50E-03	3.73E-02	8.97E-03	1.17E-01	1.43E-02	6.94E-02	1.26E-03

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