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The Reaction of Glass during Gamma Irradiation in a Saturated Tuff Environment

Part 4: SRL 165, ATM-1c, and ATM-8 Glasses at 1E3 R/h and 0 R/h

by William L. Ebert, John K. Bates, and Thomas J. Gerding

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Chemical Technology Division

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ABSTRACT

The reaction between tuffaceous groundwater and actinide-doped SRL 165 and PNL 76-68 type glasses in a gamma radiation field has been studied at 90°C for periods up to 278 days. The primary effect of the radiation field was the acidification of the leachate through the production of nitrogen acids. Acidification of the leachate was limited by bicarbonate in the groundwater, which effectively buffered the solution at a pH near 6.4 for all exposures tested. Nonirradiated experiments were performed to represent the lowest limit of radiation exposure. The leachate pHs of these experiments increased to values near 9. Both irradiated and nonirradiated experiments were performed with and without a tuff monolith present in the reaction vessel. Neither irradiation nor the presence of tuff had a major effect on the extent of glass reaction as measured by the leachate concentrations of various glass species or analysis of the reacted glass surfaces. The reaction process resulted in the formation of an alteration or "gel" layer on the outer surface of the SRL 165 glass which was depleted of leachable species and enriched in insoluble species, relative to the original glass. The overall composition of this layer is similar to that of nontronite, an iron-rich smectite clay.

Of special concern is the behavior of the radionuclides. Irradiation was seen to reduce the Eh of the solution, as indicated by the reduction of most of the nitrate ions to nitrite. The reduction of the solution undoubtedly affected the oxidation states of the released transuranics and so their behavior in solution. Depending on the conditions and the glass type, uranium was incorporated into precipitates, adsorbed onto the stainless steel vessel surface, and dissolved in solution to differing degrees. Americium remained mainly as an insoluble residue on the outer surface of the reacting glass, while most of the released plutonium was adsorbed onto the stainless steel vessel surface. Neptunium was released into the leachate where it existed both in a suspended, perhaps colloidal, phase as well as in solution. The partitioning of the released actinides between the various sorbed phases and solution was very sensitive to the leachate pH and was influenced somewhat by the presence of the tuff monolith.

I. INTRODUCTION

The U.S. Department of Energy was delegated the authority by the Waste Policy Act of 1982 to locate, construct, and operate a repository for the permanent disposal of high-level nuclear waste. The proposed repository is to be located in a deep-burial site in a stable geological horizon in which spent fuel and high-level reprocessed waste are contained. After emplacement of the waste in the repository, the dominant avenue of radionuclide release, if any, is expected to be via groundwater transport. In order for radionuclides to be released into the environment surrounding the repository, groundwater must first come into contact with the waste form, react with the waste form to free the radionuclides, and then transport them away from the near-field locality.

One approach for reducing the release of radionuclides is to provide multiple barriers to groundwater infiltration. The repository geohydrology itself may be an effective barrier. The engineering of the repository will be such to minimize the disturbance of the rock and to best accommodate the thermal effects of the emplaced waste. It has also been determined that the waste will be enclosed in a container and sealed effectively from the groundwater for an initial containment period of 300/1000 years. Only after the container is breached can groundwater come into direct contact with the waste form, which itself acts as a barrier to radionuclide release.

The two candidate materials for storage in the repository are spent fuel from commercial nuclear power plants and high-level reprocessed nuclear waste from either the Defense Waste Processing Facility at Savannah River Laboratory (SRL), or the West Valley Demonstration Plan. The reprocessed waste will be in the form of a borosilicate glass. Much effort has been directed towards finding the best glass formulation for high-level waste reprocessing, and the behavior of the glass in the repository will vary with the conditions encountered in the repository.

The Nevada Nuclear Waste Storage Investigations (NNWSI) Project has been evaluating the volcanic tuff beds of Yucca Mountain, Nevada, as a potential repository site. This site is described as unsaturated [SCP], although isolated pockets of standing water may occur. As part of the waste package program, which is being directed by Lawrence Livermore National Laboratory (LLNL), Argonne National Laboratory (ANL) has been studying the interactions of components expected to be present in a tuff repository. Irradiation of moist air is known to generate nitric acid [BURNS] which, when dissolved in the leachate, acidifies the system. Glass reactions have been observed to be accelerated under such conditions in previous work [McVAY, BARKATT]. This report describes modified MCC-1-type leaching experiments performed using synthetic nuclear waste glass and actual tuffaceous groundwater in the presence of a gamma radiation field. Experiments have been performed previously under gamma radiation exposures of 2E5 R/h [BATES-1] and 1E4 R/h [ABRAJANO]. The present experiments were performed under a gamma radiation exposure rate of 1E3 R/h and in the absence of radiation to better quantify the affect of radiation on the

glass reaction. The entire set of experiments was not designed to simulate the repository environment, rather it was designed only to monitor the interactions of those components expected to be present in the repository, including actual repository groundwater, tuff rock, 304L stainless steel, simulated nuclear waste glass, and air, as a function of gamma radiation.

This report discusses the results of leaching experiments performed in a gamma radiation field with exposure rate of 1E3 R/h and in the absence of a radiation field. A comparison of the results of experiments containing ATM-1c and ATM-8 glass with the results of similar experiments under other exposure rates is presented elsewhere [BATES-2], while a comparison of experiments involving the SRL 165 type glasses will be presented later [EBERT].

II. EXPERIMENTAL

The experiments involved placing two glass disks of a given composition and one caliche-free tuff wafer into a 304L stainless steel vessel. The tuff wafer was placed on the bottom of the vessel and the glass disks were placed on a 304L stainless steel support that rested on top of the tuff wafer. Analogous experiments were performed without a tuff wafer present to more clearly demonstrate the role of tuff rock in the reaction. The amount of EJ-13 water added to a vessel was varied slightly to maintain a glass surface area to leachant volume ratio near 30 m^{-1} and an air to leachant volume ratio near 0.3. The vessels were sealed using silicone rubber gaskets and compression fittings. This assembly and associated experimental procedures are similar to that used in previous experiments [BATES-1, ABRAJANO]. A sketch of the experimental vessel is shown in Fig. 1.

Experiments were performed using four different synthetic waste glass formulations. Two of the glass compositions were based on SRL black frit (similar to SRL 165 type glass). One of these SRL 165 type glasses was doped with uranium, cesium, and strontium, and is referred to as SRL U glass, while the other was additionally doped with neptunium-237, plutonium-239, and americium-241, and is referred to as SRL A glass. Leaching experiments were also performed using ATM-1c glass, a type of Pacific Northwest Laboratory 76-68 glass containing uranium, and glass ATM-8, which contains uranium, neptunium-237, and plutonium-239. While the composition(s) of the glass(es) which will contain the actual waste to be placed in the repository has not yet been determined, it is presently thought that it will be similar to that of SRL 165. The ATM glass formulations were developed for a different feed, and are not planned for use in waste disposal. Experiments were performed using the PNL 76-68 type glasses because the large data base already available for these compositions may prove useful as a test case for validating computer simulation models, such as those using EQ3/6, as well as contributing to the further study of corrosive mechanisms of glasses in general.

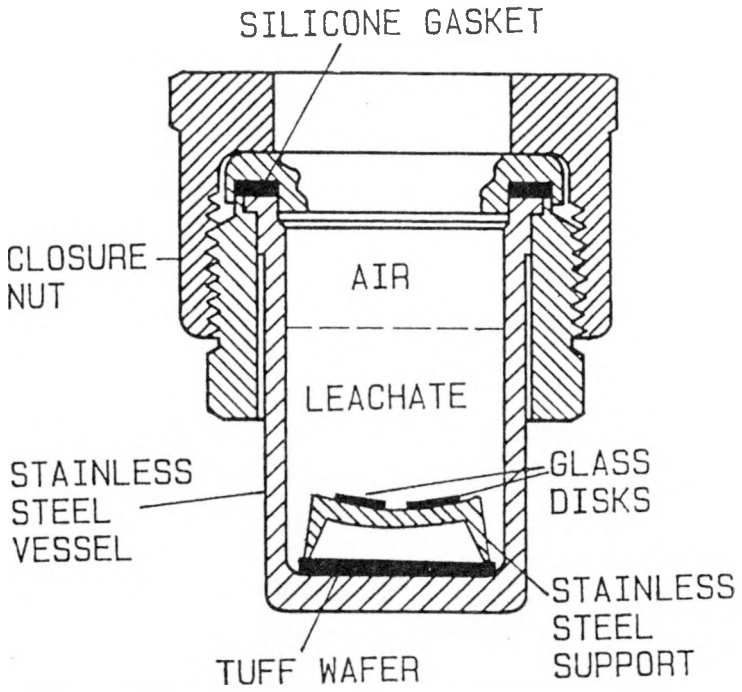


Fig. 1. Sketch of Reaction Vessel Assembly Used in these Experiments

The SRL 165 type glasses were prepared at ANL by doping black frit which was supplied by Savannah River Laboratory (SRL). The same stock has been used throughout the entire experimental series, although the dopant concentrations have varied slightly. The ATM-1c and ATM-8 glasses were supplied by the Materials Characterization Center (MCC) as standard test materials [WALD-1, -2]. The glass supplied was core drilled and cut at ANL. The glasses were analyzed at ANL after they were produced, as well as by the MCC and LLNL, and the compositions are given in Table 1.

The leachant used in this series of gamma irradiation experiments consists of actual groundwater obtained from well J-13 on Jackass Flats of the Nevada test site. This source has been used for all the NNWSI gamma irradiation experiments performed at ANL. A description of the method by which the groundwater is collected and an assay have been given by Knauss et al. [KNAUSS] and Delany [DELANY], respectively. In an effort to better simulate the groundwater in the repository environment, the J-13 groundwater was reacted with pulverized tuff rock at 90°C to produce the leachant solution, referred to hereafter as EJ-13.* A similar procedure was used to prepare the EJ-13 solution used in all experiments performed in FY 1984, FY 1985, and FY 1986. This procedure is presented in detail in Appendix I.

*The groundwater obtained from well J-13 is presumably equilibrated with the tuff rock at about 37°C, while the repository is expected to be at higher temperatures during the isolation period.

Table 1. Compositions of the Glasses Used in FY 1986 Gamma Irradiation Experiments

	SRL 165[a]		ATM-1c[b]		ATM-8	
Formula	Oxide wt %	Cation wt %	Oxide wt %	Cation wt %	Oxide wt %	Cation wt %
Al_2O_3	4.08	2.16	0.68	0.36	1.10	0.58
$^{241}Am_2O_3$	6.28E-4[c]	5.71E-4	-	-	-	-
B_2O_3	6.76	2.10	9.14	2.84	8.36	2.60
BaO	0.06	0.05	0.50	0.41	0.58	0.47
CaO	1.62	1.16	2.38	1.70	2.36	1.69
CeO_2	<0.05	<0.041	0.91	0.74	0.11	0.09
Cr_2O_3	<0.01	<0.007	0.42	0.29	0.48	0.33
Cs_2O	0.072	0.07	0.90	0.85	0.97[d]	0.91
Fe_2O_3	11.74	8.21	9.05	6.33	8.57	5.99
La_2O_3	<0.05	<0.043	4.19	3.76	4.88	4.38
Li_2O	4.18	1.94	-	-	-	-
MgO	0.70	0.42	0.16	0.10	0.15	0.09
MnO_2	2.79	1.76	0.02	0.01	0.05	0.03
MoO_3	<0.01	<0.007	1.89	1.26	2.11	1.41
Na_2O	10.85	8.05	12.40	9.20	12.62	9.36
Nd_2O_3	<0.05	<0.043	1.39	1.19	1.61	1.38
NiO	0.85	0.67	0.21	0.17	0.26[d]	0.20
$^{237}NpO_2$	2.62E-2[c]	2.31E-2	-	-	0.38	0.34
P_2O_5	0.023	0.01	0.60	0.27	0.57	0.25
$^{239}PuO_2$	2.2E-2[c]	1.94E-2	-	-	0.10	0.09
SiO_2	52.86	24.71	41.02	19.18	37.80	17.67
SrO	0.11	0.08	0.43	0.36	0.49	0.41
TiO_2	0.14	0.08	2.88	1.73	2.70	1.62
UO_2	0.92	0.81	3.96	3.49	4.20	3.7
ZnO	0.04	0.03	4.52	3.63	4.42	3.55
ZrO_2	0.66	0.49	1.78	1.32	2.35	1.74
TOTAL	98.45		99.43		97.22	

[a]SRL 165 black frit composition used for SRL U and SRL A glasses.

[b]Compositions reported are averages of multiple analyses at different laboratories.

[c]Present in SRL A only.

[d]Determined at LLNL only.

Tuff monoliths were supplied by LLNL. These had been core drilled from Fran Ridge near the proposed repository site, and cut into wafers approximately 2 mm thick and 2.5 cm in diameter. One face of each wafer was polished to facilitate surface analyses to be performed at LLNL after the experiments were terminated. The tuff wafers were preconditioned before being placed in the experimental vessel by soaking in J-13 well water at 90°C for about two hours. This served to dissolve any residual caliche material and saturate most of the pore volume of the tuff.

The reaction vessels had been used in previous years' experiments performed at higher exposure rates. They were fabricated by Parr Corp., Moline, IL, from 304L stainless steel stock provided by ANL. The support stands on which the glass disks were placed were also fabricated from 304L stainless steel. These were supplied new for each set of experiments by LLNL.

A simplified matrix of the types of experiments performed is presented in Table 2. Experiments were run with and without a tuff wafer present at exposure rates of 1E3 R/h or 0 R/h. In addition to the experiments containing glass, blank experiments were run which contained only EJ-13 water or EJ-13 water plus a tuff wafer. These experiments were helpful in understanding the effects of a radiation field on the groundwater alone. The leachate ion concentrations in these blank experiments were also used to define the background concentrations of various species for the experiments which include glass.* The vessels of the irradiated experiments were placed in a 90°C oven in the ^{60}Co gamma radiation facility at ANL. Dosimetry had been performed inside an empty vessel in the oven and the appropriate adjustments made to yield an exposure rate of about 1E3 R/h inside the vessel. Vessels were arranged in the oven so all would receive the same exposure. The vessels used in the nonirradiated experiments were placed in a 90°C oven in the high-level waste studies laboratory at ANL. Each experimental series was run for 28, 56, 91, 181, and 278 days. Additional nonirradiated experiments using SRL U and SRL A glasses, with and without tuff, and blanks were run for 14 days. All experiments were completed within the longest experimental duration, which was 278 days. The decay of the gamma source is negligible over this period.

A few nonirradiated experiments with EJ-13 water were also performed using Teflon™ gaskets in place of the silicone rubber gaskets. Since silicone rubber may contaminate the leachate with excess silicon, the Teflon™ gasket experiments were performed as a check of potential silicon contamination. Teflon™ gaskets are known to release fluoride and lose their integrity when placed in a gamma radiation field, and so Teflon™ is not a viable gasket material option for these experiments.

*As discussed previously by [BATES-1] and [ABRAJANO], the EJ-13 plus tuff experiments were not true blanks for the EJ-13 plus tuff plus glass experiments because of the possible interaction between the tuff and glass.

Table 2. Simplified Experimental Matrix Used for FY 1986 Gamma Irradiation Experiments. Prereacted J-13 groundwater was used as the leachant for all experiments (see text).

	1E3 R/h[a]		0 R/h[b]	
Glass	With Tuff[c]	Without Tuff	With Tuff	Without Tuff
SRL U[d]	2[f]	2	2	2
SRL A[e]	2	2	2	2
ATM-1c	2	2	-	-
ATM-8	2	2	-	-
None	2	2	2	2

[a]Irradiated experiments were run for 28, 56, 91, 181, and 278 days.

[b]Nonirradiated experiments were run for 14, 28, 56, 91, 181, and 278 days.

[c]Caliche-free Topopah spring tuff monolith wafer.

[d]SRL 165 black frit doped with U, Cs, Sr.

[e]SRL 165 black frit doped with U, Cs, Sr, ^{237}Np, ^{239}Pu, ^{241}Am.

[f]Indicates duplicate experiments were performed.

At the termination of an experiment, the appropriate vessels were removed from the oven and allowed to cool to near room temperature. The procedure for opening the vessels and analyzing the contents has been outlined previously [BATES-1]. All vessels were opened and the components removed within two hours of having cooled. The leachate pH was measured and aliquots were removed for later analysis of various anions (ion chromatography), released radionuclides (alpha spectroscopy), and the total carbon content of the leachate (chemical oxidation to CO_2 followed by infra-red quantification). The glass disks and tuff wafer (if present) were removed and the leachate was acidified to near pH 1 using conc. HNO_3 to dissolve any species adsorbed onto the stainless steel vessel or support stand. The acidified leachate was sealed in the vessel with the support stand present for about 20 hours at 90°C. Aliquots of the acidified leachate were then analyzed for actinides (alpha spectroscopy, atomic fluorescence spectroscopy), and other cations (inductively coupled plasma atomic emission spectroscopy). Finally, the empty vessel was rinsed using a solution of nitric and hydrofluoric acids to dissolve any remaining species adsorbed on the vessel or stand. An aliquot of this solution was analyzed for actinides. Except for the sample filtered to determine the filterable fraction of actinides (see section III.D.3), all leachate analyses were performed using the unfiltered leachate.

The glass and tuff disks were removed from the vessels before acidification, rinsed using high purity water, then air dried. The glass disks were then weighed to determine weight change. Some of the reacted glass surfaces were analyzed using a scanning electron microscope (SEM) with an associated energy-dispersive x-ray fluorescence spectrometer (EDS), secondary ion mass spectrometry (SIMS), resonant nuclear reaction spectroscopy (RNRS), or ion microprobe analysis (IMA).

These experiments have produced a very large amount of data which is used to characterize the interactions which occurred. The data will be discussed below under the two major headings of Leachate Analyses and Surface Analyses. In the Leachate Analyses section, the analytical results of the leachate solutions and of those species which were adsorbed onto the stainless steel reaction vessel are presented. The net weight change of the glass disks themselves is included in this section in order to more easily relate the normalized elemental weight change to that of the glass disks. The results of various surface analyses of the reacted glasses are discussed in the Surface Analyses section.

The reaction as a whole is discussed in the Discussion section. A description of the glass reaction is presented therein. A few comments regarding the repository relevance of these experiments follow the Discussion section. The data tables which include all the raw data plus most computations are presented together in Section VII for convenience.

III. LEACHATE ANALYSES

The compositions of the SRL U and SRL A glasses differ only in that the latter formulation includes doped actinides at very small concentrations. The dissolution behavior of the nonradioactive matrix elements indicates that these glasses react essentially identically. The small amount of radionuclides present in the SRL A glasses may induce some local radiolysis effects, but these are not measurable in the analyses. While the results of both glass types are presented in the data tables, the discussions will be focused on what is observed in the experiments including SRL U glass because of the more extensive surface analyses performed on these samples. Discussion of the actinide releases will, of course, involve the SRL A glasses. Since the ATM glasses have different compositions, the leachate results of both will be discussed.

A. Leachate pH

The leachate pH values were measured using a Beckman combination pH glass electrode immediately after opening the vessels. (The vessels were allowed to cool to near room temperature before they were opened.) Equilibration of the leachate with CO_2 in the air during analysis has the potential of complicating some measurements (through the production of carbonic acid). To minimize the dissolution of CO_2, the solutions were not stirred during the measurement. Previous experiments [BATES-1] had shown

dissolved gases to be present in the leachates which complicated the pH measurements. The present experiments did not contain noticeable amounts of dissolved gases. The pH value stabilized to within 0.01 units (the accuracy of the meter) within one or two minutes and was recorded. The pH meter was calibrated using standard buffers at pH 7.00 and 10.00 shortly before the measurements were made. The buffers used for calibrating the probe were reanalyzed after the two or three hours necessary to analyze all the leachate solutions to check for probe stability. The drift in the measured pH values of the buffers was always less than the 0.01 unit accuracy of the probe quoted by the manufacturer. Because of the initial instability of the readings and the possible interference of dissolved gases, the pH values are thought to be good within ±0.02 units.

The measured pH values of all the experiments are included in Section VII, Data Table A. The average values of duplicate experiments are plotted as a function of the reaction time in Figs. 2a-d. The variation in pH values between duplicate experiments is larger than the stated error in the pH measurement. The average value is plotted rather than individual values for clarity. The difference in the results of duplicate experiments are typically smaller than the size of the symbol. A few experiments showed anomalously acidic pH values, presumably due to extraneous vessel interaction. Some of these experiments showing anomalous pH values also showed atypically high chloride ion concentrations. A cutting fluid containing chlorine was used during vessel fabrication and small sulfur/chlorine-rich inclusions were noted in the glass. If either type of inclusion should rupture during the experiment, the leachate would become contaminated, most noticeably with chloride and, apparently, hydrogen ions. Such anomalous results occurred in both irradiated and nonirradiated experiments though never in experiments with a tuff wafer present. The acid contamination must be quite extreme, for the high concentration of bicarbonate in EJ-13 water was not sufficient to buffer the solution against acidification (see below for an extended discussion regarding bicarbonate in EJ-13 water).

The horizontal lines in Figs. 2a-d represent the pH of the leachant used for experiments of differing durations. The leachant used for the 91-, 181-, and 278-day experiments was measured to have a pH of 7.56 when these experiments were initiated. About six months later, when the 56-day experiments were assembled, the pH of the same EJ-13 stock solution was measured to be 8.23. This original stock solution was also found to be depleted in nitrate ion. Since nitrate is a reactant in the radiolytic production of nitric acid [VAN KONYNENBURG], which is an important reaction in this series of experiments, a fresh EJ-13 stock solution was prepared. This new stock solution was found to have ion concentrations similar to the original EJ-13 stock solution, but a higher pH, 8.23. Table 3 gives the compositions of the leachants used in these experiments.

As shown in Fig. 2a, the leachates of the nonirradiated experiments with EJ-13 water only or EJ-13 water plus tuff are slightly more acidic than the starting leachant for experiments with reaction times less than 91 days and slightly more basic than the starting leachant for experiments

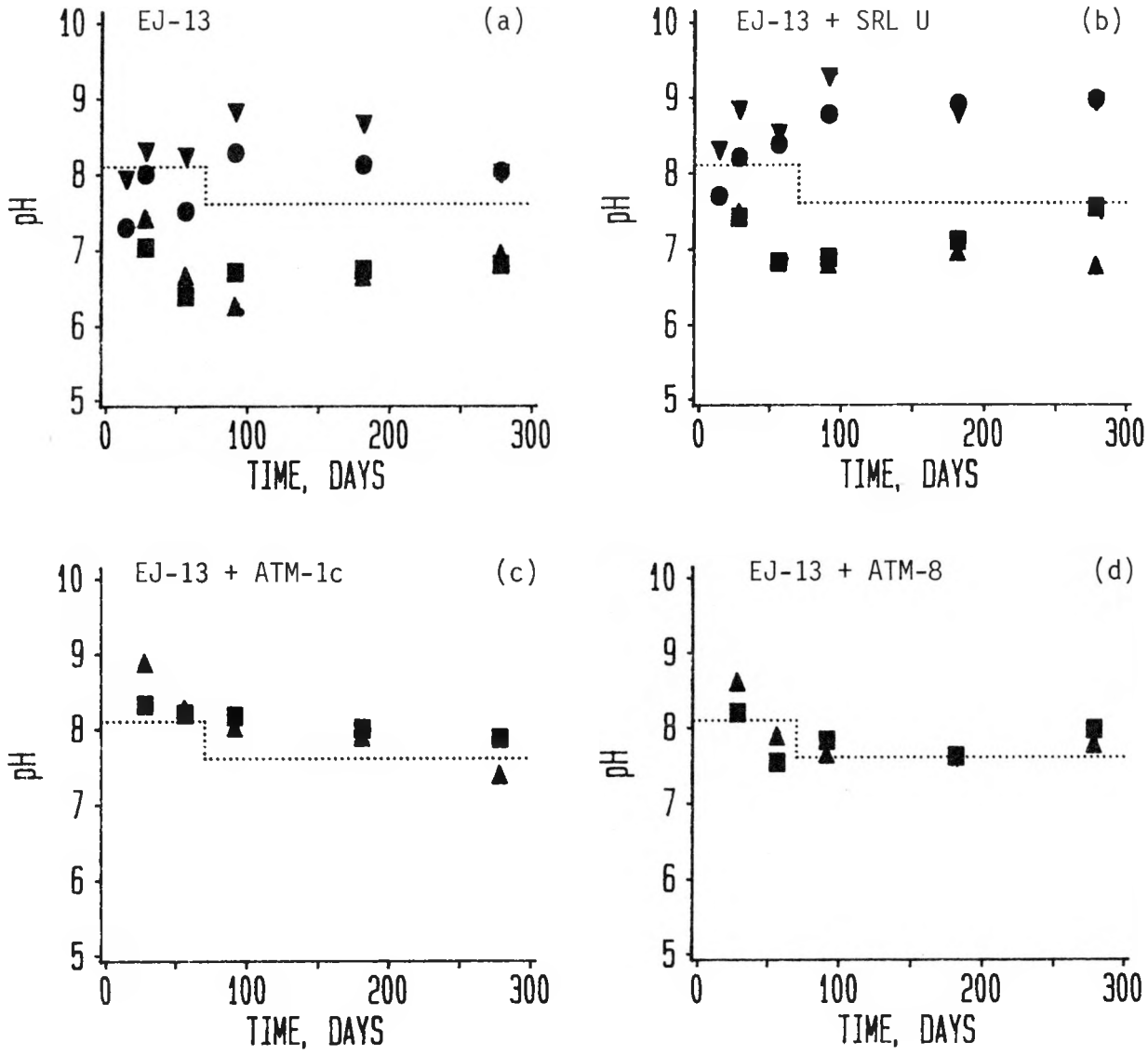


Fig. 2. Leachate pH vs. Reaction Time for EJ-13 Plus: (a) EJ-13 Only, (b) SRL U Glass, (c) ATM-1c, and (d) ATM-8 Glass; irradiated, without tuff (▲) or with tuff (■); nonirradiated, without tuff (▼) or with tuff (●). The horizontal lines indicate the pH of the leachants used in different experiments.

Table 3. Leachant Compositions for Gamma Irradiation Experiments, Experimental Series in μg/mL

	FY 86[a]	FY 86[b]	FY 86[c]	FY 85[d]	FY 84[e]	
R/h	1E3, 0	1E3, 0	1E3, 0	1E4	2E5	J-13[f]
pH	8.10	8.23	7.56	7.61	8.10	6.9
Al	0.43	<0.10	0.30	<0.10	0.63	0.03
B	0.17	0.11	0.14	0.14	0.16	-
Ca	7.10	7.34	8.10	11.9	9.08	11.5
Li	0.041	0.039	0.044	0.046	0.044	0.06
Mg	0.25	0.31	0.34	0.95	0.96	1.76
Na	49.3	41.4	44.6	45.4	46.5	45
Si	35.7	30.2	34.5	30.6	34.4	30.0
NO_3^-	7.2	2.0	6.1	8.4	7.6	10.1
F^-	2.8	2.4	2.5	2.5	2.4	
HCO_3^-	120	121	N/A[g]	N/A	N/A	
Cl^-	8.4	7.4	7.0	7.7	7.2	

[a]Leachant used for 14- and 28-day experiments.

[b]Leachant used for 56-day experiments.

[c]Leachant used for 91-, 181-, and 278-day experiments.

[d]Taken from [ABRAJANO].

[e]Taken from [BATES-2].

[f]Table 1, K. N. Thomas, Los Alamos Report LA-10960-MS (December 1987).

[g]Not analyzed.

with reaction times greater than 91 days. Except for the 56-day experiments and the 14-day experiments with tuff, the nonirradiated experiments have final pH values not too different from 8. The blank experiments assembled with Teflon^{TM} gaskets had pH values near 7.6, however. It will be shown later that interaction of the leachate with the silicone rubber gaskets may lead to an increase in the leachate pH. This is supported by the fact that the long-term nonirradiated blank experiments with silicone gaskets are more basic than the original leachant pH (which was 7.56).

The irradiated blank experiments containing EJ-13 water or EJ-13 water plus tuff are seen in Fig. 2a to all be acidified relative to the starting leachants. This is due primarily to the radiolytically produced nitric and nitrous acids dissolved in the leachate [VAN KONYNENBURG]. After about 56 days exposure to the gamma field, a total exposure of about 1.3 MR, the leachate reaches its most acidic pH value. Longer exposure times do not result in further acidification because of the high bicarbonate ion concentration which, along with dissolved CO_2, successfully buffers the leachate to pH values above 6.4 (pK_a HCO_3^-/H_2CO_3 = 6.4 at 90°C). A few leachates attain more acidic pH values presumably through extraneous vessel interactions. The presence of tuff in these irradiated "blank" experiments does not appear to influence the leachate pH. Typical J-13 groundwater contains about 120 ppm bicarbonate ion which is sufficient to neutralize the acid produced at all exposures tested in these experiments and also in previous experiments at higher exposure rates [BATES-1]. Higher air-to-liquid volume ratios may allow the acid levels to exceed the buffering capacity of EJ-13 water and so result in leachates having pH values below 6.4.

Figure 2b shows the leachate pH values for the experiments including SRL U glass. The nonirradiated experiments have, for the most part, more basic leachates than the starting leachants and the irradiated experiments have leachates which are always more acidic than the starting leachants. For experiments with radiation, the pH trends as a function of reaction time are nearly identical to the trends of the EJ-13 only and EJ-13 plus tuff experiments shown in Fig. 2a. For experiments without radiation, the pHs are still trending more basic after 278 days when glass is present, while without glass the pHs are trending more acidic. All the experiments with SRL U glass have pH values that range between 0.5 and 1 pH unit more basic than the corresponding blank experiments. This shift upwards is in part due to the exchange of protons from the leachate with leachable glass ions such as lithium and sodium. Such a reaction tends to deplete the leachate of protons and so makes the solution more basic. Again, the presence of a tuff wafer in an experiment with glass does not appear to substantially influence the leachate pH value for most reaction periods.

Finally, Figs. 2c,d present the leachate pH data for experiments which included ATM-1c and ATM-8 glasses, respectively. Only irradiated experiments were performed using these glasses in this work. (Nonirradiated experiments using ATM-1c and ATM-8 glasses are discussed elsewhere [BATES-2].) As shown by the blank experiments, the leachates would be acidified to near pH 6.4 in the absence of glass. Glass hydrolysis tends to make the leachate more basic, and so counteracts the acidifying influence of the radiolysis reaction. The present results show that the

reaction of the ATM glasses serves to neutralize the radiolytically produced nitric acid at every reaction time tested, for the leachate pH values are nearly all more basic than the initial leachant. The higher final pH values of the experiments with ATM glasses suggests they are more reactive than the SRL glasses since the pH increases due primarily to glass reaction. Other data will be seen to support the contention that the ATM glasses reacted faster than the SRL glasses. The ATM-1c glasses may have reacted slightly more than ATM-8 glasses after a given reaction time since the ATM-1c leachates are slightly more basic than the ATM-8 leachates in most instances.

The pH trends of these experiments are useful as gross indicators of the overall progress of the experiment. The experiments without glass present demonstrate the effect of gamma radiation on NNWSI groundwater; namely that the radiolytically produced acids lower the solution pH to near a value of 6.4. The high concentration of bicarbonate ion (near 120 ppm) in the groundwater prevents the pH from dropping below 6.4 as, along with dissolved CO_2, it acts to buffer the solution against further acidification. In J-13 water, there is enough bicarbonate to successfully neutralize the acid produced by an exposure 1000 times the highest exposure encountered for these experimental conditions, that is, for an air-to-leachant-volume ratio of 0.3, according to the Burns formulation of nitric acid production [BURNS] (see also Appendix II). Larger air-to-leachant-volume ratios may produce high enough nitric acid concentrations to overcome the buffering capacity of EJ-13 water.

B. Total Carbon Content

The present experiments were analyzed to determine the total carbon content of the leachates. The bicarbonate ion in solution was seen earlier to play a very important role in buffering the leachate against acidification by radiolytically produced nitrogen acids. Measuring the inorganic carbon content of the leachate may allow one to further quantify that neutralization reaction. Also, carbonate ions in solution may complex released actinide species and thereby affect their transport. The total carbon content of the leachates was measured for experiments with no glass, with SRL U glass, and with ATM-1c glass. The leachates of experiments containing actinide-doped glasses were not analyzed to avoid contamination of the instrument.

Analyses were performed using a Dohrmann carbon analyzer in the high-level waste studies laboratory. Samples are injected into a flowing stream of a potassium persulfate solution where all the carbon in the sample, both organic and inorganic, is oxidized under ultraviolet light to $CO_2(g)$ which is quantified using infrared absorption spectroscopy. The instrument provides a ppm value of elemental carbon that is directly proportional to the integrated CO_2 peak vs. time curve. The instrument was calibrated using a standard potassium hydrogen phthalate solution which contained 400 ppm elemental carbon. This instrument uses the analysis of a single standard plus an assumed zero to define the calibration curve. Repeated injections of the 400 ppm elemental carbon standard gave readings that were

reproducible to within 1 ppm. The same 250 μL syringe was used to measure all standard and sample aliquots. Aliquots of 200 μL were used for all analyses. The 400 ppm standard was reanalyzed after completing the analysis of all the leachates to check the instrument stability. The reading was typically within 1 ppm of the starting value, although a few times it differed by as much as 5 ppm. The error in sample analysis is probably due in part to drifting in the instrument, although the detector was always preheated for at least 48 hours before analysis. Error in the repeated analysis of the standard may be due in part to differences in the aliquot volumes of, perhaps, up to 2 μL due to reading error of the syringe scale. This represents up to 1% volume error that could produce a 4 ppm difference in analysis of the standard, but only a 0.5 ppm difference in the analysis of the most concentrated sample analyzed.

By acidifying the sample to convert all inorganic carbon to CO_2 and then sparging the sample with oxygen to evolve the CO_2, most of the inorganic carbon in the sample is removed. An analysis of the remaining solution then represents the organic carbon content only, as organics are not removed to a significant extent by the acidification/sparging procedure. Only random leachates were analyzed for organic carbon. The inorganic carbon content is obtained as the difference between the total and organic carbon contents.

The complete compilation of total carbon content results is included in Section VII, Data Table B. The results are expressed as the concentration of elemental carbon, in μg/mL. Also included in Data Table B are the total carbon contents of the leachants used. Figure 3a shows the total carbon content of the blank leachants plotted against the reaction time. The horizontal line represents the total carbon content of the leachant used. Except for 28-day irradiated experiment without tuff, the leachates all show increased carbon contents relative to the leachant. The presence of tuff in an experiment does not seem to have a large effect on the carbon content, although the nonirradiated experiments containing EJ-13 water plus tuff (circular symbols) did consistently have the highest carbon concentrations in this group of experiments. Also, the experiments with glass showed slightly higher carbon contents when tuff wafers were present (see Fig. 3b). The inclusion of glass in an experiment does not have a large influence on the total carbon content, as can be seen by the similarity between Figs. 3a and 3b.

There are several possible sources of the observed increase in carbon. The stainless steel vessels contain about 0.03 weight percent carbon. In order for this carbon to be released into solution, a very large amount of the vessel surface must be corroded. The iron that would have to have been released into solution is many hundreds of times greater than that measured in any of the leachates. Only a few of the vessels showed any obvious sign of reaction with the leachate, such as discoloration or pitting. Dissolution of carbon from the vessels is not likely to be responsible for the increase of carbon in solution.

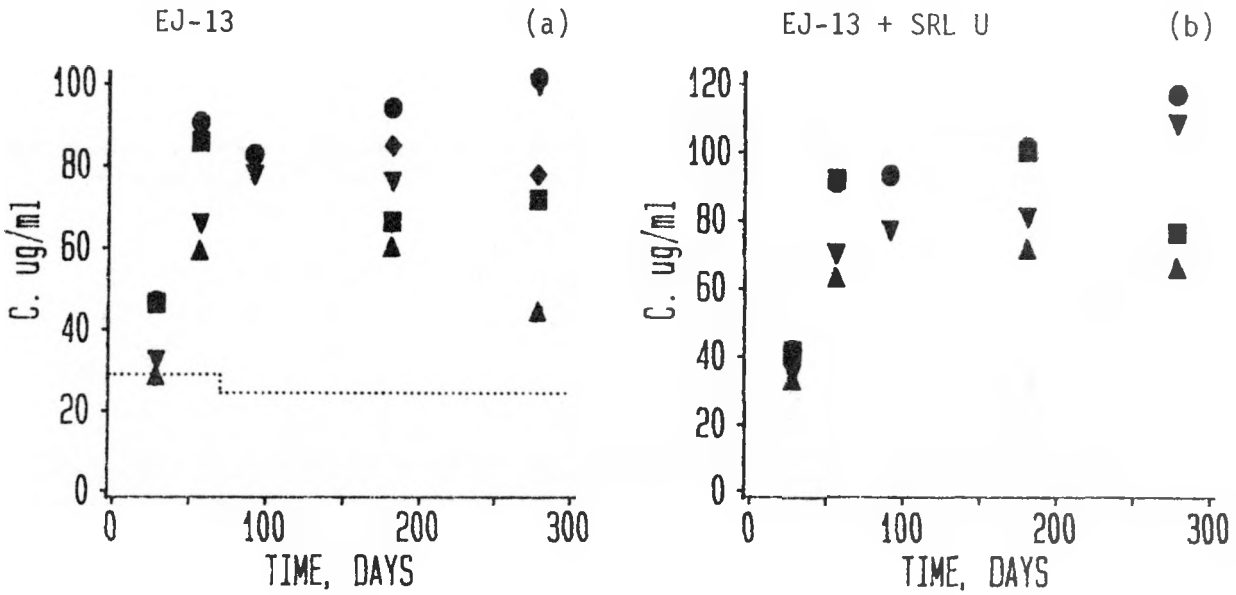


Fig. 3. Elemental Carbon Concentration vs. Reaction Time for EJ-13 Plus: (a) EJ-13 Only, (b) SRL U Glass; irradiated, without tuff (▲) or with tuff (■); nonirradiated, without tuff (▼) or with tuff (●). The horizontal line indicates the carbon content of the initial leachants used in different experiments.

The air above the leachant in the vessel contains, at 20°C when the vessel was sealed, about 0.03 kPa of CO_2. This represents about 7.6E-8 moles of CO_2 in the 6 mL gas phase, or about 0.912 μg of elemental carbon. If this were to be dissolved completely into the 16 mL of leachant, it would represent only 0.06 μg/mL elemental carbon. Since the vessels were found to leak slightly, the contribution of gas phase CO_2 is expected to be even less than this. Certainly, the gas phase cannot be responsible for the observed carbon increase.

After opening the vessels, a thin film was noticed on the surfaces of many of the leachates, though not all of them. It is interesting to note that the total carbon content in the leachates of the blank experiments run using Teflon™ gaskets was also higher than in the leachant (diamond symbol in Fig. 3a). Although no oily film was observed on these leachate surfaces, subsequent experiments in which Teflon™ gaskets were used did show a film in some cases [BATES-2]. Additionally, such a surface film was seen in previous experiments [BATES-1] which also utilized silicone rubber gaskets. These experiments showed a systematic increase in the leachate silicon concentration with reaction time (see discussion of silicon concentrations in Section III.D.1). This is, in part, attributed to a release of silicon from the gaskets. It is possible that organic carbon too might be released from the gaskets.

An additional set of experiments was run to determine if organic carbon could be released from the silicone rubber gaskets in EJ-13 water at 90°C. Four stainless steel vessels were fit with Teflon™ gaskets and filled with about 10 mL of EJ-13 water (from the stock of solution used for the 14- and 28-day FY 1986 experiments). (Notice that this solution was measured to be more basic than when it was incorporated into the gamma irradiation experiments.) A silicone rubber gasket was submerged in the EJ-13 water of two of these vessels as an extreme measure of gasket-water interaction. The vessels were then sealed with compression fittings and placed in a 90°C oven for 16 days. At the termination of these experiments, the leachate was analyzed for pH, total carbon, and organic carbon. The results are summarized in Table 4. The pH of the experiments that did not include a silicone gasket decreased slightly from the leachant value, while the experiments that included a silicone gasket increased significantly from the leachant value. The total carbon did not increase from the leachant value for either experiment not including a silicone gasket, but increased about eight fold for the experiments with the gaskets. Most of the increase is in the organic carbon content.

The above experiments have shown that the silicone rubber gaskets release carbon when contacted with EJ-13 water. The silicone rubber gaskets were soaked in DIW at 90°C for several hours prior to vessel assembly. The trends observed in Figs. 3a,b suggest that carbon is released from the gaskets slowly and that more than about 30 days of exposure is required to produce a measurable increase in the leachate.

With the possibility that the silicone gaskets may contribute organic carbon, some of the leachates were reanalyzed for total and organic carbon content. (The sample submitted for anion analysis was used when available and corrections for dilution made. In some cases only the acidified leachates submitted for cation analysis were available. The total carbon content could not be reanalyzed using these solutions since they had previously been acidified and so the organic carbon contents of these experiments are less reliable). Data Table B, in Section VII, includes the data for those leachates reanalyzed to determine the organic carbon content. In most of these experiments, the inorganic carbon content is higher than in the original leachants (which were less than 30 ppm elemental carbon) but, considering the uncertainty in reanalysis of old samples, not different enough to invalidate the comparisons made. The organic content is typically one third to one half the total carbon content in both experiments using silicone rubber and Teflon™ gaskets.

The fourth possible source of carbon is experimental contamination. However, the systematically high carbon contents found for all experiments makes this an unlikely source. Also, the 28-day experiments, which showed only a very small increase in carbon, were handled in the same way as all other experimental vessels.

A fifth possible source in selected experiments is the glass. After the glass disks were cut and polished, they were rinsed in methanol. Although they were thoroughly dried prior to incorporation into the vessels, a thin film of residual methanol may have remained on the samples.

Table 4. Silicone Gasket Submersion Experiment Results

Test Type	Test Length	Leachate pH	Total Carbon (ppm)	Organic Carbon (ppm)	Inorganic Carbon (ppm)
EJ-13 + Silicone Gasket	16	9.31	217.2	207.5	9.7
EJ-13 + Silicone Gasket	16	9.41	220.3	213.3	7.0
EJ-13	16	8.00	28.8	8.9	20.0
EJ-13	16	7.98	28.9	10.7	18.2
Leachant	-	8.29	28.8	NA	NA

This may be the reason that the glass-containing experiments showed slightly higher carbon concentrations than experiments without glass. Since a similar increase in total carbon occurred in experiments with and without glass, the effects of glass appear to be negligible.

While the source of increased levels of organic carbon is unclear, the measured levels of carbon in the leachate solution are not expected to influence the results. It is unlikely that the bicarbonate or carbonate levels are affected by the contamination, and these are the species of importance to the buffering of the solution and to complexation of solutes.

C. Anion Analyses

1. Experiments without Glass

Analysis of the anions in the reacted leachates provides information primarily with regard to the radiation effects on the solution chemistry. After the vessels were opened, a 2.0 mL aliquot of the leachate was removed for anion analysis. The 2.0 mL aliquot was diluted with high purity water to reduce the chloride concentration so all anions of interest could be analyzed simultaneously. Ion chromatography was used to analyze for fluoride, chloride, nitrite, nitrate, and sulfate ions in the leachates. Analysis of known standards showed the results to be within 5% of the amount present for all ions analyzed. This is usually less than the difference in the results of duplicate experiments. The results are presented in Section VII, Data Table B. The experiments performed without glass are useful in that they show the effect of radiation on the groundwater/air system. The results include interactions of the vessel with the groundwater. The measured ion concentrations in the EJ-13 water only and EJ-13 plus tuff experiments are also used to determine the proper

background concentrations for the experiments that were performed with EJ-13 and glass, or with EJ-13, glass, and tuff, respectively. The concentrations used for background subtraction are presented in parentheses next to the blank experimental results for each reaction time in Data Table B. In cases where the blank concentrations fall near a mean value irrespective of the reaction time, that mean value is used as the background level for all reaction times. In cases where there is significant scatter with reaction time, the average of duplicate blank experiments at a given reaction time is used as the background level for that reaction time.

The leachant solutions were analyzed prior to initiating the experiments except for the leachant used for the 91-, 181-, and 278-day experiments which was analyzed about three months after these experiments were begun.

The fluoride concentrations are plotted for the blank experiments in Fig. 4. The concentration of fluoride in the leachant used for a given experiment is shown as the horizontal line in the figure. The nonirradiated experiments had leachate fluoride levels that were unchanged from the original leachant values. The average value of the duplicate blank experiments was used as the background level for these types of experiments. Figure 4 shows that irradiation increases the fluoride levels above that of the leachant for both the experiments with and without tuff, slightly more so for experiments with tuff. The fluoride levels in these blank experiments are erratic and so the average value of duplicate experiments is used as the background value for experiments with glass. The average value of the 91-day nonirradiated blank experiments containing tuff, for example, was used as the background concentration for all nonirradiated 91-day experiments with tuff and all glass types. Why the fluoride levels are slightly larger in the irradiated experiments than in the nonirradiated experiments is not known. Larger fluoride levels were not detected in previous experiments which used these same vessels and similar gasket [BATES-1, ABRAJANO]. The only difference between these and previous experiments was that the gaskets were not fabricated from identical stock silicone rubber. The concern for increased fluoride values is that fluoride ions may be involved as complexing ligands for released actinide species, and HF is known to accelerate glass reaction. However, the slightly increased fluoride levels in the present experiments are not expected to have significantly affected the glass reaction. The fluoride levels in the experiments performed using Teflon™ gaskets were seen to be similar to the leachant level. Teflon™ is known to release fluoride when irradiated and for that reason is not used in a radiation field. It does not appear to release fluoride in a hydrothermal environment alone.

The leachate chloride levels are only 1 or 2 ppm higher than the leachant level (except in the few cases where the chloride level was anomalously high). Since the chloride concentrations appeared to center near a mean value and did not show a definite time dependence, the same background concentration was used for all reaction times of a given experimental type. The value used for both the irradiated and nonirradiated experiments without tuff is 8.1 μg/mL. The values used for the experiments

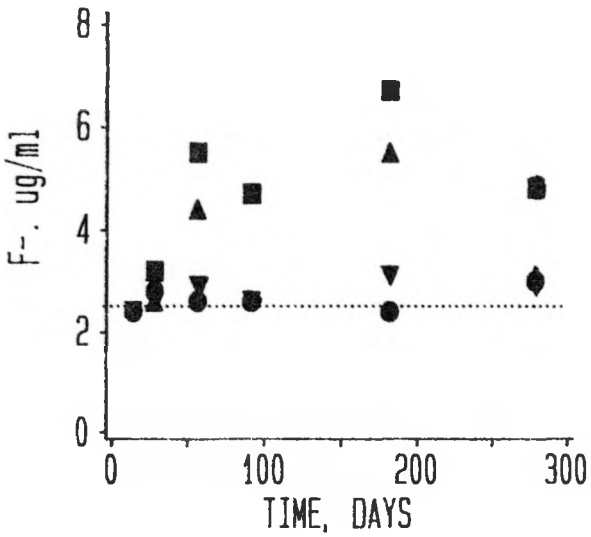


Fig. 4. Fluoride Concentration vs. Reaction Time for EJ-13 Irradiated, without Tuff (▲) or with Tuff (■); Non-irradiated, without Tuff (▼) or with Tuff (●). The horizontal line indicates the fluoride concentration in the initial leachants.

with tuff are 8.7 μg/mL for the irradiated and 8.4 μg/mL for the non-irradiated experiments with tuff. Except when there is extraneous vessel interactions, the chloride levels for the blank experiments are very similar to the leachant chloride level in all experiments. The non-irradiated experiments with EJ-13 only that were performed using Teflon™ gaskets showed higher than normal chloride levels for the 91- and 181-day experiments, but a normal value for the 278-day experiment.

The concentrations of nitrate ion in the EJ-13 only and EJ-13 + tuff blank experiments are shown in Fig. 5 for both the irradiated and nonirradiated experiments. The leachant nitrate level is shown by the horizontal lines. Notice that the leachant used for the 56-day experiments shows a much lower nitrate level than the leachants used for other experiments. This leachant was from the same stock EJ-13 solution used for the longer term experiments. It had been stored in the dark in a capped polyethylene bottle for about six months before use and had become depleted in nitrate through leakage from or reaction with the bottle. Unfortunately, it was not discovered that the nitrate level was low until after the 56-day experiments were initiated. The nonirradiated experiments appear to be slightly enriched in nitrate relative to the leachant levels in most experiments by about 1 or 2 μg/mL. The nitrate level in the nonirradiated experiments run using Teflon™ gaskets was similar to that in the analogous experiments using silicone rubber gaskets. The irradiated experiments are very much depleted in nitrate ion relative to the leachant. This depletion is a result of the reduction of nitrate to nitrite.

Figure 6 shows the nitrite ion concentrations for the irradiated experiments. No nitrite was detected in either the nonirradiated experiments with glass or the blank experiments. Only a small amount of the nitrite in the leachates of the irradiated experiments was radiolytically produced from the nitrogen gas in the air. Radiolytically produced NO_2 dissolves in the leachate to produce HNO_2 (along with HNO_3) which

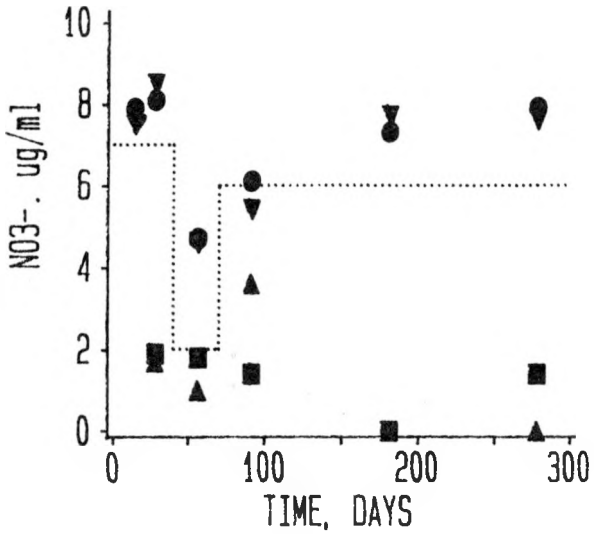


Fig. 5. Nitrate Concentration vs. Reaction Time for EJ-13 Irradiated, without Tuff (▲) or with Tuff (■); Non-irradiated, with Tuff (▼) or with Tuff (●). The horizontal line represents the nitrate concentrations of the initial leachants.

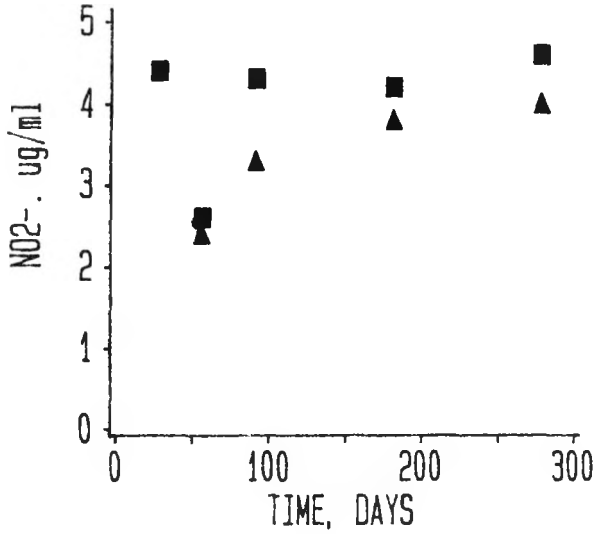


Fig. 6. Nitrite Concentration vs. Reaction Time for EJ-13 Irradiated, without Tuff (▲) or with Tuff (■).

immediately dissociates. If the leachate pH was too low, such that HNO_2 would not dissociate (pK_a = 3.37), then the nitrous acid was unstable and decomposed. The majority of the nitrite is produced by reduction of nitrate in solution. At the low exposures used in these experiments, the amount of nitric acid produced by radiolysis is small compared to the amount of nitrate in the original leachant. At the highest exposure, less than 100 nmoles of HNO_3 are generated by radiolysis (see Appendix II), which is less than 1 ppm. It can be seen in comparing Figs. 5 and 6 that the amount of fixed nitrogen in solution remains nearly constant (noting that 4 ppm NO_2^- contains the same amount of nitrogen as 5.4 ppm of NO_3^-). Notice that the 56-day experimental results show nitrite concentrations that are substantially lower than all the others. This is because of the low nitrate concentration in the leachant used for the 56-day experiments. The observation that the experiments containing tuff wafers have slightly higher nitrite levels than the corresponding experiments without tuff may indicate that the tuff surfaces catalyze the reduction of nitrate ions. It has also been suggested that the glass surface may catalyze the reduction of nitrate [VAN KONYNENBURG]. The reduction of the solution Eh indicated by the high nitrite/nitrate ratio may have a large effect on the behavior of released species having multiple oxidation states, notably iron and the transuranic elements. The average value of duplicate blank experiments was used as the background level for each experimental type.

The sulfate levels in the blank experiments were slightly greater than in the original leachants in all experimental types. Constant background concentrations were used for both irradiated and nonirradiated experiments. These values are 19.3 μg/mL for irradiated experiments without tuff and 20.1 μg/mL for irradiated experiments with tuff, 18.6 μg/mL for nonirradiated experiments without tuff, and 19.7 μg/mL for nonirradiated experiments with tuff. The experiments utilizing Teflon™ gaskets have values similar to the corresponding experiments using silicone gaskets.

Except for the nitrate and nitrite ion concentrations, the anion concentrations in the leachates are not noticeably affected by radiation. Nitrite ions are produced through the reduction of nitrate ions as the Eh of the solution changes during radiolysis. These anion results may be weakly dependent on the solution pH as well. For example, as the pH drops sulfate ions will be reprotonated to bisulfate ions. At pH values below about 3.4, nitrite ions will reprotonate and decompose. The buffering of the solution to pH values near 6.4 may influence the anion concentrations.

2. Experiments with Glass

The leachates of the experiments with glass were treated identically to the corresponding "blank" experimental leachates. The analyzed solution results were first corrected for dilution and then background corrected using the background levels determined previously from the "blank" experiments of the appropriate type of experiment (irradiated or nonirradiated, with or without tuff). The net concentrations are included in Section VII, Data Table B. The presence of glass in an experiment is not foreseen to be a major influence on the anion chemistry, although some species released during the glass reaction are complexed by anions.

Like the nonirradiated blank experiments (see Fig. 4), the nonirradiated experiments containing SRL glasses had fluoride levels similar to the original leachant levels. The irradiated experiments, on the other hand, did show a further increase in fluoride with reaction time in the experiments containing SRL glasses from that seen in the irradiated blank experiments. The irradiated experiments with ATM glasses showed a slight increase at short reaction times but a decreased level at longer times relative to the blank experiments' fluoride concentrations. The fact that the experiments containing SRL glasses showed different behavior than the experiments containing ATM glasses suggests that the fluoride is not coming (exclusively) from the silicon gaskets. Remember that the same background levels are being subtracted from SRL and ATM irradiated experiments. The presence of a tuff wafer does not appear to influence the generation or release of fluoride ions.

Except for a few experiments, especially the 28-day experiments, the chloride levels in the experiments containing glass do not differ much from the corresponding blank experiments. A few of the experiments, mostly irradiated experiments, had very high chloride levels. Many, but not all,

of these high chloride leachates also had anomalously acidic pH values. No experiment containing a tuff wafer showed such behavior. In fact, tuff appeared to stabilize the pH and chloride content to values close to the leachant levels.

The nitrate levels in the leachates of blank experiments were seen to differ between irradiated and nonirradiated experiments. The same result, namely depletion of nitrate under irradiation, is seen in the experiments containing glass. Nitrate was present in detectable concentrations in only a few of the irradiated experiments but in all of the nonirradiated experiments, as the nitrate was reduced to nitrite upon irradiation. The nitrate levels in the nonirradiated experiments do not differ significantly from the background levels. The nitrate results for SRL A and SRL U experiments containing a tuff wafer were somewhat erratic.

No nitrite was detected in the nonirradiated experiments. If the tuff wafers catalyzed the reduction of nitrate it was at undetectable levels. The nitrite concentrations for both SRL and ATM glasses were slightly greater than the background levels. Tuff-containing experiments frequently had levels that were a little lower than experiments not containing tuff, though the difference is small. This may be an artificial result of the slightly higher nitrite levels used as background for the tuff containing blanks rather than any interaction of the tuff in these experiments.

The concentration of sulfate in all the experimental leachates, both those containing glass and the blank experiments, was near 20 μg/mL. The differences in concentration between the leachant, blank, and glass containing experiments were small, on the order of 1 or 2 μg/mL. Irradiation does not appear to significantly affect the sulfate content of the leachate, nor does the presence of glass. Sulfate may act as a complexing ligand for released actinide species, though sulfate is not expected to be as strong a complexing ligand as carbonate or fluoride ions.

Overall, the presence of glass and/or tuff in an experiment did not influence the anion concentrations in the leachates. Apparently these anions are not involved with the glass reactions though they may be incorporated into secondary phases. They may also act to complex released species, such as the doped actinides.

Irradiation has a dramatic effect on the nitrate concentration of the leachate. Radiolytic reduction of nitrate to nitrite was seen to be nearly complete even in the lowest gamma radiation exposures tested, 28 days at 1E3 R/h, or 67E3R. The nitrite levels in the original leachant were below the detection limit and the nitrate levels were near 6 μg/mL. After irradiation the nitrite level increased to near 4 μg/mL for all irradiated experiments and the nitrate dropped to undetectable levels. This represents reduction of nearly all the nitrate to nitrite. The nonirradiated experiments showed little change in the nitrate levels from the original leachant concentrations.

The fluoride concentration in the irradiated blank experiments showed a slight increase from the leachant levels while the nonirradiated experiments did not show any change. The irradiated experiments with glass also showed an increase in the fluoride concentrations, even more so than the irradiated blanks. This suggests that fluoride may be released by the vessel surface, the silicone gaskets, and/or the glass. The presence or absence of tuff does not seem to affect the fluoride concentration. Such fluoride behavior was not observed in previous gamma irradiation experiments [BATES-1, ABRAJANO]. This leads us to suspect the silicone rubber gaskets to be the source, though irradiated experiments containing ATM glasses and using the same gasket material did not show a detectable increase in fluoride concentration.

D. Cation Analysis

1. Experiments without Glass

The solution concentrations of cations released during glass reaction are very useful in measuring the extent of the reaction. Use of EJ-13 water and inclusion of tuff rock in the vessel complicates the calculations because of the high initial concentrations of species common to the glass, the leachant, and tuff rock. Experiments without glass were performed in order to approximate the cation levels due to the leachant and the tuff alone.

The levels of various cations in the leachates from the blank experiments were therefore measured to monitor the effects of irradiation and tuff on the chemistry of the EJ-13 solution and to provide background levels for experiments containing glass. The leachates submitted for analysis had been acidified to near pH 1 with HNO_3 and left soaking in their experimental vessels for about 20 hours at 90°C. This was done to dissolve any species adsorbed to the vessel walls. This leachate solution was also analyzed using alpha spectroscopy to quantify ^{237}Np, ^{239}Pu, and ^{241}Am. The uranium was analyzed by fluorescence spectroscopy and cesium using atomic absorbance spectroscopy. All other analyzed cations were quantified using inductively coupled plasma (ICP) atomic absorption or atomic emission spectroscopy. The results for the cation analyses are presented in Section VII, Data Table C. The analytical error in the measurement of the diluted samples is estimated to be less than 10% of the amount present for all cations analyzed using ICP spectroscopy. The estimated error in each measurement is usually negligible in comparison to the difference in results of duplicate experiments.

The acidification of the leachate to free actinides from the vessel wall and support stand simultaneously dissolved a small amount of the metal. This leads to increased levels of iron, chromium, nickel, manganese, and to lesser extents, silicon, phosphorus, sulfur, and carbon in the acidified leachates. The measured releases of iron, chromium (in the ATM glasses), nickel, and manganese from the glasses are complicated by this process. The blank experiments were treated identically to the

experiments with glass present and so also contained iron dissolved during acidification. Because the extent of vessel dissolution is not expected to be reproducible due to varying vessel histories, the blank correction for iron background is probably inaccurate. Also, the blanks did not include a stainless steel support and so provided less steel surface to the leachate. Although the results for iron and nickel are included in the data tables, they are probably not representative of the amounts released from the glasses and therefore will not be discussed further with regard to glass corrosion. Vessel contribution of its minor constituents to the leachate will be neglected. It should be noted, however, that the results from other experiments using SRL U and SRL A glasses indicate that the levels of iron, chromium, nickel, and manganese are either very near or below detection limits for unacidified leachates. Also, it will be shown later that iron is not released into solution as the glass corrodes but becomes enriched in the outer surface of an alteration layer which forms during the reaction.

Topopah spring tuff is about 75% by weight SiO_2 and 12% Al_2O_3. It also contains small amounts of potassium, sodium, iron, calcium, magnesium, titanium, and manganese. The reaction of J-13 water with pulverized tuff at 90°C has been studied extensively [KNAUSS], and results mainly in an increase in the silicon level. Typical EJ-13 water has a pH value near 8. Acidification of this solution by irradiation may alter the solubilities of some species. The introduction of other ions not normally found in tuff rock into the leachate by reacting glass may also alter the solubilities of some species.

The values used for background subtraction of experiments with glass are given in parentheses next to the results of the blank experiments for every reaction time in Data Table C for each cation. In cases where the concentrations at all reaction times appear to be distributed around a mean value, that mean value is used for all reaction times. In other cases the average value of duplicate experiments is used for each reaction time.

The boron concentrations of the nonirradiated blank experiments and the leachant are very similar. Neither radiation nor tuff appears to significantly affect the boron concentration in EJ-13 water. The leachate pH, which in the blank experiments varies between 6.4 and 8, has no noticeable effect on the boron concentration in solution. It is noted that the boron concentration is usually between 10 and 300 ppb larger in the reacted blank experiments than in the starting EJ-13 water. However, the total boron increase in the blank experiments is only a small fraction of that released when glass is present.

Figure 7 shows the average calcium levels of duplicate irradiated and nonirradiated blank experiments. In both cases the experiments without tuff (triangular symbols) have calcium concentrations very similar to those of the initial leachants (shown by the horizontal line). The experiments with tuff (square and circular symbols), on the other hand, show calcium levels consistently lower than the initial leachant levels. The nonirradiated experiments with tuff, which had pH values very near those of the leachants, showed the greatest decrease in calcium. The calcium values of

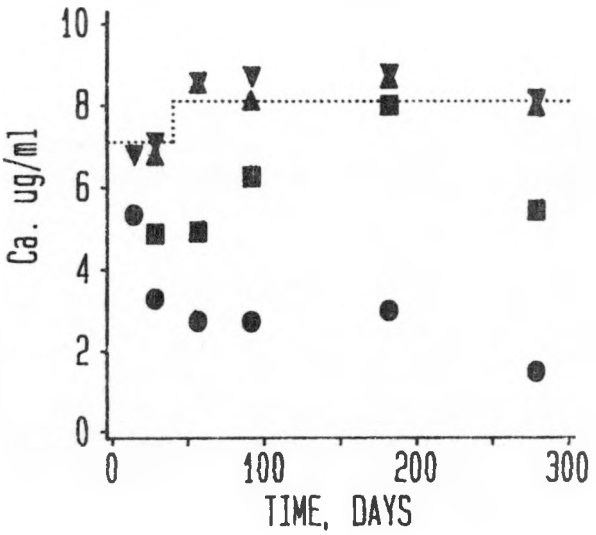


Fig. 7. Calcium Concentration vs. Reaction Time for EJ-13 Irradiated, without Tuff (▲) or with Tuff (■); Non-irradiated, without Tuff (▼) or with Tuff (●). The horizontal line represents the calcium concentration of the initial leachants.

duplicate experiments are similar in all cases, even the apparently high results for the irradiated experiment with tuff reacted for 181 days (see Data Table C). The influence of tuff on the calcium concentration is rather dramatic, as described by the results of [OVERSBY] for hydrothermal experiments involving crushed tuff and J-13 groundwater. The J-13 groundwater originally contains about 12.5 μg/mL calcium. Reaction with tuff, during the 14-day prereaction period and during the experiment, depletes the solution of calcium, presumably through precipitation of $CaCO_3$. The presence of tuff is seen to have a similar influence in both the nonirradiated and irradiated blank experiments, namely reducing the solution concentration of calcium. Experiments without tuff retain the leachant level of calcium in solution. The average value of duplicate blank experiments were used as the background levels for all four types of experiment containing glass.

The results of the blank experiments for magnesium are shown in Fig. 8 for both the irradiated and nonirradiated experiments. The experiments without tuff (shown by the triangular symbols) were found to have magnesium concentrations very similar to the leachant levels. The nonirradiated experiments with tuff showed an initial increase in magnesium followed by a decrease back to the leachant level after about 56 days. The irradiated experiments with tuff had higher levels of magnesium for all time periods. The difference in behavior of the irradiated and nonirradiated blank experiments with tuff may be due to the different pHs of the leachates and lower magnesium solubilities at the higher pH. The lower calcium concentrations in the nonirradiated experiments with tuff (see Fig. 7) probably indicate more calcite is formed than in the irradiated experiments with tuff. The lower magnesium in the nonirradiated blank experiments with tuff may be a result of magnesium incorporation into the calcite. The blank experiments without tuff had no source of magnesium and so could retain only the leachant concentration.

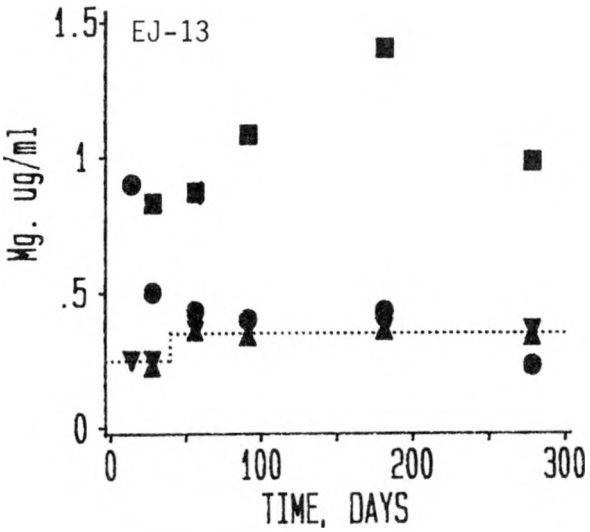


Fig. 8. Magnesium Concentration vs. Reaction Time for EJ-13 Irradiated, without Tuff (▲) or with Tuff (■); Non-irradiated, without Tuff (▼) or with Tuff (●). The horizontal line represents the magnesium concentration of the initial leachants.

The sodium content of the EJ-13 leachant is near 45 μg/mL. The sodium contents are shown in Fig. 9 for irradiated and nonirradiated blank experiments. Notice that the sodium content of the leachant used for the 14- and 28-day experiments was much higher than in the other leachants. In the presence of tuff, the sodium concentration in the irradiated experiments increases somewhat with time. However, in the nonirradiated experiments the sodium concentrations remain near the leachant levels at all reaction times suggesting that sodium, too, may be incorporated into precipitates. The duplicate experiments showed greater variance in the sodium content than any other analyzed cation. The results of the experiments with tuff appear to be more systematic than the hydrothermal results of [OVERSBY], however. The increase in the sodium content with time seen in the irradiated experiments with tuff may be related to the leachate pH. The average values of the sodium results were used as the background levels for all experiment types.

Silicon analysis is complicated by use of silicone rubber gaskets. As can be seen by the silicon levels in the blank experiments, Figs. 10a,b, there is a definite increase in silicon concentration as a function of reaction time in all experiments. In Figs. 10a,b, the symbols represent the average silicon concentration of duplicate experiments while the error bars locate the individual results. The increase in silicon appears to be best fit by a linear relationship for both irradiated experimental types (i.e., both with and without tuff) and for the nonirradiated experiments without tuff. Nonirradiated experiments with tuff show a silicon increase that appears to be nearly parabolic in time. The irradiated experiments with tuff show a somewhat more rapid linear increase in silicon content through 91 days but then slow after the concentration reaches ~70 μg/mL. [OVERSBY] found a similar increase in silicon content with reaction time in tuff/J-13 water equilibration experiments at 90°C, and concluded that saturation with respect to SiO_2 is expected to occur at a concentration near 120 μg/mL.

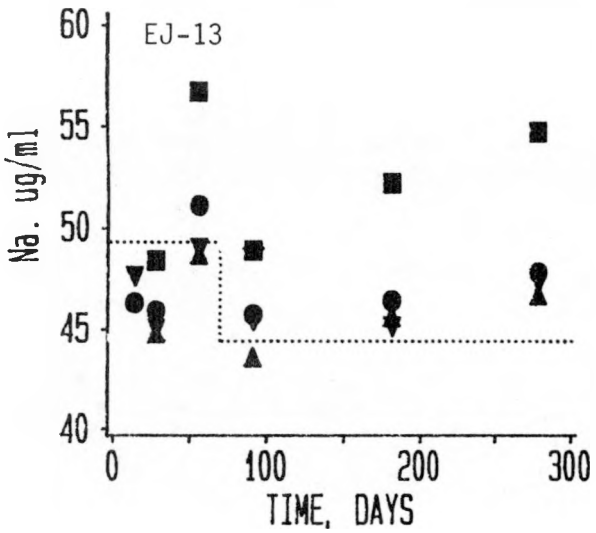


Fig. 9. Sodium Concentration vs. Reaction Time for EJ-13 Irradiated, without Tuff (▲) or with Tuff (■); Non-irradiated, without Tuff (▼) or with Tuff (●). The horizontal line represents the sodium concentration of the initial leachants.

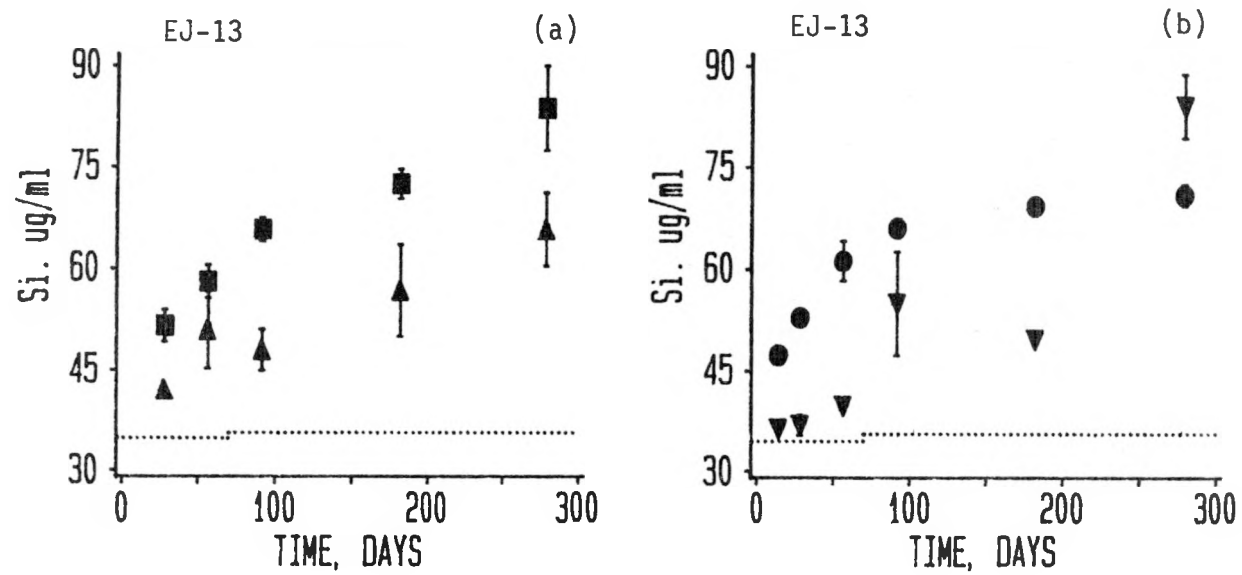


Fig. 10. Silicon Concentration vs. Reaction Time for EJ-13 (a) Irradiated, without Tuff (▲) or with Tuff (■); and (b) Nonirradiated, without Tuff (▼) or with Tuff (●). The horizontal lines represent the silicon concentration of the initial leachants.

The silicon in the blank experiments performed without tuff is apparently being released mainly from the silicone rubber gasket. Some silicon is also released from the tuff wafer, when present, more so in the irradiated experiments. This is indicated by the slightly greater slope for the experiments with tuff. The EJ-13 water only experiments that used Teflon™ gaskets all showed silicon levels near that of the leachant. This strongly suggests that the silicone gaskets are releasing silicon into the solution. While the increased silicon concentration as a function of time suggests that silicon was released during the experimental time period, it is possible that some silicon was released during the acid soak procedure after the experiments were terminated. The gaskets appeared to remain intact, although small pieces may have been inadvertently introduced into the acidified solution. Such contamination would cause random increases in silicon concentration. If silicon contamination occurred during the acid soak, then the increase in the silicon concentration would not affect the glass reaction, though the measured silicon concentration would be too high. The values of the fit curves at the reaction times of interest were used as the background levels.

As seen in Fig. 11, the strontium concentrations in the non-irradiated blank experiments both with tuff and without tuff were very near the leachant level, which is shown by the dotted line. The leachant level for the 91-, 181- and 278-day experiments was used as the background concentration for all the nonirradiated experiments without tuff. The nonirradiated experiments with tuff had levels slightly below the leachant level in most experiments. The irradiated experiments with tuff showed a significant increase in strontium concentration relative to the initial leachant levels, while the strontium levels in the irradiated experiments without tuff remained unchanged compared to the leachant. The increase of strontium in the presence of tuff is likely due to leaching of the tuff under the relatively acidic pHs of the irradiated solutions.

Use of the results from the blank experiments as background levels for experiments with glass assumes that conditions affecting the solubilities, such as the leachate pHs, are similar in the blank and experimental leachates. While the leachates of the experiments containing SRL U glass had pH values only slightly greater than the corresponding blanks, the experiments with ATM-1c and ATM-8 glasses had leachates with pHs significantly higher than the blanks. Such pH differences will tend to alter the solubilities and distributions of some elements, especially in the presence of a tuff surface, and so the blanks may not represent the background levels as well in these cases.

The presence of tuff and the acidification of the leachant affected the leachate concentrations of several species. Calcium was lost from solution when a tuff wafer was present regardless of the leachate pH. Magnesium, sodium, silicon, and strontium levels increased when tuff was present in the irradiated experiments. However, except for silicon, the concentration levels for these elements remained at the leachant levels under nonirradiated conditions with or without tuff present. Silicon levels increased under all conditions tested, due to both the reaction of tuff and to gasket contamination.

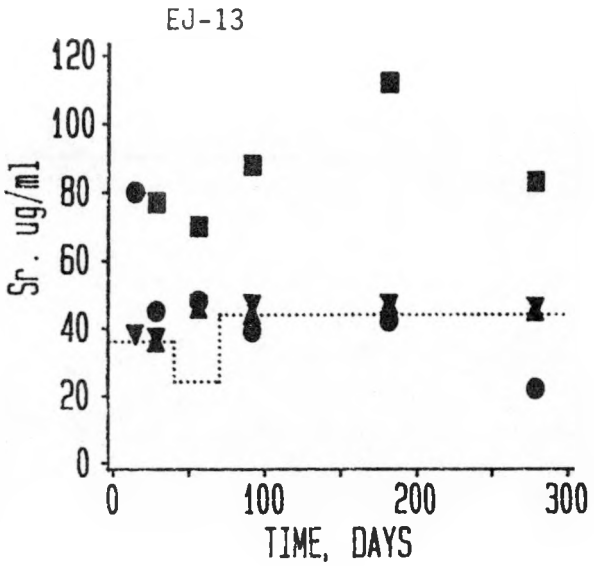


Fig. 11. Strontium Concentration vs. Reaction Time for EJ-13 Irradiated, without Tuff (▲) or with Tuff (■); Non-irradiated, without Tuff (▼) or with Tuff (●). The horizontal line represents the strontium concentration of the initial leachants.

2. Experiments with Glass

The experiments containing glass were treated procedurally the same as the blank experiments. Both the glass disks and tuff wafer, if present, were removed from the vessel prior to leachate acidification.

Figures 12-20 plot the normalized elemental mass loss for some of the cations of interest as a function of the reaction time. The normalized elemental mass loss of a species i, NL(i), is the mass of species i measured in solution normalized to the geometric surface area of the glass in the experiment and the weight fraction of species i in the glass. A sample calculation is presented in Appendix II. Such normalization allows the direct comparison of the results of different glasses or of different components from the same glass.

Figure 12 shows the boron results for (a) irradiated and non-irradiated experiments including SRL U glass, and irradiated experiments including (b) ATM-1c, and (c) ATM-8 glasses. The background level of boron is only a few percent of the total boron concentration in all cases. The ATM-1c glass is seen to release slightly more boron than does the ATM-8 glass. Both ATM glasses release far more boron than either SRL glass under the conditions tested. This indicates a greater extent of corrosion in the case of the ATM glasses. The normalized boron mass loss curves appear to be nearly parabolic in time for all cases. This suggests the release of boron from these glasses is diffusionally controlled throughout the experimental period tested.

The experimental calcium levels are either near to or less than the background calcium levels in most experiments. This causes extreme scatter as the resulting calcium mass losses are the small differences between two large numbers. Nevertheless, a trend appears wherein the NL(Ca) goes through a minimum after nearly 150 days. It was mentioned

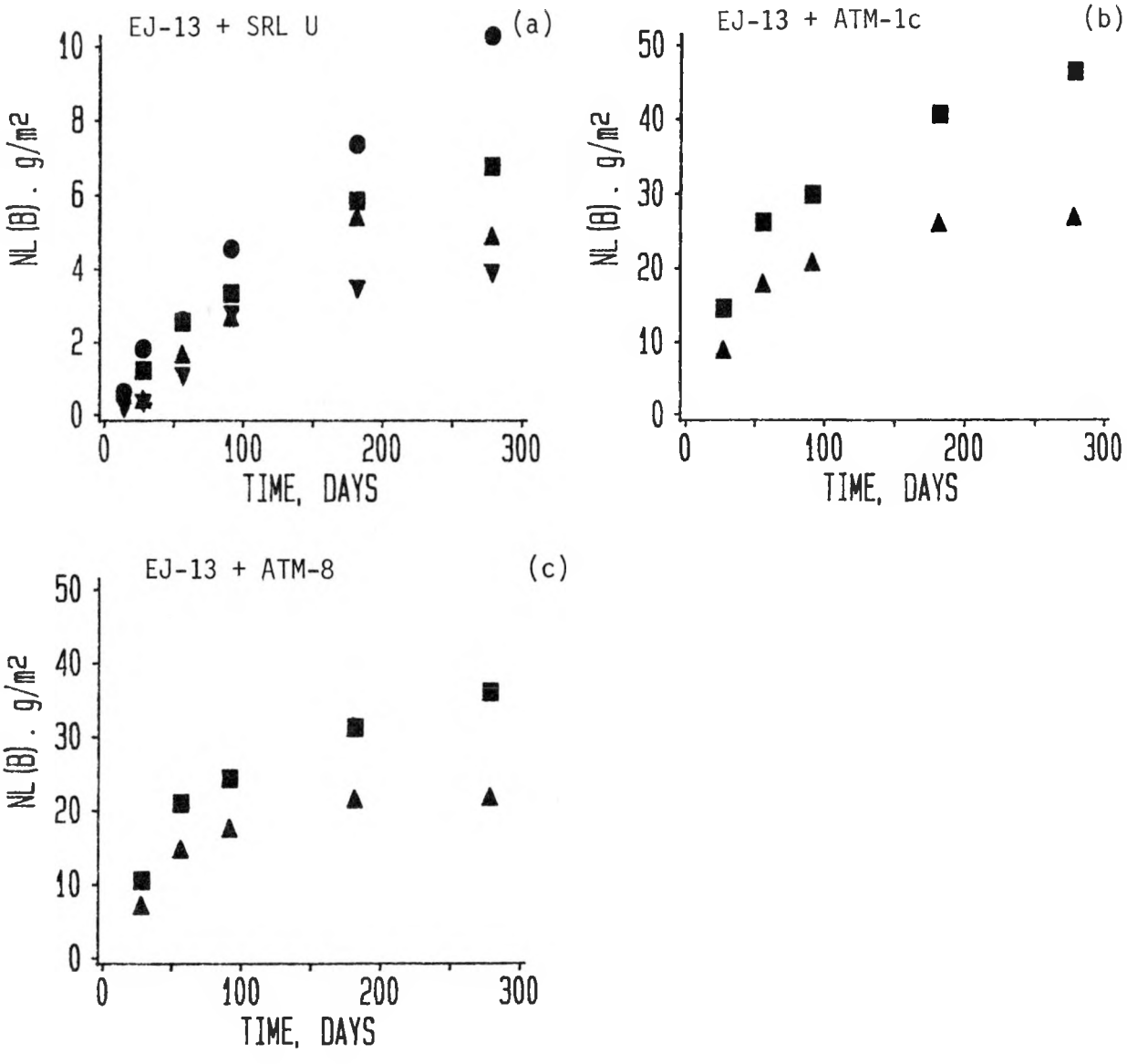


Fig. 12. Normalized Boron Mass Loss vs. Reaction Time for EJ-13 Plus: (a) SRL U, irradiated, without tuff (▲) or with tuff (■); (b) ATM-1c; and (c) ATM-8 glass, irradiated, without tuff (▼) or with tuff (●).

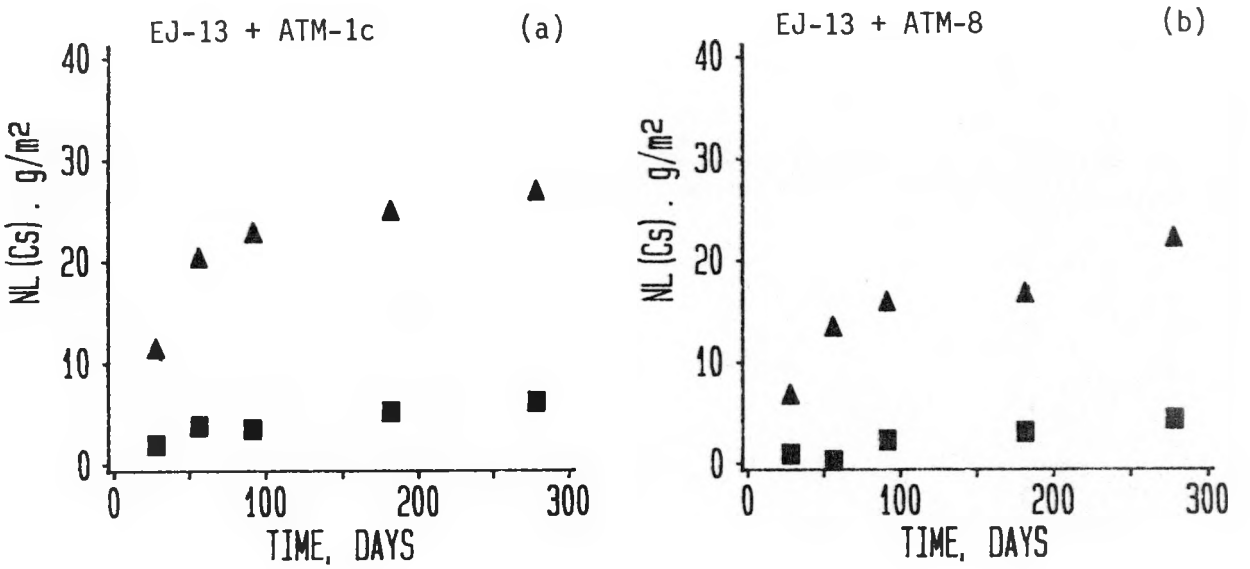


Fig. 13. Normalized Cesium Mass Loss vs. Reaction Time for EJ-13 Plus: (a) ATM-1c, and (b) ATM-8 Glass Irradiated, without Tuff (▲) or with Tuff (■).

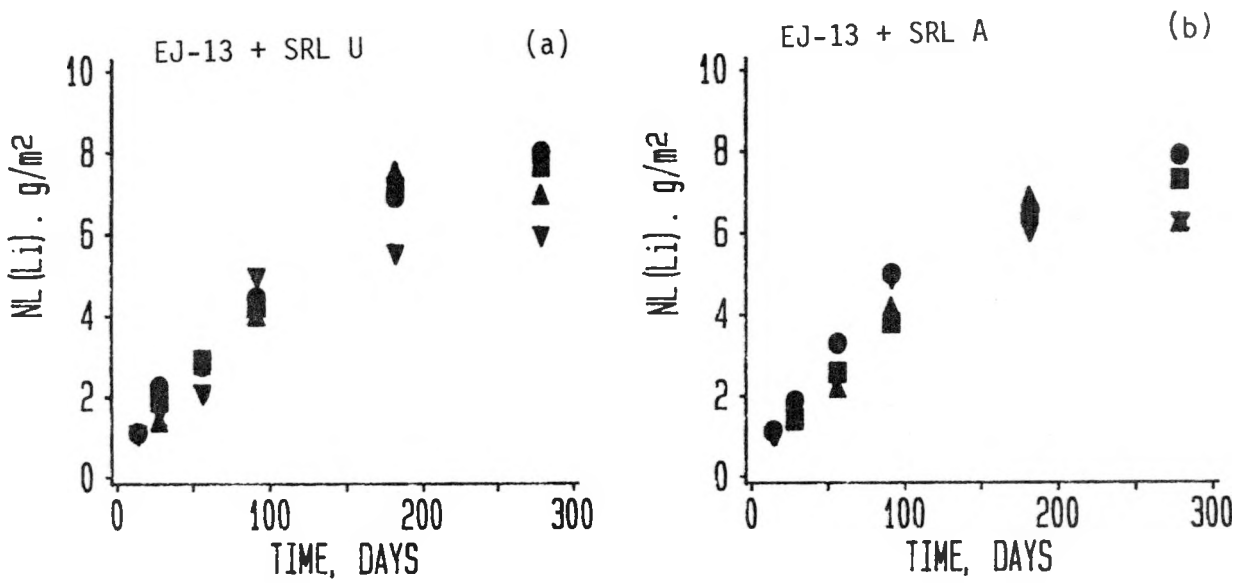


Fig. 14. Normalized Lithium Mass Loss vs. Reaction Time for EJ-13 Plus: (a) SRL U, and (b) SRL A Glass Irradiated, without Tuff (▲) or with Tuff (■); Nonirradiated, without Tuff (▼) or with Tuff (●).

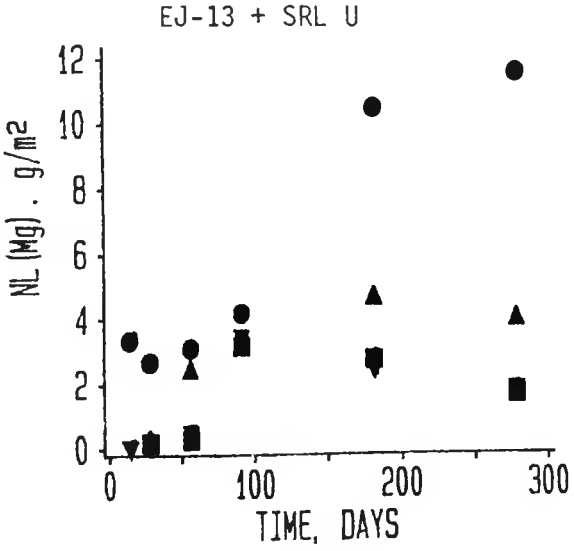
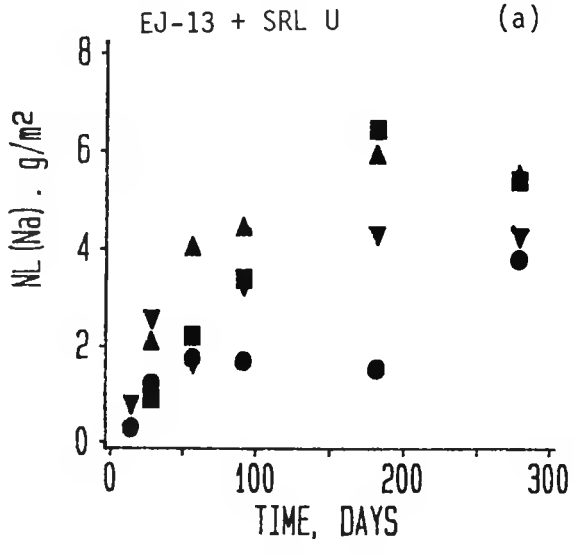
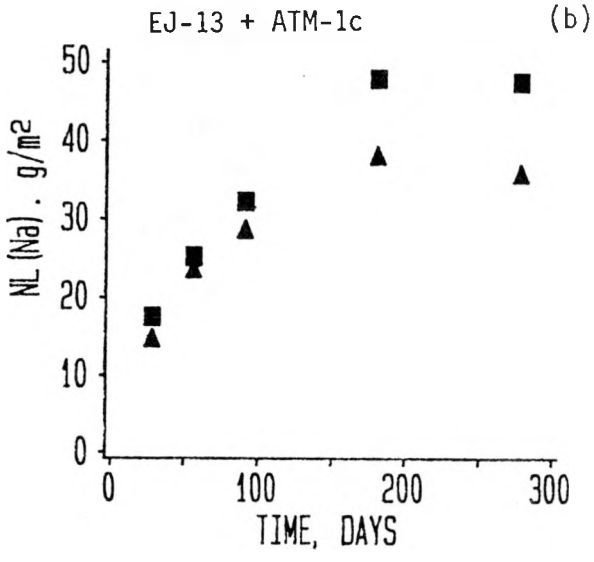


Fig. 15. Normalized Magnesium Mass Loss vs. Reaction Time for EJ-13 Plus SRL U, Irradiated, without Tuff (▲) or with Tuff (■); Nonirradiated, without Tuff (▼) or with Tuff (●).





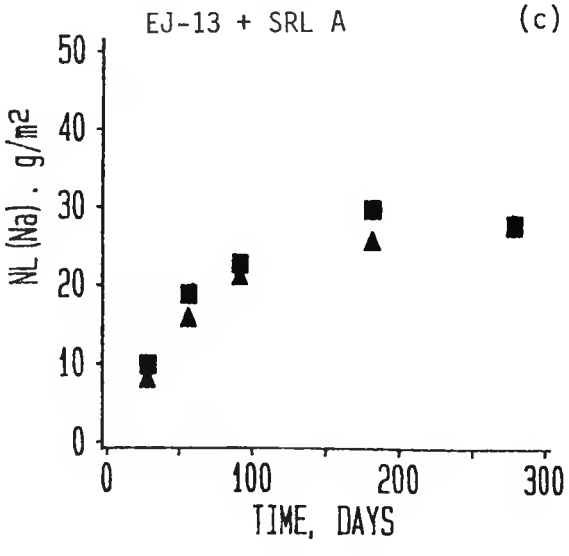


Fig. 16. Normalized Sodium Mass Loss vs. Reaction Time for EJ-13 Plus: (a) SRL U glass, (b) ATM-1c glass, and (c) ATM-8 glass; irradiated, without tuff (▲) or with tuff (■); nonirradiated, without tuff (▼) or with tuff (●).

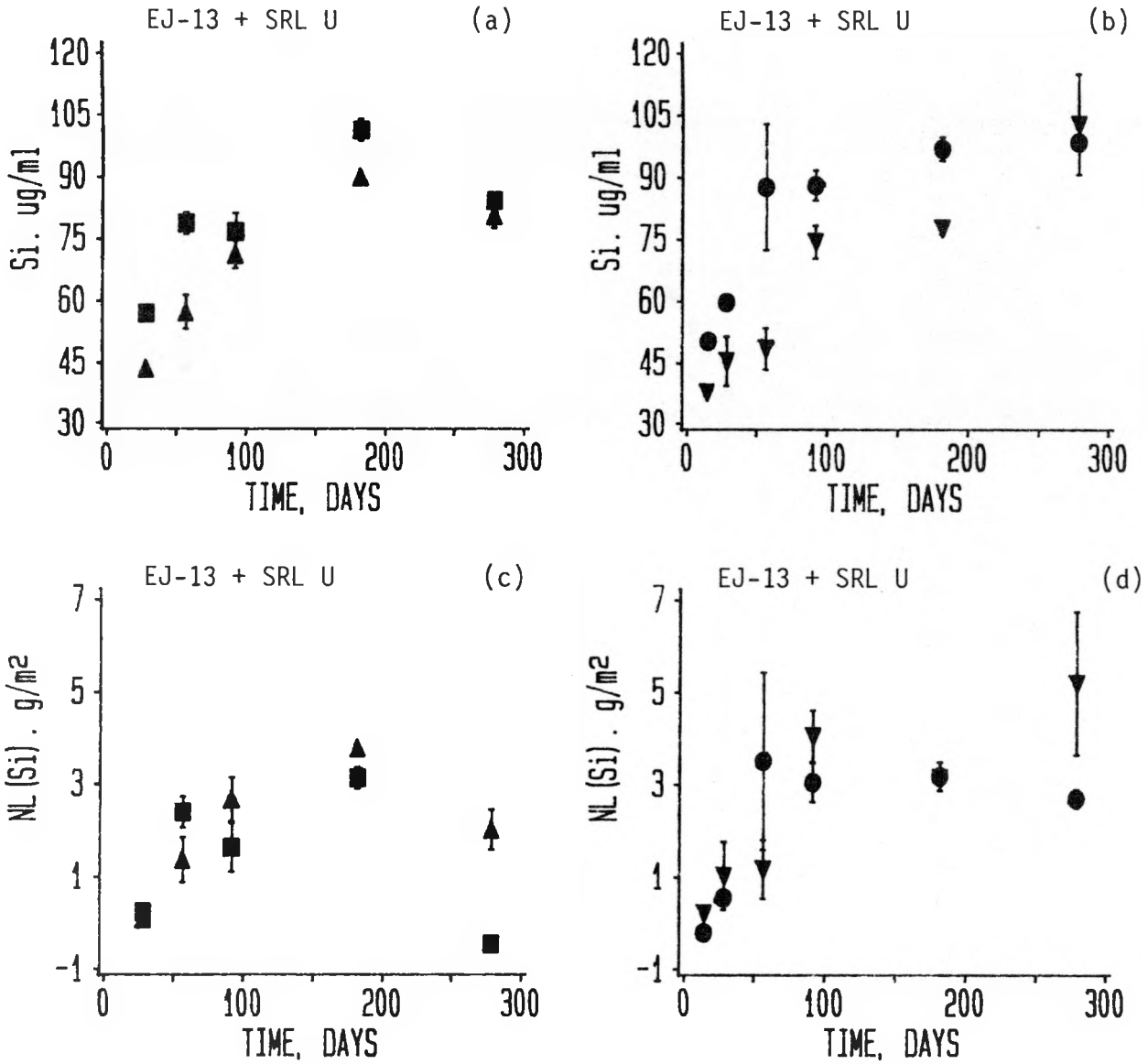


Fig. 17. Concentration of Silicon in the Leachates of Experiments with SRL U Glass: (a) irradiation, (b) nonirradiated, and the normalized silicon mass loss vs. reaction time for SRL U glass; and (c) irradiated, without tuff (▲) or with tuff (■); and (d) nonirradiated, without tuff (▼) or with tuff (●).

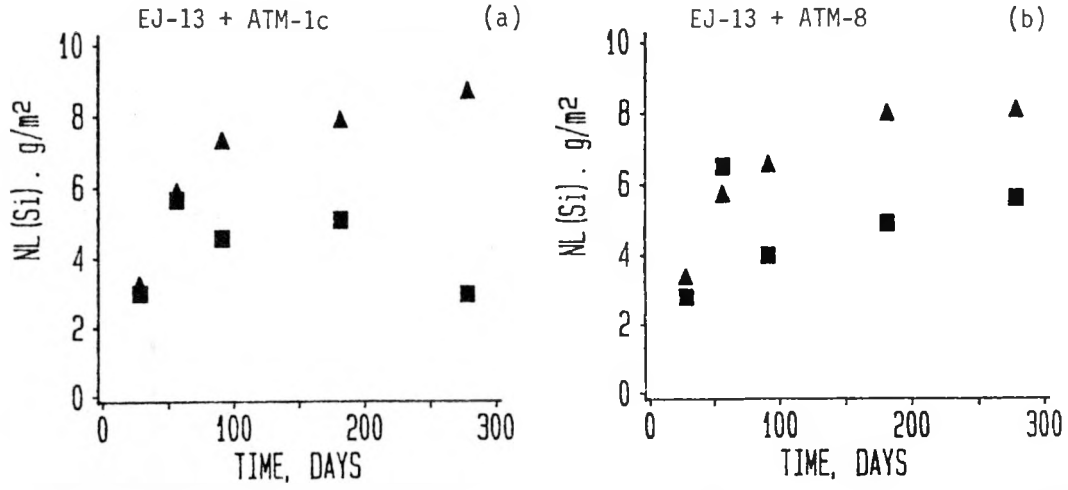


Fig. 18. Normalized Silicon Mass Loss vs. Reaction Time for EJ-13 Plus: (a) ATM-1c Glass and (b) ATM-8 Glass, Irradiated, without Tuff (▲) or with Tuff (■).

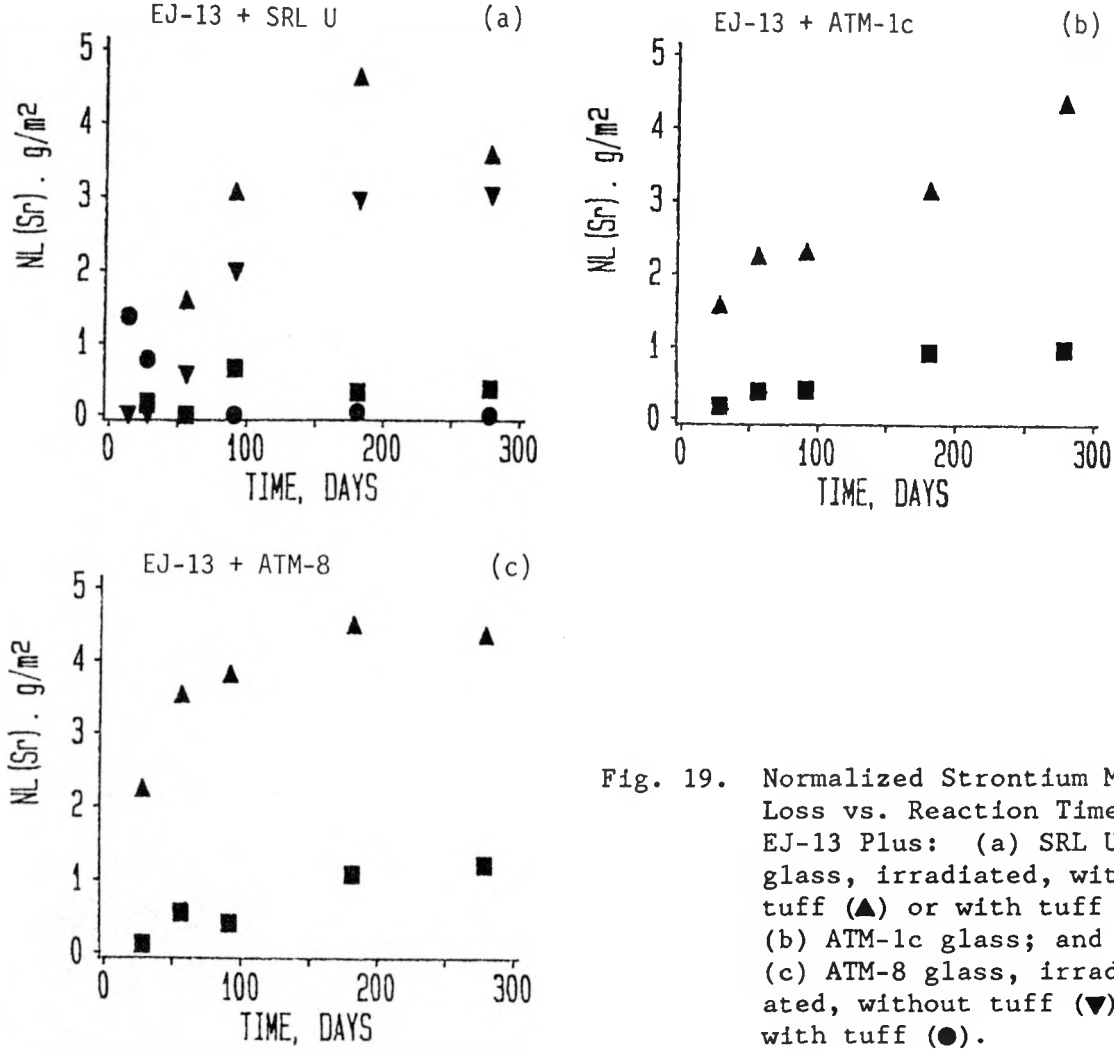


Fig. 19. Normalized Strontium Mass Loss vs. Reaction Time for EJ-13 Plus: (a) SRL U glass, irradiated, without tuff (▲) or with tuff (■); (b) ATM-1c glass; and (c) ATM-8 glass, irradiated, without tuff (▼) or with tuff (●).

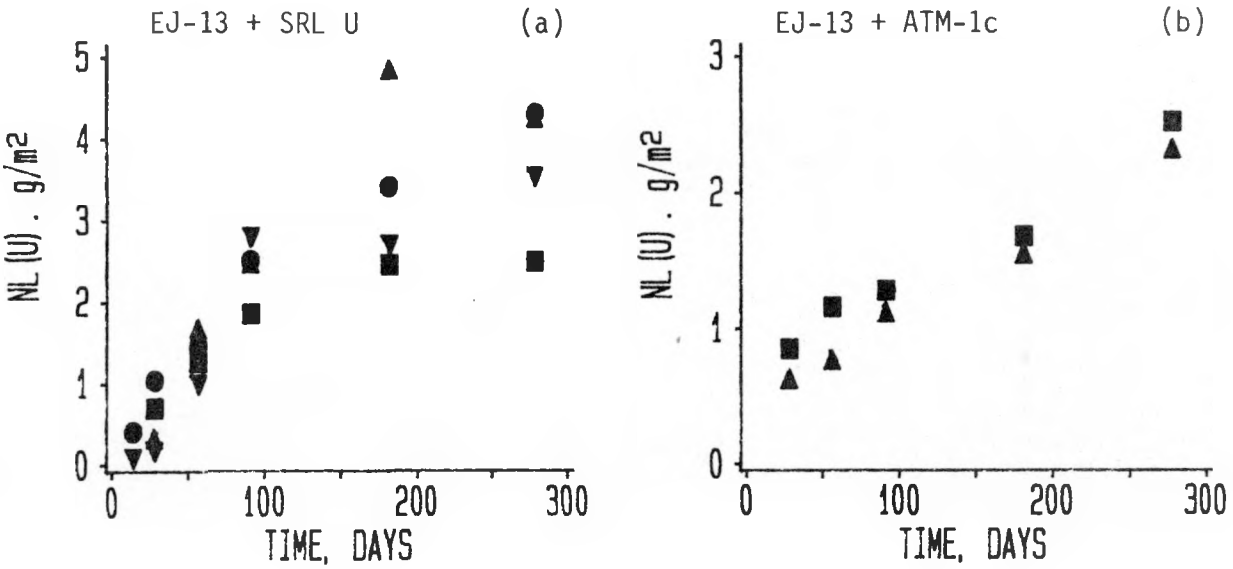


Fig. 20. Normalized Uranium Mass Loss vs. Reaction Time for EJ-13 Plus: (a) SRL U and (b) ATM-1c glass, irradiated, without tuff (▲) or with tuff (■); nonirradiated, without tuff (▼) or with tuff (●).

earlier when discussing the calcium results of the blank experiments that the tuff wafer may scavenge calcium from the leachate through precipitation of $CaCO_3$. The presence of glass does not appreciably change the solution concentrations of calcium in these experiments, probably due to the fact that the solutions are nearly saturated with respect to a calcium-rich phase even before the glasses react. It is interesting to note that the leachates of experiments containing the ATM glasses were even further depleted in calcium, relative to the blank experiments, when tuff was not present. Both the SRL and ATM glasses contain calcium. Since the leachant is nearly saturated, with respect to $CaCO_3$ or another Ca-bearing phase, all excess calcium will likely be contained in precipitates.* Alternatively, the calcium may remain on the surface of the reacting glass, unable to be solvated. The change in the leachate pH with reaction and/or irradiation will also influence the calcium concentration by changing the solubilities of calcium-containing precipitates. Further evidence regarding calcium behavior can be obtained from analysis of surface reaction products using SEM/EDS.

Cesium was analyzed using atomic absorption spectroscopy. Figures 13a,b show the release of cesium from ATM-1c and ATM-8 glasses, respectively. The SRL 165 type glasses contain less than 0.1 wt % Cs_2O and the leachates were not analyzed for cesium. The presence of a tuff wafer effectively depletes the leachate of cesium. The ATM-1c glass appears to

*The solution capacity for calcium will likely vary as the solution chemistry changes.

react a little more than the ATM-8 glass, as witnessed by the lower NL(Cs) values of ATM-8 leachates at a given reaction time. The cesium appears to be released diffusionally from both glasses, evidenced by the parabolic shape of the curve. Surface analyses of the tuff is expected to show a large amount of cesium either sorbed or contained in precipitates.

The lithium releases are plotted in Figs. 14a,b for the SRL U and SRL A glasses. The ATM glasses do not contain lithium. The SRL U and SRL A glasses react similarly in similar environments. (The SRL A results for lithium release are included here because of the frequent use of lithium as a measure of the extent of reaction.) Lithium is a useful indicator of the extent of the ion-exchange reaction between the glass and water infiltrating the glass since it has very high solubility limits and so its release is not expected to be significantly quenched by solubility constraints. Irradiation does not appear to influence the release of lithium from either glass nor does the presence of tuff.

It was seen earlier in the blank experiments that the presence of tuff had a strong influence on the leachate magnesium concentrations. It was suggested that the solubility of magnesite ($MgCO_3$) or magnesium in calcite may control the magnesium concentration. Irradiated blank experiments showed substantially higher concentrations of magnesium at all reaction times while the nonirradiated blank experiments showed an initial increase at short reaction times but a reduction to the leachant level after about 56 days.

The presence of tuff also shows a strong influence on the magnesium releases of the test glasses, as shown in Fig. 15 for SRL U. The behavior of the tuff-containing experiments is quite different in the irradiated and nonirradiated experiments with SRL glasses. Both SRL U and SRL A glasses released magnesium in the presence and absence of radiation. The presence of tuff in the irradiated experiments is seen to reduce the leachate concentrations in most of the experiments. In the nonirradiated experiments, however, tuff appears to increase the magnesium concentration in the leachate compared to nonirradiated experiments without tuff. Tuff does not have a large influence on the irradiated ATM experiments. The ATM experiments had leachate concentrations similar to the irradiated SRL experiments although the ATM leachate pHs were nearer the pHs of the nonirradiated experiments (~8). The small difference in leachate pH may not strongly influence the magnesium solubility. Analysis of the glass and tuff surfaces should clarify these solution results.

The normalized sodium mass loss is plotted in Figs. 16a-c for the various experiment types. The background concentration of sodium was found to represent about 80% of the total sodium measured in the experiments with SRL glasses and 30% of the sodium in the experiments with ATM glasses. The NL(Na) values might be expected to show a great deal of scatter, as they are calculated as small differences between two large numbers. Data Table C shows duplicate experiments gave similar results, however. Irradiation appears to accelerate the release of sodium slightly. The sodium concentration in the leachates of the nonirradiated experiments is

reduced slightly in the presence of tuff, though tuff had little effect on the irradiated experiments. Experiments with ATM glasses and tuff showed a slightly greater release of sodium than the experiments without tuff.

The silicon concentrations are shown in Figs. 17a-d. The symbols plotted are the average values of duplicate experiments, the individual results being located by the error bars. In many cases, the difference between duplicate experiments is smaller than the symbol. Like sodium, the background concentration of silicon was high relative to the concentration of silicon in the experiments with glass, typically near 75%. Figures 17a,b show the actual solution concentrations of silicon measured, without background subtraction. The irradiated experiments show a slight dropoff in the silicon concentration at 278 days while the nonirradiated experiments show rather similar concentrations at 91, 181, and 278 days. Figures 17c,d show the normalized silicon mass losses, using the background subtracted values. The NL(Si) values appear to be rather well behaved except for the 278-day results of the irradiated experiments with tuff. This is probably not an artifact of the background levels selected but an indication of a change in leachate chemistry. It may be an indication of slow precipitation reactions occurring at 278 days, while supersaturated solutions exist in shorter term experiments. The analogous results for SRL A showed a similar drop for the 278-day irradiated experiments. The leachate concentrations of several species have been seen to be lower in the 278-day experiments than in the 181-day experiments. The fact that the release patterns of silicon in all experiments look similar to those of other glass species (with the possible exception of the 278-day experiments with tuff) lends support to the assigned background levels of silicon derived from the blank and blank plus tuff experiments, especially since the background level represents such a large part of the total measured silicon.

Figures 18a,b show the NL(Si) from the ATM glasses. Notice that the presence of tuff appears to quench the release of silicon. This may be due to the higher background silicon concentrations in experiments with tuff because the tuff promotes precipitation and so inhibits the solution from supersaturating.

Strontium was a dopant in both the SRL U and SRL A glasses and is also present in the ATM glasses. There was also found to be a small amount of strontium in the EJ-13 leachant. The normalized elemental mass losses of strontium from the glasses are plotted vs. the reaction time in Figs. 19a-c. Tuff is seen to have a definite sorbtive effect which removes almost all of the strontium from solution both in irradiated and non-irradiated experiments. A measurable amount of strontium is expected to be found on the surfaces of the tuff wafers reacted with glass present. The release rate of strontium from the experiments without a tuff wafer appears to show patterns similar to the release of other cations, namely decreasing in time.

The uranium in the acidified leachate was analyzed using fluorescence spectroscopy. The calculated normalized uranium mass losses are plotted as a function of reaction time in Figs. 20a,b for the SRL U and ATM-1c containing experiments. The results of SRL A and ATM-8 experiments are included in the discussion of actinide release which follows. Neither the uranium adsorbed onto the tuff wafer nor that which remains on the reacted glass surface in precipitate form is included in these normalized results. The release pattern from the SRL U glass is similar to that seen before, namely slowing with reaction time. Normalized release from the ATM-1c glass is less than from the SRL glass and more linear with the reaction time, with little difference between tuff-containing and tuff-absent experiments. The fact that the pH values of the irradiated ATM experiments and the nonirradiated SRL experiments were both near 8 and tuff had no obvious influence on the solution concentrations suggests that the leachate pH is, along with the availability of a tuff surface for nucleation, controlling the uranium solubility through some uranium precipitate. SEM analysis of the tuff and glass surfaces should indicate that the irradiated experiments with tuff have more uranium on these surfaces than the nonirradiated experiments.

3. Actinides

The SRL A and ATM-8 glasses contain transuranic elements (classified as actinides in this report), the behavior of which are important in determining whether the specified release regulations for repository licensing can be met. The primary mechanism by which these radionuclides escape the repository is expected to be through groundwater transport. The surrounding tuff and steel canister may act to reduce the transport rate through precipitate formation or adsorption. All test components were, therefore, analyzed for the presence of transuranics in an effort to completely characterize the distribution of released actinide species.

Actinide species released from the glasses in the experiments may remain dissolved in the leachate, may become incorporated into colloidal material which remains suspended in the leachate, may adsorb onto the stainless steel vessel or the tuff wafer, if present, or may become incorporated into precipitates. The presence of actinides on the tuff wafer will be detected during surface (SIMS or ion microprobe) analysis of the tuff. The actinides remaining in the leachate or adsorbed on the vessel walls were quantified using fluorescence spectroscopy for uranium and alpha spectroscopy for ^{237}Np, ^{239}Pu, and ^{241}Am. Discussion of the uranium results for experiments including SRL U and ATM-1c glasses was included in Section III.D.2. The uranium release from SRL A and ATM-8 glass is presented here for comparison with the release behavior of the other actinide species.

Four differently treated leachate samplings as well as the tuff wafer surface were analyzed to characterize the distribution of the actinides released from the glass. An aliquot of the unfiltered leachate was taken immediately after the vessel was opened. This solution contained both dissolved actinides and those actinides associated with colloidal

material, either as suspended precipitates, complexed actinides, or adsorbates on other colloids. Another sample of the leachate was filtered to remove most of the suspended material. About 0.5 mL of the leachate was centrifuged through a 50 Å filter and an aliquot of the filtrant solution analyzed. (The leachate of only one of each set of duplicate experiments was filtered.)

A third sample, one of the acidified leachate, was analyzed. Acidification of the leachate with conc. HNO_3 to a pH value near 1 dissolves most of the species adsorbed on the stainless steel since the solubilities of Np, Pu, Am, and U are much higher at pH 1 than at the experimental leachate pHs which ranged between 6 and 9. This analysis of the "acid soak" leachate includes the originally dissolved and colloidal species as well as species removed from the vessel walls. After the acidified leachate had been removed from the vessel, the vessel and stainless steel support were rinsed with a solution containing hydrofluoric and nitric acids to dissolve any actinides that may have still remained on the vessel after the acid soak. An aliquot of the rinse or "acid wash" solution was analyzed. Only the acid soaked sample was analyzed for uranium.

In preparation for counting analysis, aliquots were stippled onto a stainless steel planchet and allowed to evaporate about 24 hours at room temperature. The planchets were then heated in a flame to fix the actinides to the stainless steel. A collodion solution was used to affix the remaining residue to the planchet to prevent it from scattering or falling out of the planchet. Each sample was analyzed using counting techniques. No separations were performed and neptunium, plutonium, and americium were quantified concurrently.

The samples are identified as being unfiltered (UF), filtered (F), acid soaked (AS), or acid washed (AW) according to how they were treated, as described above. The complete data table for the alpha spectroscopy analyses is presented in Section VII, Data Table D. In calculating the total mass of an actinide released from the glass in an experiment, the mass dissolved and the mass in colloidal form as well as the mass adsorbed to the stainless steel and tuff must be known. The total mass present in the leachate is either dissolved or suspended and is included in An(UF), where An refers to an actinide species. The adsorbed mass (stainless steel only) is included in the An(AS). An(AS) also includes the originally dissolved and suspended colloidal actinides that remain in the leachate during acidification. These fractions must be subtracted from the measured An(AS) mass to obtain the mass of the actinides adsorbed to the stainless steel.

The mass of actinides in the An(AW) aliquot is part of the fraction adsorbed on the stainless steel vessel surface and must be added to that part of the An(AS) aliquot that was also adsorbed to determine the total mass adsorbed. One face of the tuff wafers present in experiments was also analyzed. (The face analyzed was that face which was the top surface during the reaction. Because the tuff wafer was positioned nearer

the detector during analysis than were the planchets, a separate determination of the detector efficiency was made with a standard at this position.) Complete microprobe analyses of the tuff wafers is underway at LLNL, and the results of these analyses will be presented elsewhere.

The results of the counting analyses are presented in Data Table D in Section VII. (The uranium analyses were presented in Data Table C in Section VII.) The relevant leachate and aliquot volumes are included in the table. The actinide masses given in the table refer to the masses calculated for the entire leachate volume. A sample calculation of the masses present in the various fractions is included in Appendix II. The results are summarized in Table 5 where the mass of an actinide measured to be in a particular phase is reported in nanograms. These phases include a nonfilterable or dissolved phase, An(diss), a filterable or suspended phase, An(sus), a phase adsorbed onto the stainless steel vessel, An(ads), and a phase adsorbed onto the tuff wafer, An(tuff). The sum of the dissolved and suspended phase, An(diss) and An(sus), is included as an aqueous phase, An(aq), which is equivalent to the mass in the unfiltered leachate, An(UF). The total actinide mass is simply the sum of An(aq), An(ads), and An(tuff). The total mass, An(total), is used to calculate the normalized actinide mass losses, NL(An), both of which are included in Table 5. The weight fractions of actinides in the glasses as presented in Table 1 were used in these calculations, and a sample calculation is included in Appendix II. Finally, the measured solubilities of the various actinides in the leachates were determined using the An(diss) results and the leachate volumes from Data Table A. These results are given under the heading An(sol) and are molar concentrations.

The distribution of released actinides, to a first approximation, is expected to be insensitive to the identity of the glass from which they were released. The solution pH and Eh will control the distribution of these species amongst the various phases, which may include a "retained" phase on the surface of the reacted glass itself. As can be seen in Table 5, plutonium and americium are strongly adsorbed onto the stainless steel. Only a small fraction of the released plutonium and americium adsorb onto tuff, when present, and only very small amounts are dissolved into the leachate. The influence of solution pH on the normalized release of americium is shown dramatically by the results of experiments 328 and 374 which had anomalous vessel reactions occur to acidify the leachate to a pH near 5. In these "acidic" experiments, the NL(Am) values are an order of magnitude greater than in experiments having more neutral leachates while other glass components show typical releases. This is interpreted to result from the increase solubility of americium at these lower pH values. Under the more neutral conditions of typical experiments, the americium solubility is sufficiently low that americium either adsorbs to the metal surface or remains on the reacting surface as residue as the surrounding glass dissolves. At lower pH values the americium is able to dissolve as the surface reacts and so does not accumulate on the surface. The normalized americium release in these two "acidic" experiments is similar to that of other released species.

Table 5. Actinide Fractionation Results

Exp't Number	Exp't Length	pH	An	An(diss) ng	An(sus) ng	An(aq) ng	An(ads) ng	An(tuff) ng	An(total) ng	NL(An) g/m^2	An(sol) mol/L
SRL A, 1E3 R/h											
320	28	7.40	U	-	-	-	-	-	363	0.09	-
			Np	7	7	14	3	-	17	0.19	1.94E-9
			Pu	0	0	0	3	-	3	0.03	7.18E-12
			Am	0	0	0	0.044	-	0.044	0.02	1.65E-17
321	28	7.54	U	-	-	-	-	-	757	0.18	-
			Np	-	-	24	8	-	32	0.27	-
			Pu	-	-	0	7	-	7	0.07	-
			Am	-	-	0.006	0.110	-	0.116	0.04	-
322	56	6.96	U	-	-	-	-	-	3570	0.86	-
			Np	39	82	121	4	-	125	1.05	1.10E-8
			Pu	0	2	2	30	-	33	0.33	1.22E-10
			Am	0	0.007	0.007	0.205	-	0.212	0.07	1.08E-16
323	56	6.94	U	-	-	-	-	-	4480	1.13	-
			Np	-	-	123	79	-	202	1.79	-
			Pu	-	-	1	41	-	42	0.44	-
			Am	-	-	0.004	0.148	-	0.152	0.05	-
324	91	6.69	U	-	-	-	-	-	8000	2.00	-
			Np	14	208	222	28	-	250	2.17	3.94E-9
			Pu	0	2	2	123	-	125	1.29	2.96E-11
			Am	0	0.000	0.000	0.347	-	0.347	0.12	0
325	91	6.94	U	-	-	-	-	-	10900	2.71	-
			Np	-	-	384	49	-	433	3.65	-
			Pu	-	-	2	81	-	83	0.83	-
			Am	-	-	0.000	0.147	-	0.147	0.05	-
326	181	7.26	U	-	-	-	-	-	18000	4.13	-
			Np	140	427	567	127	-	694	5.81	4.03E-8
			Pu	0	1	1	264	-	265	2.64	3.59E-11
			Am	0	0.009	0.009	0.473	-	0.482	0.16	0
327	181	7.22	U	-	-	-	-	-	18600	4.57	-
			Np	-	-	507	476	-	983	8.46	-
			Pu	-	-	1	227	-	228	2.34	-
			Am	-	-	0.003	0.383	-	0.386	0.13	-
328	278	5.35	U	-	-	-	-	-	15700	3.81	-
			Np	157	325	482	24	-	507	4.23	4.47E-8
			Pu	0	2	2	25	-	27	0.27	5.56E-11
			Am	0	0.000	0.000	10.469	-	10.469	3.53	3.94E-17
329	278	7.56	U	-	-	-	-	-	16100	3.88	-
			Np	-	-	494	24	-	518	4.39	-
			Pu	-	-	3	252	-	255	2.57	-
			Am	-	-	0.009	0.629	-	0.638	0.22	-

Table 5 (Cont'd)

Exp't Number	Exp't Length	pH	An	An(diss) ng	An(sus) ng	An(aq) ng	An(ads) ng	An(tuff)* ng	An(total) ng	NL(An) g/m^2	An(sol) mol/L
SRL A + Tuff, 1E3 R/h											
330	28	7.38	U	-	-	-	-	-	1820	0.43	-
			Np	20	39	59	16	0	75	0.61	5.82E-9
			Pu	0	1	1	10	0	11	0.11	1.65E-11
			Am	0	0.011	0.011	0.098	0.005	0.112	0.04	7.51E-17
331	28	7.34	U	-	-	-	-	-	2140	0.55	-
			Np	-	-	58	18	0	76	0.69	-
			Pu	-	-	0	14	0	14	0.15	-
			Am	-	-	0.003	0.081	0.001	0.085	0.03	-
332	56	6.96	U	-	-	-	-	-	4490	1.09	-
			Np	73	55	128	126	0	254	2.16	2.12E-8
			Pu	1	5	6	59	4	68	0.69	1.53E-10
			Am	0.001	0.044	0.045	0.457	0.022	0.524	0.18	2.83E-19
333	56	6.80	U	-	-	-	-	-	5170	1.27	-
			Np	-	-	227	17	0	244	2.09	-
			Pu	-	-	6	45	4	56	0.57	-
			Am	-	-	0.040	0.222	0.015	0.277	0.10	-
334	91	6.83	U	-	-	-	-	-	5990	1.50	-
			Np	36	103	139	1	0	140	1.23	1.06E-8
			Pu	0	31	31	113	10	154	1.61	7.32E-11
			Am	0	0.239	0.239	0.879	0.131	1.249	0.44	0
335	91	7.04	U	-	-	-	-	-	6210	1.48	-
			Np	-	-	110	394	0	504	4.21	-
			Pu	-	-	11	104	5	120	1.19	-
			Am	-	-	0.047	0.526	0.023	0.596	0.20	-
336	181	7.20	U	-	-	-	-	-	10200	2.50	-
			Np	190	0	0	580	0	770	6.63	5.53E-8
			Pu	1	69	70	223	10	303	3.11	3.85E-10
			Am	0.005	0.483	0.488	1.655	0.012	2.155	0.75	3.14E-16
337	181	7.30	U	-	-	-	-	-	10100	2.37	-
			Np	-	-	480	366	0	846	6.96	-
			Pu	-	-	16	226	5	247	2.42	-
			Am	-	-	0.089	0.999	0.050	1.138	0.38	-
338	278	7.56	U	-	-	-	-	-	10500	2.62	-
			Np	162	404	566	351	0	884	7.72	4.77E-8
			Pu	2	57	59	227	11	297	3.09	5.50E-10
			Am	0.015	0.423	0.438	1.970	0.108	2.516	0.89	1.87E-16
339	278	7.69	U	-	-	-	-	-	10300	2.48	-
			Np	-	-	600	187	0	789	6.63	-
			Pu	-	-	73	240	16	329	3.29	-
			Am	-	-	0.595	2.327	0.144	3.066	1.04	-

*Measured weight has been multiplied by 2 to account for both faces.

Table 5 (Cont'd)

Exp't Number	Exp't Length	pH	An	An(diss) ng	An(sus) ng	An(aq) ng	An(ads) ng	An(tuff) ng	An(total) ng	NL(An) g/m^2	An(sol) mol/L
SRL A, 0 R/h											
364	14	8.28	U	-	-	-	-	-	249	0.06	-
			Np	4	2	6	1	-	7	0.06	9.82E-10
			Pu	0	0	0	2	-	2	0.02	6.88E-12
			Am	0	1	1	0.025	-	0.026	0.01	0
365	14	8.30	U	-	-	-	-	-	176	0.04	-
			Np	-	-	5	1	-	6	0.05	-
			Pu	-	-	0	1	-	1	0.01	-
			Am	-	-	0	0.014	-	0.014	0.00	-
366	28	8.93	U	-	-	-	-	-	1820	0.45	-
			Np	18	40	58	8	-	66	0.57	5.14E-9
			Pu	0	1	1	17	-	18	0.18	2.53E-11
			Am	0.001	0.035	0.036	0.187	-	0.223	0.08	2.40E-16
367	28	8.91	U	-	-	-	-	-	2140	0.47	-
			Np	-	-	61	25	-	86	0.71	-
			Pu	-	-	1	21	-	22	0.22	-
			Am	-	-	0.008	0.244	-	0.252	0.08	-
368	56	8.74	U	-	-	-	-	-	2480	0.58	-
			Np	11	21	32	51	-	83	0.68	3.04E-9
			Pu	0	0	0	30	-	30	0.29	1.43E-11
			Am	0.001	0.014	0.015	0.405	-	0.420	0.14	1.55E-16
369	56	8.97	U	-	-	-	-	-	6930	1.68	-
			Np	-	-	75	142	-	217	1.84	-
			Pu	-	-	1	52	-	53	0.54	-
			Am	-	-	0.019	0.373	-	0.392	0.13	-
370	91	9.21	U	-	-	-	-	-	12200	3.04	-
			Np	-	-	191	410	-	601	5.23	-
			Pu	0	1	1	92	-	93	0.96	2.94E-11
			Am	0	0.010	0.010	0.247	-	0.257	0.09	0
371	91	9.24	U	-	-	-	-	-	11500	2.76	-
			Np	-	-	537	13	-	550	4.63	-
			Pu	-	-	4	102	-	106	1.06	-
			Am	-	-	0.201	0.268	-	0.469	0.16	-
372	181	7.23	U	-	-	-	-	-	6670	1.64	-
			Np	157	370	527	320	-	847	7.30	4.48E-8
			Pu	0	3	3	182	-	185	1.90	2.32E-11
			Am	0	0.197	0.197	3.238	-	3.435	1.20	1.00E-16

Cont'd

Table 5 (Cont'd)

Exp't Number	Exp't Length	pH	An	An(diss) ng	An(sus) ng	An(aq) ng	An(ads) ng	An(tuff) ng	An(total) ng	NL(An) g/m^2	An(sol) mol/L
SRL A, 0 R/h - Cont'd											
373	181	9.12	U	-	-	-	-	-	14700	3.50	-
			Np	-	-	121	598	-	719	5.99	-
			Pu	-	-	1	212	-	213	2.11	-
			Am	-	-	0.009	0.784	-	0.793	0.27	-
374	278	5.04	U	-	-	-	-	-	23000	5.73	-
			Np	187	457	644	75	-	719	9.28	5.36E-8
			Pu	0	3	3	68	-	71	0.74	8.72E-11
			Am	0.003	0.341	0.344	8.873	-	9.217	3.25	8.46E-16
375	278	7.54	U	-	-	-	-	-	13000	3.17	-
			Np	-	-	72	804	-	876	7.49	-
			Pu	-	-	0	230	-	230	2.34	-
			Am	-	-	0.006	0.606	-	0.612	0.21	-

Table 5 (Cont'd)

Exp't Number	Exp't Length	pH	An	An(diss) ng	An(sus) ng	An(aq) ng	An(ads) ng	An(tuff)* ng	An(total) ng	NL(An) g/m^2	An(sol) mol/L
SRL A + Tuff, 0 R/h											
376	14	7.60	U	-	-	-	-	-	1960	0.49	-
			Np	23	29	29	54	0	106	0.94	6.82E-9
			Pu	0	1	1	7	1	9	0.09	1.97E-11
			Am	0.000	0.011	0.011	0.08	0.005	0.054	0.02	1.59E-17
377	14	7.77	U	-	-	-	-	-	1830	0.44	-
			Np	-	-	45	24	0	69	0.58	-
			Pu	-	-	1	9	1	11	0.11	-
			Am	-	-	0.007	0.067	0.008	0.082	0.03	-
378	28	8.10	U	-	-	-	-	-	3290	0.87	-
			Np	34	58	92	2	6	100	0.93	9.85E-9
			Pu	0	1	1	23	2	26	0.29	1.80E-11
			Am	0.000	0.009	0.009	0.089	0.016	0.114	0.04	5.13E-17
379	28	8.47	U	-	-	-	-	-	3400	0.85	-
			Np	-	-	87	37	6	130	1.14	-
			Pu	-	-	6	18	2	26	0.27	-
			Am	-	-	0.061	0.170	0.018	0.249	0.09	-
380	56	8.49	U	-	-	-	-	-	6320	1.49	-
			Np	92	11	103	158	0	261	2.16	2.69E-8
			Pu	0	22	22	63	5	90	0.89	1.07E-10
			Am	0.001	0.180	0.181	0.389	0.067	0.637	0.21	1.66E-16
381	56	8.25	U	-	-	-	-	-	3830	0.98	-
			Np	-	-	45	114	0	159	1.43	-
			Pu	-	-	18	28	1	47	0.50	-
			Am	-	-	0.236	0.646	0.007	0.889	0.32	-
382	91	8.85	U	-	-	-	-	-	10800	2.56	-
			Np	90	169	258	109	0	367	3.04	2.63E-8
			Pu	0	53	53	95	2	150	1.48	1.00E-10
			Am	0.001	0.367	0.368	0.574	0.009	0.951	0.32	3.11E-16
383	91	8.80	U	-	-	-	-	-	9350	2.38	-
			Np	-	-	213	26	0	239	2.12	-
			Pu	-	-	66	156	8	230	2.43	-
			Am	-	-	0.462	0.967	0.108	1.537	0.55	-
384	181	8.90	U	-	-	-	-	-	15200	3.67	-
			Np	71	361	432	33	0	465	3.92	2.09E-8
			Pu	0	84	84	251	5	340	3.41	1.07E-10
			Am	0.001	0.349	0.350	1.584	0.040	01.974	0.67	3.62E-16

Cont'd

Table 5 (Cont'd)

Exp't Number	Exp't Length	pH	An	An(diss) ng	An(sus) ng	An(aq) ng	An(ads) ng	An(tuff)* ng	An(total) ng	NL(An) g/m^2	An(sol) mol/L
SRL A + Tuff, 0 R/h - Cont'd											
385	181	8.81	U	-	-	-	-	-	13900	3.41	-
			Np	-	-	210	74	0	284	2.43	-
			Pu	-	-	54	303	5	362	3.70	-
			Am	-	-	0.264	1.471	0.058	1.793	0.62	-
386	278	9.02	U	-	-	-	-	-	16100	4.03	-
			Np	109	18	127	400	0	527	4.61	3.24E-7
			Pu	0	144	144	349	28	521	5.43	5.18E-11
			Am	0.001	0.805	0.806	3.222	0.504	4.532	1.60	1.99E-16
387	278	9.07	U	-	-	-	-	-	16000	3.84	-
			Np	-	-	127	638	0	765	6.42	-
			Pu	-	-	114	373	28	515	5.14	-
			Am	-	-	0.596	3.082	0.317	3.995	1.36	-

*Measured values have been multiplied by 2 to account for both faces.

Table 5 (Cont'd)

Exp't Number	Exp't Length	pH	An	An(diss) ng	An(sus) ng	An(aq) ng	An(ads) ng	An(tuff) ng	An(total) ng	NL(An) g/m^2	An(sol) mol/L
ATM-8, 1E3 R/h											
408	28	8.67	U	-	-	-	-	-	11990	0.65	-
			Np	1237	1862	3099	37	-	3136	1.85	3.50E-7
			Pu	1	3	4	82	-	86	0.19	1.50E-10
409	28	8.54	U	-	-	-	-	-	13160	0.74	-
			Np	-	-	3357	168	-	3525	2.15	-
			Pu	-	-	2	100	-	102	0.23	-
410	56	7.92	U	-	-	-	-	-	16150	0.87	-
			Np	1276	3458	4734	482	-	5216	3.04	3.63E-7
			Pu	0	7	7	202	-	209	0.46	1.05E-10
411	56	7.85	U	-	-	-	-	-	18510	1.01	-
			Np	-	-	4205	1475	-	5680	3.37	-
			Pu	-	-	4	214	-	218	0.49	-
412	91	7.61	U	-	-	-	-	-	20040	1.06	-
			Np	2503	2585	5088	5318	-	10406	5.99	7.31E-7
			Pu	1	2	3	375	-	378	0.82	1.80E-10
413	91	7.68	U	-	-	-	-	-	18460	1.01	-
			Np	-	-	5197	4373	-	9570	5.66	-
			Pu	-	-	3	451	-	454	1.01	-
414	181	7.70	U	-	-	-	-	-	27660	1.52	-
			Np	3205	3819	7024	2146	-	9170	5.47	9.20E-7
			Pu	1	2	3	612	-	615	1.39	1.46E-10
415	181	7.54	U	-	-	-	-	-	28510	1.57	-
			Np	-	-	7745	1107	-	8852	5.28	-
			Pu	-	-	3	454	-	457	1.03	-
416	278	7.78	U	-	-	-	-	-	31630	1.73	-
			Np	1895	6598	8493	1867	-	10360	6.14	5.44E-7
			Pu	0	5	5	604	-	609	1.36	9.00E-10
417	278	5.82	U	-	-	-	-	-	27880	1.48	-
			Np	-	-	6744	36	-	6780	3.92	-
			Pu	-	-	4	593	-	597	1.30	-

Table 5 (Cont'd)

Exp't Number	Exp't Length	pH	An	An(diss) ng	An(sus) ng	An(aq) ng	An(ads) ng	An(tuff)* ng	An(total) ng	NL(An) g/m^2	An(sol) mol/L
ATM-8 + Tuff, 1E3 R/h											
418	28	8.36	U	-	-	-	-	-	11000	0.60	-
			Np	1696	2584	4280	34	0	4314	2.55	4.92E-7
			Pu	0	2	2	82	-	84	0.19	8.67E-11
419	28	8.05	U	-	-	-	-	-	14250	0.77	-
			Np	-	-	5585	218	0	5803	3.40	-
			Pu	-	-	20	62	6	88	0.19	-
420	56	7.59	U	-	-	-	-	-	19090	1.02	-
			Np	2081	5925	8006	624	124	8756	5.07	6.10E-7
			Pu	0	0	0	137	10	153	0.33	-
421	56	7.84	U	-	-	-	-	-	8744	0.47	-
			Np	-	-	8598	95	37	8730	5.15	-
			Pu	-	-	7	234	6	247	0.55	-
422	91	7.95	U	-	-	-	-	-	20500	1.11	-
			Np	0	511	511	5435	0	5946	3.50	0
			Pu	0	3	3	207	66	277	0.62	2.60E-13
423	91	7.70	U	-	-	-	-	-	21440	1.17	-
			Np	-	-	7553	4098	0	11651	6.88	-
			Pu	-	-	2	237	10	249	0.56	-
424	181	7.51	U	-	-	-	-	-	35270	1.92	-
			Np	3923	5968	9891	1395	0	11286	6.67	1.14E-7
			Pu	0	4	4	365	14	383	0.85	4.76E-11
425	181	7.74	U	-	-	-	-	-	31650	1.70	-
			Np	-	-	9580	5180	0	14760	8.61	-
			Pu	-	-	4	368	20	392	0.86	-
426	278	8.01	U	-	-	-	-	-	37260	2.00	-
			Np	5	16	21	9039	717	9777	5.69	1.46E-9
			Pu	0	0	0	298	12	310	0.68	0
427	278	7.92	U	-	-	-	-	-	35740	1.94	-
			Np	-	-	9619	1453	0	11072	6.53	-
			Pu	-	-	2	467	20	489	1.09	-

*Measured weight has been multiplied by 2 to account for both faces.

A significant fraction of neptunium was found in the leachate of all experiments, both in the suspended and dissolved phases. Only a small amount of neptunium was detected on the tuff wafers, while a measurable amount was adsorbed onto the stainless steel vessel surfaces. Figures 21a and 21c show the distribution of neptunium between the aqueous (dissolved plus suspended) and adsorbed (on stainless steel) phases as a function of pH for SRL A and ATM-8 containing experiments, respectively. Experiments that were not irradiated and reached higher leachate pHs sometimes showed more neptunium on the steel than in the leachate, although most experiments showed there to be more neptunium in the leachate than adsorbed on the steel. Figures 21b and 21d show the fraction of neptunium in the leachate that is dissolved (nonfilterable) to be about 30% of the total neptunium in the leachate, although the experiments show a great deal of scatter in this ratio. This means there is about twice as much neptunium in the filterable fraction as in the nonfilterable fraction. The solid collected on the filter was not identified.

The normalized actinide mass losses are plotted in Figs. 22a-d for the experiments containing SRL A glass and in Figs. 23a-c for the experiments containing ATM-8 glass. The symbols represent the average of duplicate experiments. The individual analyses have estimated errors in the number of counts of 50% for neptunium-237, and 20% for both plutonium-239 and americium-241. The neptunium error is much larger because of the overlap of the low energy plutonium tail and the neptunium peak. No chemical separations were performed to isolate these two nuclides.

Neptunium is seen to have the greatest normalized release for both glass types. The presence of the tuff does not appear to affect the neptunium release. Neither does tuff appear to affect the release of uranium. The nonirradiated experiments with tuff show the lowest uranium releases in the SRL A experiments, as they did in the SRL U experiments. This is contrary to the other elemental releases which generally show the nonirradiated experiments with tuff to be the most reactive, although the differences are small. It should be remembered that the uranium associated with the tuff wafers and with the glass specimens has not been included in these releases. Except for americium, the presence of tuff does not have a strong influence on the release rates of the actinides. The slight increase in the release of americium in the presence of tuff is probably an artifact of the small amounts of americium measured in solution or found associated with the tuff. Notice the normalized americium mass loss is very small compared to that of the other actinides. The tuff wafers are currently being analyzed at LLNL.

Irradiation does not appear to significantly affect the release of actinides from the glass, although it was seen to influence the distribution of the actinides that were released. Two experiments having anomalously acidic leachates did show americium releases that were several orders of magnitude greater than the americium releases found in experiments with more typical leachate pH values. This can be understood by considering the radionuclide solubilities. Table 6 gives the approximate molar solubilities of uranium, neptunium, plutonium, and americium in water

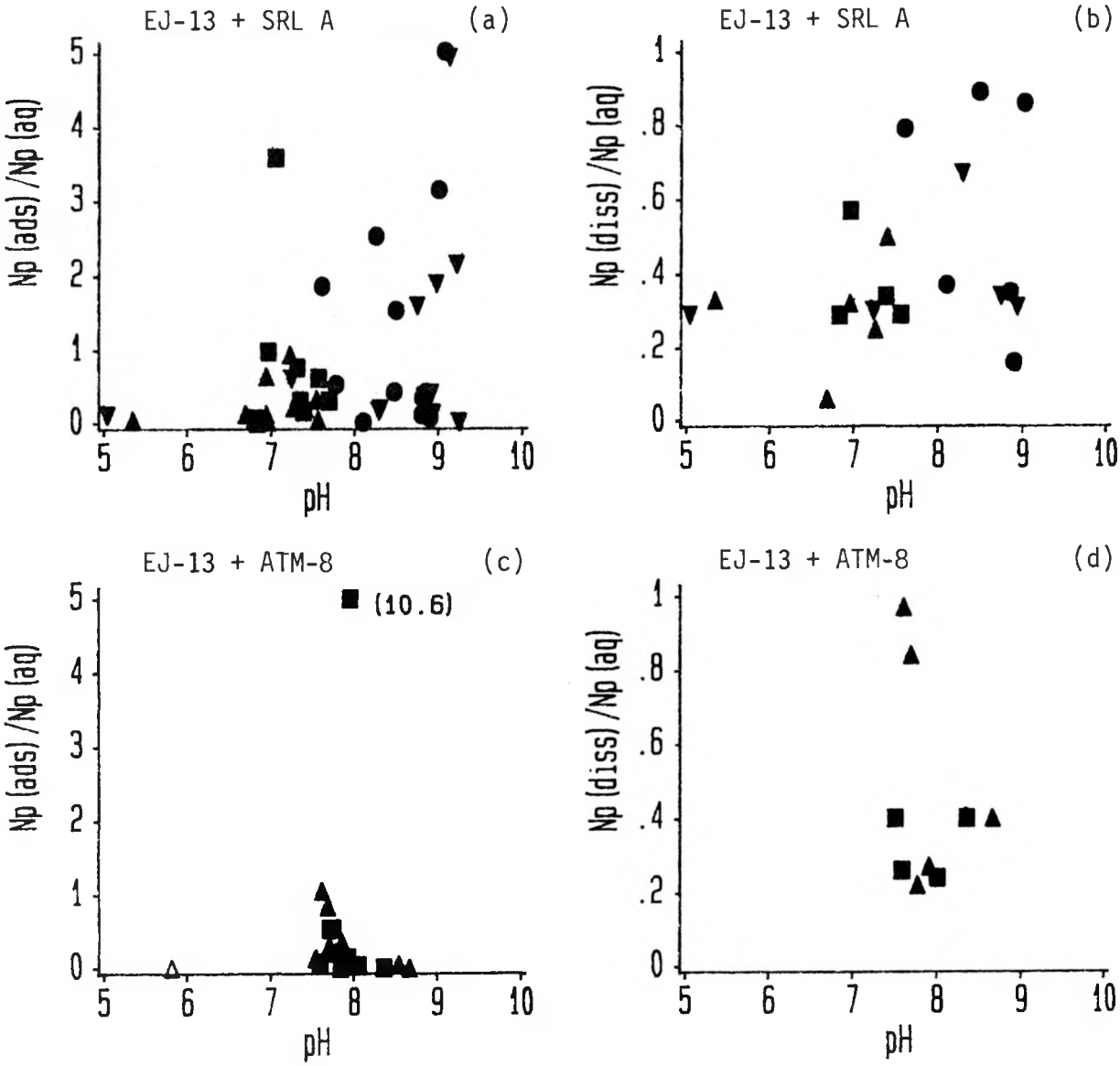


Fig. 21. Ratio of the Adsorbed and Aqueous Fractions of Neptunium vs. pH for EJ-13 Plus: (a) SRL A glass, (c) ATM-8 glass, and the ratio of the dissolved (nonfilterable); and aqueous fractions vs. pH for EJ-13 Plus: (b) SRL A glass, and (d) ATM-8 glass, irradiated, without tuff (▲) or with tuff (■); nonirradiated, without tuff (▼) or with tuff (●).

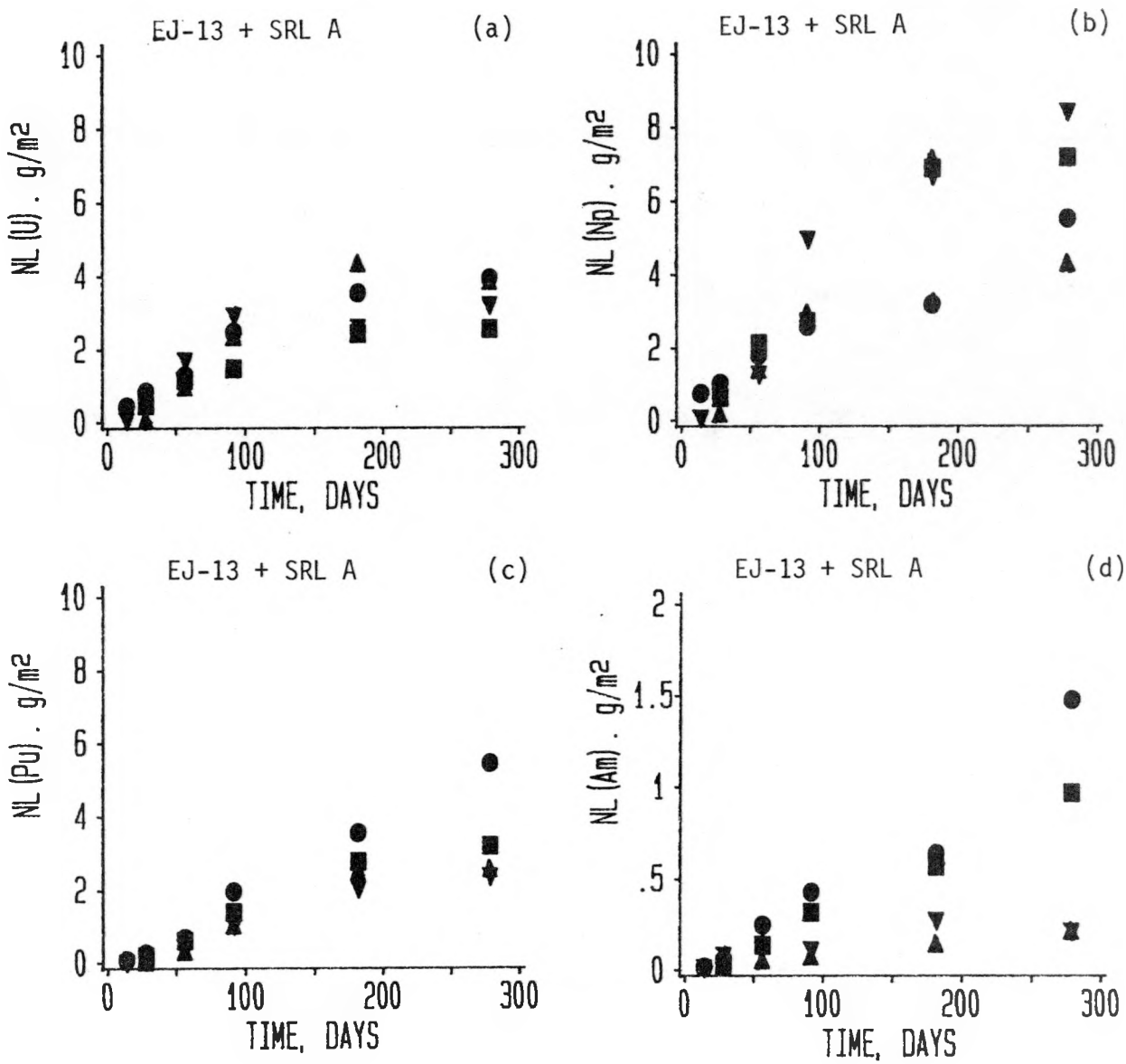


Fig. 22. Normalized Actinide Mass Loss vs. Reaction Time for EJ-13 Plus SRL A Glass: (a) uranium, (b) neptunium, (c) plutonium, and (d) americium, irradiated, without tuff (▲) or with tuff (■); nonirradiated, without tuff (▼) or with tuff (●).

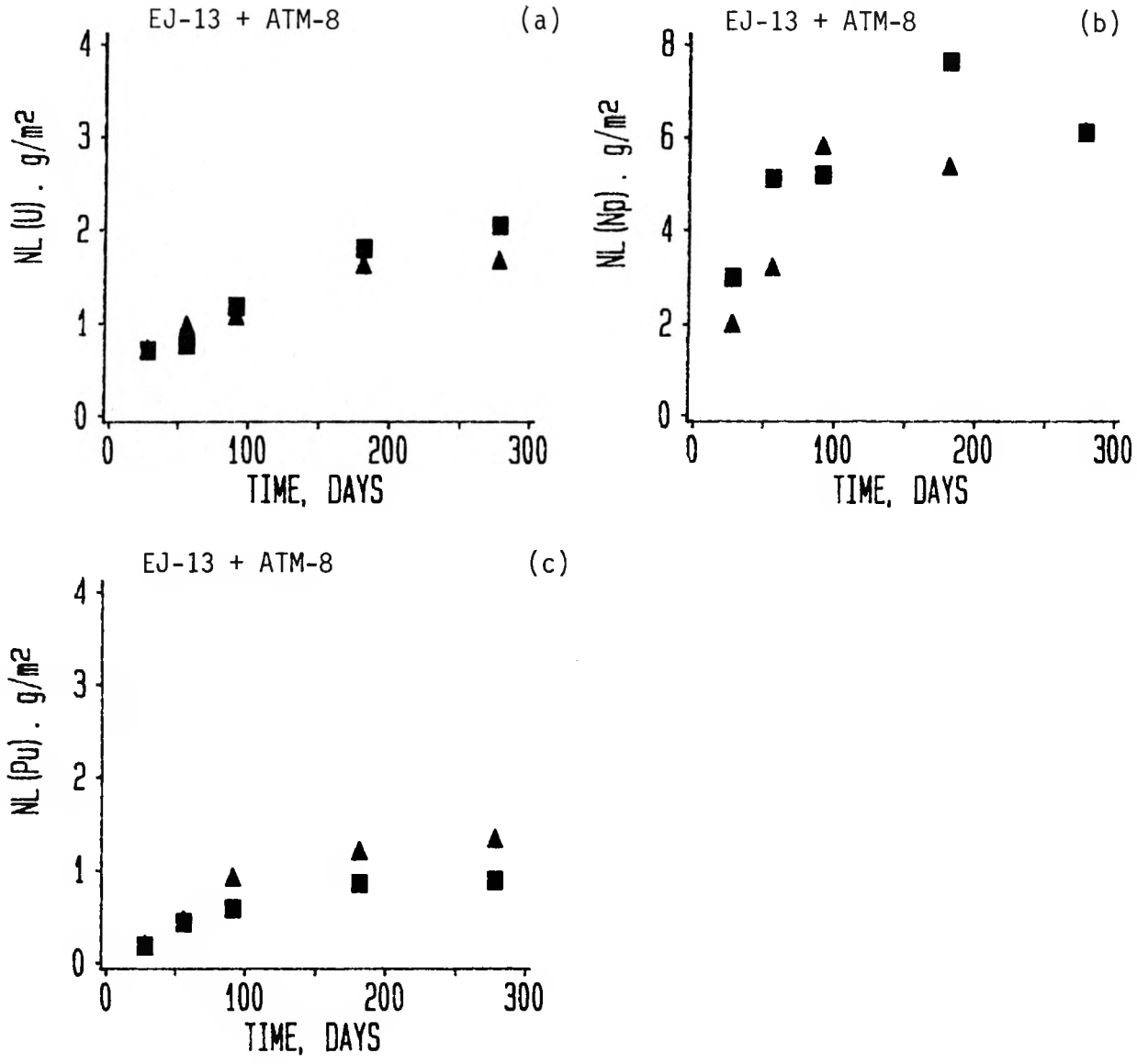


Fig. 23. Normalized Actinide Mass Loss vs. Reaction Time for EJ-13 Plus ATM-8 Glass: (a) uranium, (b) neptunium, and (c) plutonium, irradiated, without tuff (▲) or with tuff (■).

Table 6. Approximate Actinide Solubilities in Tuffaceous Groundwater, in moles/L

	pH		
	6.4[a]	7[a]	7.6[b]
U	1×10^{-6}	1×10^{-6}	4×10^{-3}
Np	1×10^{-2}	2×10^{-2}	3×10^{-3}
Pu	2×10^{-8}	2×10^{-8}	2×10^{-9}
Am	1×10^{-2}	1×10^{-4}	1×10^{-8}

[a]From [ALLARD], DIW in equilibrium with $10^{-3.5}$ atm CO_2 at 25°C.

[b]From [KERRISK], in tuff groundwater at 25°C or 90°C. The pH of typical tuff groundwater in 7.6.

which is in equilibrium with $10^{-3.5}$ atm of CO_2 [ALLARD]. Also included are the solubilities measured in tuff groundwater [KERRISK]. Although the absolute solubility values are approximate, the trends can be used to explain the observed results.

The oxidation states of the transuranics in solution will have a large influence on the exact solubilities. Because the oxidation states were not determined, the solubilities in Table 6 are used only to compare the trends of the various transuranics. The observation that the leachate is reduced through radiolysis of the liquid phase, evidenced by the increase in the nitrite/nitrate ratio, suggests the speciation of the released transuranics may differ in the irradiated and nonirradiated experiments which would account for the different behavior.

The low solubilities of americium and plutonium inhibit their dissolution as the glass reacts, so these nuclides either remain on the surface of the reacting glass as insoluble residue or are adsorbed onto colloidal materials and suspended in solution. They may then sorb onto the stainless steel or tuff surfaces. Uranium and neptunium have sufficiently high solubilities that they are readily released from the glass surface into solution, from which they may be adsorbed onto the stainless steel or tuff surfaces. Most of the americium remains on the glass surface as evidenced by its very low normalized release. Plutonium, however, is released at the same rate as silicon and does not accumulate on the glass surface. Apparently, the plutonium can be transported through the leachate to the vessel walls more easily than americium despite having similarly low solubilities, perhaps because of different degrees of sorption to colloids. In the event the leachate becomes acidified, the solubilities of americium and plutonium increase and so both elements are freed from the surface into solution from which they may subsequently adsorb onto the steel or tuff surfaces.

E. Weight Change

The glass disks were removed from the leachate shortly after the experiments were terminated. They were rinsed with high purity water then allowed to dry in air at room temperature at least seven days then weighed to determine the weight change due to reaction. The weight change is a rough indication of the extent of glass reaction. It is not an ideal gauge because of the possibility of secondary phases precipitating back onto the glass surface which will reduce the measured weight change to too low a value (a shortcoming it shares with the solution results). Nevertheless, the weight change is a useful measure of the net extent of the glass reaction.

All of the glasses from experiments of a given reaction time were weighed on the same day. The glasses were weighed on a five-place balance which had a reported precision of 0.00002 g per measurement. The accuracy was checked against the 5.00000 g standard with which the instrument had been certified. The zero was checked after every two measurements and was found to vary less than the precision of the measurement. The zero of the balance is important since the majority of the disks had a mass of less than 0.5 g. If the zero was found to have drifted slightly between measurements, it was readjusted immediately. The accuracy of the balance was checked after all glasses had been weighed and was found to drift less than 0.00004 g in the worst case and usually less than 0.00002 g. Since the zero was checked throughout the measurement procedure and was never found to drift more than 0.00001 g, and since the glass weights were nearer zero than five grams, we estimate the total error in measuring the glass weight change to be 0.00002 g for the two times each glass was weighed, before and after reaction. The presence of precipitates on the glass surfaces and unavoidable sample damage during handling probably introduces greater uncertainty (with regard to the weight change reflecting the extent of glass reaction) than the error in measurement. The weighing error will, therefore, be ignored.

The total weight change of the two glass disks in the vessel was divided by the total surface area of the two disks to obtain the normalized weight change for the experiment. The simple geometric surface area was used as calculated from the measured diameters and thicknesses of the glass disks. These were measured to the nearest 0.01 mm using a standardized caliper. Only one measurement of each disk's diameter and thickness was taken. The glass disks were not perfectly symmetric, and it is estimated that the diameter may have varied by as much as 0.5 mm in the worst cases. Therefore, only three significant figures are retained for the surface area values used. The relevant data for the glass weight change measurements are included in Section VII, Data Table A. The weight changes of the two disks are not considered separately since they react simultaneously with the leachate. It is interesting to note that the disks which had had one face ground to 600 grit to facilitate surface analysis showed consistently lower weight losses than the glasses which were reacted having two "as cut" faces, that is, faces reacted without further treatment (estimated to have a 240 grit surface). SEM analyses suggest the 600 grit surfaces to have slightly thinner reaction layers than the "as-cut" surfaces, probably an

indication that some surface strain was removed by the further treatment of the 600 grit surface. It is expected that an "as-cut" surface has more high energy sites than a 600 grit surface. Such high energy sites which may include cracks that penetrate into the glass would be expected to react quickly and be most obvious in the short time experiments.

The normalized weight losses of the glasses used in these experiments are shown plotted against the reaction time in Figs. 24a-c. It is assumed that there is no measurement error. It can be seen in Fig. 24 that irradiation has little influence on the extent of glass reaction as measured by the weight loss. A correlation exists between the weight loss and the presence of the tuff wafer, with the weight loss being slightly larger with tuff present. This effect is observed in all irradiated and nonirradiated experiments. The ATM-1c glass appears to react more than the ATM-8 glass in the irradiated experiments. Both ATM glasses react faster than the SRL glasses. The normalized weight change behavior is very similar to the normalized elemental release behavior of most released species. In the absence of tuff, the reaction appears to have slowed appreciably after 91 to 181 days. When tuff is present, the reaction has continued beyond 278 days in some cases.

F. Discussion of Leachate Results

It is a common practice to plot the cation release data as a function of the square root of the reaction time. If the data are linear on such a plot, it is consistent with a diffusional release mechanism due to the $t^{1/2}$ dependence of random diffusion. Figures 25a,b show the boron and lithium leachate results plotted against the square root of the reaction time for the irradiated and nonirradiated experiments with SRL U glass. The experiments with tuff appear linear for all reaction times. While the irradiated experiments without tuff are linear through 181 days, the 278-day results are lower than predicted by the extrapolated line. The nonirradiated experiments without tuff do not appear to be linear with the square root of the reaction time. This is due to the 56- and 91-day results which are lower and higher, respectively, than expected from fitting a straight line to the other data. Since it does not appear that irradiation affects the mechanism of the boron or lithium release according to the leachate results presented here, the 56- and 91-day data may be misleading. Notice that all the linear fits to these data have non-zero y-intercepts. According to the plots, release of these elements into solution does not begin until about three days of reaction. This is probably meaningless in view of the long reaction periods used in these experiments and the effect of the logarithmic scale overemphasizing the short-term results. Previous experiments performed at 1E4 R/h [ABRAJANO] have shown similar indications of a diffusive release mechanism for boron from this glass type. SIMS (Secondary Ion Mass Spectroscopy) results support the diffusive release trend of boron from this glass in both the present (see Section IV.D) and previous [ABRAJANO] experiments.

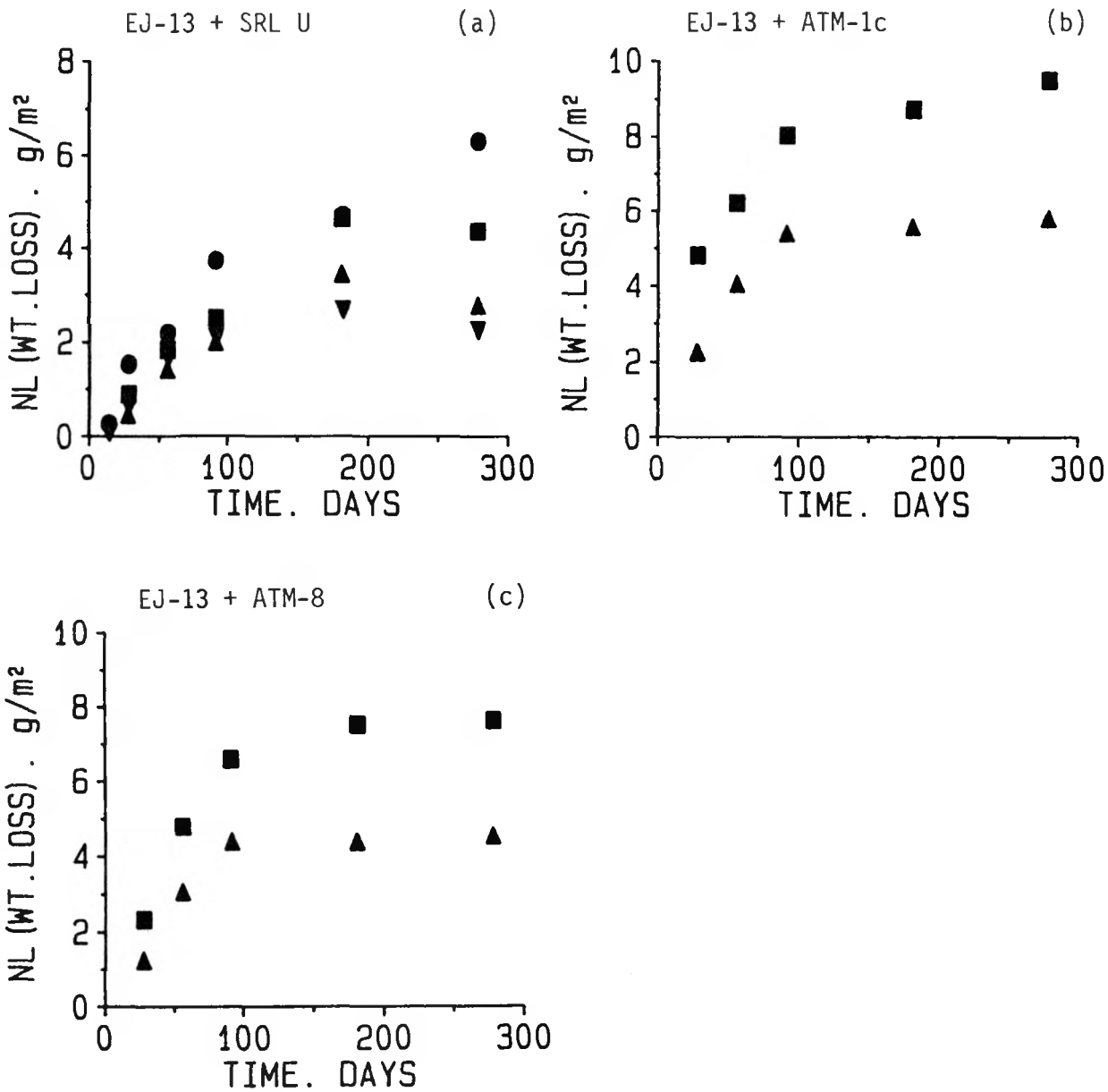


Fig. 24. Normalized Glass Weight Loss vs. Reaction Time for EJ-13 Plus: (a) SRL U glass, irradiated, without tuff (▲) or with tuff (■); nonirradiated, without tuff (▼) or with tuff (●); (b) ATM-1c glass, irradiated, without tuff (▲) or with tuff (■); and (c) ATM-8 glass, irradiated, without tuff (▼) or with tuff (●).

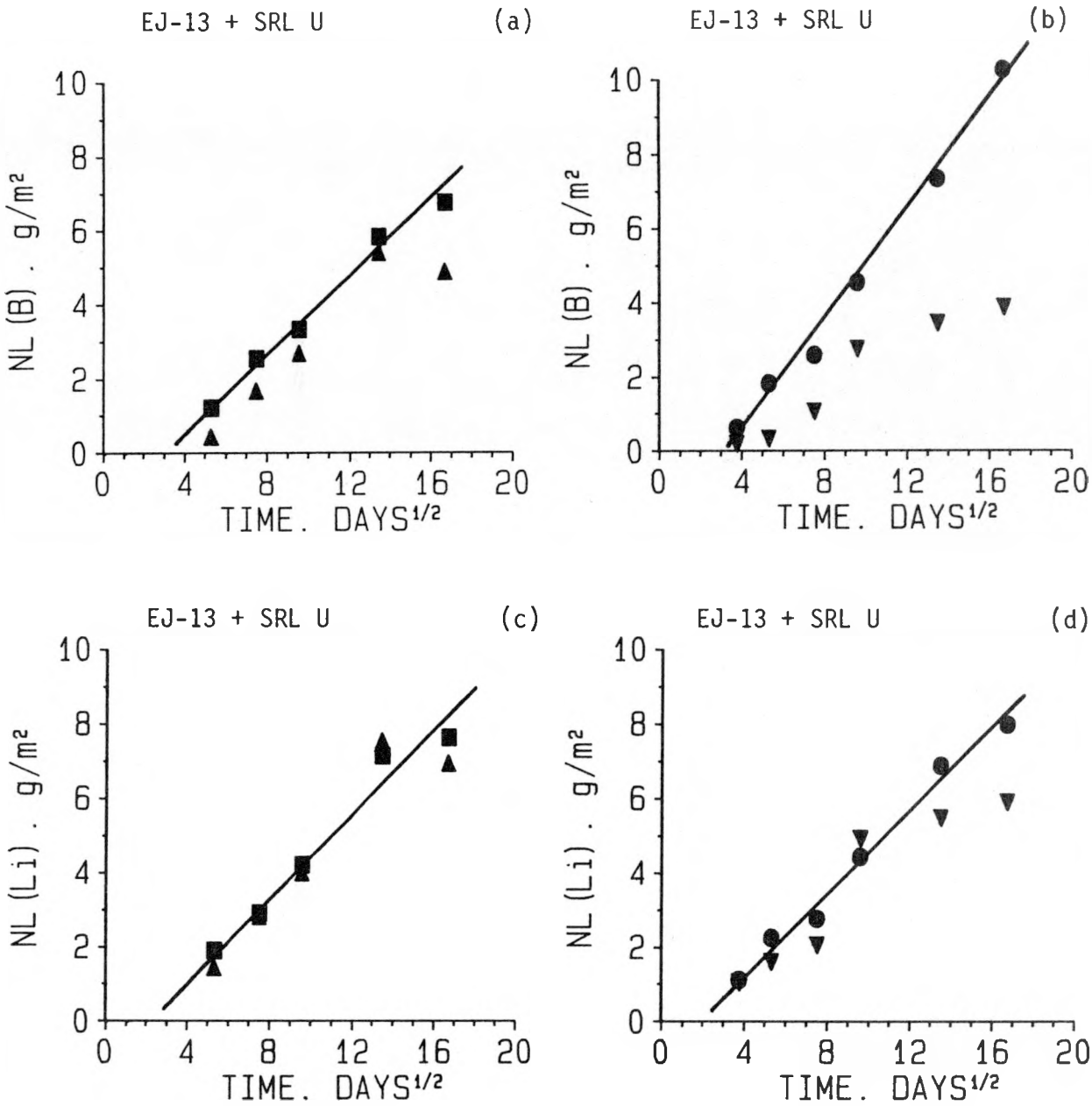


Fig. 25. Normalized Boron Mass Loss from SRL U Glass vs. the Square Root of the Reaction Time for EJ-13 Plus SRL U Glass: (a) irradiated, without tuff (▲) or with tuff (■); (b) nonirradiated, without tuff (▼) or with tuff (●); and Normalized Lithium Mass Loss from SRL U Glass vs. the Square Root of the Reaction Time for EJ-13 Plus SRL U Glass: (c) irradiated, without tuff (▲) or with tuff (■); and (d) nonirradiated, without tuff (▼) or with tuff (●).

Lithium was seen in previous experiments to have a diffusive release pattern from SRL U and SRL A glasses [BATES-1, ABRAJANO]. The results of irradiated experiments, Fig. 25c, show the lithium release to be linear with $t^{1/2}$, again with a non-zero y-intercept. This strongly suggests that the x-axis scale is too inaccurate for such extrapolation. The presence of tuff does not appear to affect the lithium release rate in the irradiated experiments. The nonirradiated experiments without tuff show the lithium release to be linear with the square root of time, Fig. 25d. As in the case of boron, the lithium releases in the nonirradiated experiments without tuff appear deviant at 56 and 91 days.

The leachate and glass weight loss data suggest that irradiation has little effect on the release and dissolution behavior of the matrix species of the glasses tested. Secondary phases may have a "buffering" influence on the release of some species by maintaining the solution under near-saturated conditions in these experiments. The extent of reaction may not be well represented by the leachate results in some experiments since the leachate concentrations become less representative of the amounts actually released from the glasses as precipitation occurs. As the solution approaches saturation, the concentrations of dissolving species become nearly constant and so imply the reaction has stopped.* Likewise, the precipitation of secondary phases back onto the glass surface may bely the actual weight change of the glass due to reaction. As precipitates form on the reacting glass surface, the mass loss due to reaction is counteracted by mass gain due to the precipitates. Only an integrated analysis that includes surface and leachate results can be expected to correctly characterize the glass reaction.

The leachate results of these experiments indicated a slight increase in the extent of the glass reaction when tuff wafers were present. It is thought that the major influence of tuff on the leachate chemistry was accounted for by the fact that the leachant used was actual tuffaceous groundwater which had been further reacted with pulverized tuff at the reaction temperature, 90°C. Tuff would be expected to quench the glass reaction by contributing species common to the glass into solution and so slowing the dissolution of the glass matrix through saturation effects. The presence of tuff in the blank experiments did increase the silicon content of the leachates at long reaction times in both the irradiated and nonirradiated experiments. In fact, the blank experiments with tuff appear to have sufficiently high silicon concentrations after about 100 days (70 ppm Si or 130 ppm SiO_2) that several potential precipitates may be expected to form.** Slow precipitation kinetics may allow the leachates to supersaturate at even longer reaction times. The tuff disk provides a large surface area for nucleating precipitates, and it may well be that it is this nucleating ability rather than interactions through the solution phase which accelerates the reaction of the glasses (or reduces the leachate concentration through precipitation). Surface analysis of the tuff should help clarify the role of tuff surfaces in these experiments.

*The solubilities will likely vary as the solution chemistry changes.

**Silica concentrations between 80 and 100 ppm at 90°C are supersaturated in quartz, cristobalite, tridymite, and chalcedony [BOURCIER]. Amorphous silica is near saturation as well [WICKS].

Irradiation does affect the distribution of some released actinide species because of the changes in the leachate pH and Eh. Americium was found sorbed on the stainless steel vessel at all pHs reached in these experiments. When the leachate was unnaturally acidified to pHs near 5 by extraneous vessel reaction, the amount of americium found on the stainless steel was about ten times that found under more neutral pHs. Apparently the acidification of the leachate allowed the americium to enter the solution from which it adsorbed onto the steel.

IV. SURFACE ANALYSES

Analysis of the reacted glass surfaces provides complementary information to the solution results. Identification of secondary phases formed on the glass surfaces provides a more complete description of the behavior of glass species released into solution as they precipitate onto, segregate to, or remain on the reacting surface without dissolving, etc. As a glass hydrates, the outer surfaces become altered due to composition changes associated with leaching, restructuring, or reprecipitation. The reacted region is often referred to as an alteration layer, a gel layer, or a hydration rind. Although alteration layer may be a better description, it will be referred to as a "gel layer"* to maintain consistency with previous reports [ABRAJANO].

Several surface analytical techniques have been used to more completely characterize the reacted glass surfaces. Scanning electron microscopy (SEM) with associated energy-dispersive x-ray emission spectroscopy (EDS) was used to locate and elementally analyze secondary phases. The SEM was also used to measure the thickness of the alteration layers present on glass surfaces reacted for the longer times using the polished cross-sections. The cross-sectioned layers were also analyzed using EDS. Because EDS analysis is insensitive to lithium and boron, alternative techniques were used to analyze these elements.

The reacted surfaces were elementally depth profiled using secondary ion mass spectrometry (SIMS). This technique is sensitive to all species that can be vaporized by ion sputtering. Analysis of sputtered hydrogen is possible using this technique, but complicated by a high hydrogen background. Instead, hydrogen was depth profiled in selected samples using resonant nuclear reaction spectroscopy (RNRS).

Finally, those samples which contained the radionuclide dopants, SRL A and ATM-8 glasses, were analyzed using ion microprobe analysis (IMA), which is identical in principle to SIMS, to profile the radionuclides.

*This layer has been referred to as a "gel" in the sense that the layer is thought to be similar to a colloidal gel resulting from partial break down and hydrolysis of the glass network, although no evidence is presented that the layer is indeed a gel.

Other surface analytical capabilities are still in development. These include a temperature programmable desorption (TPD) device for analyzing the water incorporated into the alteration layer, and a laser Raman microprobe which will allow structural characterization of the microcrystalline precipitates formed during the reaction. Also, a wavelength dispersive x-ray detector is to be added to the SEM which will allow analysis of boron and oxygen. Samples generated in this series of experiments will be analyzed using these techniques in the near future.

A. SEM Analysis

Extensive SEM analysis was performed on the reacted as-cut surface of one glass disk from each of the duplicate glass-containing experiments. The glass disk analyzed was usually the vessel mate of the sample having the ground surface analyzed using SIMS or IMA. For SEM analysis, the selected disks were fixed to an aluminum mounting stub using double-sided tape. The top surface of the disk, which was also the top surface during reaction, was coated with a thin (~200 Å) film of evaporated carbon which acts to drain the electrons from the surface during SEM analysis and so reduce electrostatic charging. This is a standard procedure for electron beam analysis of insulators.

A large portion of the surface was viewed in the SEM by scanning long zig-zag swaths. A surface was characterized by its general background appearance as well as by the presence of precipitates. The surface was surveyed using both secondary electron detection and backscattered electron detection. The latter generates a signal that increases with the electron density of the area probed. High atomic weight elements are highlighted using this detection mode. In fact, semi-quantitative analysis is possible using this detection mode, as is discussed later in CARD analyses.

Secondary phases as well as the general surface background were analyzed qualitatively using energy dispersive x-ray emission spectroscopy (EDS). The region in which secondary electrons and x-rays are produced is generally much larger than the area bombarded by the electron beam. The spatial and depth resolution of EDS is typically on the order of one or two micrometers, and therefore some signal from the region surrounding the area of interest will be included with the analysis of very small precipitates. The presence of secondary phases on the reacted glass surfaces provides complementary information to the leachate results since leached or etched species will either remain in solution or precipitate back onto the glass surface. (The mass balance is not complete, however, since species may also adsorb onto the tuff wafer.) The general appearance of the surface also provides evidence of the extent of reaction.

Another useful view of the reacted surface is in cross-section. After the surfaces themselves were viewed and analyzed, the glass disks were sawed into two pieces normal to the flat surface. This was accomplished using a wafering blade with distilled water as a lubricant. The disks were clamped along one edge with the top surface upwards while the blade cut the disks from the bottom. The half of the disk that was not clamped was

retained as an archive of the reacted surface. While the disks were cut using a low saw speed to minimize disturbance of the top surface, some lubricant inevitably seeped onto the surface carrying cutting fragments which were deposited on the surface. These fragments were clearly visible on the surfaces of the disk halves when viewed on the SEM. Fortunately, the fragments are usually restricted to the region very near the cut edge and have a distinct appearance. The half of the disk that had been clamped was mounted in epoxy resin so that the freshly cut surface was exposed. After the resin set, this surface was successively ground using 320-grit, 400-grit, and then 600-grit carbide abrasives. The surface was then polished using a 0.3 micron alumina/kerosene slurry in a mechanical vibratory polisher for two to fours hours, washed in hot water, and then dried. It was coated with ~200 Å of carbon using a carbon rod evaporation coater. What results is a polished cross-section of the reacted glass disk which shows a very thin yet recognizable altered layer on the outer edges of the glass. Because the surface of the cross-section is smooth and flat, quantitative x-ray analysis may be performed on both the reacted layer and bulk glass. In some instances, precipitates were simultaneously cross-sectioned and so could also be analyzed. Difficulties in analysis of cross-sections of reacted glasses have been encountered in the past due to preferential removal of the sometimes softer reaction layer during polishing. This leaves a ditch along the reaction layer between the harder unreacted glass and resin. Such topographical differences complicate the quantitative x-ray analysis of the layer. Another problem associated with analyzing the layer is that the primary electron beam is destructive to the layer, either through further dehydration or vaporization of the layer. Evidence of beam-induced degradation of the unreacted glass has also been observed. Analyses, especially of the layer, therefore were conducted at low beam currents and shortened analysis times to reduce the beam effects.

1. SEM General Surface Appearance

a. Reacted SRL U and SRL A Samples

The general surface appearances of those SRL A samples that were analyzed using the SEM were very similar to those of the corresponding SRL U samples. The unreacted as-cut surfaces had a wavy appearance where the glass was abraded during the wafering process. The crests of these waves looked to be sharp while the troughs appeared quite smooth. A photomicrograph of a typical unreacted glass surface was shown in [BATES-1, Fig. 4a]. The sharp edges are expected to be more highly reactive than the smooth areas in between. Indeed, experiments in which glass was reacted only 14 days showed preferential reaction along these edges, smoothing them to produce a lobed appearance. Figure 26a shows the surface of sample 323 which was reacted 28 days in a gamma field with tuff present. This sample shows the typical smoothing of sharp edges seen in all samples. Bates [BATES-1] found the edges of "as-cut" SRL glasses to be reacted in a similar manner after only 7 days.

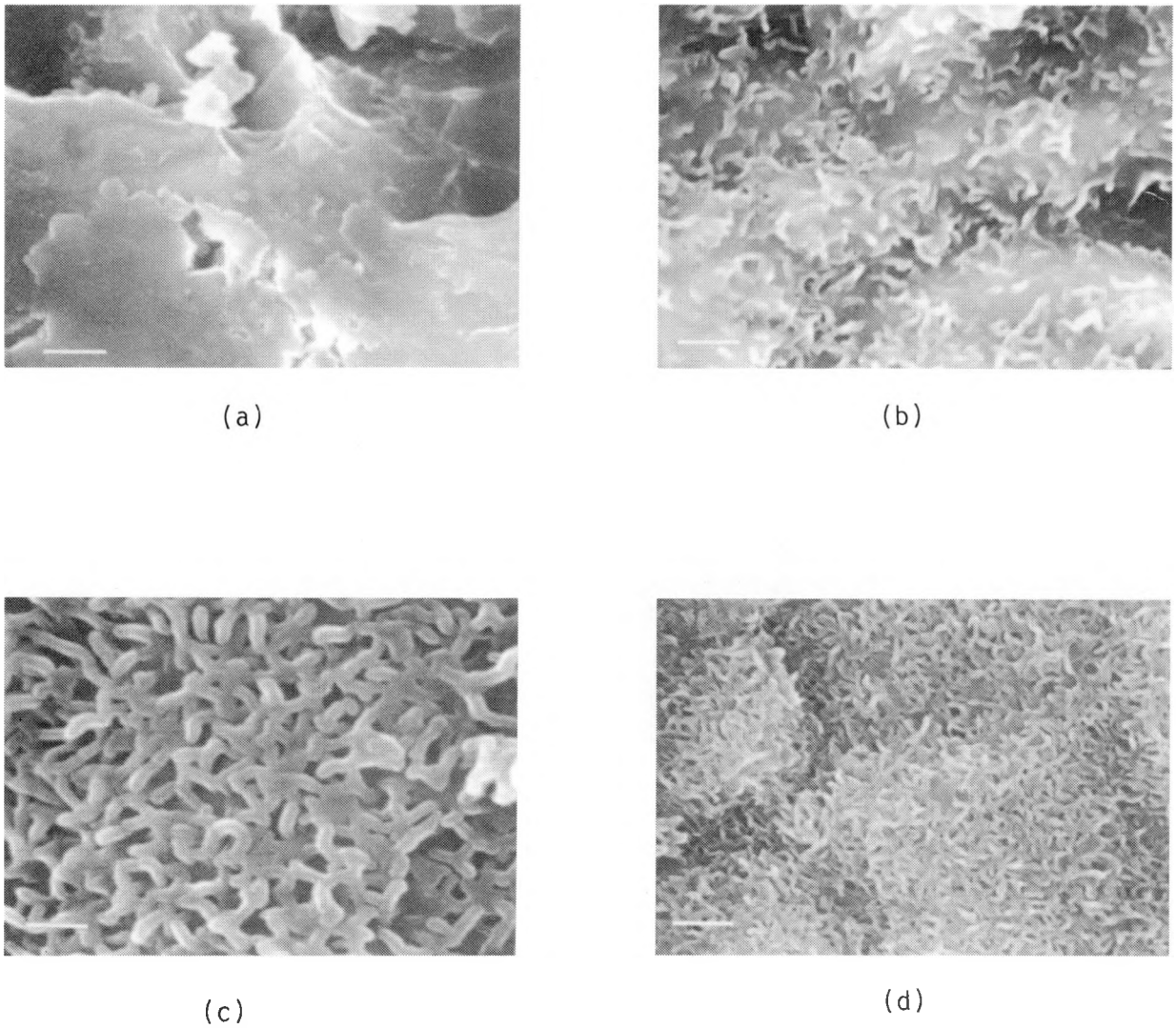


Fig. 26. Photomicrographs of the General Surface Appearance of Samples Reacted in a 1E3 R/h Gamma Field at 90°C in the Presence of a Tuff Wafer: (a) sample 323, reacted 28 days; (b) sample 325, reacted 56 days; (c) sample 331, reacted 91 days; and (d) of sample 425 which was reacted 278 days without irradiation in the presence of tuff wafer. The bar represents 1 μm.

After 56 days of reaction, all samples analyzed showed alteration of the entire glass surface. The extent of this alteration varied with experimental conditions, with the nonirradiated experiment with tuff having the most-developed alteration and the nonirradiated experiment without tuff having the least-developed alteration. The degree of development is with regard to the appearance of this alteration after longer reaction times. The irradiated experiment without tuff was slightly more altered than that of the corresponding irradiated experiment. Figure 26b shows a photomicrograph of the surface of sample 325, which was reacted 56 days in a gamma field with a tuff wafer present. This micrograph shows clearly the small fiber-like features which develop in conjunction with the smooth underlying surface. Isolated features similar to these fiber-like growths were seen on some of the samples reacted only 14 or 28 days, especially on the samples reacted without tuff and without radiation.

After 91 days of reaction, all samples analyzed were seen to be totally covered with this alteration phase, which now has a chain-mail-like appearance. Figure 26c shows the surface of sample 331, which was reacted 91 days in a gamma field without a tuff wafer. This phase is comprised of random, multidentate fiber-like features which seem to intertwine to form a mat-like layer. This phase is referred to as the alteration or gel layer. It was found to be present on all samples reacted 91 days or more. The appearance of the phase varies somewhat from sample to sample, the fibers sometimes being thinner, or the phase more open looking, though there was no apparent trend with respect to reaction time or experimental conditions. Figure 26d shows the alteration phase formed on sample 425 which was reacted 278 days with tuff and without radiation. This micrograph shows the surface retaining its general topology with the surface phase following the general contours of the original surface. Note that the photomicrographs in Figs. 26a-d were all obtained at the same magnification. The compact appearance of the surface phase of sample 415, which was reacted 278 days, compared to that of sample 423, which was reacted 181 days, is not atypical of the variation of appearance between samples, even from duplicate experiments.

In following a given experiment type through increasing reaction times, similar stages can be seen. First, the sharp edges produced during wafering, which are thought to be high energy sites, are preferred reaction sites and so are initially smoothed. Next, small nodules or fiber-like growths develop on the surface. While the other experiments showed a few of these nodules on the shorter reaction time samples, the nonirradiated no-tuff sample contained a large number of them after reacting only 14 days. These individual fiber-like features, which were usually less than a micrometer long and perhaps a tenth of a micrometer thick at longer reaction times, developed into a mat which encrusted the surface after 91 days of reaction. In some instances these features appeared more like the edges of plate-like growths, and in others like a randomly arranged bunch of short fibers. The density of these features (number of fibers per unit surface area) increased slightly with reaction time, except for the irradiated experiments with tuff where the density decreased noticeably. This chain-mail-like appearance dominates the surface after 56 or 91 days.

While the progression of the surface appearance from smooth to nodule to chain-mail seems well established, it should be remembered that these photomicrographs show the surfaces of different samples that probably had slightly different starting surface topologies. Comparison of the apparent fiber densities of the reacted surfaces is by itself inconclusive evidence with regard to the extent of reaction.

b. Reacted ATM-1c and ATM-8 Samples

The reacted ATM-1c glasses all had a general surface appearance that was very similar to the reacted SRL U glasses, as can be seen in Fig. 27. The surface shown is that of sample 509, which was reacted 91 days with a tuff wafer present. All other reacted samples analyzed had a general surface appearance that was very similar to this. The surfaces had a distinct honeycombed appearance after only 28 days of reaction. In agreement with what was seen in the leachate data, both the ATM-1c and ATM-8 glass compositions reacted faster than the SRL 165 glass composition to produce an alteration phase within the shortest reaction time tested. The light features seen on the surface in Fig. 27 are phases which contain phosphorus and lanthanum. Some of these phases appear to lie within or beneath the alteration layer which forms on the outermost surface. These small phases were seen on all samples, even after only 28 days of reaction. The number density of these phases does appear to increase somewhat with reaction time.

The honeycomb appearance of the general surface background tends to open slightly with increased reaction time, as did the surface phases on most of the SRL glass samples. Since the glass surface had reacted to a large extent even after the shortest reaction time, the development of the alteration layer on the ATM glasses is not as discernible as it was as in the SRL U reactions.

2. SEM Cross-Section Analysis

a. Reacted SRL U Samples

Cross-sections of the reacted glass samples were used to measure the thickness of the region that was altered during reaction. Since the composition and structure of this region differ from the unreacted glass, it was clearly visible in the SEM. Density changes in a sample are evident in the SEM image because the electron scattering behavior of the two (or more) regions generate different image intensities. Figures 28a-c show photomicrographs of the cross-sections of samples 331 and 425 SRL U glasses, which were reacted for 91 and 278 days, respectively. The micrographs clearly show the reacted layers on the outer edge of the cross-sections. Cracks which penetrate into the sample can be seen to have reacted to an extent similar to the outer surface. Reaction in the cracks is evident after 56 days in the nonirradiated experiments. After reacting 91 days, the layer is visible on the surface of all samples analyzed.

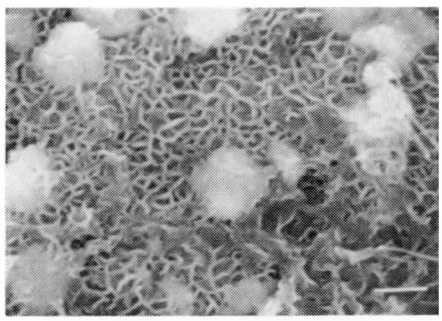


Fig. 27. Photomicrograph of the Surface of Sample 509 Showing the General Appearance of All Reacted ATM-1c Samples. The bar represents 1 μm.

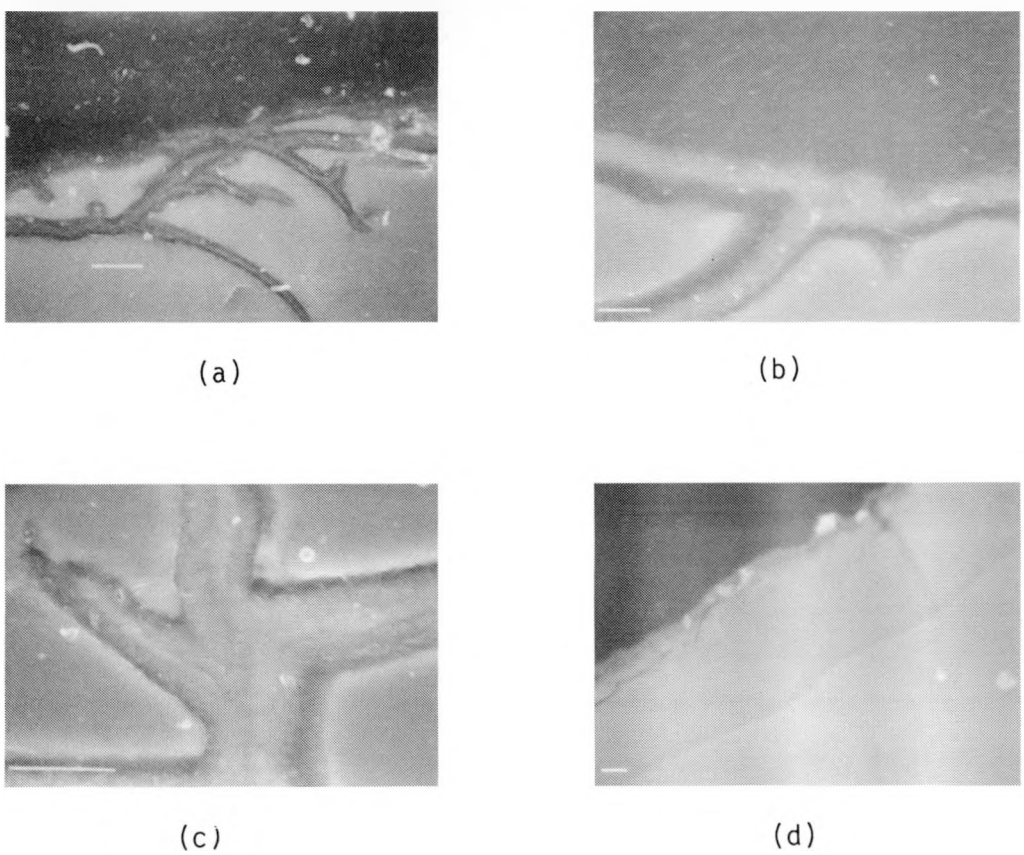


Fig. 28. Photomicrograph of the Cross-Sections of SRL U Glasses: (a) sample 331, reacted for 91 days with radiation, with tuff; (b) and (c) samples 425, reacted 278 days, without radiation, with tuff; and a photomicrograph of the cross-section of ATM-1c glass; and (d) sample 509, reacted 91 days, with radiation, with tuff. The bar represents 2 μm.

In all of the cross-sectioned SRL U glasses analyzed using the SEM, a dark region between the alteration layer and the unreacted glass was seen (see Fig. 28). Because this dark region is so thin, only a few tenths of a micrometer in width, the nature of this region cannot be determined for certain. It may be an artifact of the mounting or polishing procedure, or it may be a compositionally distinct region. In an effort to better define the character of this region, SRL U glass was reacted with EJ-13 water at 200°C in an attempt to produce thicker layers which could be better analyzed. These glasses showed glass/layer interfaces similar to those produced at 90°C in cross-section. The alteration layers on these samples reacted at 200°C are much thicker than on those glasses reacted at 90°C, though the compositions as analyzed using EDS are very similar. The thicker alteration layers appeared to have pulled away from the glass leaving finger-like strands of reacted layer material reaching towards the glass. The presence of these strands suggests that the dark area is not a result of preferential polishing, but is actually mounting resin which has penetrated the alteration phase or cracks within the phase and has filled the void between the alteration phase and the glass which may have formed as the layer dried after reaction.

A knowledge of whether the dark region is mounting resin or a trench created by polishing is important in the measurement of the alteration layer thickness. We have elected to exclude the darker area from the measurement. In most regions the dark area was measured to be only a few tenths of a micron thick. This is similar to the layer thicknesses measured for the samples reacted 56 days. The fibrous appearance of the phase noted in the surface images was also evident in the cross-sections. The interfaces between the alteration phase and the resin were not sharp. Strands of the alteration layer reached into the resin in both directions. These strands were not included in the measured thicknesses.

The sample faces generally had shallow cracks less than a micron deep. The sample edges, which were core-drilled, contained a large number of cracks, some of which penetrate more than ten microns into the glass. The thickest altered layer measured, that of sample 425, is only about 1.2 microns. Many cracks occur parallel to the surface. Reaction as measured by thickness of the reacted crack region appears to be more extensive where there is a confluence of crack growth. Such an area can be seen near the center of the alteration layer of Fig. 28a. In previous studies [GLASS], one half of the thickness of the reacted crack region has been used to estimate the extent of reaction. In the present set of experiments, crack measurements were not used because of the variability in measured thickness within cracks on the same sample (see Fig. 28).

The entire perimeter of the surface cross-section was viewed in order to obtain representative thickness measurements. It is estimated that the surface area in these cracks available for reaction with the leachate is similar to the geometric surface area of the sample itself. Reaction occurring in these cracks should be taken into account when comparing the measured layer thickness to the computed normalized depletion depth.

The measured layer thicknesses of the cross-sectioned glasses are given in Table 7. The nonirradiated glasses reacted with tuff present consistently showed thicker reaction layers than glasses from the other experiments reacted for the same length of time. This is in agreement with the leachate and glass weight loss data discussed earlier. The thicknesses presented in Table 7 are representative of the overall surface, not including cracks, and should probably be viewed as representative to within about 20%. These thickness measurements are plotted against the reaction time in Fig. 29. Notice that the thicknesses increase similarly to the normalized glass weight change, and that the order of reaction extent is the same as that predicted by the leachate results, namely nonirradiated + tuff > irradiated + tuff ~ irradiated > nonirradiated.

The appearance of alteration layers in the cross-sections is consistent with the general surface appearance shown in Fig. 26, though the cross-section images do not give any clue to explaining the subtleties discussed earlier with regard to the densities of the chain-mail features. There is no way of judging how deeply the chain-mail phase penetrates into the altered region. It may be limited to the outermost surface and so appear in the cross-sections as an outer fringe on the surface. Figure 28c shows a high magnification photomicrograph of the alteration phase in a crack region of sample 425. The appearance of the altered layer in this cross-section suggests the layer to be somewhat stratified. The layer in the cracks has an apparent "rib" in the center that usually produces brighter secondary and backscattered electron images. This rib was probably the original crack where insoluble species remained early in the reaction. Because these layers are so thin, no analysis to unequivocally characterize these features has been done.

b. Reacted ATM-1c Samples

The leachate results show clearly that the ATM-1c and ATM-8 glasses react much more than the SRL glasses. The cross-sections of the reacted glasses support this conclusion. Figure 28d presents the photomicrograph of the cross-section of ATM-1c glass, sample 509, which has been reacted 91 days in a radiation field with tuff present. The altered layers that form on ATM-1c glasses are all very much thicker than the layers present on the SRL U glasses and they have a very different appearance. The outermost surface of the alteration layer (solution/surface interface) has a structured appearance similar to the SRL glass layers. Between this thin outer surface layer and the bulk glass is another altered region which constitutes most of the thickness of the altered glass. This thicker region has the same texture as the bulk glass except that it appears darker than the bulk glass in both the secondary and backscattered electron image. These contrast differences suggest the electron density of the center region is less than that of the bulk glass. Note that there is no interlayer penetration of resin nor reacted crack penetration similar to that noted with the SRL glasses. The measured alteration layer extends from the outer surface layer to the bulk glass.

Table 7. Altered Layer Thicknesses as Measured using the SEM

Sample Number	Reaction Time (days)	Layer* Thickness (μm)	Sample Number	Reaction Time (days)	Layer Thickness (μm)
[SRL U, 1E3 R/h]			[SRL U + TUFF, 1E3 R/h]		
305	56	0.0	325	56	0.0
311	91	0.2	331	91	0.3
313	181	1.0	335	181	0.7
317	278	0.7	337	278	0.7
[SRL U, 0 R/h]			[SRL U + TUFF, 0 R/h]		
389	56	0.0	413	56	0.3
393	91	0.4	419	91	0.4
397	181	0.5	423	181	1.0
403	278	0.5	425	278	1.2
[ATM-1c, 1E3 R/h]			[ATM-1c + TUFF, 1E3 R/h]		
479	28	0.6	497	28	1.5
483	56	5.0	501	56	5.5
487	91	6.0	505	91	10.0
489	181	7.0	509	181	13.0
493	278	8.1	513	278	13.0

*Excluding the resin between the alteration layer and the bulk.

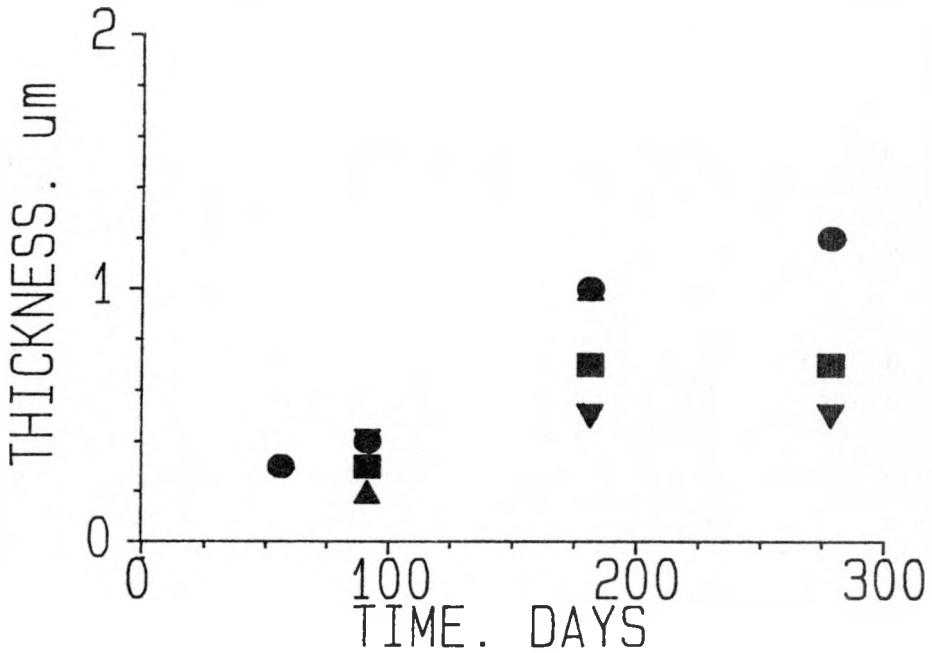


Fig. 29. Measured Layer Thickness of SRL U Glass vs. Reaction Time for Experiments Irradiated without Tuff (▲) or with Tuff (■), or Nonirradiated without Tuff (▼) or with Tuff (●).

The layer thickness is expected to be proportional to the depletion depth of leached ions less the thickness of the outer surface that is etched (if any), with the caveat that the layer may have changed in thickness during dessication. Table 7 includes the measured layer thicknesses for the different ATM-1c samples analyzed. These data show a trend similar to the leachate and weight loss data wherein the reaction, as measured by the layer thickness, slows noticeably after about 91 days. Because the layers are so thick and usually penetrate deeper into the sample than the surface cracks, the layers are quite uniform in thickness across the sample. The measured thicknesses of the layers on the ATM-1c glasses are therefore more representative of the volume of glass reacted than were the measurements for the SRL U glasses.

Notice in the photomicrograph of the cross-sections of the ATM-1c glass, Fig. 28d, that there is a sharp interface between the reacted layer and the unreacted glass different than that seen in the cross-sections of SRL U glasses in Figs. 28a-c. The layers on the ATM-1c glasses are not separated from the bulk as the SRL U layers were. The same polishing procedures were used for the cross-sections of both glass types. This fact, plus the general appearance of the layers in cross-section, suggests the layers that form on the two glass types may be generated by different mechanisms. Compositional analysis of the layers provides some indication of the dominant processes occurring during the reactions.

B. X-Ray Microanalysis

1. EDS Analysis of Reacted Samples

a. Reacted SRL U and SRL A Samples

Energy dispersive x-ray emission spectroscopy (EDS) was performed during the SEM analyses of all reacted surfaces and on selected cross-sections. Figure 30a shows the EDS spectrum of an unreacted SRL U glass surface with the peaks of interest identified. This and all subsequent spectra, unless otherwise noted, were obtained using a 20 keV primary beam and collecting for 200 seconds.

Slight changes in peak intensities were seen in the EDS spectra of the surfaces of samples of increasing reaction time due to the increasing alteration layer thicknesses. The altered layer is depleted in sodium and enriched with iron and magnesium. During analysis, the incident electron beam at 20 keV penetrates the surface to produce x-rays in regions a micron or more below the surface (although most of the x-rays are generated within 0.5 μm of the surface). These x-rays escape only slightly attenuated by the outer layers and are detected along with x-rays produced at the immediate surface. For most samples, the layer thickness is less than the depth resolution of the technique. As the layer becomes thicker, however, the amount of signal from the underlying unreacted glass decreases and the spectrum becomes more representative of the layer. The sodium results are very valuable in this regard since the layer is known to be almost completely depleted in sodium while the bulk contains about 11 wt % Na_2O. EDS analysis of the surfaces of samples reacted 91 days or more show very little sodium, indicating that the spectra are representative of the layer. The cross-sections of the 91-day samples show the altered layers to be about 0.5 microns thick.

Figure 30b shows the spectrum of the surface of sample 425 which was reacted 278 days with a tuff wafer present without radiation. Notice the sodium peak has virtually disappeared and a substantial magnesium peak has developed. The iron peak has also increased in size relative to the silicon peak. While these analyses are not quantitative, they do indicate concentration changes between the bulk and layer that are expected to be seen in cross-section analyses.

2. EDS Analysis of Reacted Glass Cross-Sections

a. Reacted SRL U Samples

Selected polished cross-sections were analyzed using a line profile analysis option of the EDS system. In this mode the incident electron beam is swept repeatedly across the sample and the peak intensities of selected elements stored as a function of beam position. While this mode of analysis is not quantitative, it serves as a preview of the quantitative analyses. Figures 31a,b show the results of such an analysis across the altered layer of sample 425, which was reacted for 278 days in

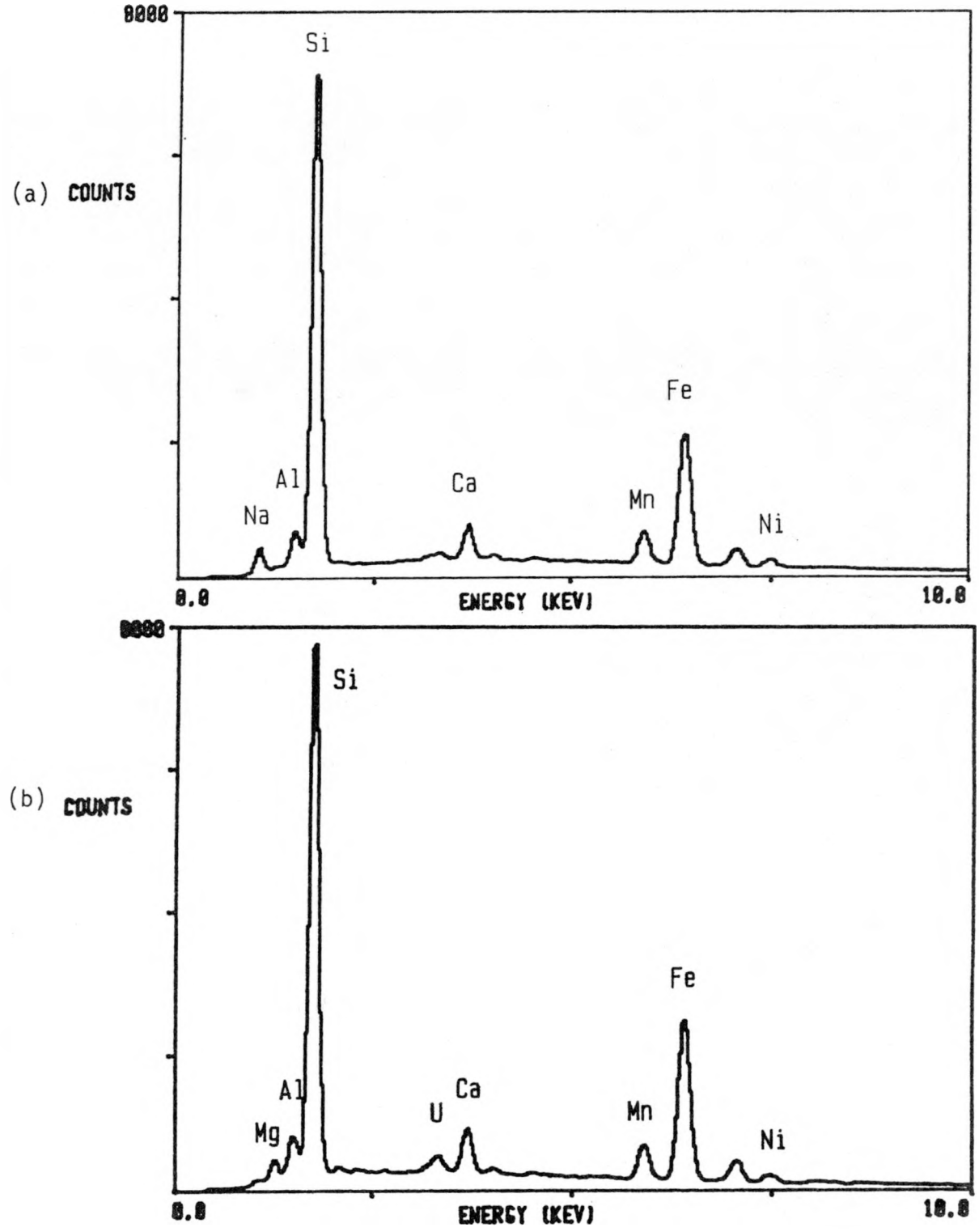


Fig. 30. EDS Spectrum of (a) Unreacted SRL U Glass and (b) Sample 425, Reacted 278 Days.

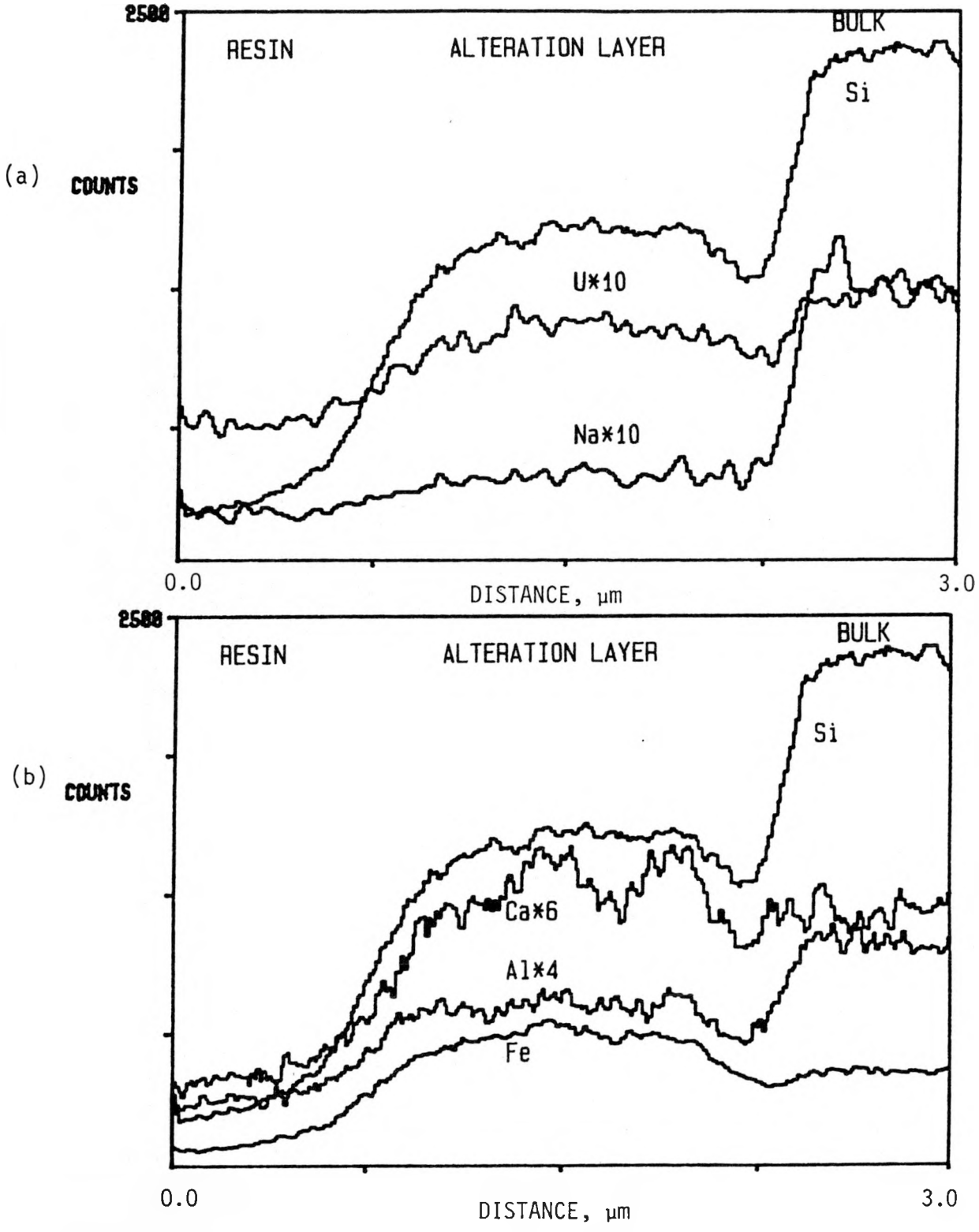


Fig. 31. EDS Line Profile Analysis of the Near-Surface Region of SRL U Sample 425, Reacted 278 Days, Nonirradiated, with Tuff; Line Profiles of (a) Silicon, Uranium, and Sodium; (b) Silicon, Aluminum, Iron, and Calcium.

the absence of gamma radiation with a tuff wafer present. The profiles of silicon, uranium, and sodium are shown in Fig. 31a, and the profiles of silicon, calcium, aluminum, and iron are shown in Fig. 31b. The left-most region of the line profiles is the mounting resin. The next region is the altered layer. The line profiles do not show sharp interfaces because of the poor spatial resolution of the technique. The decrease in all signal levels in the region between the layer and the bulk is due to mounting resin which has seeped in between the layer and the bulk. The resin does not produce x-rays. The signal that is collected with the beam centered in this region is due to the overlap of the analyzed volume with either the neighboring altered layer or unreacted bulk. The sodium signal in the alteration phase region is similar to the sodium signal in the resin, which can be viewed as a background level, and is much lower than in the unreacted bulk. The composition differences between the bulk and the layer are qualitatively the same as determined in the analyses of the surface. Sodium, uranium, aluminum, and apparently silicon are depleted in the layer while calcium and iron are enriched, relative to the bulk glass.

i. Quantitative X-Ray Microanalysis

Quantitative x-ray microanalysis was performed on the alteration layers of the polished cross-sections of four 278-day SRL U samples and one 181-day SRL U sample. The unreacted glass in the center of the cross-section of each sample was used as the composition standard for the analysis of the layer on that sample. Minor glass constituents (those present in the original glass at less than 1%) were not included in the analyses. The ZAF corrected k-ratio method of analysis as contained in the Princeton Gamma-Tech System IV software was used, and the analyses were done using a 10 keV accelerating voltage.

The minimum volume of the sample that can be analyzed using EDS may be approximated by a sphere about one micron in diameter tangent to the surface. (The actual sampled volume depends on the accelerating voltage of the electron beam, the angle of incidence, and the material analyzed.)* The layers present on the reacted SRL U glasses are often of the same thickness as the minimum diameter that can be analyzed. Therefore, regions adjacent to the alteration layers likely will contribute to the measurement. Very few x-rays will be generated in the resin and so the overall effect of the alteration layers being thinner than the probed area and being, perhaps, infiltrated with resin will be a reduction in the number of x-rays produced. This was shown clearly in the line profiles discussed earlier. The quantitative analysis software incorrectly interprets this reduction in the number of x-rays produced as (uniformly) reduced concentrations of all elements in the layer, relative to the bulk glass. The relative elemental composition of the layer will still be correct, however. By assuming a reference element to have the same

*Separate measurements indicate that, in the mounting resin which is expected to have the largest sampled volume, at an accelerating voltage of 10 kV, the sample volume has a diameter of about 1 to 1.5 μm.

concentration in the bulk and in the layer, the elemental weight percents measured to be in the layers can be rescaled and so be directly compared to the bulk composition. The results of SIMS analyses show the silicon concentration to be nearly constant throughout the near-surface region profiled (see Appendix III). The reason that silicon has a smaller peak in the layer than in the bulk in EDS analysis is because there are fewer silicon atoms in the volume sampled in the layer than in the volume sampled in the bulk. (This is illustrated schematically in Appendix III, Fig. III-2.)

Table 8 summarizes the quantitative analyses performed on the unreacted bulk and the alteration layers of five reacted SRL U samples. The bulk analysis included in the table is that of sample 425. The bulk glass of each cross-section was used as the composition standard for that sample's layer. The results of bulk analyses of all samples are very similar. Several locations of the layer or bulk were analyzed for each sample. The differences in compositions for analyses performed at different locations was only a few percent for bulk analyses and typically less than ten percent for layer analyses for each element. The values presented are the average values of multiple analyses for every layer. Lithium and boron were assumed to be present in their analytically determined concentrations in the bulk and to be totally depleted in the alteration layers. Only those elements listed in Table 8 were assumed to be present for the analysis. The calculated total weight percent of the average analysis is included in the table. The totals of the layer analyses differ from 100% because the analyzed volume includes varying amounts of resin. These values are therefore related to the thickness of the analyzed layers. When possible, regions where the layers were unusually thick (due to cracks) were analyzed. Lower totals indicate that a smaller fraction of the analyzed volume contained layer and a larger fraction contained mounting resin. Analyses with higher totals are naturally more reliable. The values presented in Table 8 represent the overall composition of the layer which may be comprised of several phases. The analyses are presented to show the general trends of elemental enrichment or depletion upon reaction and not to quantitatively deduce phase compositions.

The data are presented in Table 8 both as elemental weight percents and as elemental stoichiometries which have been normalized to eight silicon atoms per formula. The original elemental weight percent data (not presented) indicated the alteration layer to have reduced numbers of counts for sodium and silicon, while other elements showed an increase in the number of counts compared to the bulk glass. As mentioned earlier, these values are misleading because of the effectively smaller sample volume of the layer analyses. Water is probably also present in the altered layers. Water, which cannot be detected using EDS, will also tend to reduce the apparent ion concentrations. The most revealing aspect of these analyses, when presented as stoichiometries, is near tripling the iron-to-silicon ratio in the layer compared to the bulk. Magnesium, aluminum, calcium, and manganese are also enriched in the layer relative to the bulk. Sodium and presumably lithium and boron are depleted in the layer.

Table 8. Quantitative Analysis of Alteration Layers of SRL U Glasses. Values represent the averages of multiple analysis, with a typical standard deviation of σ = 10%. Minor components have been ignored in determining the stoichiometry

Sample Number		Unreacted Bulk (425)	317	337	403	423	425
Experiment Type		0	278 d γ	278 d γ Tuff	278 d	181 d Tuff	278 d Tuff
Layer Thickness (μm)		0	0.7	0.7	0.5	1.0	1.2
Quantitative Analysis Results Elemental Weight %	Na	7.95	0.78	1.41	1.40	0.79	1.15
	Mg	0.41	0.32	0.47	0.70	0.96	1.13
	Al	2.18	2.61	2.18	2.01	1.69	1.80
	Si	24.66	9.75	13.24	13.36	16.09	18.86
	Ca	1.16	1.06	1.25	1.32	1.62	1.74
	Mn(IV)	1.50	1.75	1.58	2.23	1.98	1.92
	Fe(III)	8.43	7.96	14.48	9.59	13.56	15.48
	Ni(IV)	0.70	0.32	0.47	0.53	0.48	0.56
	Zr(IV)	0.48	0.53	0.78	0.52	0.69	0.79
	U(IV)	0.70	0.23	0.30	0.45	0.35	0.15
	Li[a]	1.98	-	-	-	-	-
	B[a]	2.14	-	-	-	-	-
	Total[b]	98.3	44.35	62.04	56.19	67.36	75.7
Formula Normalized to 8 Si	Na	3.13	0.78	1.05	1.03	0.46	0.60
	Mg	0.17	0.28	0.35	0.51	0.56	0.55
	Al	0.70	2.22	1.34	1.23	0.87	0.80
	Si	8	8	8	8	8	8
	Ca	0.26	0.61	0.53	0.56	0.56	0.50
	Mn(IV)	0.26	0.72	0.47	0.67	0.56	0.40
	Fe(III)	1.39	3.28	4.38	2.87	3.38	3.30
	Li[a]	2.52	-	-	-	-	-
	B[a]	1.74	-	-	-	-	-

[a]Lithium and boron are assumed to be totally depleted in the alteration layer.

[b]Total elemental weight percent of analysis, including oxygen by stoichiometry. The wide range is a result of the electron beam sampling areas other than the layer, which do not generate x-rays.

The accuracy of these stoichiometries is somewhat compromised by the rescaling procedure (inherent in the use of stoichiometries) used to account for the layers being thinner than the probe area. The rescaling error in layer analysis is less in samples 423 and 425 because they are the thickest layers analyzed. Some elements show a variance in composition in the layers formed in different experiments. Some of the variance is probably due to the analytical error involved as a result of the layers being so thin. The region analyzed may also include more than one phase. Some of the difference may also be due to the fact that the layers have been in contact with different leachate solutions. Samples 403, 423, and 425 were taken from nonirradiated experiments, which reached higher final pHs. Tuff was included in the experiments which produced the layers on samples 337, 423, and 425. The compositional differences do not follow any obvious trends, except perhaps for some general differences between the irradiated and nonirradiated experiments. Because of the difficulties described previously in performing these analyses, the most representative results are expected to be for sample 425. At a 10 V acceleration voltage the beam diameter was measured to be about 1.5 μm in the resin. It will be slightly smaller in the layer because of the higher density of the layer, and so the 1.2 μm layer is expected to produce the most reliable results.

Table 9 shows the determination of the layer formula for sample 425 where it is assumed that the difference between the total weight percent of the bulk and that of the layer is due entirely to water. While this approximation ignores resin, lithium, and boron that may be present in the layer, it provides a means of computing the water content of the layer. From these stoichiometries, the layer can be expressed as the formula

$$(Ca_{0.1}Na_{0.6})(Al_{0.1}Mg_{0.6}Fe_{3.3})(Si_8O_{20})(OH_4)\cdot 15H_2O$$

with excess CaO and Al_2O_3. The nickel, zirconium, and uranium and other minor elements have not been included in this formulation. The formula has been expressed in this form to stress the similarity to smectite clays, which have the general formula:

$$(1/2Ca,Na)_{0.7}(Al,Mg,Fe)_4[(Si,Al)_8O_{20}](OH)_4\cdot nH_2O.$$

The sodium and calcium are exchange cations and may be replaced by potassium, cesium, strontium, magnesium, or hydrogen. The number of Y-cations, $(Al,Mg,Fe)_4$ which are distinguished by their tetrahedral coordination, can sometimes exceed four atoms per formula, probably with magnesium occupying interlayer sites. It might be expected that the availability of these cations would be affected by the different experimental conditions, especially the leachate pH. The interlayers of smectite clays are known to swell with additional water and probably contain a large number of impurities as well. The formation of smectite clays is favored by alkaline conditions and the presence of magnesium [DEER]. The altered layer that

Table 9. Calculation of Alteration Layer Formula Including Water

	Quantitative Results, wt %			
	Ele. wt %	Renormalized	Mole %[a]	Formula
Na	1.15 ± 0.19	1.17	0.05	0.58
Mg	1.13 ± 0.29	1.15	0.05	0.58
Al	1.80 ± 0.14	1.83	0.07	0.81
Si	18.86 ± 1.36	19.19	0.69	8.00
Ca	1.74 ± 0.33	1.77	0.04	0.46
Mn(IV)	1.92 ± 0.44	1.95	0.04	0.46
Fe(III)	15.48 ± 1.90	15.75	0.28	3.25
Ni	0.56 ± 0.13	-	-	-
Zr	0.79 ± 0.16	-	-	-
U(IV)	0.38 ± 0.14	-	-	-
O[b]	33.18 ± 02.67	33.76	2.11	24.46
H_2O[c]	23.01	23.42	1.30	15.07

[a]g-atoms of element/100 g glass.

[b]Oxygen by stoichiometry.

[c]Water by weight % difference from bulk.

The quantitative analysis results were used to generate the average elemental weight percents of the major constituents. The amount of oxygen was computed by stoichiometry for the cations. The amount of water is that necessary to bring the total elemental weight percent to 100%. Nickel, zirconium, and uranium were neglected and the weight percents renormalized to 100%. The mole percents were computed by dividing the elemental weight percents by the atomic weight of that element, or by the molecular weight of water. The formula was then calculated by normalizing the mole percent of silicon to eight.

forms on the reacted SRL U glasses appears to have a general formula similar to that of the iron-rich smectite, nontronite, which is a di-octahedral clay. The magnesium-rich smectites saponite and hectorite are tri-octahedral clays. Complete solid solutions of di- and tri-octahedral clays are not expected. The laminar appearance of the layers formed on the SRL U glasses may be indicative of alternating layers of di- and tri-octahedral clay phases.

ii. CARD Analysis

Scintillation detectors such as the Robinson detector can be used to obtain compositional information for a particular sample. This method is commonly referred to as "compositional analysis using the Robinson detector," or CARD. It has been found that the electron backscattering efficiency of elements increases monotonically with the atomic number (more correctly with the electron density) of the sample. Because the electron beam of an SEM does not provide atomic resolution, it is the effective backscatter efficiency of the material within the volume producing the backscattered electrons, which is typically $>1\ \mu m^3$, that is determined. This sampled volume, which differs as a function of sample material and electron beam energy, determines the spatial resolution of the technique. The response characteristics of the detector to pure elemental standards can be used to generate an intensity vs. atomic number curve. The detector response to a multielemental sample has a corresponding value on the atomic number axis (not necessarily an integer value) that is unique to that sample. This is referred to as the atomic number factor (ANF) of that sample. The ANF of a compound may be calculated if the detector response curve is known. Comparison of measured and calculated ANF values of a sample can be helpful in determining the actual composition of a phase and in detecting the presence of elements not detectable using EDS.

The CARD technique has been used in an attempt to quantify the amount of water present in the alteration layers of the reacted SRL U and ATM-1c samples. The response curve of the Robinson detector was calibrated using two standard elements; carbon and silicon were used for the SRL U glass, while silicon and germanium were used for the ATM-1c glass. The results are summarized in Table 10. If the measured ANF values (as well as the calculated ANF values) are greater in the layer than in the bulk, this means the layer has a greater electron density than the bulk. Such an ANF increase is due to the enrichment of species in the layer such as calcium that are heavier than the glass, and depletion of species that are lighter than the glass. The ANF values measured at several locations on the layer typically agreed within 0.2 units, which is the generally accepted ANF resolution of the technique. ANF values were calculated using the compositions of representative EDS quantitative analyses results for the bulk glass and for the layer. Lithium and boron were assumed to be present in their analytical glass compositions in the bulk and totally depleted in the layer. Minor glass constituents (those present at less than 0.1% elemental concentration in the original glass) were neglected. Water was added to the alteration layer composition to bring the total

Table 10. CARD Results for Reacted SRL U and ATM-1c Glass Samples

Sample Number	Unreacted Glass		Alteration Layer		
	Measured	Calculated	Measured	Calculated* w/o H_2O	Calculated* w/15% H_2O
SRL 425	12.2-12.4	12.3	13.1-13.2	12.8	13.3
ATM-1c 489	16.1-16.3	16.3	15.9-16.1		
ATM-1c 493	16.1-16.3	16.3	16.1-16.2		

*Calculated using Robinson detector sensitivity curve provided by V. Robinson and glass/layer compositions presented previously for SRL U and ATM-1c.

elemental weight percent to 100% for both the SRL U and ATM-1c glasses.* The good agreement between the measured and calculated ANF values supports the contention that water (or resin) is present in the layer. The qualitative difference between the ANF values of the bulk and layer are consistent with other results, namely that the alteration layers of the SRL U glasses are enriched in heavy elements. Notice that adding 15 weight percent of water to the layer only resulted in a change of 0.6 in the calculated ANF. The technique is not sensitive to small changes in the concentrations of light elements because the detector response curve is nearly flat for atomic numbers below about 10.

b. Reacted ATM-1c Samples

Line profiles of the ATM-1c polished cross-sections were also obtained. Figure 32a shows the line profiles of silicon, sodium, and molybdenum and Fig. 32b the line profiles of silicon, uranium, calcium, and iron for the cross-section of sample 509 which is representative of all ATM-1c cross-sections. The plot shows three distinct regions representing the resin, the reacted layer, and the unreacted glass, from left to right. The silicon profile appears only slightly depleted across the layer and into the unreacted glass. This is consistent with the similar appearance in the SEM of the reacted layer and the unreacted glass. The thickness of the layer is sufficient that the entire sampled volume is within the layer,

*This procedure overestimates the water content by ignoring the resin contribution to the analyzed volume in the SRL U glasses. Because the backscatter efficiency of water and resin are expected to be similar, this simplification is expected to have little effect on the calculated ANF.

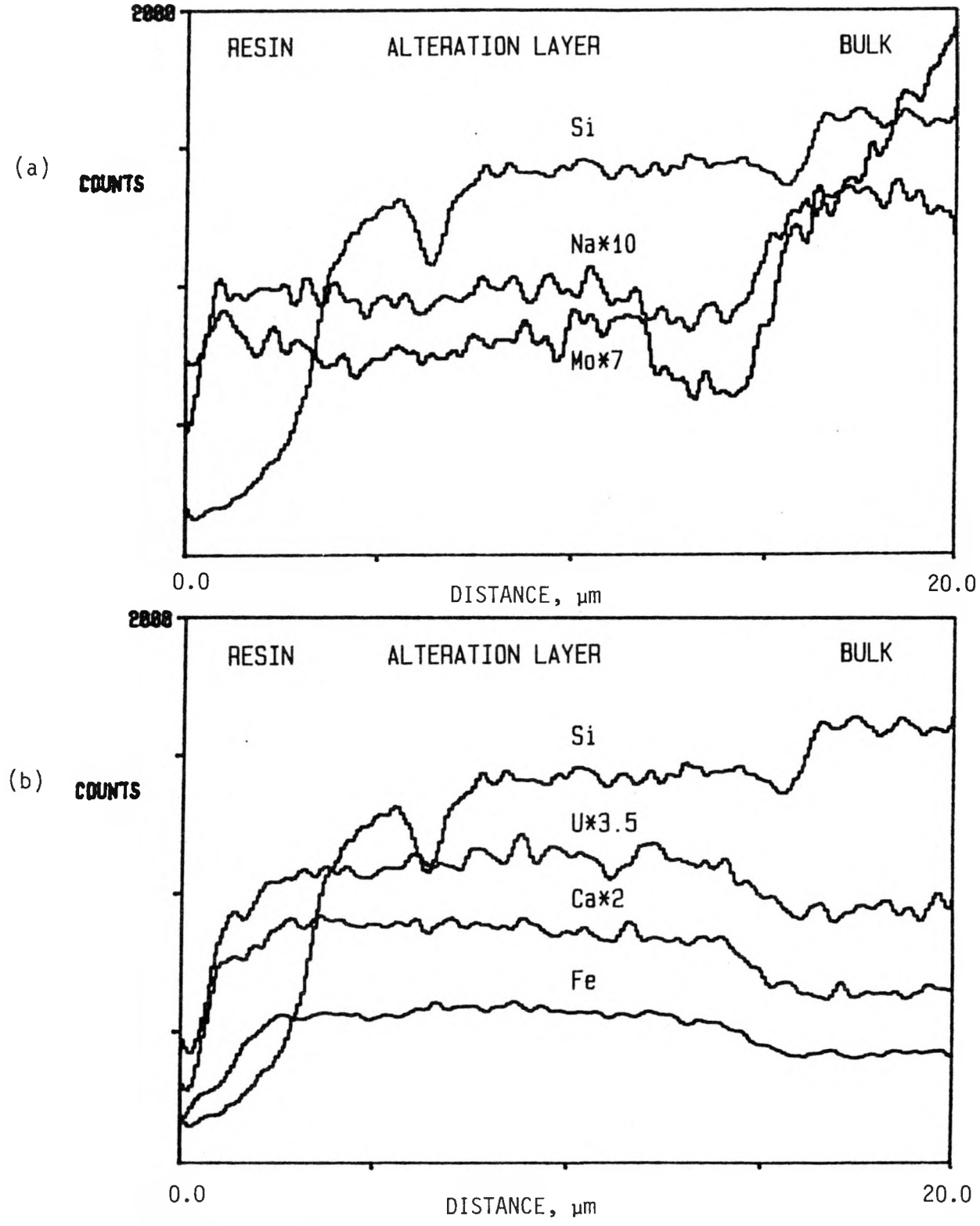


Fig. 32. EDS Line Profile Analysis of the Near-Surface Region of ATM-1c Sample 509, Reacted 181 Days, Irradiated, with Tuff; Line Profiles of (a) Silicon, Sodium, and Molybdenum; and (b) Silicon, Uranium, Calcium, and Iron.

contrary to the thinner SRL U layers. Calcium is seen to be moderately enriched in the layer and sodium depleted in the layer, similar to the SRL U results. Iron is also slightly enriched in the reacted layer, as shown in Fig. 32b. Molybdenum is depleted in the layer.

Because of the complicated composition of the ATM-1c glass and the resulting large number of peak overlaps in the EDS spectra, quantitative analysis was not performed on these samples.

C. SEM/EDS Surface Precipitates

1. Reacted SRL U and SRL A Samples

The surface of at least one reacted glass from each experiment type and duration was analyzed using the SEM to identify secondary phases which were produced during the reaction. This was done to determine if common precipitates were formed under similar test conditions. Precipitates and contaminants were found on the surfaces of all samples analyzed with the SEM (Table 11). Contaminants included stainless steel shards on a large number of samples and tin and copper containing particles on a few samples. These were probably deposited on the surface during the wafering procedure when the samples were produced from the original glass bulk or during sample handling. The SRL 165 glasses may have included impurities containing tin and copper. The ATM glasses also had inclusions (Cr-rich spinels, and insoluble Pd/Ru regions) that were present when the glass was produced. Some samples had fragments of platinum from the crucible used when the glass was made.

The procedures used in these experiments do not prevent the formation of precipitates during the quenching of the vessel from 90°C to room temperature. The solubilities of most secondary phases will be lower at room temperature than at 90°C and therefore some precipitates may form on the glasses during the quench. It is not possible to tell from the surface analyses if a given precipitate was formed during the reaction or is an experimental artifact of quenching the solution. We will assume in the following discussion that the precipitates seen were formed during the reaction rather than during the quench. This is probably a good assumption, since the temperature change of the quench is only about 60-65°C, and previous experiments investigating the formation of precipitates in MCC-1 type experiments found no difference between quenched and non-quenched samples at 90°C [MEANS].

One factor that influences which precipitates are formed is the solution pH. Because the irradiated leachates maintained pH values between ~7.5 and 8 while the nonirradiated leachates only reached pH values between 8 and 9, the pH difference between irradiated and nonirradiated leachates is probably not great enough to cause a significant difference in precipitates. The presence of tuff in a reaction will not likely affect the precipitates formed since the species dissolved from the tuff are present in similar concentrations in all EJ-13 leachates, but may affect the quantity of precipitates forming on the glass due to the availability of the tuff surface for nucleation.

Table 11. Condensed Table of Precipitates Found on Reacted SRL U Surfaces

Sample Number	Reaction Time (days)	pH	"Clay"	Al-Rich	Ca-Rich	U-Rich	Other
SRL U, 1E3 R/h							
301	28	7.54		√		√	
305	56	6.81	√			√	
311	91	6.80	√	√	√	√	KCl
313	181	6.87	√	√	√	√	
371	278	5.25	√	√	√		Si
SRL U + TUFF, 1E3 R/h							
323	28	7.37				√	S, P
325	56	6.91	√			√	
327	56	6.75	√	√	√	√	
331	91	6.99	√	√	√		
335	181	7.10	√	√	√		
337	278	7.53	√	√	√		Si
SRL U, 0 R/h							
383	14	8.31				√	
385	28	8.85					
389	56	8.42	√	√		√	
393	91	9.27	√			√	NaCl
397	181	9.06	√		√		
403	278	9.06	√	√	√		
SRL U + TUFF, 0 R/h							
405	14	7.73					Ba, S
409	28	8.14					Ba, S
413	56	8.41	√		√	√	
419	91	8.85	√				
423	181	8.98	√		√	√	
425	278	8.99	√		√		

Most samples reacted 91 days or more showed small areas (<1 μm) on the glass surface (gel layer) that were rich in aluminum. No identifiable precipitates could be seen, rather the alteration phase appeared brighter in small areas. Perhaps aluminum-rich precipitates were buried within the gel. More aluminum-rich areas were seen in the irradiated experiments than in the nonirradiated experiments.

Silicon-rich precipitates were found on the irradiated samples reacted 278 days, but not on the nonirradiated 278-day samples. This corresponds with the leachate results which showed a large decrease in the background corrected silicon concentration after 181 days in the irradiated experiments. (The actual silicon concentrations were similar at 278 days and 181 days in the irradiated experiments, about 80 ppm, but the background correction for the 278-day experiments was much greater than that for the 181-day experiments.) The nonirradiated experiments had similar background corrected concentrations at 181 and 278 days.

A few calcium-rich regions were seen on some samples, although not enough to correlate to experiment type. The leachate calcium levels suggest that the leachate is nearly saturated with respect to a calcium-rich phase. The alteration phase appears to incorporate most of the calcium, though some calcite crystals were found on some samples.

Almost all the samples analyzed were found to have one or more uranium-containing precipitates. Only a few such precipitates were found on samples from tuff-containing experiments while a larger number were found on most samples from tuff-absent experiments. This is probably due to the fact that the tuff provides as many nucleating sites as the glass for the precipitates. Uranium-containing precipitates are very easy to locate using backscattered electron detection. The heavy uranium atoms are very efficient electron backscatterers and so the uranium precipitates appear very bright in the backscattered electron image. These precipitates are quite small and could not be clearly imaged using backscattered electrons. Table 11 summarizes the surface analysis for precipitates on the SRL U glass samples. The alteration phase seen to form on all glasses reacted 56 days or longer is referred to as clay for convenience, although it has not been structurally identified. Figures 33a-c present typical photomicrographs and EDS spectra of the aluminum-, calcium-, and uranium-rich precipitates found on many samples.

Except for the aluminum-rich features and the calcium- and uranium-containing precipitates, no other precipitates were common on all samples. There was no noticeable accumulation of a given precipitate with increased reaction time in any of the experimental series. In general, the samples that were reacted with a tuff wafer present had a larger number of precipitates on the surface than the corresponding samples without tuff present, though, as mentioned, they had fewer uranium-containing precipitates. This was somewhat surprising from the perspective that the presence of the tuff surface was expected to reduce the number of precipitates formed on the glass simply because of the available surface area. However, since the leachate was never completely equilibrated with the tuff, tuff dissolution contributed to the saturation of several species, most

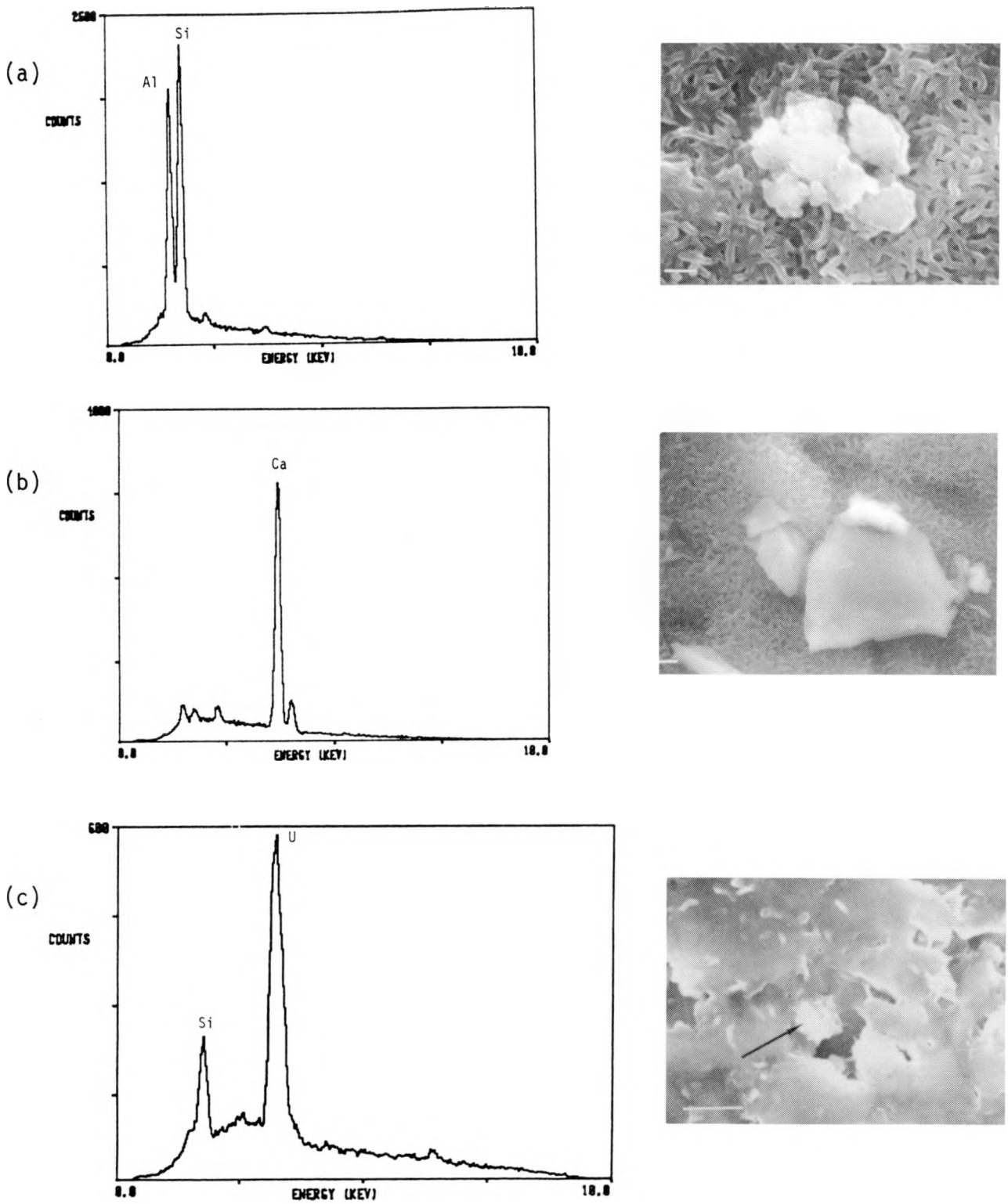


Fig. 33. Photomicrographs and EDS Spectra of Unidentified Typical Surface Precipitates Found on SRL U Samples: (a) Aluminum Rich, (b) Silicon Rich, and (c) Uranium Rich.

importantly of silicon, in the leachate and subsequent precipitation formation. Irradiation, through an influence on the leachate pH, did not have a noticeable effect on the number or types of precipitates found, although a total inventory was not taken on any of the samples. This is not surprising since the irradiated solutions attained final pH values not too different from the nonirradiated experiments.

While most samples were found to have only a few widely scattered precipitates, a few samples contained areas having a high density of a common precipitate. Sample 419 was unusual in that a large part of the surface was covered with a certain precipitate. Sample 419 was reacted 91 days with tuff present and was not irradiated. A magnified image of a typical precipitate is shown in Fig. 34a and the accompanying EDS spectrum is shown in Fig. 34b. All the precipitates have a similar "deflated basketball" appearance. The spectrum is very similar to that of the general background except for increased sodium and chlorine peaks in the precipitates. This same precipitate was also seen to form on sample 397, which was reacted 181 days without a tuff wafer and without radiation.

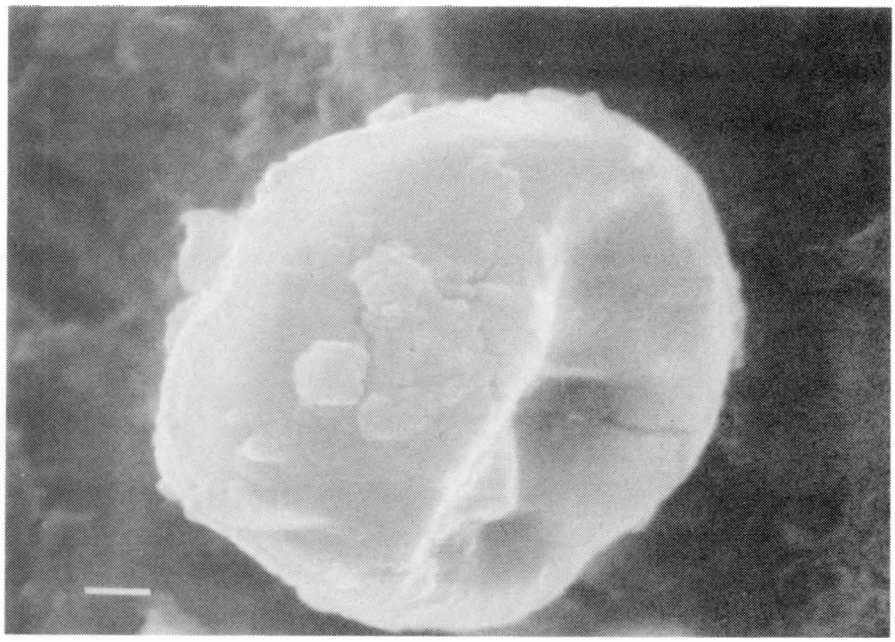
Samples of SRL A glass were examined with a particular emphasis of observing whether any Np, Pu, or Am could be identified on the surface or associated with any precipitate. No enrichment of transuranic elements could be found. This is not surprising in that EDS has a detection limit of about 0.2 wt % for a heavy element in a light element matrix. The transuranic elements, which are present in the bulk glass at a maximum concentration of ~0.025 oxide weight percent, have not been concentrated to the extent that they can be observed. However, the ion microprobe results discussed latter help describe the behavior of these elements.

Because all the precipitates found are so small, X-ray diffraction (XRD) analysis for structural determination was not feasible. Some of these precipitates will be analyzed using a laser Raman microprobe which is currently under development.

2. Reacted ATM-1c and ATM-8 Samples

The ATM-1c and ATM-8 glasses reacted to produce similar secondary phases. A photomicrograph of a typical backscattered electron image of a reacted ATM-1c surface is shown in Fig. 35a. A high density of small precipitates, the lighter features in Fig. 35a, are seen to cover the surface of the sample. Figure 35b shows a photomicrograph of these small features at higher magnification using secondary electron detection. An EDS spectrum of a typical precipitate is shown in Fig. 35c, and the background spectrum of a reacted ATM-1c glass is shown in Fig. 35d. The spectrum of the precipitate differs slightly from that of the general background, namely in the increased phosphorus, calcium, and lanthanum peaks. Because these precipitates are so small, typically less than 1 μm in diameter, a significant volume of the background is sampled along with the precipitate. Similar precipitates have been found in other leaching experiments of ATM glasses [BATES-2], and have been identified using XRD as

(a)



(b)

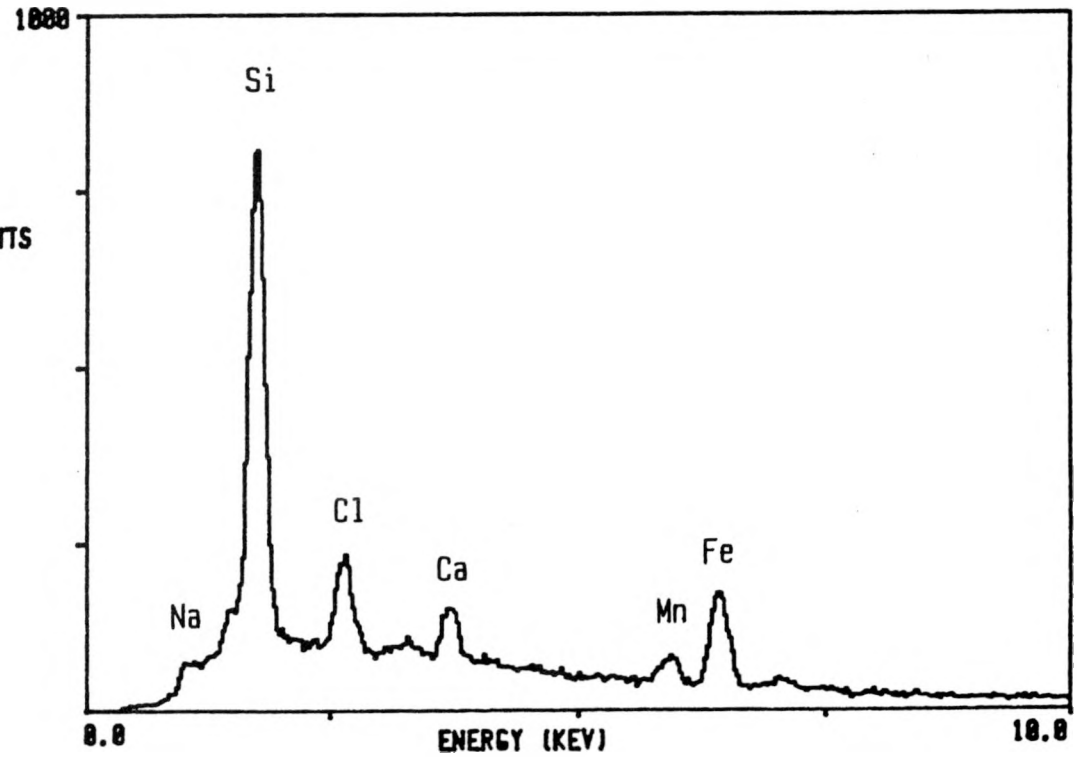


Fig. 34. (a) Photomicrograph and (b) EDS Spectrum of Unidentified Precipitate Found on Some SRL U Reacted Surfaces. The bar represents 1 μm.

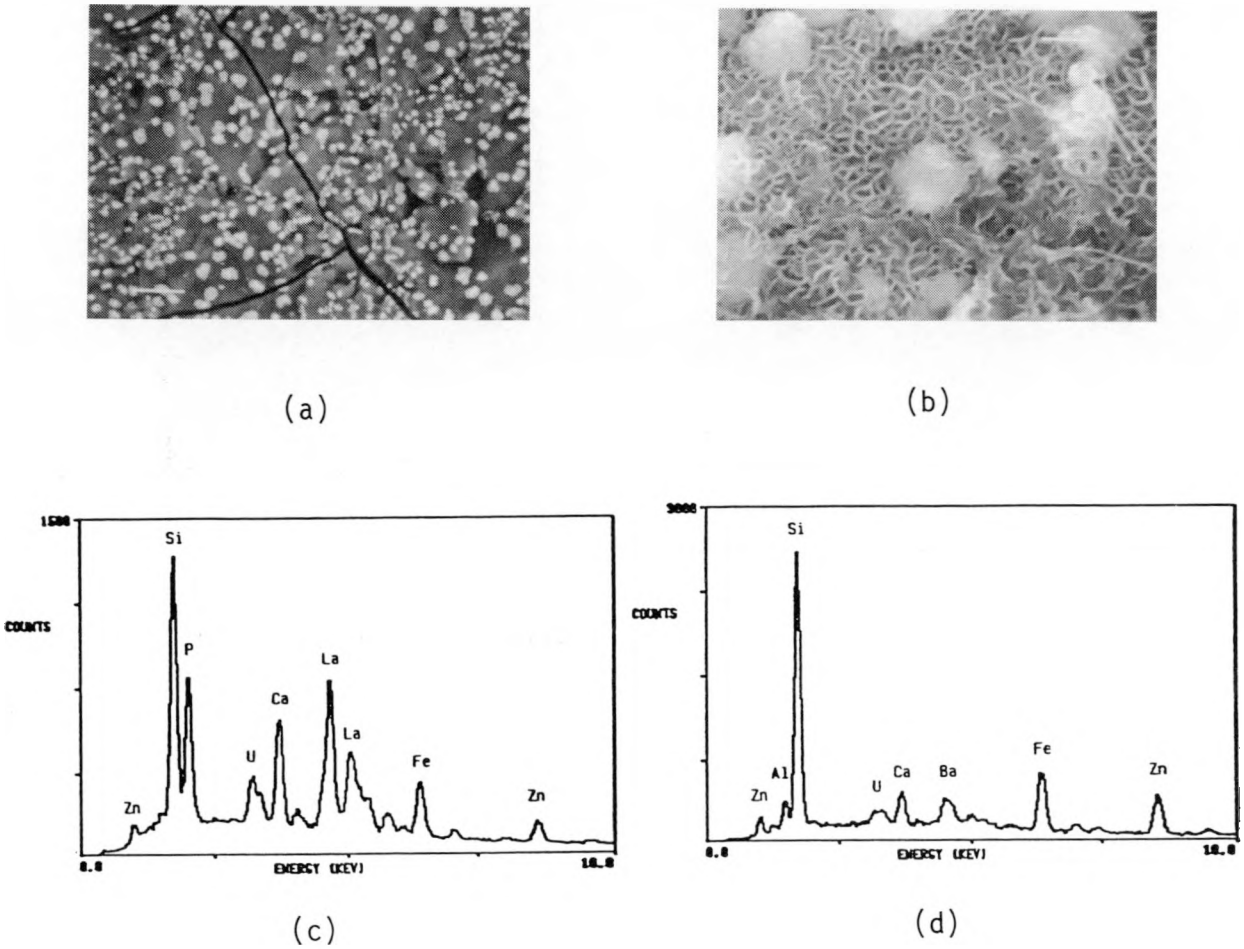


Fig. 35. (a) Photomicrograph of Backscattered Electron Image of Typical ATM-1c Reacted Surface, (b) Photomicrograph of Secondary Electron Image of Precipitates Common to Reacted ATM-1c Surfaces, and EDS Spectra of (c) Precipitate and (d) Background of ATM-1c. Bar represents 10 μm in (a) and 1 μm in (b).

$LaPO_4$ with minor calcium substitution. The number and, to a lesser extent, the size of the precipitates appear to increase with increased reaction time. Both experiments with and without a tuff wafer present show this increase in the number of these precipitates.

A second type of precipitate was observed on some of the samples from experiments without tuff. Figure 36a is a photomicrograph of the surface of sample 479 which was reacted only 28 days with a tuff wafer present. This is a backscattered electron image. The surface can be seen to be covered with small $LaPO_4$ precipitates. One of the large bright features in the center of the micrograph is shown at higher magnification in Fig. 38b. It contains sulfur, barium, and strontium, as shown in the EDS spectrum of a typical precipitate in Fig. 36b. These precipitates have also been observed previously, and are thought to be barite with some strontium substitution, $(Ba,Sr)SO_4$. These precipitates have various appearances ranging from very smooth regular shapes to highly lobed, as the precipitate in the figure. Some surfaces included another sulfur-rich feature, a typical image of which is shown in the photomicrograph in Fig. 36d. The EDS spectrum of this feature is shown in Fig. 36e. Such precipitates were found on samples reacted both with and without a tuff wafer present, though they were not found on all samples.

Except for an occasional contaminant, the surfaces of the ATM-1c samples were found to contain only these three types of secondary phases, in addition to the general background reacted layer. All samples were covered to a large degree with the phosphate phase. Samples which were reacted without tuff often had $(Ba,Sr)SO_4$ precipitates, and some samples showed the presence of an unidentified sulfur-rich phase that did not contain barium, independent of the presence or absence of a tuff wafer. No $(Ba,Sr)SO_4$ precipitates could be found on samples reacted with tuff present. No uranium-, neptunium-, plutonium-, or americium-containing precipitates were found on the ATM-1c or ATM-8 samples.

D. SIMS Analysis of Reacted SRL U Samples

Secondary ion mass spectroscopy (SIMS) can be used to profile elemental concentrations as a function of distance beneath the surface by analyzing the secondary ions emitted from the surface while the surface is being sputtered with a high energy (0.5-5 keV) primary ion beam. The surface is continually eroded by the sputtering process which exposes material further and further below the reacted surface. By adjusting the energy and mass filters of the analyzer, the concentrations of a selected species can be measured at increasing depths beneath the original surface.

A few experimental limitations which may influence the quantitative accuracy of the concentration vs. depth profiles should be discussed. First, the energy distribution of the secondary ions will vary with the surface conditions. If the surface charges positively (due to accumulation of positive charge from the primary ion beam, which is Ar^+ or Ne^+ in our case), then the energy distribution of the sputtered secondaries will be shifted to higher energies and so the detector will sample a different

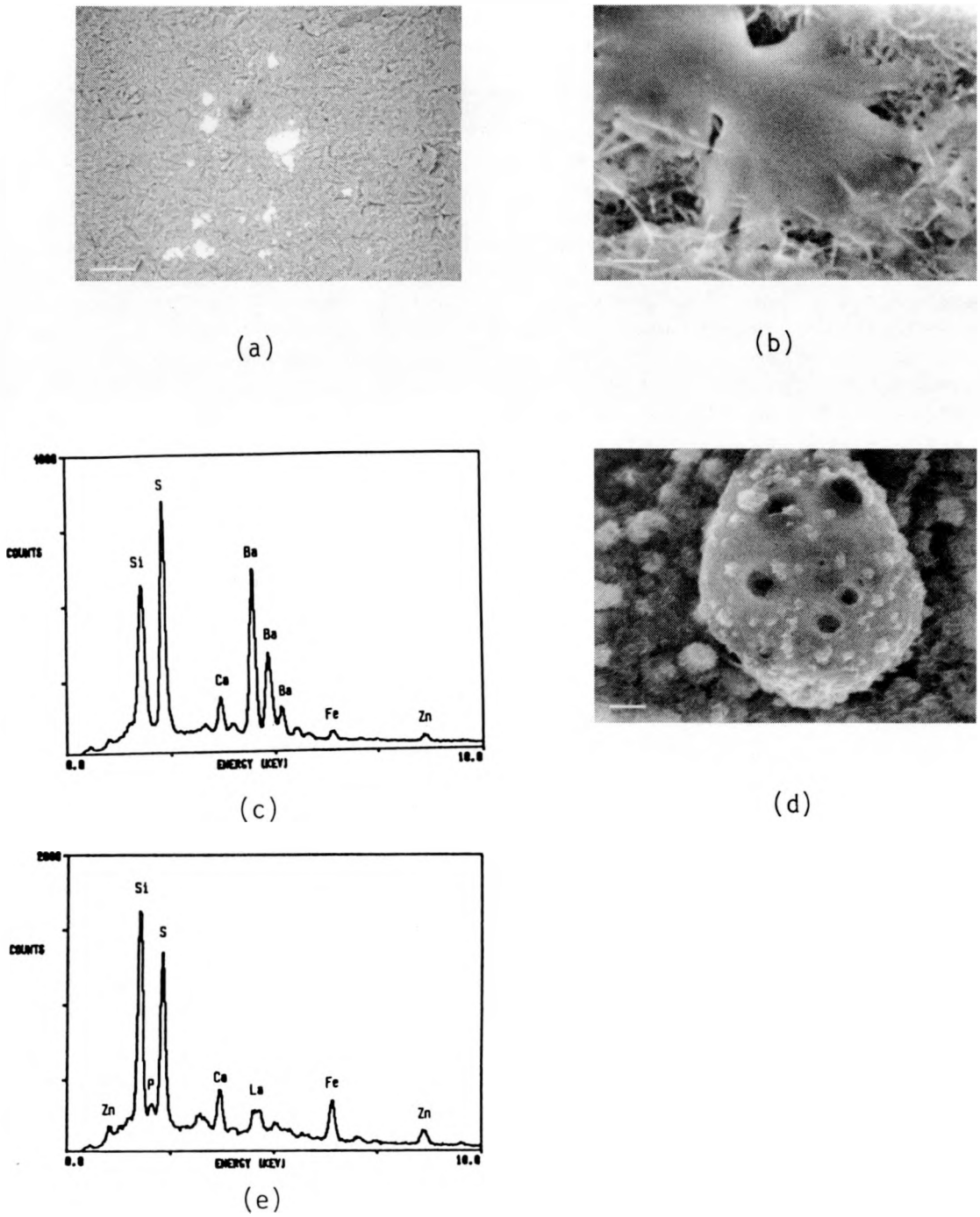


Fig. 36. (a) Photomicrograph of Backscattered Image of Typical ATM-1c Reacted Surface Showing Large Precipitates, (b) Secondary Electron Image of Precipitate, (c) EDS Spectrum of Precipitate. Bar represents 40 μm in (a) and 1 μm in (b). (d) Photomicrograph of Secondary Electron Image of Sulfur-Containing Precipitate, and (e) EDS Spectrum of Precipitate. Bar represents 2 μm.

portion of the secondary ion energy distribution. In addition, the sputtering characteristics of the surface may change during sputtering so that the sputtering yield for some species may change. This means that for a constant incident beam current, the secondary ion yield for a given element may not be constant with sputtering time. Both of these charge-induced complications reduce the quantitative accuracy of the technique. The analyses discussed below are only used to deduce the qualitative trends in the elemental concentrations.

A knowledge of the rate of erosion allows conversion of the measured sputter time to depth in the sample. An effort has been made to accurately determine the sputter rate of our instrument for the glasses of interest. There is no reason to expect the sputter rate of the alteration layer to be the same as that of the unreacted glass. For this reason both unreacted glass samples and reacted glass samples were sputtered for times sufficient to produce measurable sputter craters. These craters were then profiled using a Dektak IIA profilimeter at LLNL and ANL and the sputter rate determined (see Appendix IV).

One surface of one of the samples in every vessel had been ground to a 600 grit finish prior to reaction to provide a (relatively) smooth surface for SIMS analysis. The extent of reaction on this ground surface was slightly less than on the as-cut surfaces (which are equivalent to about a 240-grit ground surface) as observed directly using the SEM and indirectly by the glass weight loss measurements.

Figures 37-44 show the SIMS profiles of representative SRL U samples. The intensity plotted is the ratio of the intensity of the peak of interest to the silicon-28 peak. This technique of ratioing intensities is used to correct for instrumental changes that may occur between sampling times in the same sample, such as the incident ion current or surface potential. This treatment convolutes any change in the silicon concentration with changes in the other elemental concentrations. We have assumed that the silicon concentration does not change appreciably with depth. This is supported in the present analyses by the fact that the absolute intensity of the ^{28}Si peak remains constant (within the sensitivity of this technique) as the sample is sputtered, when corrected for traceable instrumental changes (see Appendix III). The symbols in the figures represent the intensity ratios of data that was collected at four, six, or eight minute intervals as the sample was continuously sputtered. The lines drawn through the points are not regressive fits to the data, but are included to more clearly illustrate the trends of the profiles.

In spite of the sometimes large scatter in the data, the profiles have unmistakable trends, shown by the lines in the figures. The x-axis in each figure is the sputtering time. This is proportional to the depth in the sample from which the signal is being generated. Measurement of sputtered craters gave sputtering rates of 0.02 $\mu m\ min^{-1}$ for both reacted and unreacted SRL U glass at an incident Ar^+ beam of 4 keV and a rate of 0.01 $\mu m\ min^{-1}$ at an incident Ar^+ beam energy of 2 keV. Depth axes derived from these sputter rates are included in the plots.

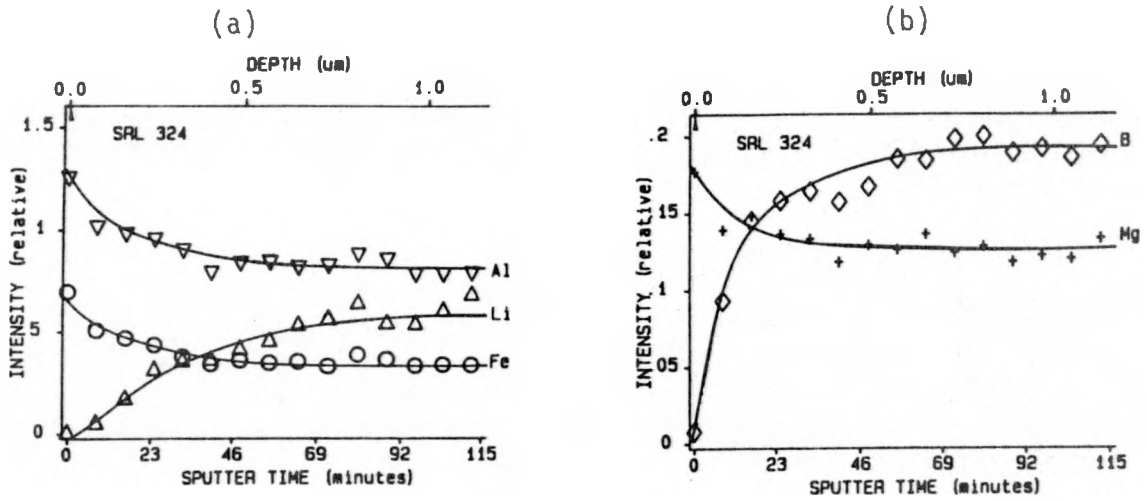


Fig. 37. SIMS Profiles of Sample 324, SRL U Glass, Reacted 28 Days, Irradiated, with Tuff: (a) Li-6, Al-27, Fe-56; and (b) B-11, Mg-23. The arrows on the depth axes indicate the layer thickness of the cross-sectioned sample that was the vessel mate of sample 324 measured using the SEM.

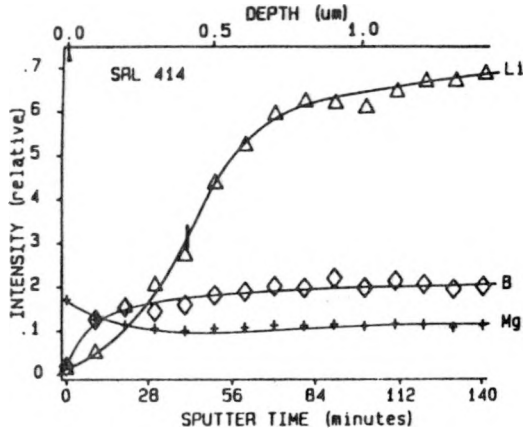


Fig. 38. SIMS Profiles of Sample 414, SRL U Glass, Reacted 56 Days, Nonirradiated, with Tuff: Li-7, B-11, Mg-23. The arrow on the depth axis indicates the layer thickness of the cross-sectioned sample that was the vessel mate of sample 414 measured using the SEM.

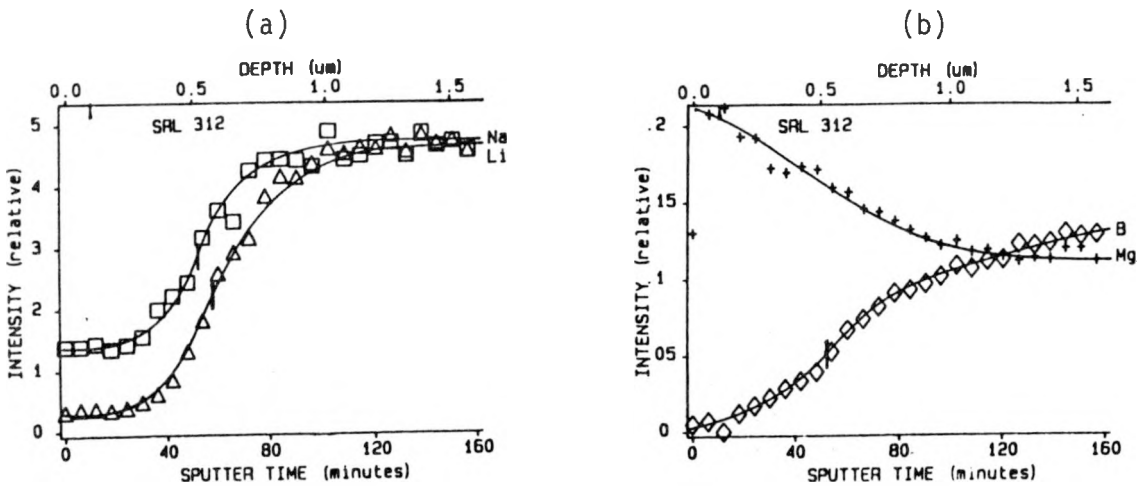


Fig. 39. SIMS Profiles of Sample 312, SRL U Glass, Reacted 56 Days, Irradiated, with Tuff: (a) Li-7, Na-23; and (b) B-11, Mg-23. The arrows on the depth axes indicate the layer thickness of the cross-sectioned sample that was the vessel mate of sample 312 measured using the SEM.

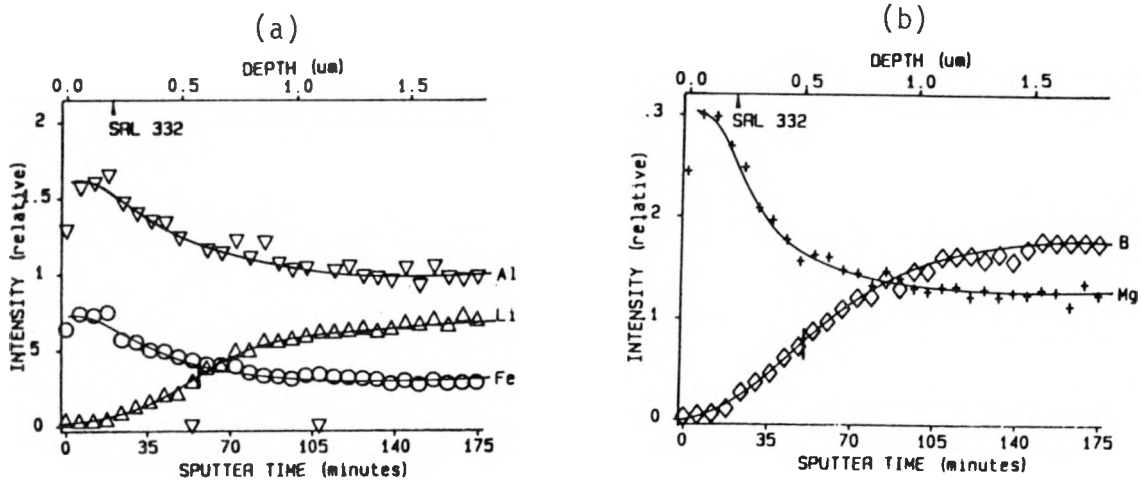


Fig. 40. SIMS Profiles of Sample 332, SRL U Glass, Reacted 91 Days, Irradiated, with Tuff: (a) Li-6, Al-23, Fe-56; and (b) B-11, Mg-23. The arrows on the depth axes indicate the layer thickness of the sample that was the vessel mate of sample 332 measured using the SEM.

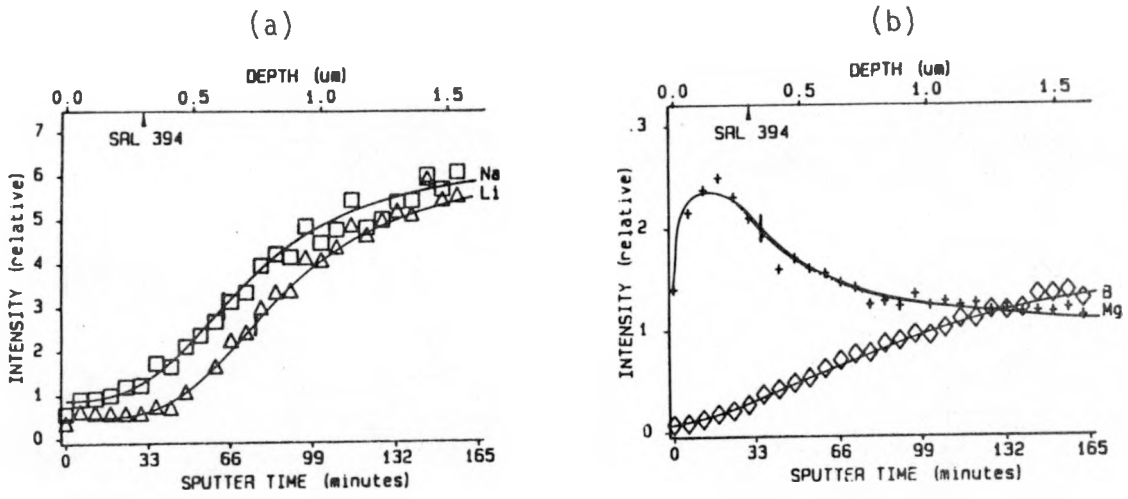


Fig. 41. SIMS Profiles of Sample 394, SRL U Glass, Reacted 91 Days, Nonirradiated, without Tuff: (a) Li-7, Na-23; and (b) B-11, Mg-23. The arrows on the depth axes indicate the layer thickness of the cross-sectioned sample that was the vessel mate of sample 394 measured using the SEM.

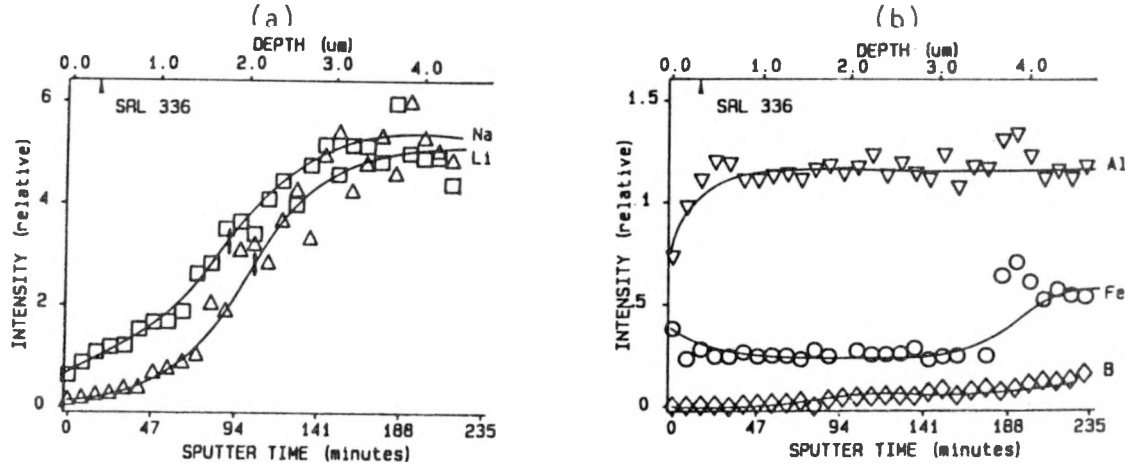


Fig. 42. SIMS Profiles of Sample 336, SRL U Glass, Reacted 181 Days, Irradiated, with Tuff: (a) Li-7, Na-23; and (b) B-11, Al-27, Fe-56. The arrows on the depth axes indicate the layer thickness of the sample that was the vessel mate of sample 336 measured using the SEM.

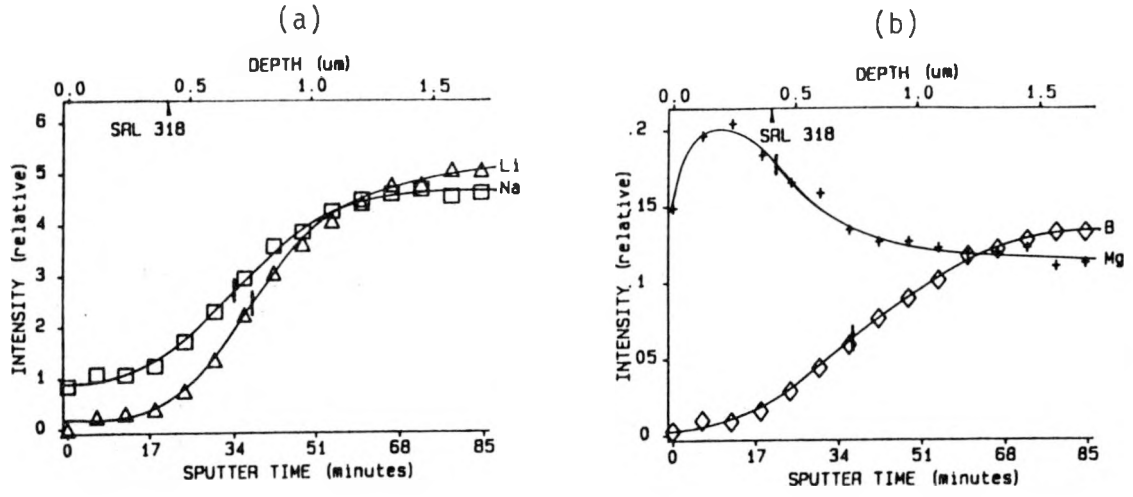


Fig. 43. SIMS Profiles of Sample 318, SRL U Glass, Reacted 278 Days, Irradiated, without Tuff: (a) Li-7, Na-23; and (b) B-11, Mg-23. The arrows on the depth axes indicate the layer thickness of the cross-sectioned sample that was the vessel mate of sample 318 measured using the SEM.

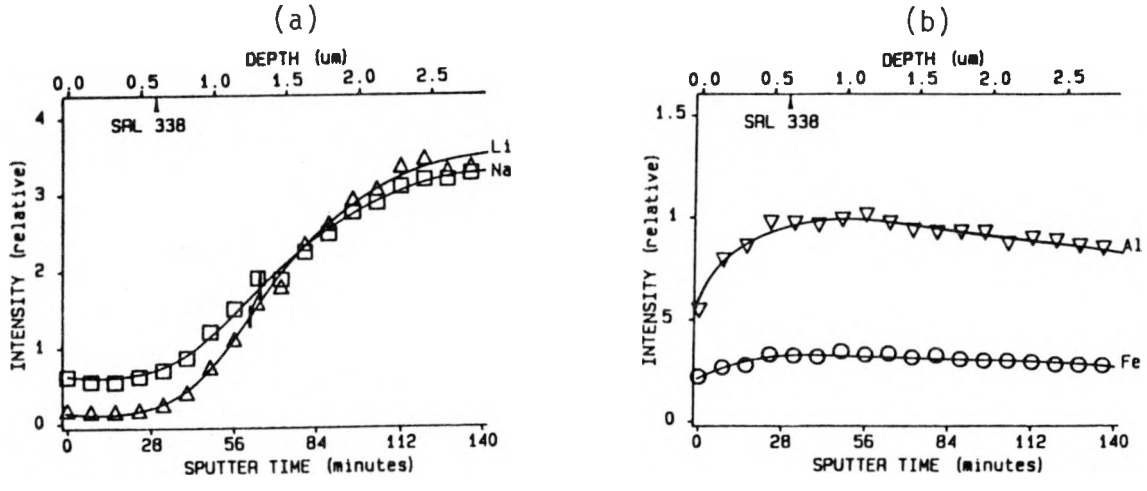


Fig. 44. SIMS Profiles of Sample 338, SRL U Glass, Reacted 278 Days, Irradiated, with Tuff: (a) Li-7, Na-23; and (b) Al-27, Fe-56. The arrows on the depth axes indicate the layer thickness of the sample that was the vessel mate of sample 338 measured using the SEM.

As was observed in the EDS analyses of the reacted SRL U glasses, the layers are seen in these SIMS profiles to be depleted in sodium and uranium, and enriched in aluminum, iron, and magnesium (relative to silicon). The layer is also seen to be depleted in boron and lithium, elements which cannot be detected by EDS. The profiles of these elements are sigmoidal after about 91 days of reaction for all experimental types. The leachate data seen earlier supports a diffusion controlled release of these elements. The sigmoid shape of these profiles are also consistent with diffusional release.

In Figs. 37-44, the layer thickness as measured by SEM analysis of the samples that were vessel mates of the SIMS analyzed samples are indicated by arrows on the depth axes. Because of the different surface textures of the starting sample surfaces, the extent of reaction is slightly greater on the "as-cut" surfaces which were measured with the SEM than on the "polished" surfaces ground to a 600-grit finish used for SIMS analyses.*

Several events occur during sputtering which complicate the elemental concentration profiles. Since sputtering involves breaking surface bonds the higher energy sites having weaker bonds will be preferentially sputtered. Contrary to popular terminology, the surface is not "milled" in a uniform manner, but rather the surface becomes increasingly rough as sputtering proceeds. SEM analysis of a typical sputtered region of SRL U glass showed the surface to be composed of a myriad of stalagmite-like features. In addition to uneven sputtering, atomic mixing occurs in the sputtered region. These effects tend to decrease the depth resolution of the technique so that even a step concentration change at an interface will produce a sigmoidal profile. It should be borne in mind that these sputtering artifacts will be convoluted with all depth profiles, and will probably become more pronounced at greater sputter depths.

The profiles of the different elements are seen to fall into two categories: species which are depleted in the altered region, sodium, lithium, and boron; and species which are enriched in the altered region or on the outermost surface, aluminum, magnesium, and iron. The depleted species have profiles that are flat and at very low levels in the outer region and then increase sigmoidally until they reach a constant level in

*Two reacted SRL U samples which had previously been analyzed using SIMS were mounted and cross-sectioned in order to compare the thicknesses of the layers on both the polished and as-cut surfaces. The measured weight changes of glass samples having one face polished were consistently less than their vessel mates having two as-cut faces (see Section VII, Data Table A). Depending on how the alteration layer forms, one might expect a thinner layer to be present on the polished face than on an as-cut face because of the initially rougher surface will react preferentially. SEM analysis of the cross-sections showed the layers on the polished faces to be only about 10-20% thinner than the layer on the as-cut faces. This difference is much less than that predicted by the differences in the glass weight change results, which suggested about a 50% difference in layer thickness.

the unreacted glass. The enriched species all have greater levels in the near-surface region, although sometimes they appear to be depleted at the outermost surface. They then decrease sigmoidally until they reach their lowest level in the unreacted glass. The true concentration changes seen in going from the layer to the bulk is not measured to be a sharp concentration step in part because of the sputtering artifacts and limited depth resolution of the process. The concentration profiles are not expected to be sharp at the interface, but they are probably not as diffuse as these profiles indicate.

Identification of the alteration layer thickness was straightforward in the SEM analyses since the bulk and layer had different average electron densities which produced contrast differences in the image. Determining the layer thickness in the SIMS profiles is not as obvious. Consider first the simple sigmoidal profiles of the depleted species, lithium, sodium, and boron. Diffusion from a step concentration gradient within a common matrix produces a sigmoidal profile that flattens with increased time. The inflection point is a convenient marker for defining the depletion depth of these species.* At short reaction times where a measurable depleted region has not formed, the depletion depth cannot be so easily defined.

Other species show enrichment in the alteration layer or on the outer surface. Those that are enriched in the layer provide a means of marking the layer-bulk interface. Magnesium provides a good measure of the layer depth as it is noticeably enriched in the layer relative to the bulk. The concentration profile of magnesium appears representative of other species enriched in the layer, although some of the other species have profiles that are different from sample to sample, for example aluminum. The behavior of the magnesium profile is similar in all samples analyzed. Its profile is sigmoidal near the apparent layer/glass interface and so the inflection point of the magnesium profile will be used to mark the layer thickness.

In the SIMS profiles shown in Figs. 37-44, the inflection points are located by short vertical lines drawn through the lines indicating the concentration trend. Generally, the magnesium layer thickness marker occurs at the smallest depth followed by the SEM measured thickness and then those of the depleted elements. That the layer thickness defined by the magnesium profile is less than the SEM measured thickness is consistent with the finding that the polished faces have slightly thinner layers than the as-cut surfaces.**

*A symmetrical profile is expected only when the matrices on either side of the step concentration profile are identical. Such is not the case in these experiments where the depleted side of the concentration step is initially the leachate and then the depleted "gel" or alteration layer.

**The comparison of layer thicknesses of different samples or different techniques is naturally only approximate. The SEM is sensitive to contrasts of electron scattering cross-sections whereas the SIMS profiles depend on sputtering cross-sections. It is felt that the close agreement of the Mg profiles and measured SEM thicknesses justifies the use of Mg to measure the depth in the SIMS analyses.

As seen by these profiles, elements are not enriched or depleted to common depths. Even lithium and sodium show slightly different depletion depths, even though they are thought to be released by the same mechanism. Boron, too, while it shows a similar leaching behavior, is depleted to slightly lesser depths than is lithium. The fact that sodium is depleted to lesser depths and has a slightly flatter (more diffuse) profile than lithium can be attributed to the solution concentrations of sodium which become sufficiently high at the longer reaction times to slow the diffusion of sodium. Both lithium and boron have sufficiently high solution capacities that their diffusion out of the glass is unrestricted in these leachates. That boron is depleted less than lithium is due to the difference in release mechanism wherein boron cannot be released until water first infiltrates the glass structure and ion-exchanges a proton for lithium.

The concentration profiles of individual species are determined by the equilibration of the species in the glass, layer, and solution phases. Though the equilibrations are not always independent of the concentrations of other species either because of precipitation formation or competing reactions, each species may have a unique concentration profile. Different glass constituents which serve similar functions in the glass structure, such as network formers or modifiers, will tend to have similar profiles.

The elements lithium, boron, and sodium all appear to be depleted to depths beyond what has been referred to as the alteration layer, that is, that layer seen in the SEM. As discussed earlier in the CARD analysis section, the exchange of lithium, boron, or even sodium with water probably does not change the glass density enough to be detected in the SEM image. (Less dense regions will produce fewer secondary electrons and so appear darker than regions having greater densities.)

The species which are responsible for the contrast difference between the alteration layer and the unreacted glass are probably those species that are enriched in the outer region, such as aluminum, magnesium, and especially calcium and iron, which have ANF contributions greater than the average ANF of the unreacted bulk. The lighter depleted elements contribute very little to the glass ANF and so their presence or absence is of little importance to the image contrast.

It is essential that the means of measurement be consistent when discussing the extent of glass reaction. Comparison of the rate determined by the leachate concentrations of the leached elements to the SEM measured layer thickness may be misleading because the SEM is insensitive to the absence of these elements. Leachate concentration of these elements should be compared to the SIMS-measured layer thicknesses. What we have been referring to as the alteration layer corresponds to the average SIMS profile of the enriched species, which is represented well by the magnesium profile. The leached species are by this definition depleted to a depth beyond the alteration phase.

E. Resonant Nuclear Reaction Spectroscopy of SRL U Glasses

A nuclear reaction occurs between 6.3 MeV nitrogen ions and hydrogen to produce carbon, an alpha particle, and a gamma photon. Resonant nuclear reaction spectroscopy (RNRS) utilizes this reaction to profile hydrogen in solids. By calculating the energy loss of an incident nitrogen ion beam as it penetrates the sample and measuring the emitted gamma intensity, a concentration vs. depth profile can be obtained by varying the incident nitrogen energy. This technique is not sensitive to the chemical state of the hydrogen and so does not differentiate between free water, bound water, hydronium, or hydroxyl species.* Hydrogen profiles were obtained to complement the SIMS profiles of leached species. Hydrogen is thought to be present in the layer in hydroxyl groups produced by the various reactions and in water.

Several of the reacted SRL U glass samples were profiled using RNRS. Analyses were performed at the State University of New York in Albany, New York (SUNY-Albany) in the laboratory of W. Lanford. The profiles of selected samples are shown in Fig. 45a-d. The general shapes of these profiles become sigmoidal at the longer reaction times. It is thought that ion exchange occurs during the reaction wherein the alkali metals lithium and sodium are replaced by a hydronium ion, or a proton. The profiles of hydrogen and of the depleted species should therefore be complementary, as they appear to be. The nearly flat region near the surface (left-hand side of the spectra) of the 181- and 278-day samples locates the alteration layer in which the ion-exchange reaction is nearly complete and the layer has become water-saturated. The abscissa is proportional to depth through the stopping power of the sample. At greater depths (higher energies) the hydrogen concentration decreases and the alkali metal concentrations increase due to limited water penetration. The reported energy loss as a function of penetration depth is 2 meV per μm. Such a factor suggests the hydrogen enrichment depth is only 0.6 μm after 278 days of reaction less than that measured using SIMS or the SEM.

F. Ion Microprobe Analysis

An ion microprobe was used to profile the radionuclides in the near-surface region of the reacted SRL A samples. The principles of this technique are identical to those of SIMS. The results are of poorer quality than those of the SIMS analyses due to the low concentration of the transuranic elements in the sample. Nevertheless, qualitative trends in the distributions of the radionuclides can be seen in the profiles which are helpful in characterizing their behavior. Figures 46a-d show some exemplary profiles. In these plots, the actual intensity is plotted vs.

*A competing reaction involving lithium also occurs. However, since the lithium concentration was so low in the altered region, no interference was expected.

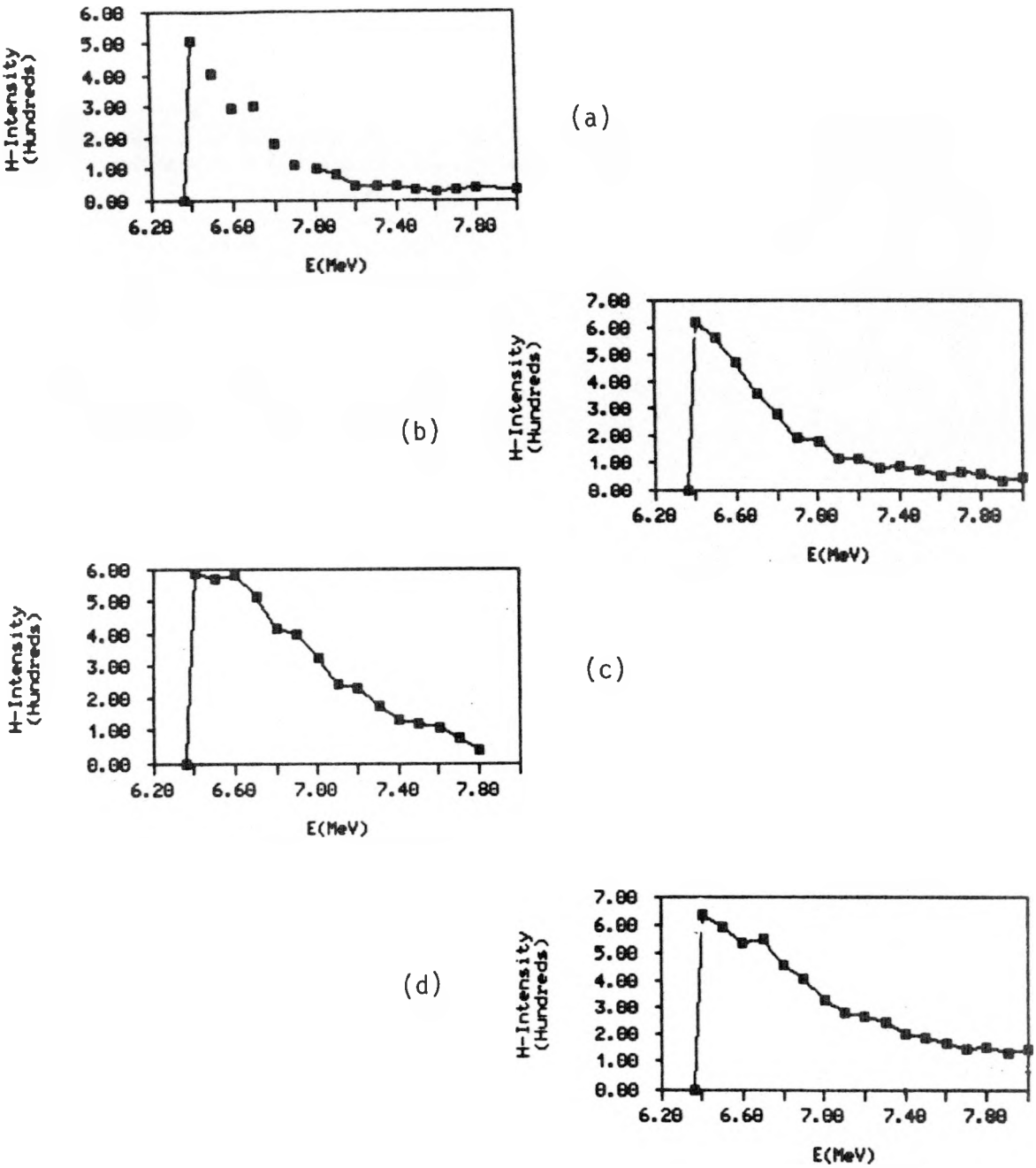


Fig. 45. Resonant Nuclear Reaction Spectra (Hydrogen Profiles) of SRL U Sample: (a) 308, reacted 56 days, 1E3 R/h without tuff; (b) 392, reacted 56 days, nonirradiated, without tuff; (c) 400, reacted 181 days, nonirradiated, without tuff; and (d) 404, reacted 278 days, nonirradiated, without tuff.

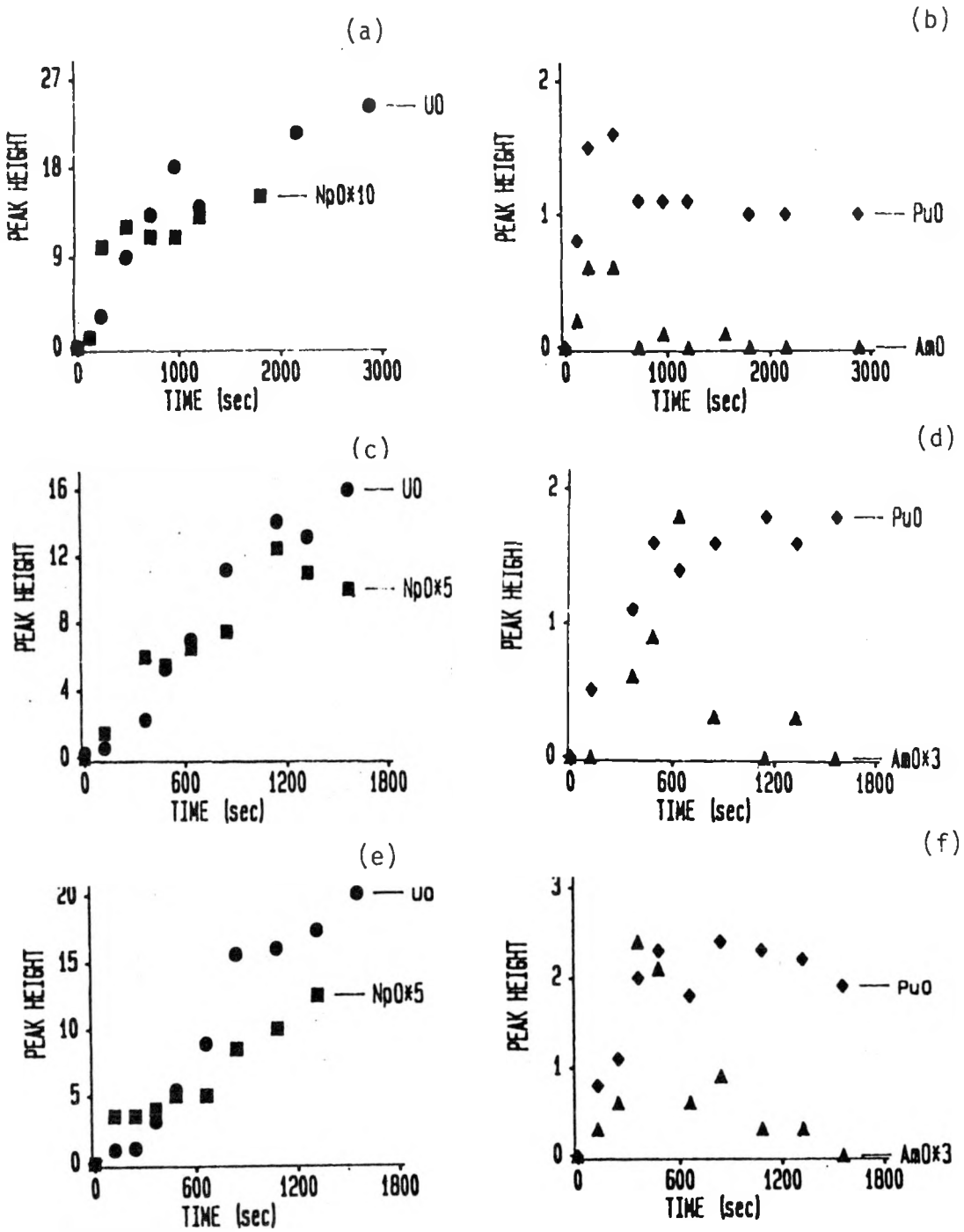


Fig. 46. Ion Microprobe Analyses of (a) and (b) Sample 438, Reacted 91 Days, 1E3 R/h; (c) and (d) 336, Reacted 56 Days, 1E3 R/h with Tuff Present; and (e) and (f) 462, Reacted 56 days, Nonirradiated, with Tuff Present.

the sputter time. The sputter rate is approximately 0.08 μm sec^{-1}. In these analyses, the samples were coated with about 300 Å of nickel to reduce sample charging. Time zero on the plots refers to the actual start of the sputtering. Nearly 300 seconds are required to sputter through the nickel and reach the glass surface. The samples were usually sputtered for times only long enough to analyze the near-surface region of the sample.

The trends seen in Figs. 46a-d are that uranium and neptunium are depleted in the outer region (alteration layer) of the reacted glass. Americium is enriched at the outermost surface of the samples. A more accurate SIMS analysis is necessary to characterize the americium distribution precisely. Plutonium has a flat profile in most analysis, though some profiles show a slight enrichment at the surface. These trends are consistent with the leachate results of the actinide distribution, as discussed below.

G. Discussion of Surface Analyses

Surface analysis showed the outer surfaces of the reacted glasses to be altered both in appearance and composition from the unreacted glass. This reaction region has been referred to as an alteration region or alteration phase, and is used as a measure of the extent of reaction. The ATM glasses had reacted to a large extent within even the shortest reaction period tested, 28 days, while the SRL glass reacted to a lesser extent. The outermost surfaces of the two glass types as observed in normal incidence had a similar chain-mail-like appearance, although the reacted regions as seen in cross-section were quite different.

As seen by the SRL glass results, neither irradiation nor the presence of tuff had a major effect on the extent of reaction or on the composition of the secondary phases. In all cases, SRL glasses produced an alteration layer that was sufficiently thick to be measured in the SEM after about 91 days of reaction. Other precipitates were present on the surfaces of these layers. Aluminum-rich regions and uranium-containing precipitates were found on most of the reacted SRL glass surfaces, though there were no other common precipitates found on samples reacted similarly.

What is referred to as the alteration phase or gel layer forms on or from the reacted surface and has a distinct "structured" appearance that penetrates to the bulk. In most cases the alteration layer, when viewed in cross-section, seemed to have separated from the bulk thereby allowing the mounting resin to seep into the interface. In some areas small amounts of the layer material appeared to have remained fixed to the bulk while being separated from the rest of the layer. It is uncertain whether this separation occurred during the reaction, when the sample was dried, or during the mounting and polishing procedure. The composition of the alteration layer was very similar to that of an iron-rich smectite clay, nontronite. Smectite clays are known to form on hydrated/leached basalts which are used as natural analogs for SRL 165 [BYERS]. The alteration layers were depleted in leachable elements and enriched in those elements expected to have low solubilities in these leachates, namely iron, calcium,

and aluminum. The SIMS results suggest that aluminum was most concentrated on the outermost surface, while iron was distributed evenly throughout the layer. Magnesium was assumed to be enriched throughout the alteration layer (i.e., to a depth similar to the layer thicknesses measured on cross-sectioned samples reacted the same length of time using the SEM) and was used to define the alteration layer thickness measured in the SIMS analyses. The surface concentration profiles of lithium, boron, and sodium, as measured by SIMS, showed these elements to be depleted to depths greater than the layer thickness measured using the SEM. While the layer seen in the SEM is almost totally depleted in these elements, the adjacent bulk glass appears to be depleted in these elements as well. The behavior of the depleted elements seems unaffected by the presence or nature of the alteration layer, though the sodium profile may be somewhat affected by high sodium concentrations in the leachate. If these species are depleted beyond the alteration layer/glass interface, which appears to separate, then it might be expected that their SIMS profiles would show an anomaly as the void was crossed. Neither the SIMS profiles of these elements nor the RNRS profile of hydrogen show any indication of a disruption due to the alteration layer/bulk interface. It is therefore likely that the separation occurs when the sample is mounted in resin for cross-section analysis or during sample dessication.

The reaction layers of the ATM glass showed a similar chain-link-like mat to cover the surface, but cross-section analysis revealed this phase to be restricted to the outermost surface. A second, thicker region formed beneath the "clay" similar in appearance to the unreacted glass except the region had a lower electron density. EDS/WDS analysis showed the region to be depleted in sodium and boron but not significantly enriched in insoluble species. This layer is better described as a simple leached layer and there is no evidence that the structure is altered from that of the unreacted glass. This is very different from the SRL glasses which showed good evidence of the reacted layer being restructured. Although the leached layers of the ATM-1c glasses showed a slight enrichment of calcium and iron relative to the bulk glass, the dominant reaction is the ion-exchange reaction freeing the leachable species. SIMS analyses performed on the outer sections of the ATM-1c samples were consistent with that obtained in the EDS/WDS profiles was obtained.

V. DISCUSSION

These experiments have produced a large volume of data which, when combined with the results of previous experiments, serve to characterize the interactions which occur between components expected to be present in a repository in tuff. The interaction of tuff and groundwater in a gamma radiation field has been measured by leachate analysis. The corrosion of synthetic waste glasses has been studied through leachate analysis as well as detailed surface analysis of the reacted glasses. The general findings of the leachate and surface analyses have been discussed in sections III.F

and IV.G, respectively. In this section the reaction as a whole will be discussed. A rigorous methodology describing the treatment of the reaction process describing the results of the 1 x 10^4 R experiments has been given previously [ABRAJANO]. The discussion that follows builds on the previously reported mechanism in a qualitative manner.

The leachate and SIMS results show lithium, boron, and sodium to be released from the glass at a rate that decreases parabolically with the reaction time. Lithium and sodium are probably freed from the glass in an ion-exchange reaction with a hydrogen species. In this sense, the glass can be considered as an ion-exchange resin where an equilibrium between alkali in the leachate and alkali in the glass with hydronium ion is established. Boron is an unlikely ion-exchange partner and is probably released through a hydrolysis reaction. As water infiltrates the glass and ion-exchanges with the alkali metal ions, the glass network begins to open thereby allowing more water into the ion exchange region (transition zone per [ABRAJANO]). The increase of water content along with the production of hydroxyl ions in the ion-exchange reaction supports a decomposition of the glass matrix through base catalyzed hydrolysis reactions, thereby releasing boron and similarly bonded species. Boron species are then free to migrate out of the glass transition zone, through the gel layer and into the solution. The high solubility limit of boron in the solution allows total solvation of the freed boron, and so boron does not accumulate in the gel region. Similar release of boron from waste glasses has been suggested by others [LANZA] also. Other species, such as uranium and neptunium, show release behavior similar to boron, except the mobility of these elements through the gel seems to be somewhat restricted, uranium more so than neptunium, as evidenced by a smooth increase in concentration as the bulk is approached from the outer surface. This may be due to limited solubilities in the leachate.

Other species that are freed from the glass matrix have limited solubilities in the leachates and so are not totally solvated by the leachate. If a species becomes saturated in solution, and no stable precipitates form, the alteration layer will become enriched in that species. The reaction releasing such a species from the glass may then become unfavorable because of the high concentration of that species in the alteration layer.

The observed alteration layer has a striated appearance that is different than the bulk. It has a composition similar to nontronite, an iron-rich smectite clay, though its structure has not yet been confirmed. This layer is seen to form on reacted SRL glass surfaces after only 56 days of reaction and to persist through the longest time tested, 278 days. The thickness of the gel increases with time in a near parabolic fashion such that the thickness after reacting 278 days is only slightly greater than the thickness after reacting 181 days. This behavior is analogous to the leachate results of those cations that are not diffusionally released

(notably silicon and plutonium), and to the net glass weight change. Presumably, the growth of the layer slows to nearly a stop after 181 days, perhaps indicating a "steady-state" condition wherein the dissolution and formation rates of the layer become similar.*

The leachate concentrations of species released from the glass can be used to predict the depletion depths of these species in the glass if the glass density is known. This depletion depth is an upper limit and will be greater than the observed thickness if etching or shrinkage [GRAMBOW] of the gel layer occurs. The so-called normalized depletion depth of an element i is calculated by dividing the normalized elemental mass loss (presented in Data Table C for the cations and Data Table D for the actinide elements) by the glass density, which is 2.7 g/mL for both SRL U and SRL A glass and about 3.0 g/mL for ATM-1c and ATM-8 glass. The geometric surface area and estimated depleted volume are used to compute the depletion depth. For example, boron** had an average NL(B) of 6.7 g/m^2 in the 278-day irradiated SRL U experiments with tuff. The normalized depletion depth of boron, ND(B), is calculated to be 2.5 μm. The measured alteration layer thickness using the boron SIMS profile of sample 318 was only about 0.9 μm, about one third of the calculated ND(B). The SEM-measured layer thickness of sample 318 was only 0.4 μm. The difference is due in part to etching and in part to the fact that the boron is depleted to a slightly greater depth than the SEM-measured alteration layer thickness. An additional contribution to the difference between the measured layer thickness and that calculated from NL(B) is the presence of cracks in the samples which provide surface area that is available for reaction. The cracks are not accounted for in either the depth calculation or the normalized elemental mass loss calculations because the geometric specimen area is used. If the cracks provided an amount of surface area similar to the measured geometric surface area, which is not an unrealistic assumption in the short-term experiments, then the NL(i) results as calculated are a factor of two too large. The resulting ND(i) calculations would also be too large by a factor of two. Doubling the available surface area results in a calculated boron depletion depth of 1.3 μm which is in better agreement with the measured depletion depth. Since the glass samples were prepared in similar fashion, the error in surface area introduced by ignoring the cracks will affect all $(NL)_i$ calculations similarly, and so the comparisons between NL(i) results made earlier are still valid. However, the effect of crack reaction becomes less of a factor with longer reaction times as noted in the ATM-1c and longer term SRL U experiments where the gel layer begins to encompass the cracks and the measured layer thickness is representative.

*The release of species which have large solubility limits, such as boron and lithium, does not stop after 91, 181, or 278 days of reaction. The formation of the gel layer does not act as a barrier to slow the release of these elements. The release of other components is limited by solubility.

**While boron was seen to be depleted to a greater depth than the alteration layer seen in the SEM, it is expected to be totally dissolved and so most representative of the extent of reaction as measured by leachate analyses.

VI. CONCLUSIONS AND REPOSITORY RELEVANCE

An ambitious series of experiments has been performed to determine the leaching behavior of SRL 165- and PNL 76-68-type glasses in tuffaceous groundwater in a gamma radiation field at 90°C. Experiments were designed specifically to monitor the interactions between components expected to be present in a tuff repository--though they were not designed to simulate a particular repository scenario. These experiments, which were performed both in the absence of a gamma field and under a gamma radiation field having an exposure rate of 1E3 R/h, along with previous experiments performed under fields having exposure rates of 1E4 R/h and 2E5 R/h, showed there to be very little influence of radiation on the reaction of the SRL type glasses. The means by which radiation is expected to affect the reaction is through the production of nitric and nitrous acids from nitrogen gas in the air and subsequent acidification of the leachate to pHs known to be detrimental to glass. The bicarbonate concentration of tuffaceous groundwater successfully buffered the leachate to pH values more basic than about 6.4, and so prevented the system from becoming acidic enough to significantly effect the dissolution rate.

The behavior of the doped radionuclides in the system was of particular interest. Uranium and neptunium were released from the glass as it became hydrated and were depleted in the gel. Uranium was found both contained in precipitates and adsorbed onto the stainless steel vessel surfaces. Neptunium was associated with a filterable colloidal fraction in the leachate (as a suspension) as well as having a high solution concentration. The solubility of neptunium is relatively high under the experimental conditions. Plutonium and americium were released from the gel as it etched, but because both species have very low solubilities at the experimental pH values, most of the americium remained on the glass surface as insoluble residue while most plutonium was adsorbed onto the stainless steel vessel surface.

These experiments provide valuable information regarding the interactions which occur between components expected to be present in a tuff repository. A worst-case occurrence would be a premature breach of the stainless steel container, possibly at a bad weld site, and subsequent infiltration of liquid water to fill the container. These experiments are directly applicable to such an event. The results predict any radionuclides released through glass reaction would either remain on the glass surface as a precipitate or as an insoluble residue, or adsorb onto the stainless steel container. Because of their low solubilities in these solutions, only a very small fraction of radionuclides would be able to escape the immediate region.

Since the repository horizon is predicted to remain dry throughout the isolation period, the likelihood of liquid water contacting the waste form or even the canister is highly remote.

These and previous experiments performed under various gamma radiation exposures used experimental designs with common air-to-leachant volume ratios, glass surface area-to-leachant volume ratios, glass compositions, vessel materials, groundwater, and tuff. All these materials are expected to be present in the repository. The actual gamma field that will be present will vary with time and location in the repository, as will the temperature. The larger radiation exposure rates used in these and previous experiments are probably much higher than those that will be present during the isolation period, when the waste will experience exposures closer to 50 mR/h. It was seen that the leachate pH was buffered to 6.4 by the bicarbonate-carbonate buffer and the reaction was not accelerated.

The glass surface area-to-leachate volume ratio is smaller in these experiments than is expected in the repository. This difference will be manifested in the leachate pH as discussed above in that the leachate will become acidic more quickly even at low exposures. Smaller leachate volumes will have lower capacities for released species and so more precipitates will form on the glass. Transport of released radionuclides away from the repository will be eliminated without the presence of a liquid phase.

VII. DATA TABLES

This section presents the complete set of data in the form of several data tables which contain:

A: Complete Matrix with Component Data

B: Complete Anion Analysis Results

C: Complete Cation Analysis Results

D: Complete Actinide Analysis Results

DATA TABLE A: Experimental Matrix for FY 1986
Gamma Irradiation Experiments

This table contains data essential to performing the experiments including component weight change data and (quenched) leachate pH. The "LPE NET MASS" refers to the mass of leachate solution submitted for analysis. It does not include any dilution performed by the analyst.

Data Table A. NNWSI FY 1986 Gamma Irradiation Experiments Matrix

EXP'T TYPE	EXP'T NUMBER	SAMPLE NUMBER	EXP'T DURATION (days)	DATE IN	DATE OUT	VESSEL NUMBER	GLASS THICKNESS (mm)	GLASS DIAMETER (mm)	GLASS SURFACE AREA (mm**2)	GLASS MASS IN (g)	GLASS MASS OUT (g)	GLASS MASS CHANGE (g)
SRL U	G-300	301	28	7/24	8/21	139	1.98	10.83	252	0.46676	0.46656	-0.00020
		302					1.92	11.06	259	0.45356	0.45349	-0.00007
	G-301	303	28	7/24	8/21	56	1.94	10.80	249	0.47303	0.47290	-0.00013
		304					1.80	10.75	242	0.43547	0.43539	-0.00008
	G-302	305	56	7/8	9/2	131	1.90	10.75	246	0.45900	0.45877	-0.00023
		306					1.91	10.78	247	0.46390	0.47365	0.00975
	G-303	307	56	7/8	9/2	135	1.98	10.88	254	0.48531	0.48473	-0.00058
		308					1.93	10.75	247	0.46814	0.46776	-0.00038
	G-304	309	91	12/18	3/19	83	1.92	10.98	256	0.48174	0.48100	-0.00074
		310					1.98	11.00	258	0.49544	0.49495	-0.00049
	G-305	311	91	12/18	3/19	68	1.92	10.80	248	0.47078	0.47030	-0.00048
		312					1.42	11.01	240	0.35439	0.35407	-0.00032
	G-306	313	181	12/18	6/18	106	1.74	10.87	245	0.42665	0.42577	-0.00088
		314					1.93	11.04	258	0.48190	0.48095	-0.00095
	G-307	315	181	12/16	6/18	107	1.90	10.74	245	0.45836	0.45745	-0.00091
		316					2.32	10.77	261	0.51030	0.50956	-0.00074
	G-308	317	278	12/18	9/24	108	1.95	10.91	254	0.48997	0.48918	-0.00079
		318					1.97	10.78	249	0.45511	0.45450	-0.00061
	G-309	319	278	12/18	9/24	109	1.92	10.80	248	0.46574	0.46497	-0.00077
		320					1.42	10.68	227	0.34054	0.33999	-0.00055
SRL U + TUFF	G-310	321	28	7/24	8/21	118	1.93	10.86	251	0.47163	0.47131	-0.00032
		322					1.92	10.77	247	0.46265	0.46248	-0.00017
	G-311	323	28	7/24	8/21	44	2.15	10.75	254	0.47447	0.47420	-0.00027
		324					2.40	10.77	263	0.52533	0.52517	-0.00016
	G-312	325	56	7/8	9/2	69	1.98	10.90	254	0.48087	0.48036	-0.00051
		326					2.31	10.75	260	0.54634	0.54597	-0.00037
	G-313	327	56	7/8	9/2	130	1.92	10.90	252	0.45269	0.45208	-0.00061
		328					1.87	10.80	247	0.45205	0.45168	-0.00037
	G-314	329	91	12/18	3/19	69	1.97	10.86	252	0.48782	0.48717	-0.00065
		330					1.68	10.88	243	0.41755	0.41711	-0.00044
	G-315	331	91	12/18	3/19	87	1.87	10.95	253	0.47163	0.47087	-0.00076
		332					1.94	10.52	238	0.46818	0.46758	-0.00060
	G-316	333	181	12/18	6/18	110	1.90	10.85	250	0.46144	0.46010	-0.00134
		334					1.91	10.78	247	0.46323	0.46221	-0.00102
	G-317	335	181	12/18	6/18	111	1.98	10.92	255	0.48412	0.48283	-0.00129
		336					2.32	10.96	269	0.55272	0.55164	-0.00108
	G-318	337	278	12/18	9/24	112	1.90	10.76	246	0.46477	0.46362	-0.00115
		338					1.78	10.87	246	0.42835	0.42734	-0.00101
	G-319	339	278	12/18	9/24	113	1.93	10.72	246	0.46827	0.46702	-0.00125
		340					1.99	10.75	249	0.45822	0.45733	-0.00089
SRL A	G-320	341	28	7/24	8/21	114	1.80	11.23	262	0.47441	0.47438	-0.00003
		342					1.27	10.90	230	0.31206	0.31210	0.00004
	G-321	343	28	7/24	8/21	44	1.77	10.92	248	0.44818	0.44820	0.00002
		344					2.19	10.90	262	0.54294	0.54292	-0.00002
	G-322	345	56	7/8	9/2	55	1.83	10.88	248	0.45961	0.45947	-0.00014
		346					1.92	11.24	266	0.46703	0.46692	-0.00011
	G-323	347	56	7/8	9/2	123	1.77	10.91	248	0.44762	0.44745	-0.00017

Data Table A (Cont'd)

EXP'T TYPE	EXP'T NUMBER	SAMPLE NUMBER	LEACHATE pH OUT	SUPPORT MASS IN (g)	SUPPORT MASS OUT (g)	SUPPORT MASS CHANGE (g)	MASS EJ-13 IN (g)	ASSEMBLY MASS IN (g)	ASSEMBLY MASS OUT (g)	ASSEMBLY MASS CHANGE (g)	LPE NET MASS (g)	NORMALIZED GLASS MASS LOSS (g/m**2)
SRL U	G-300	301	7.54	4.9294	4.9298	0.0004	14.87	304.84	304.80	-0.04	-	0.53
		302										
	G-301	303	7.42	4.9219	4.9220	0.0001	14.91	303.47	303.44	-0.03	12.44	0.43
		304										
	G-302	305	6.81	4.9848	4.9848	0.0000	14.91	302.72	302.67	-0.05	12.33	0.93
		306										
	G-303	307	6.84	5.0262	5.0254	-0.0008	14.89	305.88	305.83	-0.05	12.27	1.92
		308										
	G-304	309	4.70	4.8973	4.8971	-0.0002	14.89	302.00	301.92	-0.08	12.54	2.39
		310										
	G-305	311	6.80	4.9422	4.9422	0.0000	14.91	300.86	300.76	-0.10	12.13	1.64
		312										
	G-306	313	6.87	4.9748	4.9744	-0.0004	14.87	302.27	302.19	-0.08	12.28	3.64
		314										
	G-307	315	7.04	4.8930	4.8930	0.0000	14.87	302.07	301.89	-0.18	12.12	3.26
		316										
	G-308	317	5.25	4.9479	4.9480	0.0001	14.89	305.25	305.13	-0.12	12.28	2.78
		318										
	G-309	319	6.78	4.9156	4.9157	0.0001	14.87	305.37	305.15	-0.22	12.24	2.78
		320										
SRL U + TUFF	G-310	321	7.47	4.9838	4.9838	0.0000	14.59	303.87	303.85	-0.02	11.89	0.98
		322										
	G-311	323	7.37	4.8928	4.8930	0.0002	14.59	306.34	306.31	-0.03	-	0.83
		324										
	G-312	325	6.91	5.0298	5.0302	0.0004	14.50	306.14	306.08	-0.06	11.69	1.71
		326										
	G-313	327	6.75	4.9364	4.9366	0.0002	14.49	311.47	311.41	-0.06	11.73	1.96
		328										
	G-314	329	6.99	4.9084	4.9081	-0.0003	14.60	303.87	303.73	-0.14	12.09	2.20
		330										
	G-315	331	6.78	4.9431	4.9428	-0.0003	14.62	304.48	304.46	-0.02	11.86	2.77
		332										
	G-316	333	7.12	4.9183	4.9181	-0.0002	14.59	309.72	309.58	-0.14	11.86	4.75
		334										
	G-317	335	7.10	4.9054	4.9051	-0.0003	14.56	305.23	305.11	-0.12	11.84	4.52
		336										
	G-318	337	7.56	4.9195	4.9184	-0.0011	14.60	303.22	303.00	-0.22	11.86	4.39
		338										
	G-319	339	7.53	4.8850	4.8851	0.0001	14.59	305.35	305.11	-0.24	11.70	4.33
		340										
SRL A	G-320	341	7.40	5.0801	4.8982	-0.1819	14.87	302.49	302.45	-0.04	11.88	-0.02
		342										
	G-321	343	7.54	4.9491	4.8987	-0.0504	14.92	305.51	305.47	-0.04	12.29	0.00
		344										
	G-322	345	6.96	4.9202	4.9196	-0.0006	14.90	303.16	303.12	-0.04	11.69	0.49
		346										
	G-323	347	6.94	5.0752	5.0759	0.0007	14.91	303.82	303.77	-0.05	12.30	0.39

Data Table A (Cont'd)

EXP'T TYPE	EXP'T NUMBER	SAMPLE NUMBER	EXP'T DURATION (days)	DATE IN	DATE OUT	VESSEL NUMBER	GLASS THICKNESS (mm)	GLASS DIAMETER (mm)	GLASS SURFACE AREA (mm**2)	GLASS MASS IN (g)	GLASS MASS OUT (g)	GLASS MASS CHANGE (g)
		348					1.56	10.92	241	0.37879	0.37877	-0.00002
	G-324	349	91	12/18	3/19	55	1.79	10.90	248	0.44887	0.44845	-0.00042
		350					1.77	10.96	250	0.44720	0.44687	-0.00033
	G-325	351	91	12/18	3/19	65	1.93	10.92	254	0.47454	0.47393	-0.00061
		352					1.86	11.14	260	0.46293	0.46246	-0.00047
	G-326	353	181	12/18	6/18	114	1.76	11.02	252	0.44790	0.44709	-0.00081
		354					1.88	11.25	265	0.46573	0.46498	-0.00075
	G-327	355	181	12/18	6/18	115	1.74	10.99	250	0.43049	0.42974	-0.00075
		356					1.50	11.29	253	0.34679	0.34621	-0.00058
	G-328	357	278	12/18	9/24	116	1.82	11.00	253	0.44839	0.44769	-0.00070
		358					1.87	11.10	259	0.47795	0.47725	-0.00070
	G-329	359	278	12/18	9/24	117	1.78	10.91	248	0.44653	0.44580	-0.00073
		360					1.75	11.32	264	0.44740	0.45686	0.00946
SRL A + TUFF	G-330	361	28	7/24	8/21	146	1.83	11.08	257	0.47534	0.47524	-0.00010
		362					2.44	10.92	271	0.60883	0.60871	-0.00012
	G-331	363	28	7/24	8/21	143	1.84	11.19	261	0.48268	0.48259	-0.00009
		364					0.89	10.94	219	0.22349	0.22347	-0.00002
	G-332	365	56	7/8	9/2	91	1.81	11.15	259	0.47487	0.47449	-0.00038
		366					1.74	11.02	251	0.43659	0.43628	-0.00031
	G-333	367	56	7/8	9/2	38	1.83	11.10	257	0.47062	0.47021	-0.00041
		368					1.77	10.91	248	0.44445	0.44411	-0.00034
	G-334	369	91	12/18	3/19	66	1.79	10.93	249	0.44885	0.44819	-0.00066
		370					1.66	10.94	245	0.41082	0.41028	-0.00054
	G-335	371	91	12/18	3/19	67	1.88	10.90	251	0.44139	0.44077	-0.00062
		372					1.94	11.25	267	0.49674	0.49625	-0.00049
	G-336	373	181	12/18	6/18	118	1.84	11.10	258	0.47905	0.47791	-0.00114
		374					1.72	10.90	246	0.42940	0.42847	-0.00093
	G-337	375	181	12/18	6/18	119	1.97	11.17	265	0.50788	0.50688	-0.00100
		376					1.87	11.16	261	0.48985	0.48919	-0.00066
	G-338	377	278	12/18	9/24	120	1.76	11.06	253	0.44971	0.44846	-0.00125
		378					1.67	10.87	243	0.41091	0.40986	-0.00105
	G-339	379	278	12/18	9/24	121	1.88	10.93	252	0.48003	0.47839	-0.00164
		380					1.82	11.23	262	0.45786	0.45686	-0.00100
SRL U NO GAMMA	G-340	381	14	9/4	9/18	142	1.94	10.85	251	0.47044	0.47041	-0.00003
		382					2.18	10.73	254	0.47254	0.47252	-0.00002
	G-341	383	14	9/4	9/18	84	1.86	10.94	252	0.45676	0.45672	-0.00004
		384					1.84	10.76	244	0.45154	0.45154	0.00000
	G-342	385	28	7/24	8/21	87	1.78	10.86	246	0.42002	0.41990	-0.00012
		386					1.85	10.76	244	0.45248	0.45240	-0.00008
	G-343	387	28	7/24	8/21	45	1.93	10.74	246	0.46784	0.46761	-0.00023
		388					1.70	10.99	248	0.38487	0.38466	-0.00021
	G-344	389	56	7/8	9/2	89	1.92	10.76	247	0.46982	0.46969	-0.00013
		390					2.11	10.76	253	0.51451	0.51454	0.00003
	G-345	391	56	7/8	9/2	115	1.95	10.80	249	0.47981	0.47954	-0.00027
		392					1.53	10.81	236	0.36291	0.36237	-0.00054
	G-346	393	91	3/21	6/19	76	1.92	10.76	247	0.46855	0.46790	-0.00065
		394					1.69	10.80	241	0.34779	0.34732	-0.00047

Data Table A (Cont'd)

EXP'T TYPE	EXP'T NUMBER	SAMPLE NUMBER	LEACHATE pH OUT	SUPPORT MASS IN (g)	SUPPORT MASS OUT (g)	SUPPORT MASS CHANGE (g)	MASS EJ-13 IN (g)	ASSEMBLY MASS IN (g)	ASSEMBLY MASS OUT (g)	ASSEMBLY MASS CHANGE (g)	LPE NET MASS (g)	NORMALIZED GLASS MASS LOSS (g/m**2)
		348										
	G-324	349	6.69	4.9049	4.9048	-0.0001	14.94	302.95	302.86	-0.09	12.07	1.51
		350										
	G-325	351	6.94	4.8909	4.8907	-0.0002	14.87	304.87	304.79	-0.08	12.21	2.10
		352										
	G-326	353	7.29	4.9086	4.9080	-0.0006	14.85	303.39	303.23	-0.16	11.65	3.02
		354										
	G-327	355	7.22	4.9610	4.9605	-0.0005	14.87	301.28	301.13	-0.15	12.31	2.64
		356										
	G-328	357	5.35	4.9228	5.9232	1.0004	14.89	301.99	301.78	-0.21	11.75	2.74
		358										
	G-329	359	7.56	4.8935	4.8929	-0.0006	14.91	308.72	308.54	-0.18	12.26	2.85
		360										
SRL A + TUFF	G-330	361	7.38	4.8467	4.9385	0.0918	14.62	312.24	312.20	-0.04	11.39	0.42
		362								0.00		
	G-331	363	7.34	4.9135	4.8629	-0.0506	14.58	304.99	304.97	-0.02	12.01	0.23
		364										
	G-332	365	6.69	4.9729	4.9743	0.0014	14.50	308.84	308.81	-0.03	11.39	1.35
		366										
	G-333	367	6.80	4.9646	4.9646	0.0000	14.50	306.59	306.53	-0.06	11.68	1.49
		368										
	G-334	369	6.83	4.9666	4.9668	0.0002	14.52	306.00	305.93	-0.07	11.47	2.43
		370										
	G-335	371	7.04	4.7996	4.7994	-0.0002	14.63	304.33	304.23	-0.10	11.68	2.12
		372										
	G-336	373	7.20	4.8867	4.8861	-0.0006	14.59	304.40	304.30	-0.10	11.36	4.11
		374										
	G-337	375	7.30	4.8999	4.8935	-0.0064	14.59	304.46	304.28	-0.18	11.80	3.15
		376										
	G-338	377	7.56	4.8458	4.8449	-0.0009	14.57	305.87	305.65	-0.22	11.33	4.64
		378										
	G-339	379	7.69	4.9159	4.9164	0.0005	14.56	306.55	306.32	-0.23	11.86	5.13
		380										
SRL U NO GAMMA	G-340	381	8.29	4.8113	4.8109	-0.0004	14.89	306.01	306.00	-0.01	12.67	0.10
		382										
	G-341	383	8.31	4.9828	4.9826	-0.0002	14.89	306.71	306.70	-0.01	12.68	0.08
		384										
	G-342	385	8.85	5.0019	5.0019	0.0000	14.91	302.95	302.92	-0.03	12.27	0.41
		386										
	G-343	387	8.82	4.9489	4.9487	-0.0002	14.90	304.35	304.31	-0.04	12.41	0.89
		388										
	G-344	389	8.42	4.9474	4.9470	-0.0004	14.87	303.71	303.68	-0.03	12.07	0.20
		390										
	G-345	391	8.61	5.1064	5.1055	-0.0009	14.89	300.76	300.72	-0.04	12.08	1.67
		392										
	G-346	393	9.27	4.9085	4.9083	-0.0002	14.87	301.54	301.46	-0.08	12.15	2.30
		394										

Data Table A (Cont'd)

EXP'T TYPE	EXP'T NUMBER	SAMPLE NUMBER	EXP'T DURATION (days)	DATE IN	DATE OUT	VESSEL NUMBER	GLASS THICKNESS (mm)	GLASS DIAMETER (mm)	GLASS SURFACE AREA (mm**2)	GLASS MASS IN (g)	GLASS MASS OUT (g)	GLASS MASS CHANGE (g)
	G-347	395	91	3/21	6/19	77	1.94	10.91	253	0.48240	0.48287	0.00047
		396					1.88	10.96	253	0.46685	0.46637	-0.00048
	G-348	397	181	12/18	6/18	122	1.97	10.94	256	0.49051	0.48968	-0.00083
		398					1.94	10.88	252	0.47548	0.47487	-0.00061
	G-349	399	181	12/18	6/18	123	2.03	10.92	257	0.46962	0.46890	-0.00072
		400					1.90	10.86	250	0.47604	0.47548	-0.00056
	G-350	401	278	12/18	9/24	124	2.07	10.96	260	0.51455	0.51398	-0.00057
		402					1.95	10.93	255	0.48865	0.48805	-0.00060
	G-351	403	278	12/18	9/24	125	1.88	10.77	246	0.45797	0.45733	-0.00064
		404					1.85	10.74	244	0.42504	0.42459	-0.00045
SRL U + TUFF	G-352	405	14	9/4	9/18	79	1.70	10.98	248	0.42245	0.42232	-0.00013
		406					1.96	10.90	254	0.48009	0.48004	-0.00005
NO GAMMA	G-353	407	14	9/4	9/18	119	2.01	10.77	250	0.47864	0.47855	-0.00009
		408					1.89	10.80	247	0.45785	0.45783	-0.00002
	G-354	409	28	7/24	8/21	111	1.87	11.01	255	0.47726	0.47681	-0.00045
		410					1.94	10.74	247	0.46871	0.46835	-0.00036
	G-355	411	28	7/24	8/21	42	1.94	10.76	247	0.47499	0.47456	-0.00043
		412					1.90	10.83	249	0.46673	0.46643	-0.00030
	G-356	413	56	7/8	9/2	88	2.02	10.77	251	0.47722	0.47649	-0.00073
		414					1.81	10.77	243	0.42786	0.42752	-0.00034
	G-357	415	56	7/8	9/2	78	1.69	10.91	245	0.41481	0.41428	-0.00053
		416					2.13	10.22	232	0.42904	0.42853	-0.00051
	G-358	417	91	3/21	6/19	38	1.75	10.77	241	0.42330	0.42240	-0.00090
		418					1.99	11.05	261	0.50300	0.50211	-0.00089
	G-359	419	91	3/21	6/19	73	2.00	10.82	252	0.45314	0.45215	-0.00099
		420					1.92	10.74	246	0.45091	0.44996	-0.00095
	G-360	421	181	12/18	6/18	126	1.74	10.97	249	0.39227	0.39082	-0.00145
		422					2.34	10.73	260	0.55636	0.55595	-0.00041
	G-361	423	181	12/18	6/18	127	2.33	10.82	263	0.57353	0.57195	-0.00158
		424					1.93	10.78	248	0.46882	0.46747	-0.00135
	G-362	425	278	12/18	9/24	128	1.84	10.96	252	0.46723	0.46559	-0.00164
		426					1.92	10.73	246	0.46266	0.46099	-0.00167
	G-363	427	278	12/18	9/24	129	1.92	10.80	248	0.46597	0.46435	-0.00162
		428					1.87	11.24	264	0.41338	0.41195	-0.00143
SRL A	G-364	429	14	9/4	9/18	106	1.93	11.19	265	0.47795	0.47796	0.00001
NO GAMMA		430					1.56	11.42	261	0.38485	0.38491	0.00006
	G-365	431	14	9/4	9/18	111	1.80	11.14	258	0.46873	0.46572	-0.00301
		432					1.85	11.03	255	0.46319	0.46312	-0.00007
	G-366	433	28	7/24	8/21	50	1.85	10.93	251	0.46693	0.46682	-0.00011
		434					1.76	11.03	252	0.44635	0.44630	-0.00005
	G-367	435	28	7/24	8/21	29	1.85	11.12	259	0.45851	0.45843	-0.00008
		436					2.27	10.90	264	0.52561	0.52557	-0.00004
	G-368	437	56	7/8	9/2	95	1.83	11.21	262	0.48331	0.48331	0.00000
		438					1.82	11.33	266	0.47349	0.47350	0.00001
	G-369	439	56	7/8	9/2	138	1.84	11.05	256	0.46809	0.46784	-0.00025
		440					1.98	10.89	254	0.53055	0.53022	-0.00033
	G-370	441	91	3/21	6/19	87	1.78	10.89	247	0.44888	0.44844	-0.00044

Data Table A (Cont'd)

EXP'T TYPE	EXP'T NUMBER	SAMPLE NUMBER	LEACHATE pH OUT	SUPPORT MASS IN (g)	SUPPORT MASS OUT (g)	SUPPORT MASS CHANGE (g)	MASS EJ-13 IN (g)	ASSEMBLY MASS IN (g)	ASSEMBLY MASS OUT (g)	ASSEMBLY MASS CHANGE (g)	LPE NET MASS (g)	NORMALIZED GLASS MASS LOSS (g/m**2)
	G-347	395	9.27	4.8875	4.8876	0.0001	14.88	305.87	305.83	-0.04	12.22	1.89
		396										
	G-348	397	9.06	4.8225	4.8226	0.0001	14.92	302.17	302.01	-0.16	11.96	2.83
		398										
	G-349	399	8.53	4.8542	4.8539	-0.0003	14.93	303.66	303.48	-0.18	11.92	2.52
		400										
	G-350	401	8.82	4.9223	4.9223	0.0000	14.89	305.16	304.86	-0.30	12.15	2.27
		402										
	G-351	403	9.06	4.9699	4.9695	-0.0004	14.84	303.05	302.79	-0.26	10.13	2.23
		404										
SRL U + TUFF	G-352	405	7.73	4.8250	4.8248	-0.0002	14.49	307.56	307.54	-0.02	12.10	0.36
		406										
NO GAMMA	G-353	407	7.66	4.9061	4.9058	-0.0003	14.49	307.61	307.59	-0.02	12.14	0.22
		408										
	G-354	409	8.14	4.8407	4.8405	-0.0002	14.62	304.72	304.69	-0.03	11.86	1.61
		410										
	G-355	411	8.28	4.9945	4.9946	0.0001	14.59	305.60	305.53	-0.07	11.94	1.47
		412										
	G-356	413	8.41	4.9101	4.9100	-0.0001	14.50	305.93	305.89	-0.04	11.58	2.17
		414										
	G-357	415	8.34	4.9652	4.9652	0.0000	14.52	306.11	306.08	-0.03	11.69	2.18
		416										
	G-358	417	8.74	4.9419	4.9418	-0.0001	14.51	304.08	304.03	-0.05	11.75	3.56
		418										
	G-359	419	8.85	4.9420	4.9422	0.0002	14.48	308.33	308.21	-0.12	11.49	3.90
		420										
	G-360	421	8.85	4.9525	4.9524	-0.0001	14.56	304.62	304.42	-0.20	11.60	3.66
		422										
	G-361	423	8.98	4.7807	4.7808	0.0001	14.49	306.64	306.48	-0.16	11.45	5.73
		424										
	G-362	425	8.97	4.9088	4.9089	0.0001	14.53	311.41	311.12	-0.29	11.36	6.65
		426										
	G-363	427	8.99	4.8950	4.8952	0.0002	14.54	304.77	304.49	-0.28	11.54	5.95
		428										
SRL A NO GAMMA	G-364	429	8.28	4.9758	4.9748	-0.0010	14.89	301.49	301.49	0.00	11.98	-0.13
		430										
	G-365	431	8.30	4.9897	4.9897	0.0000	14.89	303.76	303.73	-0.03	12.58	0.27
		432										
	G-366	433	8.93	4.9165	4.9221	0.0056	14.90	305.55	305.52	-0.03	11.92	0.32
		434										
	G-367	435	8.91	4.9115	4.9897	0.0782	14.90	308.12	308.10	-0.02	12.68	0.23
		436										
	G-368	437	8.74	4.9846	4.9854	0.0008	14.90	309.88	309.84	-0.04	11.86	-0.02
		438										
	G-369	439	8.97	4.9138	4.9130	-0.0008	14.90	301.82	301.73	-0.09	12.28	1.14
		440										
	G-370	441	9.21	4.9098	4.9097	-0.0001	14.90	302.06	302.01	-0.05	11.58	1.75

Data Table A (Cont'd)

EXP'T TYPE	EXP'T NUMBER	SAMPLE NUMBER	EXP'T DURATION (days)	DATE IN	DATE OUT	VESSEL NUMBER	GLASS THICKNESS (mm)	GLASS DIAMETER (mm)	GLASS SURFACE AREA (mm**2)	GLASS MASS IN (g)	GLASS MASS OUT (g)	GLASS MASS CHANGE (g)
		442					1.82	10.91	249	0.45826	0.45783	-0.00043
	G-371	443	91	3/21	6/19	74	1.84	11.18	261	0.48156	0.48107	-0.00049
		444					1.70	11.10	253	0.42834	0.42798	-0.00036
	G-372	445	181	12/18	6/18	130	1.82	10.92	250	0.45456	0.45382	-0.00074
		446					1.79	11.00	252	0.45766	0.45707	-0.00059
	G-373	447	181	12/18	6/18	131	2.08	11.08	265	0.53309	0.53242	-0.00067
		448					1.78	11.08	255	0.45278	0.45227	-0.00051
	G-374	449	278	12/18	9/24	132	1.45	11.10	244	0.35856	0.35746	-0.00110
		450					1.77	11.04	253	0.42928	0.42821	-0.00107
	G-375	451	278	12/18	9/24	133	1.80	10.98	251	0.45015	0.44957	-0.00058
		452					1.74	11.11	255	0.41350	0.41300	-0.00050
SRL A + TUFF	G-376	453	14	9/4	9/18	87	1.86	11.33	268	0.37002	0.36982	-0.00020
		454					1.10	10.84	222	0.22468	0.22455	-0.00013
NO GAMMA	G-377	455	14	9/4	9/18	118	1.89	12.07	301	0.54767	0.54743	-0.00024
		456					0.86	10.92	217	0.16796	0.16784	-0.00012
	G-378	457	28	7/24	8/21	68	1.31	11.24	245	0.31980	0.31957	-0.00023
		458					0.99	10.96	223	0.21365	0.21336	-0.00029
	G-379	459	28	7/24	8/21	17	1.31	10.90	231	0.22655	0.22632	-0.00023
		460					1.86	11.22	263	0.49426	0.49410	-0.00016
	G-380	461	56	7/8	9/2	110	1.80	11.50	273	0.47357	0.47296	-0.00061
		462					1.80	10.96	251	0.46868	0.46826	-0.00042
	G-381	463	56	7/8	9/2	67	1.87	11.10	259	0.42885	0.42856	-0.00029
		464					1.11	10.88	224	0.24099	0.24086	-0.00013
	G-382	465	91	3/21	6/19	69	1.74	10.93	247	0.43377	0.43264	-0.00113
		466					2.54	10.94	275	0.56275	0.56184	-0.00091
	G-383	467	91	3/21	6/19	89	1.83	10.95	251	0.45944	0.45833	-0.00111
		468					1.45	10.88	236	0.34575	0.34487	-0.00088
	G-384	469	181	12/18	6/18	134	1.88	10.91	251	0.47173	0.47040	-0.00133
		470					1.87	11.19	262	0.48990	0.48858	-0.00132
	G-385	471	181	12/18	6/18	135	1.89	11.05	257	0.48376	0.48258	-0.00118
		472					1.74	10.93	247	0.43368	0.43257	-0.00111
	G-386	473	278	12/18	9/24	136	1.81	10.74	242	0.45629	0.45459	-0.00170
		474					1.74	11.06	253	0.43523	0.43367	-0.00156
	G-387	475	278	12/18	9/24	137	1.95	10.94	255	0.45053	0.44893	-0.00160
		476					1.81	11.21	261	0.47961	0.47796	-0.00165
ATM-1c	G-388	477	28	7/24	8/21	18	1.72	10.73	239	0.46552	0.46480	-0.00072
		478					1.85	10.72	243	0.46581	0.46544	-0.00037
	G-389	479	28	7/24	8/21	107	1.94	10.95	255	0.51474	0.51403	-0.00071
		480					1.82	10.69	241	0.48081	0.48039	-0.00042
	G-390	481	56	7/8	9/2	147	1.88	10.84	249	0.48543	0.48435	-0.00108
		482					1.83	10.78	245	0.48953	0.48863	-0.00090
	G-391	483	56	7/8	9/2	52	1.82	10.81	245	0.48954	0.48834	-0.00120
		484					1.82	10.71	241	0.48843	0.48765	-0.00078
	G-392	485	91	12/18	3/19	74	1.80	10.81	245	0.48096	0.47949	-0.00147
		486					1.76	10.71	239	0.47039	0.46921	-0.00118
	G-393	487	91	12/18	3/19	76	1.92	10.75	246	0.50832	0.50696	-0.00136
		488					1.78	10.71	240	0.47327	0.47203	-0.00124

Data Table A (Cont'd)

EXP'T TYPE	EXP'T NUMBER	SAMPLE NUMBER	LEACHATE pH OUT	SUPPORT MASS IN (g)	SUPPORT MASS OUT (g)	SUPPORT MASS CHANGE (g)	MASS EJ-13 IN (g)	ASSEMBLY MASS IN (g)	ASSEMBLY MASS OUT (g)	ASSEMBLY MASS CHANGE (g)	LPE NET MASS (g)	NORMALIZED GLASS MASS LOSS (g/m**2)
		442										
	G-371	443	9.24	4.8346	4.8340	-0.0006	14.89	303.07	303.02	-0.05	12.33	1.65
		444										
	G-372	445	7.93	4.8926	4.8922	-0.0004	14.91	302.75	302.62	-0.13	11.66	2.65
		446										
	G-373	447	9.12	4.8445	4.8439	-0.0006	14.91	303.90	303.73	-0.17	12.27	2.27
		448										
	G-374	449	5.04	4.8807	4.8801	-0.0006	14.97	305.99	305.71	-0.28	11.56	4.37
		450										
	G-375	451	7.54	4.9142	4.9144	0.0002	14.86	308.82	308.54	-0.28	11.79	2.13
		452										
SRL A + TUFF	G-376	453	7.60	4.9399	4.9400	0.0001	14.50	304.24	304.22	-0.02	11.27	0.67
		454										
NO GAMMA	G-377	455	7.77	4.9764	4.9767	0.0003	14.50	306.15	306.12	-0.03	11.66	0.70
		456										
	G-378	457	8.10	4.8987	5.0804	0.1817	14.59	307.71	307.68	-0.03	11.42	1.11
		458										
	G-379	459	8.47	4.8981	4.9490	0.0509	14.59	309.24	309.20	-0.04	11.86	0.79
		460										
	G-380	461	8.49	4.9113	4.9095	-0.0018	14.52	306.56	306.52	-0.04	11.28	1.97
		462										
	G-381	463	8.25	4.9115	4.9694	0.0579	14.50	308.45	308.38	-0.07	11.83	0.87
		464										
	G-382	465	8.85	4.8971	4.8966	-0.0005	14.49	303.98	303.91	-0.07	11.10	3.90
		466										
	G-383	467	8.80	4.9462	4.9464	0.0002	14.49	303.91	303.85	-0.06	9.87	4.09
		468										
	G-384	469	8.90	4.9048	4.9045	-0.0003	14.51	303.92	303.77	-0.15	11.13	5.16
		470										
	G-385	471	8.81	4.9442	4.9437	-0.0005	14.53	304.79	304.65	-0.14	11.57	4.54
		472										
	G-386	473	9.02	4.8930	4.8930	0.0000	14.54	309.34	309.01	-0.33	11.03	6.59
		474										
	G-387	475	9.07	4.8391	4.8390	-0.0001	14.53	307.06	306.80	-0.26	11.53	6.30
		476										
ATM-1c	G-388	477	8.84	4.9439	4.9438	-0.0001	14.89	303.15	303.10	-0.05	12.28	2.26
		478										
	G-389	479	8.92	4.9266	4.9265	-0.0001	14.90	300.92	300.90	-0.02	12.35	2.28
		480										
	G-390	481	8.12	4.8950	4.9854	0.0904	14.87	303.18	303.12	-0.06	12.26	4.02
		482										
	G-391	483	8.38	4.9615	4.9617	0.0002	14.90	302.38	302.35	-0.03	12.30	4.07
		484										
	G-392	485	7.95	4.9198	4.9195	-0.0003	14.91	305.05	304.98	-0.07	12.70	5.47
		486										
	G-393	487	8.08	4.8928	4.8926	-0.0002	14.88	300.89	300.82	-0.07	12.63	5.34
		488										

Data Table A (Cont'd)

EXP'T TYPE	EXP'T NUMBER	SAMPLE NUMBER	EXP'T DURATION (days)	DATE IN	DATE OUT	VESSEL NUMBER	GLASS THICKNESS (mm)	GLASS DIAMETER (mm)	GLASS SURFACE AREA (mm**2)	GLASS MASS IN (g)	GLASS MASS OUT (g)	GLASS MASS CHANGE (g)
	G-394	489	181	12/18	6/18	80	1.87	10.90	251	0.51648	0.51496	-0.00152
		490					1.78	10.77	242	0.47424	0.47289	-0.00135
	G-395	491	181	12/18	6/18	70	1.92	10.70	244	0.51721	0.51576	-0.00145
		492					1.74	10.67	237	0.43583	0.43471	-0.00112
	G-396	493	278	12/18	9/24	71	1.90	10.73	245	0.49373	0.49235	-0.00138
		494					1.85	10.74	244	0.49518	0.49390	-0.00128
	G-397	495	278	12/18	9/24	75	1.89	10.72	244	0.49488	0.49326	-0.00162
		496					1.80	10.71	241	0.47994	0.47857	-0.00137
ATM-1c + TUFF	G-398	497	28	7/24	8/21	122	1.88	10.75	245	0.50198	0.50106	-0.00092
		498					1.81	10.71	241	0.48277	0.48190	-0.00087
	G-399	499	28	7/24	8/21	106	1.99	10.70	247	0.49500	0.49396	-0.00104
		500					1.84	10.69	241	0.46796	0.46710	-0.00086
	G-400	501	56	7/8	9/2	134	1.92	10.75	246	0.48411	0.48240	-0.00171
		502					1.50	10.58	226	0.39927	0.39795	-0.00132
	G-401	503	56	7/8	9/2	39	1.80	10.79	244	0.48522	0.48352	-0.00170
		504					1.83	10.77	244	0.48791	0.48668	-0.00123
	G-402	505	91	12/18	3/19	90	1.84	10.84	247	0.49206	0.48978	-0.00228
		506					1.68	11.08	251	0.45328	0.45151	-0.00177
	G-403	507	91	12/18	3/19	77	1.84	10.74	243	0.49154	0.48953	-0.00201
		508					1.82	10.93	250	0.49571	0.49382	-0.00189
	G-404	509	181	12/18	6/18	78	1.80	10.81	245	0.48781	0.48545	-0.00236
		510					1.84	10.84	247	0.49931	0.49719	-0.00212
	G-405	511	181	12/18	6/18	88	1.81	10.70	241	0.48439	0.48235	-0.00204
		512					1.75	10.71	239	0.46692	0.46496	-0.00196
	G-406	513	278	12/18	9/24	81	1.80	10.73	242	0.48024	0.47767	-0.00257
		514					1.92	10.77	247	0.47665	0.47426	-0.00239
	G-407	515	278	12/18	9/24	82	1.88	10.72	244	0.49738	0.49512	-0.00226
		516					1.69	10.89	244	0.46470	0.46263	-0.00207
ATM-8	G-408	517	28	7/24	8/21	127	1.79	10.82	245	0.49337	0.49312	-0.00025
		518					1.78	10.83	245	0.48670	0.48640	-0.00030
	G-409	519	28	7/24	8/21	166	1.76	10.82	244	0.48670	0.49427	0.00757
		520					1.50	10.94	240	0.40408	0.40374	-0.00034
	G-410	521	56	7/8	9/2	77	2.02	10.82	253	0.52999	0.52922	-0.00077
		522					1.94	10.88	252	0.53954	0.53879	-0.00075
	G-411	523	56	7/8	9/2	83	1.83	10.90	249	0.50655	0.50565	-0.00090
		524					1.79	10.88	247	0.49435	0.49370	-0.00065
	G-412	525	91	12/18	3/19	50	1.82	10.92	250	0.50130	0.50017	-0.00113
		526					2.21	10.88	261	0.52598	0.52828	0.00230
	G-413	527	91	12/18	3/19	52	1.85	10.87	249	0.51293	0.51181	-0.00112
		528					1.88	10.82	248	0.50917	0.50813	-0.00104
	G-414	529	181	12/18	6/18	53	1.84	10.86	248	0.51408	0.51291	-0.00117
		530					1.77	10.83	244	0.50213	0.50119	-0.00094
	G-415	531	181	12/18	6/18	40	1.71	10.91	246	0.48090	0.47974	-0.00116
		532					1.77	10.90	247	0.48761	0.48656	-0.00105
	G-416	533	278	12/18	9/24	47	1.76	10.88	246	0.47729	0.47616	-0.00113
		534					1.90	10.85	250	0.50462	0.50335	-0.00127
	G-417	535	278	12/18	9/24	48	1.88	10.83	248	0.51359	0.51245	-0.00114

Data Table A (Cont'd)

EXP'T TYPE	EXP'T NUMBER	SAMPLE NUMBER	LEACHATE pH OUT	SUPPORT MASS IN (g)	SUPPORT MASS OUT (g)	SUPPORT MASS CHANGE (g)	MASS EJ-13 IN (g)	ASSEMBLY MASS IN (g)	ASSEMBLY MASS OUT (g)	ASSEMBLY MASS CHANGE (g)	LPE NET MASS (g)	NORMALIZED GLASS MASS LOSS (g/m**2)
	G-394	489 490	7.96	4.8649	4.8649	0.0000	14.89	308.89	308.84	-0.05	12.24	5.82
	G-395	491 492	7.81	4.9339	4.9336	-0.0003	14.89	302.61	302.44	-0.17	12.15	5.34
	G-396	493 494	7.05	4.9300	4.9299	-0.0001	14.91	303.82	303.63	-0.19	12.20	5.44
	G-397	495 496	7.72	4.9370	4.9372	0.0002	14.91	308.62	308.52	-0.10	11.99	6.17
ATM-1c + TUFF	G-398	497 498	8.42	4.9973	4.9973	0.0000	14.63	304.19	304.18	-0.01	11.95	3.68
	G-399	499 500	8.22	4.8517	4.8516	-0.0001	14.59	303.84	303.81	-0.03	11.82	5.94
	G-400	501 502	8.20	5.1235	5.0235	-0.1000	14.49	302.61	302.55	-0.06	11.72	6.42
	G-401	503 504	8.20	4.8916	4.8916	0.0000	14.49	304.09	304.04	-0.05	11.70	6.00
	G-402	505 506	8.09	4.9605	4.9601	-0.0004	14.62	304.38	304.30	-0.08	12.26	8.12
	G-403	507 508	8.24	4.9603	4.9603	0.0000	14.57	304.50	304.46	-0.04	12.27	7.90
	G-404	509 510	8.12	4.9905	4.9904	-0.0001	14.60	306.71	306.66	-0.05	11.89	9.11
	G-405	511 512	7.88	4.8719	4.8718	-0.0001	14.58	305.51	305.41	-0.10	11.33	8.34
	G-406	513 514	7.87	4.9420	4.9520	0.0100	14.58	309.30	309.17	-0.13	11.82	10.15
	G-407	515 516	6.86	4.9561	4.9460	-0.0101	14.59	308.89	308.75	-0.14	11.99	8.87
ATM-8	G-408	517 518	8.67	4.9383	4.8468	-0.0915	14.94	307.52	307.48	-0.04	11.99	1.10
	G-409	519 520	8.54	4.8626	4.9138	0.0512	14.91	304.31	304.27	-0.04	12.20	1.41
	G-410	521 522	7.92	4.8970	4.8972	0.0002	14.88	302.30	302.24	-0.06	11.72	3.01
	G-411	523 524	7.85	5.0158	5.0158	0.0000	14.90	302.12	302.07	-0.05	12.30	3.12
	G-412	525 526	7.61	4.9150	4.9150	0.0000	14.89	308.58	308.48	-0.10	11.99	4.42
	G-413	527 528	7.68	4.9188	4.9186	-0.0002	14.92	302.45	302.38	-0.07	12.37	4.35
	G-414	529 530	7.70	4.9130	4.9126	-0.0004	14.86	303.28	303.12	-0.16	11.80	4.28
	G-415	531 532	7.54	4.9193	4.9187	-0.0006	14.87	303.94	303.79	-0.15	12.21	4.48
	G-416	533 534	7.78	4.8845	4.8843	-0.0002	14.87	301.81	301.63	-0.18	11.67	4.84
	G-417	535	5.82	4.9144	4.9131	-0.0013	14.89	303.45	303.17	-0.28	12.12	4.19

Data Table A (Cont'd)

EXP'T TYPE	EXP'T NUMBER	SAMPLE NUMBER	EXP'T DURATION (days)	DATE IN	DATE OUT	VESSEL NUMBER	GLASS THICKNESS (mm)	GLASS DIAMETER (mm)	GLASS SURFACE AREA (mm**2)	GLASS MASS IN (g)	GLASS MASS OUT (g)	GLASS MASS CHANGE (g)
		536					2.22	10.85	261	0.59592	0.59493	-0.00099
ATM-8 + TUFF	G-418	537	28	7/24	8/21	73	1.85	10.86	248	0.49310	0.49253	-0.00057
		538					1.90	10.84	249	0.53059	0.53007	-0.00052
	G-419	539	28	7/24	8/21	37	1.83	11.06	256	0.51845	0.51768	-0.00077
		540					1.80	10.86	247	0.49808	0.49762	-0.00046
	G-420	541	56	7/8	9/2	70	1.92	10.89	252	0.50659	0.50533	-0.00126
		542					1.87	11.03	256	0.53085	0.52971	-0.00114
	G-421	543	56	7/8	9/2	126	1.92	10.82	249	0.49474	0.49346	-0.00128
		544					1.82	10.92	250	0.50993	0.50880	-0.00113
	G-422	545	91	12/18	3/19	79	2.15	10.82	257	0.57458	0.57275	-0.00183
		546					1.74	10.83	243	0.48267	0.48122	-0.00145
	G-423	547	91	12/18	3/19	49	1.78	10.83	245	0.49169	0.48992	-0.00177
		548					1.82	11.00	253	0.49924	0.49772	-0.00152
	G-424	549	181	12/18	6/18	39	1.78	10.96	250	0.50761	0.50557	-0.00204
		550					1.72	10.97	248	0.48345	0.48170	-0.00175
	G-425	551	181	12/18	6/18	92	1.79	10.93	249	0.48809	0.48619	-0.00190
		552					1.77	11.10	255	0.51165	0.50982	-0.00183
	G-426	553	278	12/18	9/24	93	1.89	11.00	255	0.53146	0.52918	-0.00228
		554					1.84	10.91	250	0.51265	0.51079	-0.00186
	G-427	555	278	12/18	9/24	94	1.94	10.88	252	0.50571	0.50375	-0.00196
		556					1.83	10.83	247	0.49782	0.49630	-0.00152
EJ-13	G-428		28	7/24	8/21	74						
	G-429		28	7/24	8/21	32						
	G-430		56	7/8	9/2	92						
	G-431		56	7/8	9/2	86						
	G-432		91	12/18	3/19	89						
	G-433		91	12/18	3/19	91						
	G-434		181	12/18	6/18	138						
	G-435		181	12/18	6/18	139						
	G-436		278	12/18	9/24	140						
	G-437		278	12/18	9/24	141						
EJ-13 + TUFF	G-438		28	7/24	8/21	142						
	G-439		28	7/24	8/21	34						
	G-440		56	7/8	9/2	40						
	G-441		56	7/8	9/2	53						
	G-442		91	12/18	3/19	37						
	G-443		91	12/18	3/19	38						
	G-444		181	12/18	6/18	142						
	G-445		181	12/18	6/18	143						
	G-446		278	12/18	9/24	144						
	G-447		278	12/18	9/24	145						
EJ-13 NO GAMMA	G-448		14	9/4	9/18	74						
	G-449		14	9/4	9/18	139						
	G-450		28	7/24	8/21	43						
	G-451		28	7/24	8/21	84						

Data Table A (Cont'd)

EXP'T TYPE	EXP'T NUMBER	SAMPLE NUMBER	LEACHATE pH OUT	SUPPORT MASS IN (g)	SUPPORT MASS OUT (g)	SUPPORT MASS CHANGE (g)	MASS EJ-13 IN (g)	ASSEMBLY MASS IN (g)	ASSEMBLY MASS OUT (g)	ASSEMBLY MASS CHANGE (g)	LPE NET MASS (g)	NORMALIZED GLASS MASS LOSS (g/m**2)
		536										
ATM-8 + TUFF	G-418	537	8.36	4.9220	4.9464	0.0244	14.61	310.76	310.70	-0.06	11.40	2.19
		538										
	G-419	539	8.05	5.0393	4.9113	-0.1280	14.61	304.88	304.84	-0.04	12.07	2.45
		540										
	G-420	541	7.59	4.8762	4.8756	-0.0006	14.47	305.84	305.77	-0.07	11.05	4.73
		542										
	G-421	543	7.48	5.0126	5.0121	-0.0005	14.52	304.11	304.04	-0.07	4.18	4.83
		544										
	G-422	545	7.95	4.8971	4.8969	-0.0002	14.63	312.39	312.31	-0.08	11.46	6.55
		546										
	G-423	547	7.70	4.9677	4.9278	-0.0399	14.65	311.21	311.12	-0.09	11.86	6.61
		548										
	G-424	549	7.51	4.9807	4.9806	-0.0001	14.59	304.22	304.13	-0.09	11.20	7.61
		550										
	G-425	551	7.74	4.8726	4.8723	-0.0003	14.64	308.88	308.74	-0.14	11.88	7.40
		552										
	G-426	553	8.01	4.8296	4.8297	0.0001	14.58	305.92	305.80	-0.12	11.29	8.19
		554										
	G-427	555	7.92	4.9541	4.9537	-0.0004	14.59	312.52	312.32	-0.20	11.68	6.98
		556										
EJ-13	G-428		7.44				15.48	303.69	303.62	-0.07	13.49	
	G-429		7.39				15.47	296.78	296.74	-0.04	12.91	
	G-430		6.57				16.20	302.26	302.20	-0.06	13.82	
	G-431		6.75				16.20	298.85	298.76	-0.09	13.83	
	G-432		6.26				16.19	304.05	303.97	-0.08	14.03	
	G-433		5.54				16.19	304.07	304.00	-0.07	14.06	
	G-434		6.51				16.22	298.98	298.81	-0.17	13.69	
	G-435		6.79				16.23	297.94	297.76	-0.18	13.70	
	G-436		6.91				16.16	302.66	302.44	-0.22	13.63	
	G-437		6.98				16.19	300.57	300.35	-0.22	13.72	
										0.00		
EJ-13 + TUFF	G-438		7.03				15.53	299.04	299.00	-0.04	13.00	
	G-439		7.05				15.51	305.28	305.14	-0.14	13.00	
	G-440		6.41				15.51	306.47	306.43	-0.04	12.90	
	G-441		6.37				15.50	300.42	300.37	-0.05	13.04	
	G-442		6.70				15.50	300.30	300.22	-0.08	13.14	
	G-443		6.71				15.49	302.66	302.56	-0.10	13.08	
	G-444		6.63				15.51	301.48	301.34	-0.14	12.75	
	G-445		6.84				15.47	300.08	299.89	-0.19	12.61	
	G-446		6.81				15.48	305.16	304.93	-0.23	12.74	
	G-447		6.80				15.50	298.47	298.29	-0.18	12.79	
EJ-13 NO GAMMA	G-448		7.98				16.21	300.01	299.99	-0.02	13.20	
	G-449		7.87				16.18	296.83	298.80	1.97	13.16	
	G-450		8.36				15.47	304.35	304.29	-0.06	13.20	
	G-451		8.24				15.47	296.26	296.23	-0.03	13.07	

Data Table A (Cont'd)

EXP'T TYPE	EXP'T NUMBER	SAMPLE NUMBER	EXP'T DURATION (days)	DATE IN	DATE OUT	VESSEL NUMBER	GLASS THICKNESS (mm)	GLASS DIAMETER (mm)	GLASS SURFACE AREA (mm**2)	GLASS MASS IN (g)	GLASS MASS OUT (g)	GLASS MASS CHANGE (g)
	G-452		56	7/8	9/2	80						
	G-453		56	7/8	9/2	49						
	G-454		91	3/21	6/19	83						
	G-455		91	3/21	6/19	68						
	G-456		181	12/18	6/18	146						
	G-457		181	12/18	6/18	147						
	G-458		278	12/18	9/24	148						
	G-459		278	12/18	9/24	149						
EJ-13 + TUFF NO GAMMA	G-460		14	9/4	9/18	107						
	G-461		14	9/4	9/18	122						
	G-462		28	7/24	8/21	119						
	G-463		28	7/24	8/21	79						
	G-464		56	7/8	9/2	65						
	G-465		56	7/8	9/2	76						
	G-466		91	3/21	6/19	18						
	G-467		91	3/21	6/19	37						
	G-468		181	12/18	6/18	95						
	G-469		181	12/18	6/18	84						
	G-470		278	12/18	9/24	85						
	G-471		278	12/18	9/24	72						
EJ-13 ONLY TEFLON GASKET NO GAMMA	G-472		91	12/18	3/19	73						
	G-473		181	12/18	6/18	86						
	G-474		278	12/18	9/24	150						

Data Table A (Cont'd)

EXP'T TYPE	EXP'T NUMBER	SAMPLE NUMBER	LEACHATE pH OUT	SUPPORT MASS IN (g)	SUPPORT MASS OUT (g)	SUPPORT MASS CHANGE (g)	MASS EJ-13 IN (g)	ASSEMBLY MASS IN (g)	ASSEMBLY MASS OUT (g)	ASSEMBLY MASS CHANGE (g)	LPE NET MASS (g)	NORMALIZED GLASS MASS LOSS (g/m**2)
	G-452		7.48				16.20	298.62	298.58	-0.04	13.79	
	G-453		8.23				16.22	305.87	305.82	-0.05	13.72	
	G-454		8.75				16.23	298.76	298.71	-0.05	13.80	
	G-455		8.87				16.19	304.47	304.38	-0.09	13.68	
	G-456		4.73				16.23	301.29	301.11	-0.18	13.70	
	G-457		8.65				16.16	303.23	303.04	-0.19	13.56	
	G-458		7.87				16.17	297.63	297.31	-0.32	13.37	
	G-459		8.23				16.18	303.88	303.58	-0.30	13.56	
EJ-13 + TUFF NO GAMMA	G-460		7.27				15.47	298.89	298.87	-0.02	13.20	
	G-461		7.34				15.47	304.80	304.77	-0.03	13.16	
	G-462		8.06				15.49	302.96	302.91	-0.05	13.01	
	G-463		7.90				15.48	301.07	301.03	-0.04	12.87	
	G-464		7.40				15.48	303.50	303.46	-0.04	12.88	
	G-465		7.62				15.49	299.98	299.91	-0.07	12.86	
	G-466		8.35				15.45	298.07	297.99	-0.08	12.64	
	G-467		8.17				15.50	297.41	297.34	-0.07	12.84	
	G-468		7.98				15.45	300.57	300.50	-0.07	12.92	
	G-469		8.12				15.50	304.90	304.78	-0.12	12.83	
	G-470		8.04				15.47	299.68	299.49	-0.19	12.66	
	G-471		8.02				15.51	307.02	306.87	-0.15	12.88	
EJ-13 ONLY TEFLON GASKET NO GAMMA	G-472		7.66				16.16	305.32	305.31	-0.02	13.54	
	G-473		7.19				16.18	301.62	301.63	0.01	13.83	
	G-474		7.45				16.17	298.00	298.02	0.02	13.68	

DATA TABLE B: Anion Results for FY 1986 Gamma Irradiation Experiments

This table contains the anion data obtained by ion chromatography analysis and dissolved carbon analysis. The data is presented as (*) ACL analyzed results, (**) ACL results corrected for dilution, (***) ACL results corrected for dilution and background subtracted. The concentration of "fixed nitrogen" refers to the sum of nitric and nitrous ion concentrations. The total carbon concentrations presented are of undiluted leachate and the concentrations for experiments with glass have not been background corrected using the blank experiment results. Several of the leachates were acidified and sparged with oxygen gas and then analyzed for the organic carbon content. This analysis was performed several weeks after the experiments were terminated, and the organic content reported is probably about 10% too low, as the total carbon contents were 0-10% lower when analyzed long after the experiments were terminated.

Data Table B. Anion Results for FY 1986 Gamma Irradiation Experiments

EXP'T TYPE	EXP'T NUMBER	EXP'T LENGTH	pH	F- (ug/ml)			Cl- (ug/ml)			NO2- (ug/ml)			NO3- (ug/ml)			FIXED NITROGEN (umol/ml)
				*	**	***	*	**	***	*	**	***	*	**	***	***
	G-300	28	7.54	1.3	2.6	0.0	4.3	8.6	0.5	2.3	4.6	0.2	0.5	1.0	-0.7	-0.01
	G-301	28	7.42	1.3	2.6	0.0	4.2	8.4	0.3	2.3	4.6	0.2	0.5	1.0	-0.7	-0.01
	G-302	56	6.81	1.9	3.8	-0.6	3.7	7.4	-0.7	1.3	2.6	0.2	L0.5			0.00
	G-303	56	6.84	2.0	4.0	-0.4	3.8	7.6	-0.5	1.6	3.2	0.8	L0.5			0.02
SRL U	G-304	91	4.70	5.2	7.2	2.5	64.6	88.8	80.7	L0.2			4.0	5.5	1.3	0.02
	G-305	91	6.80	4.1	5.6	0.9	18.5	25.4	17.3	3.1	4.3	1.0	1.1	1.5	-2.7	-0.02
	G-306	182	6.87	3.2	6.4	0.9	15.9	31.8	23.7	2.2	4.4	0.6	L1			0.01
	G-307	182	7.04	3.1	6.2	0.7	6.1	12.2	4.1	2.1	4.2	0.4	L1			0.01
	G-308	278	5.25	2.4	4.8	1.7	3.9	7.8	-0.3	2.0	4.0	0.0	L0.5			0.00
	G-309	278	6.78	2.5	5.0	1.9	3.9	7.8	-0.3	2.2	4.4	0.4	L0.5			0.01
	G-310	28	7.47	1.4	2.8	-0.4	4.4	8.8	0.1	2.2	4.4	0.0	0.8	1.6	-0.3	-0.00
	G-311	28	7.37	1.4	2.8	-0.4	4.9	9.8	1.1	2.4	4.8	0.4	0.8	1.6	-0.3	0.00
	G-312	56	6.91	2.3	4.6	-0.9	4.0	8.0	-0.7	1.6	3.2	0.6	L0.5			0.01
	G-313	56	6.75	2.5	5.0	-0.5	3.9	7.8	-0.9	1.4	2.8	0.2	L0.5			0.00
SRL U +	G-314	91	6.99	3.8	5.2	0.5	5.7	7.8	-0.9	2.7	3.7	-0.6	1.4	1.9	0.5	-0.00
TUFF	G-315	91	6.78	3.9	5.4	0.7	6.0	8.3	-0.4	1.0	1.4	-2.9	0.9	1.2	-0.2	-0.07
	G-316	182	7.12	4.1	8.2	1.5	4.4	8.8	0.1	2.3	4.6	0.4	L1			0.01
	G-317	182	7.10	3.7	7.4	0.7	4.4	8.8	0.1	2.2	4.4	0.2	L1			0.00
	G-318	278	7.56	3.1	6.2	1.4	4.4	8.8	0.1	2.3	4.6	0.0	L0.5			0.00
	G-319	278	7.53	2.8	5.6	0.8	4.5	9.0	0.3	2.2	4.4	-0.2	L0.5			-0.00
	G-320	28	7.40	1.3	2.6	0.0	4.2	8.4	0.3	2.4	4.8	0.4	0.5	1.0	-0.7	-0.00
	G-321	28	7.54	1.3	2.6	0.0	4.3	8.6	0.5	2.4	4.8	0.4	0.7	1.4	-0.3	0.00
	G-322	56	6.96	1.8	3.6	-0.8	3.7	7.4	-0.7	1.4	2.8	0.4	L0.5			0.01
	G-323	56	6.94	1.9	3.8	-0.6	3.7	7.4	-0.7	1.4	2.8	0.4	L0.5			0.01
SRL A	G-324	91	6.69	3.7	5.1	0.4	21.7	29.8	21.7	3.0	4.1	0.8	0.9	1.2	-0.3	0.01
	G-325	91	6.94	3.7	5.1	0.4	5.7	7.8	-0.3	3.3	4.5	1.2	0.9	1.2	-0.3	0.02
	G-326	182	7.29	3.2	6.4	0.9	3.8	7.6	-0.5	2.3	4.6	0.8	L1			0.02
	G-327	182	7.22	3.1	6.2	0.7	3.8	7.6	-0.5	2.2	4.4	0.6	L1			0.01
	G-328	278	5.35	2.5	5.0	1.9	3.9	7.8	-0.3	2.1	4.2	0.2	L0.5			0.00
	G-329	278	7.56	2.6	5.2	2.1	3.8	7.6	-0.5	2.0	4.0	0.0	L0.5			0.00
	G-330	28	7.38	1.4	2.8	-0.4	4.6	9.2	0.5	2.3	4.6	0.2	0.7	1.4	-0.5	-0.00
	G-331	28	7.34	1.4	2.8	-0.4	4.7	9.4	0.7	2.3	4.6	0.2	0.7	1.4	-0.5	-0.00
	G-332	56	6.69	2.3	4.6	-0.9	3.9	7.8	-0.9	1.5	3.0	0.4	0.5	1.0	-0.8	-0.00
	G-333	56	6.80	2.3	4.6	-0.9	4.2	8.4	-0.3	1.7	3.4	0.8	L0.5			0.02
SRL A +	G-334	91	6.83	3.8	5.2	0.5	6.1	8.4	-0.3	3.1	4.3	0.0	1.0	1.4	0.0	0.00
TUFF	G-335	91	7.04	3.8	5.2	0.5	6.1	8.4	-0.3	3.3	4.5	0.2	0.9	1.2	-0.2	0.00
	G-336	182	7.20	3.8	7.6	0.9	4.1	8.2	-0.5	2.2	4.4	0.2	L1			0.00
	G-337	182	7.30	3.5	7.0	0.3	4.3	8.6	-0.1	2.4	4.8	0.6	L1			0.01
	G-338	278	7.56	3.1	6.2	1.4	4.2	8.4	-0.3	2.2	4.4	0.2	L0.5			0.00
	G-339	278	7.69	3.0	6.0	1.2	4.1	8.2	-0.5	2.2	4.4	0.2	L0.5			0.00

Data Table B (Cont'd)

EXP'T NUMBER	SO4= (ug/ml) *	SO4= (ug/ml) **	SO4= (ug/ml) C ***	TOTAL C (ug/ml) **	ORGANIC C (ug/ml) **
G-300	10.6	18.4	-0.9	32.56	
G-301	9.8	19.6	0.3	33.59	
G-302	9.2	18.4	-0.9	64.06	
G-303	10.7	21.4	2.1	62.40	
G-304	14.8	20.4	1.1	-	
G-305	15.8	21.7	2.4	-	
G-306	9.6	19.2	-0.1	67.72	
G-307	9.7	19.4	0.1	76.43	
G-308	10.3	20.6	1.3	67.20	
G-309	10.0	20.0	0.7	65.43	14.71
G-310	11.1	22.2	2.1	40.38	
G-311	11.8	23.6	3.5	42.15	
G-312	10.9	21.8	1.7	92.18	
G-313	9.6	19.2	-0.9	91.81	
G-314	14.4	19.8	-0.3	-	
G-315	14.1	19.4	-0.7	-	
G-316	10.8	21.6	1.5	107.00	
G-317	10.2	20.4	0.3	94.26	
G-318	10.2	20.4	0.3	82.01	
G-319	10.8	21.6	1.5	70.94	
G-320	9.9	19.8	0.5	-	
G-321	10.3	20.6	1.3	-	
G-322	9.2	18.4	-0.9	-	
G-323	9.6	19.2	-0.1	-	
G-324	14.2	19.5	0.2	-	
G-325	15.9	21.9	2.6	-	
G-326	9.5	19.0	-0.3	-	
G-327	9.5	19.0	-0.3	-	
G-328	9.8	19.6	0.3	-	
G-329	9.4	18.8	-0.5	-	
G-330	10.0	20.0	-0.1	-	
G-331	10.5	21.0	0.9	-	
G-332	9.7	19.4	-0.7	-	
G-333	10.4	20.8	0.7	-	
G-334	15.6	21.5	1.4	-	
G-335	15.6	21.5	1.4	-	
G-336	10.0	20.0	-0.1	-	
G-337	9.6	19.2	-0.9	-	
G-338	9.9	19.8	-0.3	-	
G-339	10.2	20.4	0.3	-	

Data Table B (Cont'd)

EXP'T TYPE	EXP'T NUMBER	TEST LENGTH	pH	F- (ug/ml)			Cl- (ug/ml)			NO2- (ug/ml)			NO3- (ug/ml)			NITROGEN (umol/ml)
				*	**	***	*	**	***	*	**	***	*	**	***	***
	G-340	14	8.29	1.2	2.4	0.0	4.0	8.0	-0.1	-			3.9	7.8	0.3	0.00
	G-341	14	8.31	1.2	2.4	0.0	4.0	8.0	-0.1	-			3.7	7.4	-0.1	-0.00
	G-342	28	8.85	1.3	2.6	0.0	5.0	10.0	1.9	L0.3			3.7	7.4	-1.1	-0.02
	G-343	28	8.82	1.2	2.4	-0.2	4.3	8.6	0.5	L0.3			4.0	8.0	-0.5	-0.01
	G-344	56	8.42	1.4	2.8	-0.1	3.8	7.6	-0.5	L0.3			2.1	4.2	-0.4	-0.01
	G-345	56	8.61	1.3	2.6	-0.3	3.8	7.6	-0.5	L0.3			2.3	4.6	0.0	0.00
SRL U	G-346	91	9.27	1.2	2.4	-0.2	3.8	7.6	-0.5	L0.3			2.6	5.2	-0.2	-0.00
NO GAMMA	G-347	91	9.27	1.3	2.6	0.0	3.9	7.8	-0.3	L0.3			2.8	5.6	0.2	0.00
	G-348	182	9.06	1.2	2.4	-0.7	16.0	32.0	23.9	L0.3			3.7	7.4	-0.3	-0.00
	G-349	182	8.53	1.3	2.6	-0.5	43.6	87.2	79.1	L0.3			4.0	8.0	0.3	0.00
	G-350	278	8.82	1.9	3.8	0.9	23.7	47.4	39.3	L0.3			3.9	7.8	0.2	0.00
	G-351	278	9.06	1.8	3.6	0.7	23.3	46.6	38.5	L0.3			4.0	8.0	0.4	0.01
	G-352	14	7.73	1.3	2.6	0.2	4.2	8.4	0.0	-			4.0	8.0	0.1	0.00
	G-353	14	7.66	1.3	2.6	0.2	4.7	9.4	1.0	-			4.1	8.2	0.3	0.00
	G-354	28	8.14	1.2	2.4	-0.4	4.5	9.0	0.6	L0.3			4.0	8.0	-0.1	-0.00
	G-355	28	8.28	1.2	2.4	-0.4	4.4	8.8	0.4	L0.3			4.0	8.0	-0.1	-0.00
	G-356	56	8.41	1.4	2.8	0.2	4.2	8.4	0.0	L0.3			2.4	4.8	0.1	0.00
	G-357	56	8.34	1.4	2.8	0.2	4.0	8.0	-0.4	L0.3			2.3	4.6	-0.1	-0.00
SRL U +	G-358	91	8.74	1.3	2.6	0.0	4.1	8.2	-0.2	L0.3			2.3	4.6	-1.5	-0.02
TUFF	G-359	91	8.85	1.4	2.8	0.2	4.2	8.4	0.0	L0.3			2.4	4.8	-1.3	-0.02
NO GAMMA	G-360	182	8.85	1.3	2.6	0.2	4.6	9.2	0.8	L0.3			4.1	8.2	0.9	0.01
	G-361	182	8.98	1.3	2.6	0.2	4.5	9.0	0.6	L0.3			4.1	8.2	0.9	0.01
	G-362	278	8.97	1.6	3.2	0.2	8.3	16.6	8.2	L0.3			5.1	10.2	2.6	0.04
	G-363	278	8.99	1.7	3.4	0.4	4.2	8.4	0.0	L0.3			3.8	7.6	0.0	0.00
	G-364	14	8.28	1.2	2.4	0.0	4.0	8.0	-0.1	-			4.0	8.0	0.5	0.01
	G-365	14	8.30	1.2	2.4	0.0	4.0	8.0	-0.1	-			3.9	7.8	0.3	0.00
	G-366	28	8.93	1.3	2.6	0.0	4.0	8.0	-0.1	L0.3			4.0	8.0	-0.5	-0.01
	G-367	28	8.91	1.3	2.6	0.0	4.0	8.0	-0.1	L0.3			4.1	8.2	-0.3	-0.00
	G-368	56	8.74	1.3	2.6	-0.3	3.7	7.4	-0.7	L0.3			2.2	4.4	-0.2	-0.00
	G-369	56	8.97	1.2	2.4	-0.5	3.4	6.8	-1.3	L0.3			2.1	4.2	-0.4	-0.01
SRL A	G-370	91	9.21	1.2	2.4	-0.2	3.8	7.4	-0.7	L0.3			2.8	5.6	-0.2	-0.00
NO GAMMA	G-371	91	9.24	1.3	2.6	0.0	3.8	7.6	-0.5	L0.3			2.8	5.6	-0.2	-0.00
	G-372	182	7.93	1.3	2.6	-0.5	42.9	85.8	77.7	L0.3			4.1	8.2	0.5	0.01
	G-373	182	9.12	1.1	2.2	-0.9	10.4	20.8	12.7	L0.3			3.9	7.8	0.1	0.00
	G-374	278	5.04	2.0	4.0	1.1	68.4	136.0	127.9	L0.3			3.8	7.6	0.0	0.00
	G-375	278	7.54	1.5	3.0	0.1	28.0	56.0	47.9	L0.3			3.6	7.2	-0.4	-0.01
	G-376	14	7.60	1.3	2.6	0.2	4.4	8.8	0.4	-			3.8	7.6	-0.3	-0.00
	G-377	14	7.77	1.3	2.6	0.2	4.3	8.6	0.2	-			3.5	7.0	-0.9	-0.01
	G-378	28	8.10	1.4	2.8	0.0	4.4	8.8	0.4	L0.3			4.0	8.0	-0.1	-0.00
	G-379	28	8.47	1.4	2.8	0.0	4.3	8.6	0.2	L0.3			4.4	8.8	0.7	0.01
	G-380	56	8.49	1.4	2.8	0.2	4.1	8.2	-0.2	L0.3			2.4	4.8	-0.1	-0.00
	G-381	56	8.25	1.4	2.8	0.2	4.3	8.6	0.2	L0.3			1.6	3.2	-1.5	-0.02
SRL A +	G-382	91	8.85	1.4	2.8	0.2	4.0	8.0	-0.4	L0.3			2.2	4.4	-1.7	-0.03
TUFF	G-383	91	8.80	1.4	2.8	0.2	4.0	8.0	-0.4	L0.3			1.9	3.8	-2.3	-0.04
NO GAMMA	G-384	182	8.90	1.3	2.6	0.2	4.5	9.0	0.6	L0.3			4.3	8.6	1.3	0.02
	G-385	182	8.81	1.3	2.6	0.2	4.4	8.8	0.4	L0.3			4.2	8.4	1.1	0.02
	G-386	278	9.02	1.5	3.0	0.0	4.4	8.8	0.4	L0.3			4.1	8.2	0.3	0.00
	G-387	278	9.07	1.5	3.0	0.0	4.7	9.4	1.0	L0.3			3.8	7.6	-0.3	-0.00

Data Table B (Cont'd)

EXP'T NUMBER	SO4= (ug/ml) C *	SO4= (ug/ml) C **	SO4= (ug/ml) C ***	TOTAL C (ug/ml) **	ORGANIC C (ug/ml) **
G-340	9.6	19.2	0.6	-	
G-341	10.2	20.4	1.8	-	
G-342	10.5	21.0	2.4	34.98	
G-343	10.7	21.4	2.8	34.98	
G-344	10.3	20.6	2.0	67.42	
G-345	9.9	19.8	1.2	72.56	27.56
G-346	9.8	19.6	1.0	79.46	
G-347	10.0	20.0	1.4	75.13	
G-348	9.6	19.2	0.6	82.39	
G-349	10.0	20.0	1.4	80.06	
G-350	9.3	18.6	0.0	95.44	
G-351	9.3	18.6	0.0	121.10	
G-352	9.4	18.8	-0.9	-	
G-353	9.5	19.0	-0.7	-	
G-354	10.0	20.0	0.3	41.99	15.06
G-355	9.6	18.2	-1.5	41.49	
G-356	12.2	24.4	4.7	89.01	
G-357	9.6	19.2	-0.5	92.03	
G-358	10.0	20.0	0.3	89.18	
G-359	10.6	21.2	1.5	97.52	
G-360	10.6	21.2	1.5	98.53	
G-361	9.8	19.6	-0.1	104.90	
G-362	10.7	21.4	1.7	115.00	
G-363	9.8	19.6	-0.1	118.90	
G-364	9.8	19.6	1.0	-	
G-365	9.9	19.8	1.2	-	
G-366	9.6	19.2	0.6	-	
G-367	10.1	20.2	1.6	-	
G-368	9.6	19.2	0.6	-	
G-369	9.4	18.8	0.2	-	
G-370	10.0	20.0	1.4	-	
G-371	10.1	20.2	1.6	-	
G-372	9.6	19.2	0.6	-	
G-373	9.2	18.4	-0.2	-	
G-374	9.5	19.0	0.4	-	
G-375	9.4	18.8	0.2	-	
G-376	9.5	19.0	-0.7	-	
G-377	9.5	19.0	-0.7	-	
G-378	9.8	19.6	-0.1	-	
G-379	9.8	19.6	-0.1	-	
G-380	9.6	19.2	-0.5	-	
G-381	10.0	20.0	0.3	-	
G-382	10.4	20.8	1.1	-	
G-383	10.5	21.0	1.3	-	
G-384	9.7	19.4	-0.3	-	
G-385	9.8	19.6	-0.1	-	
G-386	9.9	19.8	0.1	-	
G-387	9.7	19.4	-0.3	-	

Data Table B (Cont'd)

TEST TYPE	TEST NUMBER	TEST LENGTH	pH	F- (ug/ml) *	F- (ug/ml) **	F- (ug/ml) ***	Cl- (ug/ml) *	Cl- (ug/ml) **	Cl- (ug/ml) ***	NO2- (ug/ml) *	NO2- (ug/ml) **	NO2- (ug/ml) ***	NO3- (ug/ml) *	NO3- (ug/ml) **	NO3- (ug/ml) ***	FIXED NITROGEN (umol/ml) ***
	G-388	28	8.84	1.4	2.8	0.2	4.2	8.4	0.3	2.3	4.6	0.2	0.9	1.8	0.1	0.01
	G-389	28	8.92	1.3	2.6	0.0	4.1	8.2	0.1	2.2	4.4	0.0	0.8	1.6	-0.1	-0.00
	G-390	56	8.12	2.7	5.4	1.0	3.9	7.8	-0.3	1.3	2.6	0.2	L0.5			0.00
	G-391	56	8.38	2.8	5.6	1.2	4.0	8.0	-0.1	1.2	2.4	0.0	L0.5			0.00
ATM-1c	G-392	91	7.95	4.1	5.6	0.9	5.9	8.1	0.0	3.2	4.4	1.1	0.8	1.1	-3.1	-0.03
	G-393	91	8.08	3.7	5.1	0.4	5.1	7.0	-1.1	3.1	4.3	1.0	0.8	1.1	-3.1	-0.03
	G-394	182	7.96	2.5	5.0	0.5	4.0	8.0	-0.1	L0.3			L1			0.00
	G-395	182	7.81	2.7	5.4	-0.1	4.0	8.0	-0.1	2.1	4.2	0.4	L1			0.01
	G-396	278	7.05	1.6	3.2	0.1	4.0	8.0	-0.1	2.1	4.2	0.2	L0.5			0.00
	G-397	278	7.72	1.5	3.0	-0.1	3.9	3.8	-4.3	L0.3			L0.5			0.00
	G-398	28	8.42	1.9	3.8	0.6	4.3	8.6	-0.1	2.5	5.0	0.6	0.9	1.8	-0.1	0.01
	G-399	28	8.22	2.1	4.2	1.0	4.4	8.8	0.1	2.6	5.2	0.8	0.7	1.4	-0.5	0.01
	G-400	56	8.20	3.0	6.0	0.5	4.5	9.0	0.3	1.7	3.4	0.8	L0.5			0.02
	G-401	56	8.20	2.8	5.6	0.1	4.5	9.0	0.3	1.6	3.2	0.6	L0.5			0.01
ATM-1c	G-402	91	8.09	3.8	5.2	0.5	5.9	8.1	-0.6	1.4	1.9	-2.4	L0.4			-0.05
+ TUFF	G-403	91	8.24	3.8	5.2	0.5	5.9	8.1	-0.6	1.0	1.4	-2.9	L0.4			-0.06
	G-404	182	8.12	2.9	5.8	-0.9	4.6	9.2	0.5	L0.3			L1			0.00
	G-405	182	7.88	3.5	7.0	0.3	4.6	9.2	0.5	2.2	4.4	0.2	L1			0.00
	G-406	278	7.87	1.5	3.0	-1.8	4.6	9.2	0.5	L0.3			L0.5			0.00
	G-407	278	6.86	2.2	4.4	-0.4	4.6	9.2	0.5	2.6	5.2	0.6	0.7	1.4	0.0	0.01
	G-408	28	8.67	1.4	2.8	0.2	4.1	8.2	0.1	2.2	4.4	0.0	0.7	1.4	-0.3	-0.00
	G-409	28	8.54	1.4	2.8	0.2	4.2	8.4	0.3	2.3	4.6	0.2	0.8	1.6	-0.1	0.00
	G-410	56	7.92	2.5	5.0	0.6	4.1	8.2	0.1	1.3	2.6	0.2	L0.5			0.00
	G-411	56	7.85	2.6	5.2	0.8	4.3	8.6	0.5	1.4	2.8	0.4	L0.5			0.01
ATM-8	G-412	91	7.61	4.0	5.5	0.8	5.6	7.7	-0.4	3.2	4.4	1.1	0.9	1.2	-3.0	-0.02
	G-413	91	7.68	4.0	5.5	0.8	5.8	8.0	-0.1	3.3	4.5	1.2	0.9	1.2	-3.0	-0.02
	G-414	182	7.70	2.8	5.6	0.1	4.1	8.2	0.1	2.3	4.6	0.8	L1			0.02
	G-415	182	7.54	2.8	5.6	0.1	4.1	8.2	0.1	2.2	4.4	0.6	L1			0.01
	G-416	278	7.78	2.0	4.0	0.9	4.1	8.2	0.1	2.2	4.4	0.4	L0.5			0.01
	G-417	278	5.82	1.9	3.8	0.7	4.1	8.2	0.1	2.4	4.8	0.8	0.7	1.4	1.4	0.04
	G-418	28	8.36	1.9	3.8	0.6	4.4	8.8	0.1	2.4	4.8	0.4	1.0	2.0	0.1	0.01
	G-419	28	8.05	2.0	4.0	0.8	4.4	8.8	0.1	2.3	4.6	0.2	1.1	2.2	0.3	0.01
	G-420	56	7.59	3.2	6.4	0.9	4.6	9.2	0.5	1.7	3.4	0.8	L0.5			0.02
	G-421	56	7.48	3.4	6.8	1.3	4.8	9.6	0.9	1.6	3.2	-0.6	0.5	1.0	-0.8	-0.03
ATM-8 +	G-422	91	7.95	3.9	5.4	0.7	6.3	8.7	-0.0	0.5	0.7	-3.6	1.1	1.5	0.1	-0.08
TUFF	G-423	91	7.70	4.1	5.6	0.9	6.4	8.8	0.1	3.5	4.8	0.5	0.9	1.2	0.2	0.01
	G-424	182	7.51	3.6	7.2	0.5	4.7	9.4	0.7	2.0	4.0	-0.2	L1			-0.00
	G-425	182	7.74	3.8	7.6	0.9	4.6	9.2	0.5	2.4	4.8	0.6	L1			0.01
	G-426	278	8.01	2.3	4.6	-0.2	4.6	9.2	0.5	L0.3			L0.5			0.00
	G-427	278	7.92	2.2	4.4	-0.4	4.6	9.2	0.5	2.5	5.0	0.4	L0.5			0.01

Data Table B (Cont'd)

TEST NUMBER	SO4= (ug/ml) *	**	***	TOTAL C (ug/ml) **	ORGANIC C (ug/ml) **
G-388	10.9	21.8	2.5	37.49	9.82
G-389	9.8	19.6	0.3	36.30	
G-390	10.0	20.0	0.7	70.43	
G-391	10.4	20.8	1.5	70.84	12.95
G-392	14.7	20.2	0.9	-	
G-393	14.4	19.8	0.5	-	
G-394	10.4	20.8	1.5	96.56	
G-395	10.8	21.6	2.3	91.39	
G-396	10.4	20.8	1.5	82.07	
G-397	9.7	19.4	0.1	87.80	
G-398	10.0	20.0	-0.1	59.67	
G-399	10.2	20.4	0.3	63.64	
G-400	10.6	21.6	1.5	96.38	
G-401	12.1	24.2	4.1	90.68	15.96
G-402	16.5	22.7	2.6	-	
G-403	15.9	21.9	1.8	-	
G-404	12.2	24.4	4.3	110.10	
G-405	12.2	24.4	4.3	112.40	
G-406	11.1	22.2	2.1	103.50	
G-407	10.8	21.6	1.5	108.20	
G-408	10.0	20.0	0.7	-	
G-409	9.9	19.8	0.5	-	
G-410	10.2	20.4	1.1	-	
G-411	10.3	20.6	1.3	-	
G-412	15.6	21.5	2.2	-	
G-413	15.7	21.6	2.3	-	
G-414	10.4	20.8	1.5	-	
G-415	10.4	20.8	1.5	-	
G-416	10.2	20.4	1.1	-	
G-417	10.2	20.4	1.1	-	
G-418	10.1	20.2	0.1	-	
G-419	10.2	20.4	0.3	-	
G-420	10.4	20.8	0.7	-	
G-421	11.2	22.4	2.3	-	
G-422	14.4	19.8	-0.3	-	
G-423	14.8	20.4	0.3	-	
G-424	11.1	22.2	2.1	-	
G-425	10.9	21.8	1.7	-	
G-426	11.1	22.2	2.1	-	
G-427	10.5	21.0	0.9	-	

Data Table B (Cont'd)

EXP'T TYPE	EXP'T NUMBER	EXP'T LENGTH	pH	F- (ug/ml) *	F- (ug/ml) **		Cl- (ug/ml) *	Cl- (ug/ml) **		NO2- (ug/ml) *	NO2- (ug/ml) **		NO3- (ug/ml) *	NO3- (ug/ml) **	
	G-428	28	7.44	1.3	2.6		4.2	8.4		2.2	4.4		Ø.9	1.8	
	G-429	28	7.39	1.3	2.6	(2.6)	4.2	8.4	(8.1)	2.2	4.4	(4.4)	Ø.8	1.6	(1.7)
	G-43Ø	56	6.57	2.2	4.4		3.9	7.8		1.2	2.4		Ø.5	1.Ø	
	G-431	56	6.75	2.2	4.4	(4.4)	3.8	7.6	(8.1)	1.2	2.4	(2.4)	LØ.5		(1.Ø)
EJ-13	G-432	91	6.26	3.2	4.4		6.2	8.5		2.4	3.3		3.4	4.7	
	G-433	91	5.54	3.6	4.9	(4.7)	16.4	22.6	(8.1)	LØ.2		(3.3)	2.6	3.6	(4.2)
	G-434	182	6.51	2.8	5.6		4.Ø	8.Ø		1.7	3.4		L1		
	G-435	182	6.79	2.7	5.4	(5.5)	3.9	7.8	(8.1)	2.1	4.2	(3.8)	L1		(Ø)
	G-436	278	6.91	1.6	3.2		4.1	8.2		2.Ø	4.Ø		LØ.5		
	G-437	278	6.98	1.5	3.Ø	(3.1)	4.1	8.2	(8.1)	2.Ø	4.Ø	(4.Ø)	LØ.5		(Ø)
	G-438	28	7.Ø3	1.6	3.2		4.4	8.8		2.2	4.4		Ø.9	1.8	
	G-439	28	7.Ø5	1.6	3.2	(3.2)	4.4	8.8	(8.7)	2.2	4.4	(4.4)	1.Ø	2.Ø	(1.9)
	G-44Ø	56	6.41	2.8	5.6		4.4	8.8		1.1	2.2		1.Ø	2.Ø	
	G-441	56	6.37	2.7	5.4	(5.5)	4.3	8.6	(8.7)	1.5	3.Ø	(2.6)	Ø.8	1.6	(1.8)
EJ-13 +	G-442	91	6.7Ø	3.5	4.8		6.3	8.7		3.Ø	4.1		1.1	1.5	
TUFF	G-443	91	6.71	3.3	4.5	(4.7)	5.6	7.7	(8.7)	3.2	4.4	(4.3)	Ø.9	1.2	(1.4)
	G-444	182	6.63	3.6	7.2		4.6	9.2		1.9	3.8		L1		
	G-445	182	6.84	3.1	6.2	(6.7)	4.3	8.6	(8.7)	2.3	4.6	(4.2)	L1		(Ø)
	G-446	278	6.81	2.3	4.6		4.2	8.4		2.4	4.8		LØ.5		
	G-447	278	6.8Ø	2.5	5.Ø	(4.8)	4.2	8.4	(8.7)	2.2	4.4	(4.6)	Ø.7	1.4	(1.4)
	G-448	14	7.98	1.2	2.4		4.Ø	8.Ø		-			3.8	7.6	
	G-449	14	7.87	1.2	2.4	(2.4)	3.9	7.8	(8.1)	-		(Ø)	3.7	7.4	(7.5)
	G-45Ø	28	8.36	1.3	2.6		4.2	8.4		LØ.3			3.6	7.2	
	G-451	28	8.24	1.3	2.6	(2.6)	4.1	8.2	(8.1)	LØ.3		(Ø)	5.4	10.8	(8.5)
	G-452	56	7.48	1.5	3.Ø		3.9	7.8		LØ.3			2.4	4.8	
	G-453	56	8.23	1.4	2.8	(2.9)	3.8	7.6	(8.1)	LØ.3		(Ø)	2.1	4.2	(4.6)
EJ-13	G-454	91	8.75	1.3	2.6		3.8	7.6		LØ.3			2.7	5.4	
NO GAMMA	G-455	91	8.87	1.3	2.6	(2.6)	3.8	7.6	(8.1)	LØ.3		(Ø)	2.7	5.4	(5.4)
	G-456	182	4.73	1.7	3.4		31.1	62.2		LØ.3			3.8	7.6	
	G-457	182	8.65	1.4	2.8	(3.1)	14.1	28.2	(8.1)	LØ.3		(Ø)	3.9	7.8	(7.7)
	G-458	278	7.87	1.5	3.Ø		26.Ø	52.Ø		LØ.3			3.8	7.6	
	G-459	278	8.12	1.4	2.8	(2.9)	20.8	41.6	(8.1)	LØ.3		(Ø)	3.8	7.6	(7.6)
	G-46Ø	14	7.27	1.2	2.4		4.6	9.2		-			4.Ø	8.Ø	
	G-461	14	7.34	1.2	2.4	(2.4)	4.1	8.2	(8.4)	-		(Ø)	3.9	7.8	(7.9)
	G-462	28	8.Ø6	1.4	2.8		4.3	8.6		LØ.3			4.Ø	8.Ø	
	G-463	28	7.9Ø	1.4	2.8	(2.8)	4.3	8.6	(8.4)	LØ.3		(Ø)	4.1	8.2	(8.1)
	G-464	56	7.4Ø	1.3	2.6		4.1	8.2		LØ.3			2.2	4.4	
	G-465	56	7.62	1.3	2.6	(2.6)	4.1	8.2	(8.4)	LØ.3		(Ø)	2.5	5.Ø	(4.7)
EJ-13 +	G-466	91	8.35	1.4	2.8		4.3	8.6		LØ.3			3.4	6.8	
TUFF	G-467	91	8.17	1.2	2.4	(2.6)	4.1	8.2	(8.4)	LØ.3		(Ø)	2.7	5.4	(6.1)
NO GAMMA	G-468	182	7.98	1.2	2.4		4.1	8.2		LØ.3			3.6	7.2	
	G-469	182	8.12	1.2	2.4	(2.4)	4.1	8.2	(8.4)	LØ.3		(Ø)	3.7	7.4	(7.3)
	G-47Ø	278	8.Ø4	1.5	3.Ø		4.Ø	8.Ø		LØ.3			3.9	7.8	
	G-471	278	8.Ø2	1.5	3.Ø	(3.Ø)	4.5	9.Ø	(8.4)	LØ.3		(Ø)	4.Ø	8.Ø	(7.9)

Data Table B (Cont'd)

TEST NUMBER	SO4= (ug/ml) *	**	***	C	TOTAL C (ug/ml) **	ORGANIC (ug/ml)
G-428	9.2	18.4			28.54	
G-429	9.3	18.6	(19.3)		28.73	
G-430	9.6	19.2			54.96	
G-431	9.3	18.6	(19.3)		63.71	
G-432	14.8	20.4			-	
G-433	13.3	18.3	(19.3)		-	
G-434	10.0	20.0			68.79	
G-435	10.0	20.0	(19.3)		51.82	
G-436	9.4	18.8			47.89	
G-437	9.4	18.8	(19.3)		41.63	
G-438	9.2	18.4			47.15	
G-439	9.6	19.2	(20.1)		45.53	19.39
G-440	10.6	21.2			90.97	
G-441	9.9	19.8	(20.1)		80.76	
G-442	13.9	19.1			-	
G-443	13.9	19.1	(20.1)		-	
G-444	10.4	20.8			71.19	
G-445	10.2	20.4	(20.1)		61.32	
G-446	9.8	19.6			64.25	
G-447	9.8	19.6	(20.1)		79.10	
G-448	9.1	18.2			-	
G-449	8.9	17.8	(18.6)		-	
G-450	9.4	18.8			33.54	
G-451	9.1	18.2	(18.6)		31.12	
G-452	9.5	19.0			65.22	
G-453	9.3	18.6	(18.6)		66.34	
G-454	9.4	18.8			71.48	
G-455	9.4	18.8	(18.6)		83.86	
G-456	9.7	19.4			73.28	
G-457	9.5	19.0	(18.6)		78.73	
G-458	9.4	18.8			101.80	
G-459	9.1	18.2	(18.6)		97.48	
G-460	9.4	18.8			-	
G-461	9.1	18.2	(19.7)		-	
G-462	9.4	18.8			46.18	
G-463	9.4	18.8	(19.7)		47.36	
G-464	9.4	18.8			86.97	
G-465	9.2	18.4	(19.7)		94.15	
G-466	10.3	20.6			82.00	
G-467	9.7	19.4	(19.7)		83.40	
G-468	9.4	18.8			95.14	
G-469	9.6	19.2	(19.7)		93.15	
G-470	23.1	46.2			97.46	
G-471	10.9	21.8	(19.7)		105.60	51.04

Data Table B (Cont'd)

EXP'T TYPE	EXP'T NUMBER	EXP'T LENGTH	pH	F- (ug/ml) *	F- (ug/ml) **	F- (ug/ml) ***	Cl- (ug/ml) *	Cl- (ug/ml) **	Cl- (ug/ml) ***	NO2- (ug/ml) *	NO2- (ug/ml) **	NO2- (ug/ml) ***	NO3- (ug/ml) *	NO3- (ug/ml) **	NO3- (ug/ml) ***	
TEFLON	G-472	91	7.66	2.0	2.8	-0.1	12.0	16.5	8.4	L0.2			5.6	7.7	0.1	0.12
	G-473	182	7.19	1.2	2.4	-0.5	7.6	15.2	7.1	L0.3			3.7	7.4	-0.2	0.12
	G-474	278	7.45	1.2	2.4	-0.5	4.0	8.0	-0.1	L0.3			3.5	7.0	-0.6	0.11
EJ-13	91,181,278		7.58	1.8	2.5		5.1	7.0		L0.2			4.4	6.1		0.10
LEACHATE	56		8.23	1.2	2.4		3.7	7.4		L0.3			1.0	2.0		0.03
	14,28		8.29	1.4	2.8		4.2	8.4		L0.3			3.6	7.2		
	HPW	182		L0.1			L0.2			L0.3			L1			0.00

EXP'T NUMBER	SO4= (ug/ml) *	SO4= (ug/ml) **	SO4= (ug/ml) ***	TOTAL C (ug/ml) **	ORGANIC C (ug/ml) **
G-472	13.9	19.1	0.5	-	
G-473	9.6	19.2	0.6	84.89	
G-474	8.7	17.4	-1.2	77.78	45.57
91,181,278	13.1	18.0		-	
56	9.2	18.4		24.19	
14,28	9.0	18.0		28.83	8.90
HPW	L1				

* ACL RESULT
** DILUTION CORRECTED
*** BACKGROUND CORRECTED
CARBON RESULTS PRESENTED AS ELEMENTAL CARBON

DATA TABLE C: Cation Results for FY 1986 Gamma Irradiation Experimental Leachates

This table contains the cation results as analyzed using atomic absorbance or atomic emission spectroscopy. Data are presented as (*) ACL analyzed results, (**) ACL results corrected for dilution, (***) ACL results corrected for dilution and background subtraction, (****) normalized elemental mass loss. The weight percent of a species as presented in Table 1 was used to calculate the normalized elemental mass loss. These values are given in parenthesis for all elements in their respective columns for the experiments performed with glass. The concentrations used for background correction are given in parentheses next to the results of the blank experiments. NOTE: THE REPORTED VALUES ARE FOR SOLUTIONS THAT HAVE BEEN ACID SOAKED IN THE STAINLESS STEEL VESSELS. THEREFORE, THE RESULTS FOR Cr, Fe, Mn, AND Ni ARE LIKELY TO BE REPRESENTATIVE OF METAL REACTION INSTEAD OF GLASS REACTION.

Data Table C. Cation Results for FY 1986 Gamma Irradiation Experimental Leachates

TEST TYPE	TEST NUMBER	TOTAL SOLUTION MASS (g)	MASS SOLUTION SUBMITTED (g)	GLASS SURFACE AREA (mm**2)	pH	Al (ng/ml) *	Al (ng/ml) **	Al (ng/ml) ***	NL(Al) (g/m**2) ****	B (ng/ml) *	B (ng/ml) **	B (ng/ml) ***	NL(B) (g/m**2) ****
									(2.16)				(2.10)
	G-300	14.83	-	510	7.54	-	-	-	-	-	-	-	-
	G-301	14.88	12.44	491	7.42	760	1070	695	0.98	340	477	307	0.44
	G-302	14.86	12.38	493	6.81	940	1320	945	1.32	530	745	575	0.83
	G-303	14.84	12.27	500	6.84	1460	2060	1685	2.32	1380	1940	1770	2.50
SRL U	G-304	14.81	12.54	514	4.70	720	1290	915	1.22	1240	2230	2060	2.83
	G-305	14.81	12.13	488	6.80	740	1350	975	1.37	1050	1910	1740	2.52
	G-306	14.79	12.28	503	6.87	1050	1900	1525	2.08	2220	4020	3850	5.40
	G-307	14.69	12.12	506	7.04	1080	1970	1595	2.15	2210	4030	3860	5.35
	G-308	14.47	12.28	503	5.25	1400	1970	1595	2.13	2670	3760	3590	4.93
	G-309	14.70	12.24	475	6.78	1300	1830	1455	2.09	2430	3420	3250	4.80
	G-310	14.57	11.89	498	7.47	370	526	326	0.44	760	1080	875	1.22
	G-311	14.56	-	518	7.37	-	-	-	-	-	-	-	0.00
	G-312	14.44	11.69	514	6.91	490	700	500	0.65	1380	1970	1765	2.37
	G-313	14.43	11.73	499	6.75	850	1210	1010	1.35	1520	2170	1965	2.71
SRL U+	G-314	14.46	12.09	496	6.99	1140	2080	1880	2.54	1320	2410	2205	3.07
TUFF	G-315	14.60	11.86	491	6.78	480	884	684	0.94	1470	2710	2505	3.56
	G-316	14.45	11.86	497	7.12	530	976	776	1.05	2420	4460	4255	5.90
	G-317	14.44	11.84	524	7.10	530	977	777	0.99	2460	4530	4325	5.69
	G-318	14.38	11.86	492	7.56	570	810	610	0.83	3670	5220	5015	6.99
	G-319	14.35	11.70	494	7.53	660	942	742	1.00	3400	4850	4645	6.43
									(2.16)				(2.10)
	G-320	14.83	11.88	492	7.40	620	881	506	0.71	250	355	185	0.27
	G-321	14.88	12.29	510	7.54	600	844	469	0.64	280	394	224	0.31
	G-322	14.86	11.69	515	6.96	850	1210	835	1.12	600	857	687	0.95
	G-323	14.86	12.30	488	6.94	840	1180	805	1.14	650	914	744	1.08
SRL A	G-324	14.85	12.07	498	6.69	630	1150	775	1.07	850	1550	1380	1.97
	G-325	14.79	12.63	514	6.94	840	1500	1125	1.50	1320	2360	2190	3.01
	G-326	14.69	11.65	517	7.29	1120	2080	1705	2.25	1930	3580	3410	4.62
	G-327	14.72	12.31	503	7.22	1010	1830	1455	1.97	1920	3480	3310	4.62
	G-328	14.78	11.75	512	5.35	1330	1900	1525	2.04	2300	3280	3110	4.29
	G-329	14.73	12.26	511	7.56	1430	2010	1635	2.18	2290	3220	3050	4.19
	G-330	14.56	11.39	528	7.38	410	590	390	0.50	520	748	543	0.72
	G-331	14.56	12.01	480	7.34	330	467	267	0.38	550	779	574	0.83
	G-332	14.47	11.39	510	6.69	590	849	649	0.85	1170	1680	1475	2.00
	G-333	14.44	11.68	505	6.80	490	700	500	0.66	1260	1800	1595	2.18
SRL A +	G-334	14.45	11.47	494	6.83	440	823	623	0.85	1220	2280	2075	2.90
TUFF	G-335	14.53	11.66	518	7.04	530	983	783	1.02	1340	2490	2285	3.06
	G-336	14.49	11.36	503	7.20	560	1050	850	1.14	2250	4230	4025	5.53
	G-337	14.41	11.80	526	7.30	580	1070	870	1.10	2210	4080	3875	5.06
	G-338	14.35	11.33	496	7.56	840	1210	1010	1.36	3470	5000	4795	6.62
	G-339	14.33	11.86	515	7.69	780	1110	910	1.18	3530	5020	4815	6.40

Data Table C (Cont'd)

TEST NUMBER	Ba (ng/ml)			NL(Ba) (g/m**2)	Ca (ug/ml)			NL(Ca) (g/m**2)	Ce (ng/ml)			NL(Ce) (g/m**2)	Cr (ng/ml)			NL(Cr) (g/m**2)
	*	**	***	****	*	**	***	****	*	**	***	****	*	**	***	****
				(0.05)				(1.16)				(0.04)				(0.01)
G-300	-				-	-	-	-	-				-			
G-301	-				5.17	7.25	0.47	1.23	-				-			
G-302	-				6.10	8.57	0.03	0.08	-				-			
G-303	-				6.15	8.66	0.12	0.31	-				-			
G-304	35	63	63	3.64	5.23	9.39	1.27	3.16	L100				310	557	396	114.31
G-305	29	53	53	3.22	4.79	8.73	0.61	1.60	L100				480	875	714	217.17
G-306	35	63	63	3.71	5.30	9.61	0.95	2.41	-				-			
G-307	38	69	69	4.01	4.94	9.01	0.35	0.88	-				-			
G-308	-				5.69	8.01	0.03	0.07	-				-			
G-309	-				5.62	7.92	-0.06	-0.16	-				-			
G-310	-				4.28	6.08	1.21	3.06	-				-			
G-311	-				-	-	-	-	-				-			
G-312	-				3.85	5.50	0.58	1.41	-				-			
G-313	-				4.08	5.82	0.90	2.25	-				-			
G-314	29	53	53	3.10	3.19	5.82	-0.44	-1.11	L100				530	968	827	241.66
G-315	29	53	53	3.16	4.09	7.53	1.27	3.26	L100				450	829	670	199.78
G-316	34	63	63	3.67	2.78	5.12	-2.88	-7.23	-				-			
G-317	34	63	63	3.48	4.02	7.41	0.59	1.40	-				-			
G-318	-				3.73	5.30	-0.13	-0.33	-				-			
G-319	-				4.18	5.97	0.54	1.35	-				-			
				(0.05)				(1.16)				(0.04)				(0.01)
G-320	-				5.03	7.15	0.37	0.96	-				-			
G-321	-				5.09	7.16	0.39	0.98	-				-			
G-322	-				6.21	8.87	0.33	0.82	-				-			
G-323	-				6.04	8.50	-0.04	-0.11	-				-			
G-324	27	49	49	2.93	4.73	8.64	0.52	1.34	L100				440	804	643	192.30
G-325	29	52	52	3.00	4.43	7.93	-0.19	-0.47	L100				440	788	627	188.93
G-326	38	71	71	4.04	4.69	8.71	0.05	0.12	-				-			
G-327	37	67	67	3.93	4.75	8.60	-0.06	-0.15	-				-			
G-328	-				5.58	7.95	-0.03	-0.07	-				-			
G-329	-				5.91	8.32	0.34	0.85	-				-			
G-330	-				4.93	7.09	2.22	5.30	-				-			
G-331	-				5.05	7.15	2.28	5.97	-				-			
G-332	-				4.13	5.94	1.02	2.50	-				-			
G-333	-				4.01	5.73	0.81	2.00	-				-			
G-334	32	60	60	3.52	2.01	3.76	-2.50	-6.31	L100				450	842	683	200.12
G-335	30	56	56	3.15	3.56	6.60	0.34	0.82	L100				450	835	676	198.86
G-336	38	71	71	4.10	2.43	4.56	-3.44	-8.56	-				-			
G-337	35	65	65	3.57	3.78	6.98	-1.02	-2.41	-				-			
G-338	-				3.42	4.93	-0.50	-1.25	-				-			
G-339	-				2.73	3.88	-1.55	-3.73	-				-			

Data Table C (Cont'd)

TEST NUMBER	Cs (mg/ml)			NL(Cs) (g/m**2)	Fe (ug/ml)			NL(Fe) (g/m**2)	La (ng/ml)			NL(La) (g/m**2)	Li (ng/ml)			NL(Li) (g/m**2)
	*	**	***	****	*	**	***	****	*	**	***	****	*	**	***	****
				(0.07)				(8.21)				(0.04)				(1.94)
G-300					-	-	-	-	-				-	-	-	-
G-301					12.6	17.7	17.00	6.28	-				660	925	881	1.45
G-302					12.2	14.3	-0.95	-0.35	-				940	1320	1276	2.06
G-303					14.7	20.7	-0.95	-0.34	-				1660	2340	2296	3.58
G-304					1.57	2.82	1.57	0.55	L20				2120	3810	3766	5.67
G-305					3.06	5.58	4.33	1.60	L20				1400	2550	2506	4.00
G-306					3.09	5.60	3.80	1.36	-				2830	5130	5086	7.78
G-307					4.39	8.00	6.20	2.20	-				2640	4810	4766	7.21
G-308					5.38	7.57	5.37	1.89	-				3340	4700	4656	6.98
G-309					6.14	8.64	6.44	2.43	-				3060	4310	4266	6.89
G-310					11.1	15.8	15.4	5.50	-				890	1260	1179	1.90
G-311					-	-	-	0.00	-				-	-	-	-
G-312					10.0	14.3	13.6	4.66	-				1410	2010	1929	2.92
G-313					13.4	19.1	18.4	6.50	-				1360	1940	1859	2.90
G-314					3.40	6.21	5.36	1.91	L20				1460	2670	2589	4.02
G-315					3.05	5.62	4.77	1.73	L20				1560	2870	2789	4.41
G-316					4.23	7.79	6.59	2.34	-				2540	4680	4599	7.03
G-317					4.05	7.46	6.26	2.11	-				2760	5090	5009	7.25
G-318					4.84	6.88	5.38	1.92	-				3630	5160	5079	7.78
G-319					5.27	7.52	6.02	2.13	-				3500	5000	4919	7.50
				(0.07)				(8.21)				(0.04)				(1.94)
G-320					9.55	13.6	12.9	4.74	-				603	857	813	1.33
G-321					10.0	14.1	13.4	4.76	-				688	968	924	1.46
G-322					10.6	15.1	14.2	5.00	-				990	1410	1366	2.10
G-323					9.67	13.60	12.7	4.70	-				1040	1460	1416	2.29
G-324					2.77	5.06	3.81	1.39	L20				1290	2360	2316	3.64
G-325					3.77	6.75	5.50	1.93	L20				1770	3170	3126	4.72
G-326					5.07	9.41	7.61	2.64	-				2530	4700	4656	6.90
G-327					4.62	8.37	6.57	2.34	-				2510	4550	4506	6.87
G-328					6.10	8.70	6.50	2.29	-				2980	4250	4206	6.34
G-329					6.17	8.69	6.49	2.28	-				2940	4140	4096	6.16
G-330					9.46	13.5	13.2	4.45	-				697	1003	922	1.43
G-331					9.75	13.8	13.5	4.98	-				661	936	855	1.47
G-332					10.3	14.8	14.1	4.89	-				1160	1670	1589	2.45
G-333					10.5	15.0	14.3	4.99	-				1280	1830	1749	2.70
G-334					3.46	6.47	5.62	2.01	L20				1320	2470	2389	3.73
G-335					3.25	6.03	5.18	1.77	L20				1430	2650	2569	3.84
G-336					4.34	8.15	6.95	2.44	-				2380	4470	4389	6.65
G-337					4.33	7.99	6.79	2.27	-				2400	4430	4349	6.26
G-338					6.13	8.84	7.34	2.59	-				3570	5150	5069	7.70
G-339					6.17	8.77	7.27	2.47	-				3380	4800	4719	6.90

Data Table C (Cont'd)

TEST NUMBER	Mg (ng/ml)			NL (Mg) (g/m**2)	Mn (ng/ml)			NL (Mn) (g/m**2)		Mo (ng/ml)		NL (Mo) (g/m**2)		Na (ug/ml)			NL (Na) (g/m**2)
	*	**	***	****	*	**	***	****	*	**	***	****	*	**	***	****	
				(0.42)				(1.76)				(0.01)					(0.05)
G-300	-	-	-	-	-	-	-	-	-				-	-	-	-	-
G-301	280	393	48	0.35	500	701	621	1.07	-				36.4	51.0	1.2	0.45	
G-302	410	576	231	1.66	450	632	552	0.95	-				38.1	53.6	4.9	1.84	
G-303	590	830	485	3.43	890	1250	1170	1.98	-				42.1	59.3	10.6	3.91	
G-304	480	862	517	3.55	1180	2120	2040	3.35	L20				32.6	58.5	14.9	5.34	
G-305	430	784	439	3.18	460	838	758	1.31	L20				30.1	54.9	11.3	4.27	
G-306	580	1050	705	4.94	420	761	681	1.14	-				34.4	62.4	16.8	6.14	
G-307	560	1020	675	4.68	520	948	868	1.43	-				33.6	61.3	15.7	5.67	
G-308	650	915	570	3.91	620	872	792	1.30	-				44.8	63.0	15.3	5.48	
G-309	640	901	556	4.10	660	929	849	1.50	-				44.1	62.1	14.4	5.55	
G-310	740	1051	31	0.22	330	469	344	0.57	-				35.8	50.9	2.5	0.91	
G-311	-	-	-	-	-	-	-	0.00	-				-	-	-	0.00	
G-312	690	985	-35	-0.23	340	485	315	0.50	-				44.3	63.3	6.6	2.31	
G-313	770	1100	80	0.55	520	742	572	0.94	-				43.8	62.5	5.8	2.09	
G-314	620	1130	110	0.77	200	365	165	0.27	L20				31.4	57.3	8.4	3.05	
G-315	800	1470	450	3.19	280	516	316	0.54	L20				32.0	58.9	10.0	3.70	
G-316	560	1030	10	0.07	270	497	217	0.36	-				38.1	70.2	18.0	6.52	
G-317	780	1440	420	2.76	340	627	347	0.54	-				38.3	70.6	18.4	6.31	
G-318	750	1070	50	0.35	250	355	5	0.01	-				49.7	70.7	16.0	5.82	
G-319	880	1260	240	1.66	340	485	135	0.22	-				48.1	68.7	14.0	5.06	
				(0.42)				(1.76)				(0.01)					(0.05)
G-320	250	355	10	0.07	300	426	346	0.59	-				35.8	50.2	5.4	2.03	
G-321	270	380	35	0.24	330	464	384	0.64	-				36.2	50.7	5.9	2.14	
G-322	410	585	240	1.65	520	742	662	1.09	-				37.6	53.7	10.1	3.63	
G-323	420	591	246	1.79	470	661	581	1.01	-				38.6	54.3	10.7	4.05	
G-324	390	712	367	2.61	440	804	724	1.23	L20				29.7	54.3	10.7	3.98	
G-325	490	877	532	3.66	670	1200	1120	1.84	L20				31.6	56.9	13.3	4.77	
G-326	590	1100	755	5.12	630	1170	1090	1.76	-				32.6	60.5	14.9	5.27	
G-327	560	1010	665	4.64	510	923	843	1.40	-				32.9	59.6	14.0	5.10	
G-328	630	898	553	3.81	610	870	790	1.30	-				42.2	60.2	13.5	4.85	
G-329	670	943	598	4.11	700	985	905	1.48	-				43.2	60.8	14.1	5.05	
																by zero	
G-330	850	1220	200	1.32	240	345	220	0.35	-				35.2	50.7	2.3	0.79	
G-331	880	1250	230	1.66	260	368	243	0.42	-				35.5	50.3	1.9	0.72	
G-332	740	1070	50	0.34	400	576	405	0.66	-				42.4	60.6	3.9	1.38	
G-333	720	1030	10	0.07	340	486	316	0.51	-				42.4	60.6	3.9	1.39	
G-334	410	767	-253	-1.76	210	393	193	0.32	L20				33.7	63.0	14.1	5.13	
G-335	700	1300	280	1.87	200	371	171	0.27	L20				32.2	59.7	10.8	3.77	
G-336	510	958	-62	-0.43	270	507	227	0.37	-				35.8	67.3	15.1	5.41	
G-337	810	1500	480	3.14	320	591	311	0.48	-				34.6	63.9	11.7	3.99	
G-338	740	1070	50	0.35	480	692	342	0.56	-				47.3	68.2	13.5	4.86	
G-339	620	881	-139	-0.92	410	583	233	0.37	-				49.3	70.1	15.4	5.34	

Data Table C (Cont'd)

TEST NUMBER	Nd (ng/ml)			NL (Nd) (g/m**2)	Ni (ng/ml)			NL (Ni) (g/m**2)	Si (ug/ml)			NL (Si) (g/m**2)	Sr (ng/ml)			NL (Sr) (g/m**2)
	*	**	***	****	*	**	***	****	*	**	***	****	*	**	***	****
				(0.04)				(0.67)				(24.71)				(0.08)
G-300					-	-	-	-	-	-	-	-	-	-	-	-
G-301					1320	1850	1740	7.88	31.2	43.7	0.7	0.09	34	48	4	0.15
G-302					720	1010	900	4.06	37.8	53.1	7.1	0.87	49	69	25	0.94
G-303					1300	1830	1720	7.63	43.7	61.5	15.5	1.86	74	104	60	2.23
G-304					530	952	842	3.63	37.7	67.7	18.7	2.18	80	144	100	3.61
G-305					430	784	674	3.06	40.9	74.6	25.6	3.15	61	111	67	2.55
G-306					450	816	706	3.10	49.5	89.7	31.7	3.78	101	183	139	5.11
G-307					570	1040	930	4.04	49.4	90.1	32.1	3.78	87	159	115	4.18
G-308					780	1100	990	4.26	55.1	77.5	13.5	1.57	104	146	102	3.67
G-309					810	1140	1030	4.77	59.4	83.6	19.6	2.46	95	134	90	3.49
G-310					720	1020	955	4.18	40.1	57	2.0	0.24	61	87	5	0.18
G-311					-	-	-	0.00	-	-	-	-	-	-	-	0.00
G-312					700	999	934	3.92	53.2	76.0	18.0	2.05	56	80	-2	-0.07
G-313					890	1270	1205	5.21	57.1	81.4	23.4	2.74	59	84	2	0.07
G-314					320	584	519	2.26	44.5	81.2	18.2	2.16	47	86	4	0.15
G-315					290	534	469	2.09	39.1	72.0	9.0	1.09	62	114	32	1.19
G-316					320	589	524	2.28	53.5	98.5	24.5	2.89	41	76	-6	-0.22
G-317					410	756	691	2.85	56.5	104	30.1	3.37	58	107	25	0.86
G-318					360	512	447	1.95	59.0	83.9	-4.1	-0.49	61	87	5	0.18
G-319					420	599	534	2.32	59.2	84.5	-3.5	-0.41	68	97	15	0.55
				(0.04)				(0.67)				(24.71)				(0.08)
G-320					630	895	785	3.54	31.9	45.3	2.3	0.28	30	43	-1	-0.04
G-321					710	999	889	3.88	31.6	44.5	1.5	0.18	32	5	-39	-1.43
G-322					800	1140	1030	4.45	41.9	59.8	13.8	1.62	52	74	30	1.08
G-323					670	942	832	3.79	36.9	51.9	5.9	0.73	53	75	31	1.18
G-324					420	767	657	2.93	48.8	89.2	40.2	4.86	57	104	60	2.24
G-325					520	931	821	3.54	36.6	65.5	16.5	1.93	64	115	71	2.56
G-326					630	1170	1060	4.50	51.1	94.9	36.9	4.25	81	150	106	3.77
G-327					590	1070	960	4.20	52.4	94.9	36.9	4.37	80	145	101	3.70
G-328					800	1140	1030	4.45	59.3	84.5	20.5	2.40	100	143	99	3.58
G-329					1020	1440	1330	5.73	67.1	94.5	20.5	2.39	106	149	105	3.79
G-330					560	806	741	3.06	38.1	54.8	2.3	0.26	74	106	24	0.83
G-331					600	850	785	3.56	41.4	58.6	1.5	0.18	75	106	24	0.91
G-332					700	1010	945	4.01	46.9	67.5	10.5	1.21	61	88	6	0.21
G-333					680	971	906	3.87	49.8	71.1	14.1	1.63	59	84	2	0.07
G-334					300	561	496	2.17	45.5	85.1	22.1	2.62	30	56	-26	-0.95
G-335					310	575	510	2.14	40.9	75.8	12.8	1.46	54	100	18	0.63
G-336					360	676	611	2.63	51.0	95.8	21.8	2.55	36	68	-14	-0.50
G-337					360	664	599	2.45	50.5	93.2	19.2	2.13	34	63	-19	-0.65
G-338					460	663	598	2.59	65.1	93.8	5.8	0.68	57	82	0	0.00
G-339					470	668	603	2.51	60.9	86.6	-1.4	-0.16	47	67	-15	-0.52

Data Table C (Cont'd)

TEST NUMBER	Ti (ng/ml)			NL(Ti) (g/m**2)	U (ng/ml)			NL(U) (g/m**2)	Zn (ng/ml)			NL(Zn) (g/m**2)	Zr (ng/ml)			NL(Zr) (g/m**2)
	*	**	***	****	*	**	***	****	*	**	***	****	*	**	***	****
				(0.08)				(0.81)				(0.03)				(0.49)
G-300	-	-	-	-	-	-	-	-	-				L20			
G-301	33	46	46	1.74	77.8	109	109	0.34	-				L20			
G-302	27	38	38	1.43	198	278	278	0.86	-				L20			
G-303	30	42	42	1.56	581	818	818	2.48	-				L20			
G-304	L10				493	885	885	2.67	41	74	45	4.33	L20			
G-305	L10				417	760	760	2.34	35	64	35	3.55	L20			
G-306	12	22	22	0.81	900	1630	1630	4.92	-				L20			
G-307	15	27	27	0.98	882	1610	1610	4.77	-				21	38	38	0.23
G-308	L20				1033	1450	1450	4.38	-				30	42	42	0.25
G-309	20	28	28	1.08	932	1310	1310	4.17	-				34	48	48	0.30
G-310	31	44	44	1.61	166	236	236	0.70	-				L20			
G-311	-	-	-	-	-	-	-	-	-				L20			
G-312	31	44	44	1.55	305	435	435	1.22	-				L20			
G-313	37	53	53	1.92	319	455	455	1.32	-				L20			
G-314	13	24	24	0.88	321	586	586	1.77	29	53	53	5.16	27	49	49	0.29
G-315	12	22	22	0.82	355	654	654	1.95	22	41	41	4.08	23	42	42	0.26
G-316	20	37	37	1.35	466	858	858	2.53	-				76	140	140	0.83
G-317	17	31	31	1.07	470	866	866	2.42	-				48	88	88	0.50
G-318	20	28	28	1.02	584	830	830	2.47	-				53	75	75	0.45
G-319	20	29	29	1.05	603	861	861	2.52	-				49	70	70	0.42
				(0.08)				(0.81)				(0.03)				(0.49)
G-320	29	41	41	1.55	21.7	30.8	30.8	0.09	-				L20			
G-321	28	39	39	1.43	43.8	61.6	61.6	0.18	-				L20			
G-322	32	46	46	1.66	214	305	305	0.86	-				L20			
G-323	32	45	45	1.71	259	364	364	1.13	-				L20			
G-324	L10				365	667	667	2.00	40	73	44	4.39	L20			
G-325	13	23	23	0.83	497	890	890	2.71	29	52	23	2.21	L20			
G-326	16	33	33	1.17	797	1480	1480	4.13	-				26	48	48	0.28
G-327	17	31	31	1.14	832	1510	1510	4.57	-				21	38	38	0.23
G-328	22	31	31	1.12	938	1340	1340	3.81	-				35	50	50	0.30
G-329	21	30	30	1.08	930	1310	1310	3.88	-				35	49	49	0.29
G-330	33	47	47	1.63	111	160	160	0.43	-				L20			
G-331	28	40	40	1.52	126	178	178	0.55	-				L20			
G-332	38	55	55	1.96	274	394	394	1.09	-				L20			
G-333	33	47	47	1.68	310	443	443	1.27	-				L20			
G-334	16	30	30	1.10	279	522	522	1.50	38	71	71	6.93	46	86	86	0.51
G-335	12	22	22	0.77	287	532	532	1.48	180	334	334	31.27	25	46	46	0.26
G-336	22	41	41	1.48	477	896	896	2.50	-				71	133	133	0.78
G-337	19	35	35	1.20	463	855	855	2.37	-				45	83	83	0.46
G-338	29	42	42	1.52	644	928	928	2.62	-				84	121	121	0.72
G-339	31	44	44	1.53	611	869	869	2.48	-				113	160	160	0.91

Data Table C (Cont'd)

TEST TYPE	TEST NUMBER	TOTAL SOLUTION MASS (g)	MASS SOLUTION SUBMITTED (g)	GLASS SURFACE AREA (mm**2)	pH	Al (ng/ml) *	Al (ng/ml) **	Al (ng/ml) ***	NL(Al) (g/m**2) ****	B (ng/ml) *	B (ng/ml) **	B (ng/ml) ***	NL(B) (g/m**2) ****
									(2.16)				(2.10)
	G-340	14.88	12.67	505	8.29	1640	2290	1930	2.64	190	265	115	0.16
	G-341	14.88	12.68	496	8.31	590	823	463	0.64	230	320	170	0.24
	G-342	14.88	12.27	490	8.85	1020	1440	1080	1.52	200	282	132	0.19
	G-343	14.86	12.41	495	8.82	750	1050	690	0.96	350	491	341	0.49
	G-344	14.84	12.07	500	8.42	1580	2240	1880	2.59	173	245	95	0.13
	G-345	14.85	12.06	485	8.61	930	1320	960	1.36	620	877	727	1.06
SRL U	G-346	14.79	12.15	487	9.27	930	1690	1330	1.87	1160	2110	1960	2.84
NO GAMMA	G-347	14.84	12.22	507	9.27	880	1600	1240	1.68	1120	2040	1890	2.64
	G-348	14.76	11.96	508	9.06	980	1800	1440	1.94	1270	2330	2180	3.02
	G-349	14.75	11.92	507	8.53	580	1070	710	0.96	1580	2900	2750	3.82
	G-350	14.59	12.15	515	8.82	1230	1740	1380	1.82	2000	2820	2670	3.61
	G-351	14.58	10.13	489	9.06	1300	1940	1580	2.18	2020	3020	2870	4.08
	G-352	14.47	12.10	502	7.73	370	523	313	0.42	490	692	487	0.67
	G-353	14.47	12.14	498	7.66	370	522	312	0.42	440	621	416	0.58
	G-354	14.59	11.86	502	8.14	410	583	373	0.50	1110	1580	1375	1.91
	G-355	14.52	11.94	496	8.28	490	695	485	0.66	1020	1450	1245	1.74
	G-356	14.46	11.58	494	8.41	820	1170	960	1.30	1470	2110	1905	2.66
	G-357	14.49	11.69	477	8.34	1120	1600	1390	1.96	1350	1930	1725	2.50
SRL U +	G-358	14.46	11.75	502	8.74	520	962	752	1.00	1900	3510	3305	4.54
TUFF	G-359	14.36	12.21	498	8.84	670	1220	1010	1.35	1910	3471	3266	4.49
NO GAMMA	G-360	14.36	11.60	509	8.85	930	1730	1520	1.99	3020	5620	5415	7.29
	G-361	14.33	11.45	511	8.98	930	1740	1530	1.99	3030	5670	5465	7.31
	G-362	14.24	11.36	498	8.97	1400	2020	1810	2.40	5480	7890	7685	10.49
	G-363	14.29	11.54	513	8.99	1220	1750	1540	1.99	5360	7680	7475	9.94
									(2.16)				(2.10)
	G-364	14.86	11.98	525	8.28	670	950	590	0.77	200	283	133	0.18
	G-365	14.86	12.58	513	8.30	910	1270	910	1.22	190	266	116	0.16
	G-366	14.87	11.92	503	8.93	820	1160	800	1.10	370	525	375	0.53
	G-367	14.88	11.68	523	8.91	720	1020	660	0.87	390	554	404	0.55
	G-368	14.86	11.86	528	8.74	900	1280	920	1.20	430	611	461	0.62
	G-369	14.81	12.28	510	8.97	1100	1550	1190	1.60	920	1300	1150	1.59
SRL A	G-370	14.85	11.58	497	9.21	910	1690	1330	1.85	1220	2270	2120	3.03
NO GAMMA	G-371	14.84	12.33	514	9.24	890	1610	1250	1.67	1060	1920	1770	2.44
	G-372	14.78	11.66	502	7.93	720	1340	980	1.34	1620	3010	2860	4.02
	G-373	14.74	12.27	520	9.12	1230	2230	1870	2.46	1490	2700	2550	3.45
	G-374	14.69	11.56	497	5.04	940	1350	990	1.36	3100	4440	4290	6.05
	G-375	14.58	11.79	506	7.54	1140	1620	1260	1.68	2160	3080	2930	4.03
	G-376	14.48	11.27	490	7.60	410	592	382	0.52	530	765	560	0.79
	G-377	14.47	11.66	517	7.77	420	600	390	0.51	520	743	538	0.72
	G-378	14.56	11.42	467	8.10	450	647	437	0.63	860	1240	1035	1.54
	G-379	14.55	11.86	495	8.47	520	739	529	0.72	780	1110	905	1.27
	G-380	14.48	11.28	523	8.49	760	1100	890	1.14	1890	2730	2525	3.33
	G-381	14.43	11.63	483	8.25	550	782	572	0.79	910	1300	1095	1.56
SRL A +	G-382	14.42	11.10	523	8.85	640	1220	1010	1.29	2090	3970	3765	4.96
TUFF	G-383	14.43	9.87	487	8.80	680	1370	1160	1.60	1980	3980	3775	5.34
NO GAMMA	G-384	14.36	11.13	514	8.90	980	1860	1650	2.14	3080	5840	5635	7.51
	G-385	14.39	11.57	505	8.81	1010	1880	1670	2.21	2650	4940	4735	6.44
	G-386	14.21	11.03	495	9.02	1440	2090	1880	2.50	4980	7237	7032	9.63
	G-387	14.27	11.53	516	9.07	1400	2010	1800	2.31	5030	7210	7005	9.24

Data Table C (Cont'd)

TEST NUMBER	Ba (ng/ml) *	**	***	NL(Ba) (g/m**2) ****	Ca (ug/ml) *	**	***	NL(Ca) (g/m**2) ****	Ce (ng/ml) *	**	***	NL(Ce) (g/m**2) ****	Cr (ng/ml) *	**	***	NL(Cr) (g/m**2) ****
				(0.05)				(1.16)				(0.04)				(0.01)
G-340	-				5.12	7.14	0.37	0.94	-				-			
G-341	-				4.95	6.90	0.13	0.34	-				-			
G-342	-				4.91	6.91	-0.17	-0.45	-				-			
G-343	-				4.93	6.92	-0.16	-0.42	-				-			
G-344	-				5.91	8.36	-0.20	-0.51	-				-			
G-345	-				5.86	8.29	-0.27	-0.71	-				-			
G-346	35	64	64	3.89	4.52	8.23	-0.47	-1.23	-				-			
G-347	34	62	62	3.64	4.45	8.08	-0.62	-1.57	-				-			
G-348	38	70	70	4.08	4.81	8.82	0.06	0.15	-				-			
G-349	28	51	51	2.97	4.92	9.04	0.28	0.70	-				-			
G-350	-				5.63	7.95	-0.18	-0.44	-				-			
G-351	-				5.45	8.14	0.01	0.03	-				-			
G-352	-				3.40	4.80	-0.53	-1.32	-				-			
G-353	-				3.75	5.29	-0.04	-0.10	-				-			
G-354	-				2.57	3.65	0.38	0.95	-				-			
G-355	-				2.82	4.00	0.73	1.84	-				-			
G-356	-				1.72	2.46	-0.24	-0.61	-				-			
G-357	-				1.54	2.20	-0.50	-1.31	-				-			
G-358	26	48	48	2.77	1.10	2.03	-0.68	-1.69	-				-			
G-359	30	55	55	3.18	0.96	1.74	-0.97	-2.42	-				-			
G-360	44	82	82	4.64	1.27	2.36	-0.35	-0.85	-				-			
G-361	43	80	80	4.50	1.19	2.23	-0.48	-1.16	-				-			
G-362	-				1.34	1.93	0.45	1.11	-				-			
G-363	-				1.44	2.06	0.58	1.40	-				-			
				(0.05)				(1.16)				(0.04)				(0.01)
G-364	-				4.98	7.09	0.32	0.78	-				-			
G-365	-				4.98	6.96	0.19	0.48	-				-			
G-366	-				4.90	6.96	-0.12	-0.31	-				-			
G-367	-				4.80	6.82	-0.26	-0.64	-				-			
G-368	-				5.87	8.34	-0.22	-0.53	-				-			
G-369	-				5.77	8.12	-0.44	-1.10	-				-			
G-370	28	52	52	3.12	4.51	8.40	-0.30	-0.78	-				-			
G-371	29	52	52	3.01	4.55	8.23	-0.47	-1.17	-				-			
G-372	28	52	52	3.07	5.10	9.47	0.71	1.81	-				-			
G-373	43	78	78	4.43	4.51	8.18	-0.58	-1.42	-				-			
G-374					6.98	10.00	1.87	4.77	-				-			
G-375					5.51	7.85	-0.28	-0.70	-				-			
G-376	-				3.30	4.76	-0.57	-1.46	-				-			
G-377	-				3.19	4.56	-0.77	-1.86	-				-			
G-378	-				2.75	3.95	0.68	1.83	-				-			
G-379	-				1.97	2.80	-0.47	-1.19	-				-			
G-380	-				1.49	2.15	-0.55	-1.31	-				-			
G-381	-				1.85	2.63	-0.07	-0.18	-				-			
G-382	29	55	55	3.04	0.91	1.73	-0.98	-2.34	-				-			
G-383	35	70	70	4.16	1.00	2.01	-0.70	-1.79	-				-			
G-384	41	78	78	4.37	1.19	2.26	-0.45	-1.09	-				-			
G-385	40	75	75	4.28	1.32	2.46	-0.25	-0.62	-				-			
G-386	-				1.47	2.14	0.66	1.64	-				-			
G-387	-				1.53	2.19	0.71	1.70	-				-			

Data Table C (Cont'd)

TEST NUMBER	Cs (ng/ml) *	Cs (ng/ml) **	Cs (ng/ml) ***	NL(Cs) (g/m**2) ****	Fe (ug/ml) *	Fe (ug/ml) **	Fe (ug/ml) ***	NL(Fe) (g/m**2) ****	La (ng/ml) *	La (ng/ml) **	La (ng/ml) ***	NL(La) (g/m**2) ****	Li (ng/ml) *	Li (ng/ml) **	Li (ng/ml) ***	NL(Li) (g/m**2) ****
				(0.07)				(8.21)				(0.04)				(1.94)
G-340					9.63	13.40	13.10	4.71	-				483	674	630	1.02
G-341					9.22	12.90	12.60	4.61	-				504	703	659	1.09
G-342					9.46	13.3	12.8	4.74	-				673	947	903	1.48
G-343					10.4	14.6	14.1	5.17	-				795	1120	1076	1.74
G-344					8.67	12.3	11.4	4.12	-				770	1090	1046	1.67
G-345					10.4	14.7	13.8	5.16	-				1090	1540	1496	2.44
G-346					5.32	9.69	8.54	3.16	-				1770	3220	3176	5.05
G-347					4.91	8.92	7.77	2.78	-				1750	3180	3136	4.81
G-348					5.29	9.70	8.00	2.84	-				1870	3430	3386	5.15
G-349					2.88	5.29	3.59	1.28	-				2110	3880	3836	5.83
G-350					6.87	9.70	7.65	2.65	-				2840	4010	3966	5.87
G-351					7.33	11.00	8.95	3.25	-				2600	3880	3836	5.97
G-352					9.15	12.90	12.35	4.35	-				537	759	721	1.13
G-353					10.00	14.10	13.55	4.81	-				522	737	699	1.11
G-354					8.06	11.5	10.91	3.87	-				1120	1590	1552	2.39
G-355					11.2	15.9	15.34	5.48	-				990	1410	1372	2.13
G-356					10.8	15.5	14.91	5.33	-				1320	1890	1852	2.86
G-357					11.6	16.6	16.01	5.93	-				1190	1700	1662	2.67
G-358					3.19	5.90	5.35	1.88	-				1650	3050	3012	4.54
G-359					4.57	8.31	7.76	2.73	-				1600	2910	2872	4.34
G-360					6.82	12.7	12.14	4.18	-				2470	4600	4562	6.71
G-361					6.70	12.5	11.99	4.10	-				2610	4890	4852	7.08
G-362					10.20	14.70	14.15	4.94	-				3810	5490	5452	8.11
G-363					9.20	13.20	12.65	4.30	-				3820	5480	5442	7.89
				(0.04)				(8.21)				(0.04)				(1.94)
G-364					9.54	13.60	13.30	4.59	-				454	647	603	0.95
G-365					9.44	13.20	12.90	4.56	-				499	697	653	1.04
G-366					11.2	15.9	15.4	5.55	-				803	1140	1096	1.74
G-367					8.76	12.6	4.8	1.68	-				776	1100	1056	1.62
G-368					10.1	14.4	13.5	4.63	-				930	1320	1276	1.92
G-369					12.1	17.0	16.1	5.72	-				1510	2130	2086	3.20
G-370					4.85	9.03	7.88	2.88	-				1830	3410	3366	5.27
G-371					4.87	8.81	7.66	2.70	-				1640	2970	2926	4.43
G-372					2.56	4.75	3.05	1.10	-				2190	4056	4016	6.18
G-373					6.94	12.6	10.9	3.77	-				2190	3970	3926	5.81
G-374					2.26	3.24	1.19	0.43	-				4430	6356	6306	9.70
G-375					6.42	9.15	7.10	2.50	-				2940	4190	4146	6.23
G-376					9.87	14.30	13.75	4.96					477	689	651	1.05
G-377					10.80	15.40	14.85	5.07					593	847	809	1.22
G-378					8.87	12.7	12.20	4.64	-				817	1180	1142	1.90
G-379					8.35	11.9	11.32	4.06	-				853	1210	1172	1.84
G-380					10.9	15.7	15.18	5.13	-				1590	2300	2262	3.29
G-381					10.7	15.2	14.67	5.35	-				900	1280	1242	1.98
G-382					4.09	7.77	7.22	2.43	-				1790	3400	3362	4.84
G-383					5.20	10.5	9.91	3.58	-				1670	3360	3322	5.14
G-384					6.74	12.8	12.23	4.17	-				2470	4690	4652	6.77
G-385					6.56	12.2	11.67	4.06	-				2250	4190	4152	6.17
G-386					10.40	15.10	14.55	5.10					3630	5280	5242	7.83
G-387					9.99	14.30	13.75	4.64					3890	5580	5542	7.97

Data Table C (Cont'd)

TEST NUMBER	Mg (ng/ml)			NL (Mg) (g/m**2)	Mn (ng/ml)			NL (Mn) (g/m**2)	Mo (ng/ml)			NL (Mo) (g/m**2)	Na (ug/ml)			NL (Na) (g/m**2)
	*	**	***	****	*	**	***	****	*	**	***	****	*	**	***	****
				(0.42)				(1.76)				(0.01)				(8.05)
G-340	260	363	18	0.13	230	321	241	0.40	-				35.5	49.5	1.9	0.70
G-341	230	321	-24	-0.17	280	391	311	0.53	-				35.8	49.9	2.3	0.86
G-342	230	324	-21	-0.15	260	366	286	0.49	-				36.6	51.5	6.5	2.45
G-343	270	379	34	0.24	540	758	678	1.16	-				37.1	52.0	7.0	2.62
G-344	300	424	79	0.56	280	396	316	0.53	-				36.7	51.9	2.9	1.07
G-345	280	396	51	0.37	560	792	712	1.24	-				38.9	55.0	6.0	2.29
G-346	480	874	529	3.83	660	1200	1120	1.94	-				29.7	54.1	8.7	3.29
G-347	440	799	454	3.17	670	1220	1140	1.90	-				29.8	54.1	8.7	3.17
G-348	380	697	352	2.44	590	1080	1000	1.65	-				30.4	55.8	10.7	3.87
G-349	200	367	22	0.15	220	404	324	0.54	-				31.6	58.1	13.0	4.71
G-350	400	565	220	1.49	540	762	682	1.10	-				41.2	58.2	10.9	3.85
G-351	420	627	282	2.00	610	911	831	1.41	-				40.0	59.7	12.4	4.60
G-352	550	777	432	2.97	230	325	300	0.49	-				33.5	47.3	1.0	0.36
G-353	620	875	530	3.68	240	339	314	0.52	-				33.3	47.0	0.7	0.25
G-354	510	725	380	2.64	260	370	345	0.57	-				34.8	49.5	3.6	1.30
G-355	520	738	393	2.74	390	553	528	0.88	-				34.6	49.1	3.2	1.17
G-356	580	830	485	3.39	400	573	548	0.91	-				39.5	56.6	5.5	2.00
G-357	520	742	397	2.88	400	571	546	0.94	-				37.8	54.0	3.9	1.47
G-358	440	814	469	3.22	180	333	308	0.50	-				27.1	50.1	4.7	1.68
G-359	610	1110	765	5.26	280	509	484	0.79	-				25.5	46.3	0.6	0.22
G-360	1050	1950	1605	10.81	390	726	701	1.13	-				28.3	52.6	6.2	2.18
G-361	1000	1870	1525	10.20	390	730	705	1.13	-				29.5	55.2	8.8	3.07
G-362	1550	2230	1885	12.87	590	850	825	1.34	-				40.8	58.8	11	3.92
G-363	1320	1890	1545	10.27	560	803	778	1.23	-				40.7	58.3	10.5	3.64
				(0.42)				(1.76)				(0.01)				(8.05)
G-364	230	328	-17	-0.11	280	399	319	0.51	-				35.1	50.0	2.4	0.84
G-365	260	363	18	0.12	290	405	325	0.54	-				35.5	49.6	2.0	0.72
G-366	290	412	67	0.47	440	625	545	0.92	-				36.0	50.7	5.7	2.10
G-367	270	384	39	0.26	390	554	474	0.77	-				35.9	50.5	5.5	1.95
G-368	340	483	138	0.93	410	583	503	0.81	-				37.0	52.3	3.3	1.16
G-369	430	605	260	1.80	670	943	863	1.43	-				39.8	56.3	7.3	2.64
G-370	460	856	511	3.65	590	1100	1020	1.74	-				29.3	54.6	9.2	3.42
G-371	440	796	451	3.11	580	1050	970	1.60	-				29.2	52.8	7.4	2.66
G-372	460	854	509	3.58	240	445	365	0.61	-				31.2	57.9	12.8	4.69
G-373	540	979	634	4.29	770	1400	1320	2.13	-				30.6	55.9	10.8	3.81
G-374	870	1250	905	6.38	2850	4080	4000	6.73	-				47.8	68.5	21.2	7.80
G-375	350	499	154	1.06	450	641	561	0.92	-				41.2	58.7	11.4	4.09
G-376	560	808	463	3.26	230	332	307	0.52	-				33.2	47.9	1.6	0.59
G-377	540	772	427	2.85	290	414	389	0.62	-				33.8	48.3	2.0	0.70
G-378	510	733	386	2.86	240	345	320	0.57	-				33.9	48.7	2.8	1.09
G-379	400	569	224	1.57	300	426	401	0.67	-				36.2	51.5	5.6	2.05
G-380	580	837	492	3.25	410	592	567	0.89	-				37.9	54.7	3.6	1.24
G-381	420	598	253	1.80	280	398	373	0.63	-				36.9	52.5	1.4	0.52
G-382	540	1030	685	4.51	280	532	507	0.80	-				25.8	49.0	3.3	1.13
G-383	650	1310	965	6.82	280	563	538	0.91	-				25.1	50.5	4.8	1.77
G-384	1060	2010	1665	11.10	370	702	677	1.08	-				28.2	53.5	7.1	2.47
G-385	1160	2160	1815	12.34	410	764	739	1.20	-				27.7	51.6	5.2	1.85
G-386	1600	2330	1985	13.60	540	785	760	1.24	-				38.9	56.5	8.7	3.11
G-387	1600	2290	1945	12.83	550	789	764	1.20	-				39.8	57.1	9.3	3.20

Data Table C (Cont'd)

TEST NUMBER	Nd (ng/ml)			NL(Nd) (g/m**2)	Ni (ng/ml)			NL(Ni) (g/m**2)	Si (ug/ml)			NL(Si) (g/m**2)	Sr (ng/ml)			NL(Sr) (g/m**2)
	*	**	***	****	*	**	***	****	*	**	***	****	*	**	***	****
				(0.04)				(0.67)				(24.71)				(0.08)
G-340					670	934	774	3.41	27.4	38.2	2.2	0.26	29	40	-4	-0.15
G-341					620	865	705	3.16	26.8	37.4	1.4	0.17	30	42	-2	-0.08
G-342					570	802	642	2.91	27.9	39.3	2.3	0.28	28	39	-5	-0.19
G-343					760	1070	910	4.09	36.7	51.5	14.5	1.77	35	49	5	0.19
G-344					510	721	561	2.49	30.6	43.3	4.3	0.52	34	48	4	0.15
G-345					650	919	759	3.48	37.9	53.6	14.6	1.81	49	69	25	0.96
G-346					440	801	641	2.91	43.1	78.5	37.5	4.62	54	98	54	2.05
G-347					430	781	621	2.72	38.7	70.3	29.3	3.48	53	96	52	1.91
G-348					490	899	739	3.21	41.6	76.3	25.3	2.98	62	114	70	2.55
G-349					230	423	263	1.14	43.0	79.0	28.0	3.30	74	136	92	3.35
G-350					610	861	701	2.97	64.2	90.6	31.6	3.63	89	126	82	2.91
G-351					690	1030	870	3.88	77.0	115.0	56.0	6.76	86	128	84	3.13
G-352					580	820	770	3.32	35.0	49.5	-2.5	-0.29	51	72	34	1.23
G-353					670	946	896	3.90	36.1	51.0	-1.0	-0.12	56	79	41	1.49
G-354					510	725	675	2.94	41.5	59.0	4.0	0.47	38	54	16	0.58
G-355					660	936	886	3.88	42.6	60.4	5.4	0.64	45	64	26	0.95
G-356					880	1260	1210	5.30	50.5	72.3	13.3	1.58	27	39	1	0.04
G-357					870	1240	1190	5.40	48.1	103.2	44.2	5.44	25	36	-2	-0.08
G-358					360	666	616	2.65	45.6	84.3	22.3	2.61	17	31	-7	-0.25
G-359					420	763	713	3.08	50.5	91.8	29.8	3.48	16	29	-9	-0.33
G-360					590	1100	1050	4.43	50.5	93.9	24.9	2.86	21	39	1	0.04
G-361					580	1090	1040	4.36	53.3	99.8	30.8	3.50	21	39	1	0.04
G-362					790	1140	1090	4.66	69.4	100	25.0	2.90	26	37	-1	-0.04
G-363					730	1050	1000	4.17	67.7	97	22.0	2.49	24	34	-4	-0.14
				(0.04)				(0.67)				(24.71)				(0.08)
G-364					650	926	766	3.24	27.5	39.2	3.2	0.37	29	41	-3	-0.11
G-365					680	950	790	3.42	27.6	38.6	2.6	0.31	29	41	-3	-0.11
G-366					690	979	819	3.62	30.4	46.2	9.2	1.10	35	50	6	0.22
G-367					690	981	821	3.49	29.7	42.2	5.2	0.60	36	51	7	0.25
G-368					660	938	778	3.27	33.5	47.6	8.6	0.98	44	63	19	0.67
G-369					690	971	811	3.52	41.0	57.7	18.7	2.20	56	79	35	1.27
G-370					410	763	603	2.70	39.1	72.8	31.8	3.86	48	89	45	1.69
G-371					390	706	546	2.36	38.6	69.8	28.8	3.38	55	100	56	2.03
G-372					150	278	118	0.52	52.9	98.2	47.2	5.64	87	161	117	4.32
G-373					580	1050	890	3.77	60.1	109.0	58.0	6.66	65	118	74	2.63
G-374					1360	1950	1790	7.91	64.8	92.8	33.8	4.05	175	251	207	7.66
G-375					570	813	653	2.81	59.2	84.4	25.4	2.97	96	137	93	3.36
G-376					690	996	946	4.18	35.5	51.0	-1.0	-0.12	50	72	34	1.26
G-377					700	1000	950	3.97	37.1	53.0	1.0	0.11	48	69	31	1.09
G-378					560	805	755	3.52	46.3	66.6	11.6	1.47	43	62	24	0.94
G-379					580	825	775	3.41	40.1	57.0	2.0	0.24	32	45	7	0.26
G-380					840	1210	1160	4.80	52.4	75.6	16.6	1.86	29	42	4	0.14
G-381					760	1080	1030	4.61	46.6	66.3	7.3	0.89	29	41	3	0.11
G-382					360	684	634	2.62	54.6	103.7	41.7	4.66	15	28	-10	-0.35
G-383					440	885	835	3.70	42.9	86.3	24.3	2.92	16	32	-6	-0.22
G-384					580	1100	1050	4.39	53.2	100.9	31.9	3.62	21	40	2	0.07
G-385					630	1170	1120	4.77	53.4	99.5	30.5	3.52	22	41	3	0.11
G-386					820	1190	1140	4.90	64.1	122.1	-10.9	-1.27	29	42	4	0.14
G-387					790	1130	1080	4.47	69.7	130.0	-5.3	-0.59	30	43	5	0.17

Data Table C (Cont'd)

TEST NUMBER	Ti (ng/ml)			NL(Ti) (g/m**2)		U (ng/ml)		NL(U) (g/m**2)		Zn (ng/ml)		NL(Zn) (g/m**2)		Zr (ng/ml)			NL(Zr) (g/m**2)
	*	**	***	****	*	**	***	****	*	**	***	****	*	**	**	***	****
				(0.08)				(0.81)				(0.03)					(0.49)
G-340	29	40	40	1.48	7.45	10.4	10.4	0.03	-				L20				
G-341	27	38	38	1.43	34	47.7	47.7	0.15	-				L20				
G-342	27	38	38	1.44	10.9	15.3	15.3	0.05	-				L20				
G-343	35	49	49	1.84	92.5	130	130	0.40	-				L20				
G-344	26	40	40	1.49	11.2	15.8	15.8	0.05	-				L20				
G-345	39	55	55	2.11	226	320	320	0.99	-				L20				
G-346	22	40	40	1.52	511	931	931	2.87	-				42	76	76		0.47
G-347	21	38	38	1.39	503	914	914	2.73	-				35	64	64		0.38
G-348	22	40	40	1.46	588	1079	1079	3.14	-				49	90	90		0.53
G-349	13	24	24	0.87	426	783	783	2.28	-				L20				
G-350	25	35	35	1.24	867	1220	1220	3.56	-				50	71			0.00
G-351	28	42	42	1.57	918	1370	1370	3.51	-				52	78			0.00
G-352	29	41	41	1.48	112	158	158	0.47	-				L20				
G-353	32	45	45	1.64	84.8	120	120	0.36	-				L20				
G-354	28	40	40	1.46	255	363	363	1.06	-				L20				
G-355	31	44	44	1.61	238	338	338	1.01	-				L20				
G-356	43	62	62	2.27	349	500	500	1.45	-				L20				
G-357	38	54	54	2.05	340	485	485	1.47	-				L20				
G-358	14	26	26	0.94	451	834	834	2.41	-				68	126	126		0.74
G-359	22	40	40	1.45	481	874	874	2.65	-				100	182	182		1.07
G-360	30	56	56	1.98	672	1250	1250	3.53	-				120	223	223		1.29
G-361	32	60	60	2.11	640	1198	1198	3.32	-				140	262	262		1.50
G-362	53	76	76	2.72	1070	1540	1540	4.35	-				250	360	360		2.11
G-363	44	63	63	2.20	1070	1530	1530	4.26	-				200	364	364		2.07
				(0.08)				(0.81)				(0.03)					(0.49)
G-364	29	41	41	1.45	14.6	20.8	20.8	0.06	-				L20				
G-365	26	36	36	1.31	10.0	14.0	14	0.04	-				L20				
G-366	30	43	43	1.59	108	153	153	0.45	-				L20				
G-367	32	45	45	1.60	119	169	169	0.47	-				L20				
G-368	34	48	48	1.69	147	209	209	0.58	-				L20				
G-369	36	51	51	1.86	401	564	564	1.68	-				L20				
G-370	20	37	37	1.39	566	1054	1054	3.04	-				27	50	50		0.21
G-371	20	36	36	1.30	514	930	930	2.76	-				42	76	76		0.30
G-372	11	20	20	0.74	308	572	572	1.64	-				L20				
G-373	28	51	51	1.81	662	1200	1200	3.50	-				75	136	136		0.53
G-374	L20				1387	1990	1990	5.73	-				27	39	39		0.16
G-375	23	33	33	1.19	771	1100	1100	3.17	-				45	64	64		0.26
G-376	28	40	40	1.48	120	173	173	0.49	-				L20				
G-377	30	43	43	1.51	110	157	157	0.44	-				L20				
G-378	30	43	43	1.68	200	288	288	0.87	-				L20				
G-379	28	40	40	1.47	202	287	287	0.85	-				L20				
G-380	40	58	58	2.01	386	560	560	1.49	-				L20				
G-381	34	48	48	1.80	228	324	324	0.98	-				L20				
G-382	18	34	34	1.17	513	974	974	2.56	-				84	160	160		0.63
G-383	26	52	52	1.93	471	947	947	2.38	-				110	221	221		0.93
G-384	33	63	63	2.21	722	1369	1369	3.67	-				130	247	247		0.98
G-385	33	61	61	2.18	646	1203	1203	3.41	-				120	224	224		0.91
G-386	54	78	78	2.81	1008	1460	1460	4.03	-				240	349	349		1.44
G-387	51	73	73	2.53	968	1390	1390	3.84	-				209	300	300		1.19

Data Table C (Cont'd)

TEST TYPE	TEST NUMBER	TOTAL SOLUTION MASS (g)	MASS SOLUTION SUBMITTED (g)	GLASS SURFACE AREA (mm**2)	pH	Al (ng/ml) *	Al (ng/ml) **	Al (ng/ml) ***	NL(Al) (g/m**2) **** (0.36)	B (ng/ml) *	B (ng/ml) **	B (ng/ml) ***	NL(B) (g/m**2) **** (2.84)
	G-388	14.84	12.28	482	8.84	350	493	118	1.01	5440	7660	7490	8.14
	G-389	14.88	12.35	496	8.92	200	281	-94	-0.79	6710	9430	9260	9.81
	G-390	14.81	12.26	493	8.12	180	253	-122	-1.02	11700	16500	16330	17.30
	G-391	14.87	12.30	487	8.38	1430	2010	1635	13.90	12300	17300	17130	18.46
ATM-1c	G-392	14.84	12.70	484	7.95	130	232	-143	-1.22	11000	19600	19430	21.02
	G-393	14.81	12.63	486	8.08	110	197	-178	-1.51	10700	19200	19030	20.44
	G-394	14.84	12.24	493	7.96	170	309	-66	-0.55	14200	25800	25630	27.21
	G-395	14.72	12.15	482	7.81	170	310	-65	-0.55	12600	23000	22830	24.62
	G-396	14.72	12.20	489	7.85	170	240	-135	-1.13	16800	23700	23530	25.01
	G-397	14.81	11.99	485	7.72	180	255	-120	-1.02	18800	26600	26430	28.48
	G-398	14.62	11.95	486	8.42	230	326	126	1.05	9840	14000	13795	14.64
	G-399	14.56	11.82	488	8.22	290	413	213	1.77	9800	13900	13695	14.42
	G-400	14.43	11.72	472	8.20	520	742	542	4.61	17500	25000	24795	26.74
	G-401	14.44	11.70	488	8.20	470	671	471	3.88	17200	24600	24395	25.47
ATM-1c + TUFF	G-402	14.54	12.26	499	8.09	230	417	217	1.76	16100	29200	28995	29.83
	G-403	14.53	12.27	493	8.24	180	326	126	1.03	15800	28700	28495	29.61
	G-404	14.56	11.89	492	8.12	260	478	278	2.29	21900	40300	40095	41.87
	G-405	14.48	11.33	480	7.88	250	470	270	2.27	19500	36700	36495	38.86
	G-406	14.45	11.82	489	7.87	230	327	127	1.05	33500	47700	47495	49.55
	G-407	14.45	11.99	488	6.86	210	298	98	0.81 (0.58)	29000	41100	40895	42.73 (2.60)
	G-408	14.90	11.99	499	8.67	300	425	50	0.26	4200	5950	5780	6.66
	G-409	14.87	12.20	483	8.54	240	338	-37	-0.20	4530	6390	6220	7.38
	G-410	14.82	11.72	505	7.92	320	457	82	0.42	8480	12100	11930	13.50
	G-411	14.85	12.30	496	7.85	240	338	-37	-0.19	9590	13500	13330	15.37
ATM-8	G-412	14.79	11.99	511	7.61	170	312	-63	-0.31	8550	15700	15530	17.31
	G-413	14.85	12.37	497	7.68	160	289	-86	-0.44	8290	15000	14830	17.09
	G-414	14.70	11.80	493	7.70	200	369	-6	-0.03	10200	18800	18630	21.43
	G-415	14.72	12.21	493	7.54	210	382	7	0.04	10000	18200	18030	20.75
	G-416	14.69	11.67	496	7.78	260	371	-4	-0.02	13900	19900	19730	22.53
	G-417	14.61	12.12	509	5.82	240	339	-36	-0.18	13000	18400	18230	20.17
	G-418	14.55	11.40	498	8.36	360	360	160	0.81	6200	8920	8715	9.82
	G-419	14.57	12.07	502	8.05	269	269	69	0.35	6910	9770	9565	10.69
	G-420	14.40	11.05	508	7.59	349	349	149	0.73	13200	19200	18995	20.76
	G-421	14.45	4.18	499	7.48	1410	5520	5320	26.62	4660	18300	18095	20.20
ATM-8 + TUFF	G-422	14.55	11.46	500	7.95	220	412	212	1.06	11400	21300	21095	23.64
	G-423	14.56	11.86	498	7.70	170	313	113	0.57	11600	21400	21195	23.89
	G-424	14.50	11.20	498	7.51	340	343	143	0.72	14800	28000	27795	31.17
	G-425	14.50	11.88	504	7.74	290	534	334	1.66	14800	27200	26995	29.91
	G-426	14.46	11.29	505	8.01	270	396	196	0.97	24100	34800	34595	38.14
	G-427	14.39	11.68	499	7.92	260	371	171	0.85	20500	29300	29095	32.35

Data Table C (Cont'd)

TEST NUMBER	Ba (ng/ml)			NL(Ba) (g/m**2)	Ca (ug/ml)			NL(Ca) (g/m**2)	Ce (ng/ml)			NL(Ce) (g/m**2)	Cr (ng/ml)			NL(Cr) (g/m**2)
	*	**	***	****	*	**	***	****	*	**	***	****	*	**	***	****
				(0.41)				(1.70)				(0.74)				(0.29)
G-388	110	155	155	1.17	2.82	3.97	-2.90	-5.27	L100				1180	1660	1498	15.96
G-389	83	117	117	0.86	2.44	3.43	-3.44	-6.09	L100				1240	1740	1578	16.38
G-390	98	138	138	1.01	2.57	3.62	-4.92	-8.71	L100				1160	1630	1469	15.24
G-391	130	183	183	1.37	2.90	4.08	-4.46	-8.03	L100				1310	1840	1679	17.72
G-392	59	105	105	0.79	2.28	4.07	-4.05	-7.32	L100				570	1018	857	9.08
G-393	47	84	84	0.63	1.85	3.31	-4.81	-8.63	L100				510	913	752	7.91
G-394	60	109	109	0.80	2.54	4.61	-4.05	-7.18	L100				460	835	674	7.01
G-395	60	109	109	0.81	2.54	4.63	-4.03	-7.26	L100				470	856	695	7.34
G-396	93	131	131	0.96	3.81	5.37	-2.61	-4.63	L100				790	1110	949	9.88
G-397	102	144	144	1.07	4.27	6.05	-1.93	-3.47	L100				670	949	788	8.32
G-398	80	113	113	0.83	2.96	4.20	-0.67	-1.19	L100				1290	1830	1671	17.36
G-399	85	121	121	0.88	3.55	5.05	0.18	0.32	L100				1330	1890	1731	17.84
G-400	120	171	171	1.28	3.48	4.96	0.04	0.07	L100				1690	2410	2251	23.77
G-401	110	157	157	1.14	3.29	4.70	-0.22	-0.38	L100				1700	2430	2271	23.22
G-402	58	105	105	0.75	2.68	4.86	-1.40	-2.41	L100				400	726	567	5.71
G-403	37	67	67	0.48	2.39	4.33	-1.93	-3.35	L100				430	780	621	6.32
G-404	50	92	92	0.67	2.22	4.08	-3.92	-6.84	L100				390	717	558	5.71
G-405	57	107	107	0.79	3.41	6.41	-1.59	-2.83	L100				470	884	725	7.56
G-406	80	114	114	0.82	4.60	6.55	1.12	1.95	L100				560	797	638	6.52
G-407	59	84	84	0.61	3.77	5.34	-0.09	-0.16	L100				640	907	748	7.65
				(0.47)				(1.69)				(0.09)				(0.33)
G-408	110	156	156	0.99	3.81	5.40	-1.47	-2.60	L100				1360	1930	1769	16.05
G-409	109	154	154	1.01	3.84	5.41	-1.46	-2.66	L100				1230	1730	1569	14.66
G-410	140	197	197	1.23	4.11	5.86	-2.68	-4.66	L100				1260	1800	1639	14.61
G-411	140	197	197	1.26	4.29	6.03	-2.51	-4.45	L100				1190	1670	1509	13.71
G-412	90	165	165	1.02	3.35	6.14	-1.98	-3.40	L100				550	1008	847	7.44
G-413	85	154	154	0.98	2.98	5.38	-2.74	-4.86	L100				590	1065	905	8.22
G-414	87	161	161	1.02	3.27	6.04	-2.62	-4.64	L100				600	1107	946	8.57
G-415	93	169	169	1.08	3.65	6.63	-2.03	-3.59	L100				540	981	820	7.44
G-416	122	174	174	1.10	4.73	6.76	-1.22	-2.14	L100				880	1250	1089	9.89
G-417	106	150	150	0.92	6.96	9.83	1.85	3.15	L100				790	1120	959	8.36
G-418	78	112	112	0.70	2.98	4.29	-0.58	-1.01	L100				1280	1840	1681	14.92
G-419	75	106	106	0.66	3.70	5.23	0.36	0.62	L100				1200	1700	1541	13.57
G-420	100	145	145	0.88	3.91	5.68	0.76	1.28	L100				1400	2030	1871	16.11
G-421	110	431	431	2.66	1.82	7.13	2.22	3.81	L100				1880	7360	7201	63.33
G-422	52	97	97	0.60	2.86	5.35	-0.91	-1.57	L100				490	917	756	6.69
G-423	44	81	81	0.51	2.51	4.62	-1.64	-2.84	L100				520	958	799	7.10
G-424	67	127	127	0.79	4.57	8.64	0.64	1.10	L100				490	927	768	6.79
G-425	62	114	114	0.70	3.84	7.07	-0.93	-1.59	L100				530	975	816	7.12
G-426	190	274	274	1.67	5.29	7.63	2.20	3.73	L100				880	1270	1111	9.65
G-427	69	99	99	0.61	4.05	5.79	0.36	0.62	L100				870	1240	1081	9.47

Data Table C (Cont'd)

TEST NUMBER	Cs (ng/ml)			NL(Cs) (g/m**2)	Fe (ug/ml)			NL(Fe) (g/m**2)	La (ng/ml)			NL(La) (g/m**2)	Li (ng/ml)			NL(Li) (g/m**2)
	*	**	***	****	*	**	***	****	*	**	***	****	*	**	***	****
				(0.85)				(6.33)				(3.76)				(0)
G-388	1.8	2.5	2.5	9.08	9.56	13.6	12.9	6.29	25	35	35	0.03	-			
G-389	2.2	3.1	3.1	10.97	9.87	13.9	13.2	6.26	29	41	41	0.03	-			
G-390	3.5	4.9	4.9	17.35	9.45	13.3	12.4	5.87	27	38	38	0.03	-			
G-391	3.6	5.1	5.1	18.37	10.1	14.2	13.3	6.41	26	37	37	0.03	-			
G-392	3.1	5.5	5.5	19.88	3.20	5.71	4.46	2.17	30	54	54	0.04	40	71	27	
G-393	3.1	5.6	5.6	20.10	2.82	5.05	3.80	1.83	24	43	43	0.03	42	75	31	
G-394	3.5	6.3	6.4	22.71	2.60	4.72	2.92	1.39	29	53	53	0.04	44	80	36	
G-395	3.2	5.8	5.8	20.90	2.43	4.43	0.00	0.00	33	60	60	0.05	40	73	29	
G-396	4.4	6.2	6.2	22.02	4.15	5.85	3.65	1.74	100	141	141	0.11	-			
G-397	4.9	6.9	6.9	24.84	3.91	5.54	3.34	1.61	59	84	84	0.07	-			
G-398	0.36	0.5	0.5	1.77	10.1	14.3	14.0	6.66	40	54	54	0.04	-			
G-399	0.38	0.5	0.5	1.76	10.7	15.2	14.9	7.03	32	46	46	0.04	-			
G-400	0.7	1.0	1.0	3.60	14.0	20.0	19.3	9.32	45	64	64	0.05	-			
G-401	0.7	0.9	0.9	3.14	13.2	18.8	18.1	8.50	36	51	51	0.04	-			
G-402	0.5	0.9	0.9	3.09	2.13	3.86	3.01	1.39	36	69	69	0.05	50	91	10	
G-403	0.5	0.9	0.9	3.12	2.07	3.75	2.90	1.35	33	60	60	0.05	57	103	22	
G-404	0.7	1.3	1.3	4.54	3.36	6.18	4.98	2.33	66	121	121	0.10	68	125	44	
G-405	0.7	1.3	1.3	4.63	2.46	4.63	3.43	1.64	54	102	102	0.08	45	85	4	
G-406	1.2	1.7	1.7	5.93	3.11	4.43	2.93	1.37	68	97	97	0.08	-			
G-407	1.0	1.4	1.4	4.89	3.23	4.58	3.08	1.44	50	71	71	0.06	-			
				(0.91)				(5.99)				(4.38)				(0)
G-408	1.4	2.0	2.0	6.81	10.5	14.9	14.2	7.09	33	47	47	0.03	-			
G-409	1.5	2.1	2.1	6.94	9.36	13.2	12.5	6.43	44	62	62	0.04	-			
G-410	2.7	3.9	3.9	12.91	10.1	14.4	13.5	6.61	50	71	71	0.05	-			
G-411	3.0	4.2	4.2	14.11	9.50	13.4	12.4	6.23	50	70	70	0.05	-			
G-412	2.6	4.8	4.8	16.15	2.26	4.1	2.9	1.40	60	110	110	0.07	31.0	57.0	13.0	
G-413	2.6	4.7	4.7	15.80	2.47	4.5	3.2	1.61	53	96	96	0.07	29.0	52.0	8.0	
G-414	2.7	5.0	5.0	16.41	2.35	4.3	2.5	1.27	64	118	118	0.08	22.0	41.0	-3.0	
G-415	2.8	5.1	5.1	17.17	1.91	3.5	1.7	0.83	73	133	133	0.09	28.0	51.0	7.0	
G-416	2.7	5.3	5.3	17.55	3.39	4.8	2.6	1.31	120	171	171	0.12	-			
G-417	5.7	8.1	8.1	26.87	3.11	4.4	2.2	1.05	110	155	155	0.10	-			
G-418	0.2	0.3	0.3	0.99	9.78	14.1	13.7	6.71	33	47	47	0.03	-			
G-419	0.2	0.3	0.3	0.99	9.10	12.9	12.5	6.07	37	52	52	0.03	-			
G-420	0.1	0.1	0.1	0.34	10.1	14.7	14.0	6.63	62	90	90	0.06	-			
G-421	0.0	0.1	0.1	0.33	15.7	61.5	60.8	29.45	64	251	251	0.17	-			
G-422	0.4	0.8	0.8	2.57	2.29	4.28	3.43	1.67	51	95	95	0.06	38	71	-10	
G-423	0.4	0.7	0.7	2.27	2.06	3.79	2.94	1.44	53	98	98	0.07	39	72	-9	
G-424	0.5	1.0	1.0	3.25	2.03	3.84	2.64	1.28	75	142	142	0.09	43	81	0	
G-425	0.5	0.9	0.9	3.00	2.37	4.36	3.16	1.52	75	138	138	0.09	49	90	9	
G-426	1.1	1.6	1.6	5.21	9.68	14.00	12.50	5.98	250	361	361	0.24	-			
G-427	0.8	1.1	1.1	3.57	3.66	5.23	3.73	1.80	88	126	126	0.08	-			

Data Table C (Cont'd)

TEST NUMBER	Mg (ng/ml)			NL (Mg) (g/m**2)		Mn (ng/ml)		NL (Mn) (g/m**2)		Mo (ng/ml)		NL (Mo) (g/m**2)		Na (ug/ml)			NL (Na) (g/m**2)
	*	**	***	****	*	**	***	****	*	**	***	****	*	**	***	****
				(0.10)				(0.01)				(1.26)				(9.20)
G-388	220	310	-35	-1.08	210	296	216	66.68	2490	3500	3500	8.58	56.0	78.8	34.0	11.41
G-389	200	351	6	0.18	250	351	271	81.51	3010	4230	4230	10.10	61.0	85.7	40.9	13.37
G-390	250	352	7	0.21	230	324	244	73.43	5320	7490	7490	17.89	76.5	108	59.3	19.40
G-391	240	338	-7	-0.21	250	352	272	83.26	5730	8060	8060	19.58	79.0	111	62.3	20.73
G-392	270	482	137	4.21	110	196	116	35.63	5090	9090	9060	22.09	65.5	117	73.4	24.51
G-393	210	376	31	0.95	68	122	42	12.81	4880	8740	8700	21.06	63.6	114	70.4	23.34
G-394	240	436	91	2.74	86	156	76	22.92	6550	11900	11900	28.48	82.0	149	103.4	33.89
G-395	210	382	37	1.13	73	133	53	16.23	5750	10500	10500	25.52	75.5	138	92.4	30.76
G-396	220	310	-35	-1.06	110	155	75	22.64	7660	10800	10800	25.87	93.4	132.0	85.3	27.99
G-397	360	510	165	5.05	140	198	118	36.11	8520	12100	12100	29.36	102.0	145.0	98.3	32.70
G-398	490	695	-325	-9.79	250	355	230	69.31	4510	6400	6400	15.31	65.4	92.8	44.4	14.54
G-399	600	854	-166	-4.96	250	356	231	69.05	4550	6480	6480	15.37	66.6	94.8	46.4	15.08
G-400	1240	1770	750	22.97	350	499	186	56.97	8090	11500	11500	27.96	85.0	121	64.3	21.41
G-401	880	1260	240	7.12	390	557	387	114.74	8010	11400	11400	26.83	86.3	123	66.3	21.37
G-402	520	943	-77	-2.25	120	218	18	5.26	6950	12600	12600	29.22	76.6	139	90.1	28.62
G-403	450	816	-204	-6.02	82	149	-51	-15.05	7430	13500	13400	31.38	71.5	130	81.1	26.01
G-404	740	1360	340	10.08	84	155	-125	-37.07	10400	19100	19100	44.96	101	186	133.8	43.13
G-405	670	1260	240	7.26	99	186	-94	-28.43	9200	17300	17300	41.52	89.2	168	115.8	38.07
G-406	1090	1550	530	15.70	150	213	-137	-40.59	15600	22200	22200	52.20	133.0	189.0	134.3	43.25
G-407	720	1020	0	0.00	100	142	-208	-61.72	13400	19000	19000	44.75	120.0	170.0	115.3	37.19
				(0.09)				(0.03)				(1.41)				(9.36)
G-408	250	354	9	0.30	280	397	317	31.64	2220	3150	3150	6.69	48.1	68.2	23.4	7.49
G-409	240.0	338.0	-7	-0.24	230.0	324.0	244	25.08	2370	3340	3340	7.30	49.6	69.9	25.1	8.27
G-410	340.0	485.0	140	4.58	210.0	300.0	220	21.57	4480	6390	6390	13.33	60.0	94.1	45.5	14.30
G-411	320.0	450.0	105	3.50	220.0	309.0	229	22.88	5120	7200	7200	15.31	71.0	100.0	51.3	16.43
G-412	270.0	495.0	150	4.83	79.0	145.0	65	6.28	4550	8340	8340	17.15	60.1	110.0	66.4	20.56
G-413	260.0	470.0	125	4.16	120.0	217.0	137	13.68	4400	7950	7950	16.89	59.6	105.0	64.4	20.62
G-414	250.0	461.0	116	3.85	62.0	114.0	34	3.39	5520	10200	10200	21.64	68.0	126.0	80.4	25.69
G-415	240.0	436.0	91	3.03	58.0	105.0	25	2.49	5420	9850	9850	20.91	66.9	122.0	76.4	24.43
G-416	360.0	514.0	169	5.57	98.0	140.0	60	5.94	7260	10400	10400	21.90	99.6	142.0	95.3	30.23
G-417	320.0	452.0	107	3.42	82.0	116.0	36	3.45	6840	9660	9660	19.71	86.2	122.0	75.3	23.15
G-418	540	777	-243	-7.91	220	316	191	18.65	3310	4760	4760	9.89	51.8	74.5	26.1	8.17
G-419	620	877	-143	-4.62	250	354	229	22.18	3680	5200	5200	10.72	59.0	83.4	35.0	10.87
G-420	590	857	-163	-5.15	250	363	193	18.28	7130	10400	10400	20.96	77.3	112	55.2	16.79
G-421	410	1610	590	19.02	430	1680	1510	146.07	2390	9360	9360	19.27	30.6	120	63.3	19.63
G-422	510	954	-66	-2.14	170	318	118	11.46	6320	11800	11800	24.38	64.4	120	71.1	22.13
G-423	380	700	-320	-10.42	72	133	-67	-6.55	6300	11600	11600	24.11	64.6	119	70.1	21.95
G-424	790	1490	470	15.23	87	165	-280	-27.21	8180	15500	15500	32.05	78.5	148	95.8	29.84
G-425	700	1290	270	8.64	137	252	-28	-2.69	8170	15033	15033	30.71	77.7	143	90.8	27.94
G-426	1260	1820	800	25.40	280	404	54	5.16	13000	18800	18800	38.22	83.4	120	65.3	20.00
G-427	830	1186	166	5.33	120	171	-179	-17.25	11200	16000	16000	32.81	115	164	109.3	33.76

Data Table C (Cont'd)

TEST NUMBER		Nd (ng/ml) *	**	***	NL(Nd) (g/m**2) ****	Ni (ng/ml) *	**	***	NL(Ni) (g/m**2) ****	Si (ug/ml) *	**	***	NL(Si) (g/m**2) ****	Sr (ng/ml) *	**	***	NL(Sr) (g/m**2) ****
					(1.19)				(0.17)				(19.18)				(0.36)
G-388	L100					760	1070	960	17.43	43.2	60.8	17.8	2.87	173	243	199	1.71
G-389	L100					760	1070	960	16.98	47.2	66.3	23.3	3.65	155	218	174	1.45
G-390	L100					750	1060	950	16.82	58.6	82.5	36.5	5.73	200	282	236	1.99
G-391	L100					940	1320	1210	21.79	60.1	84.5	38.5	6.14	240	338	294	2.50
G-392	L100					390	696	586	10.59	57.0	102	52.8	8.45	197	352	308	2.63
G-393	L100					360	644	534	9.58	49.4	88.4	39.4	6.27	156	279	235	1.99
G-394	L100					340	617	507	8.99	59.3	108	49.7	7.81	230	418	374	3.13
G-395	L100					280	510	400	7.21	59.6	109	50.6	8.07	230	419	375	3.19
G-396	L100					520	733	623	11.06	81.2	114	50.0	7.87	360	508	464	3.89
G-397	L100					580	822	712	12.82	87.4	124	60.0	9.57	430	609	565	4.80
G-398	L100					800	1140	1075	19.06	51.3	72.8	17.8	2.80	66	94	12	0.10
G-399	L100					850	1210	1145	20.13	53.0	75.4	20.4	3.18	79	112	30	0.25
G-400	L100					1300	1860	1795	32.34	68.7	98.0	40.0	6.39	91	130	48	0.41
G-401	L100					1520	2170	2105	36.71	63.2	90.2	32.2	4.98	89	127	45	0.37
G-402	L100					340	617	552	9.49	50.3	91.2	28.2	4.30	78	141	59	0.48
G-403	L100					320	580	515	8.94	52.1	94.5	31.5	4.84	68	123	41	0.34
G-404	L100					390	717	652	11.37	56.5	104	29.9	4.63	100	184	102	0.84
G-405	L100					410	771	706	12.56	58.0	109	35.1	5.53	108	203	121	1.02
G-406	L100					620	882	817	14.24	73.8	105	17.0	2.63	156	222	140	1.15
G-407	L100					500	709	644	11.24	77.0	109	21.0	3.25	126	178	97	0.80
					(1.38)				(0.20)				(17.67)				(0.41)
G-408	L100					850	1200	1090	16.32	42.6	60.4	17.4	2.95	240	340	295	2.16
G-409	L100					770	1090	980	15.11	46	64.9	21.9	3.82	250	352	308	2.30
G-410	L100					900	1280	1170	17.21	55	76.5	32.5	5.41	300	514	470	3.87
G-411	L100					820	1150	1040	15.59	58.2	81.9	35.9	6.09	390	549	505	3.69
G-412	L100					430	788	678	9.83	49.5	90.7	41.7	6.64	330	605	561	3.97
G-413	L100					370	669	559	8.38	47.8	86.4	37.4	6.34	300	542	498	3.64
G-414	L100					350	646	536	8.02	53.6	98.9	40.9	6.93	340	628	584	4.26
G-415	L100					300	545	435	6.51	61.5	112	53.8	9.11	380	691	647	4.72
G-416	L100					600	857	747	11.09	85.3	122	58.0	9.75	510	729	685	4.98
G-417	L100					490	692	582	8.37	73.6	104.0	40.0	6.51	410	579	535	3.75
G-418	L100					810	1170	1105	16.19	49.4	71.1	16.1	2.67	63	91	9	0.06
G-419	L100					730	1030	965	14.02	51.4	72.7	17.7	2.91	76	107	25	0.18
G-420	L100					850	1240	1175	16.69	60.8	85.3	30.3	4.87	98	142	60	0.42
G-421	L100					1240	4860	4795	69.58	27.5	108	49.7	8.16	45	176	94	0.87
G-422	L100					360	674	609	8.87	45.9	85.9	22.9	3.77	79	148	66	0.47
G-423	L100					300	552	487	7.14	47.9	88.2	25.2	4.18	70	129	47	0.34
G-424	L100					440	830	767	11.18	57.6	109	34.9	5.76	136	257	175	1.24
G-425	L100					380	699	634	9.13	53.7	98.8	24.8	4.04	115	212	130	0.91
G-426	L100					670	967	902	12.93	100	144	56.0	9.09	220	317	235	1.64
G-427	L100					570	814	749	10.83	70.9	101	13.0	2.13	135	193	111	0.78

Data Table C (Cont'd)

TEST NUMBER	Ti (ng/ml)			NL(Ti) (g/m**2)	U (ng/ml)			NL(U) (g/m**2)	Zn (ng/ml)			NL(Zn) (g/m**2)	Zr (ng/ml)			NL(Zr) (g/m**2)
	*	**	***	****	*	**	***	****	*	**	***	****	*	**	***	
				(1.73)				(3.49)				(3.63)				(1.32)
G-388	47	66	66	0.12	616	867	867	0.63	890	1250	1250	1.06	L20			
G-389	48	67	67	0.12	633	889	889	0.64	780	1100	1100	0.91	L20			
G-390	49	69	69	0.12	805	1131	1131	0.81	1400	1970	1970	1.63	L20			
G-391	35	49	49	0.09	712	1001	1001	0.73	1410	1980	1980	1.67	L20			
G-392	50	89	89	0.16	919	1641	1641	1.24	1850	3300	3280	2.78	23	41	41	0.10
G-393	41	73	73	0.13	755	1352	1352	1.01	1480	2650	2620	2.20	L20			
G-394	38	69	69	0.12	1246	2262	2262	1.61	2800	5080	5050	4.20	L20			
G-395	38	69	69	0.12	1125	2049	2049	1.48	2030	3700	3670	3.10	L20			
G-396	79	111	111	0.19	2110	2990	2990	2.14	3970	5600	5600	4.66	39	55	55	0.13
G-397	77	109	109	0.19	2540	3600	3600	2.56	5170	7330	7330	6.18	40	40	40	0.09
G-398	46	65	65	0.11	840	1191	1191	0.84	730	1040	1040	0.86	L20			
G-399	42	60	60	0.10	880	1252	1252	0.87	770	1100	1100	0.91	L20			
G-400	60	86	86	0.15	1210	1726	1726	1.23	3000	4280	4280	3.61	L20			
G-401	58	83	83	0.14	1140	1627	1627	1.12	2140	3060	3060	2.50	L20			
G-402	44	80	80	0.14	1106	2006	2006	1.42	2100	3810	3810	3.07	22	40	40	0.09
G-403	33	60	60	0.10	917	1663	1663	1.19	1640	2970	2970	2.41	L20			
G-404	46	85	85	0.15	1292	2376	2376	1.65	2810	5170	5170	4.22	24	44	44	0.10
G-405	41	77	77	0.13	1362	2562	2562	1.74	2560	4820	4820	4.02	L20			
G-406	56	80	80	0.14	2880	4100	4100	2.85	4530	6450	6450	5.26	27	38	38	0.09
G-407	39	55	55	0.09	2310	3270	3270	2.31	3450	4890	4890	4.00	L20			
				(1.62)				(3.70)				(3.55)				(1.74)
G-408	45	64	64	0.12	706	1000	1000	0.65	1070	1520	1520	1.28	L20			
G-409	46	65	65	0.12	765	1079	1079	0.74	970	1370	1370	1.19	L20			
G-410	58	83	83	0.15	966	1378	1378	0.87	1760	2510	2510	2.08	L20			
G-411	52	73	73	0.14	1070	1505	1505	1.01	1670	2350	2350	1.98	L20			
G-412	38	70	70	0.13	912	1671	1671	1.06	2060	3775	3752	3.09	L20			
G-413	40	72	72	0.13	827	1494	1494	1.01	1850	3343	3320	2.80	L20			
G-414	37	68	68	0.13	1270	2344	2344	1.52	2490	4596	4567	3.85	L20			
G-415	34	62	62	0.11	1285	2335	2335	1.57	2220	4035	4006	3.38	L20			
G-416	62	89	89	0.16	1900	2710	2710	1.73	4410	6300	6300	5.27	33	47	47	0.08
G-417	66	88	88	0.16	1630	2300	2300	1.48	3830	5410	5410	4.38	36	51	51	0.08
G-418	42	60	60	0.11	671	965	965	0.60	790	1136	1136	0.94	L20			
G-419	43	61	61	0.11	835	1181	1181	0.77	650	919	919	0.75	L20			
G-420	51	74	74	0.13	1190	1728	1728	1.02	980	1423	1423	1.14	L20			
G-421	51	200	200	0.36	534	2092	2092	0.47	1300	5092	5092	4.16	L20			
G-422	30	56	56	0.10	956	1789	1789	1.11	1700	3180	3162	2.59	L20			
G-423	32	59	59	0.11	982	1808	1808	1.17	1280	2357	2339	1.93	L20			
G-424	41	78	78	0.14	1665	3149	3149	1.92	2460	4652	4652	3.82	22	42	42	0.07
G-425	44	81	81	0.14	1448	2664	2664	1.70	2400	4416	4416	3.58	27	50	50	0.08
G-426	44	63	63	0.11	2290	3300	3300	2.00	4860	7010	4416	3.57	23	33	33	0.05
G-427	47	67	67	0.12	2140	3060	3060	1.94	3510	5010	5010	4.08	24	34	34	0.06

Data Table C (Cont'd)

TEST TYPE	TEST NUMBER	TOTAL SOLUTION MASS (g)	MASS SOLUTION SUBMITTED (g)	ACL DILUTION	pH	Al (ng/ml) *	Al (ng/ml) **	Al (ng/ml)	B (ng/ml) *	B (ng/ml) **	B (ng/ml)
	G-428	15.41	13.49	5	7.44	300	411		120	164	
	G-429	15.43	12.91	5	7.39	370	513	(375)	160	222	(170)
	G-430	16.14	13.82	5	6.57	280	381		115	157	
	G-431	16.11	13.83	5	6.75	240	327	(375)	121	165	(170)
EJ-13	G-432	16.11	14.03	10	6.26	200	342		51	87	
	G-433	16.12	14.06	10	5.54	190	325	(375)	110	188	(170)
	G-434	16.05	13.69	10	6.51	210	363		85	147	
	G-435	16.05	13.70	10	6.79	220	380	(375)	86	149	(170)
	G-436	15.94	13.63	5	6.91	290	396		400	547	
	G-437	15.97	13.72	5	6.98	300	409	(375)	104	142	(170)
	G-438	15.49	13.00	5	7.03	120	166		150	208	
	G-439	15.37	13.00	5	7.05	690	955	(200)	190	263	(205)
	G-440	15.47	12.90	5	6.41	190	264		160	222	
	G-441	15.45	13.04	5	6.37	L100	-	(200)	150	208	(205)
EJ-13 +	G-442	15.42	13.14	10	6.70	100	176		97	171	
TUFF	G-443	15.39	13.08	10	6.71	100	176	(200)	95	167	(205)
	G-444	15.37	12.75	10	6.63	170	303		110	196	
	G-445	15.28	12.61	10	6.84	280	502	(200)	115	206	(205)
	G-446	15.25	12.74	5	6.81	L100			143	199	
	G-447	15.32	12.79	5	6.80	L100		(200)	139	193	(205)
	G-448	16.19	14.16	5	7.98	300	406		130	176	
	G-449	16.15	14.19	5	7.87	320	433	(360)	140	189	(150)
	G-450	15.41	13.20	5	8.36	350	483		190	262	
	G-451	15.44	13.07	5	8.24	320	442	(360)	130	180	(150)
	G-452	16.16	13.79	5	7.48	240	327		110	150	
	G-453	16.17	13.72	5	8.23	230	314	(360)	114	156	(150)
EJ-13	G-454	16.18	13.80	10	8.75	180	310		80	138	
NO GAMMA	G-455	16.10	13.68	10	8.87	170	294	(360)	86	149	(150)
	G-456	16.05	13.70	10	4.73	180	311		85	147	
	G-457	15.97	13.56	10	8.65	210	365	(360)	86	149	(150)
	G-458	15.85	13.37	5	7.87	280	345		118	162	
	G-459	15.88	13.56	5	8.12	250	342	(360)	99	136	(150)
	G-460	15.45	13.20	5	7.27	130	179		190	262	
	G-461	15.44	13.16	5	7.34	130	179	(210)	160	221	(205)
	G-462	15.44	13.01	5	8.06	100	138		170	235	
	G-463	15.44	12.87	5	7.90	140	194	(210)	150	208	(205)
	G-464	15.44	12.88	5	7.40	100	139		140	194	
	G-465	15.42	12.86	5	7.62	L100		(210)	140	194	(205)
EJ-13 +	G-466	15.37	12.64	10	8.35	160	286		123	220	
TUFF	G-467	15.43	12.84	10	8.17	140	249	(210)	170	302	(205)
NO GAMMA	G-468	15.38	12.92	10	7.98	260	461		124	220	
	G-469	15.38	12.83	10	8.12	190	338	(210)	108	192	(205)
	G-470	15.29	12.66	5	8.04	L100			117	163	
	G-471	15.39	12.88	5	8.02	L100		(210)	142	197	(205)

Data Table C (Cont'd)

TEST NUMBER	Ba (ng/ml) *	**		Ca (ug/ml) *	**		Ce (ng/ml) *	**		Cr (ng/ml) *	**	
G-428	-			4.86	6.66		-			-		
G-429	-		(Ø)	4.97	6.89	(6.78)	-		(Ø)	-		(161)
G-430	-			6.30	8.58		-			-		
G-431	-		(Ø)	6.24	8.50	(8.54)	-		(Ø)	-		(161)
G-432	L20			4.74	8.11		L100			94	161	
G-433	L20		(Ø)	4.75	8.12	(8.12)	L100		(Ø)	68	116	(161)
G-434	L20			5.04	8.71		-			-		
G-435	L20		(Ø)	4.98	8.61	(8.66)	-		(Ø)	-		(161)
G-436	-			5.86	8.01		-			-		
G-437	-		(Ø)	5.82	7.94	(7.98)	-		(Ø)	-		(161)
G-438	-			3.34	4.62		-			-		
G-439	-		(Ø)	3.70	5.12	(4.87)	-		(Ø)	-		(159)
G-440	-			3.35	4.65		-			-		
G-441	-		(Ø)	3.75	5.19	(4.92)	-		(Ø)	-		(159)
G-442	L20			3.43	6.04		L100			90	158	
G-443	L20		(Ø)	3.67	6.47	(6.26)	L100		(Ø)	90	159	(159)
G-444	L20			4.79	8.54		-			-		
G-445	L20		(Ø)	4.16	7.45	(8.00)	-		(Ø)	-		(159)
G-446	-			3.98	5.54		-			-		
G-447	-		(Ø)	3.82	5.31	(5.43)	-		(Ø)	-		(159)
G-448	-			4.96	6.71		-			-		
G-449	-		(Ø)	5.05	6.83	(6.77)	-		(Ø)	-		(Ø)
G-450	-			5.16	7.11		-			-		
G-451	-		(Ø)	5.09	7.04	(7.08)	-		(Ø)	-		(Ø)
G-452	-			6.31	8.60		-			-		
G-453	-		(Ø)	6.24	8.51	(8.56)	-		(Ø)	-		(Ø)
G-454	L20			5.02	8.65		-			-		
G-455	L20		(Ø)	5.06	8.75	(8.70)	-		(Ø)	-		(Ø)
G-456	L20			5.07	8.76		-			-		
G-457	L20		(Ø)	5.04	8.75	(8.76)	-		(Ø)	-		(Ø)
G-458	-			6.02	8.27		-			-		
G-459	-		(Ø)	5.84	7.99	(8.13)	-		(Ø)	-		(Ø)
G-460	-			4.20	5.79		-			-		
G-461	-		(Ø)	3.52	4.86	(5.33)	-		(Ø)	-		(Ø)
G-462	-			2.15	2.98		-			-		
G-463	-		(Ø)	2.41	3.35	(3.27)	-		(Ø)	-		(Ø)
G-464	-			2.17	3.01		-			-		
G-465	-		(Ø)	1.74	2.42	(2.72)	-		(Ø)	-		(Ø)
G-466	L20			1.44	2.58		-			-		
G-467	L20		(Ø)	1.60	2.84	(2.71)	-		(Ø)	-		(Ø)
G-468	L20			1.80	3.19		-			-		
G-469	L20		(Ø)	1.56	2.77	(2.98)	-		(Ø)	-		(Ø)
G-470	-			0.74	1.03		-			-		
G-471	-		(Ø)	1.39	1.93	(1.48)	-		(Ø)	-		(Ø)

Data Table C (Cont'd)

TEST NUMBER	Cs (ng/ml)		Fe (ug/ml)			La (ng/ml)		Li (ng/ml)		
	*	**	*	**		*	**	*	**	
G-428	-		0.45	0.62		-		-		
G-429	-	(0)	2.03	2.82	(0.70)	-	(0)	-		(44)
G-430	-		3.94	5.37		-		-		
G-431	-	(0)	0.44	0.60	(0.95)	-	(0)	-		(44)
G-432	-		0.48	0.82		L20		29	50	
G-433	-	(0)	0.30	0.51	(1.25)	L20	(0)	24	41	(44)
G-434	-		1.29	2.23		-		24	41	
G-435	-	(0)	1.18	2.04	(1.80)	-	(0)	L20		(44)
G-436	-		1.61	2.20		-		35	48	
G-437	-	(0)	1.66	2.26	(2.20)	-	(0)	35	48	(44)
G-438	-		0.58	0.80		-		-		
G-439	-	(0)	9.87	13.7	(0.35)	-	(0)	-		(81)
G-440	-		3.45	4.79		-		-		
G-441	-	(0)	0.56	0.77	(0.70)	-	(0)	-		(81)
G-442	-		0.25	0.44		L20		44	77	
G-443	-	(0)	0.29	0.51	(0.85)	L20	(0)	38	67	(81)
G-444	-		0.84	1.50		-		45	80	
G-445	-	(0)	0.85	1.52	(1.20)	-	(0)	42	75	(81)
G-446	-		1.07	1.49		-		78	109	
G-447	-	(0)	0.93	1.29	(1.50)	-	(0)	76	106	(81)
G-448	-		0.39	0.53		-		34	46	
G-449	-	(0)	0.78	1.05	(0.30)	-	(0)	36	48	(44)
G-450	-		0.70	0.97		-		-		
G-451	-	(0)	0.27	0.37	(0.50)	-	(0)	-		(44)
G-452	-		0.49	0.67		-		-		
G-453	-	(0)	0.47	0.64	(0.90)	-	(0)	-		(44)
G-454	-		0.32	0.55		-		22	38	
G-455	-	(0)	0.44	0.76	(1.15)	-	(0)	23	40	(44)
G-456	-		1.18	2.04		-		25	43	
G-457	-	(0)	1.11	1.93	(1.70)	-	(0)	23	40	(44)
G-458	-		1.59	2.18		-		35	48	
G-459	-	(0)	1.76	2.41	(2.05)	-	(0)	36	49	(44)
G-460	-		0.48	0.66		-		33	46	
G-461	-	(0)	0.48	0.66	(0.55)	-	(0)	30	41	(38)
G-462	-		0.40	0.55		-		-		
G-463	-	(0)	0.35	0.49	(0.55)	-	(0)	-		(38)
G-464	-		0.44	0.61		-		-		
G-465	-	(0)	0.23	0.32	(0.55)	-	(0)	-		(38)
G-466	-		0.78	1.40		-		L20		
G-467	-	(0)	0.15	0.27	(0.55)	-	(0)	L20		(38)
G-468	-		0.45	0.80		-		L20		
G-469	-	(0)	0.23	0.41	(0.55)	-	(0)	21	37	(38)
G-470	-		0.39	0.54		-		27	38	
G-471	-	(0)	0.46	0.56	(0.55)	-	(0)	28	39	(38)

Data Table C (Cont'd)

TEST NUMBER	Cs (ng/ml) *	Cs (ng/ml) **		Fe (ug/ml) *	Fe (ug/ml) **		La (ng/ml) *	La (ng/ml) **		Li (ng/ml) *	Li (ng/ml) **	
G-428	-			Ø.45	Ø.62		-			-		
G-429	-		(Ø)	2.Ø3	2.82	(Ø.7Ø)	-		(Ø)	-		(44)
G-43Ø	-			3.94	5.37		-			-		
G-431	-		(Ø)	Ø.44	Ø.6Ø	(Ø.95)	-		(Ø)	-		(44)
G-432	-			Ø.48	Ø.82		L2Ø			29	5Ø	
G-433	-		(Ø)	Ø.3Ø	Ø.51	(1.25)	L2Ø		(Ø)	24	41	(44)
G-434	-			1.29	2.23		-			24	41	
G-435	-		(Ø)	1.18	2.Ø4	(1.8Ø)	-		(Ø)	L2Ø		(44)
G-436	-			1.61	2.2Ø		-			35	48	
G-437	-		(Ø)	1.66	2.26	(2.2Ø)	-		(Ø)	35	48	(44)
G-438	-			Ø.58	Ø.8Ø		-			-		
G-439	-		(Ø)	9.87	13.7	(Ø.35)	-		(Ø)	-		(81)
G-44Ø	-			3.45	4.79		-			-		
G-441	-		(Ø)	Ø.56	Ø.77	(Ø.7Ø)	-		(Ø)	-		(81)
G-442	-			Ø.25	Ø.44		L2Ø			44	77	
G-443	-		(Ø)	Ø.29	Ø.51	(Ø.85)	L2Ø		(Ø)	38	67	(81)
G-444	-			Ø.84	1.5Ø		-			45	8Ø	
G-445	-		(Ø)	Ø.85	1.52	(1.2Ø)	-		(Ø)	42	75	(81)
G-446	-			1.Ø7	1.49		-			78	1Ø9	
G-447	-		(Ø)	Ø.93	1.29	(1.5Ø)	-		(Ø)	76	1Ø6	(81)
G-448	-			Ø.39	Ø.53		-			34	46	
G-449	-		(Ø)	Ø.78	1.Ø5	(Ø.3Ø)	-		(Ø)	36	48	(44)
G-45Ø	-			Ø.7Ø	Ø.97		-			-		
G-451	-		(Ø)	Ø.27	Ø.37	(Ø.5Ø)	-		(Ø)	-		(44)
G-452	-			Ø.49	Ø.67		-			-		
G-453	-		(Ø)	Ø.47	Ø.64	(Ø.9Ø)	-		(Ø)	-		(44)
G-454	-			Ø.32	Ø.55		-			22	3Ø	
G-455	-		(Ø)	Ø.44	Ø.76	(1.15)	-		(Ø)	23	4Ø	(44)
G-456	-			1.18	2.Ø4		-			25	43	
G-457	-		(Ø)	1.11	1.93	(1.7Ø)	-		(Ø)	23	4Ø	(44)
G-458	-			1.59	2.18		-			35	48	
G-459	-		(Ø)	1.76	2.41	(2.Ø5)	-		(Ø)	36	49	(44)
G-46Ø	-			Ø.48	Ø.66		-			33	46	
G-461	-		(Ø)	Ø.48	Ø.66	(Ø.55)	-		(Ø)	3Ø	41	(38)
G-462	-			Ø.4Ø	Ø.55		-			-		
G-463	-		(Ø)	Ø.35	Ø.49	(Ø.55)	-		(Ø)	-		(38)
G-464	-			Ø.44	Ø.61		-			-		
G-465	-		(Ø)	Ø.23	Ø.32	(Ø.55)	-		(Ø)	-		(38)
G-466	-			Ø.78	1.4Ø		-			L2Ø		
G-467	-		(Ø)	Ø.15	Ø.27	(Ø.55)	-		(Ø)	L2Ø		(38)
G-468	-			Ø.45	Ø.8Ø		-			L2Ø		
G-469	-		(Ø)	Ø.23	Ø.41	(Ø.55)	-		(Ø)	21	37	(38)
G-47Ø	-			Ø.39	Ø.54		-			27	38	
G-471	-		(Ø)	Ø.46	Ø.56	(Ø.55)	-		(Ø)	28	39	(38)

Data Table C (Cont'd)

TEST NUMBER	Mg (ng/ml) *	Mg (ng/ml) **		Mn (ng/ml) *	Mn (ng/ml) **		Mo (ng/ml) *	Mo (ng/ml) **		Na (ug/ml) *	Na (ug/ml) **	
G-428	170	233		13	18		-			32.7	44.8	
G-429	170	236	(345)	52	72	(80)	-		(0)	32.3	44.8	(44.8)
G-430	270	368		97	132		-			35.8	48.8	
G-431	260	354	(345)	12	16	(80)	-		(0)	35.6	48.5	(48.7)
G-432	200	342		18	31		L20			25.6	43.8	
G-433	200	342	(345)	11	19	(80)	L20		(0)	25.4	43.4	(43.6)
G-434	210	363		95	164		-			26.5	45.8	
G-435	210	363	(345)	49	85	(80)	-		(0)	26.2	45.3	(45.6)
G-436	250	341		64	87		-			34.4	47.0	
G-437	250	341	(345)	63	86	(80)	-		(0)	33.9	46.3	(46.7)
G-438	580	803		63	87		-			34.8	48.2	
G-439	620	858	(1020)	550	762	(125)	-		(0)	35.1	48.6	(48.4)
G-440	600	833		170	236		-			41.7	57.9	
G-441	660	913	(1020)	180	249	(170)	-		(0)	40.1	55.5	(56.7)
G-442	600	1060		78	137		L20			27.9	49.1	
G-443	620	1090	(1020)	71	125	(200)	L20		(0)	27.6	48.7	(48.9)
G-444	840	1500		300	535		-			29.6	52.8	
G-445	720	1290	(1020)	150	269	(280)	-		(0)	28.8	51.6	(52.2)
G-446	710	988		240	334		-			38.2	53.2	
G-447	700	974	(1020)	410	570	(350)	-		(0)	40.5	56.3	(54.7)
G-448	180	244		12	16		-			35.0	47.4	
G-449	190	257	(345)	31	42	(80)	-		(0)	35.3	47.7	(47.6)
G-450	180	249		54	75		-			32.5	44.8	
G-451	180	249	(345)	10	14	(80)	-		(0)	32.6	45.1	(45.0)
G-452	270	368		18	25		-			36.1	49.2	
G-453	260	355	(345)	23	31	(80)	-		(0)	35.7	48.7	(49.0)
G-454	210	362		12	21		-			26.1	45.0	
G-455	220	380	(345)	15	26	(80)	-		(0)	26.5	45.8	(45.4)
G-456	220	380		180	311		-			26.0	44.9	
G-457	210	365	(345)	75	130	(80)	-		(0)	26.1	45.3	(45.1)
G-458	260	357		120	165		-			34.3	47.1	
G-459	260	356	(345)	130	178	(80)	-		(0)	34.7	47.5	(47.3)
G-460	720	993		23	32		-			33.7	46.5	
G-461	590	814	(345)	21	29	(25)	-		(0)	33.3	46.0	(46.3)
G-462	330	458		20	28		-			32.8	45.4	
G-463	380	528	(345)	11	15	(25)	-		(0)	33.4	46.4	(45.9)
G-464	340	472		51	71		-			37.1	51.5	
G-465	280	389	(345)	14	19	(25)	-		(0)	36.5	50.7	(51.1)
G-466	220	394		43	77		-			25.7	46.0	
G-467	230	409	(345)	7	12	(25)	-		(0)	25.5	45.3	(45.7)
G-468	260	461		14	25		-			26.5	47.0	
G-469	230	409	(345)	8	14	(25)	-		(0)	25.5	45.3	(45.4)
G-470	120	167		8	11		-			34.8	48.5	
G-471	210	292	(345)	13	18	(25)	-		(0)	34.0	47.2	(47.8)

Data Table C (Cont'd)

TEST NUMBER	Nd (ng/ml) *	Nd (ng/ml) **		Ni (ng/ml) *	Ni (ng/ml) **		Si (ug/ml) *	Si (ug/ml) **		Sr (ng/ml) *	Sr (ng/ml) **	
G-428	-			43	59		30.9	42.4		26	36	
G-429	-		(0)	350	486	(110)	30.1	41.8	(43)	27	37	(44)
G-430	-			390	531		33.1	45.1		34	46	
G-431	-		(0)	25	34	(110)	41.6	56.6	(46)	34	46	(44)
G-432	L100			45	77		26.2	44.8		26	44	
G-433	L100		(0)	29	50	(110)	29.8	51.0	(49)	26	44	(44)
G-434	-			120	207		36.8	63.6		27	47	
G-435	-		(0)	45	78	(110)	28.8	49.8	(58)	27	47	(44)
G-436	-			130	178		52.1	71.2		33	45	
G-437	-		(0)	94	128	(110)	44.1	60.2	(64)	33	45	(44)
G-438	-			52	72		35.4	49		49	68	
G-439	-		(0)	3240	4490	(65)	38.9	53.9	(55)	62	86	(82)
G-440	-			450	624		40.0	55.5		47	65	
G-441	-		(0)	45	62	(65)	43.7	60.5	(58)	54	75	(82)
G-442	L100			L20			36.3	63.9		49	86	
G-443	L100		(0)	22	39	(65)	38.3	67.5	(63)	51	90	(82)
G-444	-			44	78		41.9	74.7		68	121	
G-445	-		(0)	70	125	(65)	39.2	70.2	(74)	58	104	(82)
G-446	-			56	78		55.5	77.3		61	85	
G-447	-		(0)	40	56	(65)	64.7	90.0	(88)	57	79	(82)
G-448	-			44	60		27.1	36.7		27	37	
G-449	-		(0)	120	162	(160)	26.7	36.1	(36)	28	38	(44)
G-450	-			200	276		27.9	38.5		27	37	
G-451	-		(0)	26	36	(160)	25.6	35.4	(37)	27	37	(44)
G-452	-			56	76		28.8	39.2		35	48	
G-453	-		(0)	47	64	(160)	29.6	40.4	(39)	34	46	(44)
G-454	-			25	43		27.4	47.2		27	47	
G-455	-		(0)	26	45	(160)	36.2	62.6	(41)	27	47	(44)
G-456	-			220	380		28.7	49.6		27	47	
G-457	-		(0)	85	148	(160)	28.6	49.6	(51)	27	47	(44)
G-458	-			120	165		64.7	88.9		34	47	
G-459	-		(0)	150	205	(160)	57.9	79.3	(59)	33	45	(44)
G-460	-			42	58		33.4	46.1		63	87	
G-461	-		(0)	44	61	(50)	35.1	48.4	(52)	52	72	(38)
G-462	-			32	44		38.0	52.6		31	43	
G-463	-		(0)	42	58	(50)	38.2	53.0	(55)	34	47	(38)
G-464	-			65	90		41.9	58.2		31	43	
G-465	-		(0)	38	53	(50)	46.2	64.2	(59)	24	33	(38)
G-466	-			106	190		36.1	64.6		21	38	
G-467	-		(0)	L20		(50)	38.0	67.5	(62)	22	39	(38)
G-468	-			73	129		39.9	70.7		25	44	
G-469	-		(0)	L20		(50)	38.2	67.9	(69)	22	39	(38)
G-470	-			L20			49.7	69.3		11	15	
G-471	-		(0)	42	58	(50)	52.3	72.6	(75)	21	29	(38)

Data Table C (Cont'd)

TEST NUMBER	Ti (ng/ml) *	Ti (ng/ml) **		U (ng/ml) *	U (ng/ml) **		Zn (ng/ml) *	Zn (ng/ml) **		Zr (ng/ml) *	Zr (ng/ml) **	
G-428	L10			-			-			L20		
G-429	L10		(0)	-		(0)	-		(0)	L20		(0)
G-430	L10			-			-			L20		
G-431	L10		(0)	-		(0)	-		(0)	L20		(0)
G-432	L10			-			L10			L20		
G-433	L10		(0)	-		(0)	17	29	(0)	L20		(0)
G-434	L10			-			-			L20		
G-435	L10		(0)	-		(0)	-		(0)	L20		(0)
G-436	L10			-			-			L20		
G-437	L10		(0)	-			-		(0)	L20		(0)
G-438	L10			-			-			L20		
G-439	L10		(0)	-		(0)	-		(0)	L20		(0)
G-440	L10			-			-			L20		
G-441	L10		(0)	-		(0)	-		(0)	L20		(0)
G-442	L10			-			L10			L20		
G-443	L10		(0)	L0.5		(0)	L10		(0)	L20		(0)
G-444	L10			L1			-			L20		
G-445	L10		(0)	-		(0)	-		(0)	L20		(0)
G-446	L10			-			-			L20		
G-447	L10		(0)	-		(0)	-		(0)	L20		(0)
G-448	L10			-			-			L20		
G-449	L10		(0)	-		(0)	-		(0)	L20		(0)
G-450	L10			-			-			L20		
G-451	L10		(0)	-		(0)	-		(0)	L20		(0)
G-452	L10			-			-			L20		
G-453	L10		(0)	-		(0)	-		(0)	L20		(0)
G-454	L10			-			-			L20		
G-455	L10		(0)	-		(0)	-		(0)	L20		(0)
G-456	L10			-			-			L20		
G-457	L10		(0)	-		(0)	-		(0)	L20		(0)
G-458	L10			-			-			L20		
G-459	L10		(0)	-		(0)	-		(0)	L20		(0)
G-460	L10			-			-			L20		
G-461	L10		(0)	-		(0)	-		(0)	L20		(0)
G-462	L10			-			-			L20		
G-463	L10		(0)	-		(0)	-		(0)	L20		(0)
G-464	L10			-			-			L20		
G-465	L10		(0)	-		(0)	-		(0)	L20		(0)
G-466	L10			-			-			L20		
G-467	L10		(0)	-		(0)	-		(0)	L20		(0)
G-468	L10			-			-			L20		
G-469	L10		(0)	-		(0)	-		(0)	L20		(0)
G-470	L10			-			-			L20		
G-471	L10		(0)	-		(0)	-		(0)	L20		(0)

Data Table C (Cont'd)

EXP'T TYPE	EXP'T NUMBER	TOTAL SOL'N MASS (g)	MASS SOL'N SUBMITTED (g)	ACL DILUTION	pH	Al (ng/ml) *	Al (ng/ml) **	Al (ng/ml) ***	B (ng/ml) *	B (ng/ml) **	B (ng/ml) ***
TEFLON	G-472	16.15	13.54	10.00	7.66	210	365	63	84	146	3
NO GAMMA	G-473	16.17	13.83	10.00	7.19	220	379	41	84	145	3
	G-474	16.17	13.68	5.00	7.45	190	259		82	112	
EJ-13	91,181,278			0.00	7.58		300		137		
LEACHATE	56			0.00	8.23		L100		74		
	14,28		13.70	0.00			430		170		

TEST NUMBER	Ba (ng/ml) *	Ba (ng/ml) **	Ba (ng/ml) ***	Ca (ug/ml) *	Ca (ug/ml) **	Ca (ug/ml) ***	Ce (ng/ml) *	Ce (ng/ml) **	Cr (ng/ml) *	Cr (ng/ml) **
G-472	L20			4.78	8.30	-0.40	L100		130	220
G-473	L20			4.96	8.54	-0.22				
G-474	-			5.58	7.62					
91,181,278	L20				8.10			L100		L20
56	-				4.89			-		-
14,28	-				7.10			-		-

TEST NUMBER	Cs (ng/ml) *	Cs (ng/ml) **	Fe (ug/ml) *	Fe (ug/ml) **	Fe (ug/ml) ***	La (ng/ml) *	La (ng/ml) **	La (ng/ml) ***	Li (ng/ml) *	Li (ng/ml) **	Li (ng/ml) ***
G-472	-		0.63	1.09	0.43	L20			29	50	39
G-473	-		0.86	1.48	-0.03	-			21	36	6
G-474	-		1.69	2.31		-			32	44	
91,181,278				L0.01			L20			44	
56				L0.01			-			26	
14,28				L0.01			-			41	

* ACL RESULT
** DILUTION CORRECTED
*** BACKGROUND CORRECTED
**** NORMALIZED ELEMENTAL MASS LOSS
- SOLUTION NOT ANALYSED FOR THIS COMPONENT
L LESS THAN DETECTION LIMIT

Data Table C (Cont'd)

TEST NUMBER	Mg (ng/ml) *	**	***	Mn (ng/ml) *	**	***	Mo (ng/ml) *	**	Na (ug/ml) *	**	***
G-472	210	365	-6	38	66	42	L20		25.6	44.5	0.9
G-473	210	362	-10	48	83	-47	-		25.5	43.9	-1.3
G-474	250	341		110	150		-		34.1	46.6	
91,181,278		340			L10			L20		44.4	
56		210			L5			-		27.6	
14,28		250			L5			-		49.3	

TEST NUMBER	Nd (ng/ml) *	**	Ni (ng/ml) *	**	***	Si (ug/ml) *	**	***	Sr (ng/ml) *	**	***
G-472	L100		64	111	67	21.4	37.2	-17.7	26	45	-2
G-473	-		160	275	127	21.3	36.7	-12.9	27	46	-1
G-474	-		89	122		23.3	31.3		32	44	
91,181,278		L100		L20			34.5			44	
56		-		L20			30.1			24	
14,28		-		L20			35.7			36	

TEST NUMBER	Ti (ng/ml) *	**	U (ng/ml) *	**	Zr (ng/ml) *	**	Zn (ng/ml) *	**
G-472	L10		-		11	19	L20	
G-473	L10		-		-		L20	
G-474	L10		-		-		L20	
91,181,278		L10		L1		L10		L20
56		L10		L1		-		L20
14,28		L10		L1		-		L20

DATA TABLE D: Alpha-Spectroscopy Results for FY 1986
Gamma Irradiation Experiments

This table contains the complete analytical results for radionuclide analysis. The detector efficiency is in units of counts/dissociation, and the background in counts/second. UF represents the results of the unfiltered aliquot, F represents the aliquot of the sample filtered through a 50 Å filter, AS represents the aliquot of the acid soak leachate, AW represents the aliquot of the acid wash of the vessel, and T represents analysis of one of the tuff wafer's faces. All leachate and wash solution results are normalized to the original leachate or wash solution volume. The atomic weight fractions of the actinides presented in Table 1 were used to calculate the normalized elemental weight losses. For convenience, the data necessary to compute the actinide masses are tabulated below.

		at. wt. fraction	half-life (sec)	$\mu g \cdot s/dis$
SRL A	Np	2.3×10^{-4}	6.75×10^{13}	3.83×10^{-2}
	Pu	1.9×10^{-4}	7.61×10^{11}	4.36×10^{-4}
	Am	5.7×10^{-6}	1.36×10^{10}	7.87×10^{-6}
ATM-8	Np	3.4×10^{-3}	6.75×10^{13}	3.83×10^{-2}
	Pu	9.0×10^{-4}	7.61×10^{11}	4.36×10^{-4}

Data Table D. Alpha-Spectroscopy Results for FY 1986 Gamma Irradiation Experiments

EXP'T NUMBER	pH	DETECTOR EFFICIENCY (c/dis)	BACKGROUND Np-237 (c/s)	BACKGROUND Pu-239 (c/s)	BACKGROUND Am-241 (c/s)	SURFACE AREA (mm**2)	SOLUTION VOLUME (ml)	ALIQUOT VOLUME (ml)	LIVE TIME (sec)	Np-237 COUNTS (counts)	FRACTION MASS (ug)	TOTAL MASS* (ug)	NL(Np) (g/m**2)
SRL A													
320 UF	7.40	0.1920	0.00020	0.00010	0.00100	492	14.83	0.10	175051	119	0.0142	[0.479]	
320 F		0.1920	0.00020	0.00010	0.00100	492	14.83	0.30	165185	147	0.0068	(1.9E-9)	
320 AS		0.1920	0.00020	0.00010	0.00100	492	12.33	0.10	25416	18	0.0125		
320 AW		0.1940	0.00020	0.00010	0.00010	492	19.00	0.50	59220	30	0.0023	0.017	0.15
321 UF	7.54	0.1920	0.00020	0.00010	0.00100	510	14.88	0.10	149204	150	0.0239		
321 AS		0.1965	0.00010	0.00020	0.00030	510	12.78	0.10	25417	23	0.0201		
321 AW		0.1990	0.00020	0.00020	0.00040	510	19.00	0.50	59217	80	0.0084	0.032	0.27
322 UF	6.96	0.1894	0.00020	0.00010	0.00100	515	14.86	0.10	165644	698	0.1207	[0.321]	
322 F		0.1904	0.00020	0.00010	0.00100	515	14.86	0.20	66572	186	0.0388	(1.1E-8)	
322 AS		0.1894	0.00020	0.00010	0.00100	515	12.36	0.10	56595	235	0.0989		
322 AW		0.1940	0.00020	0.00010	0.00100	515	19.00	0.50	55674	44	0.0044	0.125	1.05
323 UF	6.94	0.1944	0.00010	0.00020	0.00030	488	14.86	0.10	171478	735	0.1226		
323 AS		0.1944	0.00010	0.00020	0.00030	488	12.76	0.10	56600	343	0.1499		
323 AW		0.1990	0.00020	0.00020	0.00040	488	19.00	0.50	55668	279	0.0352	0.202	1.79
324 UF	6.69	0.1456	0.00020	0.00012	0.00105	498	14.85	0.10	57015	335	0.2219	[0.062]	
324 F		0.1456	0.00020	0.00012	0.00105	498	14.85	0.10	277664	154	0.0139	(3.9E-9)	
324 AS		0.1456	0.00020	0.00012	0.00105	498	12.35	0.10	64171	378	0.1850		
324 AW		0.1456	0.00020	0.00012	0.00105	498	19.00	0.50	77309	235	0.0284	0.250	2.17
325 UF	6.94	0.1956	0.00020	0.00012	0.00105	514	14.79	0.10	57265	770	0.3839		
325 AS		0.1456	0.00020	0.00012	0.00105	514	12.49	0.10	19149	200	0.3368		
325 AW		0.1456	0.00020	0.00012	0.00105	514	19.00	0.50	85765	326	0.0360	0.433	3.65
326 UF	7.26	0.1907	0.00020	0.00012	0.00105	517	14.69	0.10	55720	1082	0.5674	[0.247]	
326 F		0.1926	0.00020	0.00012	0.00105	517	14.69	0.20	79556	780	0.1404	(4.0E-8)	
326 AS		0.1926	0.00020	0.00012	0.00105	517	12.19	0.10	9661	224	0.5576		
326 AW		0.1940	0.00023	0.00013	0.00105	517	19.00	0.50	16034	89	0.0399	0.694	5.81
327 UF	7.22	0.1956	0.00015	0.00017	0.00035	503	14.72	0.10	57116	1092	0.5070		
327 AS		0.1926	0.00020	0.00012	0.00105	503	12.62	0.10	10370	352	0.8474		
327 AW		0.1990	0.00019	0.00019	0.00040	503	19.00	0.50	16038	123	0.0547	0.983	8.46
328 UF	5.35	0.1974	0.00015	0.00017	0.00105	512	14.78	0.10	88699	1506	0.4829	[0.325]	
328 F		0.1904	0.00020	0.00012	0.00105	512	14.78	0.30	245749	3933	0.1567	(4.5E-8)	
328 AS		0.1957	0.00015	0.00017	0.00035	512	12.28	0.10	10257	175	0.4067		
328 AW		0.1940	0.00023	0.00013	0.00105	519	19.00	0.50	11627	30	0.0176	0.507	4.23
329 UF	7.56	0.1904	0.00020	0.00012	0.00105	511	14.73	0.10	88586	1493	0.4938		
329 AS		0.1974	0.00015	0.00017	0.00035	511	12.63	0.10	8056	140	0.4225		
329 AW		0.1990	0.00013	0.00013	0.00040	511	19.00	0.50	11628	39	0.0236	0.518	4.39
SRL A + TUFF													
330 UF	7.38	0.1965	0.00010	0.00020	0.00030	528	14.58	0.10	175051	379	0.0587	[0.343]	
330 F		0.1965	0.00010	0.00020	0.00030	528	14.58	0.30	165167	387	0.0201	(5.8E-9)	
330 AS		0.1920	0.00020	0.00010	0.00100	528	12.08	0.10	76628	160	0.0455		
330 AW		0.1929	0.00020	0.00010	0.00100	528	19.00	0.50	90482	211	0.0161	0.075	0.61
330 T		0.2014	0.00023	0.00013	0.00105	1	1.00	1.00	145180	30	0.0000		
331 UF	7.34	0.1965	0.00010	0.00020	0.00030	480	14.56	0.10	149309	321	0.0582		
331 AS		0.1965	0.00010	0.00020	0.00030	480	12.46	0.10	76178	160	0.0486		
331 AW		0.1999	0.00020	0.00020	0.00040	480	19.00	0.50	90453	243	0.0181	0.076	0.69
331 T		0.1955	0.00019	0.00019	0.00040	1	1.00	1.00	145178	30	0.0000		
332 UF	6.96	0.1904	0.00020	0.00010	0.00100	510	14.47	0.18	75337	612	0.1282	[0.567]	
332 F		0.1974	0.00010	0.00020	0.00100	510	14.47	0.10	66588	179	0.0727	(2.1E-8)	
332 AS		0.1894	0.00020	0.00010	0.00100	510	11.97	0.10	9326	85	0.2159		
332 AW		0.1940	0.00020	0.00010	0.00100	510	19.00	0.50	53154	122	0.0157	0.254	2.16
332 T		0.1955	0.00019	0.00019	0.00040	1	1.00	1.00	74728	14	0.0000		

Data Table D (Cont'd)

EXP'T NUMBER	Pu-239 COUNTS (counts)	FRACTION MASS (ug)	TOTAL MASS* (ug)	NL(Pu) (g/m**2)	Am-241 COUNTS (counts)	FRACTION MASS (ng)	TOTAL MASS* (ng)	NL(Am) (g/m**2)
320 UF	62	0.0001	[0.298]		170	0.0000	[0.000]	
320 F	54	0.0000	(7.2E-12)		170	0.0001	(1.7E-17)	
320 AS	255	0.0028			239	0.0424		
320 AW	16	0.0000	0.003	0.03	72	0.0017	0.044	0.02
321 UF	223	0.0005			291	0.0058		
321 AS	592	0.0065			569	0.1128		
321 AW	66	0.0001	0.007	0.07	46	0.0006	0.116	0.04
322 UF	1038	0.0021	[0.206]		345	0.0067	[0.058]	
322 F	177	0.0004	(1.2E-10)		75	0.0004	(1.1E-16)	
322 AS	6411	0.0322			2324	0.2053		
322 AW	823	0.0013	0.033	0.33	258	0.0056	0.212	0.07
323 UF	508	0.0009			154	0.0036		
323 AS	8183	0.0413			1650	0.1487		
323 AW	420	0.0006	0.042	0.44	108	0.0023	0.152	0.05
324 UF	238	0.0018	[0.058]		57	0.0000	[0.000]	
324 F	99	0.0001	(3.0E-11)		77	0.0000	(0.00)	
324 AS	21494	0.1237			3408	0.3467		
324 AW	486	0.0007	0.125	1.29	97	0.0004	0.347	0.12
325 UF	430	0.0024			41	0.0000		
325 AS	4228	0.0824			439	0.1474		
325 AW	497	0.0006	0.083	0.83	100	0.0002	0.147	0.05
326 UF	245	0.0014	[0.088]		141	0.0090	[0.000]	
326 F	70	0.0001	(3.6E-11)		75	0.0000	(0.00)	
326 AS	9206	0.2626			955	0.4861		
326 AW	332	0.0018	0.265	2.64	56	0.0038	0.482	0.16
327 UF	209	0.0011			53	0.0034		
327 AS	8249	0.2269			789	0.3861		
327 AW	211	0.0011	0.228	2.34	8	0.0001	0.386	0.13
328 UF	476	0.0017	[0.116]		96	0.0002	[0.738]	
328 F	458	0.0002	(5.6E-11)		275	0.0001	(3.9E-17)	
328 AS	830	0.0221			21782	10.4622		
328 AW	727	0.0053	0.027	0.27	68	0.0074	10.469	3.53
329 UF	680	0.0025			217	0.0085		
329 AS	7268	0.2513			1017	0.6325		
329 AW	597	0.0043	0.255	2.57	52	0.0061	0.638	0.22
SRL A + TUFF								
330 UF	552	0.0010	[0.060]		386	0.0111	[0.024]	
330 F	121	0.0001	(1.7E-11)		72	0.0003	(7.5E-17)	
330 AS	3054	0.0109			1688	0.1039		
330 AW	227	0.0002	0.011	0.11	210	0.0020	0.112	0.04
330 T	23645	0.0004			9299	0.0025		
331 UF	193	0.0004			109	0.0025		
331 AS	3843	0.0139			1280	0.0822		
331 AW	200	0.0002	0.014	0.15	95	0.0010	0.085	0.03
331 T	24621	0.0004			5462	0.0015		
332 UF	1937	0.0047	[0.112]		1086	0.0445	[0.022]	
332 F	123	0.0005	(1.5E-10)		78	0.0010	(2.8E-19)	
332 AS	2115	0.0624			934	0.4921		
332 AW	588	0.0009	0.068	0.69	183	0.0038	0.524	0.18
332 T	56542	0.0017			20162	0.0108		

Data Table D (Cont'd)

333	UF	6.80	0.1931	0.00020	0.00010	0.00100	505	14.44	0.10	87247	707	0.2265		
333	AS		0.1944	0.00010	0.00020	0.00030	505	12.34	0.10	9326	69	0.1776		
333	AW		0.1990	0.00020	0.00020	0.00040	505	19.00	0.50	53143	133	0.0169	0.244	2.09
333	T		0.2014	0.00023	0.00013	0.00105	1	1.00	1.00	74730	14	0.0000		
334	UF	6.83	0.1925	0.00020	0.00012	0.00105	494	14.45	0.10	72940	368	0.1394	[0.261]	
334	F		0.1456	0.00020	0.00012	0.00105	494	14.45	0.10	229700	266	0.0364	(1.1E-8)	
334	AS		0.1904	0.00020	0.00012	0.00105	494	11.95	0.10	7421	17	0.0503		
334	AW		0.1956	0.00015	0.00017	0.00035	494	19.00	0.50	75756	23	0.0011	0.140	1.23
334	T		0.1456	0.00020	0.00012	0.00105	494	1.00	1.00	5538	1	0.0000		
335	UF	7.04	0.2009	0.00015	0.00017	0.00035	518	14.53	0.10	72937	300	0.1099		
335	AS		0.1956	0.00015	0.00017	0.00035	518	12.43	0.10	9929	200	0.4870		
335	AW		0.1456	0.00020	0.00012	0.00105	518	19.00	0.50	57422	17	0.0010	0.504	4.21
335	T		0.1958	0.00015	0.00017	0.00035	518	1.00	1.00	5538	1	0.0000		
336	UF	7.20	0.1957	0.00015	0.00017	0.00035	503	14.49	0.10	87232	565	0.1795	[1.057]	
336	F		0.1956	0.00015	0.00017	0.00105	503	14.49	0.20	79533	1075	0.1898	(5.5E-8)	
336	AS		0.1926	0.00020	0.00012	0.00105	503	11.99	0.10	9966	265	0.6297		
336	AW		0.1940	0.00023	0.00013	0.00105	503	19.00	0.50	10101	149	0.1090	0.770	6.63
336	T		0.2014	0.00023	0.00013	0.00105	503	1.00	1.00	1861	0	0.0000		
337	UF	7.30	0.1926	0.00020	0.00012	0.00105	526	14.41	0.10	57715	978	0.4802		
337	AS		0.1956	0.00015	0.00017	0.00035	526	12.31	0.10	10370	271	0.6267		
337	AW		0.1990	0.00019	0.00019	0.00040	526	19.00	0.50	10107	223	0.1601	0.846	6.96
337	T		0.1955	0.00019	0.00019	0.00040	526	1.00	1.00	1861	0	0.0000		
338	UF	7.56	0.1904	0.00020	0.00012	0.00105	496	14.35	0.10	24209	479	0.5658	[0.287]	
338	F		0.1974	0.00015	0.00017	0.00035	496	14.35	0.20	245788	2902	0.1624	(4.8E-8)	
338	AS		0.1957	0.00015	0.00017	0.00035	496	11.85	0.10	9694	275	0.6549		
338	AW		0.1925	0.00020	0.00012	0.00105	496	19.00	0.50	79662	1734	0.1632	0.884	7.72
338	T		0.2014	0.00023	0.00013	0.00105	496	1.00	1.00	730	0	0.0000		
339	UF	7.69	0.1974	0.00015	0.00017	0.00105	515	14.33	0.10	24218	526	0.6001		
339	AS		0.1957	0.00015	0.00017	0.00035	515	12.23	0.10	7554	165	0.5196		
339	AW		0.2009	0.00015	0.00017	0.00035	515	19.00	0.50	79658	1996	0.1806	0.789	6.63
339	T		0.1955	0.00019	0.00019	0.00040	515	1.00	1.00	730	0	0.0000		
SRL A no gamma														
364	UF	8.28	0.1957	0.00015	0.00017	0.00035	525	14.86	0.10	155967	55	0.0059	[0.587]	
364	F		0.1931	0.00020	0.00012	0.00105	525	14.86	0.30	183007	101	0.0035	(9.8E-10)	
364	AS		0.1974	0.00015	0.00017	0.00035	525	12.36	0.10	86751	30	0.0047		
364	AW		0.1929	0.00023	0.00013	0.00105	525	19.00	0.50	153427	63	0.0014	0.007	0.06
365	UF	8.30	0.1904	0.00020	0.00012	0.00105	513	14.86	0.10	168889	60	0.0046		
365	AS		0.1904	0.00020	0.00012	0.00105	513	12.76	0.10	86742	28	0.0032		
365	AW		0.2009	0.00019	0.00019	0.00040	513	19.00	0.50	153433	42	0.0006	0.006	0.05
366	UF	8.93	0.1920	0.00020	0.00010	0.00100	503	14.87	0.10	195129	419	0.0578	[0.314]	
366	F		0.1894	0.00020	0.00012	0.00105	503	14.87	0.30	142951	287	0.0181	(5.1E-9)	
366	AS		0.1920	0.00020	0.00010	0.00100	503	12.37	0.10	62205	132	0.0475		
366	AW		0.1940	0.00020	0.00010	0.00010	503	19.00	0.50	71842	93	0.0082	0.066	0.57
367	UF	8.91	0.1965	0.00010	0.00020	0.00030	523	14.88	0.10	195129	430	0.0611		
367	AS		0.1965	0.00010	0.00020	0.00030	523	12.78	0.10	62341	154	0.0591		
367	AW		0.1190	0.00020	0.00020	0.00040	523	19.00	0.50	71836	118	0.0177	0.086	0.71
368	UF	8.74	0.1940	0.00020	0.00010	0.00100	528	14.86	0.10	161655	211	0.0324	[0.330]	
368	F		0.1904	0.00020	0.00010	0.00100	528	14.86	0.20	158318	145	0.0107	(3.0E-9)	
368	AS		0.1894	0.00020	0.00010	0.00100	528	12.36	0.10	25635	75	0.0682		
368	AW		0.1929	0.00023	0.00013	0.00105	528	19.00	0.50	68036	14	0.0000	0.083	0.68
369	UF	8.97	0.1944	0.00015	0.00017	0.00035	510	14.81	0.10	161654	437	0.0746		
369	AS		0.1944	0.00015	0.00017	0.00035	510	12.71	0.10	25635	215	0.2064		
369	AW		0.1999	0.00019	0.00019	0.00040	510	19.00	0.50	68048	14	0.0001	0.217	1.84
370	UF	9.21	0.1931	0.00020	0.00012	0.00105	497	14.85	0.10	166623	1110	0.1905	[3.315]	
370	F		0.1926	0.00020	0.00012	0.00105	497	14.85	0.20	142750	6129	0.6314	(1.8E-7)	

Data Table D (Cont'd)

333	UF	1572	0.0058			684	0.0402		
333	AS	1680	0.0497			472	0.2508		
333	AW	868	0.0013	0.056	0.57	152	0.0037	0.277	0.10
333	T	58474	0.0017			14899	0.0077		
334	UF	6900	0.0309	[0.008]		3028	0.2385	[0.00]	
334	F	162	0.0003	(7.3E-11)		213	0.0000	(0.00)	
334	AS	3748	0.1380			1623	1.0727		
334	AW	2076	0.0023	0.154	1.61	522	0.0100	1.249	0.44
334	T	9357	0.0051			6745	0.0656		
335	UF	2619	0.0113			630	0.0471		
335	AS	4018	0.1119			1117	0.5596		
335	AW	1014	0.0020	0.120	1.19	207	0.0052	0.596	0.20
336	T	5937	0.0024			1591	0.0115		
336	UF	18702	0.0691	[0.019]		7348	0.4877	[0.009]	
336	F	671	0.0013	(3.9E-10)		209	0.0046	(3.1E-16)	
336	AS	10299	0.2801			4045	1.9790		
336	AW	386	0.0032	0.303	3.11	50	0.0060	2.155	0.75
336	T	4467	0.0052			2404	0.0503		
337	UF	2902	0.0163			938	0.0893		
337	AS	8941	0.2362			2250	1.0705		
337	AW	569	0.0047	0.247	2.42	31	0.0040	1.138	0.38
337	T	1970	0.0024			1159	0.0250		
338	UF	4375	0.0593	[0.032]		1754	0.4226	[0.034]	
338	F	2973	0.0019	(5.5E-10)		1333	0.0145	(1.9E-16)	
338	AS	10131	0.2755			4789	2.3473		
338	AW	1648	0.0018	0.297	3.09	473	0.0076	2.516	0.89
338	T	1922	0.0057			1012	0.0540		
339	UF	5630	0.0734			2552	0.5947		
339	AS	8346	0.3006			4322	2.8060		
339	AW	2067	0.0021	0.329	3.29	780	0.0140	3.066	1.04
339	T	2544	0.0078			1312	0.0722		
SRL A no gamma									
364	UF	68	0.0001	[0.278]		89	0.0013	[0.000]	
364	F	62	0.0000	(6.9E-12)		184	0.0000	(0.00)	
364	AS	509	0.0016			484	0.0257		
364	AW	37	0.0000	0.002	0.02	172	0.0001	0.026	0.01
365	UF	26	0.0000			169	0.0000		
365	AS	166	0.0005			325	0.0142		
365	AW	39	0.0000	0.001	0.01	69	0.0001	0.014	0.00
366	UF	840	0.0014	[0.063]		1331	0.0354	[0.012]	
366	F	130	0.0001	(2.5E-11)		210	0.0009	(2.4E-16)	
366	AS	4078	0.0184			3699	0.2958		
366	AW	108	0.0001	0.018	0.18	147	0.0030	0.223	0.08
367	UF	308	0.0005			325	0.0081		
367	AS	4191	0.0190			2883	0.2347		
367	AW	1444	0.0028	0.022	0.22	495	0.0163	0.252	0.08
368	UF	166	0.0003	[0.164]		549	0.0144	[0.039]	
368	F	63	0.0001	(1.4E-11)		187	0.0006	(1.6E-16)	
368	AS	2579	0.0286			2069	0.4085		
368	AW	1129	0.0014	0.030	0.29	529	0.0104	0.420	0.14
369	UF	513	0.0010			559	0.0186		
369	AS	4661	0.0517			1929	0.3845		
369	AW	1046	0.0013	0.053	0.54	269	0.0053	0.392	0.13
370	UF	296	0.0006	[0.188]		454	0.0101	[0.000]	
370	F	106	0.0001	(2.9E-11)		146	0.0000	(0.00)	

Data Table D (Cont'd)

370 AS		0.1926	0.00020	0.00012	0.00105	497	12.35	0.10	10363	244	0.5737			
370 AW		-	-	-	-	497				-		0.601	5.23	
371 UF	9.24	0.1907	0.00020	0.00012	0.00105	514	14.84	0.10	28003	510	0.5372			
371 AS		0.1926	0.00020	0.00012	0.00105	514	12.74	0.10	12224	230	0.4719			
371 AW		0.1940	0.00023	0.00013	0.00105	514	19.00	0.50	54703	159	0.0201	0.550	4.63	
372 UF	7.93	0.1925	0.00020	0.00012	0.00105	502	14.78	0.10	73631	1332	0.5265	[0.298]		
372 F		0.1926	0.00020	0.00012	0.00105	502	14.78	0.20	57348	624	0.1571	(4.5E-8)		
372 AS		0.1925	0.00020	0.00012	0.00105	502	12.28	0.10	16209	500	0.7493			
372 AW		0.1990	0.00019	0.00019	0.00040	502	19.00	0.50	54693	191	0.0242	0.847	7.30	
373 UF	9.12	0.1907	0.00020	0.00012	0.00105	520	14.74	0.10	55678	238	0.1207			
373 AS		0.1956	0.00015	0.00017	0.00035	520	12.64	0.10	9965	265	0.6549			
373 AW		0.1990	0.00019	0.00019	0.00040	520	19.00	0.50	31332	208	0.0472	0.719	5.99	
374 UF	5.04	0.1904	0.00020	0.00012	0.00105	497	14.69	0.10	14290	314	0.6439	[0.290]		
374 F		0.1931	0.00020	0.00012	0.00105	497	14.69	0.30	162862	3160	0.1866	(5.4E-8)		
374 AS		0.1904	0.00020	0.00012	0.00105	497	12.19	0.10	11398	395	0.8455			
374 AW		0.1929	0.00023	0.00013	0.00105	497	19.00	0.50	62796	1091	0.1294	1.065	9.28	
375 UF	7.54	0.1974	0.00015	0.00017	0.00035	506	14.58	0.10	89791	243	0.0724			
375 AS		0.1974	0.00015	0.00017	0.00035	506	12.48	0.10	11398	376	0.7957			
375 AW		0.1999	0.00019	0.00019	0.00040	506	19.00	0.50	62784	617	0.0702	0.876	7.49	
SRL A + TUFF no gamma														
376 UF	7.60	0.1904	0.00020	0.00012	0.00105	490	14.48	0.10	145838	289	0.0519	[0.450]		
376 F		0.1957	0.00015	0.00017	0.00035	490	14.48	0.40	182939	631	0.0234	(6.8E-9)		
376 AS		0.1957	0.00015	0.00017	0.00035	490	11.98	0.10	66393	254	0.0862			
376 AW		0.1929	0.00023	0.00013	0.00105	490	19.00	0.50	82740	161	0.0130	0.106	0.94	
376 T		0.2014	0.00023	0.00013	0.00105	490	1.00	1.00	6603	1	0.0000			
377 UF	7.77	0.1974	0.00015	0.00017	0.00035	517	14.47	0.10	146039	253	0.0445			
377 AS		0.1957	0.00015	0.00017	0.00035	517	12.37	0.10	72009	140	0.0435			
377 AW		0.1999	0.00019	0.00019	0.00040	517	19.00	0.50	82731	248	0.0205	0.069	0.58	
377 T		0.1955	0.00019	0.00019	0.00040	517	1.00	1.00	6604	1	0.0000			
378 UF	8.10	0.1920	0.00020	0.00012	0.00105	467	14.56	0.10	91361	308	0.0922	[0.369]		
378 F		0.1944	0.00010	0.00020	0.00030	467	14.56	0.30	142922	522	0.0340	(9.9E-9)		
378 AS		0.1931	0.00020	0.00010	0.00100	467	12.06	0.10	85159	302	0.0801			
378 AW		0.1940	0.00020	0.00010	0.00100	467	19.00	0.50	170582	122	0.0039	0.100	0.93	
378 T		0.2014	0.00023	0.00013	0.00105	467	1.00	1.00	5958	100	0.0032			
379 UF	8.47	0.1965	0.00010	0.00020	0.00030	495	14.55	0.10	91435	290	0.0872			
379 AS		0.1957	0.00010	0.00020	0.00030	495	12.45	0.10	85158	354	0.0989			
379 AW		0.1990	0.00020	0.00020	0.00040	495	19.00	0.50	170566	216	0.0078	0.130	1.14	
379 T		0.1955	0.00019	0.00019	0.00040	495	1.00	1.00	5957	100	0.0033			
380 UF	8.49	0.1894	0.00020	0.00012	0.00105	523	14.48	0.10	61098	227	0.1030	[0.896]		
380 F		0.1974	0.00015	0.00017	0.00105	523	14.48	0.20	158254	1063	0.0923	(2.7E-8)		
380 AS		0.1904	0.00020	0.00012	0.00105	523	11.98	0.10	17125	173	0.2388			
380 AW		0.1929	0.00023	0.00013	0.00105	523	19.00	0.50	82799	100	0.0074	0.261	2.16	
380 T		0.2014	0.00023	0.00013	0.00105	523	1.00	1.00	4286	0	0.0000			
381 UF	8.25	0.1944	0.00015	0.00017	0.00035	483	14.43	0.10	61096	105	0.0446			
381 AS		0.1974	0.00015	0.00017	0.00035	483	12.33	0.10	17124	112	0.1530			
381 AW		0.1999	0.00019	0.00019	0.00040	483	19.00	0.50	82796	17	0.0001	0.159	1.43	
381 T		0.1955	0.00019	0.00017	0.00040	493	1.00	1.00	4286					
382 UF	8.85	0.1926	0.00020	0.00012	0.00105	523	14.42	0.10	56758	522	0.2582	[0.349]		
382 F		0.1956	0.00015	0.00017	0.00035	523	14.42	0.30	142738	1386	0.0900	(2.6E-8)		
382 AS		0.1956	0.00015	0.00017	0.00035	523	11.92	0.10	12221	175	0.3310			
382 AW		-	-	-	-	523				-		0.367	3.04	
382 T		0.2014	0.00023	0.00013	0.00105	525	1.00	1.00	3406	0	0.0000			
383 UF	8.80	0.1956	0.00015	0.00017	0.00035	487	14.43	0.10	13408	103	0.2130			
383 AS		0.1956	0.00015	0.00017	0.00035	487	12.33	0.10	10363	85	0.1945			
383 AW		0.1940	0.00023	0.00013	0.00105	487	19.00	0.50	26234	56	0.0143	0.239	2.12	

Data Table D (Cont'd)

370	AS	3441	0.0927			538	0.2561		
370	AW	-		0.093	0.96	-		0.257	0.09
371	UF	303	0.0036			949	0.2007		
371	AS	4451	0.1048			1032	0.4331		
371	AW	265	0.0004	0.106	1.06	109	0.0014	0.469	0.16
372	UF	738	0.0033	[0.025]		2487	0.1973	[0.002]	
372	F	35	0.0001	(2.3E-11)		67	0.0004	(1.0E-16)	
372	AS	10646	0.1824			10980	3.3881		
372	AW	1138	0.0017	0.185	1.90	846	0.0226	3.435	1.20
373	UF	104	0.0006			139	0.0088		
373	AS	7498	0.2117			1554	0.7896		
373	AW	563	0.0015	0.213	2.11	41	0.0014	0.793	0.27
374	UF	146	0.0034	[0.090]		819	0.3409	[0.009]	
374	F	471	0.0003	(8.7E-11)		416	0.0030	(8.5E-16)	
374	AS	2752	0.0673			20561	9.0638		
374	AW	1886	0.0026	0.071	0.74	3869	0.0937	9.217	3.25
375	UF	111	0.0003			129	0.0063		
375	AS	9503	0.2295			1401	0.6085		
375	AW	603	0.0008	0.230	2.34	155	0.0031	0.612	0.21
SRL A + TUFF no gamma									
376	UF	326	0.0007	[0.097]		416	0.0108	[0.005]	
376	F	186	0.0001	(2.0E-11)		71	0.0001	(1.6E-17)	
376	AS	2254	0.0090			642	0.0448		
376	AW	233	0.0002	0.009	0.09	163	0.0014	0.054	0.02
376	T	1038	0.0003			454	0.0026		
377	UF	277	0.0006			215	0.0065		
377	AS	3010	0.0115			1056	0.0711		
377	AW	249	0.0002	0.011	0.11	136	0.0019	0.082	0.03
377	T	988	0.0003			639	0.0039		
378	UF	372	0.0013	[0.048]		240	0.0094	[0.019]	
378	F	111	0.0001	(1.8E-8)		56	0.0002	(5.1E-17)	
378	AS	7505	0.0239			1742	0.0954		
378	AW	454	0.0002	0.026	0.29	325	0.0014	0.114	0.04
378	T	2467	0.0009			1193	0.0078		
379	UF	1686	0.0059			993	0.0614		
379	AS	7122	0.0231			3672	0.2139		
379	AW	956	0.0004	0.026	0.27	832	0.0067	0.249	0.09
379	T	2895	0.0011			1370	0.0092		
380	UF	4016	0.0218	[0.017]		1906	0.1810	[0.003]	
380	F	395	0.0004	(1.1E-10)		198	0.0006	(1.7E-16)	
380	AS	4836	0.0773			1895	0.5415		
380	AW	3053	0.0032	0.090	0.89	690	0.0113	0.637	0.21
380	T	5097	0.0026			3671	0.0334		
381	UF	3429	0.0181			2494	0.2359		
381	AS	2686	0.0426			2854	0.8158		
381	AW	1380	0.0014	0.047	0.50	1136	0.0199	0.889	0.32
381	T	880	0.0005			393	0.0037		
382	UF	9286	0.0533	[0.006]		3598	0.3665	[0.003]	
382	F	484	0.0003	(1.0E-10)		130	0.0011	(3.1E-16)	
382	AS	6399	0.1389			2246	0.8778		
382	AW	-		0.150	1.48	-		0.951	0.32
382	T	1253	0.0008			397	0.0045		
383	UF	2762	0.0661			1074	0.4620		
383	AS	7981	0.2113			2829	1.3496		
383	AW	71	0.0002	0.230	2.43	21	0.0000	1.537	0.55

Data Table D (Cont'd)

383	T		0.1955	0.00019	0.00019	0.00040	487	1.00	1.00	3405	0	0.0000		
384	UF	8.90	0.1981	0.00015	0.00017	0.00035	514	14.36	0.10	55682	874	0.4319	[0.165]	
384	F		0.1956	0.00015	0.00017	0.00035	514	14.36	0.20	57342	299	0.0712	(2.1E-8)	
384	AS		0.1926	0.00020	0.00012	0.00105	514	11.86	0.10	8264	130	0.3665		
384	AW		0.1990	0.00019	0.00019	0.00040	514	19.00	0.50	77134	360	0.0328	0.465	3.92
384	T		0.2014	0.00023	0.00013	0.00105	514	1.00	1.00	880	0	0.0000		
385	UF	8.81	0.1926	0.00020	0.00012	0.00105	505	14.39	0.10	13294	100	0.2097		
385	AS		0.1956	0.00015	0.00017	0.00035	505	12.29	0.10	8264	50	0.1421		
385	AW		0.1990	0.00019	0.00019	0.00040	505	19.00	0.50	14700	152	0.0743	0.284	2.43
385	T		0.1955	0.00019	0.00019	0.00040	505	1.00	1.00	880	0	0.0000		
386	UF	9.02	0.1931	0.00020	0.00012	0.00105	495	14.21	0.10	63820	300	0.1269	[0.860]	
386	F		0.1957	0.00015	0.00017	0.00035	495	14.21	0.20	162853	1302	0.1092	(3.2E-8)	
386	AS		0.1904	0.00020	0.00012	0.00105	495	11.71	0.10	7184	169	0.5498		
386	AW		0.1929	0.00023	0.00013	0.00105	495	19.00	0.50	16143	3	0.0000	0.527	4.61
386	T		0.2014	0.00023	0.00013	0.00105	495	1.00	1.00	830	0	0.0000		
387	UF	9.07	0.1957	0.00015	0.00017	0.00035	516	14.27	0.10	63816	300	0.1272		
387	AS		0.1974	0.00015	0.00017	0.00035	516	12.17	0.10	7184	228	0.7464		
387	AW		0.1999	0.00019	0.00019	0.00040	516	19.00	0.50	16143	3	0.0000	0.765	6.42
387	T		0.1955	0.00019	0.00019	0.00040	516	1.00	1.00	832	0	0.0000		

Data Table D (Cont'd)

383	T	6078	0.0040			4597	0.0542		
384	UF	14772	0.0837	[0.004]		3433	0.3490	[0.004]	
384	F	142	0.0004	(1.1E-10)		45	0.0013	(3.6E-16)	
384	AS	10089	0.3273			3211	1.8738		
384	AW	560	0.0006	0.340	3.41	38	0.0001	1.974	0.67
384	T	1038	0.0025			454	0.0201		
385	UF	2196	0.0537			611	0.2635		
385	AS	10357	0.3428			2827	1.6861		
385	AW	1117	0.0063	0.362	3.70	49	0.0044	1.793	0.62
385	T	988	0.0025			639	0.0292		
386	UF	28766	0.1444	[0.000]		8966	0.8058	[0.001]	
386	F	209	0.0002	(5.2E-11)		96	0.0007	(2.0E-16)	
386	AS	12288	0.4580			5737	3.8517		
386	AW	1822	0.0097	0.521	5.43	391	0.0358	4.532	1.60
386	T	5455	0.0142			5365	0.2520		
387	UF	23004	0.1144			6663	0.5958		
387	AS	12297	0.4594			5267	3.5477		
387	AW	1515	0.0078	0.515	5.14	301	0.0272	3.995	1.36
387	T	5393	0.0144			3290	0.1588		

ATOMIC WEIGHT FRACTIONS OF ACTINIDES IN GLASS
f(Np) SRL A = 2.31E-4
f(Pu) SRL A = 1.94E-4
f(Am) SRL A = 5.71E-6

UF UNFILTERED SOLUTION (DISSOLVED INTO TOTAL VOLUME)
F FILTERED THROUGH 50 A (DISSOLVED INTO TOTAL VOLUME)
[ ] MASS Pu(F)/Pu(UF)
( ) SOLUBILITY IN MOLES/LITER
AS ACID SOAKED SOLUTION (DISSOLVED INTO REDUCED VOLUME)
AW ACID WASHED VESSEL SOLUTION
T TUFF WAFER SURFACE (VALUE REPORTED REFERS TO ONLY ONE SIDE OF WAFER)
- NOT ANALYSED
* TOTAL MASS REPRESENTS An(UF) + An(adsorbed on vessel)
+ An(adsorbed on tuff)

Data Table D (Cont'd)

EXP'T NUMBER	pH	DETECTOR EFFICIENCY	Np-237 (c/s)	Pu-239 (c/s)	Am-241 (c/s)	SURFACE AREA (mm*2)	SOLUTION VOLUME (ml)	ALIQUOT VOLUME (ml)	LIVE TIME (sec)	Np-237 COUNTS (counts)	FRACTION MASS (ug)	TOTAL MASS* (ug)	NL(Np) (g/m**2)
ATM-8													
408 UF	8.67	0.1894	0.00020	0.00010		499	14.90	0.10	77355	7967	3.0994	[0.399]	
408 F		0.1920	0.00020	0.00010		499	14.90	0.30	144677	18073	1.2365	(3.5E-7)	
408 AS		0.1944	0.00010	0.00020		499	12.40	0.10	10415	1193	2.7979		
408 AW		0.1940	0.00020	0.00010		499	19.00	0.50	16943	88	0.0375	3.136	1.85
409 UF	8.54	0.1944	0.00010	0.00020		483	14.87	0.10	77354	8865	3.3569		
409 AS		0.1894	0.00020	0.00010		483	12.77	0.10	11614	1346	2.9897		
409 AW		0.1990	0.00020	0.00020		483	19.00	0.50	16934	306	0.1308	3.525	2.15
410 UF	7.92	0.1894	0.00020	0.00010		505	14.82	0.10	24551	3880	4.7335	[0.286]	
410 F		0.1904	0.00020	0.00010		505	14.82	0.15	76425	4918	1.2768	(3.6E-7)	
410 AS		0.1894	0.00020	0.00010		505	12.32	0.10	7533	1351	4.4662		
410 AW		0.1940	0.00020	0.00010		505	19.00	0.50	18763	205	0.0805	5.216	3.04
411 UF	7.85	0.1944	0.00010	0.00020		496	14.85	0.10	24548	3528	4.2048		
411 AS		0.1974	0.00010	0.00020		496	12.75	0.10	12522	2537	5.0130		
411 AW		0.1990	0.00020	0.00020		496	19.00	0.50	18763	190	0.0726	5.680	3.37
412 UF	7.61	0.1456	0.00020	0.00012		511	14.45	0.10	17467	2340	5.0882	[0.492]	
412 F		0.1956	0.00015	0.00017		511	14.45	0.03	93165	2485	2.5033	(7.3E-7)	
412 AS		0.1456	0.00020	0.00012		511	11.95	0.10	8153	2500	9.6394		
412 AW		0.1958	0.00015	0.00017		511	19.00	0.50	57416	376	0.0476	10.406	5.99
413 UF	7.68	0.1956	0.00015	0.00017		497	14.55	0.10	27881	5086	5.1965		
413 AS		0.1956	0.00015	0.00017		497	12.45	0.10	8153	2954	8.8353		
413 AW		0.1456	0.00020	0.00012		497	19.00	0.50	29068	9	0.0011	9.570	5.66
414 UF	7.70	0.1926	0.00020	0.00012		493	14.70	0.10	20171	4847	7.0235	[0.456]	
414 F		0.1926	0.00020	0.00012		493	14.70	0.10	52978	5815	3.2050	(9.2E-7)	
414 AS		0.1956	0.00015	0.00017		493	12.20	0.10	10679	3594	8.0418		
414 AW		0.1929	0.00023	0.00013		493	19.00	0.50	14007	256	0.1363	9.170	5.47
415 UF	7.54	0.1926	0.00020	0.00012		493	14.72	0.10	19200	5080	7.7445		
415 AS		0.1956	0.00015	0.00017		493	12.62	0.10	7870	2437	7.6536		
415 AW		0.1999	0.00019	0.00019		493	19.00	0.50	14004	202	0.1037	8.852	5.28
416 UF	7.78	0.1931	0.00020	0.00012		496	14.69	0.10	26198	7636	8.4927	[0.223]	
416 F		0.1931	0.00020	0.00012		496	14.69	0.17	60294	8674	1.8951	(5.4E-7)	
416 AS		0.1904	0.00020	0.00012		496	12.19	0.10	7281	2703	9.1047		
416 AW		0.1940	0.00023	0.00013		496	19.00	0.50	31330	235	0.0546	10.360	6.14
417 UF	5.82	0.1957	0.00015	0.00017		509	14.61	0.10	26197	6178	6.7435		
417 AS		0.1974	0.00015	0.00017		509	12.51	0.10	7290	1750	5.8271		
417 AW		0.1925	0.00020	0.00012		509	19.00	0.50	12446	2	0.0000	6.780	3.92
ATM-8 + TUFF													
418 UF	8.36	0.1938	0.00020	0.00010		498	14.55	0.10	15173	2260	4.2802	[0.396]	
418 F		0.1965	0.00010	0.00020		498	14.55	0.30	144674	25957	1.6963	(4.9E-7)	
418 AS		0.1920	0.00020	0.00010		498	12.05	0.10	20716	3084	3.5762		
418 AW		0.1894	0.00020	0.00010		498	19.00	0.50	90229	420	0.0343	4.314	2.55
418 T		0.2014	0.00023	0.00013		498	1.00	1.00	2568	0	0.0000		
419 UF	8.05	0.1894	0.00020	0.00010		502	14.57	0.10	16744	3175	5.5849		
419 AS		0.1965	0.00010	0.00020		502	12.47	0.10	20716	4264	5.0039		
419 AW		0.1944	0.00010	0.00020		502	19.00	0.50	90231	126	0.0097	5.803	3.40
419 T		0.1955	0.00019	0.00019		502	1.00	1.00	2569	0	0.0000		
420 UF	7.59	0.1894	0.00020	0.00012		508	14.40	0.10	76106	20924	8.0057	[0.260]	
420 F		0.1974	0.00015	0.00017		508	14.40	0.18	75685	10149	2.0805	(6.1E-7)	
420 AS		0.1894	0.00020	0.00012		508	11.90	0.10	9581	2939	7.3821		
420 AW		0.1940	0.00023	0.00013		508	19.00	0.50	10170	164	0.1193	8.756	5.07
420 T		0.2014	0.00023	0.00013		508	1.00	1.00	2132	700	0.0624		

Data Table D (Cont'd)

EXP'T NUMBER	Pu-239 COUNTS (counts)	FRACTION MASS (ug)	TOTAL MASS* (ug)	NL(Pu) (g/m**2)
ATM-8				
408 UF	848	0.0037	[0.143]	
408 F	700	0.0005	(1.5E-10)	
408 AS	3149	0.0839		
408 AW	132	0.0007	0.086	0.19
409 UF	582	0.0024		
409 AS	3993	0.1009		
409 AW	203	0.0010	0.102	0.23
410 UF	492	0.0068	[0.055]	
410 F	134	0.0004	(1.1E-10)	
410 AS	5427	0.2040		
410 AW	906	0.0041	0.209	0.46
411 UF	313	0.0042		
411 AS	9380	0.2106		
411 AW	1370	0.0061	0.218	0.49
412 UF	125	0.0030	[0.205]	
412 F	70	0.0006	(1.8E-10)	
412 AS	8555	0.3749		
412 AW	1530	0.0022	0.378	0.82
413 UF	220	0.0025		
413 AS	13216	0.4492		
413 AW	1005	0.0039	0.454	1.01
414 UF	146	0.0024	[0.216]	
414 F	88	0.0005	(1.5E-10)	
414 AS	24086	0.6125		
414 AW	473	0.0029	0.615	1.39
415 UF	198	0.0034		
415 AS	12710	0.4536		
415 AW	398	0.0023	0.457	1.03
416 UF	371	0.0047	[0.068]	
416 F	105	0.0003	(9.0E-10)	
416 AS	15534	0.5947		
416 AW	4603	0.0125	0.609	1.36
417 UF	308	0.0038		
417 AS	15517	0.5873		
417 AW	1296	0.0089	0.597	1.30
ATM-8 + TUFF				
418 UF	71	0.0015	[0.201]	
418 F	435	0.0003	(8.7E-11)	
418 AS	6167	0.0813		
418 AW	2650	0.0026	0.084	0.19
418 T	-			
419 UF	104	0.0020		
419 AS	6024	0.0803		
419 AW	2228	0.0021	0.088	0.19
419 T	3004	0.0026		
420 UF	1322	0.0057	[0.029]	
420 F	84	0.0002	(4.8E-11)	
420 AS	4811	0.1373		
420 AW	552	0.0046	0.153	0.33
420 T	4554	0.0046		

Data Table D (Cont'd)

421	UF	7.84	0.1944	0.00015	0.00017	499	14.45	0.10	76105	22979	8.5976		
421	AS		0.1944	0.00015	0.00017	499	12.35	0.10	9581	1996	9.7190		
421	AW		0.1990	0.00019	0.00019	499	19.00	0.50	10168	83	0.0584	8.730	5.15
421	T		0.1955	0.00019	0.00019	499	1.00	1.00	2132	400	0.0367		
422	UF	7.95	0.1956	0.00015	0.00017	500	14.55	0.10	64008	1157	0.5111	[0.000]	
422	F		0.1956	0.00015	0.00017	500	14.55	0.30	229871	23	0.0000	(0.00)	
422	AS		0.1957	0.00015	0.00017	500	12.05	0.10	7421	1843	5.8574		
422	AW		0.1956	0.00015	0.00017	500	19.00	0.50	29127	9	0.0012	5.946	3.50
422	T		0.1456	0.00020	0.00012	500	1.00	1.00	1332	0	0.0000		
423	UF	7.70	0.1956	0.00015	0.00017	498	14.56	0.10	17585	4658	7.5528		
423	AS		0.1956	0.00015	0.00017	498	12.46	0.10	64176	27921	10.6185		
423	AW		0.1956	0.00015	0.00017	498	19.00	0.50	77118	687	0.0652	11.651	6.88
423	T		0.1958	0.00015	0.00017	498	1.00	1.00	1426	0	0.0000		
424	UF	7.51	0.1926	0.00020	0.00012	498	14.50	0.10	9426	3233	9.8911	[0.397]	
424	F		0.1956	0.00015	0.00017	498	14.50	0.17	52979	12442	3.9225	(1.1E-7)	
424	AS		0.1926	0.00020	0.00012	498	12.00	0.10	7841	3227	9.8231		
424	AW		0.1929	0.00023	0.00013	498	19.00	0.50	20580	182	0.0650	11.286	6.67
424	T		0.2014	0.00023	0.00013	498	1.00	1.00	1294	1	0.0001		
425	UF	7.74	0.1956	0.00015	0.00017	504	14.50	0.10	9424	3179	9.5800		
425	AS		0.1926	0.00020	0.00012	504	12.80	0.10	10678	5591	13.3319		
425	AW		0.1999	0.00019	0.00019	504	19.00	0.50	20579	213	0.0740	14.760	8.61
425	T		0.1955	0.00019	0.00019	504	1.00	1.00	1293	1	0.0001		
426	UF	8.01	0.1931	0.00020	0.00012	505	14.46	0.10	188492	144	0.0162	[0.307]	
426	F		0.1957	0.00015	0.00017	505	14.46	0.10	248891	81	0.0050	(1.5E-9)	
426	AS		0.1904	0.00020	0.00012	505	11.96	0.10	4369	1512	8.3270		
426	AW		0.2009	0.00015	0.00017	505	19.00	0.50	73632	150	0.0137	9.777	5.69
426	T		0.2014	0.00023	0.00013	505	1.00	1.00	1961	7392	0.7173		
427	UF	7.92	0.1931	0.00020	0.00012	499	14.39	0.10	156050	52584	9.6187		
427	AS		0.1974	0.00015	0.00017	499	12.69	0.10	4369	1723	9.7131		
427	AW		0.2009	0.00015	0.00017	499	19.00	0.50	12446	2	0.0001	11.072	6.53
427	T		0.1955	0.00019	0.00019	499	1.00	1.00	1961	0	0.0000		

ATOMIC WEIGHT FRACTIONS OF ACTINIDES IN GLASS
f(Np) ATM-8 = 3.4E-3
f(Pu) ATM-8 = 9.0E-4

UF UNFILTERED SOLUTION (DISSOLVED IN TOTAL VOLUME)
F FILTERED, 50 A (DISSOLVED IN TOTAL VOLUME)
[ ] MASS An(F)/An(UF)
( ) SOLUBILITY IN MOLES/LITER
AS ACID SOAKED SOLUTION (DISSOLVED IN TOTAL VOLUME LESS 2.5ml REMOVED FOR OTHER ANALYSED)
AW ACID WASHED VESSEL (19.0ml HNO3+HF soln)
T TUFF WAFER SURFACE (VALUE REPORTED REFERS TO ONLY ONE SIDE OF WAFER)
- NOT ANALYSED
* TOTAL MASS REPRESENTS An(UF) + An(adsorbed on vessel) + An(adsorbed on tuff*2)

Data Table D (Cont'd)

421	UF	1665	0.0070		
421	AS	7689	0.4257		
421	AW	2150	0.0176	0.247	0.55
421	T	2448	0.0026		
422	UF	520	0.0026	[0.000]	
422	F	41	0.0000	(2.6E-13)	
422	AS	5522	0.1994		
422	AW	4043	0.0117	0.277	0.62
422	T	14680	0.0330		
423	UF	92	0.0016		
423	AS	66574	0.2877		
423	AW	3446	0.0038	0.249	0.56
423	T	2964	0.0046		
424	UF	103	0.0035	[0.047]	
424	F	55	0.0002	(4.8E-11)	
424	AS	10533	0.3644		
424	AW	1060	0.0044	0.383	0.85
424	T	3953	0.0066		
425	UF	131	0.0044		
425	AS	13282	0.3599		
425	AW	2722	0.0109	0.392	0.86
425	T	5573	0.0096		
426	UF	142	0.0002	[0.000]	
426	F	28	0.0000	(0.00)	
426	AS	4712	0.2949		
426	AW	2541	0.0028	0.310	0.68
426	T	5024	0.0055		
427	UF	1162	0.0024		
427	AS	7254	0.4647		
427	AW	1085	0.0072	0.489	1.09
427	T	9121	0.0104		

f(Am) SRL A = 5.71 E-6
f(Np) ATM-8 = 3.40 E-3
f(Pu) ATM-8 = 9.00 E-4

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REFERENCES

ABRAJANO
T. A. Abrajano, Jr., J. K. Bates, W. L. Ebert, and T. J. Gerding, "The Reaction of Glass in a Gamma Irradiated Saturated Tuff Environment, Part 3: Long-Term Experiments at 1 x 10^4 Rad/hr," Argonne National Laboratory report ANL-88-14 (1988). HQX.880721.0013

ALLARD
B. Allard, in "Actinides in Perspective," Proc. Actinides-1981 Conf., N. M. Edelstein, ed., Pergamon Press, pp. 553-580 (1982). NNA.891212.0007

BARKATT
A. Barkatt, A. Barkatt, and W. Sousanpour, "Gamma Radiolysis of Aqueous Media and Its Effect on the Leaching Processes of Nuclear Disposal Material," Nucl. Technol. 60, 218 (1983). NNA.891101.0002

BATES-1
J. K. Bates, D. F. Fischer, and T. J. Gerding, "The Reaction of Glass in a Gamma Irradiated Saturated Tuff Environment, Part 1: SRL 165," Argonne National Laboratory report, ANL-85-62 (1986). HQS.880517.2392

BATES-2
J. K. Bates, W. L. Ebert, D. F. Fischer, and T. J. Gerding, "The Reaction of Reference Commercial Nuclear Waste Glass During Gamma Irradiation in a Saturated Tuff Environment," J. Mat. Res. 3(3), 576-579 (May/June 1988). HQX.890522.0062

BOURCIER
W. L. Bourcier, "Geochemical Modeling of Radioactive Waste Glass Dissolution Using EQ3/6: Preliminary Results and Data Needs," Lawrence Livermore National Laboratory report UCID-21869 (1990).

BURNS
W. G. Burns, W. R. Marsh, and W. S. Walters, "The Gamma Irradiation Enhanced Corrosion of Stainless and Mild Steels by Water in the Presence of Air, Argon, and Hydrogen," Radiat. Phys. Chem. 21, 259 (1983). NNA.891109.0047

BYERS
C. D. Byers, M. J. Jercinovic, and R. C. Ewing, "A Study of Natural Glass Analogues as Applied to Alteration of Nuclear Waste Glasses," U.S. Nuclear Regulatory Commission report NUREG/CR-4842, Argonne National Laboratory report ANL-86-46 (1987). SRX.870720.0172

DEER
W. A. Deer, R. A. Howie, and J. Zussman, An Introduction to the Rock-Forming Minerals, Longman Press, London, 264-269 (1972). NNA.891120.0007

DELANY

J. M. Delany, "Reaction of Topopah Spring Tuff with J-13 Water: A Geochemical Modeling Approach using the EQ3/6 Reaction Path Code," Lawrence Livermore National Laboratory report UCRL-53631 (1985). HQS.880517.2419

EBERT

W. L. Ebert, J. K. Bates, T. A. Abrajano, Jr., and T. J. Gerding, "The Influence of Penetrating Gamma Radiation on the Reaction of Simulated Nuclear Waste Glass in Tuff Groundwater," Proc. Amer. Ceram. Soc. Mtg, Indianapolis, IN, April 1989 (in press).

GLASS

B. P. Glass, "Solution of Naturally-Occurring Glasses in the Geologic Environment," Final Report for NASA Contract NAS 5-26273, CR 170518 (1982).

GRAMBOW

B. Grambow, H. P. Hermansson, I. K Bjorner, and H. Christensen, "Reaction of Nuclear Waste Glass with Slowly Flowing Solutions," in Advances in Ceramics 20, D. Clarke, W. Whiley, and A. Machiels, eds., the American Ceramic Society, 465 (1986). SRX.871020.0100

KERRISK

J. F. Kerrisk, "Solubility Limits of Radionuclide Dissolution," LA-9995-MS (1984). HQS.880517.2001

KNAUSS

K. G. Knauss, W. J. Beiringer, and D. W. Peifer, "Hydrothermal Interaction of Crushed Topopah Spring Tuff and EJ-13 Water at 90°C, 150°C, and 250°C Using Dickson-Type Gold-Bag Rocking Autoclave," Lawrence Livermore National Laboratory report UCRL-53630 (1985). HQS.880517.1395

LANZA

F. Lanza, A. Manara, L. Mammarella, P. Blasi, and G. Ceccone, "Borosilicate HLW Glass Leaching in Silica Saturated Solution," Mat. Res. Soc. Symp. Proc. Vol. 112, 685 (1988). NNA.891109.0049

LODDING-1

A. R. Lodding, E. U. Engstrom, D. E. Clark, L. O. Werme, and G. G. Wicks, Adv. Ceram. 20, 567-581 (1986).

LODDING-2

A. Lodding, H. Odelius, D. E. Clark, and L. O. Werme, "Element Profiling by Secondary Ion Mass Spectrometry of Surface Layers in Glass," Mikrochimica Acta Suppl. 11, 145 (1985).

McVAY

G. McVay and L. Pederson,"Effect of Gamma Radiation on Glass Leaching," J. Am. Ceram. Soc. 64, 154 (1981). SRX.870929.0032

MEANS

J. L. Means et al., "Long Term Performance of High-Level Waste Glass Waste Forms," U.S. Nuclear Regulatory Commission report NUREG/CR-4795, Battelle Memorial Institute report BMI-2143 (1987).

OVERSBY

V. M. Oversby, "Reaction of the Topopah Spring Tuff with J-13 Well Water at 90°C and 150°C," Lawrence Livermore National Laboratory report UCRL-53552 (1984). HQS.880517.1370

PHINNEY

D. L. Phinney et al., "Integrated Testing of SRL-165 Glass Waste Form," in Scientific Basis for Nuclear Waste Management, Vol. 84, J. K. Bates and W. B. Seefeldt, eds., Materials Research Society, Pittsburgh, PA, 433 (1987). NNA.891120.0003

SCP

Site Characterization Plan for Yucca Mountain Site, Nevada Research and Development Area, Nevada, DOE/RW-0199 (1988). HQO.881201.0002

VAN KONYNENBURG

R. A. Van Konynenburg, "Radiation Chemical Effects in Experiments to Study the Reaction of Glass in an Environment of Gamma-Irradiated Air, Groundwater, and Tuff," Lawrence Livermore National Laboratory report UCRL-53719 (1986). SRX.870114.0118

WALD-1

J. W. Wald, "Fabrication and Characterization of MCC Approved Testing Material--ATM-1 Glass," Pacific Northwest Laboratory report PNL-5577-1 (1985). SRX.860203.0446

WALD-2

J. W. Wald, "Fabrication and Characterization of MCC Approved Testing Material--ATM-8 Glass," Pacific Northwest Laboratory report PNL-5577-8 (1985). HQS.880517.2564

WICKS

G. G. Wicks, W. C. Mosley, P. G. Whitkop, and K. A. Saturday, J. Non-Crys. Sol. 49, 413 (1982). NNA.891128.0599

YMP

Yucca Mountain Project Quality Assurance Program 88-9, Rev. 2, Section VIII, Part C.

APPENDIX I

Preparation of Leachant EJ-13 Solution

The leachant used in this series of gamma irradiation experiments consisted of actual groundwater obtained from well J-13 on the Jackass Flats of the Nevada test site. About five gallons of J-13 water was provided by the NNWSI Project in FY 1984. This source has been used for all the NNWSI gamma irradiation experiments we have performed. A description of the method by which the groundwater is collected and an assay have been given by Knauss et al. [KNAUSS] and Delany [DELANY], respectively.

The groundwater was pretreated with pulverized tuff rock at 90°C to produce the leachant solution, referred to henceforth as EJ-13. Oversby [OVERSBY] has studied the reaction between J-13 groundwater and pulverized tuff at various reaction temperatures. It was concluded there that only minor changes occur in the water chemistry over long reaction times. The silica content increases slightly, being controlled by the cristobalite solubility, and the aluminum is initially supersaturated in the solution then slow precipitates out of solution. Both calcium and magnesium precipitates out of solution rapidly because of the retrograde calcium solubility. These changes in water chemistry all occur after only a few days of reaction at 90°C. It is therefore assumed that a nearly equilibrated system is present after 14 days of reaction at 90°C. The same pretreatment procedure was used to prepare the EJ-13 solution in all experiments performed in FY 1984, FY 1985, and FY 1986. The preparation procedure described below is an approved test procedure, Document NNWSI-05-009.

1. Tuff Preparation

A large piece of tuff rock was placed in a plastic bag and struck repeatedly with a hammer to produce small fragments with diameters less than an inch. These fragments were placed in a 2 L polyethylene bottle which had been previously rinsed three times (3x) with deionized water (DIW). About 25 g of these fragments were placed in this bottle and then were rinsed and decanted 3x with ~200 mL of DIW. They were then removed from the bottle and allowed to air dry. The fragments were then crushed in a grinding mill fitted with a tantalum blade and sieved through a 100 mesh sieve (opening size approximately 150 μm). The rock not passing through the sieve was pulverized using a mortar and pestal and resieved until at least 20 g of pulverized rock <100 mesh was obtained.

2. Equilibration of Pulverized Tuff with J-13 Water

The same 2 L polyethylene bottle used previously was rinsed 3x with DIW and 3x with about 50 mL of J-13 water. Then 20.30 g of pulverized tuff was added to the bottle and rinsed 3x with ~120 mL of J-13 water and decanted. A small amount of powdered rock was lost during this rinse

procedure. The bottle was then filled with about 2L of J-13 water and capped. The mixture was shaken for about two minutes and placed in a 90°C oven to sit undisturbed. Twice daily the bottle was shaken for two minutes, to prevent the tuff from clotting, and then left undisturbed in the oven. This agitation cycle was repeated for 14 days.

3. Filtering Solution

After 14 days the mixture was removed from the oven and allowed to cool to near room temperature. In the meantime, two 1 L polyethylene bottles were rinsed 3x with DIW and set in the 90°C oven to dry. A polyethylene funnel was also rinsed and dried. After cooling, the tuff-J-13 mixture was decanted through previously wetted ashless filter paper (Whatman #40). The prefiltered solution was collected in the polyethylene containers. It was then filtered through 0.2 μm Millipore filters which attach directly to a plastic syringe. The filters were wetted using ethanol then rinsed 3x with DIW and 1x with the solution. A single filter could be used for filtering about 500 mL of solution before it became too clogged to use. The filtrate was placed directly into a previously rinsed polyethylene bottle for storage.

4. Storage of EJ-13 Solution

The polyethylene bottle used to collect the filtrate was capped and placed in a dark cupboard to discourage algae growth. The shelflife of the EJ-13 solution is unknown. A thorough analysis of the solution is recommended at each usage.

The entire procedure was repeated using 10.48 g of pulverized tuff in about 1 L of J-13 water then added to the original batch to produce about 3 L of EJ-13 solution.

5. Stability of EJ-13 Solution

The resulting solution was used as the leachant for most of the experiments. It was analyzed regularly with the leachates of terminated experiments. It was found to be depleted in nitrate concentration after about 200 days of being stored in a polyethylene container and so was discarded and a fresh stock of EJ-13 solution prepared. Since blank experiments were run simultaneously to determine background correction levels for the experiments, the difference in the composition of the two leachant solutions used is accounted for by background subtraction. Previous years' experiments were limited to shorter reaction times and all experiments were run in parallel. Due to the increased number of experiments run in FY 1986, we were required to reuse reaction vessels and store the leachant for long times.

APPENDIX II

Sample Calculation: Normalized Elemental Mass Loss

As an example of the calculation of the normalized elemental mass loss, NL, the normalized boron mass loss from experiment G-309 is calculated. This was an experiment performed using SRL U glass and was irradiated at an exposure rate of 1E3 R/h for 278 days. A sample volume of 12.24 mL diluted by 5.00 mL of high purity water of the acidified leachate was submitted for analysis. The analytical result of 2.43 μg/mL is corrected for dilution:

$$2.43 \frac{\mu g}{mL} * \frac{12.24 \text{ mL} + 5 \text{ mL}}{12.24 \text{ mL}} = 3.42 \frac{\mu g}{mL} .$$

The boron concentration for the irradiated experiments with EJ-13 only run for 278 days used as the background was 0.17 μg/mL. Correcting the dilution corrected result for this background concentration gives a net boron concentration of 3.25 μg/mL.

The SRL A glass is 2.10 wt % boron. The total surface area of the glass disks used was 475 mm^2. The normalized elemental mass loss is defined by equation (II-1)

$$NL(i) = \frac{\text{(mass of i in solution)}}{\text{surface area of glass releasing i} * \text{wt. fraction of i in glass}} \qquad \text{(II-1)}$$

The normalized elemental mass loss is usually given in units of g/m^2.

The total leachate volume that the boron was released into was 14.70 mL. The mass of boron is simply 3.25 μg/mL * 14.70 mL = 47.78 μg. Solving Eq. II-1 for these values gives:

$$NL(B) = \frac{47.78 \text{ E-6 g}}{475 \text{ E-6 } m^2 * 0.021} = 4.82 \text{ g/}m^2$$

Sample Calculation: Calculation of Actinide Masses Present in Various Fractions

As an example of the calculation of the actinide mass present in the various phases (dissolved, colloidal, adsorbed on stainless steel, adsorbed on tuff), the calculations for the plutonium distribution in experiment G-386 are presented. This was an experiment which included SRL A glass and a tuff wafer, and which was nonirradiated and reacted for 278 days.

The necessary data is provided in Data Table D. The plutonium background measured prior to analysis of the unfiltered sample was 0.00012 c/s (counts per second). The detector efficiency was measured to be 0.1931 c/dis (counts per disintegration) using a ^{237}Np standard. The 386 UF sample was monitored for a total live time of 63820 seconds. This is the length of time the detector was accepting signal from the sample. During this time 28766 counts were recorded, a rate of 0.4507 c/s. Subtracting the background results in a net rate of 0.4506 c/s. Correcting for the detector efficiency gives a disintegration rate of 0.4506 c/s / 0.1931 c/dis = 2.334 dis/s.

The disintegration obeys the unimolecular rate law that is

$$\# \text{ dis/sec} = \frac{\ln 2}{t_{1/2}} * \# \text{ atoms} \qquad \text{(II-2)}$$

where $t_{1/2}$ is the half-life of the disintegrating atom. The half-life of ^{239}Pu is 2.41E4 years or 7.61E11 seconds. Solving Eq. II-2 for the number of atoms we obtain 2.562E12 atoms, or 1.0166E-9 g of ^{239}Pu. This is the mass of ^{239}Pu in the 0.10 mL aliquot that was analyzed. In the entire leachate volume of 14.21 mL there is

$$\frac{1.02E\text{-}9 \text{ g}}{0.10 \text{ mL}} * 14.21 \text{ mL} = 1.44E\text{-}7 \text{ g or } 0.144 \ \mu g \ ^{239}Pu.$$

A similar calculation of the 386F filtered leachate sample yields a mass of 0.000 μg in that sample. All the detectable ^{239}Pu was associated with colloidal particles larger than 50 Å.

To compute the mass of plutonium in the colloidal fraction that is included in the acid soaked sample, the mass present in the reduced leachate volume that is acidified (reduced by the volume removed for the anion, total carbon, An(UF), and An(F) aliquots) must be calculated. Assuming that 2.50 mL were removed, the acidified volume is 11.71 mL. (The volume of concentrated nitric acid added has been ignored.) The mass of filterable ^{239}Pu in the acid soak solution is then

$$\frac{0.144 \ \mu g}{14.21 \text{ mL}} * 11.71 \text{ mL} = 0.119 \ \mu g.$$

The mass of ^{239}Pu in 386AS is calculated to be 0.458 μg. Therefore, 0.458 μg-0.119 μg, or 0.339 μg was adsorbed onto the vessel walls. The 386AW sample contained another 0.010 μg of adsorbed Pu, so a total of 0.349 μg of ^{239}Pu was adsorbed onto the vessel.

The activity of the tuff wafer was counted directly. Similar calculations (without the volume correction) give a mass of 0.014 μg Pu on the tuff surface. It is assumed that the other face of the tuff wafer contains a similar amount of plutonium, and the total amount on the tuff is assumed to be twice that detected on the one face, in this case 0.028 μg Pu. The total plutonium released from the glass was therefore: 0 μg dissolved, 0.144 μg colloidal, 0.349 μg adsorbed on the stainless steel, and 0.028 μg on the tuff, a total of 0.521 μg.

Calculation of the Amount of Nitric Acid Produced by Radiolysis Using the Equation of Burns et al.

The Burns equation is given as

$$N = 2\ C_o\ R\ [1 - \exp(-1.45E\text{-}5 * G * D * t)] \qquad \text{(II-3)}$$

where N = the concentration of HNO_3 produced which is assumed to be totally dissolved in the liquid phase, in moles/liter,

C_o = the initial concentration of N_2 in the gas phase, in moles/liter,

R = the gas to liquid volume ratio,

G = the yield of nitric acid during radiolysis, defined here to be 1.9,

D = the exposure rate, in MR/h,

t = the exposure time, in hours.

At the reaction temperature, 90°C, the amount of N_2 can be calculated as follows. The partial pressure of N_2 in air at 90°C is 106.5 kPa = 1.05 atm. Assuming ideal behavior calculation is

$$\frac{n}{V} = \frac{P}{RT} = \frac{1.05\ \text{atm}}{0.081\ \text{L-atm mol}^{-1}\text{K}^{-1}} * 363\ \text{K} = \frac{n\ \text{moles}}{4.85E\text{-}3\text{L}}$$

n = 1.74E-4 moles and n/V = 3.58E-2 moles N_2/L air at 90°C.

Equation II-3 for small values of GDt (less than ~10^3 MR) reduces to

$$N \approx 2.90E\text{-}5\ C_o\ R\ G\ D\ t \qquad \text{(II-4)}$$

Substituting the values

C_o = 3.6E-2 moles/L

R = 0.3

G = 1.9 MR^{-1}

Eq. II-4 can be rewritten as

$$N = 5.95E\text{-}7\ Dt$$

where Dt is megaRoentgens.

For an exposure of 10^6 R, 1 MR, N = 5.95E-7 moles/L. This is the molarity of nitric acid dissolved in the leachate. With complete dissociation, this is also the hydrogen ion concentration. If the leachant was deionized water, the resulting pH of the solution due to this acid would be 6.23. EJ-13 water contains about 120 μg/mL HCO_3^-, which is 1.97E-3 M HCO_3^-. According to the above equation, the exposure necessary to exhaust this concentration of HCO_3^- in our experimental conditions is

$$1.97E\text{-}3\ \text{moles/L} = 5.95E\text{-}7\ Dt$$

$$\text{or } Dt = 3.31E3\ MR.$$

This is equivalent to an exposure time of 690 days at 2E5 R/h or 138,000 days (378 years) at 1E3 R/h.

Reference for Appendix II

BURNS
W. G. Burns, W. R. Marsh, and W. S. Walters, Radiat. Phys. Chem. 21, 259 (1983).

APPENDIX III

Selection of Silicon-28 as a Reference Element for SIMS Depth Profile

In semi-quantitative SIMS analysis of reacted glasses it is often convenient to identify a reference-element or species that has a similar concentration in the unreacted and reacted regions. The peak intensities of other species can then be normalized using the reference element to account for experimental artifacts or different sputtering cross-sections of a given element in different regions. Silicon, aluminum, and iron have been used in various analyses as the reference element [LODDING-1, -2]. Silicon-28 was determined to be the proper reference element in these experiments as shown below. Any real change in the silicon concentration will be convoluted with the concentration profiles of all other elements normalized to the silicon peak.

Data is collected as a complete mass scan (typically between m/e = 1 and m/e = 75) periodically as a sample is sputtered. The actual measured peak height of a species of interest is normalized to the silicon-28 peak height in the same spectrum. The normalized peak heights of successive scans then determine the concentration profiles. Some species show very large concentration changes as the sample is sputtered. Lithium and sodium especially show drastic increases in peak height as the unreacted glass is reached. In order to obtain more accurate results, the number of secondary ions collected was varied as the sample was sputtered by adjusting the "gate width" of the time actuated detector. In the early sputtering times the gate is opened wide so a large number of ions are sampled. The most intense peaks, typically silicon and aluminum, have currents near the maximum allowed. As the bulk is approached and lithium and sodium increase in concentration, their peak heights increase to values much higher than that of the silicon peak. The gate width must be reduced to keep the lithium and sodium peaks on scale. As the gate width is reduced, peaks of species having constant concentrations and sputtering cross-sections will also reduce. In order to compare peak heights of a given species over a profile, the measured intensity must be corrected for the change in the gate width.

If a species has a similar concentration in the unreacted and reacted regions, then the gate-corrected intensities will differ only because the species has a different sputtering cross-section in the different regions or because instrumental parameters change. The CARD measured ANF of the reacted and unreacted regions of the SRL U samples were found to be very similar indicating that the electron densities were similar in the two regions. Also, the measured sputtering rates of reacted and unreacted SRL U glasses were found to be very similar. These findings imply the sputtering cross-sections of most elements should be similar in the two regions, since the sputtering cross-section is strongly influenced by the matrix. If it is assumed that no significant instrumental changes occur during collection of a given profile, other than the change in gate-width which has been accounted for, then the profile of silicon is expected to be flat if its concentration in the two regions is the same.

Figure III-1 shows the gate-corrected intensities of lithium-7 and silicon-28 for sample 394 which was reacted 91 days without radiation and without a tuff disk present. The lithium-7 profile is seen to have the familiar sigmoidal shape, while the silicon-28 profile is essentially flat. The variance in the silicon-28 profile is of the order obtained when sputtering unreacted glass and is assumed to represent the measurement error. SIMS analysis of samples generated in previous experiments showed a similar flat silicon-28 profile except for the first few spectra where the silicon intensity was increased [ABRAJANO]. No similar surface anomaly was found in the present experiments. The larger initial silicon peak heights found by [ABRAJANO] may have been due to a surface precipitate. This is reasonable because the reacted layer (as measured by alkali depletion) of the sample Abrajano analyzed was much thicker than the region showing the high silicon signal.

The EDS analysis showed fewer silicon x-rays to be generated in the reacted layer than in the unreacted bulk of the polished cross-sections. This is interpreted to be an artifact of the analysis due to the fact that the layers are thinner than the analyzed volume by the probes, with the mounting resin occupying a significant fraction of the analyzed volume in most cases as illustrated schematically in Fig. III-2. This results in fewer silicon atoms being in the probed volume and so fewer x-rays produced when the layer is analyzed than when the bulk is analyzed. The EDS analyses of the layers were therefore normalized to the silicon results to compensate for this effect. Other experiments were performed where SRL U glass was leached in EJ-13 water at 200°C for several days in order to produce layers sufficiently thick to assure that only the layer was in the probed region. EDS analysis of these layers, which grew to be about 30 μm thick after 21 days of reaction, would indicate whether or not the thinness of the layers was responsible for the reduction in the number of counts, assuming that the layer compositions were similar. When these were analyzed in polished cross-section, a similar number of silicon counts was obtained when analyzing the layer and the bulk. These layers had EDS compositions very similar to the thin layers which had been renormalized to 100%, except the former were richer in aluminum. These findings support the renormalization procedure used to account for the presence of resin in the sampled volume of the thin alteration layers.

Both the SIMS and EDS results provide evidence that the concentration of silicon in the alteration layers of reacted SRL U glass is similar to the silicon concentration in the unreacted glass. Silicon-28 therefore is a proper choice as a reference element.

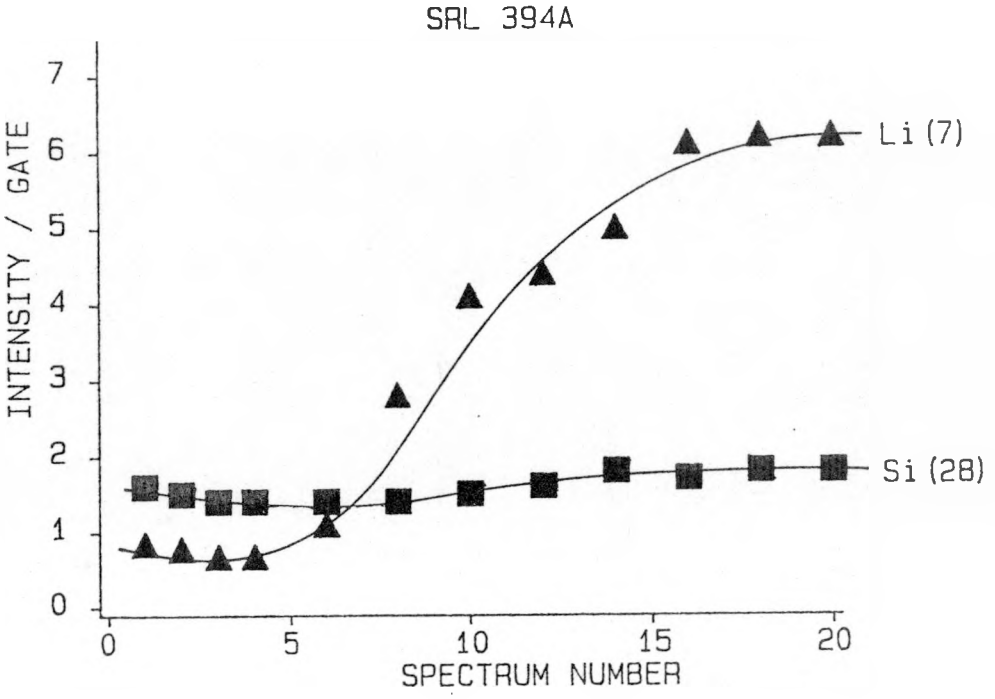

Fig. III-1. SIMS Gate-Corrected Peak Heights vs. Sputter Time for Sample SRL 394.

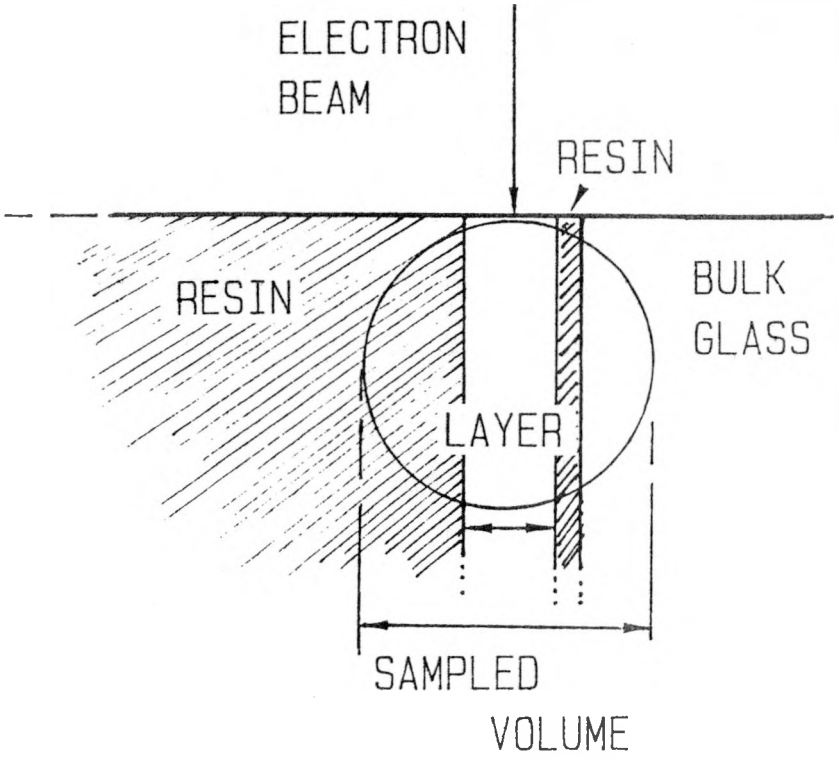

Fig. III-2. Schematic Drawing Showing the Sampled Volume and Alteration Layer Volume in EDS Analyses.